

**DEFINITIZED SUBCONTRACT NO. ZDO-3-30628-09  
UNDER  
PRIME CONTRACT NO. DE-AC36-99-GO10337**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**TYPE OF SUBCONTRACT:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
PHASE I:	\$ 999,833.00 - 50%	\$ 999,834.00 - 50%	\$1,999,667.00 - 100%
PHASE II:	\$ 998,805.00 - 50%	\$ 998,804.00 - 50%	\$1,997,609.00 - 100%
PHASE III:	<u>\$ 999,565.00 - 50%</u>	<u>\$ 999,565.00 - 50%</u>	<u>\$1,999,130.00 - 100%</u>
TOTAL:	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00 - 100%

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:** LETTER SUBCONTRACT: \$ 750,000.00 - PVP26282  
DEFINITIZED SUBCONTRACT: \$ 250,000.00 - PVP26282  
TOTAL: \$1,000,000.00

**INDEX TO  
DEFINITIZED SUBCONTRACT SCHEDULE**

<u>ARTICLE - TITLE</u>	<u>PAGE</u>
INTRODUCTION .....	1
AGREEMENT .....	1
ARTICLE 1 - THE WORK TO BE PERFORMED .....	1
ARTICLE 2 - THE PERIOD OF PERFORMANCE .....	1
ARTICLE 3 - ESTIMATED COST, COST SHARING, OBLIGATION OF FUNDS AND FINANCIAL LIMITATIONS .....	2
ARTICLE 4 - LIMITATION OF FUNDS AND LIMITATION OF COST .....	3
ARTICLE 5 - WAIVER OF FACILITIES CAPITAL COST OF MONEY .....	3
ARTICLE 6 - DATE OF INCURRENCE OF COST .....	3
ARTICLE 7 - SUBCONTRACTOR ACQUIRED PROPERTY AND TITLE .....	3
ARTICLE 8 - APPLICABLE DOCUMENTATION .....	4
ARTICLE 9 - ORDER OF PRECEDENCE .....	4
ARTICLE 10 - RIGHTS TO PROPOSAL DATA .....	4
ARTICLE 11 - SUBCONTRACT ADMINISTRATION RESPONSIBILITIES .....	5
ARTICLE 12 - KEY PERSONNEL .....	5
ARTICLE 13 - INVOICES .....	5
ARTICLE 14 - NEGOTIATED AND CEILING INDIRECT RATES .....	6
ARTICLE 15 - PUBLIC DISCLOSURE .....	7
ARTICLE 16 - ALTERATIONS TO TERMS AND CONDITIONS .....	7
ARTICLE 17 - INTEGRATION .....	9
<b>APPENDICES:</b>	
APPENDIX A - STATEMENT OF WORK	
APPENDIX B-1 - STANDARD TERMS AND CONDITIONS	
APPENDIX C-2 - INTELLECTUAL PROPERTY PROVISIONS	
APPENDIX D-1 - CLAUSES FOR SUBCONTRACTS IN EXCESS OF \$500,000	

**DEFINITIZED SUBCONTRACT NO. ZDO-3-30628-09**

**BETWEEN**

**MIDWEST RESEARCH INSTITUTE**

**NATIONAL RENEWABLE ENERGY LABORATORY DIVISION**

**AND**

**EVERGREEN SOLAR, INC.**

**SCHEDULE**

**INTRODUCTION**

THIS DEFINITIZED SUBCONTRACT, effective 09/27/02, supersedes Letter Subcontract No. ZDO-2-30628-09 in its entirety. This subcontract is effective between the Midwest Research Institute acting through its National Renewable Energy Laboratory Division (hereinafter called NREL), and Evergreen Solar, Inc. (hereinafter called "Subcontractor") whose principal offices are located in Marlboro, Massachusetts.

Midwest Research Institute has entered into Contract No. DE-AC36-99-GO10337 (hereinafter called "Prime Contract") with the Department of Energy (hereinafter called "DOE"), an agency of the U.S. Government (hereinafter called "Government"), for the operation and management of the National Renewable Energy Laboratory.

This subcontract is entered into in furtherance of the performance of the work provided for in the Prime Contract.

**AGREEMENT**

NOW, THEREFORE, the parties hereto agree to the following terms and conditions:

**ARTICLE 1 - THE WORK TO BE PERFORMED**

- A. The Subcontractor shall perform the work generally described as "Innovative Approaches To Low Cost Module Manufacturing Of String Ribbon Si PV Modules," and specifically provided for in Appendix A, Statement of Work, attached hereto and made a part hereof, pursuant to the provisions of this subcontract.
- B. Specific deliverables, quantities, due dates, reporting requirements, and addresses are set forth in Appendix A hereto.

**ARTICLE 2 - THE PERIOD OF PERFORMANCE**

- A. The period of performance under this subcontract shall be as follows:

Phase I:	09/27/02 through 03/31/03
Phase II:	04/01/03 through 03/31/04
Phase III:	04/01/04 through 05/31/05

- B. Each of these periods may be extended by mutual written agreement of the parties. NREL will make a decision, based on its sole judgement, whether or not to continue and incrementally fund each Phase prior to the completion date of each Phase. If all Phases are authorized by NREL, the total period of performance for the subcontract would be thirty-two (32) months. If NREL should decide not to authorize a Phase, the subcontract shall be considered complete upon submittal of the final version of the Annual Technical Report, with corrections as specified by NREL, if any.

**ARTICLE 3 - ESTIMATED COST, COST SHARING, OBLIGATION OF FUNDS AND FINANCIAL LIMITATIONS**

- A. Estimated Cost -- The estimated cost for the performance of the work conducted under this subcontract is \$5,996,406.00. It is agreed by the parties hereto that said total cost shall be shared as follows:

Estimated NREL Share:	\$2,998,203.00	- 50%
Estimated Subcontractor Share:	<u>\$2,998,203.00</u>	- 50%
Total:	\$5,996,406.00	- 100%

This cost sharing formula shall also apply (on the percentage basis shown above) to any increase or decrease in the estimated total cost of subcontract performance, changes under the "Changes" clause and/or terminations under the "Terminations" clause contained in Appendix B.

- B. The estimated cost specified in A above is broken down as follows for this subcontract:

	<u>Estimated NREL Share</u>	<u>Estimated Subcontractor Share</u>	<u>Total Cost</u>
Phase I:	\$ 999,833.00 -- 50%	\$ 999,834.00 -- 50%	\$1,999,667.00
Phase II:	\$ 998,805.00 -- 50%	\$ 999,804.00 -- 50%	\$1,997,609.00
Phase III:	<u>\$ 999,565.00 -- 50%</u>	<u>\$ 999,565.00 -- 50%</u>	<u>\$1,999,130.00</u>
Total:	\$2,998,203.00 -- 50%	\$2,998,203.00 -- 50%	\$5,996,406.00

This cost sharing formula for each phase shall also apply (on the percentage basis shown above) to any increase or decrease in the estimated total cost of each phase of subcontract performance, changes under the "Changes" clause and/or terminations under the "Termination" clause contained in Appendix B.

- C. The Subcontractor shall be paid for the work conducted under this subcontract in accordance with the clauses entitled "Allowable Cost and Payment" and "Cost Sharing Subcontract - No Fee" in Appendix B, and the article entitled "Invoices" in this schedule.
- D. Pursuant to the "Limitation of Funds" clause in Appendix B, the amount of \$1,000,000.00 has been allotted and is available for payment of NREL's estimated share of allowable costs for a portion of the work under this subcontract. It is estimated that the allotted amount will cover work under this subcontract through 03/31/03. This allotted amount presently obligated by NREL with respect to this subcontract, may be unilaterally increased by NREL by written notice to the Subcontractor, and may be increased or decreased by written agreement of the parties by formal modification of this subcontract.

- E. The Subcontractor is authorized by NREL's execution of this subcontract to perform that portion of Phase I work for which funds have been allotted in Paragraph D above.
- F. The Subcontractor is cautioned that, subject to the provisions of the clauses entitled "Limitation of Funds" and "Limitation of Cost" contained in Appendix B, NREL is not presently obligated to reimburse the Subcontractor for costs incurred in excess of NREL's share of funds allotted in Paragraph D above for portions of authorized work under the subcontract, and (ii) shall not be obligated to reimburse the Subcontractor for costs incurred in excess of NREL's share of the total estimated costs in paragraph B above for full performance under the subcontract.
- G. The giving of any notice by either party under this article, the article entitled "The Period of Performance" in this Schedule or the clauses entitled "Limitation of Funds" and "Limitation of Cost" in Appendix B, as applicable, shall not be construed to waive or impair any rights of NREL to terminate this subcontract under the provisions of the termination clause(s) contained in Appendix B.

#### **ARTICLE 4 - LIMITATION OF FUNDS AND LIMITATION OF COST -- SPECIAL (JULY 1999)**

The "Limitations of Funds" clause contained in Appendix B shall be operable during such time that NREL incrementally allots additional funds to this subcontract as set forth in Article 3 - Estimated Cost, Cost Sharing, Obligations of Funds, and Financial Limitations. (The Limitations of Cost clause shall be inoperable during such time.)

The "Limitations of Cost" clause contained in Appendix B shall become operable at such time that NREL allots to this subcontract an amount equal to the total estimated NREL cost share set forth in Article 3 - Estimated Cost, Cost Sharing, Obligations of Funds, and Financial Limitations. (The Limitations of Funds clause shall be inoperable at such time.)

#### **ARTICLE 5 - WAIVER OF FACILITIES CAPITAL COST OF MONEY**

The Subcontractor did not include facilities capital cost of money as a proposed cost of this subcontract. Therefore, it is an unallowable cost under this subcontract.

#### **ARTICLE 6 - DATE OF INCURRENCE OF COST**

The Subcontractor shall be entitled to reimbursement for costs incurred in an amount not to exceed \$970,236.00 (\$481,977.00 NREL share, and \$488,260.00 Subcontractor share) on or after October 1, 2001 which, if incurred after this subcontract has been entered into, would have been reimbursable under the provisions of this subcontract.

#### **ARTICLE 7 - SUBCONTRACTOR ACQUIRED PROPERTY AND TITLE**

Unless otherwise specified herein, all materials, supplies, and equipment shall be procured with funds allocated as the Subcontractor's Cost Share participation. Therefore, title to such materials, supplies, and equipment shall remain with the Subcontractor. The retention of title to such materials, supplies, and equipment with the Subcontractor shall be subject to the conditions below.

1. The Subcontractor shall not charge depreciation, amortization, or use charges for the materials, supplies, or equipment under any other Federal Government contract, subcontract, cooperative agreement, or grant either currently or in the future.
2. Said materials, supplies, or equipment shall be used for the benefit of research and development under this subcontract and any extension hereto.

#### **ARTICLE 8 - APPLICABLE DOCUMENTATION**

In addition to the terms and conditions contained in this Schedule, the following documents are attached hereto and made a part of this subcontract:

- A. Appendix A, entitled "Statement of Work" dated 10/03/02.
- B. Appendix B-1, entitled "Standard Terms and Conditions" dated 07/24/00.
- C. Appendix C-2, entitled "Intellectual Property Provisions" dated 10/22/98.
- D. Appendix D-1, entitled "Clauses for Subcontracts in Excess of \$500,000" dated 07/28/00.
- E. Subcontractor's technical proposal dated October 6, 2000, together with any revisions, is hereby incorporated by reference. In the event there is a conflict between the Subcontractor's technical proposal and any other provisions of this subcontract, the latter shall prevail.

#### **ARTICLE 9 - ORDER OF PRECEDENCE**

Any inconsistency in this subcontract, shall be resolved by giving precedence in the following order:

- A. This Schedule;
- B. Statement of Work (Appendix A);
- C. Standard Terms and Conditions (Appendix B-1);
- D. Intellectual Property Provisions (Appendix C-2);
- E. Clauses for Subcontracts in Excess of \$500,000 (Appendix D-1);
- F. The Subcontractor's technical proposal, if incorporated in this subcontract by reference or otherwise.

#### **ARTICLE 10 - RIGHTS TO PROPOSAL DATA**

Except for technical data contained on pages (None) of the Subcontractor's proposal dated October 6, 2000 which are asserted by the Subcontractor as being proprietary data, it is agreed that, as a condition of the award of this subcontract, and notwithstanding the provisions of any notice appearing on the proposal, the Government and NREL shall have the right to use, duplicate, disclose and have others do so for any purpose whatsoever, the technical data contained in the proposal upon which this subcontract is based.

**ARTICLE 11 - SUBCONTRACT ADMINISTRATION RESPONSIBILITIES**

- A. Signature Authority: This subcontract may only be modified by a formal modification signed by an authorized official of NREL.
- B. Subcontract Administration Responsibilities: The authorized official of NREL has designated Christie Johnson, as the Subcontract Administrator for this subcontract with the responsibilities for subcontract administration and negotiation of any modifications to this subcontract. The Subcontract Administrator's telephone number is (303) 384-7394.
- C. Technical Monitoring Responsibilities: The authorized official of NREL has designated Dave Mooney, as the Technical Monitor for this subcontract with the responsibilities of monitoring the technical work or services to be performed under this subcontract. The Technical Monitor does not have the authority to make any commitments or authorize any changes which may affect the subcontract's cost, scope of work, terms, or conditions. Any such changes shall be referred to the Subcontract Administrator designated in Paragraph B above. The Technical Monitor's telephone number is (303) 384-6782.

**ARTICLE 12 - KEY PERSONNEL**

- A. It having been determined that the individuals, whose names appear below, are necessary for the successful performance of this subcontract, the Subcontractor agrees to assign or have assigned such individuals to the performance of the work under this subcontract and shall not reassign or remove any of them without the consent of the Subcontract Administrator by modification to this subcontract:

<u>Name</u>	<u>Project Title</u>	<u>Telephone No.</u>
Dr. Jack Hanoka	Principal Investigator	(508) 357-2221 x719
Rich Chleboski	Vice President	(508) 357-2221 x718
Mark Fidler	Controller	(508) 357-2221

- B. Whenever, for any reason, one or more of the designated key personnel designated above, is unavailable for assignment for work under this subcontract, the Subcontractor shall, with the approval of the Subcontract Administrator, replace such individual with an individual of substantially equal abilities and qualifications.

**ARTICLE 13 - INVOICES**

Invoices for work accomplished under this subcontract shall be submitted in an original and one copy to:

National Renewable Energy Laboratory  
 Attn: Carolyn Lopez, Mailstop 2713  
 1617 Cole Boulevard  
 Golden, CO 80401-3393

To facilitate processing and payment each invoice must reference the subcontract number which appears on the cover sheet of this subcontract. Payments under this subcontract shall be made in accordance with the payment terms and to the Subcontractor's remittance name and address shown on the cover sheet of

this subcontract. Final payment under this subcontract shall be made upon execution of the closeout modification by both parties hereto (including receipt of an appropriately signed Release of Claims, appropriately signed Assignment of Refunds, Rebates, Credits and Other Amounts, final property disposition, and patent clearances, if required).

The payment terms of this subcontract shall mean net days from the date of receipt of an acceptable invoice or the date of receipt and acceptance of all deliverables or reporting requirements for the period covered by the invoice, whichever is later.

The Subcontractor shall submit its invoices in reasonable detail, broken down by category, showing the total cost incurred both currently and cumulatively less the Subcontractor's cost share and the resultant NREL cost share. An authorized official of the Subcontractor shall sign the following certification on each invoice submitted for payment:

"I certify that this invoice is correct and proper for payment, and reimbursement for these costs has not and will not be received under any other Government contract or subcontract or other source of Government funds.

\_\_\_\_\_  
Authorized Official

\_\_\_\_\_  
Date"

Subcontractor acquired equipment, as authorized hereunder, must be separately identified on invoices submitted and include backup documentation in the form of an equipment listing or a copy of the receiving report, which shall include as a minimum: the item nomenclature, purchase price, applicable shipping and installation charges, and the acquisition date. Cost Share recognition for subcontractor acquired equipment can not be made without this information.

The Subcontractor is hereby notified that NREL may withhold payment on invoices submitted, if the Subcontractor has failed to comply with or is delinquent in the submission of the reporting or deliverable requirements under this subcontract, until such time as the Subcontractor has complied or submitted such reporting or deliverable requirements.

**ARTICLE 14 - NEGOTIATED AND CEILING INDIRECT RATES**

A. The following rates were utilized in the negotiation of the estimated cost for this subcontract:

<u>Category</u>	<u>Subcontract Period Covered</u>	<u>Rate</u>	<u>Base</u>
Labor Overhead	10/01/01 through 05/31/05	25%	Direct Labor
G&A	10/01/01 through 05/31/05	30%	Total Direct Costs Excluding Equipment

The Subcontractor shall utilize the negotiated indirect rates, during the period of this subcontract, as billing/invoicing rates. In accordance with the clauses entitled "Allowable Cost and Payment", "Limitation of Funds", and "Limitation of Costs" the Subcontractor shall notify the Subcontract Administrator immediately, when its current indirect rates and the rates utilized in the

negotiation of this subcontract's estimated cost differ significantly such that the Subcontractor has or should have reason to anticipate the incurrence of costs which are in excess of, or are substantially less than, the amount set forth in Article 3 of this subcontract schedule. Such notice from the Subcontractor shall include indirect rate cost calculation and supporting data, the cost impact to the subcontract by cost categories, and proposed technical approaches for handling the potential overrun or underrun under this subcontract.

- B. In accordance with the clause entitled "Allowable Cost and Payment," the following rates shall be applied as ceiling rates to the allowable costs for the recovery of indirect costs against this subcontract if upon completion, finalization, and negotiation of the actual indirect rates for the appropriate periods covered by this subcontract, the actual indirect rates exceed the following ceiling rates:

<u>Category</u>	<u>Subcontract Period Covered</u>	<u>Rate</u>	<u>Base</u>
Labor Overhead	10/01/01 through 05/31/05	25%	Direct Labor
G&A	10/01/01 through 05/31/05	30%	Total Direct Costs Excluding Equipment

- C. The Subcontractor is cautioned that, pursuant to the clause entitled "Limitation of Cost", if this subcontract is fully funded or the clause entitled "Limitation of Funds" if this subcontract is incrementally funded, NREL shall not be obligated to reimburse the Subcontractor for indirect or direct costs incurred in excess of the allotted amount set forth in Article 3 of this subcontract schedule. This shall also apply to overruns created by an indirect rate fluctuation that the Subcontractor, as a prudent businessperson, should have been aware of, and should have informed NREL of, at the time.
- D. In accordance with the Allowable Cost and Payment clause of Appendix B, the Subcontractor shall submit an adequate final indirect cost rate proposal to the NREL Subcontract Administrator and cognizant auditor within the 6-month period following the expiration of each of its fiscal years during the period of this subcontract.

**ARTICLE 15 - PUBLIC DISCLOSURE**

- A. Publicity release of any nature in connection with this subcontract shall not be made by the Subcontractor without prior review and approval of the NREL Subcontract Administrator.

**ARTICLE 16 - ALTERATIONS TO TERMS AND CONDITIONS**

Appendix B-1 is hereby modified by adding the following clause thereto:

**“CLAUSE 49 - SUBMISSION OF COMMERCIAL TRANSPORTATION BILLS TO DOE/NREL FOR AUDIT BY THE GENERAL SERVICES ADMINISTRATION. (JUN 1997) AND COMMERCIAL BILL OF LADING NOTATIONS (APR 1984)**

*Derived from FAR 52.247-67 (FD) and FAR 52.247-1*

*(Submission requirement applies to all cost-reimbursement subcontracts when reimbursement of shipment costs is a direct charge to the subcontract.)*

*(Notation requirement applies to all cost reimbursement subcontracts when transportation is a direct charge to the subcontract and all fixed price subcontracts when direct and actual transportation cost is a separate item in the invoice (e.g. F.O.B. origin) and not included in the delivered price (e.g. F.O.B. destination))*

**SUBMISSION**

- A. 1. In accordance with paragraph A.2. of this clause, the Subcontractor shall submit to NREL for audit by the General Services Administration (GSA), legible copies of all paid freight bills/invoices, commercial bills of lading (CBL's), passenger coupons, and other supporting documents for transportation services on which NREL/DOE will assume freight charges that were paid—
- (i) By the Subcontractor under a cost-reimbursement subcontract;
2. Cost-reimbursement Subcontractors shall only submit for audit those CBL's with freight shipment charges exceeding \$50.00. Bills under \$50.00 shall be retained on-site by the Subcontractor and made available for on-site audits by NREL/DOE, or designee. This exception only applies to freight shipment bills and is not intended to apply to bills and invoices for any other transportation services.
- B. The Subcontractor shall forward copies of paid freight bills/invoices, CBL's, passenger coupons, and supporting documents as an attachment to the Subcontractor's invoice on which the transportation charges are identified for payment by NREL.
- C. Any original transportation bills or other documents requested by NREL/DOE shall be forwarded promptly by the Subcontractor to NREL. The Subcontractor shall ensure that the name NREL/DOE is stamped or written on the face of the original bill or other documents before sending it to NREL.

**NOTATION**

If the NREL Subcontract Administrator authorizes supplies to be shipped on a commercial bill of lading and the Subcontractor will be reimbursed these transportation costs as direct allowable costs, the Subcontractor shall ensure before shipment is made that the commercial shipping documents are annotated with the following notation:

“Transportation is for the U.S. Department of Energy, acting through its National Renewable Energy Laboratory (NREL) and the actual total transportation charges paid to the carrier(s) by the consignor or consignee shall be reimbursed by NREL on behalf of the Government, pursuant to cost-reimbursement contract No. DE-AC36-99GO10337. This may be confirmed by contacting The Golden Field Office, 1617 Cole Blvd. Golden, CO 80401.”

ARTICLE 17 - INTEGRATION

This subcontract contains the entire understanding between the parties, and there are no understandings or representations except those set forth or incorporated by reference herein. No subsequent modifications of this subcontract shall be of any force or effect unless in writing signed by a duly authorized official of NREL.

IN WITNESS WHEREOF, the parties hereto have executed this subcontract as of the date fully signed below.

ACCEPTED: EVERGREEN SOLAR, INC.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: Ronald Schumai

BY: Daniel Tomlin

TITLE: Vice President

TITLE: Director, C:BS

DATE: 01/08/03

DATE: 01/08/03

**Appendix A**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module Manufacturing  
of String Ribbon Si PV Modules**

ZDO-2-30628-09  
September 18, 2002

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 – 1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Scale-Up Of A Production Worthy Doping Method**

EVERGREEN shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study

various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II**

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to

reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Continuous Lamination Process**

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum lamination process.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the

backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005”.

### **3.19 Task 19 In-Line Diagnostics-2**

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSVIEW into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

## **PHASE III**

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune

module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14% Efficient Wrap-around Contact Cells**

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

### **3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine**

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Design And Develop An Improved Small, High Voltage Module**

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.

### **3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules**

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

### **3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine**

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

### **3.26 Task 26 In Line Diagnostics-3**

EVERGREEN shall continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

### **3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules**

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

#### 4.0 PROGRAM PLAN

The subcontracted research shall be conducted at EVERGREEN. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by EVERGREEN according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

##### PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	X	X	X	X	X				
Task 2	X	X	X	X					
Task 3	X	X	X	X	X	X	∇		
Task 4									
Task 5	X	X	X	X	X	X	∇		
Task 6	X	X	X	X	X	X			
Task 7	X	X	X	X	X	X	∇		
Task 8	X	X	X	X	X	X	∇		
Task 9	X	X	X	X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

EVERGREEN shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	∇		
Task 13	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 14			X	X	X	X	X	X	X					
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	∇		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	∇		
Monthly Reports	15th													
Annual Report												draft 15th		final 30th

**Phase III**

EVERGREEN shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 20							X	X	X	X	X	∇		
Task 21										X	X	∇		
Task 22	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	∇		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	∇		
Task 27									X	X	X	∇		
Monthly Reports		15th												
Annual Report												draft 15th		Final 30th

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. EVERGREEN shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

### Milestones due no later than January 31, 2003

- m-1.3.1 Demonstrate coating with reduced permeability (Task 3)
- m-1.3.2 Network for all new crystal growth machines established (Task 7)
- m-1.3.3 Bulk resistivity and laser cutting data connected to the network (Task 7)
- m-1.3.4 Initiate qualification tests (Task 8)
- m-1.3.5 Initiate in-house accelerated testing (Task 8)
- m-1.3.6 Demonstrate adequate performance under thermal cycling (Task 9)
- m-1.3.7 Demonstrate adequate performance under humidity freeze (Task 9)

### Milestones due no later than, March 31, 2003

- m-1.4.1 Test graphite parts for improved purification (Task 3)
- m-1.4.2 Test novel hot zone parts' configurations (Task 3)
- m-1.4.3 Demonstrate lifetime gains from M-1.3.1-M-1.3.3 (Task 3)
- m-1.4.4 Verify M-1.3.4 with DLTS (Task 3)
- m-1.4.5 R and D cells from Ga. Tech with efficiency > 15.5% (Task 3)
- m-1.4.6 Optimize plasma nitride process (Task 4)
- m-1.4.7 Optimize metallization firing process (Task 4)
- m-1.4.8 Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells (Task 4)
- m-1.4.9 Demonstrate reduced series resistance (Task 5)
- m-1.4.10 Demonstrate increased shunt resistance (Task 5)
- m-1.4.11 Demonstrate process monitoring using SPC charts (Task 7)
- m-1.4.12 Complete accelerated testing (Task 8)
- m-1.4.13 Complete accelerated tests (Task 9)

## **PHASE II**

### Milestones due no later than June 30, 2003

- m-2.1.1 Demonstrate reduced oxygen in hot zone (Task 11)
- m-2.1.2 Design for alternate method to introduce Ar into the hot zone (Task 11)
- m-2.1.3 Production-worthy decal application machine designed (Task 13)
- m-2.1.4 Establish parameters for glass/encapsulant lamination (Task 14)
- m-2.1.5 Identify method to modify backskin for higher impermeability (Task 15)

Milestones due no later than September 30, 2003

- m-2.2.1 Establish hot zone redesign (Task 10)
- m-2.2.2 Demonstrate growth of oxide free ribbon (Task 11)
- m-2.2.3 Establish parameters for cell/backskin lamination (Task 14)
- m-2.2.4 Develop method to modify backskin (Task 15)
- m-2.2.5 Complete design of backskin modification machine (Task 16)
- m-2.2.6 Complete identification of pick and place robot (Task 18)

Milestones due no later than December 31, 2003

- m-2.3.1 Complete design and implementation of vibration damping (Task 10)
- m-2.3.2 Complete design and deployment of boat for double sided passivation (Task 12)
- m-2.3.3 Demonstrate adequate firing through of Al paste (Task 12)
- m-2.3.4 Decal application machine developed and tested (Task 13)
- m-2.3.5 Establish process for full module lamination (Task 14)
- m-2.3.6 Identify method to form backskin edge (Task 15)
- m-2.3.7 Complete development of backskin modification machine (Task 16)
- m-2.3.8 Decision on monolithic module manufacturing method (Task 17)
- m-2.3.9 Complete design of pick and place machine (Task 18)
- m-2.3.10 Complete design for automatic bulk resistivity measurement (Task 19)

Milestones due no later than March 31, 2004

- m-2.4.1 Complete dislocation maps (Task 10)
- m-2.4.2 Demonstrate fabrication of 13% cells (Task 12)
- m-2.4.3 Establish data processing for decal application machine (Task 13)
- m-2.4.4 Develop method to form backskin edge (Task 15)
- m-2.4.5 Complete design of machine to form sealed leads (Task 16)
- m-2.4.6 Complete development of machine to form sealed leads (Task 16)
- m-2.4.7 Complete development of monolithic module manufacturing method (Task 17)
- m-2.4.8 Complete development of automatic bulk resistivity measurement (Task 19)
- m-2.4.9 Complete incorporation of RS View in module machine designs (Task 19)

## PHASE III

### Milestones due no later than June 30, 2004

m-3.1.1 Complete debug of robotic pick and place machine (Task 25)

### Milestones due no later than September 30, 2004

m-3.2.1 Complete debug of wrap-around decal application machine (Task 22)

m-3.2.2 Demonstrate viability of laser cutting small cells from large cells (Task 23)

m-3.2.3 Complete running of robotic pick and place machine (Task 25)

m-3.2.4 Complete demonstration of positional accuracy and repeatability (Task 25)

### Milestones due no later than December 31, 2004

m-3.3.1 Demonstrate impurity reduction on production machine (Task 20)

m-3.3.2 Demonstrate dislocation reduction on production machine (Task 20)

m-3.3.3 Complete reliability studies on high-voltage small modules (Task 23)

m-3.3.4 Complete automation for high-voltage small modules (Task 23)

m-3.3.5 Complete speed and quality demonstration for manufacture of frameless, monolithic module (Task 24)

### Milestones due no later than March 31, 2005

m-3.4.1 Demonstrate starting lifetimes of 5 to >10 microseconds (Task 20)

m-3.4.2 Advances made in Tasks 12 and 20 brought together (Task 21)

m-3.4.3 Demonstrate 14% wrap-around contact cells (Task 21)

m-3.4.4 Complete testing of wrap-around decal application machine (Task 22)

m-3.4.5 Complete yield demonstration for manufacture of frameless, monolithic module (Task 24)

m-3.4.6 Complete development of RS View on all automated machines for modules (Task 26)

m-3.4.7 Complete integration of all inputs into a central collection point (Task 26)

m-3.4.8 Complete demonstration of manufacturing capability (Task 27)

m-3.4.9 Demonstrate capability to make 100 modules at a yield 99% (Task 27)

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

EVERGREEN shall prepare and submit reports and deliverables in accordance with the following Sections. EVERGREEN shall also supply NREL with samples of EVERGREEN cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, EVERGREEN shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. EVERGREEN shall provide deliverables according to the following schedule:

#### PHASE I

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant. (Task 1)	2	October 31, 2002
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	October 31, 2002
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		October 31, 2002
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		October 31, 2002
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		October 31, 2002
D-1.1.6	Report on feasibility of a simple optical method for oxide determination. (Task 2)		October 31, 2002
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	October 31, 2002
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		October 31, 2002
D-1.1.9	Report describing design for prototype machine. (Task 6)		October 31, 2002
D-1.1.10	Example of thinner backskin sheets. (Task 8)		October 31, 2002

D-1.2.1	Report on installation of mixing equipment. (Task 1)		October 31, 2002
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	October 31, 2002
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	October 31, 2002
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		October 31, 2002
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		October 31, 2002
D-1.2.6	Report on dielectric layers selected. (Task 5)		October 31, 2002
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		October 31, 2002
D-1.2.8	One cell from prototype machine. (Task 6)	1	October 31, 2002
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		October 31, 2002
D-1.2.10	Report on ink choice. (Task 9)		October 31, 2002
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		October 31, 2002
D-1.3.1	Report on coating with reduced permeability. (Task 3)		January 31, 2003
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		January 31, 2003
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		January 31, 2003
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		January 31, 2003
D-1.3.5	One backskin sample. (Task 8)	1	January 31, 2003
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		January 31, 2003
D-1.3.7	Report on completed accelerated tests. (Task 9)		January 31, 2003
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		March 31, 2003

D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		March 31, 2003
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		March 31, 2003
D-1.4.4	One >15% R&D cell. (Task 3)	1	March 31, 2003
D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		March 31, 2003
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		March 31, 2003
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	March 31, 2003
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		March 31, 2003
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	March 31, 2003
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		March 31, 2003
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	March 31, 2003

## PHASE II

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		June 30, 2003
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		June 30, 2003
D-2.1.3	Report on design of production-worthy decal application machine. (Task 13)		June 30, 2003
D-2.1.4	Report on parameters for glass/encapsulant lamination. (Task 14)		June 30, 2003
D-2.1.5	Report on choice of method to modify backskin. (Task 15)		June 30, 2003
D-2.2.1	Report on hot zone redesign. (Task 10)		September 30, 2003
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)		September 30, 2003

D-2.2.3	One oxide free ribbon sample. (Task 12)	1	September 30, 2003
D-2.2.4	Report on parameters for cell/backskin lamination. (Task 14)		September 30, 2003
D-2.2.5	Report on method to modify backskin. (Task 15)		September 30, 2003
D-2.2.6	Report on design of backskin modification machine. (Task 16)		September 30, 2003
D-2.2.7	Report on identification of pick and place robot. (Task 18)		September 30, 2003
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)		December 31, 2003
D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		December 31, 2003
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		December 31, 2003
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		December 31, 2003
D-2.3.5	Report on hot roll lamination process for full module. (Task 14)		December 31, 2003
D-2.3.6	One typical full module produced with hot roll lamination process. (Task 14)	1	December 31, 2003
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		December 31, 2003
D-2.3.8	Report on development of backskin modification machine. (Task 16)		December 31, 2003
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		December 31, 2003
D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		December 31, 2003
D-2.3.11	Report on pick and place machine design. (Task 18)		December 31, 2003
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		December 31, 2003
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		March 31, 2004
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	March 31, 2004

D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		March 31, 2004
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	March 31, 2004
D-2.4.5	Report on process to make frameless modules. (Task 15)		March 31, 2004
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		March 31, 2004
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		March 31, 2004
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	March 31, 2004
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		March 31, 2004
D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		March 31, 2004

### PHASE III

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		June 30, 2004
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		September 30, 2004
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	September 30, 2004
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		September 30, 2004
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		September 30, 2004
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		December 31, 2004
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		December 31, 2004

D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	December 31, 2004
D-3.3.5	Report on speed and quality demonstration. (Task 24)		December 31, 2004
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		March 31, 2005
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	March 31, 2005
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		March 31, 2005
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		March 31, 2005
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	March 31, 2005
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		March 31, 2005
D-3.4.5	Report on yield demonstration. (Task 24)		March 31, 2005
D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		March 31, 2005
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		March 31, 2005
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		March 31, 2005
D-3.4.9	Report on module fabrication yield. (Task 27)		March 31, 2005
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	March 31, 2005

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered as one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### **5.3 REPORTING REQUIREMENTS**

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

### **5.4 REQUIRED REPORTS**

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of

performance start date is January 10, then January is the first full month for reporting purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

#### **A. MONTHLY TECHNICAL STATUS REPORT:**

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

#### **B. ANNUAL TECHNICAL PROGRESS REPORT**

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

## C. FINAL TECHNICAL REPORT

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

### 6.0 Electronic Reporting Requirements for Subcontract Report Deliverables:

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the deliverable schedule of this Statement of Work in accordance with the following electronic reporting requirements:

- a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document. The electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the

deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

- b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).
- c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:
  - Microsoft Word (v.6.0 or newer for PC or MAC)
  - WordPerfect (v.6.1 or newer for PC)
  - Microsoft PowerPoint
  - Microsoft Excel
- d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files\*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:
  - QuarkXPress (.qxd)
  - Photoshop (.psd)
  - Freehand (.fh)
  - Framemaker (.fm)
  - Pagemaker (.pm)
  - Illustrator (.ai)
  - Corel Draw (.cdr)
  - Microsoft Publisher(.pub)

\*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.

- e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

- f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.
- g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.
- h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

## 7.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**LETTER SUBCONTRACT NO. ZDO-2-30628-09  
UNDER  
PRIME CONTRACT NO. DE-AC36-99-GO10337**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**TYPE OF LETTER SUBCONTRACT:** COST SHARING - PHASED

**ANTICIPATED TYPE OF  
DEFINITIZED SUBCONTRACT:** COST SHARING- PHASED

**LETTER SUBCONTRACT  
PERIOD OF PERFORMANCE:** EXECUTION DATE THROUGH THREE (3) MONTHS

**ANTICIPATED DEFINITIZED  
SUBCONTRACT PERIOD  
OF PERFORMANCE:** PHASE I: EFFECTIVE DATE THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>LETTER SUBCONTRACT NOT-TO-EXCEED AMOUNT:</b>	NREL	SUBCONTRACTOR'S	
	<u>AMOUNT</u>	<u>COST SHARE</u>	<u>TOTAL</u>
	\$750,000.00 - 50%	\$750,000.00 - 50%	\$1,500,000.00 - 100%

<b>ANTICIPATED DEFINITIZED SUBCONTRACT ESTIMATED AMOUNT:</b>	NREL	SUBCONTRACTOR'S		
	<u>AMOUNT</u>	<u>COST SHARE</u>	<u>TOTAL</u>	
	PHASE I:	\$ 999,833.00 - 50%	\$ 999,834.00 - 50%	\$1,999,667.00 - 100%
	PHASE II:	\$ 998,805.00 - 50%	\$ 998,804.00 - 50%	\$1,997,609.00 - 100%
	PHASE III:	<u>\$ 999,565.00 - 50%</u>	<u>\$ 999,565.00 - 50%</u>	<u>\$1,999,130.00 - 100%</u>
TOTAL PRICE:	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00 - 100%	

**PAYMENT TERMS:** NET 30 DAYS

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:** \$750,000.00 - PVP26282

September 26, 2002

Evergreen Solar, Inc.  
259 Cedar Hill Street  
Marlboro, MA 01752

Attention: Rich Chleboski, Vice President

SUBJECT: Letter Subcontract No. ZD0-2-30628-09 entitled "Innovative Approaches to Low Cost Module Manufacturing of String Ribbon Si PV Modules"

Dear Mr. Chleboski:

This letter subcontract is effective upon execution between the Midwest Research Institute acting through its National Renewable Energy Laboratory Division (hereinafter called "NREL"), and Evergreen Solar, Inc., (hereinafter called the "Subcontractor") whose principal offices are located in Marlboro, Massachusetts.

Midwest Research Institute has entered into Contract No. DE-AC36-99GO10337 with the Department of Energy (hereinafter called "DOE"), an agency of the U.S. Government (hereinafter called the "Government"), for the operation and management of the National Renewable Energy Laboratory. This letter subcontract is entered into in furtherance of the performance of the work provided for in the Prime Contract.

The purpose of this letter subcontract is to allow the Subcontractor to begin work as of the effective date (execution date by NREL) on research and development entitled "Innovative Approaches to Low Cost Module Manufacturing of String Ribbon Si PV Modules."

This cost-sharing letter subcontract is written in anticipation of a definitized cost-sharing subcontract and will be in effect only until a definitive subcontract can be put in place. The first three months of Phase I of the anticipated definitized subcontract will be performed under this letter subcontract in the amount not to exceed \$1,500,000.00 of allowable and allocable costs. It is estimated that the allotted amount will cover the three (3) month period of performance of this letter subcontract, effective from the execution date by NREL. It is agreed by the parties hereto that said total not to exceed amount for this letter subcontract (and for the first three months of Phase I of the anticipated definitized subcontract) shall be shared as follows:

Estimated NREL Share:	\$ 750,000.00 - 50%
Estimated Subcontractor Share:	<u>\$ 750,000.00</u> - 50%
Total:	\$1,500,000.00 - 100%

This cost sharing formula shall also apply (on the percentage basis shown above) to any increase or decrease in the estimated total cost of the letter subcontract performance, changes under the "Changes" clause and/or terminations under the "Terminations" clause contained in Appendix B.

The following clauses are included in this letter subcontract and are in full force and effect:

**A. Execution, Commencement of Work, and Period of Performance**

1. The Subcontractor shall indicate acceptance of this letter subcontract by signing three (3) copies of the letter subcontract and returning them to Christie Johnson, Subcontract Administrator, no later than 09/30/02. Upon acceptance by both parties, the Subcontractor shall proceed with performance of the work described in Appendix A, including purchase of necessary materials.
2. The period of performance under this letter subcontract shall be the effective date through three (3) months.
3. The period of performance under the anticipated definitized subcontract shall be as follows:
  - a. Phase I: Effective Date through 03/31/03  
Phase II: 04/01/03 through 03/31/04  
Phase III: 04/01/04 through 05/31/05
  - b. Each of these periods may be extended by mutual written agreement of the parties. NREL will make a decision based on its sole judgment, whether or not to authorize the next Phase prior to the completion date of the current Phase. If all Phases are authorized by NREL, the total period of performance for the anticipated definitized subcontract would be through 05/31/05. If NREL should decide not to authorize a Phase, the anticipated definitized subcontract shall be considered complete upon submittal of the final version of the Annual Technical Report, with corrections as specified by NREL, if any.

**B. Limitation of NREL Liability**

1. In performing this letter subcontract, the Subcontractor is not authorized to make expenditures or incur obligations exceeding One Million Five Hundred Thousand Dollars and No Cents (\$1,500,000.00), said amount to include the Estimated NREL Share of Seven Hundred Fifty Thousand Dollars and No Cents (\$750,000.00) and Estimated Subcontractor Share of Seven Hundred Fifty Thousand Dollars and No Cents (\$750,000.00).
2. The maximum amount for which NREL shall be liable if this letter subcontract is terminated or a definitized subcontract is not completed is Seven Hundred Fifty Thousand Dollars and No Cents (\$750,000.00).
3. The Subcontractor shall be paid for the work conducted under this letter subcontract in accordance with the clause entitled "Allowable Cost and Payment" contained in Appendix B, the clause entitled "Payments of Allowable Costs Before Definitization," and the clause entitled "Date of Incurrence of Cost" in this letter subcontract. The Subcontractor is cautioned that, subject to the provisions of the clauses entitled "Limitation of Funds" and "Limitation of Cost" contained in Appendix B, NREL is not obligated to reimburse the

Subcontractor for costs incurred in excess of the estimated NREL share set forth in Paragraph 2 above.

4. Pursuant to the clause entitled "Limitation of Funds" in Appendix B, the amount of \$750,000.00 has been allotted and is available for payment of NREL's estimated share of allowable costs under this letter subcontract. It is estimated that the allotted amount will cover work under this letter subcontract through December 31, 2002.
5. The amount of \$750,000.00, presently obligated by NREL with respect to this letter subcontract, may be unilaterally increased by NREL by written notice to the Subcontractor, and may be increased or decreased by written agreement of the parties by formal modification of this letter subcontract.
6. The giving of any notice by either party under this letter Subcontract or the clauses entitled "Limitation of Funds" and "Limitation of Costs" in Appendix B, as applicable, shall not be construed to waive or impair any rights of NREL to terminate this letter subcontract under the provisions of the termination clause(s) contained in Appendix B.
7. The "Limitations of Funds" clause contained in Appendix B shall be operable during such time that NREL incrementally allots additional funds to this letter subcontract as set forth above. (The Limitations of Cost clause shall be inoperable during such time.)
8. The "Limitations of Cost" clause contained in Appendix B shall become operable at such time that NREL allots to this letter subcontract an amount equal to the total estimated NREL cost share set forth above. (The Limitations of Funds clause shall be inoperable at such time.)

**C. Subcontract Definitization**

1. A cost sharing definitized subcontract is contemplated. The Subcontractor has begun negotiating with the Subcontract Administrator the terms of a definitized subcontract that will include:
  - a. Satisfactory completion of a Pre-award Audit of the Indirect Rates and Accounting System of Evergreen Solar, Inc.
  - b. The following appendices which also apply to the work done under this letter subcontract, except payment shall be governed by Paragraph D of this letter subcontract:
    - (1) Appendix A, Statement of Work, dated 09/18/02;
    - (2) Appendix B-1, Standard Terms and Conditions for a Cost Sharing Subcontract, dated 07/24/00;
    - (3) Appendix C-2 Intellectual Property Provisions for a Domestic Small Business, dated 10/22/98; and,

- (4) Appendix D-1, Clauses for Subcontracts in Excess of \$500,000, dated 07/28/00.
  - c. All clauses required by law on the date of execution of the definitive subcontract, and,
  - d. Any other mutually agreeable clauses, terms, and conditions. If determined necessary by the Subcontract Administrator, the Subcontractor agrees to submit a revised proposal and cost or pricing data supporting its proposal.
2. The schedule for definitizing this letter subcontract is as follows:
- |  |   |
|--|---|
| Begin negotiations of the Definitized Subcontract: | Date of Execution of Letter Subcontract                       |
| Certificate of Current Cost or Pricing Data:       | Upon Completion of Negotiations                               |
| Execute Definitized Subcontract:                   | Three (3) Months from Date of Execution of Letter Subcontract |
3. If agreement on a definitized subcontract to supersede this letter subcontract is not reached by the target date in Paragraph 2 above, or within any extension granted by NREL, the Subcontract Administrator may determine a reasonable cost for this letter subcontract in accordance with Subpart 15.4 and Part 31 of the Federal Acquisition Regulation (FAR), as supplemented by Part 931 of the Department of Energy Acquisition Regulation (DEAR), subject to Subcontractor appeal as provided in the Disputes clause of Appendix B-1. In any event, the Subcontractor shall proceed with completion of the letter subcontract, subject only to the Limitation of NREL Liability clause.
- a. In the event agreement on a definitized subcontract is not reached, and after the Subcontract Administrator's determination of cost, the subcontract shall be governed by:
    - (1) Appendix A, Statement of Work, dated 09/18/02;
    - (2) Appendix B-1, Standard Terms and Conditions for Cost Sharing Subcontracts, dated 07/24/00;
    - (3) Appendix C-2, Intellectual Property Provisions for a Domestic Small Business, dated 10/22/98; and,
    - (4) Appendix D-1, Clauses for Subcontracts in Excess of \$500,000, dated 07/28/00.
  - b. All clauses required by law as of the date of the Subcontract Administrator's determination; and
  - c. Any other clauses, terms and conditions mutually agreed upon.
  - d. To the extent consistent with Subparagraph 3.a. above, all clauses, terms and

conditions included in this letter subcontract shall continue in effect, except those that by their nature apply only to a letter subcontract.

**D. Payments of Allowable Costs Before Definitization**

1. Reimbursement rate. Pending the placing of the definitized subcontract referred to in this letter subcontract, NREL shall promptly reimburse the Subcontractor for all allowable costs under this letter subcontract at the following rates:
  - a. One hundred percent (100%) of approved costs representing progress payments to lower-tier subcontractors under fixed-price subcontracts; provided, that NREL's payments to the Subcontractor shall not exceed eighty percent (80%) of the allowable costs of those lower-tier subcontractors.
  - b. One hundred percent (100%) of approved costs representing cost reimbursement lower-tier subcontracts; provided, that NREL's payments to the Subcontractor shall not exceed eighty-five percent (85%) of the allowable costs of those lower-tier subcontractors.
  - c. Eighty-five percent (85%) of all other approved costs.
2. Limitation of Reimbursement. To determine the amounts payable to the Subcontractor under this letter subcontract, the Subcontract Administrator shall determine allowable costs in accordance with the applicable cost principles in Part 31 of the FAR as supplemented by Part 931 of the DEAR. The total reimbursement made under this paragraph shall not exceed eighty-five percent (85%) of the maximum amount of NREL's liability, as stated in this letter subcontract.
3. Invoicing. Payments shall be made promptly to the Subcontractor when requested as work progresses but (except for small business concerns) not more often than every two weeks, in amounts approved by the Subcontract Administrator. The Subcontractor may submit to an authorized representative of the Subcontract Administrator, in such form and reasonable detail as the representative may require, an invoice in an **ORIGINAL AND ONE (1) COPY**, supported by a statement of the claimed allowable cost incurred by the Subcontractor in the performance of this letter subcontract. Invoices shall be submitted to:

National Renewable Energy Laboratory  
Attn: Ms. Carolyn Lopez, Contracts Associate  
MS 2713, 1617 Cole Blvd.  
Golden, CO 80401-3393

Each invoice shall indicate the current and cumulative costs incurred broken down by cost categories (cost elements). The cost category for lower-tier subcontracts shall indicate the total costs incurred for each lower-tier subcontract.

An authorized official of the Subcontractor shall sign the following certification on each invoice submitted for payment:

"I certify that this invoice is correct and proper for payment, and reimbursement for these costs has not and will not be received under any other Government contract or subcontract or other source of Government funds.

\_\_\_\_\_  
Authorized Official

\_\_\_\_\_  
Date"

4. Allowable Costs. For the purpose of determining allowable costs, the term "costs" includes:
  - a. Those recorded costs that result, at the time of the request for reimbursement, from payment by cash, check, or other form of actual payment for items or services purchased directly for the subcontract;
  - b. When the Subcontractor is not delinquent in payment of costs of letter subcontract performance in the ordinary course of business, costs incurred, but not necessarily paid, for:
    - (1) Materials issued from the Subcontractor's stores inventory and placed in the production process for use on the subcontract;
    - (2) Direct labor;
    - (3) Direct travel;
    - (4) Other direct in-house costs; and
    - (5) Properly allocable and allowable indirect costs as shown on the records maintained by the Subcontractor for purposes of obtaining reimbursement under Government contracts or subcontracts; and
  - c. The amount of progress payments that have been paid to the Subcontractor's lower-tier subcontractors under similar cost standards.
5. Audit. At any time before final payment, the Subcontract Administrator may have the Subcontractor's invoices and statements of costs audited. Any payment may be (a) reduced by any amounts found by the Subcontract Administrator not to constitute allowable costs, or (b) adjusted for overpayments or underpayments made on preceding invoices.
6. Waiver of Facilities Capital Cost of Money. The Subcontractor did not include facilities capital cost of money as a proposed cost of this letter subcontract. Therefore, it is an unallowable cost under this letter subcontract.

**E. Indirect Rates**

1. In accordance with the clause entitled "Allowable Costs", the following rates shall be applied as ceiling rates to the allowable costs for the recovery of indirect costs against this letter subcontract

if upon completion, finalization and negotiation of the actual indirect rates for the appropriate periods covered by this letter subcontract, the actual indirect rates exceed the following ceiling rates:

<u>Category</u>	<u>Letter Subcontract Period Covered</u>	<u>Rate</u>	<u>Base</u>
Labor Overhead	10/01/01 through 12/31/02	25%	Direct Labor
G&A	10/01/01 through 12/31/02	30%	Total Costs minus equipment

2. The Subcontractor is cautioned that NREL shall not be obligated to reimburse the Subcontractor for indirect or direct costs incurred in excess of the allotted amount set forth above. This shall also apply to overruns created by an indirect rate fluctuation that the Subcontractor, as a prudent businessperson, should have been aware of, and should have informed NREL of, at the time.

**F. Date of Incurrence of Cost**

The Subcontractor shall be entitled to reimbursement for costs incurred in a total amount not to exceed \$800,000.00 (\$400,000.00 NREL cost share and \$400,000.00 subcontractor cost share) on or after October 1, 2001 which, if incurred after this subcontract has been entered into, would have been reimbursable under the provisions of this subcontract.

**G. Subcontractor Acquired Property and Title**

Unless otherwise specified herein, all material, supplies, and equipment shall be procured with funds allocated as the Subcontractor's Cost Share participation. Therefore, title to such materials, supplies, and equipment shall remain with the Subcontractor. The retention of title to such materials, supplies, and equipment with the Subcontractor shall be subject to the conditions below.

- A. The Subcontractor shall not charge depreciation, amortization, or use charges for the equipment, supplies, or materials under any other Federal Government contract, subcontract, cooperative agreement, or grant either currently or in the future.
- B. Said equipment, supplies, or materials shall be used for the benefit of research and development under this subcontract and any extension hereto.

**H. Order of Precedence**

Any inconsistency in this letter subcontract, shall be resolved by giving precedence in the following order:

1. This Letter Subcontract Schedule;
2. Statement of Work (Appendix A);
3. Standard Terms and Conditions (Appendix B-1);

4. Intellectual Property Provisions (Appendix C-2);
5. Clauses for Subcontracts in Excess of \$500,000 (Appendix D-1);
6. Other provisions of this letter subcontract whether incorporated by reference or otherwise; and,
7. The Subcontractor's technical proposal, if incorporated in this letter subcontract by reference or otherwise.

**I. Letter Subcontract Administration Responsibilities**

1. **Signature Authority:** This subcontract may only be modified by a formal modification signed by an authorized official of NREL.
2. **Subcontract Administration Responsibilities:** The authorized official of NREL has designated Christie Johnson, as the Subcontract Administrator for this subcontract with the responsibilities for subcontract administration and negotiation of any modifications to this subcontract. The Subcontract Administrator's telephone number is (303) 384-7394.
3. **Technical Monitoring Responsibilities:** The authorized official of NREL has designated Dave Mooney, as the Technical Monitor for this subcontract with the responsibilities of monitoring the technical work or services to be performed under this subcontract. The Technical Monitor does not have the authority to make any commitments or authorize any changes which may affect the subcontract's cost, scope of work, terms, or conditions. Any such changes shall be referred to the Subcontract Administrator designated in Paragraph B above. The Technical Monitor's telephone number is (303) 384-6782.

**J. Key Personnel**

1. It having been determined that the individuals, whose names appear below, are necessary for the successful performance of this subcontract, the Subcontractor agrees to assign or have assigned such individuals to the performance of the work under this subcontract and shall not reassign or remove any of them without the consent of the Subcontract Administrator by modification to this subcontract:

<u>Name</u>	<u>Project Title</u>	<u>Telephone No.</u>
Dr. Jack Hanoka	Principal Investigator	(508) 357-2221
Rich Chleboski	Vice President	(508) 357-2221

2. Whenever, for any reason, one or more of the designated key personnel designated above, is unavailable for assignment for work under this subcontract, the Subcontractor shall, with the approval of the Subcontract Administrator, replace such individual with an individual of substantially equal abilities and qualifications.

**K. Rights to Proposal Data**

Except for technical data contained on the pages (none) of the subcontractor's proposal dated 10/09/00, which are asserted by the Subcontractor as being proprietary data, it is agreed that, as a condition of the award of this subcontract, and notwithstanding the provisions of any notice appearing on the proposal, the Government and NREL shall have the right to use, duplicate, disclose and have others do so for any purpose whatsoever, the technical data contained in the proposal upon which this subcontract is based.

IN WITNESS WHEREOF, the parties hereto have executed this letter subcontract effective as of the date executed by NREL below.

Sincerely,

Christie Johnson  
Sr. Subcontract Administrator

ACCEPTED: EVERGREEN SOLAR, INC.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: *Rohana Chelvan*

BY: *Daniel J. Comel*

TITLE: *Vice President*

TITLE: *Director, Contracts & Business Services*

DATE: 09/27/02

DATE: 09/27/02

**Appendix A**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module Manufacturing  
of String Ribbon Si PV Modules**  
ZDO-2-30628-09  
September 18, 2002

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 – 1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Scale-Up Of A Production Worthy Doping Method**

EVERGREEN shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing. This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study

various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II**

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to

reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Continuous Lamination Process**

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum lamination process.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the

backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005".

### **3.19 Task 19 In-Line Diagnostics-2**

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSVIEW into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

## **PHASE III**

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune

module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14% Efficient Wrap-around Contact Cells**

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

### **3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine**

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Design And Develop An Improved Small, High Voltage Module**

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.

### **3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules**

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

### **3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine**

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

### **3.26 Task 26 In Line Diagnostics-3**

EVERGREEN shall continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

### **3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules**

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

#### 4.0 PROGRAM PLAN

The subcontracted research shall be conducted at EVERGREEN. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by EVERGREEN according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

##### PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	X	X	X	X	X				
Task 2	X	X	X	X					
Task 3	X	X	X	X	X	X	∇		
Task 4									
Task 5	X	X	X	X	X	X	∇		
Task 6	X	X	X	X	X	X			
Task 7	X	X	X	X	X	X	∇		
Task 8	X	X	X	X	X	X	∇		
Task 9	X	X	X	X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

EVERGREEN shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	∇		
Task 13	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 14			X	X	X	X	X	X	X					
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	∇		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	∇		
Monthly Reports	15th													
Annual Report												draft 15th		final 30th

**Phase III**

EVERGREEN shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 20							X	X	X	X	X	∇		
Task 21										X	X	∇		
Task 22	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	∇		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	∇		
Task 27									X	X	X	∇		
Monthly Reports		15th												
Annual Report												draft 15th		Final 30th

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. EVERGREEN shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

**PHASE II**

Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	(Task 11)
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	(Task 11)
m-2.1.3	Production-worthy decal application machine designed	(Task 13)
m-2.1.4	Establish parameters for glass/encapsulant lamination	(Task 14)
m-2.1.5	Identify method to modify backskin for higher impermeability	(Task 15)

### Milestones due no later than September 30, 2003

- |         |   |           |
|---------|---|-----------|
| m-2.2.1 | Establish hot zone redesign                       | (Task 10) |
| m-2.2.2 | Demonstrate growth of oxide free ribbon           | (Task 11) |
| m-2.2.3 | Establish parameters for cell/backskin lamination | (Task 14) |
| m-2.2.4 | Develop method to modify backskin                 | (Task 15) |
| m-2.2.5 | Complete design of backskin modification machine  | (Task 16) |
| m-2.2.6 | Complete identification of pick and place robot   | (Task 18) |

### Milestones due no later than December 31, 2003

- |          |   |           |
|----------|---|-----------|
| m-2.3.1  | Complete design and implementation of vibration damping             | (Task 10) |
| m-2.3.2  | Complete design and deployment of boat for double sided passivation | (Task 12) |
| m-2.3.3  | Demonstrate adequate firing through of Al paste                     | (Task 12) |
| m-2.3.4  | Decal application machine developed and tested                      | (Task 13) |
| m-2.3.5  | Establish process for full module lamination                        | (Task 14) |
| m-2.3.6  | Identify method to form backskin edge                               | (Task 15) |
| m-2.3.7  | Complete development of backskin modification machine               | (Task 16) |
| m-2.3.8  | Decision on monolithic module manufacturing method                  | (Task 17) |
| m-2.3.9  | Complete design of pick and place machine                           | (Task 18) |
| m-2.3.10 | Complete design for automatic bulk resistivity measurement          | (Task 19) |

### Milestones due no later than March 31, 2004

- |         |  |           |
|---------|--|-----------|
| m-2.4.1 | Complete dislocation maps                                      | (Task 10) |
| m-2.4.2 | Demonstrate fabrication of 13% cells                           | (Task 12) |
| m-2.4.3 | Establish data processing for decal application machine        | (Task 13) |
| m-2.4.4 | Develop method to form backskin edge                           | (Task 15) |
| m-2.4.5 | Complete design of machine to form sealed leads                | (Task 16) |
| m-2.4.6 | Complete development of machine to form sealed leads           | (Task 16) |
| m-2.4.7 | Complete development of monolithic module manufacturing method | (Task 17) |
| m-2.4.8 | Complete development of automatic bulk resistivity measurement | (Task 19) |
| m-2.4.9 | Complete incorporation of RS View in module machine designs    | (Task 19) |

## PHASE III

### Milestones due no later than June 30, 2004

m-3.1.1 Complete debug of robotic pick and place machine (Task 25)

### Milestones due no later than September 30, 2004

m-3.2.1 Complete debug of wrap-around decal application machine (Task 22)

m-3.2.2 Demonstrate viability of laser cutting small cells from large cells (Task 23)

m-3.2.3 Complete running of robotic pick and place machine (Task 25)

m-3.2.4 Complete demonstration of positional accuracy and repeatability (Task 25)

### Milestones due no later than December 31, 2004

m-3.3.1 Demonstrate impurity reduction on production machine (Task 20)

m-3.3.2 Demonstrate dislocation reduction on production machine (Task 20)

m-3.3.3 Complete reliability studies on high-voltage small modules (Task 23)

m-3.3.4 Complete automation for high-voltage small modules (Task 23)

m-3.3.5 Complete speed and quality demonstration for manufacture of frameless, monolithic module (Task 24)

### Milestones due no later than March 31, 2005

m-3.4.1 Demonstrate starting lifetimes of 5 to >10 microseconds (Task 20)

m-3.4.2 Advances made in Tasks 12 and 20 brought together (Task 21)

m-3.4.3 Demonstrate 14% wrap-around contact cells (Task 21)

m-3.4.4 Complete testing of wrap-around decal application machine (Task 22)

m-3.4.5 Complete yield demonstration for manufacture of frameless, monolithic module (Task 24)

m-3.4.6 Complete development of RS View on all automated machines for modules (Task 26)

m-3.4.7 Complete integration of all inputs into a central collection point (Task 26)

m-3.4.8 Complete demonstration of manufacturing capability (Task 27)

m-3.4.9 Demonstrate capability to make 100 modules at a yield 99% (Task 27)

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

EVERGREEN shall prepare and submit reports and deliverables in accordance with the following Sections. EVERGREEN shall also supply NREL with samples of EVERGREEN cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, EVERGREEN shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. EVERGREEN shall provide deliverables according to the following schedule:

#### PHASE I

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant. (Task 1)	2	October 31, 2002
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	October 31, 2002
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		October 31, 2002
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		October 31, 2002
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		October 31, 2002
D-1.1.6	Report on feasibility of a simple optical method for oxide determination. (Task 2)		October 31, 2002
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	October 31, 2002
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		October 31, 2002
D-1.1.9	Report describing design for prototype machine. (Task 6)		October 31, 2002
D-1.1.10	Example of thinner backskin sheets. (Task 8)		October 31, 2002

D-1.2.1	Report on installation of mixing equipment. (Task 1)		October 31, 2002
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	October 31, 2002
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	October 31, 2002
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		October 31, 2002
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		October 31, 2002
D-1.2.6	Report on dielectric layers selected. (Task 5)		October 31, 2002
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		October 31, 2002
D-1.2.8	One cell from prototype machine. (Task 6)	1	October 31, 2002
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		October 31, 2002
D-1.2.10	Report on ink choice. (Task 9)		October 31, 2002
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		October 31, 2002
D-1.3.1	Report on coating with reduced permeability. (Task 3)		January 31, 2003
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		January 31, 2003
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		January 31, 2003
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		January 31, 2003
D-1.3.5	One backskin sample. (Task 8)	1	January 31, 2003
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		January 31, 2003
D-1.3.7	Report on completed accelerated tests. (Task 9)		January 31, 2003
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		March 31, 2003

D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		March 31, 2003
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		March 31, 2003
D-1.4.4	One >15% R&D cell. (Task 3)	1	March 31, 2003
D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		March 31, 2003
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		March 31, 2003
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	March 31, 2003
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		March 31, 2003
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	March 31, 2003
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		March 31, 2003
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	March 31, 2003

## PHASE II

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		June 30, 2003
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		June 30, 2003
D-2.1.3	Report on design of production-worthy decal application machine. (Task 13)		June 30, 2003
D-2.1.4	Report on parameters for glass/encapsulant lamination. (Task 14)		June 30, 2003
D-2.1.5	Report on choice of method to modify backskin. (Task 15)		June 30, 2003
D-2.2.1	Report on hot zone redesign. (Task 10)		September 30, 2003
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)		September 30, 2003

D-2.2.3	One oxide free ribbon sample. (Task 12)	1	September 30, 2003
D-2.2.4	Report on parameters for cell/backskin lamination. (Task 14)		September 30, 2003
D-2.2.5	Report on method to modify backskin. (Task 15)		September 30, 2003
D-2.2.6	Report on design of backskin modification machine. (Task 16)		September 30, 2003
D-2.2.7	Report on identification of pick and place robot. (Task 18)		September 30, 2003
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)		December 31, 2003
D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		December 31, 2003
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		December 31, 2003
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		December 31, 2003
D-2.3.5	Report on hot roll lamination process for full module. (Task 14)		December 31, 2003
D-2.3.6	One typical full module produced with hot roll lamination process. (Task 14)	1	December 31, 2003
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		December 31, 2003
D-2.3.8	Report on development of backskin modification machine. (Task 16)		December 31, 2003
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		December 31, 2003
D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		December 31, 2003
D-2.3.11	Report on pick and place machine design. (Task 18)		December 31, 2003
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		December 31, 2003
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		March 31, 2004
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	March 31, 2004

D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		March 31, 2004
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	March 31, 2004
D-2.4.5	Report on process to make frameless modules. (Task 15)		March 31, 2004
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		March 31, 2004
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		March 31, 2004
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	March 31, 2004
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		March 31, 2004
D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		March 31, 2004

### PHASE III

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		June 30, 2004
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		September 30, 2004
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	September 30, 2004
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		September 30, 2004
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		September 30, 2004
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		December 31, 2004
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		December 31, 2004

D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	December 31, 2004
D-3.3.5	Report on speed and quality demonstration. (Task 24)		December 31, 2004
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		March 31, 2005
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	March 31, 2005
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		March 31, 2005
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		March 31, 2005
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	March 31, 2005
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		March 31, 2005
D-3.4.5	Report on yield demonstration. (Task 24)		March 31, 2005
D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		March 31, 2005
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		March 31, 2005
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		March 31, 2005
D-3.4.9	Report on module fabrication yield. (Task 27)		March 31, 2005
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	March 31, 2005

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### **5.3 REPORTING REQUIREMENTS**

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

### **5.4 REQUIRED REPORTS**

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of

performance start date is January 10, then January is the first full month for reporting purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

#### **A. MONTHLY TECHNICAL STATUS REPORT:**

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

#### **B. ANNUAL TECHNICAL PROGRESS REPORT**

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

## **B1 – Electronic Format Guidelines:**

List of format options to choose from for the electronic master.

- (1) Preferably, reports should include embedded graphics, such that they can be easily converted to a PDF format. Submit a word processing file prepared by one of the following: (a) WordPerfect or (b) MS Word (Mac, DOS, or windows).
- (2) If graphics cannot be embedded in the report file NREL prefers one of the following graphics formats: EPS, TIF, GIF, WPG, CGM, WMF, or PCT.
- (3) If presenting a portable document file (.PDF) format, please keep the file manageable, not beyond 1MB.

## **C. FINAL TECHNICAL REPORT**

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

## **6.0 PERFORMANCE EVALUATION**

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**Appendix A**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module Manufacturing  
of String Ribbon Si PV Modules**

ZDO-2-30628-09

June 19, 2002

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these

goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 –1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-year duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three one-year phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I - First Year**

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address development of a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells.

EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Development Of A Production Worthy Doping Method**

EVERGREEN shall develop a new doping method for feedstock silicon using liquid spin-on dopants.

To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine

### **3.7 Task 7 In-Line Diagnostics-1**

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II - Second Year**

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality

assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Continuous Lamination Process**

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum

lamination process.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005”.

### **3.19 Task 19 In-Line Diagnostics-2**

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSVIEW into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

### **PHASE III - Third Year**

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

#### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

#### **3.21 Task 21 14% Efficient Wrap-around Contact Cells**

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

#### **3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine**

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

#### **3.23 Task 23 Design And Develop An Improved Small, High Voltage Module**

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for

these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.

### **3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules**

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

### **3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine**

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

### **3.26 Task 26 In Line Diagnostics-3**

EVERGREEN shall continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

### **3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules**

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

## **4.0 PROGRAM PLAN**

The subcontracted research shall be conducted at EVERGREEN. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by EVERGREEN according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three one-year phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

##### PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during the first year, Phase I, of this subcontract according to the following schedule:

Months	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 1	X	X	X	X	X	X								
Task 2	X	X	X	X	X									
Task 3				X	X	X	X	X	X	X	X	X		
Task 4										X	X	X		
Task 5	X	X	X	X	X	X	X	X	X	X	X	X		
Task 6	X	X	X	X	X	X	X							
Task 7						X	X	X	X	X	X	X		
Task 8	X	X	X	X	X	X	X	X	X	X	X	X		
Task 9	X	X	X	X	X	X	X	X	X	X	X	X		
Monthly Reports		15th												
Annual Report												draft 15th		final 30th

##### PHASE II

EVERGREEN shall perform and complete Tasks 10 through 19 during the second year, Phase II, of this subcontract according to the following schedule:

Months	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 10	X	X	X	X	X	X	X	X	X	X	X	X		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	X		
Task 13	X	X	X	X	X	X	X	X	X	X	X	X		
Task 14			X	X	X	X	X	X	X					
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	X		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	X		
Monthly Reports		15th												
Annual Report												draft 15th		final 30th

### Phase III

EVERGREEN shall perform and complete Tasks 20 through 27 during the third year, Phase III, of this subcontract according to the following schedule:

Months	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 20							X	X	X	X	X	X		
Task 21										X	X	X		
Task 22	X	X	X	X	X	X	X	X	X	X	X	X		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	X		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	X		
Task 27									X	X	X	X		
Monthly Reports		15th												
Annual Report												draft 15th		final 30th

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three one-year phases of the subcontract. EVERGREEN shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the following schedule:

### PHASE I

#### Milestones due on September 30, 2002

- m-1.1.1 Demonstrate process steps for uniform mixing of dopant (Task 1)
- m-1.1.2 Grow ribbon with doped feedstock using demonstrated mixing procedure (Task 1)
- m-1.1.3 Demonstrate a suitable solvent drying procedure (Task 1)
- m-1.1.4 Show suitable transport in feeder (Task 1)
- m-1.1.5 Complete chemical and optical characterization of surface oxide (Task 2)
- m-1.1.6 Demonstrate feasibility of a simple optical method for oxide determination (Task 2)
- m-1.1.7 Concept for prototype decal application machine completed (Task 6)
- m-1.1.8 Design for prototype machine completed (Task 6)
- m-1.1.9 Thinner backskin sheets formulated (Task 8)

### Milestones due on December 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

### Milestones due on March 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

### Milestones due on June 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)

m-1.4.13 Complete accelerated tests (Task 9)

## PHASE II

### Milestones due on September 30, 2003

m-2.1.1 Demonstrate reduced oxygen in hot zone (Task 11)  
m-2.1.2 Design for alternate method to introduce Ar into the hot zone (Task 11)  
m-2.1.3 Production-worthy decal application machine designed (Task 13)  
m-2.1.4 Establish parameters for glass/encapsulant lamination (Task 14)  
m-2.1.5 Identify method to modify backskin for higher impermeability (Task 15)

### Milestones due on December 31, 2003

m-2.2.1 Establish hot zone redesign (Task 10)  
m-2.2.2 Demonstrate growth of oxide free ribbon (Task 11)  
m-2.2.3 Establish parameters for cell/backskin lamination (Task 14)  
m-2.2.4 Develop method to modify backskin (Task 15)  
m-2.2.5 Complete design of backskin modification machine (Task 16)  
m-2.2.6 Complete identification of pick and place robot (Task 18)

### Milestones due on March 31, 2004

m-2.3.1 Complete design and implementation of vibration damping (Task 10)  
m-2.3.2 Complete design and deployment of boat for double sided passivation (Task 12)  
m-2.3.3 Demonstrate adequate firing through of Al paste (Task 12)  
m-2.3.4 Decal application machine developed and tested (Task 13)  
m-2.3.5 Establish process for full module lamination (Task 14)  
m-2.3.6 Identify method to form backskin edge (Task 15)  
m-2.3.7 Complete development of backskin modification machine (Task 16)  
m-2.3.8 Decision on monolithic module manufacturing method (Task 17)  
m-2.3.9 Complete design of pick and place machine (Task 18)  
m-2.3.10 Complete design for automatic bulk resistivity measurement (Task 19)

### Milestones due on June 31, 2004

m-2.4.1 Complete dislocation maps (Task 10)  
m-2.4.2 Demonstrate fabrication of 13% cells (Task 12)

m-2.4.3	Establish data processing for decal application machine	(Task 13)
m-2.4.4	Develop method to form backskin edge	(Task 15)
m-2.4.5	Complete design of machine to form sealed leads	(Task 16)
m-2.4.6	Complete development of machine to form sealed leads	(Task 16)
m-2.4.7	Complete development of monolithic module manufacturing method	(Task 17)
m-2.4.8	Complete development of automatic bulk resistivity measurement	(Task 19)
m-2.4.9	Complete incorporation of RS View in module machine designs	(Task 19)

### PHASE III

#### Milestones due on September 30, 2004

m-3.1.1	Complete debug of robotic pick and place machine	(Task 25)
---------	--	-----------

#### Milestones due on December 31, 2004

m-3.2.1	Complete debug of wrap-around decal application machine	(Task 22)
m-3.2.2	Demonstrate viability of laser cutting small cells from large cells	(Task 23)
m-3.2.3	Complete running of robotic pick and place machine	(Task 25)
m-3.2.4	Complete demonstration of positional accuracy and repeatability	(Task 25)

#### Milestones due on March 31, 2005

m-3.3.1	Demonstrate impurity reduction on production machine	(Task 20)
m-3.3.2	Demonstrate dislocation reduction on production machine	(Task 20)
m-3.3.3	Complete reliability studies on high-voltage small modules	(Task 23)
m-3.3.4	Complete automation for high-voltage small modules	(Task 23)
m-3.3.5	Complete speed and quality demonstration for manufacture of frameless, monolithic module	(Task 24)

#### Milestones due on June 31, 2005

m-3.4.1	Demonstrate starting lifetimes of 5 to >10 microseconds	(Task 20)
m-3.4.2	Advances made in Tasks 12 and 20 brought together	(Task 21)
m-3.4.3	Demonstrate 14% wrap-around contact cells	(Task 21)
m-3.4.4	Complete testing of wrap-around decal application machine	(Task 22)
m-3.4.5	Complete yield demonstration for manufacture of frameless, monolithic module	(Task 24)
m-3.4.6	Complete development of RS View on all automated machines for modules	(Task 26)
m-3.4.7	Complete integration of all inputs into a central collection point	(Task 26)

- m-3.4.8 Complete demonstration of manufacturing capability (Task 27)
- m-3.4.9 Demonstrate capability to make 100 modules at a yield 99% (Task 27)

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

EVERGREEN shall prepare and submit reports and deliverables in accordance with the following Sections. EVERGREEN shall also supply NREL with samples of EVERGREEN cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, EVERGREEN shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three one-year phases of the subcontract. EVERGREEN shall provide deliverables according to the following schedule:

#### PHASE I

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on process steps for uniform mixing of dopant. (Task 1)		End of First Quarter
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	End of First Quarter
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		End of First Quarter
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		End of First Quarter
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		End of First Quarter
D-1.1.6	Report on feasibility of a simple optical method for oxide determination. (Task 2)		End of First Quarter
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	End of First Quarter
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		End of First Quarter
D-1.1.9	Report describing design for prototype machine. (Task 6)		End of First Quarter
D-1.1.10	Example of thinner backskin sheets. (Task 8)		End of First Quarter

D-1.2.1	Report on installation of mixing equipment. (Task 1)		End of Second Quarter
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	End of Second Quarter
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	End of Second Quarter
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		End of Second Quarter
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		End of Second Quarter
D-1.2.6	Report on dielectric layers selected. (Task 5)		End of Second Quarter
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		End of Second Quarter
D-1.2.8	One cell from prototype machine. (Task 6)	1	End of Second Quarter
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		End of Second Quarter
D-1.2.10	Report on ink choice. (Task 9)		End of Second Quarter
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		End of Second Quarter
D-1.3.1	Report on coating with reduced permeability. (Task 3)		End of Third Quarter
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		End of Third Quarter
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		End of Third Quarter
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		End of Third Quarter
D-1.3.5	One backskin sample. (Task 8)	1	End of Third Quarter
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		End of Third Quarter
D-1.3.7	Report on completed accelerated tests. (Task 9)		End of Third Quarter
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		End of Fourth Quarter
D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		End of Fourth Quarter
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		End of Fourth Quarter
D-1.4.4	One >15% R&D cell. (Task 3)	1	End of Fourth Quarter

D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		End of Fourth Quarter
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		End of Fourth Quarter
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	End of Fourth Quarter
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		End of Fourth Quarter
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	End of Fourth Quarter
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		End of Fourth Quarter
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	End of Fourth Quarter

## PHASE II

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		End of Fifth Quarter
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		End of Fifth Quarter
D-2.1.3	Report on design of production-worthy decal application machine. (Task 13)		End of Fifth Quarter
D-2.1.4	Report on parameters for glass/encapsulant lamination. (Task 14)		End of Fifth Quarter
D-2.1.5	Report on choice of method to modify backskin. (Task 15)		End of Fifth Quarter
D-2.2.1	Report on hot zone redesign. (Task 10)		End of Sixth Quarter
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)		End of Sixth Quarter
D-2.2.3	One oxide free ribbon sample. (Task 12)	1	End of Sixth Quarter
D-2.2.4	Report on parameters for cell/backskin lamination. (Task 14)		End of Sixth Quarter
D-2.2.5	Report on method to modify backskin. (Task 15)		End of Sixth Quarter
D-2.2.6	Report on design of backskin modification machine. (Task 16)		End of Sixth Quarter
D-2.2.7	Report on identification of pick and place robot. (Task 18)		End of Sixth Quarter
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)		End of Seventh Quarter

D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		End of Seventh Quarter
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		End of Seventh Quarter
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		End of Seventh Quarter
D-2.3.5	Report on hot roll lamination process for full module. (Task 14)		End of Seventh Quarter
D-2.3.6	One typical full module produced with hot roll lamination process. (Task 14)	1	End of Seventh Quarter
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		End of Seventh Quarter
D-2.3.8	Report on development of backskin modification machine. (Task 16)		End of Seventh Quarter
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		End of Seventh Quarter
D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		End of Seventh Quarter
D-2.3.11	Report on pick and place machine design. (Task 18)		End of Seventh Quarter
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		End of Seventh Quarter
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		End of Eighth Quarter
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	End of Eighth Quarter
D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		End of Eighth Quarter
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	End of Eighth Quarter
D-2.4.5	Report on process to make frameless modules. (Task 15)		End of Eighth Quarter
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		End of Eighth Quarter
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		End of Eighth Quarter
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	End of Eighth Quarter
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		End of Eighth Quarter

D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		End of Eighth Quarter
----------	---	--	-----------------------

**PHASE III**

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		End of Ninth Quarter
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		End of Tenth Quarter
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	End of Tenth Quarter
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		End of Tenth Quarter
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		End of Tenth Quarter
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		End of Eleventh Quarter
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		End of Eleventh Quarter
D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		End of Eleventh Quarter
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		End of Eleventh Quarter
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	End of Eleventh Quarter
D-3.3.5	Report on speed and quality demonstration. (Task 24)		End of Eleventh Quarter
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		End of Twelfth Quarter
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	End of Twelfth Quarter
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		End of Twelfth Quarter
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		End of Twelfth Quarter
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	End of Twelfth Quarter
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		End of Twelfth Quarter
D-3.4.5	Report on yield demonstration. (Task 24)		End of Twelfth Quarter

D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		End of Twelfth Quarter
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		End of Twelfth Quarter
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		End of Twelfth Quarter
D-3.4.9	Report on module fabrication yield. (Task 27)		End of Twelfth Quarter
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	End of Twelfth Quarter

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: C. Edwin Witt, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

EVERGREEN shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. EVERGREEN shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of EVERGREEN submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), EVERGREEN shall submit two (2) copies to the NREL Technical Monitor, **one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.** If EVERGREEN is other than a small business concern, educational institution, or non-profit organization who qualifies under P.L. 98-620, the subcontractor must also obtain DOE patent clearance in accordance with Clause 1— Patent Rights (Long Form), prior to any publication or presentation concerning this subcontract effort. EVERGREEN should allow at least sixty (60) days to obtain the appropriate technical and patent clearances for the publication or presentation.

EVERGREEN is reminded that the **technical approval** and the **patent clearance** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

EVERGREEN shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### 5.3 REPORTING REQUIREMENTS

EVERGREEN shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: C. Edwin Witt, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PVMaT and NREL Procurement requirements. One copy of these reports shall also be sent to the

Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

## 5.4 REQUIRED REPORTS

EVERGREEN shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes; whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

### A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report is to be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

### B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports are to be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each year of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each year's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see B1 Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following year is not authorized and funded by NREL, then that year's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for

that year shall be extended by three months to allow for the completion of this report as the Final Technical Report.

**B1 – Electronic Format Guidelines:**

List of format options to choose from for the electronic master.

- (1) Preferably, reports should include embedded graphics, such that they can be easily converted to a PDF format. Submit a word processing file prepared by one of the following: (a) Word perfect or (b) MS Word (Mac, DOS, or windows).
- (2) If graphics cannot be embedded in the report file we prefer one of the following graphics formats: EPS, TIF, GIF, WPG, CGM, WMF, or PCT.
- (3) If presenting a portable document file (.PDF) format, please keep the file manageable, not beyond 1MB.

**C. FINAL TECHNICAL REPORT**

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final year's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the Electronic Copies of the final version of this report.

**D. SMALL BUSINESS/SMALL DISADVANTAGED BUSINESS  
SUBCONTRACTING PLAN AND REPORTS**

The subcontractor shall submit the "Subcontracting Report for Individual Contracts" (Standard Form 294) semi-annually based upon the United States Government's fiscal year (October 1 through September 30). This report is due on or before the twenty-fifth (25<sup>th</sup>) day of the month following the close of the applicable month. This report shall be prepared in accordance with Standard Form 294 instructions. The original plus two (2) copies of this report shall be submitted to the Subcontract Associate. The subcontractor shall submit the "Summary Subcontract Report" (Standard Form 295) annually. This report is due on or before the twenty-fifth (25<sup>th</sup>) day of the month following the close of the applicable year. This report shall be prepared in accordance with Standard Form 295 instructions. The original plus two (2) copies of this report shall be submitted to the Subcontract Associate.

## 6.0 PERFORMANCE EVALUATION

The performance of EVERGREEN will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Monthly Subcontract Management Summary Reports prepared on NREL Form 619A;
- v) Up to two On-Site Visits by a PVMaT-selected evaluation team to EVERGREEN per phase  
- these visits shall entail presentations and demonstrations by EVERGREEN; and
- vi) Participation by EVERGREEN in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D (PVM R&D) project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PVM R&D review committee consisting of members selected by PVM R&D project management staff. These meetings will be critical program evaluation points. The progress of EVERGREEN will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of EVERGREEN will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**Appendix A**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module Manufacturing  
of String Ribbon Si PV Modules**

ZDO-2-30628-09  
September 18, 2002

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 – 1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address development of a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Development Of A Production Worthy Doping Method**

EVERGREEN shall develop a new doping method for feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study

various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II**

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to

reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Continuous Lamination Process**

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum lamination process.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the

backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005".

### **3.19 Task 19 In-Line Diagnostics-2**

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSView into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

## **PHASE III**

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune

module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14% Efficient Wrap-around Contact Cells**

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

### **3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine**

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Design And Develop An Improved Small, High Voltage Module**

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.

### **3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules**

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

### **3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine**

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

### **3.26 Task 26 In Line Diagnostics-3**

EVERGREEN shall continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

### **3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules**

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

## 4.0 PROGRAM PLAN

The subcontracted research shall be conducted at EVERGREEN. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by EVERGREEN according to the schedules detailed in the appropriate sections that follow.

### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

#### PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	X	X	X	X	X				
Task 2	X	X	X	X					
Task 3	X	X	X	X	X	X	∇		
Task 4									
Task 5	X	X	X	X	X	X	∇		
Task 6	X	X	X	X	X	X			
Task 7	X	X	X	X	X	X	∇		
Task 8	X	X	X	X	X	X	∇		
Task 9	X	X	X	X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

EVERGREEN shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	∇		
Task 13	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 14			X	X	X	X	X	X	X					
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	∇		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	∇		
Monthly Reports	15th													
Annual Report												draft 15th		final 30th

**Phase III**

EVERGREEN shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 20							X	X	X	X	X	∇		
Task 21										X	X	∇		
Task 22	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	∇		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	∇		
Task 27									X	X	X	∇		
Monthly Reports		15th												
Annual Report												draft 15th		Final 30th

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. EVERGREEN shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

### Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

### Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

## **PHASE II**

### Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	(Task 11)
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	(Task 11)
m-2.1.3	Production-worthy decal application machine designed	(Task 13)
m-2.1.4	Establish parameters for glass/encapsulant lamination	(Task 14)
m-2.1.5	Identify method to modify backskin for higher impermeability	(Task 15)

Milestones due no later than September 30, 2003

- m-2.2.1 Establish hot zone redesign (Task 10)
- m-2.2.2 Demonstrate growth of oxide free ribbon (Task 11)
- m-2.2.3 Establish parameters for cell/backskin lamination (Task 14)
- m-2.2.4 Develop method to modify backskin (Task 15)
- m-2.2.5 Complete design of backskin modification machine (Task 16)
- m-2.2.6 Complete identification of pick and place robot (Task 18)

Milestones due no later than December 31, 2003

- m-2.3.1 Complete design and implementation of vibration damping (Task 10)
- m-2.3.2 Complete design and deployment of boat for double sided passivation (Task 12)
- m-2.3.3 Demonstrate adequate firing through of Al paste (Task 12)
- m-2.3.4 Decal application machine developed and tested (Task 13)
- m-2.3.5 Establish process for full module lamination (Task 14)
- m-2.3.6 Identify method to form backskin edge (Task 15)
- m-2.3.7 Complete development of backskin modification machine (Task 16)
- m-2.3.8 Decision on monolithic module manufacturing method (Task 17)
- m-2.3.9 Complete design of pick and place machine (Task 18)
- m-2.3.10 Complete design for automatic bulk resistivity measurement (Task 19)

Milestones due no later than March 31, 2004

- m-2.4.1 Complete dislocation maps (Task 10)
- m-2.4.2 Demonstrate fabrication of 13% cells (Task 12)
- m-2.4.3 Establish data processing for decal application machine (Task 13)
- m-2.4.4 Develop method to form backskin edge (Task 15)
- m-2.4.5 Complete design of machine to form sealed leads (Task 16)
- m-2.4.6 Complete development of machine to form sealed leads (Task 16)
- m-2.4.7 Complete development of monolithic module manufacturing method (Task 17)
- m-2.4.8 Complete development of automatic bulk resistivity measurement (Task 19)
- m-2.4.9 Complete incorporation of RS View in module machine designs (Task 19)

### PHASE III

#### Milestones due no later than June 30, 2004

m-3.1.1 Complete debug of robotic pick and place machine (Task 25)

#### Milestones due no later than September 30, 2004

m-3.2.1 Complete debug of wrap-around decal application machine (Task 22)

m-3.2.2 Demonstrate viability of laser cutting small cells from large cells (Task 23)

m-3.2.3 Complete running of robotic pick and place machine (Task 25)

m-3.2.4 Complete demonstration of positional accuracy and repeatability (Task 25)

#### Milestones due no later than December 31, 2004

m-3.3.1 Demonstrate impurity reduction on production machine (Task 20)

m-3.3.2 Demonstrate dislocation reduction on production machine (Task 20)

m-3.3.3 Complete reliability studies on high-voltage small modules (Task 23)

m-3.3.4 Complete automation for high-voltage small modules (Task 23)

m-3.3.5 Complete speed and quality demonstration for manufacture of frameless, monolithic module (Task 24)

#### Milestones due no later than March 31, 2005

m-3.4.1 Demonstrate starting lifetimes of 5 to >10 microseconds (Task 20)

m-3.4.2 Advances made in Tasks 12 and 20 brought together (Task 21)

m-3.4.3 Demonstrate 14% wrap-around contact cells (Task 21)

m-3.4.4 Complete testing of wrap-around decal application machine (Task 22)

m-3.4.5 Complete yield demonstration for manufacture of frameless, monolithic module (Task 24)

m-3.4.6 Complete development of RS View on all automated machines for modules (Task 26)

m-3.4.7 Complete integration of all inputs into a central collection point (Task 26)

m-3.4.8 Complete demonstration of manufacturing capability (Task 27)

m-3.4.9 Demonstrate capability to make 100 modules at a yield 99% (Task 27)

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

EVERGREEN shall prepare and submit reports and deliverables in accordance with the following Sections. EVERGREEN shall also supply NREL with samples of EVERGREEN cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, EVERGREEN shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. EVERGREEN shall provide deliverables according to the following schedule:

#### PHASE I

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant. (Task 1)	2	October 31, 2002
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	October 31, 2002
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		October 31, 2002
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		October 31, 2002
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		October 31, 2002
D-1.1.6	Report on feasibility of a simple optical method for oxide determination. (Task 2)		October 31, 2002
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	October 31, 2002
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		October 31, 2002
D-1.1.9	Report describing design for prototype machine. (Task 6)		October 31, 2002
D-1.1.10	Example of thinner backskin sheets. (Task 8)		October 31, 2002

D-1.2.1	Report on installation of mixing equipment. (Task 1)		October 31, 2002
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	October 31, 2002
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	October 31, 2002
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		October 31, 2002
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		October 31, 2002
D-1.2.6	Report on dielectric layers selected. (Task 5)		October 31, 2002
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		October 31, 2002
D-1.2.8	One cell from prototype machine. (Task 6)	1	October 31, 2002
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		October 31, 2002
D-1.2.10	Report on ink choice. (Task 9)		October 31, 2002
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		October 31, 2002
D-1.3.1	Report on coating with reduced permeability. (Task 3)		January 31, 2003
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		January 31, 2003
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		January 31, 2003
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		January 31, 2003
D-1.3.5	One backskin sample. (Task 8)	1	January 31, 2003
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		January 31, 2003
D-1.3.7	Report on completed accelerated tests. (Task 9)		January 31, 2003
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		March 31, 2003

D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		March 31, 2003
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		March 31, 2003
D-1.4.4	One >15% R&D cell. (Task 3)	1	March 31, 2003
D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		March 31, 2003
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		March 31, 2003
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	March 31, 2003
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		March 31, 2003
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	March 31, 2003
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		March 31, 2003
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	March 31, 2003

## PHASE II

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		June 30, 2003
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		June 30, 2003
D-2.1.3	Report on design of production-worthy decal application machine. (Task 13)		June 30, 2003
D-2.1.4	Report on parameters for glass/encapsulant lamination. (Task 14)		June 30, 2003
D-2.1.5	Report on choice of method to modify backskin. (Task 15)		June 30, 2003
D-2.2.1	Report on hot zone redesign. (Task 10)		September 30, 2003
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)		September 30, 2003

D-2.2.3	One oxide free ribbon sample. (Task 12)	1	September 30, 2003
D-2.2.4	Report on parameters for cell/backskin lamination. (Task 14)		September 30, 2003
D-2.2.5	Report on method to modify backskin. (Task 15)		September 30, 2003
D-2.2.6	Report on design of backskin modification machine. (Task 16)		September 30, 2003
D-2.2.7	Report on identification of pick and place robot. (Task 18)		September 30, 2003
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)		December 31, 2003
D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		December 31, 2003
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		December 31, 2003
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		December 31, 2003
D-2.3.5	Report on hot roll lamination process for full module. (Task 14)		December 31, 2003
D-2.3.6	One typical full module produced with hot roll lamination process. (Task 14)	1	December 31, 2003
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		December 31, 2003
D-2.3.8	Report on development of backskin modification machine. (Task 16)		December 31, 2003
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		December 31, 2003
D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		December 31, 2003
D-2.3.11	Report on pick and place machine design. (Task 18)		December 31, 2003
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		December 31, 2003
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		March 31, 2004
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	March 31, 2004

D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		March 31, 2004
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	March 31, 2004
D-2.4.5	Report on process to make frameless modules. (Task 15)		March 31, 2004
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		March 31, 2004
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		March 31, 2004
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	March 31, 2004
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		March 31, 2004
D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		March 31, 2004

### PHASE III

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		June 30, 2004
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		September 30, 2004
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	September 30, 2004
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		September 30, 2004
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		September 30, 2004
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		December 31, 2004
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		December 31, 2004

D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	December 31, 2004
D-3.3.5	Report on speed and quality demonstration. (Task 24)		December 31, 2004
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		March 31, 2005
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	March 31, 2005
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		March 31, 2005
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		March 31, 2005
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	March 31, 2005
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		March 31, 2005
D-3.4.5	Report on yield demonstration. (Task 24)		March 31, 2005
D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		March 31, 2005
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		March 31, 2005
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		March 31, 2005
D-3.4.9	Report on module fabrication yield. (Task 27)		March 31, 2005
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	March 31, 2005

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### **5.3 REPORTING REQUIREMENTS**

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

### **5.4 REQUIRED REPORTS**

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of

performance start date is January 10, then January is the first full month for reporting purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

#### **A. MONTHLY TECHNICAL STATUS REPORT:**

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

#### **B. ANNUAL TECHNICAL PROGRESS REPORT**

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

## **B1 – Electronic Format Guidelines:**

List of format options to choose from for the electronic master.

- (1) Preferably, reports should include embedded graphics, such that they can be easily converted to a PDF format. Submit a word processing file prepared by one of the following: (a) WordPerfect or (b) MS Word (Mac, DOS, or windows).
- (2) If graphics cannot be embedded in the report file NREL prefers one of the following graphics formats: EPS, TIF, GIF, WPG, CGM, WMF, or PCT.
- (3) If presenting a portable document file (.PDF) format, please keep the file manageable, not beyond 1MB.

## **C. FINAL TECHNICAL REPORT**

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

## **6.0 PERFORMANCE EVALUATION**

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**Appendix A1**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module Manufacturing  
of String Ribbon Si PV Modules**

ZDO-2-30628-09

June 19, 2002

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these

To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Continuous Lamination Process**

EVERGREEN shall develop a continuous, non-vacuum lamination process that eliminates cell cracking and which is suitable for high volume production. To accomplish this task, Evergreen shall find process conditions (such as roller temperature, pre heat temperature, speed, and roller pressure) whereby cell cracking is eliminated. Evergreen shall then develop suitable process conditions for high volume manufacturing. This task is expected to result in a high volume, continuous non-vacuum

## **PHASE III - Third Year**

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14% Efficient Wrap-around Contact Cells**

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

### **3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine**

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Design And Develop An Improved Small, High Voltage Module**

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three one-year phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

##### PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during the first year, Phase I, of this subcontract according to the following schedule:

Months	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 1	X	X	X	X	X	X								
Task 2	X	X	X	X	X									
Task 3				X	X	X	X	X	X	X	X	X		
Task 4										X	X	X		
Task 5	X	X	X	X	X	X	X	X	X	X	X	X		
Task 6	X	X	X	X	X	X	X							
Task 7						X	X	X	X	X	X	X		
Task 8	X	X	X	X	X	X	X	X	X	X	X	X		
Task 9	X	X	X	X	X	X	X	X	X	X	X	X		
Monthly Reports		15th												
Annual Report												draft 15th		final 30th

##### PHASE II

EVERGREEN shall perform and complete Tasks 10 through 19 during the second year, Phase II, of this subcontract according to the following schedule:

Months	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Task 10	X	X	X	X	X	X	X	X	X	X	X	X		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	X		
Task 13	X	X	X	X	X	X	X	X	X	X	X	X		
Task 14			X	X	X	X	X	X	X					
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	X		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	X		
Monthly Reports		15th												
Annual Report												draft 15th		final 30th

### Milestones due on December 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

### Milestones due on March 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

### Milestones due on June 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)

m-2.4.3	Establish data processing for decal application machine	(Task 13)
m-2.4.4	Develop method to form backskin edge	(Task 15)
m-2.4.5	Complete design of machine to form sealed leads	(Task 16)
m-2.4.6	Complete development of machine to form sealed leads	(Task 16)
m-2.4.7	Complete development of monolithic module manufacturing method	(Task 17)
m-2.4.8	Complete development of automatic bulk resistivity measurement	(Task 19)
m-2.4.9	Complete incorporation of RS View in module machine designs	(Task 19)

### PHASE III

#### Milestones due on September 30, 2004

m-3.1.1	Complete debug of robotic pick and place machine	(Task 25)
---------	--	-----------

#### Milestones due on December 31, 2004

m-3.2.1	Complete debug of wrap-around decal application machine	(Task 22)
m-3.2.2	Demonstrate viability of laser cutting small cells from large cells	(Task 23)
m-3.2.3	Complete running of robotic pick and place machine	(Task 25)
m-3.2.4	Complete demonstration of positional accuracy and repeatability	(Task 25)

#### Milestones due on March 31, 2005

m-3.3.1	Demonstrate impurity reduction on production machine	(Task 20)
m-3.3.2	Demonstrate dislocation reduction on production machine	(Task 20)
m-3.3.3	Complete reliability studies on high-voltage small modules	(Task 23)
m-3.3.4	Complete automation for high-voltage small modules	(Task 23)
m-3.3.5	Complete speed and quality demonstration for manufacture of frameless, monolithic module	(Task 24)

#### Milestones due on June 31, 2005

m-3.4.1	Demonstrate starting lifetimes of 5 to >10 microseconds	(Task 20)
m-3.4.2	Advances made in Tasks 12 and 20 brought together	(Task 21)
m-3.4.3	Demonstrate 14% wrap-around contact cells	(Task 21)
m-3.4.4	Complete testing of wrap-around decal application machine	(Task 22)
m-3.4.5	Complete yield demonstration for manufacture of frameless, monolithic module	(Task 24)
m-3.4.6	Complete development of RS View on all automated machines for modules	(Task 26)
m-3.4.7	Complete integration of all inputs into a central collection point	(Task 26)

D-1.2.1	Report on installation of mixing equipment. (Task 1)		End of Second Quarter
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	End of Second Quarter
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	End of Second Quarter
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		End of Second Quarter
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		End of Second Quarter
D-1.2.6	Report on dielectric layers selected. (Task 5)		End of Second Quarter
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		End of Second Quarter
D-1.2.8	One cell from prototype machine. (Task 6)	1	End of Second Quarter
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		End of Second Quarter
D-1.2.10	Report on ink choice. (Task 9)		End of Second Quarter
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		End of Second Quarter
D-1.3.1	Report on coating with reduced permeability. (Task 3)		End of Third Quarter
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		End of Third Quarter
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		End of Third Quarter
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		End of Third Quarter
D-1.3.5	One backskin sample. (Task 8)	1	End of Third Quarter
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		End of Third Quarter
D-1.3.7	Report on completed accelerated tests. (Task 9)		End of Third Quarter
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		End of Fourth Quarter
D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		End of Fourth Quarter
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		End of Fourth Quarter
D-1.4.4	One >15% R&D cell. (Task 3)	1	End of Fourth Quarter

D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		End of Seventh Quarter
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		End of Seventh Quarter
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		End of Seventh Quarter
D-2.3.5	Report on hot roll lamination process for full module. (Task 14)		End of Seventh Quarter
D-2.3.6	One typical full module produced with hot roll lamination process. (Task 14)	1	End of Seventh Quarter
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		End of Seventh Quarter
D-2.3.8	Report on development of backskin modification machine. (Task 16)		End of Seventh Quarter
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		End of Seventh Quarter
D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		End of Seventh Quarter
D-2.3.11	Report on pick and place machine design. (Task 18)		End of Seventh Quarter
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		End of Seventh Quarter
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		End of Eighth Quarter
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	End of Eighth Quarter
D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		End of Eighth Quarter
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	End of Eighth Quarter
D-2.4.5	Report on process to make frameless modules. (Task 15)		End of Eighth Quarter
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		End of Eighth Quarter
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		End of Eighth Quarter
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	End of Eighth Quarter
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		End of Eighth Quarter

D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		End of Twelfth Quarter
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		End of Twelfth Quarter
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		End of Twelfth Quarter
D-3.4.9	Report on module fabrication yield. (Task 27)		End of Twelfth Quarter
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	End of Twelfth Quarter

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: C. Edwin Witt, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

EVERGREEN shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. EVERGREEN shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

## 5.4 REQUIRED REPORTS

EVERGREEN shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes; whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

### A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report is to be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

### B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports are to be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each year of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each year's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see B1 Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following year is not authorized and funded by NREL, then that year's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for

## 6.0 PERFORMANCE EVALUATION

The performance of EVERGREEN will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Monthly Subcontract Management Summary Reports prepared on NREL Form 619A;
- v) Up to two On-Site Visits by a PVMaT-selected evaluation team to EVERGREEN per phase
  - these visits shall entail presentations and demonstrations by EVERGREEN; and
- vi) Participation by EVERGREEN in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D (PVM R&D) project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PVM R&D review committee consisting of members selected by PVM R&D project management staff. These meetings will be critical program evaluation points. The progress of EVERGREEN will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of EVERGREEN will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**Appendix A-2**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module  
Manufacturing of String Ribbon Si PV Modules**  
ZDO-2-30628-09

March 24, 2004

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for

optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, Evergreen will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 -1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. Evergreen will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of Evergreen's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. Evergreen shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, Evergreen shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. Evergreen shall design and develop a prototype machine to apply wrap-around decals.

They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Scale-Up Of A Production Worthy Doping Method**

Evergreen shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

Evergreen shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

Evergreen shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

Evergreen shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cell.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

Evergreen shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

Evergreen shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

Evergreen shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

Evergreen shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing. This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

Evergreen shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II**

During Phase II, Evergreen shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

Evergreen shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and

more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

Evergreen shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

Evergreen shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

Evergreen shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Implementation of Multiple Ribbon Growth**

During Phase I of this program, project Gemini was launched and pilot production initiated. Gemini allows for the growth of two ribbons from a single crucible and represents an opportunity to lower significantly many of the costs of producing a ribbon substrate. In Phase II, the pilot line will continue and expand to the point where a significant fraction of the Subcontractor's crystal growth machines will be Gemini machines. In addition, during Phase II, considerable R&D work will continue on

improvements in the hot zone to increase production metrics such as yield and uptime. Also, in-line diagnostics will be continually upgraded to assist in reaching the production goals. Given the successful implementation of Gemini, the next platform for multiple ribbon growth – Quad – the growth of four ribbons from a single crucible- will be investigated with a view to bringing it to the stage of pre-implementation into production. This would not occur before the third year of this project, i.e. Phase 3.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

Evergreen shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

Evergreen shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

Evergreen shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

Evergreen shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or

minus 0.005".

### **3.19 Task 19 In-Line Diagnostics-2**

Evergreen shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSVIEW into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

#### **PHASE III**

During Phase III, Evergreen shall continue to perform R&D needed to effect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on Gemini II cells leading to 14.2% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall: design and develop an improved 120-W, Gemini II module; debug, test, and fine-tune module manufacturing equipment used for such modules; debug, test, and fine-tune a diffusion machine for automated in-line diffusion using the no-etch process; and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. Finally, Evergreen shall demonstrate their state of the art manufacturing capability to make 120-W Gemini II modules at high yield and at a rate of 10-14 MW/year. Evergreen shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

Evergreen shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14.2% Efficient Gemini II Cells**

Evergreen shall combine advances made in Task 20 to routinely make 14.2% cells on Gemini II ribbon. These advances shall include: improvements in starting lifetime (Task 20); continued control of surface oxide layers such that the no-etch process can continue to be utilized; and further, tighter control of the oxide layer on the as-grown ribbon surface allowing for higher sheet resistivities in the diffusion process. The latter should help in producing an improved blue response, and this, in turn, will result in a high short-circuit current ( $J_{sc}$ ) value. At present, sheet resistivities are in the low to mid-40  $\Omega$ /square. The aim here would be to achieve values closer to 50  $\Omega$ /square. This work effort will be connected with Task 25 activities as well. In addition, a further advance will be in the decal formation and application processes, some of which will build on results from Task 22 activities.

The result of this task shall be a 14.2% efficient cell made from Gemini II string ribbon technology.

### **3.22 Task 22 Fine-Tune And Test Multi-Lane Decal Application Machine**

Evergreen shall demonstrate, fine-tune, and test a production-worthy multi-lane decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their multi-lane decal application machine at high volume, demonstrating multi-lane capability.

This task is expected to result in a complete debugging of the decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Develop 120-W Gemini II Module**

Evergreen shall produce 120-W modules based on Gemini II ribbon technology based on the results of Tasks 20 and 21. At present, Evergreen manufactures a 115-W module using Gemini I and single ribbon cells. The 120-W modules will undergo accelerated environmental testing to be certain the modules meet all standard qualification requirements. In addition, Evergreen will target yields above 98% in module lamination.

This task is expected to result in the fabrication of 120-W, Gemini II modules with high module-lamination yields.

### **3.24 Task 24 Debug And Run Crystal Growth Furnaces for Gemini II**

Evergreen shall procure additional Gemini II machines and retrofit earlier Gemini I machines or single ribbon machines following the completion of Tasks 14 and 23. The expected result for this task will be year-end yield and uptimes at least 10% absolute high than for Gemini I or single-ribbon furnaces at a volume rate between 10 and 14 MW/yr.

The expected result of this task will be the debugging of the Gemini II furnace technology in the form of new machines as well as retrofitted applications.

### **3.25 Task 25 High-Volume, Streamlined No-Etch/Diffusion Process**

Evergreen shall streamline the existing machine sequence for the no-etch/diffusion process in order to achieve continuous material flow throughout this processing step. The no-etch process, developed at Evergreen, involves wafers going directly from crystal growth into diffusion without any etching or wet chemistry. Following the belt-furnace diffusion step, the diffusant glass is removed in a continuous, belt-like process where the wafers are always horizontal and never placed in carriers. Also, this process eliminates the need for any edge isolation. Evergreen now has the entire machine sequence to perform this process in a line with an ultimate capacity of 8-10 MW/yr. To reach these production rates, it will be necessary to run 10 cells across the full width of the 38"-wide belt. Furthermore, a successful belt-to-belt transfer to the diffusant-glass-removal machine will need to be devised. A considerable amount of debugging of this equipment and process optimization will be needed before this machine sequence is fully functional as a production line.

The expected result of this task is the development of production sequence to enable continuous material flow throughout the no-etch/diffusion process at an 8-10MW/yr rate.

### **3.26 Task 26 Develop and Implement In-Line Diagnostics for Gemini II**

Evergreen shall continue to improve in-line diagnostics for Gemini II production. In-line diagnostic procedures that will be important for the Gemini II technology, particularly with the hot zone configuration labeled #6, include: 1) an improved thickness scanner; 2) an algorithm that automatically adjusts for melt-height changes; and 3) a central, computerized data collection system that will allow for analysis of the reasons for machine downtime.

The expected result of this task shall be the development and implementation of these diagnostic tools.

### **3.27 Task 27 Demonstrate Manufacturing Capability to Produce 120-W, Gemini II Modules with High Yields throughout Factory**

Evergreen shall demonstrate its manufacturing capabilities through the production of 120-W, Gemini II modules with high yields throughout the manufacturing facility. This task will be the culmination of the complete work effort under this PV Manufacturing R&D subcontract, combining the results of Tasks 20 through 26. This task shall combine the results of: 1) developing a 14.2% efficiency cell; 2) realizing the manufacturing benefits of dual-ribbon growth through Gemini II furnaces; 3) a well-controlled diffusion process; 4) improvements in decal application and formation; and 5) greater control in module assembly and yields. The success of this task will have important implications for Evergreen — laying the foundation for the further expansion beyond the goal of year-end 2004 of a production capacity of 10-14 MW/yr.

The expected result of this task is a demonstration of an overall production yield improvement of 10%.

#### 4.0 PROGRAM PLAN

The subcontracted research shall be conducted at Evergreen. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by Evergreen according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. Evergreen shall perform these tasks according to the following phased schedules:

##### PHASE I

Evergreen shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	△	X	X	X	X				
Task 2	△	X	X	X					
Task 3	△	X	X	X	X	X	▽		
Task 4					△	X	▽		
Task 5	△	X	X	X	X	X	▽		
Task 6	△	X	X	X	X	X			
Task 7	△	X	X	X	X	X	▽		
Task 8	△	X	X	X	X	X	▽		
Task 9	△	X	X	X	X	X	▽		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

Evergreen shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
Task 10	△	X	X	X	X	X	X	X	X	X	X	X	X	▽		
Task 11	△	X	X	X	X	▽										
Task 12						△	X	X	X	X	X	X	X	▽		
Task 13	△	X	X	X	X	X	X	X	X	X	X	X	X	▽		
Task 14	△	X	X	X	X	X	X	X	X	X	X					
Task 15			△	X	X	X	X	X	X	X	▽					
Task 16					△	X	X	X	X	X	X	X	X	▽		
Task 17						△	X	X	X	X	X	X	X	▽		
Task 18				△	X	X	X	X	▽							
Task 19							△	X	X	X	X	X	X	▽		
Monthly Reports	15th	15th														
Annual Report														Draft 15th		Final 30th

**Phase III**

Evergreen shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	J	J	A	S	O	N	D	J	F	M
Task 20			△	X	X	X	X	▽		
Task 21				△	X	X	X	▽		
Task 22					△	X	▽			
Task 23					△	X	X	▽		
Task 24	△	X	X	X	X	X	X	▽		
Task 25	△	X	▽							
Task 26	△	X	X	X	X	X	X	▽		
Task 27						△	X	▽		
Monthly Reports		15th								
Annual Report									Draft 15th	Final 31st

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. Evergreen shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

**PHASE II**

Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	Task 11
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	Task 11
m-2.1.3	Production-worthy decal application machine designed	Task 13
m-2.1.5	Identify method to modify backskin for higher impermeability	Task 15
m-2.1.6	Complete Gemini hot zone redesign and order parts	Task 14
m-2.1.7	14% cells on Gemini ribbon	Task 14

Milestones due no later than September 30, 2003

m-2.2.1	Establish hot zone redesign	Task 10
m-2.2.2	Demonstrate growth of oxide free ribbon	Task 11
m-2.2.3	<i>Eliminated from scope of work</i>	
m-2.2.4	Develop method to modify backskin	Task 15
m-2.2.5	Complete design of backskin modification machine	Task 16
m-2.2.6	Complete identification of pick and place robot	Task 18
m-2.2.7	Complete testing of redesigned hot zone	Task 14
m-2.2.8	Gemini yield and uptimes equivalent to single ribbon	Task 14

Milestones due no later than December 31, 2003

m-2.3.1	Complete design and implementation of vibration damping	Task 10
m-2.3.2	Complete design and deployment of boat for double sided passivation	Task 12
m-2.3.3	Demonstrate adequate firing through of Al paste	Task 12
m-2.3.4	Decal application machine developed and tested	Task 13
m-2.3.5	<i>Eliminated from scope of work</i>	
m-2.3.6	Identify method to form backskin edge	Task 15
m-2.3.7	Complete development of backskin modification machine	Task 16
m-2.3.8	Decision on monolithic module manufacturing method	Task 17
m-2.3.9	Complete design of pick and place machine	Task 18
m-2.3.10	Complete design for automatic bulk resistivity measurement	Task 19
m-2.3.11	Complete tests on elimination of inside surface oxide stripe	Task 14
m-2.3.12	Demonstrate reduced variation in front to back thickness	Task 14
m-2.3.13	Installation and running of full cluster of 20 retrofit machines	Task 14

Milestones due no later than May 31, 2004

m-2.4.1	Complete dislocation maps	Task 10
m-2.4.2	Demonstrate fabrication of 13% cells	Task 12
m-2.4.3	Establish data processing for decal application machine	Task 13
m-2.4.4	Develop method to form backskin edge	Task 15
m-2.4.5	Complete design of machine to form sealed leads	Task 16
m-2.4.6	Complete development of machine to form sealed leads	Task 16
m-2.4.7	Complete development of monolithic module manufacturing method	Task 17

m-2.4.8	Complete development of automatic bulk resistivity measurement	Task 19
m-2.4.9	Complete incorporation of RS View in module machine designs	Task 19
m-2.4.10	Installation and running of 100 new Gemini machines	Task 14
m-2.4.11	In-line diagnostics implemented on all Gemini machines	Task 14

### PHASE III

#### Milestones due no later than June 30, 2004

m-3.1.1	Complete debug of multi-lane decal application machine	Task 22
m-3.1.2	Demonstrate diffusion uniformity across the ten-cell span	Task 25
m-3.1.3	Demonstrate diffusant glass etching uniformity across the ten-cell span	Task 25
m-3.1.4	Show thickness scanner accuracy of >5x	Task 26
m-3.1.5	Build and test prototype in laboratory	Task 26
m-3.1.6	Develop algorithm in laboratory	Task 26

#### Milestones due no later than September 30, 2004

m-3.2.1	Yield 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.2	Uptimes 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.3	Show belt speeds compatible with 8-10 MW/yr rate	Task 25
m-3.2.4	Demonstration of production worthiness by running for three shifts/day for a month	Task 25
m-3.2.5	Build and test in-line diagnostics in pilot	Task 26
m-3.2.6	Test in-line diagnostic algorithm in pilot	Task 26

#### Milestones due no later than January 31, 2005

m-3.3.1	Demonstrate impurity reduction on Gemini II machine	Task 20
m-3.3.2	Demonstrate dislocation reduction on production machine	Task 20
m-3.3.3	Complete running of multi-lane decal application machine	Task 22
m-3.3.4	Form modules from Gemini II wafers that are 120W in pilot	Task 23
m-3.3.5	Demonstrate lamination yields of >98% in pilot	Task 23
m-3.3.6	Demonstrate qualification requirements met	Task 23
m-3.3.7	Demonstrate starting lifetimes of 5 to >10 microseconds	Task 20
m-3.3.8	14.2% Efficient Gemini II cells	Task 21

m-3.3.9	Advances made in Task 20 brought together	Task 21
m-3.3.10	Deploy in manufacturing	Task 23
m-3.3.11	Demonstrate lamination yields >98% in manufacturing	Task 23
m-3.3.12	Yield 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.13	Uptime 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.14	Production capacity of at least 10 MW/yr.	Task 24
m-3.3.15	Deploy algorithm in production	Task 26
m-3.3.16	Deploy in production	Task 26
	Demonstrate high yields in crystal growth with manufacturing	Task 27
m-3.3.17	capability	
	Demonstrate high yields in cell making with manufacturing	Task 27
m-3.3.18	capability	
	Demonstrate high yields in module making with manufacturing	Task 27
m-3.3.19	capability	
m-3.3.20	Combine M-3.27.1, 2, and 3 to reach capacity of 10-14 MW/yr.	Task 27

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

Evergreen shall prepare and submit reports and deliverables in accordance with the following Sections. Evergreen shall also supply NREL with samples of Evergreen cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, Evergreen shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. Evergreen shall provide deliverables according to the following schedule:

#### PHASE I Deliverables

##### Deliverables due no later than October 31, 2002

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant	2	Task 1
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2	1	Task 1
D-1.1.3	Report on a suitable solvent drying procedure		Task 1
D-1.1.4	Report on suitable transport of doped feedstock in feeder		Task 1
D-1.1.5	Report on chemical and optical characterization of surface oxide		Task 2
D-1.1.6	Report on feasibility of a simple optical method for oxide determination		Task 2
D-1.1.7	Ribbon sample grown without any surface oxide	1	Task 2
D-1.1.8	Report describing concept for prototype decal application machine		Task 6
D-1.1.9	Report describing design for prototype machine		Task 6
D-1.1.10	Example of thinner backskin sheets		Task 8

##### Deliverables due no later than October 31, 2002

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.2.1	Report on installation of mixing equipment		Task 1

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.2.2	One sample of 3" wide doped ribbon	1	Task 1
D-1.2.3	Two 12% cells made with feedstock doped with new doping process	2	Task 1
D-1.2.4	Report on finger cross section through screen-printing		Task 5
D-1.2.5	Report on decision to study alternative printing methods		Task 5
D-1.2.6	Report on dielectric layers selected		Task 5
D-1.2.7	Report on development and testing of prototype machine		Task 6
D-1.2.8	One cell from prototype machine	1	Task 6
D-1.2.9	Example of cross-linked thinner backskin		Task 8
D-1.2.10	Report on ink choice		Task 9
D-1.2.11	One sample of printed conductive material on backskin		Task 9

Deliverables due no later than January 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.3.1	Report on coating with reduced permeability		Task 3
D-1.3.2	Report on establishment of network for new crystal growth machines		Task 7
D-1.3.3	Report on resistivity and laser cutting data added to the network		Task 7
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests		Task 8
D-1.3.5	One backskin sample	1	Task 8
D-1.3.6	Report on performance under thermal cycling and humidity freeze		Task 9
D-1.3.7	Report on completed accelerated tests		Task 9

Deliverables due no later than March 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.4.1	Report on tests of improved purification graphite parts		Task 3
D-1.4.2	Report on novel hot zone parts' configurations		Task 3

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3		Task 3
D-1.4.4	One >15% R&D cell	1	Task 3
D-1.4.5	Report on optimization of plasma nitride process		Task 4
D-1.4.6	Report on optimization of metallization firing process		Task 4
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data	1	Task 4
D-1.4.8	Report on reduced series and shunt resistance		Task 5
D-1.4.9	One cell demonstrating device improvements due to contact improvements	1	Task 5
D-1.4.10	Report on real time process monitoring using SPC charts		Task 7
D-1.4.11	One sample of printed conductive material on backskin	1	Task 9

## **PHASE II Deliverables**

### Deliverables due no later than June 30, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.1.1	Report on reduced oxygen in hot zone.		Task 11
D-2.1.2	Report on design for alternate method to introduce Ar.		Task 11
D-2.1.3	Report on design of production-worthy decal application machine.		Task 13
D-2.1.5	Report on choice of method to modify backskin.		Task 15
D-2.1.6	Report on Gemini hot zone redesign		Task 14
D-2.1.7	14% full area cell made on Gemini ribbon	1	Task 14

### Deliverables due no later than September 30, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.2.1	Report on hot zone redesign.		Task 10
D-2.2.2	Report on redesign of ambient gas flow pattern		Task 11
D-2.2.3	One oxide free ribbon sample	1	Task 12

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.2.4	<i>Eliminated from scope of work</i>		
D-2.2.5	Report on method to modify backskin		Task 15
D-2.2.6	Report on design of backskin modification machine		Task 16
D-2.2.7	Report on identification of pick and place robot		Task 18
D-2.2.8	Report on testing of redesigned hot zone		Task 14
D-2.2.9	Report of comparison to single ribbon of Gemini yield and uptime		Task 14

Deliverables due no later than December 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.3.1	Report on design and implementation of vibration damping		Task 10
D-2.3.2	Report on design and deployment of boat for double sided passivation		Task 12
D-2.3.3	Report on adequate firing through of Al paste		Task 12
D-2.3.4	Report on development and testing of decal application machine		Task 13
D-2.3.5	<i>Eliminated from scope of work</i>		
D-2.3.6	<i>Eliminated from scope of work</i>		
D-2.3.7	Report on choice of method to form backskin edge		Task 15
D-2.3.8	Report on development of backskin modification machine		Task 16
D-2.3.9	Report on design of a machine to form sealed leads		Task 16
D-2.3.10	Report on decision for monolithic module manufacturing method		Task 17
D-2.3.11	Report on pick and place machine design		Task 18
D-2.3.12	Report on design of automatic bulk resistivity measurement		Task 19
D-2.3.13	Report on elimination of inside surface oxide stripe		Task 14
D-2.3.14	Report on reduced variation in front to back thickness		Task 14
D-2.3.15	Report on running of full cluster of 20 retrofit machines		Task 14

Deliverables due no later than May 31, 2004

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.4.1	Report on improved lifetimes and dislocation maps		Task 10
D-2.4.2	One 13% wrap-around cell	1	Task 12
D-2.4.3	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.4	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.5	Report on process to make frameless modules		Task 15
D-2.4.6	Report on manufacturing equipment for frameless modules		Task 16
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control		Task 17
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control	1	Task 17
D-2.4.9	Report on development of automatic bulk resistivity measurement		Task 19
D-2.4.10	Report on incorporation of RS View in module machine designs		Task 19
D-2.4.11	Report on running of 100 new Gemini machines		Task 14
D-2.4.12	Report on implementation of in-line diagnostics on all Gemini machines		Task 14

**Phase III Deliverables**

Deliverables due no later than June 30, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.1.1	Report on debug of multi-lane decal application machine		Task 22
D-3.1.2	Report on diffusion uniformity across the ten cell span		Task 25
D-3.1.3	Report on diffusant glass etching uniformity across the ten cell span		Task 25
D-3.1.4	Report on thickness scanner accuracy of >5x		Task 26
D-3.1.5	Report on building and testing prototype in lab		Task 26

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.1.6	Report on lab development of algorithm for melt height		Task 26

Deliverables due no later than September 30, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.2.1	Report on yield 10% higher than for Gemini I		Task 24
D-3.2.2	Report on Uptimes 10% higher than for Gemini I		Task 24
D-3.2.3	Report on belt speeds compatible with 8-10 MW/yr rate		Task 25
D-3.2.4	Report on production worthiness by running for 3 shifts/day for a month		Task 25
D-3.2.5	Report on building and testing prototypes in pilot		Task 26
D-3.2.6	Report on testing of algorithm for melt height in pilot		Task 26
D-3.2.7	Report on development of centralized computer data of do downtime reasons		Task 26

Deliverables due no later than January 31, 2005

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.3.1	Report on impurity reduction on Gemini II machine		Task 20
D-3.3.2	Report on dislocation reduction on production machine		Task 20
D-3.3.3	Report on deployment of algorithm in production		Task 26
D-3.3.4	Report on deployment in production of centralized computer data		Task 26
D-3.3.5	Report on deployment in manufacturing of thickness scanner		Task 26
D-3.3.6	Report on running of multi-lane decal application machine		Task 22
D-3.3.7	Report on demonstration of lamination yields of >98% in pilot		Task 23
D-3.3.8	Report on demonstration of meeting qualification requirements		Task 23
D-3.3.9	Report on starting lifetimes of 5 to >10 microseconds		Task 20
D-3.3.10	Report on advances made in Task 20		Task 21
D-3.3.11	Report on 14.2% Efficient Gemini II cells		Task 21
D-3.3.12	14.2% Efficient Gemini II cells	2	Task 21
D-3.3.13	Report on deployment in manufacturing		Task 23
D-3.3.14	Report on lamination yields >98% in manufacturing		Task 23
D-3.3.15	120 W module sent to NREL	2	Task 23
D-3.3.16	Report on yields for retrofit machines		Task 24

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.3.17	Report on uptimes for retrofit machines		Task 24
D-3.3.18	Report on production capacity of at least 10 MW/yr.		Task 24
D-3.3.19	Report on high yields in crystal growth with manufacturing capability		Task 27
D-3.3.20	Report on high yields in cell making with manufacturing capability		Task 27
D-3.3.21	Report on high yields in module making with manufacturing capability		Task 27

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: Katie Brown, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered as one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### **5.3 REPORTING REQUIREMENTS**

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: Katie Brown, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

## 5.4 REQUIRED REPORTS

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes; whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

### A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

### B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1)**

**reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

### **C. FINAL TECHNICAL REPORT**

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

#### **6.0 Electronic Reporting Requirements for Subcontract Report Deliverables:**

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the deliverable schedule of this Statement of Work in accordance with the following electronic reporting requirements:

- a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document.

The electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

- b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).
- c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:
  - Microsoft Word (v.6.0 or newer for PC or MAC)
  - WordPerfect (v.6.1 or newer for PC)
  - Microsoft PowerPoint
  - Microsoft Excel
- d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files\*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:
  - QuarkXPress (.qxd)
  - Pagemaker (.pm)
  - Photoshop (.psd)
  - Illustrator (.ai)
  - Freehand (.fh)
  - Corel Draw (.cdr)
  - Framemaker (.fm)
  - Microsoft Publisher(.pub)

\*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.

- e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied

in hard copy only.

- f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.
- g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.
- h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

## 7.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

~~Appendix B~~

*Appendix A-1*

Statement of Work for Evergreen Solar, Inc.

## Innovative Approaches to Low Cost Module Manufacturing of String Ribbon Si PV Modules

ZDO-2-30628-09

~~September 18, 2002~~

*Aug. 15, 2003*  
*Aug 19, 2003*

### 1.0 BACKGROUND

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 – 1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Scale-Up Of A Production Worthy Doping Method**

EVERGREEN shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cells.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study

various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II**

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to

reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Implementation of Multiple Ribbon Growth**

During Phase I of this program, project Gemini was launched and pilot production initiated. Gemini allows for the growth of two ribbons from a single crucible and represents an opportunity to lower significantly many of the costs of producing a ribbon substrate. In Phase II, the pilot line will continue and expand to the point where a significant fraction of *the Substrates* our crystal growth machines will be Gemini machines. In addition, during Phase II, considerable R&D work will continue on improvements in the hot zone to increase production metrics such as yield and uptime. Also, in-line diagnostics will be continually upgraded to assist in reaching the production goals. Given the successful implementation of Gemini, the next platform for multiple ribbon growth – Quad – the growth of four ribbons from a single crucible- will be investigated with a view to bringing it to the stage of pre-implementation into production. This would not occur before the third year of this project, i.e. Phase 3.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005".

### **3.19 Task 19 In-Line Diagnostics-2**

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSVIEW into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

## **PHASE III**

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout, and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14% Efficient Wrap-around Contact Cells**

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

### **3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine**

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Design And Develop An Improved Small, High Voltage Module**

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.

### **3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules**

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

### **3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine**

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

### **3.26 Task 26 In Line Diagnostics-3**

EVERGREEN shall continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

### **3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules**

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing

equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

#### 4.0 PROGRAM PLAN

The subcontracted research shall be conducted at EVERGREEN. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by EVERGREEN according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

##### PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	X	X	X	X	X				
Task 2	X	X	X	X					
Task 3	X	X	X	X	X	X	∇		
Task 4									
Task 5	X	X	X	X	X	X	∇		
Task 6	X	X	X	X	X	X			
Task 7	X	X	X	X	X	X	∇		
Task 8	X	X	X	X	X	X	∇		
Task 9	X	X	X	X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

EVERGREEN shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	∇		
Task 13	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 14	X	X	X	X	X	X	X	X	X	X	X			
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	∇		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	∇		
Monthly Reports	15th													
Annual Report												draft 15th		final 30th

**Phase III**

EVERGREEN shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 20							X	X	X	X	X	∇		
Task 21										X	X	∇		
Task 22	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	∇		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	∇		
Task 27									X	X	X	∇		
Monthly Reports		15th												
Annual Report												draft 15th		Final 30th

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. EVERGREEN shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

### Milestones due no later than January 31, 2003

- m-1.3.1 Demonstrate coating with reduced permeability (Task 3)
- m-1.3.2 Network for all new crystal growth machines established (Task 7)
- m-1.3.3 Bulk resistivity and laser cutting data connected to the network (Task 7)
- m-1.3.4 Initiate qualification tests (Task 8)
- m-1.3.5 Initiate in-house accelerated testing (Task 8)
- m-1.3.6 Demonstrate adequate performance under thermal cycling (Task 9)
- m-1.3.7 Demonstrate adequate performance under humidity freeze (Task 9)

### Milestones due no later than, March 31, 2003

- m-1.4.1 Test graphite parts for improved purification (Task 3)
- m-1.4.2 Test novel hot zone parts' configurations (Task 3)
- m-1.4.3 Demonstrate lifetime gains from M-1.3.1-M-1.3.3 (Task 3)
- m-1.4.4 Verify M-1.3.4 with DLTS (Task 3)
- m-1.4.5 R and D cells from Ga. Tech with efficiency > 15.5% (Task 3)
- m-1.4.6 Optimize plasma nitride process (Task 4)
- m-1.4.7 Optimize metallization firing process (Task 4)
- m-1.4.8 Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells (Task 4)
- m-1.4.9 Demonstrate reduced series resistance (Task 5)
- m-1.4.10 Demonstrate increased shunt resistance (Task 5)
- m-1.4.11 Demonstrate process monitoring using SPC charts (Task 7)
- m-1.4.12 Complete accelerated testing (Task 8)
- m-1.4.13 Complete accelerated tests (Task 9)

## **PHASE II**

### Milestones due no later than June 30, 2003

- m-2.1.1 Demonstrate reduced oxygen in hot zone (Task 11)
- m-2.1.2 Design for alternate method to introduce Ar into the hot zone (Task 11)
- m-2.1.3 Production-worthy decal application machine designed (Task 13)
- m-2.1.5 Identify method to modify backskin for higher impermeability (Task 15)
- m-2.1.6 Complete Gemini hot zone redesign and order parts (Task 14)

m-2.1.7 14% cells on Gemini ribbon (Task 14)

Milestones due no later than September 30, 2003

m-2.2.1 Establish hot zone redesign (Task 10)

m-2.2.2 Demonstrate growth of oxide free ribbon (Task 11)

m-2.2.4 Develop method to modify backskin (Task 15)

m-2.2.5 Complete design of backskin modification machine (Task 16)

m-2.2.6 Complete identification of pick and place robot (Task 18)

m-2.2.7 Complete testing of redesigned hot zone (Task 14)

m-2.2.8 Gemini yield and uptimes equivalent to single ribbon (Task 14)

Milestones due no later than December 31, 2003

m-2.3.1 Complete design and implementation of vibration damping  
Complete design and deployment of boat for double sided (Task 10)

m-2.3.2 passivation (Task 12)

m-2.3.3 Demonstrate adequate firing through of Al paste (Task 12)

m-2.3.4 Decal application machine developed and tested (Task 13)

m-2.3.6 Identify method to form backskin edge (Task 15)

m-2.3.7 Complete development of backskin modification machine (Task 16)

m-2.3.8 Decision on monolithic module manufacturing method (Task 17)

m-2.3.9 Complete design of pick and place machine (Task 18)

m-2.3.10 Complete design for automatic bulk resistivity measurement (Task 19)

m-2.3.11 Complete tests on elimination of inside surface oxide stripe (Task 14)

m-2.3.12 Demonstrate reduced variation in front to back thickness (Task 14)

m-2.3.13 Installation and running of full cluster of 20 retrofit machines (Task 14)

Milestones due no later than March 31, 2004

m-2.4.1 Complete dislocation maps (Task 10)

m-2.4.2 Demonstrate fabrication of 13% cells (Task 12)

m-2.4.3 Establish data processing for decal application machine (Task 13)

m-2.4.4 Develop method to form backskin edge (Task 15)

- |          |  |           |
|----------|--|-----------|
| m-2.4.5  | Complete design of machine to form sealed leads                | (Task 16) |
| m-2.4.6  | Complete development of machine to form sealed leads           | (Task 16) |
| m-2.4.7  | Complete development of monolithic module manufacturing method | (Task 17) |
| m-2.4.8  | Complete development of automatic bulk resistivity measurement | (Task 19) |
| m-2.4.9  | Complete incorporation of RS View in module machine designs    | (Task 19) |
| m-2.4.10 | Installation and running of 100 new Gemini machines            | (Task 14) |
| m-2.4.11 | In-line diagnostics implemented on all Gemini machines         | (Task 14) |

### PHASE III

#### Milestones due no later than June 30, 2004

- |         |  |           |
|---------|--|-----------|
| m-3.1.1 | Complete debug of robotic pick and place machine | (Task 25) |
|---------|--|-----------|

#### Milestones due no later than September 30, 2004

- |         |   |           |
|---------|---|-----------|
| m-3.2.1 | Complete debug of wrap-around decal application machine             | (Task 22) |
| m-3.2.2 | Demonstrate viability of laser cutting small cells from large cells | (Task 23) |
| m-3.2.3 | Complete running of robotic pick and place machine                  | (Task 25) |
| m-3.2.4 | Complete demonstration of positional accuracy and repeatability     | (Task 25) |

#### Milestones due no later than December 31, 2004

- |         |  |           |
|---------|--|-----------|
| m-3.3.1 | Demonstrate impurity reduction on production machine                                     | (Task 20) |
| m-3.3.2 | Demonstrate dislocation reduction on production machine                                  | (Task 20) |
| m-3.3.3 | Complete reliability studies on high-voltage small modules                               | (Task 23) |
| m-3.3.4 | Complete automation for high-voltage small modules                                       | (Task 23) |
| m-3.3.5 | Complete speed and quality demonstration for manufacture of frameless, monolithic module | (Task 24) |

#### Milestones due no later than March 31, 2005

- |         |  |           |
|---------|--|-----------|
| m-3.4.1 | Demonstrate starting lifetimes of 5 to >10 microseconds                      | (Task 20) |
| m-3.4.2 | Advances made in Tasks 12 and 20 brought together                            | (Task 21) |
| m-3.4.3 | Demonstrate 14% wrap-around contact cells                                    | (Task 21) |
| m-3.4.4 | Complete testing of wrap-around decal application machine                    | (Task 22) |
| m-3.4.5 | Complete yield demonstration for manufacture of frameless, monolithic module | (Task 24) |

- m-3.4.6 Complete development of RS View on all automated machines for modules (Task 26)
- m-3.4.7 Complete integration of all inputs into a central collection point (Task 26)
- m-3.4.8 Complete demonstration of manufacturing capability (Task 27)
- m-3.4.9 Demonstrate capability to make 100 modules at a yield 99% (Task 27)

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

EVERGREEN shall prepare and submit reports and deliverables in accordance with the following Sections. EVERGREEN shall also supply NREL with samples of EVERGREEN cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, EVERGREEN shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. EVERGREEN shall provide deliverables according to the following schedule:

#### PHASE I

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant. (Task 1)	2	October 31, 2002
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	October 31, 2002
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		October 31, 2002
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		October 31, 2002
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		October 31, 2002
D-1.1.6	Report on feasibility of a simple		October 31, 2002

	optical method for oxide determination. (Task 2)		
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	October 31, 2002
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		October 31, 2002
D-1.1.9	Report describing design for prototype machine. (Task 6)		October 31, 2002
D-1.1.10	Example of thinner backskin sheets. (Task 8)		October 31, 2002
D-1.2.1	Report on installation of mixing equipment. (Task 1)		October 31, 2002
D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	October 31, 2002
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	October 31, 2002
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		October 31, 2002
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		October 31, 2002
D-1.2.6	Report on dielectric layers selected. (Task 5)		October 31, 2002
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		October 31, 2002
D-1.2.8	One cell from prototype machine. (Task 6)	1	October 31, 2002
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		October 31, 2002
D-1.2.10	Report on ink choice. (Task 9)		October 31, 2002
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		October 31, 2002
D-1.3.1	Report on coating with reduced permeability. (Task 3)		January 31, 2003
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		January 31, 2003
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		January 31, 2003

D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		January 31, 2003
D-1.3.5	One backskin sample. (Task 8)	1	January 31, 2003
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		January 31, 2003
D-1.3.7	Report on completed accelerated tests. (Task 9)		January 31, 2003
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		March 31, 2003
D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		March 31, 2003
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3. (Task 3)		March 31, 2003
D-1.4.4	One >15% R&D cell. (Task 3)	1	March 31, 2003
D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		March 31, 2003
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		March 31, 2003
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	March 31, 2003
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		March 31, 2003
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	March 31, 2003
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		March 31, 2003
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	March 31, 2003

## PHASE II

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		June 30, 2003
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		June 30, 2003
D-2.1.3	Report on design of production-		June 30, 2003

	worthy decal application machine. (Task 13)	
D-2.1.5	Report on choice of method to modify backskin. (Task 15)	June 30, 2003
D-2.1.6	Report on Gemini hot zone redesign (Task 14)	June 30, 2003
D-2.1.7	14% full area cell made on Gemini ribbon (Task 14)	June 30, 2003
D-2.2.1	Report on hot zone redesign. (Task 10)	September 30, 2003
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)	September 30, 2003
D-2.2.3	One oxide free ribbon sample. (Task 12)	1 September 30, 2003
D-2.2.5	Report on method to modify backskin. (Task 15)	September 30, 2003
D-2.2.6	Report on design of backskin modification machine. (Task 16)	September 30, 2003
D-2.2.7	Report on identification of pick and place robot. (Task 18)	September 30, 2003
D-2.2.8	Report on testing of redesigned hot zone (Task 14)	September 30, 2003
D-2.2.9	Report of comparison to single ribbon of Gemini yield and uptime (Task 14)	September 30, 2003
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)	December 31, 2003
D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)	December 31, 2003
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)	December 31, 2003
D-2.3.4	Report on development and testing of decal application machine. (Task 13)	December 31, 2003
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)	December 31, 2003
D-2.3.8	Report on development of backskin modification machine. (Task 16)	December 31, 2003
D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)	December 31, 2003
D-2.3.10	Report on decision for monolithic module manufacturing method.	December 31, 2003

(Task 17)

D-2.3.11	Report on pick and place machine design. (Task 18)		December 31, 2003
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		December 31, 2003
D-2.3.13	Report on elimination of inside surface oxide stripe (Task 14)		December 31, 2003
D-2.3.14	Report on reduced variation in front to back thickness (Task 14)		December 31, 2003
D-2.3.15	Report on running of full cluster of 20 retrofit machines (Task 14)		December 31, 2003
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		March 31, 2004
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	March 31, 2004
D-2.4.3	One sample from and report on decal application machine with data processing. (Task 13)		March 31, 2004
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	March 31, 2004
D-2.4.5	Report on process to make frameless modules. (Task 15)		March 31, 2004
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		March 31, 2004
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		March 31, 2004
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	March 31, 2004
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		March 31, 2004
D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		March 31, 2004
D-2.4.11	Report on running of 100 new Gemini machines (Task 14)		March 31, 2004
D-2.4.12	Report on implementation of in-line diagnostics on all Gemini machines (Task 14)		March 31, 2004

### PHASE III

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		June 30, 2004
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		September 30, 2004
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	September 30, 2004
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		September 30, 2004
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		September 30, 2004
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		December 31, 2004
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		December 31, 2004
D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	December 31, 2004
D-3.3.5	Report on speed and quality demonstration. (Task 24)		December 31, 2004
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		March 31, 2005
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	March 31, 2005
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		March 31, 2005
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		March 31, 2005
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	March 31, 2005
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		March 31, 2005

D-3.4.5	Report on yield demonstration. (Task 24)		March 31, 2005
D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		March 31, 2005
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		March 31, 2005
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		March 31, 2005
D-3.4.9	Report on module fabrication yield. (Task 27)		March 31, 2005
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	March 31, 2005

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered as one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

## 5.3 REPORTING REQUIREMENTS

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory

ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

#### 5.4 REQUIRED REPORTS

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

##### A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

##### B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the**

**completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see **B1** Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

### **C. FINAL TECHNICAL REPORT**

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

#### **6.0 Electronic Reporting Requirements for Subcontract Report Deliverables:**

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract

report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the deliverable schedule of this Statement of Work in accordance with the following electronic reporting requirements:

- a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document. The electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.
- b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).
- c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:
  - Microsoft Word (v.6.0 or newer for PC or MAC)
  - WordPerfect (v.6.1 or newer for PC)
  - Microsoft PowerPoint
  - Microsoft Excel
- d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files\*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:
  - QuarkXPress (.qxd) • Pagemaker (.pm)

- Photoshop (.psd)
- Freehand (.fh)
- Framemaker (.fm)
- Illustrator (.ai)
- Corel Draw (.cdr)
- Microsoft Publisher(.pub)

\*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.

- e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.
- f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.
- g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.
- h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

## 7.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**APPENDIX B-1**

**STANDARD TERMS AND CONDITIONS FOR**

**(1) COST SHARING;**  
**(2) COST REIMBURSEMENT; AND,**  
**(3) COST PLUS FIXED FEE**

**SUBCONTRACTS**



APPENDIX B-1  
INDEX

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
1	PROHIBITION OF ASSIGNMENT (SPECIAL) (APR 1997) .....	1
2	DISPUTES (SPECIAL) (APR 1997) .....	1
3	YEAR 2000 CERTIFICATION AND WARRANTY OF INFORMATION TECHNOLOGY PRODUCTS AND SERVICES (SPECIAL)(FEB 1999) <i>(Applies to subcontracts and purchase orders for information technology products or services)</i> .....	2
4	DEFINITIONS (SPECIAL) (APR 1998) - <i>Derived from FAR 52.202-1(OCT 1995)</i> .....	3
5	RESTRICTIONS OF LOWER-TIER SUBCONTRACTOR SALES TO NREL/GOVERNMENT (JUL 1995) - <i>Derived from FAR 52.203-6 (Applies to subcontracts exceeding \$100,000)</i> .....	5
6	ANTI-KICKBACK PROCEDURES (JUL 1995) - <i>Derived from FAR 52.203-7 (FD) (Applies to subcontracts exceeding \$100,000)</i> .....	5
7	LIMITATION OF PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (JUN 1997) - <i>Derived from FAR 52.203-12 (Applies to subcontracts exceeding \$100,000)</i> .....	7
8	AUDIT AND RECORDS - NEGOTIATION (JUN 1999) - <i>Derived from FAR 52.215-2 (FD) (Applies to subcontracts exceeding \$100,000) (Use Alternate II of this clause for Cost-reimbursement subcontracts with State and Local Governments, educational institutions, and other nonprofit organizations)</i> .....	13
9	ALLOWABLE COST AND PAYMENT (APR 1998) - <i>Derived from FAR 52.216-7 (Applies to cost reimbursement subcontracts) (For educational institutions, substitute subpart 31.3; For State and Local Governments, substitute subpart 31.6; For other non-profit organizations, substitute subpart 31.7. See 16.307(a))</i> .....	15
10	FIXED FEE (MAR 1997) - <i>Derived from FAR 52.216-8 (Applies to cost plus fixed fee subcontracts)</i> .....	19

**APPENDIX B-1  
INDEX**

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
11	<b>COST SUBCONTRACT - NO FEE (APR 1984) -</b> <i>Derived from FAR 52.216-11</i> <i>(Applies to cost reimbursement subcontracts)</i> .....	19
12	<b>COST-SHARING SUBCONTRACT -- NO FEE (APR 1984) -</b> <i>Derived from FAR 52.216-12</i> <i>(Applies to cost sharing subcontracts)</i> .....	19
13	<b>PREDETERMINED INDIRECT COST RATES (APR 1998) -</b> <i>Derived from FAR 52.216-15</i> <i>(Applies to cost reimbursement research and development subcontracts with educational institutions when predetermined indirect cost rates are used)</i> .....	20
14	<b>UTILIZATION OF SMALL BUSINESS CONCERNS (OCT 1999) -</b> <i>Derived from FAR 52.219-8 (FD)</i> <i>(Applies to subcontracts exceeding \$100,000)</i> .....	21
15	<b>PAYMENT FOR OVERTIME PREMIUMS (JUL 1990) -</b> <i>Derived from FAR 52.222-2</i> <i>(Applies to cost reimbursement subcontracts exceeding \$100,000)</i> .....	22
16	<b>CONTRACT WORK HOURS AND SAFETY STANDARDS ACT -- OVERTIME COMPENSATION - (JUL 1995) -</b> <i>Derived from FAR 52.222-4 (FD)</i> <i>(Applies to subcontracts exceeding \$100,000 that require or involve the employment of laborers or mechanics)</i> .....	23
17	<b>WALSH-HEALEY PUBLIC CONTRACTS ACT (DEC 1996)</b> <i>Derived from FAR 52.222-20</i> <i>(Applies to subcontracts for the manufacture or furnishing of materials, supplies, articles or equipment in an amount that exceeds or may exceed \$10,000)</i> .....	24
18	<b>EQUAL OPPORTUNITY (FEB 1999)</b> <i>Derived from FAR 52.222-26 (FD)</i> .....	25
19	<b>AFFIRMATIVE ACTION FOR DISABLED VETERANS AND VETERANS OF THE VIETNAM ERA (APR 1998) -</b> <i>Derived from FAR 52.222-35 (FD)</i> <i>(Applies to subcontracts exceeding \$10,000)</i> .....	26
20	<b>AFFIRMATIVE ACTION FOR WORKERS WITH DISABILITIES (JUN 1998) -</b> <i>Derived from FAR 52.222-36 (FD)</i> <i>(Applies to subcontracts exceeding \$10,000)</i> .....	29

**APPENDIX B-1  
INDEX**

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
21	<b>EMPLOYMENT REPORTS ON DISABLED VETERANS AND VETERANS OF THE VIETNAM ERA (JAN 1999) - <i>Derived from FAR 52.222-37 (FD)</i> <i>(Applies to subcontracts exceeding \$10,000)</i> .....</b>	<b>30</b>
22	<b>AUTHORIZATION AND CONSENT (JUL 1995) - <i>Derived from FAR 52.227-1 (FD)</i> .....</b>	<b>31</b>
23	<b>NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT (AUG 1996) - <i>Derived from FAR 52.227-2</i> <i>(Applies to research, development, or demonstration, subcontracts exceeding \$100,000)</i> .....</b>	<b>32</b>
24	<b>PATENT INDEMNITY (APR 1984) - <i>Derived from FAR 52.227-3</i> <i>(The provisions of this clause shall not be applicable if this award is for the conduct of research, development, or demonstration)</i> .....</b>	<b>33</b>
25	<b>INSURANCE – LIABILITY TO THIRD PERSONS (SPECIAL MAY 1999) - <i>Derived form FAR 52.228-7</i> <i>(Applies to cost reimbursement subcontracts)</i> .....</b>	<b>34</b>
26	<b>LIMITATION OF COST (APR 1984) - <i>Derived from FAR 52.232-20</i> <i>(Applies to fully funded, cost reimbursement subcontracts)</i> .....</b>	<b>36</b>
27	<b>LIMITATION OF FUNDS (APR 1984) - Incrementally Funded <i>Derived from FAR 52.232-22</i> <i>(Applies to incrementally funded, cost reimbursement subcontracts)</i> .....</b>	<b>38</b>
28	<b>BANKRUPTCY (JUL 1995) - <i>Derived from FAR 52.242-13</i> <i>(Applies to subcontracts exceeding \$100,000)</i> .....</b>	<b>40</b>
29	<b>STOP WORK ORDER (AUG 1989) AND ALTERNATE 1 - COST REIMBURSEMENT (AUG 1989) <i>Derived from FAR 52.242-15</i> .....</b>	<b>40</b>
30	<b>CHANGES - COST REIMBURSEMENT (AUG 1987) AND ALTERNATE V -RESEARCH AND DEVELOPMENT (AUG 1987) <i>Derived from FAR 52.243-2</i> .....</b>	<b>41</b>

**APPENDIX B-1  
INDEX**

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
31	<b>LOWER-TIER SUBCONTRACTS (AUG 1998)</b> <i>Derived from FAR 52.244-2</i> <i>(Applies to all cost reimbursement subcontracts; and letter, fixed price, time and material, and labor hour subcontracts exceeding \$100,000)</i> .....	42
32	<b>SUBCONTRACTS FOR COMMERCIAL ITEMS AND COMMERCIAL COMPONENTS (OCT 1998)</b> <i>Derived from FAR 52.244-6</i> <i>(Applies to solicitations and subcontracts for supplies or services other than commercial items)</i> .....	45
33	<b>INSPECTION OF SERVICES -- COST REIMBURSEMENT (APR 1984) -</b> <i>Derived from FAR 52.246-5</i> .....	46
34	<b>INSPECTION OF RESEARCH AND DEVELOPMENT (SHORT FORM) (APR 1984) -</b> <i>Derived from FAR 52.246-9</i> .....	47
35	<b>PREFERENCE FOR U.S. - FLAG AIR CARRIERS - (JAN 1997) -</b> <i>Derived from FAR 52.247-63 (FD)</i> .....	47
36	<b>TERMINATION FOR CONVENIENCE OF NREL/GOVERNMENT (EDUCATIONAL AND OTHER NONPROFIT INSTITUTIONS (SEPT 1996) -</b> <i>Derived from FAR 52.249-5 (FD)</i> .....	48
37	<b>TERMINATION - (COST REIMBURSEMENT) (SEP 1996)</b> <i>Derived from FAR 52.249-6 (FD)</i> <i>(Applies to cost reimbursement subcontracts except subcontracts for research development work with educational or nonprofit institutions)</i> .....	50
38	<b>EXCUSABLE DELAYS (APR 1984) -</b> <i>Derived from FAR 52.249-14 (FD)</i> <i>(Applies to cost reimbursement subcontracts on a fee basis)</i> .....	55
39	<b>REFUND OF ROYALTIES (FEB 1995) -</b> <i>Derived from DEAR 952.227-9 (FD)</i> .....	56
40	<b>FOREIGN TRAVEL (FEB 1997) -</b> <i>Derived from DEAR 952.247-70 (FD)</i> .....	57

**APPENDIX B-1  
INDEX**

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
41	<b>INTEGRATION OF ENVIRONMENT, SAFETY, AND HEALTH INTO WORK PLANNING AND EXECUTION (JUN 1997) - <i>Derived from DEAR 970.5204-2 (FD) (Applies to subcontracts that involve complex or hazardous work that is to be performed on a Government-owned or -leased facility</i> .....</b>	57
42	<b>ACCOUNTS, RECORDS, AND INSPECTION (JUN 1996) - <i>Derived from DEAR 970.5204-9 (FD)</i> .....</b>	60
43	<b>PRINTING CLAUSE FOR SUBCONTRACTS (APR 1984) - <i>Derived from DEAR 970.5204-19 (FD)</i> .....</b>	61
44	<b>PROPERTY (JUN 1997) - <i>Derived from DEAR 970.5204-21 (FD) (Applies to cost reimbursement subcontracts)</i> .....</b>	62
45	<b>TAXES (APR 1984) - <i>Derived from DEAR 970.5204-23 (FD)</i> .....</b>	67
46	<b>PERMITS OR LICENSEE (APR 1984) - <i>Derived from DEAR 970.5204-29</i> .....</b>	67
47	<b>ACCESS TO AND OWNERSHIP OF RECORDS (JUN 1997) <i>Derived from DEAR 970.5204-79 (FD) (Applies to cost reimbursement subcontracts)</i> .....</b>	68
48	<b>ACCESS SECURITY (SPECIAL) (APR 1999) .....</b>	69



## CLAUSES

### **CLAUSE 1 - PROHIBITION OF ASSIGNMENT (SPECIAL) (APR 1997)**

- A. Neither this subcontract nor any interest therein nor claim thereunder shall be assigned or transferred by the Subcontractor except as expressly authorized in writing by the NREL Subcontract Administrator.
- B. When directed by DOE, the NREL Division of Midwest Research Institute may assign all its rights and obligations under this subcontract to DOE or its designee.

### **CLAUSE 2 - DISPUTES (SPECIAL) (APR 1997)**

- A. The parties agree that the appropriate forum for resolution of any dispute or claim pertaining to this subcontract shall be a court of competent jurisdiction as follows:
  - 1. Subject to paragraph (A)(2) of this clause, any such litigation shall be brought and prosecuted exclusively in Federal District Court; with venue in the United States District Court of Colorado in Denver, Colorado.
  - 2. Provided, however, that in the event that the requirements for jurisdiction in any Federal District Court are not presented, such litigation shall be brought in a court of competent jurisdiction in the county of Jefferson and State of Colorado.
- B. Any substantive issue of law in such dispute, claim, or litigation shall be determined in accordance with the body of applicable Federal law relating to the interpretation and application of clauses derived from Federal Acquisition Regulations. If there is no applicable Federal law, the law of the State of Colorado shall apply in the determination of such issues. Nothing in this clause shall grant to the Subcontractor by implication any statutory rights or remedies not expressly set forth in this subcontract.
- C. There shall be no interruption in the prosecution of the work, and the Subcontractor shall proceed diligently with the performance of this subcontract pending final resolution of any dispute, claim, or litigation arising under or related to this subcontract between the parties hereto or between the Subcontractor and lower-tier subcontractors or suppliers.
- D. The Contract Disputes Act of 1978 (41 U.S.C. Sections 601-613) shall not apply to this subcontract; provided, however, that nothing in this clause shall prohibit NREL, in its sole discretion, from sponsoring a claim of the Subcontractor for resolution under the provision of its prime contract with DOE. In the event that NREL so sponsors a claim at the request of the Subcontractor, the Subcontractor shall be bound by the decision of the cognizant DOE Contracting Officer to the same extent and in the same manner as NREL.
- E. Any disputes relative to intellectual property matters will be governed by other provisions of this subcontract.

**CLAUSE 3 - YEAR 2000 CERTIFICATION AND WARRANTY OF INFORMATION TECHNOLOGY PRODUCTS AND SERVICES (SPECIAL)(FEB 1999)**  
*(Applies to subcontracts for information technology products or services)*

A. Definitions

1. "Year 2000 Compliance," as used in this clause, means that the information technology products and services delivered or developed under this subcontract accurately process date/time data from, into, and between the twentieth and twenty-first centuries, and the years 1999 and 2000, and leap year calculations, to the extent that other information technology, used in combination with the information technology being delivered or developed under this subcontract, properly exchanges date/time data with it.
2. "Information technology products and services" as used in this clause, include, but are not limited to, hardware, software, and/or firmware and embedded systems or any other electro-mechanical or processor-based systems or services.
3. "Date/time data," as used in this clause, includes but is not limited to, calculating, comparing, and sequencing.

B. Certification

The delivery or development of information technology products or services by the Subcontractor/Supplier shall constitute constructive certification that the information technology products or services under this subcontract demonstrate Year 2000 Compliance.

C. Warranty

The Subcontractor/Supplier warrants that each commercial or noncommercial information technology product or service delivered or developed under this subcontract is Year 2000 Compliant. If the subcontract requires that specific information technology products or services must perform as a system in accordance with the foregoing warranty, then this warranty shall apply to those products or services as a system.

D. Duration and Remedies

The duration of this warranty and the remedies available to NREL/Government for breach of this warranty shall be as defined in, and subject to: 1) the terms and limitations of the general warranty provisions of this subcontract; or, 2) the terms and limitations of the Subcontractor's/Supplier's standard commercial warranty or warranties contained in this subcontract.

Notwithstanding any provision to the contrary in such warranty provision(s), or in the absence of any such warranty provision(s), the remedies available to NREL/Government under this Year 2000 Compliance warranty shall include repair or replacement, at no additional cost to NREL/Government, of any information technology product or service where noncompliance is discovered and made known to the Subcontractor/Supplier in writing within ninety (90) days after

acceptance. Nothing in this warranty shall be construed to limit any rights or remedies NREL/Government may otherwise have under this subcontract with respect to defects other than Year 2000 compliance.

E. Subcontractor/Supplier as Distributor

If the Subcontractor/Supplier is a distributor of technology information products obtained from third party manufacturers, the Subcontractor/Supplier agrees to obtain from the third party manufacturers certifications and warranties that substantially conform to the requirements of this clause.

F. Lower-tier Subcontracts

The Subcontractor/Supplier agrees to insert terms that conform substantially to the language of this clause, including this paragraph F, in all lower-tier subcontracts under this subcontract.

**CLAUSE 4 - DEFINITIONS (SPECIAL) (JUL 1998)**

*Derived from FAR 52.202-1 (OCT 1995)*

A. "Head of the agency" also called "agency head") or "Secretary" means the Secretary (or Attorney General, Administrator, Governor, Chairperson, or other chief official, as appropriate) of the agency, including any deputy or assistant chief official of the agency; and the term "authorized representative" means any person, persons, or board (other than the Contracting Officer) authorized to act for the head of the agency or Secretary.

B. "Commercial component" means any component that is a commercial item.

C. "Commercial item" means --

1. Any item, other than real property, that is of a type customarily used for nongovernmental purposes and that --
  - (i) Has been sold, leased, or licensed to the general public; or
  - (ii) Has been offered for sale, lease, or license to the general public;
2. Any item that evolved from an item described in paragraph (C)(1) of this clause through advances in technology or performance and that is not yet available in the commercial marketplace, but will be available in the commercial marketplace in time to satisfy the delivery requirements under a government solicitation;
3. Any item that would satisfy a criterion expressed in paragraphs (C)(1) or (C)(2) of this clause, but for --
  - (i) Modifications of a type customarily available in the commercial marketplace; or
  - (ii) Minor modifications of a type not customarily available in the commercial marketplace made to meet Federal Government requirements. "Minor" modifications means modifications that do not significantly alter the

nongovernmental function or essential physical characteristics of an item or component, or change the purpose of a process. Factors to be considered in determining whether a modification is minor include the value and size of the modification and the comparative value and size of the final product. Dollar values and percentages may be used as guideposts, but are not conclusive evidence that a modification is minor;

4. Any combination of items meeting the requirements of paragraphs (C)(1), (2), (3), or (5) of this clause that are of a type customarily combined and sold in combination to the general public;
  5. Installation services, maintenance services, repair services, training services, and other services if such services are procured for support of an item referred to in paragraphs (C)(1), (2), (3), or (4) of this clause, and if the source of such services --
    - (i) Offers such services to the general public and the Federal Government contemporaneously and under similar terms and conditions; and
    - (ii) Offers to use the same work force for providing the Federal Government with such services as the source uses for providing such services to the general public;
  6. Services of a type offered and sold competitively in substantial quantities in the commercial marketplace based on established catalog or market prices for specific tasks performed under standard commercial terms and conditions. This does not include services that are sold based on hourly rates without an established catalog or market price for a specific service performed;
  7. Any item, combination of items, or service referred to in subparagraphs (C)(1) through (C)(6), notwithstanding the fact that the item, combination or items, or service is transferred between or among separate divisions, subsidiaries, or affiliates of the subcontractor; or
  8. A nondevelopmental item, if the procuring agency determines the item was developed exclusively at private expense and sold in substantial quantities, on a competitive basis, to multiple State and Local Governments.
- D. "Component" means any item supplied to the Federal Government as part of an end item or of another component.
- E. "Nondevelopmental item" means --
1. Any previously developed item of supply used exclusively for governmental purposes by a Federal agency, a State or local Government, or a foreign Government with which the United States has a mutual defense cooperation agreement;
  2. Any item described in paragraph (E)(1) of this definition that requires only minor modification or modifications of a type customarily available in the commercial marketplace in order to meet the requirements of the procuring department or agency; or

3. Any item of supply being produced that does not meet the requirements of paragraph (E)(1) or (E)(2) solely because the item is not yet in use.
- F. "DOE Contracting Officer" means a person with the authority to enter into, administer, and/or terminate contracts and make related determinations and findings. The term includes certain authorized representatives of the DOE Contracting Officer acting within the limits of their authority as delegated by the DOE Contracting Officer.
- G. Except as otherwise provided in this subcontract, the term "lower-tier subcontracts" includes, but is not limited to, purchase orders and changes and modifications to purchase orders under this subcontract.
- H. The term "DOE" means the Department of Energy and "FERC" means the Federal Energy Regulatory Commission.
- I. The term "NREL" means the National Renewable Energy Laboratory Division of the Midwest Research Institute, a not-for-profit Missouri Corporation, and includes its successors and assigns of the NREL Division of Midwest Research Institute. The NREL facility is a Department of Energy-owned national laboratory, operated and managed under Contract No. DE-AC36-98-GO10337 by the NREL Division of the Midwest Research Institute.
- J. The term "Subcontractor" as used herein includes lower-tier subcontractors, independent contractors, and all other classes of persons performing any type of work under this subcontract.

**CLAUSE 5 - RESTRICTIONS ON LOWER-TIER SUBCONTRACTOR SALES  
TO NREL/GOVERNMENT (JUL 1995)**

*Derived from FAR 52.203-6*

*(Applies to subcontracts exceeding \$100,000)*

- A. Except as provided in (B) of this clause, the Subcontractor shall not enter into any agreement with an actual or prospective lower-tier subcontractor, nor otherwise act in any manner, which has or may have the effect of restricting sales by such lower-tier subcontractors directly to NREL/Government of any item or process (including computer software) made or furnished by the lower-tier subcontractor under this subcontract or under any follow-on production subcontract.
- B. The prohibition in (A) of this clause does not preclude the Subcontractor from asserting rights that are otherwise authorized by law or regulation.
- C. The Subcontractor agrees to incorporate the substance of this clause, including this paragraph (C), in all lower-tier subcontracts under this subcontract which exceed \$100,000.

**CLAUSE 6 - ANTI-KICKBACK PROCEDURES (JUL 1995)**

*Derived from FAR 52.203-7 (FD)*

*(Applies to subcontracts exceeding \$100,000)*

- A. Definitions.

"Kickback," as used in this clause, means any money, fee, commission, credit, gift, gratuity, thing of value, or compensation of any kind which is provided, directly or indirectly, to any Prime Contractor, Prime Contractor employee, Subcontractor, or Subcontractor employee for the purpose of improperly obtaining or rewarding favorable treatment in connection with a prime contract or in connection with a subcontract relating to a prime contract.

"Person," as used in this clause, means a corporation, partnership, business association of any kind, trust, joint-stock company, or individual.

"Prime contract," as used in this clause, means a contract or contractual action entered into by the United States for the purpose of obtaining supplies, materials, equipment, or services of any kind.

"Prime Contractor," as used in this clause, means a person who has entered into a prime contract with the United States.

"Prime Contractor employee," as used in this clause, means any officer, partner, employee, or agent of a Prime Contractor.

"Subcontract," as used in this clause, means a contract or contractual action entered into by a Prime Contractor or Subcontractor for the purpose of obtaining supplies, materials, equipment, or services of any kind under a prime contract.

"Subcontractor," as used in this clause, (1) means any person, other than the Prime Contractor, who offers to furnish or furnishes any supplies, materials, equipment, or services of any kind under a prime contract or a subcontract entered into in connection with such prime contract, and (2) includes any person who offers to furnish or furnishes general supplies to the Prime Contractor or a higher-tier subcontractor.

"Subcontractor employee," as used in this clause, means any officer, partner, employee, or agent of a Subcontractor.

- B. The Anti-Kickback Act of 1986 (41 U.S.C. 51-58) (the Act), prohibits any person from --
1. Providing or attempting to provide or offering to provide any kickback;
  2. Soliciting, accepting, or attempting to accept any kickback; or
  3. Including, directly or indirectly, the amount of any kickback in the contract price charged by a Prime Contractor to the United States or in the contract price charged by a Subcontractor to a Prime Contractor or higher-tier subcontractor.
- C.
1. The Subcontractor shall have in place and follow reasonable procedures designed to prevent and detect violations described in paragraph (B) of this clause in its own operations and direct business relationships.
  2. When the Subcontractor has reasonable grounds to believe that a violation described in paragraph (B) of this clause may have occurred, the Subcontractor shall promptly report in writing the possible violation. Such reports shall be made to the DOE inspector

general of the contracting agency, the head of the contracting agency if the agency does not have an inspector general, or the Department of Justice.

3. The Subcontractor shall cooperate fully with any Federal agency and/or NREL investigating a possible violation described in paragraph (B) of this clause.
4. The DOE Contracting Officer may --
  - (i) Offset the amount of the kickback against any monies owed by NREL under this subcontract and/or
  - (ii) Direct that the Subcontractor withhold from sums owed the lower-tier subcontractor the amount of the kickback. The DOE Contracting Officer may order that monies withheld under subdivision (C)(4)(ii) of this clause be paid over to NREL or the Government unless NREL or the Government has already offset those monies under subdivision (C)(4)(i) of this clause. In either case, the Subcontractor shall notify the NREL Subcontract Administrator when the monies are withheld.
5. The Subcontractor agrees to incorporate the substance of this clause, including subparagraph (C)(5) but excepting subparagraph (C)(1), in all lower-tier subcontracts under this subcontract which exceed \$100,000.

**CLAUSE 7 - LIMITATION ON PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (JUN 1997)**

*Derived from FAR 52-203-12*

*(Applies to subcontracts exceeding \$100,000)*

A. Definitions.

"Agency," as used in this clause, means executive agency as defined in FAR 2.101.

"Covered Federal action," as used in this clause, means any of the following Federal actions:

1. The awarding of any Federal contract.
2. The making of any Federal grant.
3. The making of any Federal loan.
4. The entering into of any cooperative agreement.
5. The extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

"Indian tribe" and "tribal organization," as used in this clause, have the meaning provided in section 4 of the Indian Self-Determination and Education Assistance Act (25 U.S.C. 450 B) and include Alaskan Natives.

"Influencing or attempting to influence," as used in this clause, means making, with the intent to influence, any communication to or appearance before an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with any covered Federal action.

"Local Government," as used in this clause, means a unit of Government in a State and, if chartered, established, or otherwise recognized by a State for the performance of a governmental duty, including a local public authority, a special district, an intrastate district, a council of governments, a sponsor group representative organization, and any other instrumentality of a Local Government.

"Officer or employee of an agency," as used in this clause, includes the following individuals who are employed by an agency:

1. An individual who is appointed to a position in the Government under Title 5, United States Code, including a position under a temporary appointment.
2. A member of the uniformed services, as defined in subsection 101(3), Title 37, United States Code.
3. A special Government employee, as defined in section 202, Title 18, United States Code.
4. An individual who is a member of a Federal advisory committee, as defined by the Federal Advisory Committee Act, Title 5, United States Code, appendix 2.

"Person," as used in this clause, means an individual, corporation, company, association, authority, firm, partnership, society, State, and Local Government, regardless of whether such entity is operated for profit, or not for profit. This term excludes an Indian tribe, tribal organization, or any other Indian organization with respect to expenditures specifically permitted by other Federal law.

"Reasonable compensation," as used in this clause, means, with respect to a regularly employed officer or employee of any person, compensation that is consistent with the normal compensation for such officer or employee for work that is not furnished to, not funded by, or not furnished in cooperation with the Federal Government.

"Reasonable payment," as used in this clause, means, with respect to professional and other technical services, a payment in an amount that is consistent with the amount normally paid for such services in the private sector.

"Recipient," as used in this clause, includes the Subcontractor and all lower-tier subcontractors. This term excludes an Indian tribe, tribal organization, or any other Indian organization with respect to expenditures specifically permitted by other Federal law.

"Regularly employed," as used in this clause, means, with respect to an officer or employee of a person requesting or receiving a Federal contract, an officer or employee who is employed by such person for at least one hundred and thirty (130) working days within one (1) year immediately preceding the date of the submission that initiates agency consideration of such person for receipt of such contract. An officer or employee who is employed by such person for

less than one hundred and thirty (130) working days within one (1) year immediately preceding the date of the submission that initiates agency consideration of such person shall be considered to be regularly employed as soon as he or she is employed by such person for one hundred and thirty (130) working days.

"State," as used in this clause, means a State of the United States, the District of Columbia, the Commonwealth of Puerto Rico, a territory or possession of the United States, an agency or instrumentality of a State, and multi-State, regional, or interstate entity having governmental duties and powers.

B. Prohibitions.

1. Section 1352 of Title 31, United States Code, among other things, prohibits a recipient of a Federal contract, grant, loan, or cooperative agreement from using appropriated funds to pay any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with any of the following covered Federal actions: the awarding of any Federal contract; the making of any Federal grant; the making of any Federal loan; the entering into of any cooperative agreement; or the modification of any Federal contract, grant, loan, or cooperative agreement.
2. The Act also requires Subcontractors to furnish a disclosure if any funds other than Federal appropriated funds (including profit or fee received under a covered Federal transaction) have been paid, or will be paid, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with a Federal contract, grant, loan, or cooperative agreement.
3. The prohibitions of the Act do not apply under the following conditions:
  - (i) Agency and legislative liaison by own employees.
    - a. The prohibition on the use of appropriated funds, in subparagraph (B)(1) of this clause, does not apply in the case of a payment of reasonable compensation made to an officer or employee of a person requesting or receiving a covered Federal action if the payment is for agency and legislative liaison activities not directly related to a covered Federal action.
    - b. For purposes of subdivision (B)(3)(i)(a) of this clause, providing any information specifically requested by an agency or Congress is permitted at any time.
    - c. The following agency and legislative liaison activities are permitted at any time where they are not related to a specific solicitation for any covered Federal action:

1. Discussing with an agency the qualities and characteristics (including individual demonstrations) of the person's products or services, conditions or terms of sale, and service capabilities.
  2. Technical discussions and other activities regarding the application or adaptation of the person's products or services for an agency's use.
- d. The following agency and legislative liaison activities are permitted where they are prior to formal solicitation of any covered Federal action --
1. Providing any information not specifically requested but necessary for an agency to make an informed decision about initiation of a covered Federal action;
  2. Technical discussions regarding the preparation of an unsolicited proposal prior to its official submission; and
  3. Capability presentations by persons seeking awards from an agency pursuant to the provisions of the Small Business Act, as amended by Pub.L.95-507, and subsequent amendments.
- e. Only those services expressly authorized by subdivision (B)(3)(i)(a) of this clause are permitted under this clause.
- (ii) Professional and technical services.
- a. The prohibition on the use of appropriated funds; in subparagraph (B)(1) of this clause, does not apply in the case of --
    1. A payment of reasonable compensation made to an officer or employee of a person requesting or receiving a covered Federal action or an extension, continuation, renewal, amendment, or modification of a covered Federal action, if payment is for professional or technical services rendered directly in the preparation, submission, or negotiation of any bid, proposal, or application for that Federal action or for meeting requirements imposed by or pursuant to law as a condition for receiving that Federal action.
    2. Any reasonable payment to a person, other than an officer or employee of a person requesting or receiving a covered Federal action or an extension, continuation, renewal, amendment, or modification of a covered Federal action if the payment is for professional or technical services rendered directly in the preparation, submission, or negotiation of any bid, proposal, or application for that Federal action or for meeting requirements imposed by or pursuant to law as a condition for receiving that

Federal action. Persons other than officers or employees of a person requesting or receiving a covered Federal action include consultants and trade associations.

- b. For purposes of subdivision (B)(3)(ii)(a) of this clause, "professional and technical services" shall be limited to advice and analysis directly applying any professional or technical discipline. For example, drafting of a legal document accompanying a bid or proposal by a lawyer is allowable. Similarly, technical advice provided by an engineer on the performance or operational capability of a piece of equipment rendered directly in the negotiation of a contract is allowable. However, communications with the intent to influence made by a professional (such as a licensed lawyer) or a technical person (such as a licensed accountant) are not allowable under this section unless they provide advice and analysis directly applying their professional or technical expertise and unless the advice or analysis is rendered directly and solely in the preparation, submission or negotiation of a covered Federal action. Thus, for example, communications with the intent to influence made by a lawyer that do not provide legal advice or analysis directly and solely related to the legal aspects of his or her client's proposal, but generally advocate one proposal over another are not allowable under this section because the lawyer is not providing professional legal services. Similarly, communications with the intent to influence made by an engineer providing an engineering analysis prior to the preparation or submission of a bid or proposal are not allowable under this section since the engineer is providing technical services but not directly in the preparation, submission or negotiation of a covered Federal action.
- c. Requirements imposed by or pursuant to law as a condition for receiving a covered Federal award include those required by law or regulation and any other requirements in the actual award documents.
- d. Only those services expressly authorized by subdivisions (B)(3)(ii)(a)(1) and (2) of this clause are permitted under this clause.
- e. The reporting requirements of FAR 3.803(a) shall not apply with respect to payments of reasonable compensation made to regularly employed officers or employees of a person.

C. Disclosure.

- 1. The Subcontractor who requests or receives from an agency a Federal contract shall file with that agency a disclosure form, OMB standard form LLL, Disclosure of Lobbying Activities, if such person has made or has agreed to make any payment using nonappropriated funds (to include profits from any covered Federal action), which would be prohibited under subparagraph (B)(1) of this clause, if paid for with appropriated funds.

2. The Subcontractor shall file a disclosure form at the end of each calendar quarter in which there occurs any event that materially affects the accuracy of the information contained in any disclosure form previously filed by such person under subparagraph (C)(1) of this clause. An event that materially affects the accuracy of the information reported includes--
  - (i) A cumulative increase of \$25,000 or more in the amount paid or expected to be paid for influencing or attempting to influence a covered Federal action; or
  - (ii) A change in the person(s) or individual(s) influencing or attempting to influence a covered Federal action; or
  - (iii) A change in the officer(s), employee(s), or Member(s) contacted to influence or attempt to influence a covered Federal action.
3. The Subcontractor shall require the submittal of a certification, and if required, a disclosure form by any person who requests or receives any subcontract exceeding \$100,000 under the Federal contract.
4. All lower-tier subcontractor disclosure forms (but not certifications) shall be forwarded from tier to tier until received by the Subcontractor. The Subcontractor shall submit all disclosures to the NREL Subcontract Administrator at the end of the calendar quarter in which the disclosure form is submitted by the Subcontractor. Each lower-tier subcontractor certification shall be retained in the subcontract file of the awarding Subcontractor.

D. Agreement.

The Subcontractor agrees not to make any payment prohibited by this clause.

E. Penalties.

1. Any person who makes an expenditure prohibited under paragraph (A) of this clause or who fails to file or amend the disclosure form to be filed or amended by paragraph (B) of this clause shall be subject to civil penalties as provided for by 31 U.S.C. 1352. An imposition of a civil penalty does not prevent the Government from seeking any other remedy that may be applicable.
2. Subcontractors may rely without liability on the representation made by their lower-tier subcontractors in the certification and disclosure form.

F. Cost allowability.

Nothing in this clause makes allowable or reasonable any costs which would otherwise be unallowable or unreasonable. Conversely, costs made specifically unallowable by the requirements in this clause will not be made allowable under any other provision.

**CLAUSE 8 - AUDIT AND RECORDS -- NEGOTIATION (JUN 1999)**

*Derived from FAR 52.215-2 (FD)*

*(Applies to subcontracts exceeding \$100,000) (Use Alternate II of this clause for Cost-reimbursement subcontracts with State and Local Governments, educational institutions, and other nonprofit organizations)*

A. As used in this clause, "records" includes books, documents, accounting procedures and practices, and other data, regardless of type and regardless of whether such items are written form, in the form of computer data, or in any other form.

B. Examination of Costs

If this a cost-reimbursement, incentive, time-and-materials, labor-hour, or price redeterminable subcontract, or any combination of these, the Subcontractor shall maintain and the DOE Contracting Officer, or an authorized representative of the DOE Contracting Officer, shall have the right to examine and audit all records and other evidence sufficient to reflect properly all costs claimed to have been incurred or anticipated to be incurred directly or indirectly in performance of this subcontract. This right of examination shall include inspection at all reasonable times of the Subcontractor's plants, or part of them, engaged in performing the subcontract.

C. Cost or pricing data

If the Subcontractor has been required to submit cost or pricing data in connection with any pricing action relating to this subcontract, the DOE Contracting Officer, or an authorized representative of the DOE Contracting Officer, in order to evaluate the accuracy, completeness, and currency of the cost or pricing data, shall have the right to examine and audit all of the Subcontractor's records, including computation and projections, related to --

1. The proposal for the subcontract, lower-tier subcontract, or modification;
2. The discussions conducted on the proposal(s), including those related to negotiating;
3. Pricing of the subcontract, lower-tier subcontract, or modification; or
4. Performance of the subcontract, lower-tier subcontract, or modification.

D. Comptroller General

1. The Comptroller General of the United States, or an authorized representative, shall have access to and the right to examine any of the Subcontractor's directly pertinent records involving transactions related to this subcontract or a lower-tier subcontract hereunder.
2. This paragraph may not be construed to require the Subcontractor or lower-tier subcontractor to create or maintain any record that the Subcontractor or lower-tier subcontractor does not maintain in the ordinary course of business or pursuant to a provision of law.

E. Reports

If the Subcontractor is required to furnish cost, funding, or performance reports, the DOE Contracting Officer or any authorized representative of the DOE Contracting Officer, shall have the right to examine and audit the supporting records and materials, for the purpose of evaluating --

1. The effectiveness of the Subcontractor's policies and procedures to produce data compatible with the objectives of these reports; and
2. The data reported.

F. Availability

The Subcontractor shall make available at its office at all reasonable times the records, materials, and other evidence described in paragraphs (A), (B), (C), (D), and (E) of this clause, for examination, audit, or reproduction, until 3 years after final payment under this subcontract or for any shorter period specified in Subpart 4.7, Subcontractor Records Retention, of the Federal Acquisition Regulation (FAR), or for any longer period required by statute or by other clauses of this subcontract. In addition--

1. If this subcontract is completely or partially terminated, the records relating to the work terminated shall be made available for three (3) years after any resulting final termination settlement; and
2. Records relating to appeals under the Disputes clause or to litigation or the settlement of claims arising under or relating to this subcontract shall be made available until such appeals, litigation, or claims are finally resolved.

G. The Subcontractor shall insert a clause containing all the terms of this clause, including this paragraph (G), in all lower-tier subcontracts under this subcontract that exceed the simplified acquisition threshold, and --

1. That are cost-reimbursement, incentive, time-and-materials, labor-hour, or price-redeterminable type or any combination of these;
2. For which cost or pricing data are required; or
3. That require the lower-tier subcontractor to furnish reports as discussed in paragraph (E) of this clause.

The clause may be altered only as necessary to identify properly the contracting parties and the DOE Contracting Officer or NREL Subcontract Administrator under the Government prime contract.

*Alternate II (JUN 1999)*

*(For Cost-reimbursement subcontracts with State and Local Governments, educational institutions, and other non-profit organizations, the following paragraph (H) shall be added.)*

- H. The provisions of OMB Circular No. A-133, "Audits of States, Local Governments, and Non-profit Organizations," apply to this subcontract.

**CLAUSE 9 - ALLOWABLE COST AND PAYMENT (APR 1998)**

*Derived from FAR 52.216-7*

*(For cost reimbursement subcontracts) (For educational institutions, substitute subpart 31.3; For State and Local Governments, substitute subpart 31.6; For other non-profit organizations, substitute subpart 31.7. See FAR 16.307(a))*

- A. Invoicing.

NREL shall make payments to the Subcontractor when requested as work progresses, but (except for small business concerns) not more often than once every two (2) weeks, in amounts determined to be allowable by the NREL Subcontract Administrator in accordance with Subpart 31.2 of the Federal Acquisition Regulation (FAR) in effect on the date of this subcontract and the terms of this subcontract. The Subcontractor may submit to an authorized representative of the NREL Subcontract Administrator, in such form and reasonable detail as the representative may require, an invoice or voucher supported by a statement of the claimed allowable cost for performing this subcontract.

- B. Reimbursing costs.

1. For the purpose of reimbursing allowable costs (except as provided in subparagraph (B)(2) of this section, with respect to pension, deferred profit sharing, and employee stock ownership plan contributions), the term "costs" includes only --
  - (i) Those recorded costs that, at the time of the request for reimbursement, the Subcontractor has paid by cash, check, or other form of actual payment for items or services purchased directly for the subcontract;
  - (ii) When the Subcontractor is not delinquent in paying costs of subcontract performance in the ordinary course of business, costs incurred, but not necessarily paid, for --
    - (a) Materials issued from the Subcontractor's inventory and placed in the production process for use on the subcontract;
    - (b) Direct labor;
    - (c) Direct travel;
    - (d) Other direct in-house costs; and
    - (e) Properly allocable and allowable indirect costs, as shown in the records maintained by the Subcontractor for purposes of obtaining reimbursement under Government contracts or subcontracts; and

- (iii) The amount of progress and other payments that have been paid by cash, check or other form of payment to the Subcontractor's lower-tier subcontractors under similar cost standards.
- 2. Subcontractor contributions to any pension or other post retirement benefit, profit-sharing, or employee stock ownership plan funds that are paid quarterly or more often may be included in indirect costs for payment purposes; provided, that the Subcontractor pays the contribution to the fund within thirty (30) days after the close of the period covered. Payments made thirty (30) days or more after the close of a period shall not be included until the Subcontractor actually makes the payment. Accrued costs for such contributions that are paid less often than quarterly shall be excluded from indirect costs for payment purposes until the Subcontractor actually makes the payment.
- 3. Notwithstanding the audit and adjustment of invoices or vouchers under paragraph (G) of this clause, allowable indirect costs under this subcontract shall be obtained by applying indirect costs rates established in accordance with paragraph (D) of this clause.
- 4. Any statements in specifications or other documents incorporated in this subcontract by reference designating performance of services or furnishing of materials at the Subcontractor's expense or at no cost to NREL shall be disregarded for purposes of cost-reimbursement under this clause.

C. Small business concerns.

A small business concern may be paid more often than every two (2) weeks and may invoice and be paid for recorded costs for items or services purchased directly for the subcontract, even though the concern has not yet paid for those items or services.

D. Final indirect costs rates.

- 1. Final annual indirect cost rates and the appropriate bases shall be established in accordance with Subpart 42.7 of the Federal Acquisition Regulation (FAR) in effect for the period covered by the indirect cost rate proposal.
- 2.
  - i. The Subcontractor shall submit an adequate final indirect cost rate proposal to the NREL Subcontract Administrator (or cognizant Federal agency official) and auditor within the 6-month period following the expiration of each of its fiscal years. Reasonable extensions, for exceptional circumstances only, may be requested in writing by the Subcontractor and granted in writing by the NREL Subcontract Administrator. The Subcontractor shall support its proposal with adequate supporting data.
  - ii. The proposed rates shall be based on the Subcontractor's actual cost experience for that period. The appropriate Government representative or NREL Subcontract Administrator and the Subcontractor shall establish the final indirect cost rates as promptly as practical after receipt of the Subcontractor's proposal.

3. The Subcontractor and the appropriate Government representative or NREL Subcontract Administrator shall execute a written understanding setting forth the final indirect cost rates. The understanding shall specify
  - (i) The agreed-upon final annual indirect cost rates,
  - (ii) The bases to which the rates apply,
  - (iii) The periods for which the rates apply,
  - (iv) Any specific indirect cost items treated as direct costs in the settlement, and
  - (v) The affected contract and/or subcontract, identifying any with advance agreements or special terms and the applicable rates. The understanding shall not change any monetary ceiling, contract/subcontract obligation, or specific cost allowance or disallowance provided for in this subcontract. The understanding is incorporated into this subcontract upon execution.
4. Within one hundred and twenty (120) days after settlement of the final indirect cost rates covering the year in which this subcontract is physically complete (or longer, if approved in writing by the NREL Subcontract Administrator), the Subcontractor shall submit a completion invoice or voucher to reflect the settled amounts and rates.
5. Failure by the parties to agree on a final annual indirect cost rate shall be a dispute within the meaning of the Disputes clause.

E. Billing rates.

Until final annual indirect cost rates are established for any period, NREL shall reimburse the Subcontractor at billing rates established by the NREL Subcontract Administrator, or by an authorized representative (the cognizant auditor), subject to adjustment when the final rates are established. These billing rates --

1. Shall be the anticipated final rates; and
2. May be prospectively or retroactively revised by mutual agreement, at either party's request, to prevent substantial overpayment or underpayment.

F. Quick-closeout procedures.

Quick-closeout procedures are applicable when the conditions in FAR 42.708(a) are satisfied.

G. Audit.

At any time or times before final payment, the NREL Subcontract Administrator may have the Subcontractor's invoices or vouchers and statements of cost audited. Any payment may be

1. Reduced by amounts found by the NREL Subcontract Administrator not to constitute allowable costs; or

2. Adjusted for prior overpayments or underpayments.

H. Final payment.

1. Upon approval of a completion invoice or voucher submitted by the Subcontractor in accordance with paragraph (D)(4) of this clause, and upon the Subcontractor's compliance with all terms of the subcontract, NREL shall promptly pay any balance of allowable costs and that part of the fee (if any) not previously paid.
2. The Subcontractor shall pay to NREL any refunds, rebates, credits, or other amounts (including interest, if any) accruing to or received by the Subcontractor or any assignee under this subcontract, to the extent that those amounts are properly allocable to costs for which the Subcontractor has been reimbursed by NREL. Reasonable expenses incurred by the Subcontractor for securing refunds, rebates, credits, or other amount shall be allowable costs if approved by the NREL Subcontract Administrator. Before final payment under this subcontract, the Subcontractor and each assignee whose assignment is in effect at the time of final payment shall execute and deliver --
  - (i) An assignment to NREL, in form and substance satisfactory to the NREL Subcontract Administrator, of refunds, rebates, credits, or other amounts (including interest, if any) properly allocable to costs for which the Subcontractor has been reimbursed by NREL under this subcontract; and
  - (ii) A release discharging NREL/Government, its officers, agents, and employees from all liabilities, obligations, and claims arising out of or under this contract, except --
    - (a) Specified claims stated in exact amounts, or in estimated amounts when the exact amounts are not known;
    - (b) Claims (including reasonable incidental expenses) based upon liabilities of the Subcontractor to third parties arising out of the performance of this subcontract; **provided;** that the claims are not known to the Subcontractor on the date of the execution of the release, and that the Subcontractor gives notice of the claims in writing to the NREL Subcontract Administrator within 6 years following the release date or notice of final payment date, whichever is earlier; and
    - (c) Claims for reimbursement of costs, including reasonable incidental expenses, incurred by the Subcontractor under the patent clauses of this subcontract, excluding, however, any expenses arising from the Subcontractor's indemnification of NREL/Government against patent liability.

**CLAUSE 10 - FIXED FEE (MAR 1997)**

*Derived from FAR 52.216-8*

*(Applies to cost plus fixed fee subcontracts)*

- A. NREL shall pay the Subcontractor for performing this subcontract the fixed fee specified in the Schedule.
- B. Payment of the fixed fee shall be made as specified in the Schedule; **provided**, that after payment of eighty five (85) percent of the fixed fee, the NREL Subcontract Administrator may withhold further payment of fee until a reserve is set aside in an amount that the NREL Subcontract Administrator considers necessary to protect NREL's/Government's interest. This reserve shall not exceed 15 percent of the total fixed fee or \$100,000, whichever is less. The NREL Subcontract Administrator shall release seventy five (75) percent of all fee withholds under this subcontract after receipt of the certified final indirect cost rates proposal covering the year of physical completion of this subcontract, **provided** the Subcontractor has satisfied all other subcontract terms and conditions, including the submission of the final patent and royalty reports, and is not delinquent in submitting final vouchers on prior years' settlements. The NREL Subcontract Administrator may release up to ninety (90) percent of the fee withheld under this subcontract based on the Subcontractor's past performance related to the submission and settlement of final indirect cost rate proposals.

**CLAUSE 11 - COST SUBCONTRACT - NO FEE (APR 1984)**

*Derived from FAR 52.216-11*

*(Applies to cost reimbursement subcontracts)*

- A. NREL shall not pay the Subcontractor a fee for performing this subcontract.
- B. After payment of eighty (80) percent of the total estimated cost shown in the Schedule, the NREL Subcontract Administrator may withhold further payment of allowable cost until a reserve is set aside in an amount that the NREL Subcontract Administrator considers necessary to protect NREL's/Government's interest. This reserve shall not exceed one percent of the total estimated cost shown in the Schedule or \$100,000 whichever is less.

**CLAUSE 12 - COST-SHARING SUBCONTRACT--NO FEE (APR 1984)**

*Derived from FAR 52.216-12*

*(Applies to cost sharing subcontracts)*

- A. NREL shall not pay to the Subcontractor a fee for performing this subcontract.
- B. After paying 80 percent of NREL's share of the total estimated cost of performance shown in the Schedule, the NREL Subcontract Administrator may withhold further payment of allowable cost until a reserve is set aside in an amount that the NREL Subcontract Administrator considers necessary to protect NREL's/Government's interest. This reserve shall not exceed one percent of NREL's share of the total estimated cost shown in the Schedule or \$100,000, whichever is less.

**CLAUSE 13 - PREDETERMINED INDIRECT COST RATES (APR 1998)**

*Derived from FAR 52.216-15*

*(Applies to cost reimbursement research and development subcontracts with educational institutions when predetermined indirect cost rates are used)*

- A. Notwithstanding the Allowable Cost and Payment clause of this subcontract, the allowable indirect costs under this subcontract shall be obtained by applying predetermined indirect cost rates to bases agreed upon by the parties as specified below.
- B. 1. The Subcontractor shall submit an adequate final indirect cost rate proposal to the NREL Subcontract Administrator (or cognizant Federal agency official) and auditor within the six (6)-month period following the expiration of each of its fiscal years. Reasonable extensions, for exceptional circumstances only, may be requested in writing by the Subcontractor and granted in writing by the NREL Subcontract Administrator. The Subcontractor shall support its proposal with adequate supporting data.
2. The proposed rates shall be based on the Subcontractor's actual cost experience for that period. The appropriate Government representative and the NREL Subcontract Administrator shall establish the final indirect cost rates as promptly as practical after receipt of the Subcontractor's proposal.
- C. Allowability of costs and acceptability of cost allocation methods shall be determined in accordance with FAR Subpart 31.3 in effect on the date of this subcontract.
- D. Predetermined rate agreements in effect on the date of this subcontract shall be incorporated into the subcontract Schedule. The NREL Subcontract Administrator (or cognizant Federal agency official) and Subcontractor shall negotiate rates for subsequent periods and execute a written indirect cost rate agreement setting forth the results. The agreement shall specify--
1. The agreed-upon predetermined indirect cost rates,
  2. The bases to which the rates apply,
  3. The period for which the rates apply, and
  4. The specific items treated as direct costs or any changes in the items previously agreed to be direct costs.

The indirect cost rate agreement shall not change any monetary ceiling, subcontract obligation, or specific cost allowance or disallowance provided for in this subcontract. The agreement is incorporated into this subcontract upon execution.

- E. Pending establishment of predetermined indirect cost rates for any fiscal year (or other period agreed to by the parties), the Subcontractor shall be reimbursed either at the rates fixed for the previous fiscal year (or other period) or at billing rates acceptable to the NREL Subcontract Administrator (or cognizant Federal agency official), subject to appropriate adjustment when the final rates for that period are established.

- F. Any failure by the parties to agree on any predetermined indirect cost rates under this clause shall not be considered a dispute within the meaning of the Disputes clause. If for any fiscal year (or other period specified in the Schedule) the parties fail to agree to predetermined indirect cost rates, the allowable indirect costs shall be obtained by applying final indirect cost rates established in accordance with the Allowable Cost and Payment clause.
- G. Allowable indirect costs for the period from the beginning of performance until the end of the Subcontractor's fiscal year (or other period specified in the Schedule) shall be obtained using the predetermined indirect cost rates and the bases shown in the Schedule.

**CLAUSE 14 - UTILIZATION OF SMALL BUSINESS CONCERNS (OCT 1999)**

*Derived from FAR 52.219-8 (FD)*

*(Applies to subcontracts exceeding \$100,000)*

- A. It is the policy of the United States that small business concerns, HUBZone small business concerns, small business concerns owned and controlled by socially and economically disadvantaged individuals and small business concerns owned and controlled by women shall have the maximum practicable opportunity to participate in performing contracts let by any Federal agency, including subcontracts and lower-tier subcontracts for subsystems, assemblies, components, and related services for major systems. It is further the policy of the United States that its Prime Contractors establish procedures to ensure the timely payment of amounts due pursuant to the terms of their lower-tier subcontracts with small business concerns, HUBZone small business concerns, small business concerns owned and controlled by socially and economically disadvantaged individuals and small business concerns owned and controlled by women.
- B. The Subcontractor hereby agrees to carry out this policy in the awarding of subcontracts to the fullest extent consistent with efficient contract performance. The Subcontractor further agrees to cooperate in any studies or surveys as may be conducted by the United States Small Business Administration or the awarding agency of the United States as may be necessary to determine the extent of the Subcontractor's compliance with this clause.
- C. Definitions.

As used in this subcontract--

1. "Small business concern" shall mean a small business as defined pursuant to section 3 of the Small Business Act and relevant regulations promulgated pursuant thereto.
2. "HUBZone small business concern" means a small business concern that appear on the List of Qualified HUBZone Small Business Concerns maintained by the Small Business Administration.
3. "Small business concern owned and controlled by socially and economically disadvantaged individuals" means an offeror that represents, as part of its offer, that-
  - (i) It has received certification as a small disadvantaged business concern consistent with 13 CFR 124, Subpart B;

- (ii) No material change in disadvantaged ownership and control has occurred since its certification;
- (iii) Where the concern is owned by one or more individuals, the net worth of each individual upon whom the certification is based does not exceed \$750,000 after taking into account the applicable exclusions set forth at 13 CFR 124.104(c)(2); and
- (iv) It is identified, on the date of its representation, as a certified small disadvantaged business in the database maintained by the Small Business Administration (PRO-NET).

4. "Small business concern owned and controlled by women" means a small business concern --

- (i) Which is at least fifty one (51) percent owned by one or more women, or, in the case of any publicly owned business, at least fifty one (51) percent of the stock of which is owned by one or more women; and
- (ii) Whose management and daily business operations are controlled by one or more women; and

D. Subcontractors acting in good faith may rely on written representations by their lower-tier subcontractors regarding their status as a small business concern, a HUBZone small business concern, a small business concern owned and controlled by socially and economically disadvantaged individuals or a small business concern owned and controlled by women.

**CLAUSE 15 - PAYMENT FOR OVERTIME PREMIUMS (JUL 1990)**

*Derived from FAR 52.222-2*

*(Applies to cost reimbursement subcontracts exceeding \$100,000)*

A. The use of overtime is authorized under this subcontract if the overtime premium does not exceed \* \_\_\_\_\_ or the overtime premium is paid for work --

- 1. Necessary to cope with emergencies such as those resulting from accidents, natural disasters, breakdowns of production equipment, or occasional production bottlenecks of a sporadic nature;
- 2. By indirect-labor employees such as those performing duties in connection with administration, protection, transportation, maintenance, standby plant protection, operation of utilities, or accounting;
- 3. To perform tests, industrial processes, laboratory procedures, loading or unloading of transportation conveyances, and operations in flight or afloat that are continuous in nature and cannot reasonably be interrupted or completed otherwise; or
- 4. That will result in lower overall costs to NREL/Government.

- B. Any request for estimated overtime premiums that exceeds the amount specified above shall include all estimated overtime for contract completion and shall --
1. Identify the work unit; e.g., department or section in which the requested overtime will be used, together with present workload, staffing, and other data of the affected unit sufficient to permit the NREL Subcontract Administrator to evaluate the necessity for the overtime;
  2. Demonstrate the effect that denial of the request will have on the subcontract delivery or performance schedule;
  3. Identify the extent to which approval of overtime would affect the performance or payments in connection with other Government contracts, together with identification of each affected subcontract; and
  4. Provide reasons why the required work cannot be performed by using multishift operations or by employing additional personnel.

\* *Insert either "zero" or the dollar amount agreed to during negotiations. The inserted figure does not apply to the exceptions in subparagraph (A)(1) through (A)(4) of the clause.*

**CLAUSE 16 - CONTRACT WORK HOURS AND SAFETY STANDARDS ACT --  
OVERTIME COMPENSATION (JUL 1995)**

*Derived from FAR 52.222-4 (FD)*

*(Applies to subcontracts exceeding \$100,000 that require or involve the employment of laborers or mechanics)*

A. Overtime requirements.

No Subcontractor or lower-tier subcontractor contracting for any part of the subcontract work which may require or involve the employment of laborers or mechanics (see Federal Acquisition Regulation (FAR) 22.300) shall require or permit any such laborers or mechanics in any workweek in which the individual is employed on such work to work in excess of forty (40) hours in such workweek unless such laborer or mechanic receives compensation at a rate not less than 1 ½ times the basic rate of pay for all hours worked in excess of forty (40) hours in such workweek.

B. Violation; liability for unpaid wages; liquidated damages.

In the event of any violation of the provisions set forth in paragraph (A) of this clause, the Subcontractor and any lower-tier subcontractor responsible therefor shall be liable for the unpaid wages. In addition, such Subcontractor and lower-tier subcontractor shall be liable to the United States (in the case of work done under subcontract for the District of Columbia or a territory, to such District or to such territory), and/or NREL, for liquidated damages. Such liquidated damages shall be computed with respect to each individual laborer or mechanic employed in violation of the provisions set forth in paragraph (A) of this clause in the sum of \$10 for each calendar day on which such individual was required or permitted to work in excess of the standard workweek of 40 hours without payment of the overtime wages required by provisions set forth in paragraph (A) of this clause.

C. Withholding for unpaid wages and liquidated damages.

The NREL Subcontract Administrator shall upon his or her own action or upon written request of an authorized representative of the Department of Labor withhold or cause to be withheld, from any moneys payable on account of work performed by the Subcontractor or lower-tier subcontractor under any such subcontract or any other Federal contract with the same Prime Contractor, or any other Federally-assisted contract subject to the Contract Work Hours and Safety Standards Act which is held by the same Prime Contractor, such sums as may be determined to be necessary to satisfy any liabilities of such Subcontractor or lower-tier subcontractor for unpaid wages and liquidated damages as provided in the provisions set forth in paragraph (B) of this clause.

D. Payrolls and basic records.

1. The Subcontractor or lower-tier subcontractor shall maintain payrolls and basic payroll records during the course of subcontract work and shall preserve them for a period of three (3) years from the completion of the subcontract for all laborers and mechanics working on the subcontract. Such records shall contain the name and address of each such employee, social security number, correct classifications, hourly rates of wages paid, daily and weekly number of hours worked, deductions made, and actual wages paid. Nothing in this paragraph shall require the duplication of records required to be maintained for construction work by Department of Labor regulations at 29 CFR 5.5(a)(3) implementing the Davis-Bacon Act.
2. The records to be maintained under paragraph (D)(1) of this clause shall be made available by the Subcontractor or lower-tier subcontractor for inspection, copying, or transcription by authorized representatives of Department of Energy, NREL, or the Department of Labor. The Subcontractor or lower-tier subcontractor shall permit such representatives to interview employees during working hours on the job.

E. Lower-tier Subcontracts.

The Subcontractor or lower-tier subcontractor shall insert in any lower-tier subcontracts exceeding \$100,000 the provisions set forth in paragraphs (A) through (E) of this clause and also a clause requiring the lower-tier subcontractors to include these provisions in any lower-tier subcontracts. The Subcontractor shall be responsible for compliance by any lower-tier subcontractor with the provisions set forth in paragraphs (A) through (E) of this clause.

**CLAUSE 17 - WALSH-HEALEY PUBLIC CONTRACTS ACT (DEC 1996)**

*Derived from FAR 52.222-20*

*(Applies to subcontracts for the manufacture or furnishing of materials, supplies, articles or equipment in an amount that exceeds or may exceed \$10,000)*

If this subcontract is for the manufacture or furnishing of materials, supplies, articles or equipment in an amount that exceeds or may exceed \$10,000, and is subject to the Walsh-Healey Public Contracts Act, as amended (41 U.S.C.35-45), the following terms and conditions apply:

- (a) All stipulations required by the Act and regulations issued by the Secretary of Labor (41 CFR Chapter 50) are incorporated by reference. These stipulations are subject to all applicable rulings and interpretations of the Secretary of Labor that are now, or may hereafter, be in effect.

(b) All employees whose work relates to this contract shall be paid not less than the minimum wage prescribed by regulations issued by the Secretary of Labor (41 CFR 50-202.2). Learners, student learners, apprentices, and handicapped workers may be employed at less than the prescribed minimum wage (see 41 CFR 50-202.3) to the same extent that such employment is permitted under Section 14 of the Fair Labor Standards Act (41 U.S.C.40).

**CLAUSE - EQUAL OPPORTUNITY (FEB 1999)**

*Derived from FAR 52.222-26 (FD)*

- A. If, during any 12-month period (including the twelve (12) months preceding the award of this subcontract), the Subcontractor has been or is awarded nonexempt Federal contracts and/or subcontracts that have an aggregate value in excess of \$10,000, the Subcontractor shall comply with subparagraphs B (1) through (11) below. Upon request, the Subcontractor shall provide information necessary to determine the applicability of this clause.
- B. During performance of this subcontract, the Subcontractor agrees as follows:
1. The Subcontractor shall not discriminate against any employee or applicant for employment because of race, color, religion, sex, or national origin. However, it shall not be a violation of this clause for the Subcontractor to extend a publicly announced preference in employment to Indians living on or near an Indian reservation, in connection with employment opportunities on or near an Indian reservation, as permitted by 41 CFR 60-1.5.
  2. The Subcontractor shall take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, color, religion, sex, or national origin. This shall include, but not be limited to,
    - (i) Employment,
    - (ii) Upgrading,
    - (iii) Demotion,
    - (iv) Transfer,
    - (v) Recruitment or recruitment advertising,
    - (vi) Layoff or termination,
    - (vii) Rates of pay or other forms of compensation, and
    - (viii) Selection for training, including apprenticeship.
  3. The Subcontractor shall post in conspicuous places available to employees and applicants for employment the notices to be provided by the NREL Subcontract Administrator that explain this clause.

4. The Subcontractor shall, in all solicitations or advertisements for employees placed by or on behalf of the Subcontractor, state that all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, or national origin.
5. The Subcontractor shall send, to each labor union or representative of workers with which it has a collective bargaining agreement or other contract or understanding, the notice to be provided by the NREL Subcontract Administrator advising the labor union or workers' representative of the Subcontractor's commitments under this clause, and post copies of the notice in conspicuous places available to employees and applicants for employment.
6. The Subcontractor shall comply with Executive Order 11246, as amended, and the rules, regulations, and orders of the Secretary of Labor.
7. The Subcontractor shall furnish to NREL all information required by Executive Order 11246, as amended, and by the rules, regulations, and orders of the Secretary of Labor. The subcontractor shall also file Standard Form 100 (EEO-1), or any successor form, as prescribed in 41 CFR part 60-1. Unless the Subcontractor has filed within the 12 months preceding the date of contract award, the subcontractor shall, within 30 days after contract award, apply to either the regional Office of Federal Contract Compliance Programs (OFCCP) or the local office of the Equal Employment Opportunity Commission for the necessary forms.
8. The Subcontractor shall permit access to its premises, during normal business hours, by NREL/Government or the OFCCP for the purpose of conducting on-site compliance evaluations and complaint investigations. The Subcontractor shall permit NREL/Government to inspect and copy any books, accounts, records (including computerized records), and other material that may be relevant to the matter under investigation and pertinent to compliance with Executive Order 11246, as amended, and rules and regulations that implement the Executive Order.
9. If the OFCCP determines that the Subcontractor is not in compliance with this clause or any rule, regulation, or order of the Secretary of Labor, this contract may be canceled, terminated, or suspended in whole or in part and the Subcontractor may be declared ineligible for further NREL subcontracts, under the procedures authorized in Executive Order 11246, as amended. In addition, sanctions may be imposed and remedies invoked against the Subcontractor as provided in Executive Order 11246, as amended; in the rules, regulations, and orders of the Secretary of Labor; or as otherwise provided by law.
10. The Subcontractor shall include the terms and conditions of subparagraphs (b)(1) through (11) of this clause in every lower-tier subcontract or purchase order that is not exempted by the rules, regulations, or orders of the Secretary of Labor issued under Executive Order 11246, as amended, so that these terms and conditions will be binding upon each lower-tier subcontractor or vendor.
11. The Subcontractor shall take such action with respect to any lower-tier subcontract or purchase order as the NREL subcontract administrator may direct as a means of enforcing these terms and conditions, including sanctions for noncompliance, provided,

that if the Subcontractor becomes involved in, or is threatened with, litigation with a lower-tier subcontractor or vendor as a result of any direction, the Subcontractor may request the United States to enter into the litigation to protect the interests of the United States.

- C. Notwithstanding any other clause in this contract, disputes relative to this clause will be governed by the procedures in 41 CFR 60-1.1

**CLAUSE 19 - AFFIRMATIVE ACTION FOR DISABLED VETERANS AND VETERANS OF THE VIETNAM ERA (APR 1998)**

*Derived from FAR 52.222-35 (FD)*

*(Applies to subcontracts exceeding \$10,000)*

- A. Definitions. As used in this clause --

"All employment openings" includes all positions except executive and top management, those positions that will be filled from within the Subcontractor's organization, and positions lasting three (3) days or less. This term includes full-time employment, temporary employment of more than three (3) days' duration, and part-time employment.

"Appropriate office of the State employment service system" means the local office of the Federal-State national system of public employment offices with assigned responsibility to serve the area where the employment opening is to be filled, including the District of Columbia, Guam, the Commonwealth of Puerto Rico, and the Virgin Islands.

"Positions that will be filled from within the Subcontractor's organization" means employment openings for which no consideration will be given to persons outside the Subcontractor's organization (including any affiliates, subsidiaries, and parent companies) and includes any openings that the Subcontractor proposes to fill from regularly established "recall" lists. The exception does not apply to a particular opening once an employer decides to consider applicants outside of its organization.

"Veteran of the Vietnam era" means a person who --

1. Served on active duty for a period of more than 180 days, any part of which occurred between August 5, 1964, and May 7, 1975, and was discharged or released there from with other than a dishonorable discharge; or
2. Was discharged or released from active duty for a service-connected disability if any part of such active duty was performed between August 5, 1964 and May 7, 1975.

- B. General.

1. Regarding any position for which the employee or applicant for employment is qualified, the Subcontractor shall not discriminate against the individual because the individual is a disabled veteran or a veteran of the Vietnam era. The Subcontractor agrees to take affirmative action to employ, advance in employment, and otherwise treat qualified special disabled and Vietnam Era veterans without discrimination based upon their disability or veterans' status in all employment practices such as --

- (i) Employment;
  - (ii) Upgrading;
  - (iii) Demotion or transfer;
  - (iv) Recruitment;
  - (v) Advertising;
  - (vi) Layoff or termination;
  - (vii) Rates of pay or other forms of compensation; and
  - (viii) Selection for training, including apprenticeship.
2. The Subcontractor agrees to comply with the rules, regulations, and relevant orders of the Secretary of Labor (Secretary) issued under the Vietnam Era Veterans' Readjustment Assistance Act of 1972 (the Act), as amended.

C. Listing openings.

1. The Subcontractor agrees to list all employment openings existing at subcontract award or occurring during subcontract performance, at an appropriate office of the State employment service system in the locality where the opening occurs. These openings include those occurring at any Subcontractor facility, including one not connected with performing this subcontract. An independent corporate affiliate is exempt from this requirement.
2. State and Local Government agencies holding Federal contracts or subcontracts of \$10,000 or more shall also list all their suitable openings with the appropriate office of the State employment service.
3. The listing of suitable employment openings with the State employment service system is required at least concurrently with using any other recruitment source or effort and involves the obligations of placing a bona fide job order, including accepting referrals of veterans and nonveterans. This listing does not require hiring any particular job applicant or hiring from any particular group of job applicants and is not intended to relieve the Subcontractor from any requirements of Executive Orders or regulations concerning nondiscrimination in employment.
4. Whenever the Subcontractor becomes contractually bound to the listing terms of this clause, it shall advise the State employment service system, in each State where it has establishments, of the name and location of each hiring location in the State. As long as the Subcontractor is contractually bound to these terms and has so advised the State system, it need not advise the State system of subsequent contracts/subcontracts. The Subcontractor may advise the State system when it is no longer bound by this subcontract clause.

D. Applicability.

1. This clause does not apply to the listing of employment openings which occur and are filled outside the fifty (50) states, the District of Columbia, the Commonwealth of Puerto Rico, Guam, and the Virgin Islands.

E. Postings.

1. The Subcontractor agrees to post employment notices stating
  - (i) The Subcontractor's obligation under the law to take affirmative action to employ and advance in employment qualified disabled veterans and veterans of the Vietnam era, and
  - (ii) The rights of applicants and employees.
2. These notices shall be posted in conspicuous places that are available to employees and applicants for employment. They shall be in a form prescribed by the Deputy Assistant Secretary for Federal Contract Compliance Programs, Department of Labor (Deputy Assistant Secretary), and provided by or through the NREL Subcontract Administrator.
3. The Subcontractor shall notify each labor union or representative of workers with which it has a collective bargaining agreement or other contract understanding, that the Subcontractor is bound by the terms of the Act, and is committed to take affirmative action to employ, and advance in employment, qualified disabled veterans and veterans of the Vietnam era.

F. Noncompliance.

If the Subcontractor does not comply with the requirements of this clause, appropriate actions may be taken under the rules, regulations, and relevant orders of the Secretary issued pursuant to the Act.

G. Lower-tier Subcontracts.

The Subcontractor shall include the terms of this clause in every lower-tier subcontract or purchase order of \$10,000 or more unless exempted by rules, regulations, or orders of the Secretary. The Subcontractor shall act as specified by the Director to enforce the terms, including action for noncompliance.

**CLAUSE 20 - AFFIRMATIVE ACTION FOR WORKERS WITH DISABILITIES (JUN 1998)**

*Derived from FAR 52.222-36 (FD)*

*(Applies to subcontracts exceeding \$10,000)*

A. General.

1. Regarding any position for which the employee or applicant for employment is qualified, the Subcontractor shall not discriminate against any employee or applicant because of physical or mental disability. The Subcontractor agrees to take affirmative action to employ, advance in employment, and otherwise treat qualified individuals with disabilities without discrimination based upon their physical or mental disability in all employment practices such as --
  - (i) Recruitment, advertising, and job application procedures;
  - (ii) Hiring, upgrading, promotion, award of tenure, demotion, transfer, layoff, termination, right of return from layoff, and rehiring;
  - (iii) Rates of pay or any other form of compensation and changes in compensation;
  - (iv) Job assignments, job classifications, organizational structures, position descriptions, lines of progression, and seniority lists;
  - (v) Leaves of absence, sick leave, or any other leave;
  - (vi) Fringe benefits available by virtue of employment, whether or not administered by the Subcontractor;
  - (vii) Selection and financial support for training, including apprenticeships, professional meetings, conferences, and other related activities, and selection for leaves of absence to pursue training;
  - (viii) Activities sponsored by the Subcontractor, including social or recreational programs; and
  - (ix) Any other term, condition, or privilege of employment.
2. The Subcontractor agrees to comply with the rules, regulations, and relevant orders of the Secretary of Labor (Secretary) issued under the Rehabilitation Act of 1973 (29 U.S.C.793) (the Act), as amended.

**B. Postings.**

1. The Subcontractor agrees to post employment notices stating --
  - (i) The Subcontractor's obligation under the law to take affirmative action to employ and advance in employment qualified individuals with disabilities; and
  - (ii) The rights of applicants and employees.
2. These notices shall be posted in conspicuous places that are available to employees and applicants for employment. The Subcontractor shall ensure that applicants and employees with disabilities are informed of the contents of the notice (e.g., the Subcontractor may have the notice read to a visually disabled individual, or may lower the posted notice so that it might be read by a person in a wheelchair). The notices shall

be in a form prescribed by the Deputy Assistant Secretary for Federal Contract Compliance of the U.S. Department of Labor (Deputy Assistant Secretary) and shall be provided by or through the DOE Contracting Officer.

3. The Subcontractor shall notify each labor union or representative of workers with which it has a collective bargaining agreement or other contract understanding, that the Subcontractor is bound by the terms of Section 503 of the Act and is committed to take affirmative action to employ, and advance in employment, qualified individuals with physical or mental disabilities.

C. Noncompliance.

If the Subcontractor does not comply with the requirements of this clause, appropriate actions may be taken under the rules, regulations, and relevant orders of the Secretary issued pursuant to the Act.

D. Lower-tier Subcontracts.

The Subcontractor shall include the terms of this clause in every subcontract or purchase order in excess of \$10,000 unless exempted by rules, regulations, or orders of the Secretary. The Subcontractor shall act as specified by the Deputy Assistant Secretary to enforce the terms, including action for noncompliance.

**CLAUSE 21 - EMPLOYMENT REPORTS ON DISABLED VETERANS AND VETERANS OF THE VIETNAM ERA (APR 1998)**

*Derived from FAR 52.222-37 (FD)*

*(Applies to subcontracts exceeding \$10,000)*

- A. Unless the Subcontractor is a State or Local Government agency, the Subcontractor shall report at least annually, as required by the Secretary of Labor, on:
  1. The number of disabled veterans and the number of veterans of the Vietnam era in the workforce of the Subcontractor by job category and hiring location; and
  2. The total number of new employees hired during the period covered by the report, and of that total, the number of disabled veterans, and the number of veterans of the Vietnam era.
- B. The above items shall be reported by completing the form entitled "Federal Contractor Veterans' Employment Report VETS-100."
- C. Reports shall be submitted no later than March 31 of each year beginning March 31, 1988.
- D. The employment activity report required by paragraph (A)(2) of this clause shall reflect total hires during the most recent twelve (12)-month period as of the ending date selected for the employment profile report required by paragraph (A)(1) of this clause. Subcontractors may select an ending date:

1. As of the end of any pay period during the period January through March 1st of the year the report is due, or
  2. As of December 31, if the Subcontractor has previous written approval from the Equal Employment Opportunity Commission to do so for purposes of submitting the Employer Information Report EEO-1 (Standard Form 100).
- E. The count of veterans reported according to paragraph (A) of this clause shall be based on voluntary disclosure. Each Subcontractor subject to the reporting requirements at 38 U.S.C. 4212 shall invite all disabled veterans and veterans of the Vietnam era who wish to benefit under the affirmative action program at 38 U.S.C. 4212 to identify themselves to the Subcontractor. The invitation shall state that the information is voluntarily provided; that the information will be kept confidential; that disclosure or refusal to provide the information will not subject the applicant or employee to any adverse treatment; and that the information will be used only in accordance with the regulations promulgated under 38 U.S.C. 4212.
- F. Lower-tier Subcontracts.

The Subcontractor shall include the terms of this clause in every lower-tier subcontract or purchase order of \$10,000 or more unless exempted by rules, regulations, or orders of the Secretary.

**CLAUSE 22 - AUTHORIZATION AND CONSENT (JUL 1995)**  
*Derived from FAR 52-227-1 (FD)*

- A. The Government authorizes and consents to all use and manufacture, in performing this subcontract or any subcontract at any tier, of any invention described in and covered by a United States patent
1. Embodied in the structure or composition of any article the delivery of which is accepted by the NREL/Government under this subcontract or;
  2. Used in machinery, tools, or methods whose use necessarily results from compliance by the Subcontractor or a lower-tier subcontractor with--
    - (i) Specifications or written provisions forming a part of this subcontract or
    - (ii) Specific written instructions given by the Government working through NREL directing the manner of performance. The entire liability to the Government for infringement of a patent of the United States shall be determined solely by the provisions of the indemnity clause, if any, included in this subcontract or any subcontract hereunder (including any lower-tier subcontract), and the Government assumes liability for all other infringement to the extent of the authorization and consent hereinabove granted.
- B. The Subcontractor agrees to include, and require inclusion of, this clause, suitably modified to identify the parties, in all subcontracts at any tier for supplies or services (including construction, architect-engineer services, and materials, supplies, models, samples, and design or testing services expected to exceed the simplified acquisition threshold); however, omission of this

clause from any lower-tier subcontract, including those at or below the simplified acquisition threshold, does not affect this authorization and consent.

**ALTERNATE I (APR 1984)**

*Alternate I of this clause is applicable if this award is for the conduct of research, development, or demonstration*

The following is substituted for paragraph (A) of the clause:

- A. The Government authorizes and consents to all use and manufacture of any invention described in and covered by a United States patent in the performance of this subcontract or any subcontract at any tier.

**ALTERNATE II (APR 1984)**

*Alternate II of this clause is applicable if this award includes an order or lower-tier subcontract for communication services and facilities*

The following is substituted for paragraph (A) of the clause:

- A. The Government authorizes and consents to all use and manufacture in the performance of any order at any tier or subcontract at any tier placed under this subcontract for communication services and facilities for which rates, charges, and tariffs are not established by a Government regulatory body, of any invention described in and covered by a United States patent
  - 1. Embodied in the structure or composition of any article the delivery of which is accepted by the Government through NREL under this subcontract or
  - 2. Used in machinery, tools, or methods whose use necessarily results from compliance by the Subcontractor or a lower-tier subcontractor with specifications or written provisions forming a part of this subcontract or with specific written instructions given by the DOE through NREL directing the manner of performance.

**CLAUSE 23 - NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT (AUG 1996)**

*Derived from FAR 52.227-2*

*(Applies to construction, research, development, or demonstration, subcontracts exceeding \$100,000)*

- A. The Subcontractor shall report to the DOE through NREL, promptly and in reasonable written detail, each notice or claim of patent or copyright infringement based on the performance of this subcontract of which the Subcontractor has knowledge.
- B. In the event of any claim or suit against NREL/Government on account of any alleged patent or copyright infringement arising out of the performance of this subcontract or out of the use of any supplies furnished or work or services performed under this subcontract, the Subcontractor shall

furnish to the Government, when requested by the DOE through NREL, all evidence and information in possession of the Subcontractor pertaining to such suit or claim. Such evidence and information shall be furnished at the expense of the Government except where the Subcontractor has agreed to indemnify the Government.

- C. The Subcontractor agrees to include, and require inclusion of, this clause in all subcontracts at any tier for supplies or services (including construction and architect-engineer lower-tier subcontracts and those for material, supplies, models, samples, or design or testing services) expected to exceed the simplified acquisition threshold at FAR 2.101.

**CLAUSE 24 - PATENT INDEMNITY (APR 1984)**

*Derived from FAR 52.227-3*

*(The provisions of this clause shall not be applicable if this award is for the conduct of research, development, or demonstration)*

- A. The Subcontractor shall indemnify the NREL/Government and its officers, agents, and employees against liability, including costs, for infringement of any United States patent (except a patent issued upon an application that is now or may hereafter be withheld from issue pursuant to a Secrecy Order under 35 U.S.C. 181) arising out of the manufacture or delivery of supplies, the performance of services, or the construction, alteration, modification, or repair of real property (hereinafter referred to as "construction work") under this subcontract, or out of the use or disposal by or for the account of the Government of such supplies or construction work.
- B. This indemnity shall not apply unless the Subcontractor shall have been informed as soon as practicable by the NREL/Government of the suit or action alleging such infringement and shall have been given such opportunity as is afforded by applicable laws, rules, or regulations to participate in its defense. Further, this indemnity shall not apply to
1. An infringement resulting from compliance with specific written instructions of the DOE through NREL directing a change in the supplies to be delivered or in the materials or equipment to be used, or directing a manner of performance of the subcontract not normally used by the Subcontractor,
  2. An infringement resulting from addition to or change in supplies or components furnished or construction work performed that was made subsequent to delivery or performance, or
  3. A claimed infringement that is unreasonably settled without the consent of the Subcontractor, unless required by final decree of a court of competent jurisdiction.

**ALTERNATE I (APR 1984)**

*Alternate I of this clause is not applicable to the items specifically listed and/or identified*

The following paragraph (C) is added to the clause:

- C. This patent indemnification shall not apply to the following items:
-

[List and/or identify the items to be excluded from this indemnity.]

**ALTERNATE II (APR 1984)**

*Alternate II of this clause is applicable to the items specifically listed and/or identified*

The following paragraph (C) is added to the clause:

C. This patent indemnification shall cover the following items:

---

[List and/or identify the items to be included under this indemnity.]

**ALTERNATE III (JUL 1995)**

*Alternate III of this clause is applicable if this award includes a lower-tier subcontract for communication services and facilities*

The following paragraph is added to the clause:

- ( ) As to subcontracts at any tier for communication service, this clause shall apply only to individual communication service authorizations over the simplified acquisition threshold issued under this subcontract and covering those communications services and facilities
1. That are or have been sold or offered for sale by the Subcontractor to the public,
  2. That can be provided over commercially available equipment, or
  3. That involve relatively minor modifications.

**CLAUSE 25 - INSURANCE--LIABILITY TO THIRD PERSONS (SPECIAL - MAY 1999)**

*Derived from FAR 52.228-7*

*(Applies to cost reimbursement subcontracts)*

- A.
1. Except as provided in subparagraph (A)(2) of this clause, the Subcontractor shall provide and maintain workers' compensation, employer's liability, comprehensive general liability (bodily injury), comprehensive automobile liability (bodily injury and property damage) insurance, and such other insurance as the NREL Subcontract Administrator may require under this subcontract.
  2. The Subcontractor may, with the approval of the NREL Subcontract Administrator, maintain a self-insurance program; **provided** that, with respect to workers' compensation, the Subcontractor is qualified pursuant to statutory authority.
  3. The Subcontractor shall provide and maintain during the entire performance of this contract, at least the kinds and minimum amounts of insurance required in this clause, with insurers approved by the NREL Subcontract Administrator.

Insurance Type	Bodily Injury		Property Damage
	Each Person	Each Occurrence	
Workers' Compensation	As required by law	As required by law	
Employer's Liability	\$100,000	\$100,000	
Comprehensive General Liability	\$500,000	\$500,000	\$100,000
Automobile Liability	\$200,000	\$500,000	\$20,000

- B. The Subcontractor agrees to submit for the NREL Subcontract Administrator's approval, to the extent and in the manner required by the NREL Subcontract Administrator, any other insurance that is maintained by the Subcontractor in connection with the performance of this subcontract and for which the Subcontractor seeks reimbursement.
- C. The Subcontractor shall be reimbursed --
1. For that portion
    - (i) Of the reasonable cost of insurance allocable to this subcontract, and
    - (ii) Required or approved under this clause; and
  2. For certain liabilities (and expenses incidental to such liabilities) to third persons not compensated by insurance or otherwise without regard to and as an exception to the limitation of cost or the limitation of funds clause of this subcontract. These liabilities must arise out of the performance of this subcontract, whether or not caused by the negligence of the Subcontractor or of the Subcontractor's agents, servants, or employees, and must be represented by final judgments or settlements approved in writing by NREL/Government. These liabilities are for --
    - (i) Loss of or damage to property (other than property owned, occupied, or used by the Subcontractor, rented to the Subcontractor, or in the care, custody, or control of the Subcontractor); or
    - (ii) Death or bodily injury.
- D. NREL's/Government's liability under paragraph (C) of this clause is subject to the availability of appropriated funds at the time a contingency occurs. Nothing in this subcontract shall be construed as implying that the Congress will, at a later date, appropriate funds sufficient to meet deficiencies.
- E. The Subcontractor shall not be reimbursed for liabilities (and expenses incidental to such liabilities)-
1. For which the Subcontractor is otherwise responsible under the express terms of any clause specified in the Schedule or elsewhere in the subcontract;

2. For which the Subcontractor has failed to insure or to maintain insurance as required by the NREL Subcontract Administrator; or
3. That result from willful misconduct or lack of good faith on the part of any of the Subcontractor's directors, officers, managers, superintendents, or other representatives who have supervision or direction of --
  - (i) All or substantially all of the Subcontractor's business;
  - (ii) All or substantially all of the Subcontractor's operations at any one plant or separate location in which this subcontract is being performed; or
  - (iii) A separate and complete major industrial operation in connection with the performance of this subcontract.

F. The provisions of paragraph (E) of this clause shall not restrict the right of the Subcontractor to be reimbursed for the cost of insurance maintained by the Subcontractor in connection with the performance of this subcontract, other than insurance required in accordance with this clause; **provided**, that such cost is allowable under the Allowable Cost and Payment clause of this subcontract.

G. If any suit or action is filed or any claim is made against the Subcontractor, the cost and expense of which may be reimbursable to the Subcontractor under this subcontract, and the risk of which is then uninsured or is insured for less than the amount claimed, the Subcontractor shall --

1. Immediately notify the NREL Subcontract Administrator and promptly furnish copies of all pertinent papers received;
2. Authorize NREL/Government representatives to collaborate with counsel for the insurance carrier in settling or defending the claim when the amount of the liability claimed exceeds the amount of coverage; and
3. Authorize NREL/Government representatives to settle or defend the claim and to represent the Subcontractor in or to take charge of any litigation, if required by the NREL/Government, when the liability is not insured or covered by bond. The Subcontractor may, at its own expense, be associated with NREL/Government representatives in any such claim or litigation.

**CLAUSE 26 - LIMITATION OF COST (APR 1984)**

*Derived from FAR 52.232-20*

*(Applies to fully funded, cost reimbursement subcontracts)*

A. The parties estimate that performance of this subcontract, exclusive of any fee, will not cost NREL more than --

1. The estimated cost specified in the Schedule or,

2. If this is a cost-sharing subcontract, NREL's share of the estimated cost specified in the Schedule.

The Subcontractor agrees to use its best efforts to perform the work specified in the Schedule and all obligations under this subcontract within the estimated cost, which, if this is a cost-sharing subcontract, includes both NREL's and the Subcontractor's share of the cost.

- B. The Subcontractor shall notify the NREL Subcontract Administrator in writing whenever it has reason to believe that --
  1. The costs the Subcontractor expects to incur under this subcontract in the next sixty (60) days, when added to all costs previously incurred, will exceed 75 percent of the estimated cost specified in the Schedule; or
  2. The total cost for the performance of this subcontract, exclusive of any fee, will be either greater or substantially less than had been previously estimated.
- C. As part of the notification, the Subcontractor shall provide the NREL Subcontract Administrator a revised estimate of the total cost of performing this subcontract.
- D. Except as required by other provisions of this subcontract, specifically citing and stated to be an exception to this clause --
  1. NREL is not obligated to reimburse the Subcontractor for cost incurred in excess of
    - (i) The estimated cost specified in the Schedule or,
    - (ii) If this is a cost-sharing subcontract, the estimated cost to NREL specified in the Schedule; and
  2. The Subcontractor is not obligated to continue performance under this subcontract (including actions under the Termination clause of this subcontract) or otherwise incur costs in excess of the estimated cost specified in the Schedule, until the NREL Subcontract Administrator --
    - (i) Notifies the Subcontractor in writing that the estimated cost has been increased and
    - (ii) Provides a revised estimated total cost of performing this subcontract. If this is a cost-sharing subcontract, the increase shall be allocated in accordance with the formula specified in the Schedule.
- E. No notice, communication, or representation in any form other than that specified in subparagraph (D)(2) above, or from any person other than the NREL Subcontract Administrator, shall affect this subcontract's estimated cost to NREL. In the absence of the specified notice, NREL is not obligated to reimburse the Subcontractor for any costs in excess of the estimated cost or, if this is a cost-sharing subcontract, for any costs in excess of the estimated cost to NREL specified in the Schedule, whether those excess costs were incurred during the course of the subcontract or as a result of termination.

- F. If the estimated cost specified in the Schedule is increased, any costs the Subcontractor incurs before the increase that are in excess of the previously estimated cost shall be allowable to the same extent as if incurred afterward, unless the NREL Subcontract Administrator issues a termination or other notice directing that the increase is solely to cover termination or other specified expenses.
- G. Change orders shall not be considered an authorization to exceed the estimated cost to NREL specified in the Schedule, unless they contain a statement increasing the estimated cost.
- H. If this subcontract is terminated or the estimated cost is not increased, NREL and the Subcontractor shall negotiate an equitable distribution of all property produced or purchased under the subcontract, based upon the share of costs incurred by each.

**CLAUSE 27 - LIMITATION OF FUNDS (APR 1984)**

*Derived from FAR 52.232-22*

*(Applies to incrementally funded, cost reimbursement subcontracts)*

- A. The parties estimate that performance of this subcontract will not cost NREL more than
  - 1. The estimated cost specified in the Schedule or,
  - 2. If this is a cost-sharing subcontract, NREL's share of the estimated cost specified in the Schedule.

The Subcontractor agrees to use its best efforts to perform the work specified in the Schedule and all obligations under this subcontract within the estimated cost, which, if this is a cost-sharing subcontract, includes both NREL's and the Subcontractor's share of the cost.

- B. The Schedule specifies the amount presently available for payment by NREL and allotted to this subcontract, the items covered, NREL's share of the cost if this is a cost-sharing subcontract, and the period of performance it is estimated the allotted amount will cover. The parties contemplate that NREL will allot additional funds incrementally to the subcontract up to the full estimated cost to NREL specified in the Schedule, exclusive of any fee. The Subcontractor agrees to perform, or have performed, work on the subcontract up to the point at which the total amount paid and payable by NREL under the subcontract approximates but does not exceed the total amount actually allotted by NREL to the subcontract.
- C. The Subcontractor shall notify the NREL Subcontract Administrator in writing whenever it has reason to believe that the costs it expects to incur under this subcontract in the next sixty (60) days, when added to all costs previously incurred, will exceed seventy-five (75) percent of--
  - 1. The total amount so far allotted to the subcontract by NREL or,
  - 2. If this is a cost-sharing subcontract, the amount then allotted to the subcontract by NREL plus the Subcontractor's corresponding share.

The notice shall state the estimated amount of additional funds required to continue performance for the period specified in the Schedule.

- D. Sixty (60) days before the end of the period specified in the Schedule, the Subcontractor shall notify the NREL Subcontract Administrator in writing of the estimated amount of additional funds, if any, required to continue timely performance under the subcontract or for any further period specified in the Schedule or otherwise agreed upon, and when the funds will be required.
- E. If, after notification, additional funds are not allotted by the end of the period specified in the Schedule or another agreed-upon date, upon the Subcontractor's written request the NREL Subcontract Administrator will terminate this subcontract on that date in accordance with the provisions of the Termination clause of this subcontract. If the Subcontractor estimates that the funds available will allow it to continue to discharge its obligations beyond that date, it may specify a later date in its request, and the NREL Subcontract Administrator may terminate this subcontract on that later date.
- F. Except as required by other provisions of this subcontract, specifically citing and stated to be an exception to this clause --
1. NREL is not obligated to reimburse the Subcontractor for costs incurred in excess of the total amount allotted by NREL to this subcontract; and
  2. The Subcontractor is not obligated to continue performance under this subcontract (including actions under the Termination clause of this subcontract) or otherwise incur costs in excess of --
    - (i) The amount then allotted to the subcontract by NREL or;
    - (ii) If this is a cost-sharing subcontract, the amount then allotted by NREL to the subcontract plus the Subcontractor's corresponding share, until the NREL Subcontract Administrator notifies the Subcontractor in writing that the amount allotted by NREL has been increased and specifies an increased amount, which shall then constitute the total amount allotted by NREL to this subcontract.
- G. The estimated cost shall be increased to the extent that
1. The amount allotted by NREL or,
  2. If this is a cost-sharing subcontract, the amount then allotted by NREL to the subcontract plus the Subcontractor's corresponding share, exceeds the estimated cost specified in the Schedule.
- If this is a cost-sharing subcontract, the increase shall be allocated in accordance with the formula specified in the Schedule.
- H. No notice, communication, or representation in any form other than that specified in subparagraph (F)(2) above, or from any person other than the NREL Subcontract Administrator, shall affect the amount allotted by NREL to this subcontract. In the absence of the specified notice, NREL is not obligated to reimburse the Subcontractor for any costs in excess of the total amount allotted by NREL to this subcontract, whether incurred during the course of the subcontract or as a result of termination.

- I. When and to the extent that the amount allotted by NREL to the subcontract is increased, any costs the Subcontractor incurs before the increase that are in excess of --
  - 1. The amount previously allotted by NREL or;
  - 2. If this is a cost-sharing subcontract, the amount previously allotted by NREL to the subcontract plus the Subcontractor's corresponding share, shall be allowable to the same extent as if incurred afterward, unless the NREL Subcontract Administrator issues a termination or other notice and directs that the increase is solely to cover termination or other specified expenses.
- J. Change orders shall not be considered an authorization to exceed the amount allotted by NREL specified in the Schedule, unless they contain a statement increasing the amount allotted.
- K. Nothing in this clause shall affect the right of NREL/Government to terminate this subcontract. If this subcontract is terminated, NREL and the Subcontractor shall negotiate an equitable distribution of all property produced or purchased under the subcontract, based upon the share of costs incurred by each.
- L. If NREL does not allot sufficient funds to allow completion of the work, the Subcontractor is entitled to a percentage of the fee specified in the Schedule equaling the percentage of completion of the work contemplated by this subcontract.

**CLAUSE 28 - BANKRUPTCY (JUL 1995)**

*Derived from FAR 52.242-13*

*(Applies to subcontracts exceeding \$100,000)*

In the event the Subcontractor enters into proceedings relating to bankruptcy, whether voluntary or involuntary, the Subcontractor agrees to furnish, by certified mail or electronic commerce method authorized by the contract, written notification of the bankruptcy to the NREL Subcontract Administrator responsible for administering the subcontract. This notification shall be furnished within five (5) days of the initiation of the proceedings relating to bankruptcy filing. This notification shall include the date on which the bankruptcy petition was filed, the identity of the court in which the bankruptcy petition was filed, and a listing of Government contract numbers and contracting offices for all Government contracts against which final payment has not been made. This obligation remains in effect until final payment under this subcontract.

**CLAUSE 29 - STOP WORK ORDER (AUG 1989) AND ALTERNATE 1 - COST REIMBURSEMENT (AUG 1989)**

*Derived from FAR 52.242-15*

- A. The NREL Subcontract Administrator may, at any time, by written order to the Subcontractor, require the Subcontractor to stop all, or any part, of the work called for by this subcontract for a period of ninety (90) days after the order is delivered to the Subcontractor, and for any further period to which the parties may agree. The order shall be specifically identified as a stop-work order issued under this clause. Upon receipt of the order, the Subcontractor shall immediately comply with its terms and take all reasonable steps to minimize the incurrence of costs allocable to the work covered by the order during the period of work stoppage. Within a period of ninety

(90) days after a stop-work is delivered to the Subcontractor, or within any extension of that period to which the parties shall have agreed, the NREL Subcontract Administrator shall either --

1. Cancel the stop-work order; or
  2. Terminate the work covered by the order as provided in the Default or the Termination clause of this subcontract.
- B. If a stop-work order issued under this clause is canceled or the period of the order or any extension thereof expires, the Subcontractor shall resume work. The NREL Subcontract Administrator shall make an equitable adjustment and the subcontract shall be modified, in writing, accordingly, if --
1. The stop-work order results in an increase in the time required for, or in the Subcontractor's cost properly allocable to, the performance of any part of this subcontract; and
  2. The Subcontractor asserts its right to the adjustment within thirty (30) days after the end of the period of work stoppage; provided, that, if the NREL Subcontract Administrator decides the facts justify the action, the NREL Subcontract Administrator may receive and act upon the claim submitted at any time before final payment under this subcontract.
- C. If a stop-work order is not canceled and the work covered by the order is terminated for the convenience of NREL/Government, the NREL Subcontract Administrator shall allow reasonable costs resulting from the stop-work order in arriving at the termination settlement.
- D. If a stop-work order is not canceled and the work covered by the order is terminated for default, the NREL Subcontract Administrator shall allow, by equitable adjustment or otherwise, reasonable costs resulting from the stop-work order.

***Alternate I (Apr 1984)***

If this clause is inserted in a cost-reimbursement subcontract, substitute in paragraph (A)(2) the words "the Termination clause of this subcontract" for the words "the Default, or the Termination for Convenience of NREL/Government clause of this subcontract." In paragraph (B) substitute the words "an equitable adjustment in the delivery schedule, the estimated cost, the fee, or a combination thereof, and in any other terms of the subcontract that may be affected" for the words "an equitable adjustment in the delivery schedule or subcontract price, or both."

**CLAUSE 30 - CHANGES - COST REIMBURSEMENT (AUG 1987) AND ALTERNATE V - RESEARCH AND DEVELOPMENT(AUG 1987)**

***Derived from FAR 52.243-2***

- A. The NREL Subcontract Administrator may at any time, by written order, and without notice to the sureties, if any, make changes within the general scope of this subcontract in any one or more of the following:
1. Drawings, designs, or specifications.

2. Method of shipment or packing.
  3. Place of inspection, delivery, or acceptance.
- B. If any such change causes an increase or decrease in the estimated cost of, or the time required for, performance of any part of the work under this subcontract, whether or not changed by the order, or otherwise affects any other terms and conditions of this subcontract, the NREL Subcontract Administrator shall make an equitable adjustment in the --
1. Estimated cost or delivery or completion schedule, or both;
  2. Amount of any fixed fee; and
  3. Other affected terms and shall modify the subcontract accordingly.
- C. The Subcontractor must assert its right to an adjustment under this clause within thirty (30) days from the date of receipt of the written order. However, if the NREL Subcontract Administrator decides that the facts justify it, the NREL Subcontract Administrator may receive and act upon a proposal submitted before final payment of the subcontract.
- D. Failure to agree to any adjustment shall be a dispute under the Disputes clause. However, nothing in this clause shall excuse the Subcontractor from proceeding with the subcontract as changed.
- E. Notwithstanding the terms and conditions of paragraphs (A) and (B) above, the estimated cost of this subcontract and, if this subcontract is incrementally funded, the funds allotted for the performance of this subcontract, shall not be increased or considered to be increased except by specific written modification of the subcontract indicating the new subcontract estimated cost and, if this subcontract is incrementally funded, the new amount allotted to the subcontract. Until this modification is made, the Subcontractor shall not be obligated to continue performance or incur costs beyond the point established in the Limitation of Cost clause or Limitation of Funds article of this subcontract.

**CLAUSE 31 - LOWER-TIER SUBCONTRACTS (AUG 1998)**

*Derived from FAR 52.244-2*

*(Applies to all cost reimbursement subcontracts; and letter, fixed price, time and material, and labor hour subcontracts exceeding \$100,000)*

A. Definitions.

As used in this clause-

"Approved purchasing system" means a Subcontractor's purchasing system that has been reviewed and approved in accordance with Part 44 of the Federal Acquisition Regulation (FAR)

"Consent to lower-tier subcontract" means the NREL Subcontract Administrator's written consent for the Subcontractor to enter into a particular lower-tier subcontract.

"Lower-tier subcontract" means any contract, as defined in FAR Subpart 2.1, entered into by a lower-tier subcontractor to furnish supplies or services for performance of the prime contract or a lower-tier subcontract. It includes, but is not limited to, purchase orders, and changes and modifications to purchase orders.

- B. This clause does not apply to lower-tier subcontracts for special test equipment when the subcontract contains the clause at FAR 52.245-18, Special Test Equipment.
- C. When this clause is included in a fixed-price type subcontract, consent to lower-tier subcontract is required only on unpriced subcontract actions (including unpriced modifications or unpriced delivery orders), and only if required in accordance with paragraph (D) or (E) or this clause.
- D. If the Subcontractor does not have an approved purchasing system, consent to lower-tier subcontract is required for any lower-tier subcontract that--
  - 1. Is of the cost-reimbursement, time-and-materials, or labor-hour type; or
  - 2. Is fixed-price and exceeds--
    - (i) For a subcontract awarded by the Department of Defense, the Coast Guard, or the National Aeronautics and Space Administration, the greater of the simplified acquisition threshold (\$100,000) or five (5) percent of the total estimated cost of the subcontract; or
    - (ii) For subcontracts awarded by a civilian agency other than the Coast Guard and the National Aeronautics and Space Administration, either the simplified acquisition threshold (\$100,000) or five (5) percent of the total estimated cost of the subcontract.
- E. If the Subcontractor has an approved purchasing system, the Subcontractor nevertheless shall obtain the NREL Subcontract Administrator's written consent before placing the following lower-tier subcontracts:

Lower tier subcontracts requiring written consent are identified in the subcontract schedule.

- F. 1. The Subcontractor shall notify the NREL Subcontract Administrator reasonably in advance of placing any lower-tier subcontract or modification thereof for which consent is required under paragraph (C), (D), or (E) of this clause, including the following information:
  - (i) A description of the supplies or services to be lower-tier subcontracted.
  - (ii) Identification of the type of lower-tier subcontract to be used.
  - (iii) Identification of the proposed lower-tier subcontractor.
  - (iv) The proposed lower-tier subcontract price.

- (v) The lower-tier subcontractor's current, complete, and accurate cost or pricing data and Certificate of Current Cost or Pricing Data, if required by other subcontract provisions.
- (vi) The lower-tier subcontractor's Disclosure Statement or Certificate relating to Cost Accounting Standards when such data are required by other provisions of this subcontract.
- (vii) A negotiation memorandum reflecting --
  - a. The principal elements of the lower-tier subcontract price negotiations;
  - b. The most significant considerations controlling establishment of initial or revised prices;
  - c. The reason cost or pricing data were or were not required;
  - d. The extent, if any, to which the Subcontractor did not rely on the lower-tier subcontractor's cost or pricing data in determining the price objective and in negotiating the final price;
  - e. The extent to which it was recognized in the negotiation that the lower-tier subcontractor's cost or pricing data were not accurate, complete, or current; the action taken by the Subcontractor and the lower-tier subcontractor; and the effect of any such defective data on the total price negotiated;
  - f. The reasons for any significant difference between the Subcontractor's price objective and the price negotiated; and
  - g. A complete explanation of the incentive fee or profit plan when incentives are used. The explanation shall identify each critical performance element, management decisions used to quantify each incentive element, reasons for the incentives, and a summary of all trade-off possibilities considered.

2. The Subcontractor is not required to notify the NREL Subcontract Administrator in advance of entering into any lower-tier subcontract for which consent is not required under paragraph (C), (D), or (E) or this clause.

G. Unless the consent or approval specifically provides otherwise, neither consent by the NREL Subcontract Administrator to any subcontract nor approval of the Subcontractor's purchasing system shall constitute a determination --

- 1. Of the acceptability of any subcontract terms or conditions;
- 2. Of the allowability of any cost under this subcontract; or
- 3. To relieve the Subcontractor of any responsibility for performing this subcontract.

- H. No lower-tier subcontract or modification thereof placed under this subcontract shall provide for payment on a cost-plus-a-percentage-of-cost basis, and any fee payable under cost-reimbursement type lower-tier subcontracts shall not exceed the fee limitations in FAR 15.404-4(c)(4)(i).
- I. The Subcontractor shall give the NREL Subcontract Administrator immediate written notice of any action or suit filed and prompt notice of any claim made against the Subcontractor by any lower-tier subcontractor or vendor that, in the opinion of the Subcontractor, may result in litigation related in any way to this subcontract, with respect to which the Subcontractor may be entitled to reimbursement from NREL/Government.
- J. NREL/Government reserves the right to review the Subcontractor's purchasing system as set forth in FAR Subpart 44.3.
- K. Paragraphs (D) and (F) of this clause do not apply to the following lower-tier subcontracts, which were evaluated during negotiations:

Lower tier subcontracts evaluated during negotiations are identified in the subcontract schedule.

**CLAUSE 32 - SUBCONTRACTS FOR COMMERCIAL ITEMS AND COMMERCIAL COMPONENTS (OCT 1998)**

*Derived from FAR 52.244-6*

*(Applies to solicitations and subcontracts for supplies or services other than commercial items)*

- (a) Definitions.
  - "Commercial item," as used in this clause, has the meaning contained in the clause at 52.202-1, Definitions. "Subcontract," as used in this clause, includes a transfer of commercial items between divisions, subsidiaries, or affiliates of the Contractor or subcontractor at any tier.
- (b) To the maximum extent practicable, the Contractor shall incorporate, and require its subcontractors at all tiers to incorporate, commercial items or nondevelopmental items as components of items to be supplied under this contract.
- (c) Notwithstanding any other clause of this contract, the Contractor is not required to include any FAR provision or clause, other than those listed below to the extent they are applicable and as may be required to establish the reasonableness of prices under Part 15, in a subcontract at any tier for commercial items or commercial components:
  - (1) 52.222-26, Equal Opportunity (E.O.11246);
  - (2) 52.222-35, Affirmative Action for Disabled Veterans and Veterans of the Vietnam Era (38 U.S.C.4212(a));

(3) 52.222-36, Affirmative Action for Workers with Disabilities (29 U.S.C.793); and

(4) 52.247-64, Preference for Privately Owned U.S.-Flagged Commercial Vessels (46 U.S.C.1241) (flow down not required for subcontracts awarded beginning May 1, 1996).

(d) The Contractor shall include the terms of this clause, including this paragraph (d), in subcontracts awarded under this contract.

**CLAUSE 33 - INSPECTION OF SERVICES--COST-REIMBURSEMENT (APR 1984)**

*Derived from FAR 52.246-5*

- A. Definition. "Services," as used in this clause, includes services performed, workmanship, and material furnished or used in performing services.
- B. The Subcontractor shall provide and maintain an inspection system acceptable to NREL covering the services under this subcontract. Complete records of all inspection work performed by the Subcontractor shall be maintained and made available to NREL/Government during subcontract performance and for as long afterwards as the subcontract requires.
- C. NREL/Government have the right to inspect and test all services called for by the subcontract, to the extent practicable at all places and times during the term of the subcontract. Such inspections and tests shall be performed in a manner that will not unduly delay the work.
- D. If any of the services performed do not conform with subcontract requirements, NREL may require the Subcontractor to perform the services again in conformity with subcontract requirements, for no additional fee. When the defects in services cannot be corrected by reperformance, NREL may--
  - 1. Require the Subcontractor to take necessary action to ensure that future performance conforms to subcontract requirements; and
  - 2. Reduce any fee payable under the subcontract to reflect the reduced value of the services performed.
- E. If the Subcontractor fails to promptly perform the services again or take the action necessary to ensure future performance in conformity with subcontract requirements, NREL may--
  - 1. By subcontract or otherwise, perform the services and reduce any fee payable by an amount that is equitable under the circumstances ;or
  - 2. Terminate the subcontract for default.

**CLAUSE 34 - INSPECTION OF RESEARCH AND DEVELOPMENT  
(SHORT FORM) (APR 1984)**

*Derived from FAR 52.246-9*

NREL/Government have the right to inspect and evaluate the work performed or being performed under the subcontract, and the premises where the work is being performed, at all reasonable times and in a manner that will not unduly delay the work. If NREL/Government perform inspections or evaluations on the premises of the Subcontractor or a lower-tier subcontractor, the Subcontractor shall furnish and shall require lower-tier subcontractors to furnish all reasonable facilities and assistance for the safe and convenient performance of these duties.

**CLAUSE 35 - PREFERENCE FOR U.S.-FLAG AIR CARRIERS (JAN 1997)**

*Derived from FAR 52.247-63 (FD)*

- A. "International air transportation," as used in this clause, means transportation by air between a place in the United States and a place outside the United States or between two places both of which are outside the United States.

"United States," as used in this clause, means the fifty (50) States, the District of Columbia, the Commonwealth of Puerto Rico, and possessions of the United States.

"U.S.-flag air carrier," as used in this clause, means an air carrier holding a certificate under 49 U.S.C. Chapter 411.

- B. Section 5 of the International Air Transportation Fair Competitive Practices Act of 1974 (49 U.S.C. 40118) (Fly America Act) requires that all Federal agencies and Government Contractors and Subcontractors use U.S.-flag air carriers for U.S. Government-financed international air transportation of personnel (and their personal effects) or property, to the extent that service by those carriers is available. It requires the Comptroller General of the United States, in the absence of satisfactory proof of the necessity for foreign-flag air transportation, to disallow expenditures from funds, appropriated or otherwise established for the account of the United States, for international air transportation secured aboard a foreign-flag air carrier if a U.S.-flag air carrier is available to provide such services.
- C. The Subcontractor agrees, in performing work under this subcontract, to use U.S.-flag air carriers for international air transportation of personnel (and their personal effects) or property to the extent that service by those carriers is available.
- D. In the event that the Subcontractor selects a carrier other than a U.S.-flag air carrier for international air transportation, the Subcontractor shall include a statement on vouchers involving such transportation essentially as follows:

**STATEMENT OF UNAVAILABILITY OF U.S.-FLAG AIR CARRIERS**

International air transportation of persons (and their personal effects) or property by U.S.-flag air carrier was not available or it was necessary to use foreign-flag air carrier service for the following reasons (see section 47.403 of the Federal Acquisition Regulation): *(State reasons):*

---

- E. The Subcontractor shall include the substance of this clause, including this paragraph (E), in each lower-tier subcontract or purchase under this subcontract that may involve international air transportation.

**CLAUSE 36 - TERMINATION FOR CONVENIENCE OF NREL/GOVERNMENT  
(EDUCATIONAL AND OTHER NONPROFIT INSTITUTIONS) (SEP 1996)**

*Derived from FAR 52.249-5 (FD)*

- A. NREL may terminate performance of work under this subcontract in whole or, from time to time, in part if the NREL Subcontract Administrator determines that a termination is in NREL's/Government's interest. The NREL Subcontract Administrator shall terminate by delivering to the Subcontractor a Notice of Termination specifying the extent of termination and the effective date.
- B. After receipt of a Notice of Termination and except as directed by the NREL Subcontract Administrator, the Subcontractor shall immediately proceed with the following obligations:
1. Stop work as specified in the notice.
  2. Place no further subcontracts or orders (referred to as lower-tier subcontracts in this clause), except as necessary to complete the continued portion of the subcontract.
  3. Terminate all applicable lower-tier subcontracts and cancel or divert applicable commitments covering personal services that extend beyond the effective date of termination.
  4. Assign to NREL, as directed by the NREL Subcontract Administrator, all right, title, and interest of the Subcontractor under the lower-tier subcontracts terminated, in which case NREL shall have the right to settle or pay any termination settlement proposal arising out of those terminations.
  5. With approval or ratification to the extent required by the NREL Subcontract Administrator, settle all outstanding liabilities and termination settlement proposals arising from the termination of lower-tier subcontracts; approval or ratification will be final for purposes of this clause.
  6. Transfer title to the Government (if not already transferred) and, as directed by the NREL Subcontract Administrator, deliver to NREL any information and items that, if the subcontract had been completed, would have been required to be furnished, including--
    - (i) Materials or equipment produced, in process, or acquired for the work terminated; and
    - (ii) Completed or partially completed plans, drawings, and information.
  7. Complete performance of the work not terminated.

8. Take any action that may be necessary, or that the NREL Subcontract Administrator may direct, for the protection and preservation of the property related to this subcontract that is in the possession of the Subcontractor and in which the Government has or may acquire an interest.
9. Use its best efforts to sell, as directed or authorized by the NREL Subcontract Administrator, termination inventory other than that retained by the Government under subparagraph (B)(6) of this clause; **provided**, however, that the Subcontractor--
  - (i) Is not required to extend credit to any purchaser; and
  - (ii) May acquire the property under the conditions prescribed by, and at prices approved by, the NREL Subcontract Administrator. The proceeds of any transfer or disposition will be applied to reduce any payments to be made by NREL under this subcontract, credited to the price or cost of the work, or paid in any other manner directed by the NREL Subcontract Administrator.
- C. The Subcontractor shall submit complete termination inventory schedules no later than one hundred twenty (120) days from the effective date of termination, unless extended in writing by the NREL Subcontract Administrator upon written request of the Subcontractor within this one hundred twenty (120)-day period.
- D. After termination, the Subcontractor shall submit a final termination settlement proposal to the NREL Subcontract Administrator in the form and with the certification prescribed by the NREL Subcontract Administrator. The Subcontractor shall submit the proposal promptly but no later than one (1) year from the effective date of termination unless extended in writing by the NREL Subcontract Administrator upon written request of the Subcontractor with this one (1)-year period. If the Subcontractor fails to submit the termination settlement proposal within the time allowed, the NREL Subcontract Administrator may determine, on the basis of information available, the amount, if any, due the Subcontractor because of the termination and shall pay the amount determined.
- E. Subject to paragraph (D) of this clause, the Subcontractor and the NREL Subcontract Administrator may agree upon the whole or any part of the amount to be paid because of the termination. This amount may include reasonable cancellation charges incurred by the Subcontractor and any reasonable loss on outstanding commitments for personal services that the Subcontractor is unable to cancel; **provided**, that the Subcontractor exercised reasonable diligence in diverting such commitments to other operations. The subcontract shall be amended and the Subcontractor paid the agreed amount.
- F. The cost principles and procedures in Part 31.3 of the Federal Acquisition Regulations (FAR), in effect on the date of the subcontract, shall govern all costs claimed, agreed to, or determined under this clause; however, if the Subcontractor is not an educational institution, and is a nonprofit organization under Office of Management and Budget (OMB) Circular A-122, "Cost Principles for Nonprofit Organizations," July 8, 1980, those cost principles shall apply; **provided**, that if the Subcontractor is a nonprofit institution listed in Attachment C of OMB Circular A-122, the cost principles at FAR 31.2 for commercial organizations shall apply to such Subcontractor.

- G. NREL may, under the terms and conditions it prescribes, make partial payments against costs incurred by the Subcontractor for the terminated portion of this subcontract, if the NREL Subcontract Administrator believes the total of these payments will not exceed the amount to which the Subcontractor will be entitled.
- H. The Subcontractor has the right of appeal as provided under the Disputes clause, except that if the Subcontractor failed to submit the termination settlement proposal within the time provided in paragraph (D) and failed to request a time extension, there is no right of appeal.

**CLAUSE 37 - TERMINATION (COST-REIMBURSEMENT) (SEP 1996)**

*Derived from FAR 52.249-6 (FD)*

*(Applies to cost reimbursement subcontracts except subcontracts for research and development work with educational or nonprofit institutions)*

- A. NREL may terminate performance of work under this subcontract in whole or, from time to time, in part, if --
  - 1. The NREL Subcontract Administrator determines that a termination is in NREL's/Government's interest; or
  - 2. The Subcontractor defaults in performing this subcontract and fails to cure the default within ten (10) days (unless extended by the NREL Subcontract Administrator) after receiving a notice specifying the default. "Default" includes failure to make progress in the work so as to endanger performance.
- B. The NREL Subcontract Administrator shall terminate by delivering to the Subcontractor a Notice of Termination specifying whether termination is for default of the Subcontractor or for convenience of NREL/Government, the extent of termination, and the effective date. If, after termination for default, it is determined that the Subcontractor was not in default or that the Subcontractor's failure to perform or to make progress in performance is due to causes beyond the control and without the fault or negligence of the Subcontractor as set forth in the Excusable Delays clause, the rights and obligations of the parties will be the same as if the termination was for the convenience of NREL/Government.
- C. After receipt of a Notice of Termination, and except as directed by the NREL Subcontract Administrator, the Subcontractor shall immediately proceed with the following obligations, regardless of any delay in determining or adjusting any amounts due under this clause:
  - 1. Stop work as specified in the notice.
  - 2. Place no further lower-tier subcontracts or orders (referred to as lower-tier subcontracts in this clause), except as necessary to complete the continued portion of the subcontract.
  - 3. Terminate all lower-tier subcontracts to the extent they relate to the work terminated.
  - 4. Assign to NREL, as directed by the NREL Subcontract Administrator, all right, title, and interest of the Subcontractor under the lower-tier subcontracts terminated, in which case NREL shall have the right to settle or to pay any termination settlement proposal arising out of those terminations.

5. With approval or ratification to the extent required by the NREL Subcontract Administrator, settle all outstanding liabilities and termination settlement proposals arising from the termination of lower-tier subcontracts, the cost of which would be reimbursable in whole or in part, under this subcontract; approval or ratification will be final for purposes of this clause.
  6. Transfer title to the Government (if not already transferred) and, as directed by the NREL Subcontract Administrator, deliver to NREL --
    - (i) The fabricated or unfabricated parts, work in process, completed work, supplies, and other material produced or acquired for the work terminated;
    - (ii) The completed or partially completed plans, drawings, information, and other property that, if the subcontract had been completed, would be required to be furnished to NREL; and
    - (iii) The jigs, dies, fixtures, and other special tools and tooling acquired or manufactured for this subcontract, the cost of which the Subcontractor has been or will be reimbursed under this subcontract.
  7. Complete performance of the work not terminated.
  8. Take any action that may be necessary, or that the NREL Subcontract Administrator may direct, for the protection and preservation of the property related to this subcontract that is in the possession of the Subcontractor and in which NREL/Government has or may acquire an interest.
  9. Use its best efforts to sell, as directed or authorized by the NREL Subcontract Administrator, any property of the types referred to in subparagraph (C)(6) of this clause; **provided**, however, that the Subcontractor--
    - (i) Is not required to extend credit to any purchaser; and
    - (ii) May acquire the property under the conditions prescribed by, and at prices approved by, the NREL Subcontract Administrator. The proceeds of any transfer or disposition will be applied to reduce any payments to be made by NREL under this subcontract, credited to the price or cost of the work, or paid in any other manner directed by the NREL Subcontract Administrator.
- D. The Subcontractor shall submit complete termination inventory schedules no later than one hundred twenty (120) days from the effective date of termination, unless extended in writing by the NREL Subcontract Administrator upon written request of the Subcontractor within this one hundred twenty (120)-day period.
- E. After expiration of the plant clearance period as defined in Subpart 45.6 of the Federal Acquisition Regulation, the Subcontractor may submit to the NREL Subcontract Administrator a list, certified as to quantity and quality, of termination inventory not previously disposed of, excluding items authorized for disposition by the NREL Subcontract Administrator. The Subcontractor may request the NREL/Government to remove those items or enter into an

agreement for their storage. Within fifteen (15) days, NREL/Government will accept the items and remove them or enter into a storage agreement. The NREL Subcontract Administrator may verify the list upon removal of the items, or if stored, within forty-five (45) days from submission of the list, and shall correct the list, as necessary, before final settlement.

- F. After termination, the Subcontractor shall submit a final termination settlement proposal to the NREL Subcontract Administrator in the form and with the certification prescribed by the NREL Subcontract Administrator. The Subcontractor shall submit the proposal promptly, but no later than one (1) year from the effective date of termination, unless extended in writing by the NREL Subcontract Administrator upon written request of the Subcontractor within this one (1)-year period. However, if the NREL Subcontract Administrator determines that the facts justify it, a termination settlement proposal may be received and acted on after one (1) year or any extension. If the Subcontractor fails to submit the proposal within the time allowed, the NREL Subcontract Administrator may determine, on the basis of information available, the amount, if any, due the Subcontractor because of the termination and shall pay the amount determined.
- G. Subject to paragraph (F) of this clause, the Subcontractor and the NREL Subcontract Administrator may agree on the whole or any part of the amount to be paid (including an allowance for fee) because of the termination. The subcontract shall be amended, and the Subcontractor paid the agreed amount.
- H. If the Subcontractor and the NREL Subcontract Administrator fail to agree in whole or in part on the amount of costs and/or fee to be paid because of the termination of work, the NREL Subcontract Administrator shall determine, on the basis of information available, the amount, if any, due the Subcontractor and shall pay the amount, which shall include the following:
1. All costs reimbursable under this subcontract, not previously paid, for the performance of this subcontract before the effective date of termination, and those costs that may continue for a reasonable time with the approval of or as directed by the NREL Subcontract Administrator; however, the Subcontractor shall discontinue those costs as rapidly as practicable.
  2. The cost of settling and paying termination settlement proposals under terminated subcontracts that are properly chargeable to the terminated portion of the subcontract if not included in subparagraph (H)(1) of this clause.
  3. The reasonable costs of settlement of the work terminated, including--
    - (i) Accounting, legal, clerical, and other expenses reasonably necessary for the preparation of termination settlement proposals and supporting data;
    - (ii) The termination and settlement of lower-tier subcontracts (excluding the amounts of such settlements); and
    - (iii) Storage, transportation, and other costs incurred, reasonably necessary for the protection or disposition of the termination inventory. If the termination is for default, no amounts for the preparation of the Subcontractor's termination settlement proposal may be included.

4. A portion of the fee payable under the subcontract, determined as follows:
  - (i) If the subcontract is terminated for the convenience of NREL/Government, the settlement shall include a percentage of the fee equal to the percentage of completion of work contemplated under the subcontract, but excluding subcontract effort included in lower-tier subcontractor's termination proposals, less previous payments for fee.
  - (ii) If the subcontract is terminated for default, the total fee payable shall be such proportionate part of the fee as the total number of articles (or amount of services) delivered to and accepted by NREL is to the total number of articles (or amount of services) of a like kind required by the subcontract.
5. If the settlement includes only fee, it will be determined under subparagraph (H)(4) of this clause.
- I. The cost principles and procedures in Part 31 of the Federal Acquisition Regulation, in effect on the date of this subcontract, shall govern all costs claimed, agreed to, or determined under this clause.
- J. The Subcontractor shall have the right of appeal, under the Disputes clause, from any determination made by the NREL Subcontract Administrator under paragraph (F), (H), or (L) of this clause, except that if the Subcontractor failed to submit the termination settlement proposal within the time provided in paragraph (F) and failed to request a time extension, there is no right of appeal. If the NREL Subcontract Administrator has made a determination of the amount due under paragraph (F), (H), or (L) of this clause, NREL shall pay the Subcontractor--
  1. The amount determined by the NREL Subcontract Administrator if there is no right of appeal or if no timely appeal has been taken; or
  2. The amount finally determined on an appeal.
- K. In arriving at the amount due the Subcontractor under this clause, there shall be deducted --
  1. All unliquidated advance or other payments to the Subcontractor, under the terminated portion of this subcontract.
  2. Any claim which NREL/Government has against the Subcontractor under this subcontract; and
  3. The agreed price for, or the proceeds of sale of materials, supplies, or other things acquired by the Subcontractor or sold under this clause and not recovered by or credited to NREL/Government.
- L. The Subcontractor and NREL Subcontract Administrator must agree to any equitable adjustment in fee for the continued portion of the subcontract when there is a partial termination. The NREL Subcontract Administrator shall amend the subcontract to reflect the agreement.

- M. 1. NREL may, under the terms and conditions it prescribes, make partial payments and payments against costs incurred by the Subcontractor for the terminated portion of the subcontract, if the NREL Subcontract Administrator believes the total of these payments will not exceed the amount to which the Subcontractor will be entitled.
2. If the total payments exceed the amount finally determined to be due, the Subcontractor shall repay the excess to NREL/Government upon demand, together with interest computed at the rate established by the Secretary of the Treasury under 50 U.S.C. App. 1215(b)(2). Interest shall be computed for the period from the date the excess payment is received by the Subcontractor to the date the excess is repaid. Interest shall not be charged on any excess payment due to a reduction in the Subcontractor's termination settlement proposal because of retention or other disposition of termination inventory until ten (10) days after the date of the retention or disposition, or a later date determined by the NREL Subcontract Administrator because of the circumstances.
- N. The provisions of the clause relating to fee are inapplicable if this subcontract does not include a fee.

*ALTERNATE IV (SEP 1996).*

*(If the subcontract is a TIME-AND-MATERIAL or LABOR- HOUR subcontract, substitute the following paragraphs (H) and (L) for paragraphs (H) and (L) of the basic clause:)*

- H. If the Subcontractor and the NREL Subcontract Administrator fail to agree in whole or in part on the amount to be paid because of the termination of work, the NREL Subcontract Administrator shall determine, on the basis of information available, the amount, if any, due the Subcontractor and shall pay the amount determined as follows:
1. If the termination is for the convenience of NREL/Government, include--
- (i) An amount for direct labor hours (as defined in the Schedule of the subcontract) determined by multiplying the number of direct labor hours expended before the effective date of termination by the hourly rate(s) in the Schedule, less any hourly rate payments already made to the Subcontractor;
  - (ii) An amount (computed under the provisions for payment of materials) for material expenses incurred before the effective date of termination, not previously paid to the Subcontractor;
  - (iii) An amount for labor and material expenses computed as if the expenses were incurred before the effective date of termination if they are reasonably incurred after the effective date, with the approval of or as directed by the NREL Subcontract Administrator; however, the Subcontractor shall discontinue these expenses as rapidly as practicable;
  - (iv) If not included in subdivision (H)(1)(i), (ii), or (iii) of this clause, the cost of settling and paying termination settlement proposals under terminated subcontracts that are properly chargeable to the terminated portion of the subcontract; and

- (v) The reasonable costs of settlement of the work terminated, including--
  - a. Accounting, legal, clerical, and other expenses reasonably necessary for the preparation of termination settlement proposals and supporting data;
  - b. The termination and settlement of Lower-tier subcontracts (excluding the amounts of such settlements); and
  - c. Storage, transportation, and other costs incurred, reasonably necessary for the protection or disposition of the termination inventory.

2. If the termination is for default of the Subcontractor, include the amounts computed under subparagraph (H)(1) of this clause but omit--

- (i) Any amount for preparation of the Subcontractor's termination settlement proposal; and
- (ii) The portion of the hourly rate allocable to profit for any direct labor hours expended in furnishing materials and services not delivered to and accepted by NREL/Government.

\* \* \* \* \*

I. If the termination is partial, the Subcontractor may file with the NREL Subcontract Administrator a proposal for an equitable adjustment of the price(s) for the continued portion of the subcontract. The NREL Subcontract Administrator shall make any equitable adjustment agreed upon. Any proposal by the Subcontractor for an equitable adjustment under this clause shall be requested within ninety (90) days from the effective date of termination, unless extended in writing by the NREL Subcontract Administrator.

**CLAUSE 38 - EXCUSABLE DELAYS (APR 1984)**

*Derived from FAR 52.249-14 (FD)*

*(Applies to cost reimbursement subcontracts on a fee basis)*

A. Except for defaults of subcontractors at any tier, the Subcontractor shall not be in default because of any failure to perform this subcontract under its terms if the failure arises from causes beyond the control and without the fault or negligence of the Subcontractor. Examples of these causes are--

- 1. Acts of God or of the public enemy,
- 2. Acts of the Government in either its sovereign or contractual capacity,
- 3. Fires,
- 4. Floods,
- 5. Epidemics,

6. Quarantine restrictions,
7. Strikes,
8. Freight embargoes, and
9. Unusually severe weather.

In each instance, the failure to perform must be beyond the control and without the fault or negligence of the Subcontractor. "Default" includes failure to make progress in the work so as to endanger performance.

- B. If the failure to perform is caused by the failure of a subcontractor at any tier to perform or make progress, and if the cause of the failure was beyond the control of both the Subcontractor and lower-tier subcontractor, and without the fault or negligence of either, the Subcontractor shall not be deemed to be in default, unless--
  1. The lower-tier subcontracted supplies or services were obtainable from other sources;
  2. The NREL Subcontract Administrator ordered the Subcontractor in writing to purchase these supplies or services from the other source; and
  3. The Subcontractor failed to comply reasonably with this order.
- C. Upon request of the Subcontractor, the NREL Subcontract Administrator shall ascertain the facts and extent of the failure. If the NREL Subcontract Administrator determines that any failure to perform results from one or more of the causes above, the delivery schedule shall be revised, subject to the rights of NREL/Government under the termination clause of this subcontract.

**CLAUSE 39 - REFUND OF ROYALTIES (FEB 1995)**

*Derived from DEAR 952.227-9 (FD)*

- A. The subcontract price includes certain amounts for royalties payable by the Subcontractor or lower-tier subcontractors or both, which amounts have been reported to the DOE through NREL.
- B. The term "royalties" as used in this clause refers to any costs or charges in the nature of royalties, license fees, patent or license amortization costs, or the like, for the use of or for rights in patents and patent applications in connection with performing this subcontract or any lower-tier subcontract hereunder. The term also includes any costs or charges associated with the access to, use of, or other right pertaining to data that is represented to be proprietary and is related to the performance of this subcontract or the copying of such data or data that is copyrighted.
- C. The Subcontractor shall furnish to the DOE through NREL, before final payment under this subcontract, a statement of royalties paid or required to be paid in connection with performing this subcontract and lower-tier subcontracts hereunder together with the reasons.
- D. The Subcontractor will be compensated for royalties reported under paragraph (C) of this clause, only to the extent that such royalties were included in the subcontract price and are determined by the DOE to be properly chargeable to the Government and allocable to the subcontract. To

the extent that any royalties that are included in the subcontract price are not, in fact, paid by the Subcontractor or are determined by the DOE not to be properly chargeable to the Government and allocable to the subcontract, the subcontract price shall be reduced. Repayment or credit to the Government shall be made as the DOE directs. The approval by DOE of any individual payments or royalties shall not prevent the Government from contesting at any time the enforceability, validity, scope of, or title to, any patent or the proprietary nature of data pursuant to which a royalty or other payment is to be or has been made.

- E. If, at any time within three (3) years after final payment under this subcontract, the Subcontractor for any reason is relieved in whole or in part from the payment of the royalties included in the final subcontract price as adjusted pursuant to paragraph (D) of this clause, the Subcontractor shall promptly notify the DOE through NREL of that fact and shall reimburse the Government in a corresponding amount.
- F. The substance of this clause, including this paragraph (F), shall be included in any subcontract in which the amount of royalties reported during negotiation of the subcontract exceeds \$250.

**CLAUSE 40 - FOREIGN TRAVEL (FEB 1997)**

*Derived from DEAR 952.247-70 (FD)*

- A. Foreign travel, when charged directly, shall be subject to the prior approval of the NREL Subcontract Administrator for each separate trip regardless of whether funds for such travel are contained in an approved budget. Foreign travel is defined as any travel outside of Canada, Mexico, and the United States and its territories and possessions.
- B. Request for approval shall be submitted at least forty-five (45) days prior to the planned departure date, be on a Request for Approval of Foreign Travel form, and when applicable, include a notification of proposed soviet-bloc travel.

**CLAUSE 41 - INTEGRATION OF ENVIRONMENT, SAFETY, AND HEALTH INTO WORK PLANNING AND EXECUTION (JUN 1997)**

*Derived from DEAR 970.5204-2 (FD)*

*(Applies to subcontracts that involve complex or hazardous work that is to be performed on a Government-owned or -leased facility.)*

- A. For the purposes of this clause,
  - 1. "Safety" encompasses environment, safety, and health, including pollution prevention and waste minimization; and
  - 2. "Employees" include Lower-tier subcontractor employees.
- B. In performing work under this subcontract, the Subcontractor shall perform work safely, in a manner that ensures adequate protection for employees, the public, and the environment, and shall be accountable for the safe performance of work. The Subcontractor shall exercise a degree of care commensurate with the work and the associated hazards. The Subcontractor shall ensure that management of environment, safety, and health (ES&H) functions and activities becomes an

integral but visible part of the Subcontractor's work planning and execution processes. The Subcontractor shall, in the performance of work, ensure that:

1. Line management is responsible for the protection of employees, the public, and the environment. Line management includes those Subcontractor and lower-tier subcontractor employees managing or supervising employees performing work.
2. Clear and unambiguous lines of authority and responsibility for ensuring ES&H are established and maintained at all organizational levels.
3. Personnel possess the experience, knowledge, skills, and abilities that are necessary to discharge their responsibilities.
4. Resources are effectively allocated to address ES&H, programmatic, and operational considerations. Protecting employees, the public, and the environment is a priority whenever activities are planned and performed.
5. Before work is performed, the associated hazards are evaluated and an agreed-upon set of ES&H standards and requirements are established which, if properly implemented, provide adequate assurance that employees, the public, and the environment are protected from adverse consequences.
6. Administrative and engineering controls to prevent and mitigate hazards are tailored to the work being performed and associated hazards. Emphasis should be on designing the work and/or controls to reduce or eliminate the hazards and to prevent accidents and unplanned releases and exposures.
7. The conditions and requirements to be satisfied for operations to be initiated and conducted are established and agreed-upon by NREL/Government and the Subcontractor. These agreed-upon conditions and requirements are requirements of the subcontract and binding upon the Subcontractor. The extent of documentation and level of authority for agreement shall be tailored to the complexity and hazards associated with the work and shall be established in a Safety Management System.

C. The Subcontractor shall manage and perform work in accordance with a documented Safety Management System (System) that fulfills all conditions in paragraph (B) of this clause at a minimum. Documentation of the System shall describe how the Subcontractor will:

1. Define the scope of work;
2. Identify and analyze hazards associated with the work;
3. Develop and implement hazard controls;
4. Perform work within controls; and
5. Provide feedback on adequacy of controls and continue to improve safety management.

- D. The System shall describe how the Subcontractor will establish, document, and implement safety performance objectives, performance measures, and commitments in response to DOE program and budget execution guidance while maintaining the integrity of the System. The System shall also describe how the Subcontractor will measure system effectiveness.
- E. The Subcontractor shall submit to the NREL Subcontract Administrator documentation of its System for review and approval. Dates for submittal, discussions, and revisions to the System will be established by the NREL Subcontract Administrator. Guidance on the preparation, content, review, and approval of the System will be provided by the NREL Subcontract Administrator. On an annual basis, the Subcontractor shall review and update, for DOE approval, its safety performance objectives, performance measures, and commitments consistent with and in response to DOE's program and budget execution guidance and direction. Resources shall be identified and allocated to meet the safety objectives and performance commitments as well as maintain the integrity of the entire System. Accordingly, the System shall be integrated with the Subcontractor's business processes for work planning, budgeting, authorization, execution, and change control.
- F. The Subcontractor shall comply with, and assist the DOE in complying with, ES&H requirements of all applicable laws and regulations, and applicable directives identified in the clause of this subcontract on Laws, Regulations, and DOE Directives. The Subcontractor shall cooperate with Federal and non-Federal agencies having jurisdiction over ES&H matters under this subcontract.
- G. The Subcontractor shall promptly evaluate and resolve any noncompliance with applicable ES&H requirements and the System. If the Subcontractor fails to provide resolution or if, at any time, the Subcontractor's acts or failure to act causes substantial harm or an imminent danger to the environment or health and safety of employees or the public, the NREL Subcontract Administrator may issue an order stopping work in whole or in part. Any stop work order issued by a NREL Subcontract Administrator under this clause (or issued by the Subcontractor to a lower-tier subcontractor in accordance with paragraph (I) of this clause) shall be without prejudice to any other legal or contractual rights of NREL/Government. In the event that the NREL Subcontract Administrator issues a stop work order, an order authorizing the resumption of the work may be issued at the discretion of the NREL Subcontract Administrator. The Subcontractor shall not be entitled to an extension of time or additional fee or damages by reason of, or in connection with, any work stoppage ordered in accordance with this clause.
- H. The Subcontractor is responsible for compliance with the ES&H requirements applicable to this contract regardless of the performer of the work.
- I. The Subcontractor shall include a clause substantially the same as this clause in lower-tier subcontracts involving complex or hazardous work on site at a DOE-owned or -leased facility. Such lower-tier subcontracts shall provide for the right to stop work under the conditions described in paragraph (G) of this clause. Depending on the complexity and hazards associated with the work, the Subcontractor may require that the lower-tier subcontractor submit a Safety Management System for the Subcontractor's review and approval.

**CLAUSE 42 - ACCOUNTS, RECORDS, AND INSPECTION (JUN 1996)**

*Derived from DEAR 970.5204-9 (FD)*

A. Accounts.

The Subcontractor shall maintain a separate and distinct set of accounts, records, documents, and other evidence showing and supporting all allowable costs incurred, revenues or other applicable credits, fixed-fee accruals, and the receipt, use and disposition of all Government property coming into the possession of the Subcontractor under this subcontract. The system of accounts employed by the Subcontractor shall be acceptable to NREL/Government and in accordance with generally accepted accounting principles consistently applied.

B. Inspection and Audit of Accounts and Records.

All books of account and records relating to this subcontract shall be subject to inspection and audit by NREL/Government at all reasonable times, before and during the period of retention provided for in (D) below, and the Subcontractor shall afford proper facilities for such inspection and audit.

C. Audit of Subcontractors' Records.

The Subcontractor also agrees, with respect to any lower-tier subcontracts (including fixed price or unit-price lower-tier subcontracts or purchase orders) where, under the terms of the lower-tier subcontract, costs incurred are a factor in determining the amount payable to the subcontractor of any tier, to either conduct an audit of the lower-tier subcontractor's costs or arrange for such an audit to be performed by the cognizant Government audit agency through the NREL Subcontract Administrator.

D. Disposition of Records.

Except as agreed upon by NREL and the Subcontractor, all financial and cost reports, books of account and supporting documents, and other data evidencing costs allowable, revenues, and other applicable credits under this subcontract, shall be the property of the Government, and shall be delivered to NREL or otherwise disposed of by the Subcontractor either as the NREL Subcontract Administrator may from time to time direct during the progress of the work or, in any event, as the NREL Subcontract Administrator shall direct upon completion or termination of this subcontract and final audit of accounts hereunder. Except as provided in this subcontract, all other records in the possession of the Subcontractor relating to this subcontract shall be preserved by the Subcontractor for a period of three (3) years after final payment under this subcontract or otherwise disposed of in such manner as may be agreed upon by NREL/Government and the Subcontractor.

E. Reports.

The Subcontractor shall furnish such progress reports and schedules, financial and cost reports, and other reports concerning the work under this subcontract as the NREL Subcontract Administrator may from time to time require.

F. Inspections.

NREL/Government shall have the right to inspect the work and activities of the Subcontractor under this subcontract at such time and in such manner as it shall deem appropriate.

G. Lower-tier Subcontracts.

The Subcontractor further agrees to require the inclusion of provisions similar to those in paragraphs (A) through (G) and paragraph (I) of this clause in all lower-tier subcontracts (including fixed price or unit price subcontracts or purchase orders) of any tier entered into hereunder where, under the terms of the lower-tier subcontract, costs incurred are a factor in determining the amount payable to the lower-tier subcontractor.

*(The following paragraph (H) shall be included in--*

1. *All cost-type subcontracts (or lower-tier subcontracts) involving an estimated cost exceeding \$5 million and expected to run more than two (2) years, and*
2. *Any other cost-type subcontract (or lower-tier subcontract) where deemed advisable by the DOE Head of the Contracting Activity and when the Subcontractor (or lower-tier subcontractor) already has an established internal audit organization.)*

H. Internal Audit.

The Subcontractor agrees to conduct an internal audit and examination satisfactory to NREL/Government of the records, operations, expenses, and the transactions with respect to costs claimed to be allowable under this subcontract annually and at such other times as may be mutually agreed upon. The results of such audit, including the working papers, shall be submitted or made available to the NREL Subcontract Administrator.

I. Comptroller General.

1. The Comptroller General of the United States, or an authorized representative, shall have access to and the right to examine any of the Subcontractor's directly pertinent records involving transactions related to this subcontract or a lower-tier subcontract hereunder.
2. This paragraph may not be construed to require the Subcontractor or lower-tier subcontractor to create or maintain any record that the Subcontractor or lower-tier subcontractor does not maintain in the ordinary course of business or pursuant to a provision of law.
3. Nothing in this subcontract shall be deemed to preclude an audit by the General Accounting Office of any transaction under this subcontract.

**CLAUSE 43 - PRINTING CLAUSE FOR SUBCONTRACTS (APR 1984)**

*Derived from DEAR 970.5204-19 (FD)*

- A. To the extent that duplicating or printing services may be required in the performance of this subcontract, the Subcontractor shall provide or secure such services in accordance with the Government Printing and Binding Regulations, Title 44 of the U.S. Code, and DOE Directives relative thereto.

- B. The term "Printing" includes the following processes: composition, platemaking, presswork, binding, microform publishing, or the end items produced by such processes. Provided, however, that performance of a requirement under this subcontract involving the duplication of less than 5,000 copies of a single page, or no more than 25,000 units in the aggregate of multiple pages, will not be deemed to be printing.
- C. Printing services not obtained in compliance with this guidance shall result in the cost of such printing being disallowed.
- D. In all lower-tier subcontracts hereunder which require printing (as that term is defined in Title I of the U.S. Government Printing and Binding Regulations), the Subcontractor shall include a provision substantially the same as this clause.

**CLAUSE 44 - PROPERTY (JUNE 1997)**

*Derived from DEAR 970.5204-21 (FD)*

*(Applies to cost reimbursement subcontracts)*

- A. Furnishing of Government property.

The Government reserves the right to furnish any property or services required for the performance of the work under this subcontract.

- B. Title to property.

Except as otherwise provided by the NREL Subcontract Administrator, title to all materials, equipment, supplies, and tangible personal property of every kind and description purchased by the Subcontractor, for the cost of which the Subcontractor is entitled to be reimbursed as a direct item of cost under this subcontract, shall pass directly from the vendor to the Government. The Government reserves the right to inspect, and to accept or reject, any item of such property. The Subcontractor shall make such disposition of rejected items as the NREL Subcontract Administrator shall direct. Title to other property, the cost of which is reimbursable to the Subcontractor under this subcontract, shall pass to and vest in the Government upon

1. Issuance for use of such property in the performance of this subcontract, or
2. Commencement of processing or use of such property in the performance of this subcontract, or
3. Reimbursement of the cost thereof by the Government, whichever first occurs.

Property furnished by the Government and property purchased or furnished by the Subcontractor, title to which vests in the Government, under this paragraph are hereinafter referred to as Government property. Title to Government property shall not be affected by the incorporation of the property into or the attachment of it to any property not owned by the Government, nor shall such Government property or any part thereof, be or become a fixture or lose its identity as personalty by reason of affixation to any realty.

- C. Identification.

To the extent directed by the NREL Subcontract Administrator, the Subcontractor shall identify Government property coming into the Subcontractor's possession or custody, by marking and segregating in such a way, satisfactory to the NREL Subcontract Administrator, as shall indicate its ownership by the Government.

D. Disposition.

The Subcontractor shall make such disposition of Government property which has come into the possession or custody of the Subcontractor under this subcontract as the NREL Subcontract Administrator may direct during the progress of the work or upon completion or termination of this subcontract. The Subcontractor may, upon such terms and conditions as the NREL Subcontract Administrator may approve, sell, or exchange such property, or acquire such property at a price agreed upon by the NREL Subcontract Administrator and the Subcontractor as the fair value thereof. The amount received by the Subcontractor as the result of any disposition, or the agreed fair value of any such property acquired by the Subcontractor, shall be applied in reduction of costs allowable under this subcontract or shall be otherwise credited to account to the Government, as the NREL Subcontract Administrator may direct. Upon completion of the work or the termination of this subcontract, the Subcontractor shall render an accounting, as prescribed by the NREL Subcontract Administrator, of all Government property which had come into the possession or custody of the Subcontractor under this subcontract.

E. Protection of Government property management of high-risk property and classified materials.

1. The Subcontractor shall take all reasonable precautions, and such other actions as may be directed by the NREL Subcontract Administrator, or in the absence of such direction, in accordance with sound business practice, to safeguard and protect Government property in the Subcontractor's possession or custody.
2. In addition, the Subcontractor shall ensure that adequate safeguards are in place, and adhered to, for the handling, control and disposition of high-risk property and classified materials throughout the life cycle of the property and materials consistent with the policies, practices and procedures for property management contained in the Federal Property Management regulations (41 CFR chapter 101), the Department of Energy Property Management regulations (41 CFR chapter 109), and other applicable regulations.
3. High-risk property is property, the loss, destruction, damage to, or the unintended or premature transfer of which could pose risks to the public, the environment, or the national security interests of the United States. High-risk property includes proliferation sensitive, nuclear related dual use, export controlled, chemically or radioactively contaminated, hazardous, and specially designed and prepared property, including property on the militarily critical technologies list.

F. Risk of loss of Government property.

1. (i) The Subcontractor shall not be liable for the loss or destruction of, or damage to, Government property unless such loss, destruction, or damage was caused by any of the following:

- a. Willful misconduct or lack of good faith on the part of the Subcontractor's managerial personnel;
- b. Failure of the Subcontractor's managerial personnel to take all reasonable steps to comply with any appropriate written direction of the NREL Subcontract Administrator to safeguard such property under paragraph (E) of this clause; or
- c. Failure of Subcontractor managerial personnel to establish, administer, or properly maintain an approved property management system in accordance with paragraph (I)(1) of this clause.

(ii) If, after an initial review of the facts, the NREL Subcontract Administrator informs the Subcontractor that there is reason to believe that the loss, destruction of, or damage to the Government property results from conduct falling within one of the categories set forth above, the burden of proof shall be upon the Subcontractor to show that the Subcontractor should not be required to compensate the Government for the loss, destruction, or damage.

2. In the event that the Subcontractor is determined liable for the loss, destruction or damage to Government property in accordance with (F)(1) of this clause, the Subcontractor's compensation to the Government shall be determined as follows:

- (i) For damaged property, the compensation shall be the cost of repairing such damaged property, plus any costs incurred for temporary replacement of the damaged property. However, the value of repair costs shall not exceed the fair market value of the damaged property. If a fair market value of the property does not exist, the NREL Subcontract Administrator shall determine the value of such property, consistent with all relevant facts and circumstances.
- (ii) For destroyed or lost property, the compensation shall be the fair market value of such property at the time of such loss or destruction, plus any costs incurred for temporary replacement and costs associated with the disposition of destroyed property. If a fair market value of the property does not exist, the NREL Subcontract Administrator shall determine the value of such property, consistent with all relevant facts and circumstances.

3. The portion of the cost of insurance obtained by the Subcontractor that is allocable to coverage of risks of loss referred to in paragraph (F)(1) of this clause is not allowable.

G. Steps to be taken in event of loss. In the event of any damage, destruction, or loss to Government property in the possession or custody of the Subcontractor with a value above the threshold set out in the Subcontractor's approved property management system, the Subcontractor:

1. Shall immediately inform the NREL Subcontract Administrator of the occasion and extent thereof,
2. Shall take all reasonable steps to protect the property remaining, and

3. Shall repair or replace the damaged, destroyed, or lost property in accordance with the written direction of the NREL Subcontract Administrator.

The Subcontractor shall take no action prejudicial to the right of the Government to recover therefore, and shall furnish to the Government, on request, all reasonable assistance in obtaining recovery.

- H. Government property for Government use only.

Government property shall be used only for the performance of this subcontract.

- I. Property Management.

1. Property Management System.

- (i) The Subcontractor shall establish, administer, and properly maintain an approved property management system of accounting for and control, utilization, maintenance, repair, protection, preservation, and disposition of Government property in its possession under the subcontract. The Subcontractor's property management system shall be submitted to the NREL Subcontract Administrator for approval and shall be maintained and administered in accordance with sound business practice, applicable Federal Property Management regulations and Department of Energy Property Management regulations, and such directives or instructions which the NREL Subcontract Administrator may from time to time prescribe.
- (ii) In order for a property management system to be approved, it must provide for:
  - a. Comprehensive coverage of property from the requirement identification, through its life cycle, to final disposition;
  - b. Employee personal responsibility and accountability for Government-owned property;
  - c. Full integration with the Subcontractor's other administrative and financial systems; and
  - d. A method for continuously improving property management practices through the identification of best practices established by "best in class" performers.
- (iii) Approval of the Subcontractor's property management system shall be contingent upon the completion of the baseline inventory as provided in subparagraph (I)(2) of this clause.

2. Property Inventory.

- (i) Unless otherwise directed by the NREL Subcontract Administrator, the Subcontractor shall within six months after execution of the subcontract provide a baseline inventory covering all items of Government property.
- (ii) If the Subcontractor is succeeding another Subcontractor in the performance of this subcontract, the Subcontractor shall conduct a joint reconciliation of the property inventory with the predecessor Subcontractor.

The Subcontractor agrees to participate in a joint reconciliation of the property inventory at the completion of this subcontract. This information will be used to provide a baseline for the succeeding subcontract as well as information for closeout of the predecessor subcontract.

- J. The term "Subcontractor's managerial personnel" as used in this clause means the Subcontractor's directors, officers and any of its managers, superintendents, or other equivalent representatives who have supervision or direction of:
1. All or substantially all of the Subcontractor's business; or
  2. All or substantially all of the Subcontractor's operations at any one facility or separate location to which this subcontract is being performed; or
  3. A separate and complete major industrial operation in connection with the performance of this subcontract; or
  4. A separate and complete major construction, alteration, or repair operation in connection with performance of this subcontract; or
  5. A separate and discrete major task or operation in connection with the performance of this subcontract.

*(Note: Substitute the following paragraph (J) for nonprofit Subcontractors:)*

- J. The term "Subcontractor's managerial personnel" as used in this clause means the Subcontractor's directors, officers and any of its managers, superintendents, or other equivalent representatives who have supervision or direction of all or substantially all of:
1. The Subcontractor's business; or
  2. The Subcontractor's operations at any one facility or separate location at which this subcontract is being performed; or
  3. The Subcontractor's Government property system and/or a Major System Acquisition or Major Project as defined in DOE Order 4700.1 (Version in effect on effective date of subcontract).
- K. The Subcontractor shall include this clause in cost reimbursable lower-tier subcontracts.

**CLAUSE 45 - TAXES (APR 1984)**

*Derived from DEAR 970.5204-23 (FD)*

- A. The Subcontractor agrees to notify the NREL Subcontract Administrator of any State or local tax, fee, or charge levied or purported to be levied on or collected from the Subcontractor with respect to the subcontract work, any transaction thereunder, or property in the custody or control of the Subcontractor and constituting an allowable item of cost if due and payable, but which the Subcontractor has reason to believe, or the NREL Subcontract Administrator has advised the Subcontractor, is or may be inapplicable or invalid; \* and the Subcontractor further agrees to refrain from paying any such tax, fee, or charge unless authorized in writing by the NREL Subcontract Administrator. Any State or local tax, fee, or charge paid with the approval of the NREL Subcontract Administrator or on the basis of advice from the NREL Subcontract Administrator that such tax, fee, or charge is applicable and valid, and which would otherwise be an allowable item of cost, shall not be disallowed as an item of cost by reason of any subsequent ruling or determination that such tax, fee, or charge was in fact inapplicable or invalid.

*\*Requirement for notice may be broadened to include all State and local taxes which may be claimed as allowable costs when considered to be appropriate.*

- B. The Subcontractor agrees to take such action as may be required or approved by the NREL Subcontract Administrator to cause any State or local tax, fee, or charge which would be an allowable cost to be paid under protest; and to take such action as may be required or approved by the NREL Subcontract Administrator to seek recovery of any payments made, including assignment to NREL/Government, or its designee of all rights to an abatement or refund thereof, and granting permission for NREL/Government to join with the Subcontractor in any proceedings for the recovery thereof or to sue for recovery in the name of the Subcontractor. If the NREL Subcontract Administrator directs the Subcontractor to institute litigation to enjoin the collection of or to recover payment of any such tax, fee, or charge referred to above, or if a claim or suit is filed against the Subcontractor for a tax, fee, or charge it has refrained from paying in accordance with this article, the procedures and requirements of the article entitled "Litigation and Claims" shall apply and the costs and expenses incurred by the Subcontractor shall be allowable items of costs, as provided in this subcontract, together with the amount of any judgment rendered against the Subcontractor.
- C. NREL/Government shall hold the Subcontractor harmless from penalties and interest incurred through compliance with this clause. All recoveries or credits in respect of the foregoing taxes, fees, and charges (including interest) shall inure to and be for the sole benefit of NREL/Government.

**CLAUSE 46 - PERMITS OR LICENSES (APR 1984)**

*Derived from DEAR 970.5204-29*

Except as otherwise directed by the NREL Subcontract Administrator, the Subcontractor shall procure all necessary permits or licenses and abide by all applicable laws, regulations, and ordinances of the United States and of the state, territory, and political subdivision in which the work under this subcontract is performed.

**CLAUSE 47 - ACCESS TO AND OWNERSHIP OF RECORDS (JUNE 1997)**

*Derived from DEAR 970.5204-79 (FD)*

*(Applies to cost reimbursement subcontracts)*

A. Government-owned records.

Except as provided in paragraph (B) of this clause, all records acquired or generated by the Subcontractor in its performance of this subcontract shall be the property of the Government and shall be delivered to the Government or otherwise disposed of by the Subcontractor either as the NREL Subcontract Administrator may from time to time direct during the process of the work or, in any event, as the NREL Subcontract Administrator shall direct upon completion or termination of the subcontract.

B. Subcontractor-owned records.

The following records are considered the property of the Subcontractor and are not within the scope of paragraph (A) of this clause. (The NREL Subcontract Administrator shall identify which of the following categories of records will be included in the clause.)

1. Employment-related records (such as workers' compensation files; employee relations records, records on salary and employee benefits; drug testing records, labor negotiation records; records on ethics, employee concerns, and other employee related investigations conducted under an expectation of confidentiality; employee assistance program records; and personnel and medical/ health-related records and similar files), except for those records described by the subcontract as being maintained in Privacy Act systems of records.
2. Confidential Subcontractor financial information, and correspondence between the Subcontractor and other segments of the Subcontractor located away from the NREL facility (i.e., the Subcontractor's corporate headquarters);
3. Records relating to any procurement action by the Subcontractor, except for records that under 48 CFR (DEAR) 970.5204-9, Accounts, Records, and Inspection, are described as the property of the Government; and
4. Legal records, including legal opinions, litigation files, and documents covered by the attorney-client and attorney work product privileges; and
5. [Reserved]

C. Subcontract completion or termination.

In the event of completion or termination of this subcontract, copies of any of the Subcontractor-owned records identified in paragraph (B) of this clause, upon the request of the Government, shall be delivered to DOE or its designees, including successor Subcontractors. Upon delivery, title to such records shall vest in DOE or its designees, and such records shall be protected in accordance with applicable federal laws (including the Privacy Act), as appropriate.

D. Inspection, copying, and audit of records.

All records acquired or generated by the Subcontractor under this subcontract in the possession of the Subcontractor, including those described at paragraph (B) of this clause, shall be subject to inspection, copying, and audit by the Government or its designees at all reasonable times, and the Subcontractor shall afford the Government or its designees reasonable facilities for such inspection, copying, and audit; provided, however, that upon request by the NREL Subcontract Administrator, the Subcontractor shall deliver such records to a location specified by the NREL Subcontract Administrator for inspection, copying, and audit. The Government or its designees shall use such records in accordance with applicable federal laws (including the Privacy Act), as appropriate.

E. Applicability.

Paragraphs (B), (C), and (D) of this clause apply to all records without regard to the date or origination of such records.

F. Records retention standards.

Special records retention standards, described at DOE Order 1324.5B, Records Management Program and DOE Records Schedules (version in effect on effective date of subcontract), are applicable for the classes of records described therein, whether or not the records are owned by the Government or the Subcontractor. In addition, the Subcontractor shall retain individual radiation exposure records generated in the performance of work under this subcontract until DOE authorizes disposal. The Government may waive application of these record retention schedules, if, upon termination or completion of the subcontract, the Government exercises its right under paragraph (C) of this clause to obtain copies and delivery of records described in paragraphs (A) and (B) of this clause.

G. Flow down.

The Subcontractor shall include the requirements of this clause in all lower-tier subcontracts that are of a cost-reimbursement type if any of the following factors is present:

1. The value of the lower-tier subcontract is greater than \$2 million (unless specifically waived by the NREL Subcontract Administrator);
2. The NREL Subcontract Administrator determines that the lower-tier subcontract is, or involves, a critical task related to the subcontract; or
3. The lower-tier subcontract includes 48 CFR (DEAR) 970.5204-2, Integration of Environment, Safety, and Health into Work Planning and Execution, or similar clause.

**CLAUSE 48 - ACCESS SECURITY (SPECIAL)(APR 1999)**

- A. Access to NREL operated facilities is controlled in accordance with the DOE's requirements. The Subcontractor shall ensure that any of its, or its lower-tier subcontractors, officers, employees, or agents be specifically authorized site access by an NREL employee, and identified, badged, and registered by NREL Security prior to entering any NREL operated facility.

- B. The Subcontractor shall further ensure that any of its, or its lower-tier subcontractors, officers, employees, or agents who are not U.S. citizens or U.S. permanent residents and who will perform subcontract work on NREL operated facilities for a total of thirty (30) calendar days or greater, or who are citizens of a DOE designated sensitive country, or who work for a company based in a sensitive country, or who are stateless persons, submit a completed DOE Form IA 473 to NREL six to eight weeks before access is required. Access shall be subject to DOE approval. Any such person denied access by DOE shall not be assigned by the Subcontractor to work at NREL operated facilities.
- C. The Subcontractor shall provide to the Subcontract Administrator, prior to the initiation of work, evidence, including visa types and expiration dates, that legally sufficient work permits have been obtained from the U.S. Immigration and Naturalization Service, and such permits are properly maintained, for any of its, or its lower-tier subcontractors officers, employees, or agents who are not U.S. citizens or U.S. permanent residents and who will perform subcontract work at NREL operated facilities.
- D. Further, after the Subcontractor, or its lower-tier subcontractors, has commenced subcontract work, the Subcontractor shall provide to the Subcontract Administrator similar advance notice, including visa types and expiration dates, for all subsequently assigned individuals who are not U.S. citizens or U.S. permanent residents who will perform subcontract work at NREL operated facilities.
- E. NREL reserves the right to revoke site access authorization for any person violating NREL or DOE safety and security policies and procedures.
- F. As a condition of entry to NREL premises, the Subcontractor agrees to permit NREL security personnel to search its, and its lower-tier subcontractors, officers, employees, or agents vehicles, packages, tool boxes, or other containers for the purpose of preventing prohibited articles access to NREL premises or to detect or deter the unauthorized removal of Government property from NREL.
- G. Prohibited articles include cameras, copying machines, reproduction devices, recording devices, radio transmitters, firearms, explosive devices, incendiary devices, dangerous weapons or materials, controlled substances (illegal drugs), or alcoholic beverages.
- H. The Subcontractor shall include this article, including this Paragraph H, in all lower-tier subcontracts involving work at NREL operated facilities.



# **APPENDIX C - 2**

## **INTELLECTUAL PROPERTY PROVISIONS**

### **FOR**

#### **DOMESTIC SMALL BUSINESS, EDUCATIONAL INSTITUTIONS, AND OTHER NONPROFIT ORGANIZATIONS (RESEARCH, DEVELOPMENT, OR DEMONSTRATION)**



APPENDIX C - 2

INDEX

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
1	<b>Authorization and Consent (JUL 1995),</b> <i>Alternate I of this clause is applicable if this award is for the conduct of research, development or demonstration</i> <i>Alternate II of this clause is applicable if this award includes an order or lower-tier subcontract for communication services and facilities</i> <i>Derived from FAR 52.227-1</i> .....	1
2	<b>Notice and Assistance Regarding Patent and Copyright Infringement (AUG 1996)</b> <i>The provisions of this clause shall be applicable only if the amount of this award exceeds \$100,000, and the award is for the conduct of construction, research, development, or demonstration</i> <i>Derived from FAR 52.227-2</i> .....	2
3	<b>Rights in Data - General (JUN 1987), as modified by DEAR 927.409 (Effective APR 1998), with Alternates I and V, and Paragraph (D)(3)</b> <i>If this award requires the use or delivery of limited rights data and/or restricted computer software, Alternates II and/or III are incorporated, unless modified upon recommendation of Patent Counsel</i> <i>Derived from FAR 52.227-14 and DEAR 927.409.</i> .....	3
4	<b>Additional Data Requirements (JUN 1987)</b> <i>This clause does not apply to this award if the award is for the conduct of basic or applied research, as set out elsewhere in this award, to be performed solely by a college or university, and the estimated cost is not in excess of \$500,000</i> <i>Derived from FAR 52.227-16</i> .....	12
5	<b>Rights to Proposal Data (Technical) (JUN 1987)</b> <i>Derived from FAR 52.227-23</i> .....	13



APPENDIX C - 2

INDEX

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
6	<b>Refund of Royalties (FEB 1995)</b> <i>Derived from DEAR 952.227-9</i> .....	13
7	<b>Patent Rights - Retention by Subcontractor (Short Form) (FEB 1995)</b> <i>This clause applies only if the awardee is a domestic small business or domestic nonprofit organization at the time of award, and the award is for the conduct of research, development, or demonstration</i> <i>Derived from DEAR 952.227-11</i> .....	14
<b>Attachment 1 (For Reference)</b>	<b>Patent Rights - Acquisition by the Government (FEB 1995)</b> <i>The clause applies unless the awardee is a domestic small business or domestic nonprofit organization at the time of award, and the award is for the conduct of research, development, or demonstration</i> <i>Derived from DEAR 952.227-13</i> .....	22

## CLAUSES

### CLAUSE 1 -- AUTHORIZATION AND CONSENT (JUL 1995)

*Derived from FAR 52.227-1*

- A. The Government authorizes and consents to all use and manufacture, in performing this subcontract or any subcontract at any tier, of any invention described in and covered by a United States patent
1. Embodied in the structure or composition of any article the delivery of which is accepted by the Government through NREL under this subcontract or;
  2. Used in machinery, tools, or methods whose use necessarily results from compliance by the Subcontractor or a lower-tier subcontractor with--
    - (i) Specifications or written provisions forming a part of this subcontract or
    - (ii) Specific written instructions given by the DOE through NREL directing the manner of performance. The entire liability to the Government for infringement of a patent of the United States shall be determined solely by the provisions of the indemnity clause, if any, included in this subcontract or any subcontract hereunder (including any lower-tier subcontract), and the Government assumes liability for all other infringement to the extent of the authorization and consent hereinabove granted.
- B. The Subcontractor agrees to include, and require inclusion of, this clause, suitably modified to identify the parties, in all subcontracts at any tier for supplies or services (including construction, architect-engineer services, and materials, supplies, models, samples, and design or testing services expected to exceed the simplified acquisition threshold); however, omission of this clause from any lower-tier subcontract, including those at or below the simplified acquisition threshold, does not affect this authorization and consent.

### ALTERNATE I (APR 1984)

*Alternate I of this clause is applicable if this award is for the conduct of research, development, or demonstration*

The following is substituted for paragraph (A) of the clause:

- A. The Government authorizes and consents to all use and manufacture of any invention described in and covered by a United States patent in the performance of this subcontract or any subcontract at any tier.

**ALTERNATE II (APR 1984)**

*Alternate II of this clause is applicable if this award includes an order or lower-tier subcontract for communication services and facilities*

The following is substituted for paragraph (A) of the clause:

- A. The Government authorizes and consents to all use and manufacture in the performance of any order at any tier or subcontract at any tier placed under this subcontract for communication services and facilities for which rates, charges, and tariffs are not established by a government regulatory body, of any invention described in and covered by a United States patent
1. Embodied in the structure or composition of any article the delivery of which is accepted by the Government through NREL under this subcontract or
  2. Used in machinery, tools, or methods whose use necessarily results from compliance by the Subcontractor or a lower-tier subcontractor with specifications or written provisions forming a part of this subcontract or with specific written instructions given by the DOE through NREL directing the manner of performance.

**CLAUSE 2 -- NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT (AUG 1996)**

*Derived from FAR 52.227-2*

*The provisions of this clause shall be applicable only if the amount of this award exceeds \$100,000, and the award is for the conduct of construction, research, development, or demonstration*

- A. The Subcontractor shall report to the DOE through NREL, promptly and in reasonable written detail, each notice or claim of patent or copyright infringement based on the performance of this subcontract of which the Subcontractor has knowledge.
- B. In the event of any claim or suit against the Government or NREL on account of any alleged patent or copyright infringement arising out of the performance of this subcontract or out of the use of any supplies furnished or work or services performed under this subcontract, the Subcontractor shall furnish to the Government, when

requested by the DOE through NREL, all evidence and information in possession of the Subcontractor pertaining to such suit or claim. Such evidence and information shall be furnished at the expense of the Government except where the Subcontractor has agreed to indemnify the Government.

- C. The Subcontractor agrees to include, and require inclusion of, this clause in all subcontracts at any tier for supplies or services (including construction and architect-engineer lower-tier subcontracts and those for material, supplies, models, samples, or design or testing services) expected to exceed the simplified acquisition threshold at FAR 2.101.

**CLAUSE 3 -- RIGHTS IN DATA - GENERAL (JUN 1987), AS MODIFIED BY DEAR 927.409 (EFFECTIVE APR 1998)**

*Derived from FAR 52.227-14*

*If this award requires the use or delivery of limited rights data and/or restricted computer software, Alternates II and/or III are incorporated, unless modified upon recommendation of Patent Counsel.*

A. Definitions.

1. "Computer data bases," as used in this clause, means a collection of data in a form capable of, and for the purpose of, being stored in, processed, and operated on by a computer. The term does not include computer software.
2. "Computer software," as used in this clause, means--
  - (i) Computer programs which are data comprising a series of instructions, rules, routines, or statements, regardless of the media in which recorded, that allow or cause a computer to perform a specific operation or series of operations and
  - (ii) Data comprising source code listings, design details, algorithms, processes, flow charts, formulae, and related material that would enable the computer program to be produced, created, or compiled. The term does not include computer data bases.
3. "Data," as used in this clause, means recorded information, regardless of form or the media on which it may be recorded. The term includes technical data and computer software. For the purposes of this clause, the term does not include data incidental to the administration of this subcontract, such as financial, administrative, cost and pricing, or management information.

4. "Form, fit, and function data," as used in this clause, means data relating to items, components, or processes that are sufficient to enable physical and functional interchangeability, as well as data identifying source, size, configuration, mating, and attachment characteristics, functional characteristics, and performance requirements; except that for computer software it means data identifying source, functional characteristics, and performance requirements but specifically excludes the source code, algorithm, process, formulae, and flow charts of the software.
5. "Limited rights data," as used in this clause, means data, other than computer software, developed at private expense that embody trade secrets or are commercial or financial and confidential or privileged. The Government's rights to use, duplicate, or disclose limited rights data are as set forth in the Limited Rights Notice of subparagraph (G)(2) of this section if included in this clause.
6. "Restricted computer software," as used in this clause, means computer software developed at private expense and that is a trade secret; is commercial or financial and is confidential or privileged; or is published copyrighted computer software, including minor modifications of any such computer software. The Government's rights to use, duplicate, or disclose restricted computer software are as set forth in the Restricted Rights Notice of subparagraph (G)(3) of this section if included in this clause.
7. "Technical data," as used in this clause, means recorded data, regardless of form or characteristic, that are of a scientific or technical nature. Technical data does not include computer software, but does include manuals and instructional materials and technical data formatted as a computer data base.
8. "Unlimited rights," as used in this clause, means the rights of the Government to use, disclose, reproduce, prepare derivative works, distribute copies to the public, including by electronic means, and perform publicly and display publicly, in any manner, including by electronic means, and for any purpose whatsoever, and to have or permit others to do so.

B. Allocation of rights.

1. Except as provided in paragraph (C) below regarding copyright, the Government shall have unlimited rights in:
  - (i) Data first produced in the performance of this subcontract;
  - (ii) Form, fit, and function data delivered under this subcontract;

- (iii) Data delivered under this subcontract (except for restricted computer software) that constitute manuals or instructional and training material for installation, operation, or routine maintenance and repair items, components, or processes delivered or furnished for use under this subcontract; and
- (iv) All other data delivered under this subcontract unless provided otherwise for limited rights data or restricted computer software in accordance with paragraph (G) below.

2. The Subcontractor shall have the right to:

- (i) Use, release to others, reproduce, distribute, or publish any data first produced or specifically used by the Subcontractor in the performance of this subcontract, unless provided otherwise in paragraph (D) below;
- (ii) Protect from unauthorized disclosure and use those data which are limited rights data or restricted computer software to the extent provided in paragraph (G) below;
- (iii) Substantiate use of, add or correct limited rights, restricted rights, or copyright notices and to take other appropriate action, in accordance with paragraphs (E) and (F) below; and
- (iv) Establish claim to copyright subsisting in data first produced in the performance of this subcontract to the extent provided in subparagraph (C)(1) below.

C. Copyright.

- 1. Data first produced in the performance of this subcontract. Unless provided otherwise in subparagraph (D) below, the Subcontractor may establish, without prior approval of the DOE, claim to copyright subsisting in scientific and technical articles based on or containing data first produced in the performance of this subcontract and published in academic, technical or professional journals, symposia proceedings or similar works. The prior, express written permission of the DOE is required to establish claim to copyright subsisting in all other data first produced in the performance of this subcontract. When claim to copyright is made, the Subcontractor shall affix the applicable copyright notices of 17 U.S.C. 401 or 402 and acknowledgment of Government sponsorship (including subcontract number) to the data when such data are delivered to the Government, as well as when the data are published or deposited for registration as a published work in the U.S. Copyright Office. For data other than computer software the

Subcontractor grants to the Government, and others acting on its behalf, a paid-up, nonexclusive, irrevocable worldwide license in such copyrighted data to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government. For computer software, the Subcontractor grants to the Government and others acting in its behalf, a paid-up nonexclusive, irrevocable worldwide license in such copyrighted computer software to reproduce, prepare derivative works, and perform publicly and display publicly by or on behalf of the Government.

2. Data not first produced in the performance of this subcontract. The Subcontractor shall not, without prior written permission of the DOE, incorporate in data delivered under this subcontract any data not first produced in the performance of this subcontract and which contains the copyright notice of 17 U.S.C. 401 and 402, unless the Subcontractor identifies such data and grants to the Government, or acquires on its behalf, a license of the same scope as set forth in subparagraph (1) above; provided, however, that if such data are computer software the Government shall acquire a copyright license as set forth in subparagraph (G)(3) below if included in this subcontract or as otherwise may be provided in a collateral agreement incorporated in or made part of this subcontract.
3. Removal of copyright notices.

The Government agrees not to remove any copyright notices place on data pursuant to this paragraph (C), and to include such notices on all reproductions of the data.

D. Release, publication and use of data.

1. The Subcontractor shall have the right to use, release to others, reproduce, distribute, or publish any data first produced or specifically used by the Subcontractor in the performance of this subcontract, except to the extent such data may be subject to the Federal export control or national security laws or regulations, or unless otherwise provided below in this paragraph or expressly set forth in this subcontract.
2. The Subcontractor agrees that to the extent it receives or is given access to data necessary for the performance of this subcontract which contain restrictive markings, the Subcontractor shall treat the data in accordance with such markings unless otherwise specifically authorized in writing by the DOE.
3. The Subcontractor agrees not to assert copyright in computer software first produced in the performance of this subcontract without prior written permission of the DOE Patent Counsel assisting the subcontracting activity. When such

permission is granted, the Patent Counsel shall specify appropriate terms, conditions, and submission requirements to assure utilization, dissemination, and commercialization of the data. The Subcontractor, when requested, shall promptly deliver to Patent Counsel a duly executed and approved instrument fully confirmatory of all rights to which the Government is entitled.

E. Unauthorized marking of data.

1. Notwithstanding any other provisions of this subcontract concerning inspection or acceptance, if any data delivered under this subcontract are marked with the notices specified in subparagraphs (G)(2) or (G)(3) below and use of such is not authorized by this clause, or if such data bears any other restrictive or limiting markings not authorized by this subcontract, the DOE may at any time either return the data to the Subcontractor, or cancel or ignore the markings. However, the following procedures shall apply prior to canceling or ignoring the markings.
  - (i) The DOE shall make written inquiry to the Subcontractor affording the Subcontractor 30 days from receipt of the inquiry to provide written justification to substantiate the propriety of the markings;
  - (ii) If the Subcontractor fails to respond or fails to provide written justification to substantiate the propriety of the markings within the 30-day period (or a longer time not exceeding 90 days approved in writing by the DOE for good cause shown), the Government shall have the right to cancel or ignore the markings at any time after said period and the data will not longer be made subject to any disclosure prohibitions.
  - (iii) If the Subcontractor provides written justification to substantiate the propriety of the markings within the period set in subdivision (i) above, the DOE shall consider such written justification and determine whether or not the markings are to be canceled or ignore. If the DOE determines that the markings are authorized, the Subcontractor shall be so notified in writing. If the DOE determines, with concurrence of the Head of the Contracting Activity, that the markings are not authorized, the DOE shall furnish the Subcontractor a written determination, which determination shall become the final agency decision regarding the appropriateness of the markings unless the Subcontractor files suit in a court of competent jurisdiction within 90 days of receipt of the DOE's decision. The Government shall continue to abide by the markings under this subdivision (iii) until final resolution of the matter either by the DOE's determination becoming final (in which instance the Government shall thereafter have the right to cancel or ignore the markings at any time and the data will no

longer be made subject to any disclosure prohibitions), or by final disposition of the matter by court decision if suit is filed.

2. The time limits in the procedures set forth in subparagraph (1) above may be modified in accordance with agency regulations implementing the Freedom of Information Act (5 U.S.C. 552) if necessary to respond to a request thereunder.
3. This paragraph (E) does not apply if this subcontract is for a major system or for support of a major system by a civilian agency other than NASA and the U.S. Coast Guard subject to the provisions of Title III of the Federal Property and Administrative Services Act of 1949.
4. Except to the extent the Government's action occurs as the result of final disposition of the matter by a court of competent jurisdiction, the Subcontractor is not precluded by this paragraph (E) from bringing a claim under the Contract Disputes Act, including pursuant to the Disputes clause of this subcontract, as applicable, that may arise as the result of the Government removing or ignoring authorized markings on data delivered under this subcontract.

F. Omitted or incorrect markings.

1. Data delivered to the Government without either the limited rights or restricted rights notice as authorized by paragraph (G) below, or the copyright notice required by paragraph (C) above, shall be deemed to have been furnished with unlimited rights, and the Government assumes no liability for disclosure, use, or reproduction of such data. However, to the extent the data has not been disclosed without restriction outside the Government, the Subcontractor may request, within 6 months (or a longer time approved by the DOE for good cause shown) after delivery of such data, permission to have notices placed on qualifying data at the Subcontractor's expense, and the DOE may agree to do so if the Subcontractor:
  - (i) Identifies the data to which the omitted notice is to be applied;
  - (ii) Demonstrates that the omission of the notice was inadvertent;
  - (iii) Establishes that the use of the proposed notice is authorized; and
  - (iv) Acknowledges that the Government has no liability with respect to the disclosure, use, or reproduction of any such data made prior to the addition of the notice or resulting from the omission of the notice.

2. The DOE may also

- (i) Permit correction at the Subcontractor's expense of incorrect notices if the Subcontractor identifies the data on which correction of the notice is to be made, and demonstrates that the correct notice is authorized, or
- (ii) Correct any incorrect notices.

G. Protection of limited rights data and restricted computer software.

- 1. When data other than that listed in subparagraphs (B)(1)(i), (ii), and (iii) above are specified to be delivered under this subcontract and qualify as either limited rights data or restricted computer software, if the Subcontractor desires to continue protection of such data, the Subcontractor shall withhold such data and not furnish them to the Government under this subcontract. As a condition to this withholding, the Subcontractor shall identify the data being withheld and furnish form, fit, and function data in lieu thereof. Limited rights data that are formatted as a computer data base for delivery to the Government is to be treated as limited rights data and not restricted computer software.
- 2. [Reserved.]
- 3. [Reserved.]

H. Lower-tier subcontracting.

The Subcontractor has the responsibility to obtain from its lower-tier subcontractors all data and rights therein necessary to fulfill the Subcontractor's obligations to the Government under this subcontract. If a lower-tier subcontractor refuses to accept terms affording the Government such rights, the Subcontractor shall promptly bring such refusal to the attention of the DOE and not proceed with lower-tier subcontract award without further authorization.

I. Relationship to patents.

Nothing contained in this clause shall imply a license to the Government under any patent or be construed as affecting the scope of any license or other right otherwise granted to the Government.

J. The Subcontractor agrees, except as may be otherwise specified in this subcontract for specific data items listed as not subject to this paragraph, that the DOE or an authorized representative may, up to three years after acceptance of all items to be delivered under this subcontract, inspect at the Subcontractor's facility any data withheld pursuant to

paragraph (g)(1) above, for purposes of verifying the Subcontractor's assertion pertaining to the limited rights or restricted rights status of the data or for evaluating work performance. Where the Subcontractor whose data are to be inspected demonstrates to the DOE that there would be a possible conflict of interest if the inspection were made by a particular representative, the DOE shall designate an alternate inspector.

### ALTERNATE II

(G)(2) Notwithstanding subparagraph (G)(1) of this clause, the subcontract may identify and specify the delivery of limited rights data, or the DOE may require by written request the delivery of limited rights data that has been withheld or would otherwise be withholdable. If delivery of such data is so required, the Subcontractor may affix the following "Limited Rights Notice" to the data and the Government will thereafter treat the data, subject to the provisions of paragraphs (E) and (F) of this clause, in accordance with such Notice:

#### LIMITED RIGHTS NOTICE (JUN 1987)

- A. These data are submitted with limited rights under Government Subcontract No.(identify the subcontract) (and lower-tier subcontract No. , if appropriate). These data may be reproduced and used by the Government with the express limitation that they will not, without written permission of the Subcontractor, be used for purposes of manufacture nor disclosed outside the Government or NREL; except that the Government may disclose these data outside the Government through NREL for the following purposes, if any, provided that the Government makes such disclosure subject to prohibition against further use and disclosure:

*[Agencies may list additional purposes as set forth in 27.404(d)(1) or if none, so state]*

- B. This Notice shall be marked on any reproduction of these data, in whole or in part.

### ALTERNATE III

(G)(3)(i) Notwithstanding subparagraph (G)(1) of this clause, the subcontract may identify and specify the delivery of restricted computer software, or the Government may require by written request the delivery of restricted computer software that has been withheld or would otherwise be withholdable. If delivery of such computer software is so required, the Subcontractor may affix the following "Restricted Rights Notice" to the computer software and the Government will thereafter treat the computer software, subject to paragraphs (E) and (F) of this clause, in accordance with the Notice:

## RESTRICTED RIGHTS NOTICE (JUN 1987)

- A. This computer software is submitted with restricted rights under Government Subcontract No. (identify the subcontract) (and lower-tier subcontract No. , if appropriate). It may not be used, reproduced, or disclosed by the Government or NREL except as provided in paragraph (B) of this Notice or as otherwise expressly stated in the subcontract.
- B. This computer software may be:
1. Used or copied for use in or with the computer or computers for which it was acquired, including use at any Government installation to which such computer or computers may be transferred;
  2. Used or copied for use in a backup computer if any computer for which it was acquired is inoperative;
  3. Reproduced for safekeeping (archives) or backup purposes;
  4. Modified, adapted, or combined with other computer software, provided that the modified, combined, or adapted portions of the derivative software incorporating restricted computer software are made subject to the same restricted rights;
  5. Disclosed to and reproduced for use by support service Subcontractors in accordance with subparagraphs (B)(1) through (4) of this clause, provided the Government and NREL makes such disclosure or reproduction subject to these restricted rights; and
  6. Used or copied for use in or transferred to a replacement computer.
- C. Notwithstanding the foregoing, if this computer software is published copyrighted computer software, it is licensed to the Government, without disclosure prohibitions, with the minimum rights set forth in paragraph (B) of this clause.
- D. Any others rights or limitations regarding the use, duplication, or disclosure of this computer software are to be expressly stated in, or incorporated in, the subcontract.
- E. This Notice shall be marked on any reproduction of this computer software, in whole or in part.

(G)(3)(ii) Where it is impractical to include the Restricted Rights Notice on restricted computer software, the following short-form Notice may be used in lieu thereof:

**RESTRICTED RIGHTS NOTICE SHORT FORM (JUN 1987)**

Use, reproduction, or disclosure is subject to restrictions set forth in Subcontract No. (identify the subcontract) (and lower-tier subcontract No. , if appropriate) with (name of Subcontractor and lower-tier subcontractor)."

(G)(3)(iii) If restricted computer software is delivered with the copyright notice of 17 U.S.C. 401, it will be presumed to be published copyrighted computer software licensed to the Government without disclosure prohibitions, with the minimum rights set forth in paragraph (b) of this clause, unless the Subcontractor includes the following statement with such copyright notice: "Unpublished-rights reserved under the Copyright Laws of the United States."

**CLAUSE 4 -- ADDITIONAL DATA REQUIREMENTS (JUN 1987)**

*Derived from FAR 52.227-16*

*This clause does not apply to this award if the award is for the conduct of basic or applied research, as set out elsewhere in this award, to be performed solely by a college or university, and the estimated cost is not in excess of \$500,000*

- A. In addition to the data (as defined in the clause at 52.227-14, Rights in Data-General clause or other equivalent included in this subcontract) specified elsewhere in this subcontract to be delivered, the DOE may, at any time during subcontract performance or within a period of 3 years after acceptance of all items to be delivered under this subcontract, order any data first produced or specifically used in the performance of this subcontract.
- B. The Rights in Data-General clause or other equivalent included in this subcontract is applicable to all data ordered under this Additional Data Requirements clause. Nothing contained in this clause shall require the Subcontractor to deliver any data the withholding of which is authorized by the Rights in Data-General or other equivalent clause of this subcontract, or data which are specifically identified in this subcontract as not subject to this clause.
- C. When data are to be delivered under this clause, the Subcontractor will be compensated for converting the data into the prescribed form, for reproduction, and for delivery.
- D. The DOE may release the Subcontractor from the requirements of this clause for specifically identified data items at any time during the 3-year period set forth in paragraph (A) of this clause.

**CLAUSE 5 -- RIGHTS TO PROPOSAL DATA (TECHNICAL) (JUN 1987)**

*Derived from FAR 52.227-23*

*(As prescribed in 27.409(s), the following clause has been completed and inserted in the Schedule of the subcontract:)*

Except for data contained on pages \_\_\_\_\_, it is agreed that as a condition of award of this subcontract, and notwithstanding the conditions of any notice appearing thereon, the Government shall have unlimited rights (as defined in the "Rights in Data--General" clause contained in this subcontract) in and to the technical data contained in the proposal dated \_\_\_\_\_, upon which this subcontract is based.

**CLAUSE 6 -- REFUND OF ROYALTIES (FEB 1995)**

*Derived from DEAR 952.227-9*

- A. The subcontract price includes certain amounts for royalties payable by the Subcontractor or lower-tier subcontractors or both, which amounts have been reported to the DOE through NREL.
- B. The term "royalties," as used in this clause, refers to any costs or charges in the nature of royalties, license fees, patent or license amortization costs, or the like, for the use of or for rights in patents and patent applications in connection with performing this subcontract or any lower-tier subcontract here-under. The term also includes any costs or charges associated with the access to, use of, or other right pertaining to data that is represented to be proprietary and is related to the performance of this subcontract or the copying of such data or data that is copyrighted.
- C. The Subcontractor shall furnish to the DOE through NREL, before final payment under this subcontract, a statement of royalties paid or required to be paid in connection with performing this subcontract and lower-tier subcontracts hereunder together with the reasons.
- D. The Subcontractor will be compensated for royalties reported under paragraph (C) of this clause, only to the extent that such royalties were included in the subcontract price and are determined by the DOE to be properly chargeable to the Government and allocable to the subcontract. To the extent that any royalties that are included in the subcontract price are not, in fact, paid by the Subcontractor or are determined by the DOE not to be properly chargeable to the Government and allocable to the subcontract, the subcontract price shall be reduced. Repayment or credit to the Government shall be made as the DOE directs. The approval by DOE of any individual payments or royalties shall not prevent the Government from contesting at any time the enforceability, validity, scope of, or title to, any patent or the proprietary nature of data pursuant to which a royalty or other payment is to be or has been made.

- E. If, at any time within 3 years after final payment under this subcontract, the Subcontractor for any reason is relieved in whole or in part from the payment of the royalties included in the final subcontract price as adjusted pursuant to paragraph (D) of this clause, the Subcontractor shall promptly notify the DOE of that fact and shall reimburse the Government in a corresponding amount.
- F. The substance of this clause, including this paragraph (F), shall be included in any lower-tier subcontract in which the amount of royalties reported during negotiation of the lower-tier subcontract exceeds \$250.

**CLAUSE 7 -- PATENT RIGHTS-RETENTION BY THE SUBCONTRACTOR  
(SHORT FORM) (FEB 1995)**

*Derived from DEAR 952.227-11*

*This clause applies only if the awardee is a domestic small business or domestic nonprofit organization at the time of award, and the award is for the conduct of research, development, or demonstration*

A. Definitions.

1. "Invention" means any invention or discovery which is or may be patentable or otherwise protectable under title 35 of the United States Code, or any novel variety of plant which is or may be protected under the Plant Variety Protection Act (7 U.S.C. 2321, et seq.).
2. "Made" when used in relation to any invention means the conception or first actual reduction to practice of such invention.
3. "Nonprofit organization" means a university or other institution of higher education or an organization of the type described in section 501(c)(3) of the Internal Revenue Code of 1954 (26 U.S.C. 501(c)) and exempt from taxation under section 501(a) of the Internal Revenue Code (26 U.S.C. 501(a)) or any nonprofit scientific or educational organization qualified under a state nonprofit organization statute.
4. "Practical application" means to manufacture, in the case of a composition or product; to practice, in the case of a process or method; or to operate, in the case of a machine or system; and, in each case, under such conditions as to establish that the invention is being utilized and that its benefits are, to the extent permitted by law or Government regulations, available to the public on reasonable terms.
5. "Small business firm" means a small business concern as defined at section 2 of Pub. L. 85-536 (15 U.S.C. 632) and implementing regulations of the

Administrator of the Small Business Administration. For the purpose of this clause, the size standards for small business concerns involved in Government procurement and subcontracting at 13 CFR 121.3-8 and 13 CFR 121.3-12, respectively, will be used.

6. "Subject Invention" means any invention of the Subcontractor conceived or first actually reduced to practice in the performance of work under this subcontract, provided that in the case of a variety of plant, the date of determination (as defined in section 41(d) of the Plant Variety Protection Act, 7 U.S.C. 2401(d)) must also occur during the period of subcontract performance.
7. "Agency licensing regulations" and "agency regulations concerning the licensing of Government-owned inventions" mean the Department of Energy patent licensing regulations at 10 CFR Part 781.

B. Allocation of principal rights.

The Subcontractor may retain the entire right, title, and interest throughout the world to each Subject Invention subject to the provisions of this clause and 35 U.S.C. 203. With respect to any Subject Invention in which the Subcontractor retains title, the Federal Government shall have a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States the Subject Invention throughout the world.

C. Invention disclosure, election of title, and filing of patent application by Subcontractor.

1. The Subcontractor will disclose each Subject Invention to the Department of Energy (DOE) within 2 months after the inventor discloses it in writing to Subcontractor personnel responsible for patent matters. The disclosure to DOE shall be in the form of a written report and shall identify the subcontract under which the invention was made and the inventor(s). It shall be sufficiently complete in technical detail to convey a clear understanding to the extent known at the time of the disclosure, of the nature, purpose, operation, and the physical, chemical, biological or electrical characteristics of the invention. The disclosure shall also identify any publication, on sale or public use of the invention and whether a manuscript describing the invention has been submitted for publication and, if so, whether it has been accepted for publication at the time of disclosure. In addition, after disclosure to the DOE, the Subcontractor will promptly notify that agency of the acceptance of any manuscript describing the invention for publication or of any on sale or public use planned by the Subcontractor.
2. The Subcontractor will elect in writing whether or not to retain title to any such invention by notifying DOE within 2 years of disclosure to DOE. However, in any

case where publication, on sale, or public use has initiated the 1-year statutory period wherein valid patent protection can still be obtained in the United States, the period for election of title may be shortened by DOE to a date that is no more than 60 days prior to the end of the statutory period.

3. The Subcontractor will file its initial patent application on a Subject Invention to which it elects to retain title within 1 year after election of title or, if earlier, prior to the end of any statutory period wherein valid patent protection can be obtained in the United States after a publication, on sale, or public use. The Subcontractor will file patent applications in additional countries or international patent offices within either 10 months of the corresponding initial patent application or 6 months from the date permission is granted by the Commissioner of Patents and Trademarks to file foreign patent applications where such filing has been prohibited by a Secrecy Order.
4. Requests for extension of the time for disclosure, election, and filing under subparagraphs (C)(1), (2), and (3) of this clause may, at the discretion of the agency, be granted.

D. Conditions when the Government may obtain title.

The Subcontractor will convey to the Federal agency, upon written request, title to any Subject Invention--

1. If the Subcontractor fails to disclose or elect title to the Subject Invention within the times specified in paragraph (C) of this clause, or elects not to retain title; provided, that DOE may only request title within 60 days after learning of the failure of the Subcontractor to disclose or elect within the specified times.
2. In those countries in which the Subcontractor fails to file patent applications within the times specified in paragraph (C) of this clause; provided, however, that if the Subcontractor has filed a patent application in a country after the times specified in paragraph (C) of this clause, but prior to its receipt of the written request of the Federal agency, the Subcontractor shall continue to retain title in that country.
3. In any country in which the Subcontractor decides not to continue the prosecution of any application for, to pay the maintenance fees on, or defend in reexamination or opposition proceeding on, a patent on a Subject Invention.

E. Minimum rights to Subcontractor and protection of the Subcontractor right to file.

1. The Subcontractor will retain a nonexclusive royalty-free license throughout the world in each Subject Invention to which the Government obtains title, except if the Subcontractor fails to disclose the invention within the times specified in paragraph (C) of this clause. The Subcontractor's license extends to its domestic subsidiary and affiliates, if any, within the corporate structure of which the Subcontractor is a party and includes the right to grant sublicenses of the same scope to the extent the Subcontractor was legally obligated to do so at the time the subcontract was awarded. The license is transferable only with the approval of the Federal agency, except when transferred to the successor of that part of the Subcontractor's business to which the invention pertains.
2. The Subcontractor's domestic license may be revoked or modified by DOE to the extent necessary to achieve expeditious practical application of Subject Invention pursuant to an application for an exclusive license submitted in accordance with applicable provisions at 37 CFR Part 404 and agency licensing regulations. This license will not be revoked in that field of use or the geographical areas in which the Subcontractor has achieved practical application and continues to make the benefits of the invention reasonably accessible to the public. The license in any foreign country may be revoked or modified at the discretion of DOE to the extent the Subcontractor, its licensees, or the domestic subsidiaries or affiliates have failed to achieve practical application in that foreign country.
3. Before revocation or modification of the license, DOE will furnish the Subcontractor a written notice of its intention to revoke or modify the license, and the Subcontractor will be allowed 30 days (or such other time as may be authorized by DOE for good cause shown by the Subcontractor) after the notice to show cause why the license should not be revoked or modified. The Subcontractor has the right to appeal, in accordance with applicable regulations in 37 CFR Part 404 and agency regulations concerning the licensing of Government owned inventions, any decision concerning the revocation or modification of the license.

F. Subcontractor action to protect the Government's interest.

1. The Subcontractor agrees to execute or to have executed and promptly deliver to DOE all instruments necessary to--
  - (i) Establish or confirm the rights the Government has throughout the world in those Subject Inventions to which the Subcontractor elects to retain title, and

- (ii) Convey title to DOE when requested under paragraph (D) of this clause and to enable the Government to obtain patent protection throughout the world in that Subject Invention.
2. The Subcontractor agrees to require, by written agreement, its employees, other than clerical and nontechnical employees, to disclose promptly in writing to personnel identified as responsible for the administration of patent matters and in a format suggested by the Subcontractor each Subject Invention made under subcontract in order that the Subcontractor can comply with the disclosure provisions of paragraph (C) of this clause, and to execute all papers necessary to file patent applications on Subject Inventions and to establish the Government's rights in the Subject Inventions. This disclosure format should require, as a minimum, the information required by subparagraph (C)(1) of this clause. The Subcontractor shall instruct such employees, through employee agreements or other suitable educational programs, on the importance of reporting inventions in sufficient time to permit the filing of patent applications prior to U.S. or foreign statutory bars.
3. The Subcontractor will notify DOE of any decision not to continue the prosecution of a patent application, pay maintenance fees, or defend in a reexamination or opposition proceeding on a patent, in any country, not less than 30 days before the expiration of the response period required by the relevant patent office.
4. The Subcontractor agrees to include, within the specification of any United States patent application and any patent issuing thereon covering a Subject Invention, the following statement, "This invention was made with Government support under (identify the subcontract) awarded by the United States Department of Energy. The Government has certain rights in the invention."

G. Lower-tier Subcontracts.

1. The Subcontractor will include this clause, suitably modified to identify the parties, in all subcontracts, regardless of tier, for experimental, developmental, or research work to be performed by a small business firm or domestic nonprofit organization. The lower-tier subcontractor will retain all rights provided for the Subcontractor in this clause, and the Subcontractor will not, as part of the consideration for awarding the lower-tier subcontract, obtain rights in the lower-tier subcontractor's Subject Inventions.
2. The Subcontractor shall include in all other subcontracts, regardless of tier, for experimental, developmental, demonstration, or research work the patent rights clause at 952.227-13.

3. In the case of subcontracts, at any tier, DOE, lower-tier subcontractor, and the Subcontractor agree that the mutual obligations of the parties created by this clause constitute a subcontract between the lower-tier subcontractor and DOE with respect to the matters covered by the clause; provided, however, that nothing in this paragraph is intended to confer any jurisdiction under the Contract Disputes Act in connection with proceedings under paragraph (J) of this clause.

H. Reporting on utilization of Subject Inventions.

The Subcontractor agrees to submit, on request, periodic reports no more frequently than annually on the utilization of a Subject Invention or on efforts at obtaining such utilization that are being made by the Subcontractor or its licensees or assignees. Such reports shall include information regarding the status of development, date of first commercial sale or use, gross royalties received, by the Subcontractor, and such other data and information as DOE may reasonably specify. The Subcontractor also agrees to provide additional reports as may be requested by DOE in connection with any march-in proceeding undertaken by that agency in accordance with paragraph (J) of this clause. As required by 35 U.S.C. 202(c)(5), DOE agrees it will not disclose such information to persons outside the Government without permission of the Subcontractor.

I. Preference for United States industry.

Notwithstanding any other provision of this clause, the Subcontractor agrees that neither it nor any assignee will grant to any person the exclusive right to use or sell any Subject Invention in the United States unless such person agrees that any product embodying the Subject Invention or produced through the use of the Subject Invention will be manufactured substantially in the United States. However, in individual cases, the requirement for such an agreement may be waived by DOE upon a showing by the Subcontractor or its assignee that reasonable but unsuccessful efforts have been made to grant licenses on similar terms to potential licensees that would be likely to manufacture substantially in the United States or that under the circumstances domestic manufacture is not commercially feasible.

J. March-in rights.

The Subcontractor agrees that, with respect to any Subject Invention in which it has acquired title, DOE has the right in accordance with the procedures in 37 CFR 401.6 and any supplemental regulations of the agency to require the Subcontractor, an assignee or exclusive licensee of a Subject Invention to grant a nonexclusive, partially exclusive, or exclusive license in any field of use to a responsible applicant or applicants, upon terms that are reasonable under the circumstances, and, if the Subcontractor, assignee, or exclusive licensee refuses such a request, DOE has the right to grant such a license itself if DOE determines that--

1. Such action is necessary because the Subcontractor or assignee has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the Subject Invention in such field of use;
2. Such action is necessary to alleviate health or safety needs which are not reasonably satisfied by the Subcontractor, assignee, or their licensees;
3. Such action is necessary to meet requirements for public use specified by Federal regulations and such requirements are not reasonably satisfied by the Subcontractor, assignee, or licensees; or
4. Such action is necessary because the agreement required by paragraph (I) of this clause has not been obtained or waived or because a licensee of the exclusive right to use or sell any Subject Invention in the United States is in breach of such agreement.

K. Special provisions for subcontracts with nonprofit organizations.

If the Subcontractor is a nonprofit organization, it agrees that--

1. Rights to a Subject Invention in the United States may not be assigned without the approval of the Federal agency, except where such assignment is made to an organization which has as one of its primary functions the management of inventions; provided, that such assignee will be subject to the same provisions as the Subcontractor;
2. The Subcontractor will share royalties collected on a Subject Invention with the inventor, including Federal employee co-inventors (when DOE deems it appropriate) when the Subject Invention is assigned in accordance with 35 U.S.C. 202(e) and 37 CFR 401.10;
3. The balance of any royalties or income earned by the Subcontractor with respect to Subject Inventions, after payment of expenses (including payments to inventors) incidental to the administration of Subject Inventions will be utilized for the support of scientific research or education; and
4. It will make efforts that are reasonable under the circumstances to attract licensees of Subject Inventions that are small business firms, and that it will give a preference to a small business firm when licensing a Subject Invention if the Subcontractor determines that the small business firm has a plan or proposal for marketing the invention which, if executed, is equally as likely to bring the invention to practical application as any plans or proposals from applicants that are not small business firms; provided, that the Subcontractor is also satisfied that

the small business firm has the capability and resources to carry out its plan or proposal. The decision whether to give a preference in any specific case will be at the discretion of the Subcontractor. However, the Subcontractor agrees that the Secretary of Commerce may review the Subcontractor's licensing program and decisions regarding small business applicants, and the Subcontractor will negotiate changes to its licensing policies, procedures, or practices with the Secretary of Commerce when that Secretary's review discloses that the Subcontractor could take reasonable steps to more effectively implement the requirements of this subparagraph (K)(4).

L. Communications.

1. The Subcontractor shall direct any notification, disclosure, or request to DOE provided for in this clause to the DOE Patent Counsel assisting the DOE subcontracting activity, with a copy of the communication to the DOE Contracting Officer through NREL.
2. Each exercise of discretion or decision provided for in this clause, except subparagraph (K)(4), is reserved for the DOE Patent Counsel and is not a claim or dispute and is not subject to the Contract Disputes Act of 1978.
3. Upon request of the DOE Patent Counsel or the DOE, the Subcontractor shall provide any or all of the following:
  - (i) A copy of the patent application, filing date, serial number and title, patent number, and issue date for any Subject Invention in any country in which the Subcontractor has applied for a patent;
  - (ii) A report, not more often than annually, summarizing all Subject Inventions which were disclosed to DOE individually during the reporting period specified; or
  - (iii) A report, prior to closeout of the subcontract, listing all Subject Inventions or stating that there were none.

**ATTACHMENT 1**  
**(For Reference)**

**PATENT RIGHTS-ACQUISITION BY THE GOVERNMENT (FEB 1995)**  
*Derived from DEAR 952.227-13*

*The clause applies unless the awardee is a domestic small business or domestic nonprofit organization at the time of award, and the award is for the conduct of research, development or demonstration*

As prescribed at 927.303(c), insert the following clause:

A. Definitions.

1. "Invention," as used in this clause, means any invention or discovery which is or may be patentable or otherwise protectable under title 35 of the United States Code or any novel variety of plant that is or may be protectable under the Plant Variety Protection Act (7 U.S.C. 2321, et seq.).
2. "Practical application," as used in this clause, means to manufacture, in the case of a composition or product; to practice, in the case of a process or method; or to operate, in the case of a machine or system; and, in each case, under such conditions as to establish that the invention is being utilized and that its benefits are, to the extent permitted by law or Government regulations, available to the public on reasonable terms.
3. "Subject Invention," as used in this clause, means any invention of the Subcontractor conceived or first actually reduced to practice in the course of or under this subcontract.
4. "Patent Counsel," as used in this clause, means the Department of Energy Patent Counsel assisting the procuring activity.
5. "DOE patent waiver regulations," as used in this clause, means the Department of Energy patent waiver regulations at 41 CFR 9-9.109-6 or successor regulations. See 10 CFR part 784.
6. "Agency licensing regulations" and "applicable agency licensing regulations," as used in this clause, mean the Department of Energy patent licensing regulations at 10 CFR Part 781.

B. Allocations of principal rights.

1. Assignment to the Government.

The Subcontractor agrees to assign to the Government the entire right, title, and interest throughout the world in and to each Subject Invention, except to the extent that rights are retained by the Subcontractor under subparagraph (B)(2) and paragraph (D) of this clause.

2. Greater rights determinations.

- (i) The Subcontractor, or an employee-inventor after consultation with the Subcontractor, may request greater rights than the nonexclusive license and the foreign patent rights provided in paragraph (D) of this clause on identified inventions in accordance with the DOE patent waiver regulations. A request for a determination of whether the Subcontractor or the employee-inventor is entitled to acquire such greater rights must be submitted to the Patent Counsel with a copy to the DOE through NREL at the time of the first disclosure of the invention pursuant to subparagraph (E)(2) of this clause, or not later than 8 months thereafter, unless a longer period is authorized in writing by the DOE for good cause shown in writing by the Subcontractor. Each determination of greater rights under this subcontract shall be subject to paragraph (C) of this clause, unless otherwise provided in the greater rights determination, and to the reservations and conditions deemed to be appropriate by the Secretary of Energy or designee.
- (ii) Within two (2) months after the filing of a patent application, the Subcontractor shall provide the filing date, serial number and title, a copy of the patent application (including an English-language version if filed in a language other than English), and, promptly upon issuance of a patent, provide the patent number and issue date for any Subject Invention in any country for which the Subcontractor has been granted title or the right to file and prosecute on behalf of the United States by the Department of Energy.
- (iii) Not less than thirty (30) days before the expiration of the response period for any action required by the Patent and Trademark Office, notify the Patent Counsel of any decision not to continue prosecution of the application.
- (iv) Upon request, the Subcontractor shall furnish the Government an irrevocable power to inspect and make copies of the patent application file.

C. Minimum rights acquired by the Government.

1. With respect to each Subject Invention to which the Department of Energy grants the Subcontractor principal or exclusive rights, the Subcontractor agrees as follows:
  - (i) The Subcontractor hereby grants to the Government a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced each Subject Invention throughout the world by or on behalf of the Government of the United States (including any Government agency).
  - (ii) The Subcontractor agrees that with respect to any Subject Invention in which DOE has granted it title, DOE has the right in accordance with the procedures in the DOE patent waiver regulations (10 CFR part 784) to require the Subcontractor, an assignee, or exclusive licensee of a Subject Invention to grant a nonexclusive, partially exclusive, or exclusive license in any field of use to a responsible applicant or applicants, upon terms that are reasonable under the circumstances, and if the Subcontractor, assignee, or exclusive licensee refuses such a request, DOE has the right to grant such a license itself if it determines that--
    - a. Such action is necessary because the Subcontractor or assignee has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the Subject Invention in such field of use;
    - b. Such action is necessary to alleviate health or safety needs which are not reasonably satisfied by the Subcontractor, assignee, or their licensees;
    - c. Such action is necessary to meet requirements for public use specified by Federal regulations and such requirements are not reasonably satisfied by the Subcontractor, assignee, or licensees; or
    - d. Such action is necessary because the agreement required by paragraph (I) of this clause has neither been obtained nor waived or because a licensee of the exclusive right to use or sell any Subject Invention in the United States is in breach of such agreement.
  - (iii) The Subcontractor agrees to submit on request periodic reports no more frequently than annually on the utilization of a Subject Invention or on efforts at obtaining such utilization of a Subject Invention or on efforts at obtaining such utilization that are being made by the Subcontractor or its

licensees or assignees. Such reports shall include information regarding the status of development, date of first commercial sale or use, gross royalties received by the Subcontractor, and such other data and information as DOE may reasonably specify. The Subcontractor also agrees to provide additional reports as may be requested by DOE in connection with any march-in proceedings undertaken by that agency in accordance with subparagraph (C)(1)(ii) of this clause. To the extent data or information supplied under this section is considered by the Subcontractor, its licensee, or assignee to be privileged and confidential and is so marked, the Department of Energy agrees that, to the extent permitted by law, it will not disclose such information to persons outside the Government or NREL.

- (iv) The Subcontractor agrees, when licensing a Subject Invention, to arrange to avoid royalty charges on acquisitions involving Government funds, including funds derived through a Military Assistance Program of the Government or otherwise derived through the Government, to refund any amounts received as royalty charges on a Subject Invention in acquisitions for, or on behalf of, the Government, and to provide for such refund in any instrument transferring rights in the invention to any party.
- (v) The Subcontractor agrees to provide for the Government's paid-up license pursuant to subparagraph (C)(1)(i) of this clause in any instrument transferring rights in a Subject Invention and to provide for the granting of licenses as required by subparagraph (C)(1)(ii) of this clause, and for the reporting of utilization information as required by subparagraph (C)(1)(iii) of this clause, whenever the instrument transfers principal or exclusive rights in a Subject Invention.

- 2. Nothing contained in this paragraph (C) shall be deemed to grant to the Government any rights with respect to any invention other than a Subject Invention.

D. Minimum rights to the Subcontractor.

- 1. The Subcontractor is hereby granted a revocable, nonexclusive, royalty-free license in each patent application filed in any country on a Subject Invention and any resulting patent in which the Government obtains title, unless the Subcontractor fails to disclose the Subject Invention within the times specified in subparagraph (E)(2) of this clause. The Subcontractor's license extends to its domestic subsidiaries and affiliates, if any, within the corporate structure of which the Subcontractor is a part and includes the right to grant sublicenses of the same scope to the extent the Subcontractor was legally obligated to do so at the time the

subcontract was awarded. The license is transferable only with the approval of DOE except when transferred to the successor of that part of the Subcontractor's business to which the invention pertains.

2. The Subcontractor's domestic license may be revoked or modified by DOE to the extent necessary to achieve expeditious practical application of the Subject Invention pursuant to an application for an exclusive license submitted in accordance with applicable provisions in 37 CFR Part 404 and agency licensing regulations. This license will not be revoked in that field of use or the geographical areas in which the Subcontractor has achieved practical applications and continues to make the benefits of the invention reasonably accessible to the public. The license in any foreign country may be revoked or modified at the discretion of DOE to the extent the Subcontractor, its licensees, or its domestic subsidiaries or affiliates have failed to achieve practical application in that foreign country.
3. Before revocation or modification of the license, DOE will furnish the Subcontractor a written notice of its intention to revoke or modify the license, and the Subcontractor will be allowed 30 days (or such other time as may be authorized by DOE for good cause shown by the Subcontractor) after the notice to show cause why the license should not be revoked or modified. The Subcontractor has the right to appeal, in accordance with applicable agency licensing regulations and 37 CFR Part 404 concerning the licensing of Government-owned inventions, any decision concerning the revocation or modification of its license.
4. The Subcontractor may request the right to acquire patent rights to a Subject Invention in any foreign country where the Government has elected not to secure such rights, subject to the conditions in subparagraphs (D)(4)(i) through (D)(4)(vii) of this clause. Such request must be made in writing to the Patent Counsel as part of the disclosure required by subparagraph (E)(2) of this clause, with a copy to the DOE Contracting Officer. DOE approval, if given, will be based on a determination that this would best serve the national interest.
  - (i) The recipient of such rights, when specifically requested by DOE, and three years after issuance of a foreign patent disclosing the Subject Invention, shall furnish DOE a report stating:
    - a. The commercial use that is being made, or is intended to be made, of said invention, and
    - b. The steps taken to bring the invention to the point of practical application or to make the invention available for licensing.

- (ii) The Government shall retain at least an irrevocable, nonexclusive, paid-up license to make, use, and sell the invention throughout the world by or on behalf of the Government (including any Government agency) and States and domestic municipal governments, unless the Secretary of Energy or designee determines that it would not be in the public interest to acquire the license for the States and domestic municipal governments.
- (iii) If noted elsewhere in this subcontract as a condition of the grant of an advance waiver of the Government's title to inventions under this subcontract, or, if no advance waiver was granted but a waiver of the Government's title to an identified invention is granted pursuant to subparagraph (B)(2) of this clause upon a determination by the Secretary of Energy that it is in the Government's best interest, this license shall include the right of the Government to sublicense foreign governments pursuant to any existing or future treaty or agreement with such foreign governments.
- (iv) Subject to the rights granted in subparagraphs (D)(1), (2), and (3) of this clause, the Secretary of Energy or designee shall have the right to terminate the foreign patent rights granted in this subparagraph (D)(4) in whole or in part unless the recipient of such rights demonstrates to the satisfaction of the Secretary of Energy or designee that effective steps necessary to accomplish substantial utilization of the invention have been taken or within a reasonable time will be taken.
- (v) Subject to the rights granted in subparagraphs (D)(1), (2), and (3) of this clause, the Secretary of Energy or designee shall have the right, commencing four years after foreign patent rights are accorded under this subparagraph (D)(4), to require the granting of a nonexclusive or partially exclusive license to a responsible applicant or applicants, upon terms reasonable under the circumstances, and in appropriate circumstances to terminate said foreign patent rights in whole or in part, following a hearing upon notice thereof to the public, upon a petition by an interested person justifying such hearing:
  - a. If the Secretary of Energy or designee determines, upon review of such material as he deems relevant, and after the recipient of such rights or other interested person has had the opportunity to provide such relevant and material information as the Secretary or designee may require, that such foreign patent rights have tended substantially to lessen competition or to result in undue market concentration in any section of the United States in any line of commerce to which the technology relates; or

- b. Unless the recipient of such rights demonstrates to the satisfaction of the Secretary of Energy or designee at such hearing that the recipient has taken effective steps, or within a reasonable time thereafter is expected to take such steps, necessary to accomplish substantial utilization of the invention.
- (vi) If the Subcontractor is to file a foreign patent application on a Subject Invention, the Government agrees, upon written request, to use its best efforts to withhold publication of such invention disclosures for such period of time as specified by Patent Counsel, but in no event shall the Government or its employees be liable for any publication thereof.
- (vii) Subject to the license specified in subparagraphs (D)(1), (2), and (3) of this clause, the Subcontractor or inventor agrees to convey to the Government, upon request, the entire right, title, and interest in any foreign country in which the Subcontractor or inventor fails to have a patent application filed in a timely manner or decides not to continue prosecution or to pay any maintenance fees covering the invention. To avoid forfeiture of the patent application or patent, the Subcontractor or inventor shall, not less than 60 days before the expiration period for any action required by any patent office, notify the Patent Counsel of such failure or decision, and deliver to the Patent Counsel, the executed instruments necessary for the conveyance specified in this paragraph.

E. Invention identification, disclosures, and reports.

1. The Subcontractor shall establish and maintain active and effective procedures to assure that Subject Inventions are promptly identified and disclosed to Subcontractor personnel responsible for patent matters within 6 months of conception and/or first actual reduction to practice, whichever occurs first in the performance of work under this subcontract. These procedures shall include the maintenance of laboratory notebooks or equivalent records and other records as are reasonably necessary to document the conception and/or the first actual reduction to practice of Subject Inventions, and records that show that the procedures for identifying and disclosing the inventions are followed. Upon request, the Subcontractor shall furnish the DOE a description of such procedures for evaluation and for determination as to their effectiveness.
2. The Subcontractor shall disclose each Subject Invention to the DOE Patent Counsel with a copy to the DOE Contracting Officer within 2 months after the inventor discloses it in writing to Subcontractor personnel responsible for patent matters or, if earlier, within 6 months after the Subcontractor becomes aware that a Subject Invention has been made, but in any event before any on sale, public

use, or publication of such invention known to the Subcontractor. The disclosure to DOE shall be in the form of a written report and shall identify the subcontract under which the invention was made and the inventor(s). It shall be sufficiently complete in technical detail to convey a clear understanding, to the extent known at the time of the disclosure, of the nature, purpose, operation, and physical, chemical, biological, or electrical characteristics of the invention. The disclosure shall also identify any publication, on sale, or public use of the invention and whether a manuscript describing the invention has been submitted for publication and, if so, whether it has been accepted for publication at the time of disclosure. In addition, after disclosure to DOE, the Subcontractor shall promptly notify Patent Counsel of the acceptance of any manuscript describing the invention for publication or of any on sale or public use planned by the Subcontractor. The report should also include any request for a greater rights determination in accordance with subparagraph (B)(2) of this clause. When an invention is disclosed to DOE under this paragraph, it shall be deemed to have been made in the manner specified in Sections (a)(1) and (a)(2) of 42 U.S.C. 5908, unless the Subcontractor contends in writing at the time the invention is disclosed that it was not so made.

3. The Subcontractor shall furnish the DOE through NREL the following:
  - (i) Interim reports every 12 months (or such longer period as may be specified by the DOE) from the date of the subcontract, listing Subject Inventions during that period, and certifying that all Subject Inventions have been disclosed (or that there are not such inventions) and that the procedures required by subparagraph (E)(1) of this clause have been followed.
  - (ii) A final report, within 3 months after completion of the subcontracted work listing all Subject Inventions or certifying that there were no such inventions, and listing all subcontracts at any tier containing a patent rights clause or certifying that there were no such lower-tier subcontracts.
  
4. The Subcontractor agrees to require, by written agreement, its employees, other than clerical and nontechnical employees, to disclose promptly in writing to personnel identified as responsible for the administration of patent matters and in a format suggested by the Subcontractor each Subject Invention made under subcontract in order that the Subcontractor can comply with the disclosure provisions of paragraph (C) of this clause, and to execute all papers necessary to file patent applications on Subject Inventions and to establish the Government's rights in the Subject Inventions. This disclosure format should require, as a minimum, the information required by subparagraph (E)(2) of this clause.

5. The Subcontractor agrees, subject to FAR 27.302(j), that the Government and NREL may duplicate and disclose Subject Invention disclosures and all other reports and papers furnished or required to be furnished pursuant to this clause.

F. Examination of records relating to inventions.

1. The DOE or any authorized representative shall, until 3 years after final payment under this subcontract, have the right to examine any books (including laboratory notebooks), records, and documents of the Subcontractor relating to the conception or first actual reduction to practice of inventions in the same field of technology as the work under this subcontract to determine whether--
  - (i) Any such inventions are Subject Inventions;
  - (ii) The Subcontractor has established and maintains the procedures required by subparagraphs (E)(1) and (4) of this clause;
  - (iii) The Subcontractor and its inventors have complied with the procedures.
2. If the DOE learns of an unreported Subcontractor invention which the DOE believes may be a Subject Invention, the Subcontractor may be required to disclose the invention to DOE for a determination of ownership rights.
3. Any examination of records under this paragraph will be subject to appropriate conditions to protect the confidentiality of the information involved.

G. Withholding of payment

*(NOTE: This paragraph does not apply to lower-tier subcontracts.)*

1. Any time before final payment under this subcontract, the DOE through NREL may, in the Government's interest, withhold payment until a reserve not exceeding \$50,000 or 5 percent of the amount of this subcontract, whichever is less, shall have been set aside if, in the DOE's opinion, the Subcontractor fails to--
  - (i) Convey to the Government, using a DOE-approved form, the title and/or rights of the Government in each Subject Invention as required by this clause.
  - (ii) Establish, maintain, and follow effective procedures for identifying and disclosing Subject Inventions pursuant to subparagraph (E)(1) of this clause;

- (iii) Disclose any Subject Invention pursuant to subparagraph (E)(2) of this clause;
  - (iv) Deliver acceptable interim reports pursuant to subparagraph (E)(3)(i) of this clause; or
  - (v) Provide the information regarding lower-tier subcontracts pursuant to subparagraph (H)(4) of this clause.
2. Such reserve or balance shall be withheld until the DOE has determined that the Subcontractor has rectified whatever deficiencies exist and has delivered all reports, disclosures, and other information required by this clause.
  3. Final payment under this subcontract shall not be made before the Subcontractor delivers to the DOE all disclosures of Subject Inventions required by subparagraph (E)(2) of this clause, and acceptable final report pursuant to subparagraph (E)(3)(ii) of this clause, and the Patent Counsel has issued a patent clearance certification to the DOE Contracting Officer.
  4. The DOE through NREL may decrease or increase the sums withheld up to the maximum authorized above. No amount shall be withheld under this paragraph while the amount specified by this paragraph is being withheld under other provisions of the subcontract. The withholding of any amount or the subsequent payment thereof shall not be construed as a waiver of any Government rights.

H. Lower-tier Subcontracts.

1. The Subcontractor shall include the clause at 48 CFR 952.227-11 (suitably modified to identify the parties) in all subcontracts, regardless of tier, for experimental, developmental, demonstration, or research work to be performed by a small business firm or domestic nonprofit organization, except where the work of the lower-tier subcontract is subject to an Exceptional Circumstances Determination by DOE. In all other subcontracts, regardless of tier, for experimental, developmental, demonstration, or research work, the Subcontractor shall include this clause (suitably modified to identify the parties). The Subcontractor shall not, as part of the consideration for awarding the lower-tier subcontract, obtain rights in the lower-tier subcontractor's Subject Inventions.
2. In the event of a refusal by a prospective lower-tier subcontractor to accept such a clause the Subcontractor--

- (i) Shall promptly submit a written notice to the DOE through NREL setting forth the lower-tier subcontractor's reasons for such refusal and other pertinent information that may expedite disposition of the matter; and
  - (ii) Shall not proceed with such lower-tier subcontract without the written authorization of the DOE.
3. In the case of subcontracts at any tier, DOE, the lower-tier subcontractor, and Subcontractor agree that the mutual obligations of the parties created by this clause constitute a subcontract between the lower-tier subcontractor and DOE with respect to those matters covered by this clause.
4. The Subcontractor shall promptly notify the DOE through NREL in writing upon the award of any subcontract at any tier containing a patent rights clause by identifying the lower-tier subcontractor, the applicable patent rights clause, the work to be performed under the lower-tier subcontract, and the dates of award and estimated completion. Upon request of the DOE, the Subcontractor shall furnish a copy of such lower-tier subcontract, and, no more frequently than annually, a listing of the lower-tier subcontracts that have been awarded.
5. The Subcontractor shall identify all Subject Inventions of the lower-tier subcontractor of which it acquires knowledge in the performance of this subcontract and shall notify the Patent Counsel, with a copy to the DOE through NREL, promptly upon identification of the inventions.

I. Preference for United States industry.

Unless provided otherwise, no Subcontractor that receives title to any Subject Invention and no assignee of any such Subcontractor shall grant to any person the exclusive right to use or sell any Subject Invention in the United States unless such person agrees that any products embodying the Subject Invention will be manufactured substantially in the United States. However, in individual cases, the requirement may be waived by the Government upon a showing by the Subcontractor or assignee that reasonable but unsuccessful efforts have been made to grant licenses on similar terms to potential licensees that would be likely to manufacture substantially in the United States or that under the circumstances domestic manufacture is not commercially feasible.

J. Atomic energy.

1. No claim for pecuniary award of compensation under the provisions of the Atomic Energy Act of 1954, as amended, shall be asserted with respect to any invention or discovery made or conceived in the course of or under this subcontract.

2. Except as otherwise authorized in writing by the DOE, the Subcontractor will obtain patent agreements to effectuate the provisions of subparagraph (E)(1) of this clause from all persons who perform any part of the work under this subcontract, except nontechnical personnel, such as clerical employees and manual laborers.

K. Background Patents.

1. "Background Patent" means a domestic patent covering an invention or discovery which is not a Subject Invention and which is owned or controlled by the Subcontractor at any time through the completion of this subcontract:
  - (i) Which the Subcontractor, but not the Government, has the right to license to others without obligation to pay royalties thereon, and
  - (ii) Infringement of which cannot reasonably be avoided upon the practice of any specific process, method, machine, manufacture, or composition of matter (including relatively minor modifications thereof) which is a  
  
subject of the research, development, or demonstration work performed under this subcontract.
2. The Subcontractor agrees to and does hereby grant to the Government a royalty-free, nonexclusive license under any Background Patent for purposes of practicing a subject of this subcontract by or for the Government in research, development, and demonstration work only.
3. The Subcontractor also agrees that upon written application by DOE, it will grant to responsible parties, for purposes of practicing a subject of this subcontract, nonexclusive licenses under any Background Patent on terms that are reasonable under the circumstances. If, however, the Subcontractor believes that exclusive rights are necessary to achieve expeditious commercial development or utilization, then a request may be made to DOE for DOE approval of such licensing by the Subcontractor.
4. Notwithstanding subparagraph (K)(3) of this clause, the Subcontractor shall not be obligated to license any Background Patent if the Subcontractor demonstrates to the satisfaction of the Secretary of Energy or designee that:
  - (i) A competitive alternative to the subject matter covered by said Background Patent is commercially available or readily introducible from one or more other sources; or

- (ii) The Subcontractor or its licensees are supplying the subject matter covered by said Background Patent in sufficient quantity and at reasonable prices to satisfy market needs, or have taken effective steps or within a reasonable time are expected to take effective steps to so supply the subject matter.

L. Publication.

It is recognized that during the course of the work under this subcontract, the Subcontractor or its employees may from time to time desire to release or publish information regarding scientific or technical developments conceived or first actually reduced to practice in the course of or under this subcontract. In order that public disclosure of such information will not adversely affect the patent interests of DOE or the Subcontractor, patent approval for release of publication shall be secured from Patent Counsel prior to any such release or publication.

M. Forfeiture of rights in unreported Subject Inventions.

1. The Subcontractor shall forfeit and assign to the Government, at the request of the Secretary of Energy or designee, all rights in any Subject Invention which the Subcontractor fails to report to Patent Counsel within six months after the time the Subcontractor:
  - (i) Files or causes to be filed a United States or foreign patent application thereon; or
  - (ii) Submits the final report required by subparagraph (E)(2)(ii) of this clause, whichever is later.
2. However, the Subcontractor shall not forfeit rights in a Subject Invention if, within the time specified in subparagraph (M)(1) of this clause, the Subcontractor:
  - (i) Prepares a written decision based upon a review of the record that the invention was neither conceived nor first actually reduced to practice in the course of or under the subcontract and delivers the decision to Patent Counsel, with a copy to the DOE through NREL; or
  - (ii) Contending that the invention is not a Subject Invention, the Subcontractor nevertheless discloses the invention and all facts pertinent to this contention to the Patent Counsel, with a copy to the DOE through NREL; or

(iii) Establishes that the failure to disclose did not result from the Subcontractor's fault or negligence.

3. Pending written assignment of the patent application and patents on a Subject Invention determined by the Secretary of Energy or designee to be forfeited (such determination to be a final decision under the Disputes clause of this subcontract), the Subcontractor shall be deemed to hold the invention and the patent applications and patents pertaining thereto in trust for the Government. The forfeiture provision of this paragraph (M) shall be in addition to and shall not supersede other rights and remedies which the Government may have with respect to Subject Inventions.

**APPENDIX D-1**

**CLAUSES FOR SUBCONTRACTS  
IN EXCESS OF \$500,000**

APPENDIX D-1

INDEX

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
1	PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA (OCT 1997) <i>(Derived from FAR 52.215-10)</i> .....	1
2	PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA - MODIFICATIONS (OCT 1997) <i>(Derived from FAR 52.215-11)</i> .....	3
3	LOWER-TIER SUBCONTRACTOR COST OR PRICING DATA (OCT 1997) <i>(Derived from FAR 52.215-12) (FD)</i> .....	5
4	LOWER-TIER SUBCONTRACTOR COST OR PRICING DATA MODIFICATIONS (OCT 1997) <i>(Derived from FAR 52.215-13) (FD)</i> .....	5
5	LOWER-TIER SUBCONTRACTOR'S CERTIFICATE OF CURRENT COST OR PRICING DATA (OCT 1997) <i>(Derived from FAR 15.406-2) (FD)</i> .....	6
6	NOTIFICATION OF OWNERSHIP CHANGES (OCT 1997) <i>(Derived from FAR 52.215-19) (FD)</i> .....	7
7	SMALL BUSINESS SUBCONTRACTING PLAN (OCT 1999) <i>(Derived from FAR 52.219-9) (FD)</i> .....	8
8	COST ACCOUNTING STANDARDS (APR 1998) <i>(Derived from FAR 52.230-2) (FD)</i> .....	14
9	DISCLOSURE AND CONSISTENCY OF COST ACCOUNTING PRACTICES (APR 1998) <i>(Derived from FAR 52.230-3)</i> .....	16

APPENDIX D-1

INDEX

<u>CLAUSE</u>	<u>TITLE</u>	<u>PAGE</u>
10	<b>COST ACCOUNTING STANDARDS -- EDUCATIONAL INSTITUTION (APR 1998)</b> <i>(Derived from FAR 52.230-5) (FD)</i> .....	17
11	<b>ADMINISTRATION OF COST ACCOUNTING STANDARDS (APR 1996)</b> <i>(Derived from FAR 52.230-6) (FD)</i> .....	19

## CLAUSES

### **CLAUSE 1 - PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA (OCT 1997) - *Derived from FAR 52.215-10***

- A. If any price, including profit or fee, negotiated in connection with this subcontract, or any cost reimbursable under this subcontract, was increased by any significant amount because--
1. The Subcontractor or a lower-tier subcontractor furnished cost or pricing data that were not complete, accurate, and current as certified in its Certificate of Current Cost or Pricing Data,
  2. A lower-tier subcontractor or prospective lower-tier subcontractor furnished the Subcontractor cost or pricing data that were not complete, accurate, and current as certified in the Subcontractor's Certificate of Current Cost or Pricing Data, or
  3. Any of these parties furnished data of any description that were not accurate,
- the price or cost shall be reduced accordingly and the subcontract shall be modified to reflect the reduction.
- B. Any reduction in the subcontract price under paragraph (A) of this clause due to defective data from a prospective lower-tier subcontractor that was not subsequently awarded the lower-tier subcontract shall be limited to the amount, plus applicable overhead and profit markup, by which--
1. The actual lower-tier subcontract or
  2. The actual cost to the Subcontractor, if there was no lower-tier subcontract,
- was less than the prospective lower-tier subcontract cost estimate submitted by the Subcontractor; provided, that the actual lower-tier subcontract price was not itself affected by defective cost or pricing data.
- C. 1. If the NREL Subcontract Administrator determines under paragraph (A) of this clause that a price or cost reduction should be made, the Subcontractor agrees not to raise the following matters as a defense:
- (i) The Subcontractor or lower-tier subcontractor was a sole source supplier or otherwise was in a superior bargaining position and thus the price of the subcontract would not have been modified even if accurate, complete, and current cost or pricing data had been submitted.
  - (ii) The NREL Subcontract Administrator should have known that the cost or pricing data in issue were defective even though the Subcontractor or lower-tier subcontractor took

no affirmative action to bring the character of the data to the attention of the NREL Subcontract Administrator.

- (iii) The subcontract was based on an agreement about the total cost of the subcontract and there was no agreement about the cost of each item procured under the subcontract.
  - (iv) The Subcontractor or lower-tier subcontractor did not submit a Certificate of Current Cost or Pricing Data.
2. (i) Except as prohibited by subdivision (C)(2)(ii) of this clause, an offset in an amount determined appropriate by the NREL Subcontract Administrator based upon the facts shall be allowed against the amount of a subcontract price reduction if --
- a. The Subcontractor certifies to the NREL Subcontract Administrator that, to the best of the Subcontractor's knowledge and belief, the Subcontractor is entitled to the offset in the amount requested; and
  - b. The Subcontractor proves that the cost or pricing data were available before the "as of" date specified on the Certificate of Current Cost or Pricing Data, and that the data were not submitted before such date.
- (ii) An offset shall not be allowed if --
- a. The understated data were known by the Subcontractor to be understated before the "as of" date specified on the Certificate of Current Cost or Pricing Data; and
  - b. NREL proves that the facts demonstrate that the subcontract price would not have increased in the amount to be offset even if the available data had been submitted before the "as of" date specified on the Certificate of Current Cost or Pricing Data.
- D. If any reduction in the subcontract price under this clause reduces the price of items for which payment was made prior to the date of the modification reflecting the price reduction, the Subcontractor shall be liable to and shall pay to NREL at the time such overpayment is repaid --
- 1. Simple interest on the amount of such overpayment to be computed from the date(s) of overpayment to the Subcontractor to the date NREL is repaid by the Subcontractor at the applicable underpayment rate effective for each quarter prescribed by the Secretary of the Treasury under 26 U.S.C. 6621 (a)(2), and
  - 2. A penalty equal to the amount of the overpayment, if the Subcontractor or lower-tier subcontractor knowingly submitted cost or pricing data that were incomplete, inaccurate, or noncurrent.

**CLAUSE 2 - PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA -- MODIFICATIONS (OCT 1997)**

*Derived from FAR 52-215-11*

- A. This clause shall become operative only for any modification to this subcontract involving a pricing adjustment expected to exceed the threshold for submission of cost or pricing data at FAR 15.403-4, except that this clause does not apply to any modification if an exception under FAR 15.403-1 applies.
- B. If any price, including profit or fee, negotiated in connection with any modification under this clause, or any cost reimbursable under this subcontract, was increased by any significant amount because
1. The Subcontractor or a lower-tier subcontractor furnished cost or pricing data that were not complete, accurate, and current as certified in its Certificate of Current Cost or Pricing Data,
  2. A lower-tier subcontractor or prospective lower-tier subcontractor furnished the Subcontractor cost or pricing data that were not complete, accurate, and current as certified in the Subcontractor's Certificate of Current Cost or Pricing Data, or
  3. Any of these parties furnished data of any description that were not accurate,
- the price or cost shall be reduced accordingly and the subcontract shall be modified to reflect the reduction. This right to a price reduction is limited to that resulting from defects in data relating to modifications for which this clause becomes operative under paragraph (A) of this clause.
- C. Any reduction in the subcontract price under paragraph (B) of this clause due to defective data from a prospective lower-tier subcontractor that was not subsequently awarded the lower-tier subcontract shall be limited to the amount, plus applicable overhead and profit markup, by which--
1. The actual lower-tier subcontract, or
  2. The actual cost to the Subcontractor, if there was no lower-tier subcontract,
- was less than the prospective lower-tier subcontract cost estimate submitted by the Subcontractor; provided that the actual lower-tier subcontract price was not itself affected by defective cost or pricing data.
- D. 1. If the NREL Subcontract Administrator determines under paragraph (B) of this clause that a price or cost reduction should be made, the Subcontractor agrees not to raise the following matters as a defense:
- (i) The Subcontractor or lower-tier subcontractor was a sole source supplier or otherwise was in a superior bargaining position and thus the price of the subcontract would not have been modified even if accurate, complete, and current cost or pricing data had been submitted.

- (ii) The NREL Subcontract Administrator should have known that the cost or pricing data in issue were defective even though the Subcontractor or lower-tier subcontractor took no affirmative action to bring the character of the data to the attention of the NREL Subcontract Administrator.
  - (iii) The subcontract was based on an agreement about the total cost of the subcontract and there was no agreement about the cost of each item procured under the subcontract.
  - (iv) The Subcontractor or lower-tier subcontractor did not submit a Certificate of Current Cost or Pricing Data.
2. (i) Except as prohibited by subdivision (D)(2)(ii) of this clause, an offset in an amount determined appropriate by the NREL Subcontract Administrator based upon the facts shall be allowed against the amount of a subcontract price reduction if --
- a. The Subcontractor certifies to the NREL Subcontract Administrator that, to the best of the Subcontractor's knowledge and belief, the Subcontractor is entitled to the offset in the amount requested; and
  - b. The Subcontractor proves that the cost or pricing data were available before the "as of" date specified on the Certificate of Current Cost or Pricing Data, and that the data were not submitted before such date.
- (ii) An offset shall not be allowed if --
- a. The understated data were known by the Subcontractor to be understated before the "as of" date specified on the Certificate of current Cost or Pricing Data; and
  - b. NREL proves that the facts demonstrate that the subcontract price would not have increased in the amount to be offset even if the available data had been submitted before the "as of" date specified on the Certificate of Current Cost or Pricing Data.
- E. If any reduction in the subcontract price under this clause reduces the price of items for which payment was made prior to the date of the modification reflecting the price reduction, the Subcontractor shall be liable to and shall pay to NREL at the time such overpayment is repaid --
- 1. Simple interest on the amount of such overpayment to be computed from the date(s) of overpayment to the Subcontractor to the date NREL is repaid by the Subcontractor at the applicable underpayment rate effective for each quarter prescribed by the Secretary of the Treasury under 26 U.S.C. 6621 (a)(2), and
  - 2. A penalty equal to the amount of the overpayment, if the Subcontractor or lower-tier subcontractor knowingly submitted cost or pricing data that were incomplete, inaccurate, or noncurrent.

**CLAUSE 3 - LOWER-TIER SUBCONTRACTOR COST OR PRICING DATA (OCT 1997)**

*Derived from FAR 52.215-12*

- A. Before awarding any lower-tier subcontract expected to exceed the threshold for submission of cost or pricing data at FAR 15.403-4, on the date of agreement on price or the date of award, whichever is later; or before pricing any lower-tier subcontract modification involving a pricing adjustment expected to exceed the threshold for submission of cost or pricing data at FAR 15.403-4, the Subcontractor shall require the lower-tier subcontractor to submit cost or pricing data (actually or by specific identification in writing), unless an exception under FAR 15.403-1 applies.
- B. The Subcontractor shall require the lower-tier subcontractor to certify in substantially the form prescribed in FAR 15.406-2 that, to the best of its knowledge and belief, the data submitted under paragraph (A) of this clause were accurate, complete, and current as of the date of agreement on the negotiated price of the lower-tier subcontract or lower-tier subcontract modification.
- C. In each lower-tier subcontract that exceeds the threshold for submission of cost or pricing data at FAR 15.403-4, when entered into, the Subcontractor shall insert either --
  - 1. The substance of this clause, including this paragraph (C), if paragraph (A) of this clause requires submission of cost or pricing data for the lower-tier subcontract; or
  - 2. The substance of the clause at FAR 52.215-13, Subcontractor Cost or Pricing Data -- Modifications.

**CLAUSE 4 - LOWER-TIER SUBCONTRACTOR COST OR PRICING DATA - MODIFICATIONS (OCT 1997)**

*Derived from FAR 52.215-13*

- A. The requirements of paragraphs (B) and (C) of this clause shall --
  - 1. Become operative only for any modification to this subcontract involving a pricing adjustment expected to exceed the threshold for submission of cost or pricing data at FAR 15.403-4; and
  - 2. Be limited to such modifications.
- B. Before awarding any lower-tier subcontract expected to exceed the threshold for submission of cost or pricing data at FAR 15.403-4, on the date of agreement on price or the date of award, whichever is later; or before pricing any lower-tier subcontract modification involving a pricing adjustment expected to exceed the threshold for submission of cost or pricing data at FAR 15.403-4, the Subcontractor shall require the lower-tier subcontractor to submit cost or pricing data (actually or by specific identification in writing), unless an exception under FAR 15.403-1 applies.
- C. The Subcontractor shall require the lower-tier subcontractor to certify in substantially the form prescribed in FAR 15.406-2 that, to the best of its knowledge and belief, the data submitted under paragraph (B) of this clause were accurate, complete, and current as of the date of agreement on the negotiated price of the lower-tier subcontract or lower-tier subcontract modification.

- D. The Subcontractor shall insert the substance of this clause, including this paragraph (D), in each lower-tier subcontract that exceeds the threshold for submission of cost or pricing data at FAR 15.403-4 on the date of agreement on price or the date of award, whichever is later.

**CLAUSE 5 - LOWER-TIER SUBCONTRACTOR'S CERTIFICATE OF CURRENT COST OR PRICING DATA (OCT 1997)**

*Derived from FAR 15.406-2 (FD)*

- A. When cost or pricing data are required, the Subcontractor shall require the lower-tier subcontractor to execute a Certificate of Current Cost or Pricing Data, using the format in this paragraph, and shall include the executed certificate in the subcontract file.

Lower-tier Subcontractor's Certificate of Current Cost or Pricing Data

This is to certify that, to the best of my knowledge and belief, the cost or pricing data (as defined in section 15.401 of the Federal Acquisition Regulation (FAR) and required under FAR subsection 15.403-4) submitted, either actually or by specific identification in writing, to the Subcontractor or to the Subcontractor's representative in support of \_\_\_\_\* are accurate, complete, and current as of \_\_\_\_\*\*. This certification includes the cost or pricing data supporting any advance agreements and forward pricing rate agreements between the offeror and the Subcontractor that are part of the proposal.

Firm \_\_\_\_\_

Signature \_\_\_\_\_

Name \_\_\_\_\_

Title \_\_\_\_\_

Date of execution\*\*\* \_\_\_\_\_

\* Identify the proposal, request for price adjustment, or other submission involved, giving the appropriate identifying number (e.g., RFP No.).

\*\* Insert the day, month, and year when price negotiations were concluded and price agreement was reached or, if applicable, an earlier date agreed upon between the parties that is as close as practicable to the date of agreement on price.

\*\*\* Insert the day, month, and year of signing, which should be as close as practicable to the date when the price negotiations were concluded and the lower-tier subcontract price was agreed to.

- B. The certificate does not constitute a representation as to the accuracy of the lower-tier subcontractor's judgment on the estimate of future costs or projections. It applies to the data upon which the judgment or estimate was based. This distinction between fact and judgment should be clearly understood. If the lower-tier subcontractor had information reasonably available at the time of agreement showing that the negotiated price was not based on accurate, complete, and current data, the lower-tier

subcontractor's responsibility is not limited by any lack of personal knowledge of the information on the part of its negotiators.

- C. The Subcontractor and lower-tier subcontractor are encouraged to reach a prior agreement on criteria for establishing closing or cutoff dates when appropriate in order to minimize delays associated with proposal updates. Closing or cutoff dates should be included as part of the data submitted with the proposal and, before agreement on price, data should be updated by the lower-tier subcontractor to the latest closing or cutoff dates for which the data are available. Use of cutoff dates coinciding with reports is acceptable, as certain data may not be reasonably available before normal periodic closing dates (e.g., actual indirect costs). Data within the Subcontractor's or a lower-tier subcontractor's organization on matters significant to lower-tier subcontractor management and to the Subcontractor will be treated as reasonably available. What is significant depends upon the circumstances of each acquisition.
- D. Possession of a Certificate of Current Cost or Pricing Data is not a substitute for examining and analyzing the lower-tier subcontractor's proposal.
- E. If cost or pricing data are requested by the Subcontractor and submitted by an offeror, but an exception is later found to apply, the data shall not be considered cost or pricing data and shall not be certified in accordance with this subsection.

**CLAUSE 6 - NOTIFICATION OF OWNERSHIP CHANGES (OCT 1997)**

*Derived from FAR 52.215-19 (FD)*

- A. The Subcontractor shall make the following notifications in writing:
  - 1. When the Subcontractor becomes aware that a change in its ownership has occurred, or is certain to occur, that could result in changes in the valuation of its capitalized assets in the accounting records, the Subcontractor shall notify the NREL Subcontract Administrator within thirty (30) days.
  - 2. The Subcontractor shall also notify the NREL Subcontract Administrator within thirty (30) days whenever changes to asset valuations or any other cost changes have occurred or are certain to occur as a result of a change in ownership.
- B. The Subcontractor shall --
  - 1. Maintain current, accurate, and complete inventory records of assets and their costs;
  - 2. Provide the NREL Subcontract Administrator or designated representative ready access to the records upon request;
  - 3. Ensure that all individual and grouped assets, their capitalized values, accumulated depreciation or amortization, and remaining useful lives are identified accurately before and after each of the Subcontractor's ownership changes; and

4. Retain and continue to maintain depreciation and amortization schedules based on the asset records maintained before each Subcontractor ownership change.
- C. The Subcontractor shall include the substance of this clause in all lower-tier subcontracts under this subcontract that meet the applicability requirement of FAR 15.408(k).

**CLAUSE 7 - SMALL BUSINESS SUBCONTRACTING PLAN (OCT 1999)**

*Derived from FAR 52.219-9*

- A. This clause does not apply to small business concerns.
- B. Definitions. As used in this clause--

"Commercial item" means a product or service that satisfies the definition of commercial item in section 2.101 of the Federal Acquisition Regulation.

"Commercial plan" means a lower-tier subcontracting plan (including goals) that covers the offeror's fiscal year and that applies to the entire production of commercial items sold by either the entire company or a portion thereof (e.g., division, plant, or product line).

"Individual subcontract plan" means a lower-tier subcontracting plan that covers the entire subcontract period (including option periods), applies to a specific subcontract, and has goals that are based on the offeror's planned lower-tier subcontracting in support of the specific subcontract, except that indirect costs incurred for common or joint purposes may be allocated on a prorated basis to the subcontract.

"Master plan" means a lower-tier subcontracting plan that contains all the required elements of an individual subcontract plan, except goals, and may be incorporated into individual plans, provided the master plan has been approved.

"Lower-tier Subcontract" means any agreement (other than one involving an employer-employee relationship) entered into by a subcontractor or or lower-tier subcontractor calling for supplies or services required for performance of the lower-tier subcontract.

- C. The offeror, upon request by the NREL Subcontract Administrator, shall submit and negotiate a lower-tier subcontracting plan, where applicable, that separately addresses lower-tier subcontracting with small business, HUBZone small business concerns, small disadvantaged business, and women-owned small business concerns. If the offeror is submitting an individual lower-tier subcontract plan, the plan must separately address lower-tier subcontracting with small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns, with a separate part for the basic subcontract and separate parts for each option (if any). The plan shall be included in and made a part of the resultant subcontract. The lower-tier subcontracting plan shall be negotiated within the time specified by the NREL

Subcontract Administrator. Failure to submit and negotiate the lower-tier subcontracting plan shall make the offeror ineligible for award of a subcontract.

- D. The offeror's lower-tier subcontracting plan shall include the following:
1. Goals, expressed in terms of percentages of total planned lower-tier subcontracting dollars, for the use of small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns as lower-tier subcontractors. The offeror shall include all lower-tier subcontracts that contribute to subcontract performance, and may include a proportionate share of products and services that are normally allocated as indirect costs.
  2. A statement of--
    - (i) Total dollars planned to be lower-tier subcontracted for an individual subcontract plan; or the offeror's total projected sales, expressed in dollars, and the total value of projected lower-tier subcontracts to support the sales for a commercial plan;
    - (ii) Total dollars planned to be lower-tier subcontracted to small business concerns;
    - (iii) Total dollars planned to be lower-tier subcontracted to HUBZone small business concerns;
    - (iv) Total dollars planned to be lower-tier subcontracted to small disadvantaged business concerns; and
    - (v) Total dollars planned to be lower-tier subcontracted to women-owned small business concerns.
  3. A description of the principal types of supplies and services to be lower-tier subcontracted, and an identification of the types planned for lower-tier subcontracting to--
    - (i) Small business concerns;
    - (ii) HUBZone small business concerns;
    - (iii) Small disadvantaged business concerns; and
    - (iv) Women-owned small business concerns.
  4. A description of the method used to develop the lower-tier subcontracting goals in paragraph (d)(1) of this clause.

5. A description of the method used to identify potential sources for solicitation purposes (e.g., existing company source lists, the Procurement Marketing and Access Network (PRO-Net) of the Small Business Administration (SBA), the National Minority Purchasing Council Vendor Information Service, the Research and Information Division of the Minority Business Development Agency in the Department of Commerce, or small, HUBZone, small disadvantaged, and women-owned small business trade associations). A firm may rely on the information contained in PRO-Net as an accurate representation of a concern's size and ownership characteristics for the purposes of maintaining a small, HUBZone, small disadvantaged and women-owned small business source list. Use of PRO-Net as its source list does not relieve a firm of its responsibilities (e.g., outreach, assistance, counseling, or publicizing lower-tier subcontracting opportunities) in this clause.
6. A statement as to whether or not the offeror included indirect costs in establishing lower-tier subcontracting goals, and a description of the method used to determine the proportionate share of indirect costs to be incurred with--
  - (i) Small business concerns;
  - (ii) HUBZone small business concerns;
  - (iii) Small disadvantaged business concerns; and
  - (iv) Women-owned small business concerns.
7. The name of the individual employed by the offeror who will administer the offeror's lower-tier subcontracting program, and a description of the duties of the individual.
8. A description of the efforts the offeror will make to assure that small business, HUBZone small business, small disadvantaged business and women-owned small business concerns have an equitable opportunity to compete for lower-tier subcontracts.
9. Assurances that the offeror will include the clause of this subcontract entitled "Utilization of Small Business Concerns" in all lower-tier subcontracts that offer further subcontracting opportunities, and that the offeror will require all lower-tier subcontractors (except small business concerns) that receive lower-tier subcontracts in excess of \$500,000 (\$1,000,000 for construction of any public facility) to adopt a subcontracting plan that complies with the requirements of this clause.
11. Assurances that the offeror will--
  - (i) Cooperate in any studies or surveys as may be required;

- (ii) Submit periodic reports so that the Government can determine the extent of compliance by the offeror with the lower-tier subcontracting plan;
  - (iii) Submit Standard Form (SF) 294, Subcontracting Report for Individual Contracts, and/or SF 295, Summary Subcontract Report, in accordance with the instructions on the forms or as provided in agency regulations and in paragraph (j) of this clause; and
  - (iv) Ensure that its lower-tier subcontractors agree to submit SF 294 and SF 295.
11. A description of the types of records that will be maintained concerning procedures that have been adopted to comply with the requirements and goals in the plan, including establishing source lists; and a description of the offeror's efforts to locate small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns and award lower-tier subcontracts to them. The records shall include at least the following (on a plant-wide or company-wide basis, unless otherwise indicated):
- (i) Source lists (e.g., PRO-Net), guides, and other data that identify small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns.
  - (ii) Organizations contacted in an attempt to locate sources that are small business, HUBZone small business, small disadvantaged business, or women-owned small business concerns.
  - (iii) Records on each lower-tier subcontract solicitation resulting in an award of more than \$100,000, indicating--
    - a. Whether small business concerns were solicited and, if not, why not;
    - b. Whether HUBZone small business concerns were solicited and, if not, why not;
    - c. Whether small disadvantaged business concerns were solicited and, if not, why not;
    - d. Whether women-owned small business concerns were solicited and, if not, why not; and
    - e. If applicable, the reason award was not made to a small business concern.

- (iv) Records of any outreach efforts to contact--
  - a. Trade associations;
  - b. Business development organizations; and
  - c. Conferences and trade fairs to locate small, HUBZone small, small disadvantaged, and women-owned small business sources.
- (v) Records of internal guidance and encouragement provided to buyers through--
  - a. Workshops, seminars, training, etc.; and
  - b. Monitoring performance to evaluate compliance with the program's requirements.
- (vi) On a subcontract-by-subcontract basis, records to support award data submitted by the offeror to the Government, including the name, address, and business size of each lower-tier subcontractor. Subcontractors having commercial plans need not comply with this requirement.

E. In order to effectively implement this plan to the extent consistent with efficient subcontract performance, the subcontractor shall perform the following functions:

1. Assist small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns by arranging solicitations, time for the preparation of bids, quantities, specifications, and delivery schedules so as to facilitate the participation by such concerns. Where the subcontractor's lists of potential small business, HUBZone small business, small disadvantaged business, and women-owned small business lower-tier subcontractors are excessively long, reasonable effort shall be made to give all such small business concerns an opportunity to compete over a period of time.
2. Provide adequate and timely consideration of the potentialities of small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns in all "make-or-buy" decisions.
3. Counsel and discuss lower-tier subcontracting opportunities with representatives of small business, HUBZone small business, small disadvantaged business, and women-owned small business firms.
4. Provide notice to lower-tier subcontractors concerning penalties and remedies for misrepresentations of business status as small, HUBZone small, small disadvantaged, or

women-owned small business for the purpose of obtaining a lower-tier subcontract that is to be included as part or all of a goal contained in the subcontractor's lower-tier subcontracting plan.

- F. A master plan on a plant or division-wide basis that contains all the elements required by paragraph (d) of this clause, except goals, may be incorporated by reference as a part of the lower-tier subcontracting plan required of the offeror by this clause; provided--
  - 1. The master plan has been approved;
  - 2. The offeror ensures that the master plan is updated as necessary and provides copies of the approved master plan, including evidence of its approval, to the NREL Subcontract Administrator; and;
  - 3. Goals and any deviations from the master plan deemed necessary by the NREL Subcontract Administrator to satisfy the requirements of this subcontract are set forth in the individual subcontracting plan.
  
- G. A commercial plan is the preferred type of lower-tier subcontracting plan for subcontractors furnishing commercial items. The commercial plan shall relate to the offeror's planned lower-tier subcontracting generally, for both commercial and Government business, rather than solely to the Government subcontract. Commercial plans are also preferred for lower-tier subcontractors that provide commercial items under a prime contract, whether or not the prime subcontractor is supplying a commercial item.
  
- H. Prior compliance of the offeror with other such lower-tier subcontracting plans under previous contracts will be considered by the NREL Subcontract Administrator in determining the responsibility of the offeror for award of the contract.
  
- I. The failure of the subcontractor or lower-tier subcontractor to comply in good faith with--
  - 1. The clause of this subcontract entitled "Utilization Of Small Business Concerns;" or
  - 2. An approved plan required by this clause, shall be a material breach of the subcontract.
  
- J. The subcontractor shall submit the following reports:
  - 1. Standard Form 294, Subcontracting Report for Individual Contracts. This report shall be submitted to the NREL Subcontract Administrator semiannually and at subcontract completion. The report covers lower-tier subcontract award data related to this subcontract. This report is not required for commercial plans.

2. Standard Form 295, Summary Subcontract Report. This report encompasses all the subcontracts with the awarding agency. It must be submitted semi-annually for subcontracts with the Department of Defense and annually for subcontracts with civilian agencies. If the reporting activity is covered by a commercial plan, the reporting activity must report annually all lower-tier subcontract awards under that plan. All reports submitted at the close of each fiscal year (both individual and commercial plans) shall include a breakout, in the subcontractor's format, of lower-tier subcontract awards, in whole dollars, to small disadvantaged business concerns by Standard Industrial Classification (SIC) Major Group. For a commercial plan, the subcontractor may obtain from each of its lower-tier subcontractors a predominant SIC Major Group and report all awards to that lower-tier subcontractor under its predominant SIC Major Group.

(End of clause)

**Alternate I (Jan 1999).**

When subcontracting by sealed bidding rather than by negotiation, substitute the following paragraph C. for paragraph C. of the basic clause:

- C. The apparent low bidder, upon request by the NREL Subcontract Administrator, shall submit a lower-tier subcontracting plan, where applicable, that separately addresses lower-tier subcontracting with small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns. If the bidder is submitting an individual subcontract plan, the plan must separately address lower-tier subcontracting with small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns, with a separate part for the basic contract and separate parts for each option (if any). The plan shall be included in and made a part of the resultant subcontract. The lower-tier subcontracting plan shall be submitted within the time specified by the NREL Subcontract Administrator. Failure to submit the lower-tier subcontracting plan shall make the bidder ineligible for the award of a contract.

**Alternate II (Jan 1999).**

As prescribed in 19.708(b)(1), substitute the following paragraph C. for paragraph C. of the basic clause:

- C. Proposals submitted in response to this solicitation shall include a lower-tier subcontracting plan that separately addresses lower-tier subcontracting with small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns. If the offeror is submitting an individual subcontract plan, the plan must separately address lower-tier subcontracting with small business, HUBZone small business, small disadvantaged business, and women-owned small business concerns, with a separate part for the basic subcontract and separate parts for each option (if any). The plan shall be included in and made a part of the

resultant subcontract. The lower-tier subcontracting plan shall be negotiated within the time specified by the NREL Subcontract Administrator. Failure to submit and negotiate a lower-tier subcontracting plan shall make the offeror ineligible for award of a subcontract.

**CLAUSE 8 - COST ACCOUNTING STANDARDS (APR 1998)**

*Derived from FAR 52.230-2*

**(Generally not applicable for Small Business, Foreign Government, Fixed Price, or Subcontracts under \$500,000)**

- A. Unless the subcontract is exempt under 48 CFR 9903.201-1 and 9903.201-2, the provisions of 48 CFR Part 9903 are incorporated herein by reference and the Subcontractor, in connection with this subcontract, shall --
1. (CAS-covered Contracts Only) By submission of a Disclosure Statement, disclose in writing the Subcontractor's cost accounting practices as required by 48 CFR 9903.202-1 through 9903.202-5, including methods of distinguishing direct costs from indirect costs and the basis used for allocating indirect costs. The practices disclosed for this subcontract shall be the same as the practices currently disclosed and applied on all other subcontracts and lower-tier subcontracts being performed by the Subcontractor and which contain a Cost Accounting Standards (CAS) clause. If the Subcontractor has notified the NREL Subcontract Administrator that the Disclosure Statement contains trade secrets and commercial or financial information which is privileged and confidential, the Disclosure Statement shall be protected and shall not be released outside of NREL/Government.
  2. Follow consistently the Subcontractor's cost accounting practices in accumulating and reporting subcontract performance cost data concerning this subcontract. If any change in cost accounting practices is made for the purposes of any subcontract or lower-tier subcontract subject to CAS requirements, the change must be applied prospectively to this subcontract and the Disclosure Statement must be amended accordingly. If the subcontract price or cost allowance of this subcontract is affected by such changes, adjustment shall be made in accordance with subparagraph (A)(4) or (A)(5) of this clause, as appropriate.
  3. Comply with all CAS, including any modifications and interpretations indicated thereto contained in 48 CFR Part 9904, in effect on the date of award of this subcontract or, if the Subcontractor has submitted cost or pricing data, on the date of final agreement on price as shown on the Subcontractor's signed certificate of current cost or pricing data. The Subcontractor shall also comply with any CAS (or modifications to CAS) which hereafter become applicable to a subcontract or lower-tier subcontract of the Subcontractor. Such compliance shall be required prospectively from the date of applicability to such subcontract or lower-tier subcontract.
  4. (i) Agree to an equitable adjustment as provided in the Changes clause of this subcontract if the subcontract cost is affected by a change which, pursuant to subparagraph (A)(3) of this clause, the Subcontractor is required to make to the Subcontractor's established cost accounting practices.

- (ii) Negotiate with the NREL Subcontract Administrator to determine the terms and conditions under which a change may be made to a cost accounting practice, other than a change made under other provisions of subparagraph (A)(4) of this clause; provided that no agreement may be made under this provision that will increase costs paid by NREL/Government.
  - (iii) When the parties agree to a change to a cost accounting practice, other than a change under subdivision (A)(4)(i) of this clause, negotiate an equitable adjustment as provided in the Changes clause of this subcontract.
5. Agree to an adjustment of the subcontract price or cost allowance, as appropriate, if the Subcontractor or a lower-tier subcontractor fails to comply with an applicable Cost Accounting Standard, or to follow any cost accounting practice consistently and such failure results in any increased costs paid by NREL/Government. Such adjustment shall provide for recovery of the increased costs to NREL/Government, together with interest thereon computed at the annual rate established under section 6621 of the Internal Revenue Code of 1986 (26 U.S.C. 6621) for such period, from the time the payment by the NREL/Government was made to the time the adjustment is effected. In no case shall NREL/Government recover costs greater than the increased cost to NREL/Government, in the aggregate, on the relevant subcontracts subject to the price adjustment, unless the Subcontractor made a change in its cost accounting practices of which it was aware or should have been aware at the time of price negotiations and which it failed to disclose to NREL/Government.
- B. If the parties fail to agree whether the Subcontractor or a lower-tier subcontractor has complied with an applicable CAS in 48 CFR 9904 or a CAS rule or regulation in 48 CFR 9903 and as to any cost adjustment demanded by NREL/Government, such failure to agree will constitute a dispute under the Disputes Clause of this subcontract.
  - C. The Subcontractor shall permit any authorized representatives of NREL/Government to examine and make copies of any documents, papers, or records relating to compliance with the requirements of this clause.
  - D. The Subcontractor shall include in all negotiated lower-tier subcontracts which the Subcontractor enters into, the substance of this clause, except paragraph (B), and shall require such inclusion in all other subcontracts, of any tier, including the obligation to comply with all CAS in effect on the lower-tier subcontractor's award date or if the lower-tier subcontractor has submitted cost or pricing data, on the date of final agreement on price as shown on the lower-tier subcontractor's signed Certificate of Current Cost or Pricing Data. If the lower-tier subcontract is awarded to a business unit which pursuant to 48 CFR 9903.201-2 is subject to other types of CAS coverage, the substance of the applicable clause set forth in subsection 30.201-4 of the Federal Acquisition Regulation shall be inserted. This requirement shall apply only to negotiated lower-tier subcontracts in excess of \$500,000, except that the requirement shall not apply to negotiated lower-tier subcontracts otherwise exempt from the requirement to include a CAS clause as specified in 48 CFR 9903.201-1.

**CLAUSE 9 - DISCLOSURE AND CONSISTENCY OF COST ACCOUNTING PRACTICES  
(APR 1998)**

*Derived from FAR 52.230-3*

- A. The Subcontractor, in connection with this subcontract, shall --
1. Comply with the requirements of 48 CFR 9904.401, Consistency in Estimating, Accumulating, and Reporting Costs; 48 CFR 9904.402, Consistency in Allocating Costs Incurred for the Same Purpose; 48 CFR 9904.405, Accounting for Unallowable Costs; and 48 CFR 9904.406, Cost Accounting Standard -- Cost Accounting Period, in effect on the date of award of this subcontract as indicated in 48 CFR Part 9904.
  2. (CAS-covered Contracts Only) If it is a business unit of a company required to submit a Disclosure Statement, disclose in writing its cost accounting practices as required by 48 CFR 9903.202-1 through 9903.202-5. If the Subcontractor has notified the NREL Subcontract Administrator that the Disclosure Statement contains trade secrets and commercial or financial information which is privileged and confidential, the Disclosure Statement shall be protected and shall not be released outside of the NREL/Government.
  3.
    - (i) Follow consistently the Subcontractor's cost accounting practices. A change to such practices may be proposed, however, by either the NREL/Government or the Subcontractor, and the Subcontractor agrees to negotiate with the NREL Subcontract Administrator the terms and conditions under which a change may be made. After the terms and conditions under which the change is to be made have been agreed to, the change must be applied prospectively to this subcontract, and the Disclosure Statement, if affected, must be amended accordingly.
    - (ii) The Subcontractor shall, when the parties agree to a change to a cost accounting practice and the NREL Subcontract Administrator has made the finding required in 48 CFR 9903.201-6(b), that the change is desirable and not detrimental to the interests of the NREL/Government, negotiate an equitable adjustment as provided in the Changes clause of this subcontract. In the absence of the required finding, no agreement may be made under this subcontract clause that will increase costs paid by NREL/Government.
  4. Agree to an adjustment of the subcontract price or cost allowance, as appropriate, if the Subcontractor or a lower-tier subcontractor fails to comply with the applicable CAS or to follow any cost accounting practice, and such failure results in any increased costs paid by NREL/Government. Such adjustment shall provide for recovery of the increased costs to NREL/Government together with interest thereon computed at the annual rate of interest established under the Internal Revenue Code of 1986 (26 U.S.C. 6621), from the time the payment by NREL/Government States was made to the time the adjustment is effected.
- B. If the parties fail to agree whether the Subcontractor has complied with an applicable CAS, rule, or regulation as specified in 48 CFR 9903 and 9904 and as to any cost adjustment demanded by NREL/Government, such failure to agree will constitute a dispute under the Contract Disputes Clause of this subcontract.
- C. The Subcontractor shall permit any authorized representatives of the NREL/Government to examine and make copies of any documents, papers, and records relating to compliance with the requirements of this clause.

- D. The Subcontractor shall include in all negotiated lower-tier subcontracts, which the Subcontractor enters into, the substance of this clause, except paragraph (B), and shall require such inclusion in all other subcontracts of any tier, except that --
1. If the lower-tier subcontract is awarded to a business unit which pursuant to 48 CFR 9903.201-2 is subject to other types of CAS coverage, the substance of the applicable clause set forth in subsection 30.201-4 of the Federal Acquisition Regulation shall be inserted.
  2. This requirement shall apply only to negotiated lower-tier subcontracts in excess of \$500,000.
  3. The requirement shall not apply to negotiated lower-tier subcontracts otherwise exempt from the requirement to include a CAS clause as specified in 48 CFR 9903.201-1.

**CLAUSE 10 - COST ACCOUNTING STANDARDS - EDUCATIONAL INSTITUTION (APR 1998)**  
*Derived from FAR 52.230-5 (FD)*

- A. Unless the subcontract is exempt under 48 CFR 9903.201-1 and 9903.201-2, the provisions of 48 CFR 9903 are incorporated herein by reference and the Subcontractor, in connection with this subcontract, shall --
1. (CAS-covered Subcontracts Only). If a business unit of an educational institution is required to submit a Disclosure Statement, disclose in writing the Subcontractor's cost accounting practices as required by 48 CFR 9903.202-1 through 9903.202-5, including methods of distinguishing direct costs from indirect costs and the basis used for accumulating and allocating indirect costs. The practices disclosed for this subcontract shall be the same as the practices currently disclosed and applied on all other subcontracts and lower-tier subcontracts being performed by the Subcontractor and which contain a Cost Accounting Standards (CAS) clause. If the Subcontractor has notified the NREL Subcontract Administrator that the Disclosure Statement contains trade secrets, and commercial or financial information which is privileged and confidential, the Disclosure Statement shall be protected and shall not be released outside of NREL/Government.
  2. Follow consistently the Subcontractor's cost accounting practices in accumulating and reporting subcontract performance cost data concerning this subcontract. If any change in cost accounting practices is made for the purposes of any subcontract or lower-tier subcontract subject to CAS requirements, the change must be applied prospectively to this subcontract and the Disclosure Statement, if required, must be amended accordingly. If an accounting principle change mandated under Office of Management and Budget (OMB) Circular A-21, Cost Principles for Educational Institutions, requires that a change in the Subcontractor's cost accounting practices be made after the date of this subcontract award, the change must be applied prospectively to this subcontract and the Disclosure Statement, if required, must be amended accordingly. If the subcontract price or cost allowance of this subcontract is affected by such changes, adjustment shall be made in accordance with subparagraph (A)(4) or (A)(5) of this clause, as appropriate.
  3. Comply with all CAS, including any modifications and interpretations indicated thereto contained in 48 CFR 9905 in effect on the date of award of this subcontract or, if the Subcontractor has submitted cost or pricing data, on the date of final agreement on price as

shown on the Subcontractor's signed certificate of current cost or pricing data. The Subcontractor shall also comply with any CAS (or modifications to CAS) which hereafter become applicable to a subcontract or lower-tier subcontract of the Subcontractor. Such compliance shall be required prospectively from the date of applicability to such subcontract or lower-tier subcontract.

4. (i) Agree to an equitable adjustment as provided in the Changes clause of this subcontract if the subcontract cost is affected by a change which, pursuant to subparagraph (A)(3) of this clause, the Subcontractor is required to make to the Subcontractor's established cost accounting practices.
  - (ii) Negotiate with the NREL Subcontract Administrator to determine the terms and conditions under which a change may be made to a cost accounting practice, other than a change made under other provisions of subparagraph (A)(4) of this clause; provided that no agreement may be made under this provision that will increase costs paid by NREL/Government.
  - (iii) When the parties agree to a change to a cost accounting practice, other than a change under subdivision (A)(4)(i), or (A)(4)(iv) of this clause, negotiate an equitable adjustment as provided in the Changes clause of this subcontract.
  - (iv) Agree to an equitable adjustment as provided in the Changes clause of this subcontract, if the subcontract cost is materially affected by an OMB Circular A-21 accounting principle amendment which, on becoming effective after the date of subcontract award, requires the Subcontractor to make a change to the Subcontractor's established cost accounting practices.
5. Agree to an adjustment of the subcontract price or cost allowance, as appropriate, if the Subcontractor or a lower-tier subcontractor fails to comply with an applicable Cost Accounting Standard, or to follow any cost accounting practice consistently and such failure results in any increased costs paid by NREL/Government. Such adjustment shall provide for recovery of the increased costs to NREL/Government, together with interest thereon computed at the annual rate established under section 6621 of the Internal Revenue Code of 1986 (26 U.S.C. 6621) for such period, from the time the payment by NREL/Government was made to the time the adjustment is effected. In no case shall NREL/Government recover costs greater than the increased cost to NREL/Government, in the aggregate, on the relevant subcontract subject to the price adjustment, unless the Subcontractor made a change in its cost accounting practices of which it was aware or should have been aware at the time of price negotiations and which it failed to disclose to NREL/Government.
- B. If the parties fail to agree whether the Subcontractor or a lower-tier subcontractor has complied with an applicable CAS or a CAS rule or regulation in 48 CFR 9903 and as to any cost adjustment demanded by NREL/Government, such failure to agree will constitute a dispute under the Contract Disputes Clause of this subcontract.

- C. The Subcontractor shall permit any authorized representatives of NREL/Government to examine and make copies of any documents, papers, or records relating to compliance with the requirements of this clause.
- D. The Subcontractor shall include in all negotiated lower-tier subcontracts which the Subcontractor enters into, the substance of this clause, except paragraph (B), and shall require such inclusion in all other subcontracts, of any tier, including the obligation to comply with all applicable CAS in effect on the lower-tier subcontractor's award date or, if the lower-tier subcontractor has submitted cost or pricing data, on the date of final agreement on price as shown on the lower-tier subcontractor's signed Certificate of Current Cost or Pricing Data, except that --
  - 1. If the lower-tier subcontract is awarded to a business unit which pursuant to 48 CFR 9903.201-2 is subject to other types of CAS coverage, the substance of the applicable clause set forth in 48 CFR 9903.201-4 shall be inserted;
  - 2. This requirement shall apply only to negotiated lower-tier subcontracts in excess of \$500,000; and
  - 3. The requirement shall not apply to negotiated lower-tier subcontracts otherwise exempt from the requirement to include a CAS clause as specified in 48 CFR 9903.201-1.

**CLAUSE 11 - ADMINISTRATION OF COST ACCOUNTING STANDARDS (APR 1996)**

*Derived from FAR 52.230-6 (FD)*

For the purpose of administering the Cost Accounting Standards (CAS) requirements under this subcontract, the Subcontractor shall take the steps outlined in paragraphs (A) through (G) of this clause:

- A. Submit to the NREL Subcontract Administrator a description of any cost accounting practice change, the total potential impact of the change on subcontracts containing a CAS clause, and a general dollar magnitude of the change which identifies the potential shift of costs between CAS-covered subcontracts by subcontract type (i.e., firm-fixed-price, incentive, cost-plus-fixed fee, etc.) and other Subcontractor business activity. As related to CAS-covered subcontracts, the analysis should identify the potential impact on funds of the various Agencies/Departments (i.e., Department of Energy, National Aeronautics and Space Administration, Army, Navy, Air Force, other Department of Defense, other Government) as follows:
  - 1. For any change in cost accounting practices required in accordance with subparagraph (A)(3) and subdivision (A)(4)(i) of the clause at FAR 52.230-2, Cost Accounting Standards; or subparagraph (A)(3) and subdivisions (A)(4)(i) or (A)(4)(iv) of the clause at FAR 52.230-5, Cost Accounting Standards -- Educational Institution; within sixty (60) days (or such other date as may be mutually agreed to) after award of a subcontract requiring this change.
  - 2. For any change in cost accounting practices proposed in accordance with subdivision (A)(4)(ii) or (iii) of the clauses at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost

Accounting Standards -- Educational Institution; or with subparagraph (A)(3) of the clause at FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices, not less than 60 days (or such other date as may be mutually agreed to) before the effective date of the proposed change.

3. For any failure to comply with an applicable CAS or to follow a disclosed practice (as contemplated by subparagraph (A)(5) at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost Accounting Standards -- Educational Institution; or by subparagraph (A)(4) at FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices):

- (i) Within sixty (60) days (or such other date as may be mutually agreed to) after the date of agreement with the initial finding of noncompliance, or
- (ii) In the event of Subcontractor disagreement with the initial finding of noncompliance, within sixty (60) days of the date the Subcontractor is notified by the NREL Subcontract Administrator of the determination of noncompliance.

B. After an NREL Subcontract Administrator, or cognizant Federal agency official, determination of materiality, submit a cost impact proposal in the form and manner specified by the NREL Subcontract Administrator within sixty (60) days (or such other date as may be mutually agreed to) after the date of determination of the adequacy and compliance of a change submitted pursuant to paragraph (A) of this clause. The cost impact proposal shall be in sufficient detail to permit evaluation, determination, and negotiation of the cost impact upon each separate CAS-covered subcontract and lower-tier subcontract.

1. Cost impact proposals submitted for changes in cost accounting practices required in accordance with subparagraph (A)(3) and subdivision (A)(4)(i) of the clause at FAR 52.230-2, Cost Accounting Standards; or subparagraph (A)(3) and subdivisions (A)(4)(i) or (A)(4)(iv) of the clause at FAR 52.230-5, Cost Accounting Standards -- Educational Institution; shall identify the applicable standard or cost principle and all subcontracts and lower-tier subcontracts containing the clauses entitled Cost Accounting Standards or Cost Accounting Standards -- Educational Institution, which have an award date before the effective date of that standard or cost principle.
2. Cost impact proposals submitted for any change in cost accounting practices proposed in accordance with subdivisions (A)(4)(ii) or (iii) of the clauses at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost Accounting Standards -- Educational Institution; or with subparagraph (A)(3) of the clause at FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices; shall identify all subcontracts and lower-tier subcontracts containing the clauses at FAR 52.230-2, Cost Accounting Standards, FAR 52.230-5, Cost Accounting Standards -- Educational Institution, and FAR 52.230-3, Disclosure and Consistency of Cost Accounting Practices.
3. Cost impact proposals submitted for failure to comply with an applicable CAS or to follow a disclosed practice as contemplated by subparagraph (A)(5) of the clauses at FAR 52.230-2, Cost Accounting Standards, and FAR 52.230-5, Cost Accounting Standards -- Educational Institution; or by subparagraph (A)(4) of the clause at FAR 52.230-3, Disclosure and Consistency of Cost

Accounting Practices, shall identify the cost impact on each separate CAS covered subcontract from the date of failure to comply until the noncompliance is corrected.

- C. If the submissions required by paragraphs (A) and (B) of this clause are not submitted within the specified time, or any extension granted by the NREL Subcontract Administrator, an amount not to exceed ten (10) percent of each subsequent amount determined payable related to the Subcontractor's CAS-covered prime subcontracts, up to the estimated general dollar magnitude of the cost impact, may be withheld until such time as the required submission has been provided in the form and manner specified by the NREL Subcontract Administrator.
- D. Agree to appropriate subcontract and lower-tier subcontract amendments to reflect adjustments established in accordance with subparagraphs (A)(4) and (A)(5) of the clauses at FAR 52.230-2 and 52.230-5; or with subparagraphs (A)(3) or (A)(4) of the Disclosure and Consistency of Cost Accounting Practices clause at FAR 52.230-3.
- E. For all lower-tier subcontracts subject to the clauses at FAR 52.230-2, 52.230-3, or 52.230-5 --
  - 1. So state in the body of the lower-tier subcontract, in the letter of award, or in both (self-deleting clauses shall not be used); and
  - 2. Include the substance of this clause in all negotiated subcontracts. In addition, within thirty (30) days after award of the lower-tier subcontract, submit the following information to the Subcontractor's cognizant subcontract administration office for transmittal to the subcontract administrative office cognizant of the lower-tier subcontractor's facility:
    - (i) Lower-tier Subcontractor's name and lower-tier subcontract number.
    - (ii) Dollar amount and date of award.
    - (iii) Name of Subcontractor making the award.
    - (iv) Any changes the lower-tier subcontractor has made or proposes to make to cost accounting practices that affect prime subcontracts or lower-tier subcontracts containing the clauses at FAR 52.230-2, 52.230-3, or 52.230-5, unless these changes have already been reported. If award of the lower-tier subcontract results in making one or more CAS effective for the first time, this fact shall also be reported.
- F. Notify the NREL Subcontract Administrator in writing of any adjustments required to lower-tier subcontracts under this subcontract and agree to an adjustment, based on them, to this subcontract price or estimated cost and fee. This notice is due within thirty (30) days after proposed lower-tier subcontract adjustments are received and shall include a proposal for adjusting the higher-tier subcontract or the prime contract appropriately.
- G. For lower-tier subcontracts containing the clauses at FAR 52.230-2 or 52.230-5, require the lower-tier subcontractor to comply with all Standards in effect on the date of award or of final agreement on price, as shown on the lower-tier subcontractor's signed Certificate of Current Cost or Pricing Data, whichever is earlier.

**MODIFICATION NO. 1  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	NREL'S <u>COST SHARE</u>	SUBCONTRACTOR'S <u>COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
TOTAL:	\$2,998,203.00	\$2,998,203.00	\$5,996,406.00

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

<b>FUNDED AMOUNT AND TASK CHARGE NUMBER:</b>	LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
	DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
	MOD. 1:	<u>\$ 500,000.00</u> - PVP26282
	TOTAL:	\$1,500,000.00

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraphs D and E, the Subcontractor is hereby authorized to proceed with Phase II under Definitized Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraphs D and E are hereby modified as follows:
  - a. Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs for a portion of the work under this subcontract by "\$500,000.00" from "\$1,000,000.00" to "\$1,500,000.00". It is estimated that the allotted amount will cover work under this subcontract through 09/30/03.
  - b. Paragraph E is hereby deleted in its entirety and replaced with the following:

"E. The Subcontractor is authorized by NREL's execution of this subcontract modification to perform that portion of Phase I and Phase II work for which funds have been allotted in Paragraph D above."
2. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: *Christie Johnson*  
TITLE: *Jr. Contract Administrator*  
DATE: *01/24/03*

**MODIFICATION NO. 2  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	NREL'S <u>COST SHARE</u>	SUBCONTRACTOR'S <u>COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
TOTAL:	\$2,998,203.00	\$2,998,203.00	\$5,996,406.00

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

<b>FUNDED AMOUNT AND TASK CHARGE NUMBER:</b>	LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
	DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
	MOD. 1:	\$ 500,000.00 - PVP36282
	MOD. 2:	<u>\$ 80,000.00 - PVP36282</u>
	TOTAL:	\$1,580,000.00

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to continue the Phase II work effort under Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs under this subcontract by "\$80,000.00" from "\$1,500,000.00" to "\$1,580,000.00". It is estimated that the allotted amount will cover work under this subcontract through 11/30/03.
2. Appendix A, Statement of Work, dated September 18, 2002 is hereby deleted in its entirety and replaced with the attached Appendix A-1, Statement of Work, dated August 19, 2003". The new Appendix A-1 reflects changes to the work effort as described under Phase II, Task 14.
3. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY:

TITLE:

DATE:

*Robert Johnson*  
*Sr. Contract Administrator*  
*09/12/03*

**Appendix A-1**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module Manufacturing  
of String Ribbon Si PV Modules**  
ZDO-2-30628-09  
August 19, 2003

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, EVERGREEN will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 -1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. EVERGREEN will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of EVERGREEN's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. EVERGREEN shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, EVERGREEN shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. EVERGREEN shall design and develop a prototype machine to apply wrap-around decals. They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the

quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. EVERGREEN shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Scale-Up Of A Production Worthy Doping Method**

EVERGREEN shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

EVERGREEN shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

EVERGREEN shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

EVERGREEN shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cell

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

EVERGREEN shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

EVERGREEN shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

EVERGREEN shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

EVERGREEN shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

EVERGREEN shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected

to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II**

During Phase II, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

EVERGREEN shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

EVERGREEN shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

EVERGREEN shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

EVERGREEN shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Implementation of Multiple Ribbon Growth**

During Phase I of this program, project Gemini was launched and pilot production initiated. Gemini allows for the growth of two ribbons from a single crucible and represents an opportunity to lower significantly many of the costs of producing a ribbon substrate. In Phase II, the pilot line will continue and expand to the point where a significant fraction of the Subcontractor's crystal growth machines will be Gemini machines. In addition, during Phase II, considerable R&D work will continue on improvements in the hot zone to increase production metrics such as yield and uptime. Also, in-line diagnostics will be continually upgraded to assist in reaching the production goals. Given the successful implementation of Gemini, the next platform for multiple ribbon growth – Quad – the growth of four ribbons from a single crucible- will be investigated with a view to bringing it to the stage of pre-implementation into production. This would not occur before the third year of this project, i.e. Phase 3.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

EVERGREEN shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

EVERGREEN shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a

suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

EVERGREEN shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

EVERGREEN shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or minus 0.005".

### **3.19 Task 19 In-Line Diagnostics-2**

EVERGREEN shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSView into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

## **PHASE III**

During Phase III, EVERGREEN shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on wrap-around cells leading to 14% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall also design and develop an improved small high voltage module, debug, test, and fine-tune module manufacturing equipment used for frameless, monolithic modules, debug, test, and fine-tune a robotic pick and place machine for automated monolithic module layout,

and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. And finally Evergreen shall demonstrate their state of the art manufacturing capability to make monolithic modules. EVERGREEN shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

EVERGREEN shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14% Efficient Wrap-around Contact Cells**

EVERGREEN shall combine advances made in Tasks 12 and 20 to routinely make 14% cells. To accomplish this task, Evergreen shall make cells utilizing the advances developed during Phase II to produce cells on production-worthy equipment developed for performing tasks 12 and 20. This task is expected to result in 14% wrap-around contact cells.

### **3.22 Task 22 Fine-Tune And Test Wrap-around Decal Application Machine**

EVERGREEN shall demonstrate, fine-tune, and test a production worthy wrap-around decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their wrap-around decal application machine at high volume. This task is expected to result in a complete debugging of their wrap-around decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Design And Develop An Improved Small, High Voltage Module**

EVERGREEN shall design and develop a high voltage small monolithic module suitable for automated production. To accomplish this task, Evergreen shall demonstrate the viability of laser cutting large wrap-around cells into smaller wrap-around cells, demonstrate adequate reliability for these smaller cells, and show automation capability for finishing the small high-voltage module. This task is expected to result in the demonstration of a manufacturing process capable of producing a high voltage, small module product.

### **3.24 Task 24 Debug And Test Module Manufacturing Equipment Used To Produce Frameless, Monolithic Modules**

EVERGREEN shall develop, debug, and test production size module manufacturing equipment used to produce frameless, monolithic modules. Evergreen shall demonstrate production worthy speed (time to form a completed module) and quality with a yield of 99%. This task is expected to result in demonstration of speed, quality, and yield for the processes and equipment developed in Tasks 15, 16, and 17.

### **3.25 Task 25 Develop, Debug, And Test Robotic Pick And Place Machine**

EVERGREEN shall develop, debug, and test the robotic pick and place machine designed in task 18. Evergreen shall demonstrate positional accuracy estimated to be plus or minus 0.005" or as determined from additional tests with actual equipment. This task is expected to result in a robotic pick and place machine satisfying manufacturing requirements

### **3.26 Task 26 In Line Diagnostics-3**

EVERGREEN shall continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. To accomplish this task, Evergreen shall bring together the inputs from RSView on all the machines used to make frameless and monolithic modules and integrate these inputs into a real-time response system for machine control. This task is expected to result in in-line diagnostics for real time control for frameless and monolithic module manufacturing.

### **3.27 Task 27 Demonstrate State Of The Art Si Ribbon Manufacturing Capability To Make Monolithic Modules**

EVERGREEN shall demonstrate the automated production of monolithic modules through the delivery of test results from the manufacturing line based on process improvements developed in the subcontract. The test shall be an actual run and the goal shall be a 99% yield from a run of 100 consecutive modules. This task is expected to result in a demonstration of the production of a frameless, monolithic module produced from highly automated, cost-effective high yield string ribbon Si manufacturing equipment and provide NREL data to characterize the improvements made by Evergreen under this subcontract.

## **4.0 PROGRAM PLAN**

The subcontracted research shall be conducted at EVERGREEN. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by EVERGREEN according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. EVERGREEN shall perform these tasks according to the following phased schedules:

##### PHASE I

EVERGREEN shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	X	X	X	X	X				
Task 2	X	X	X	X					
Task 3	X	X	X	X	X	X	∇		
Task 4									
Task 5	X	X	X	X	X	X	∇		
Task 6	X	X	X	X	X	X			
Task 7	X	X	X	X	X	X	∇		
Task 8	X	X	X	X	X	X	∇		
Task 9	X	X	X	X	X	X	∇		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

EVERGREEN shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 11	X	X	X	X	X	X								
Task 12						X	X	X	X	X	X	∇		
Task 13	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 14	X	X	X	X	X	X	X	X	X	X	X			
Task 15			X	X	X	X	X	X	X	X	X			
Task 16					X	X	X	X	X	X	X	∇		
Task 17						X	X	X	X	X	X			
Task 18				X	X	X	X	X	X					
Task 19							X	X	X	X	X	∇		
Monthly Reports	15th													
Annual Report												draft 15th		final 30th

**Phase III**

EVERGREEN shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 20							X	X	X	X	X	∇		
Task 21										X	X	∇		
Task 22	X	X	X	X	X	X	X	X	X	X	X	∇		
Task 23			X	X	X	X	X	X						
Task 24			X	X	X	X	X	X	X	X	X	∇		
Task 25	X	X	X	X	X	X								
Task 26									X	X	X	∇		
Task 27									X	X	X	∇		
Monthly Reports		15th												
Annual Report												draft 15th		Final 30th

*Final*

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. EVERGREEN shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

### Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

### Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

## **PHASE II**

### Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	(Task 11)
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	(Task 11)
m-2.1.3	Production-worthy decal application machine designed	(Task 13)
m-2.1.5	Identify method to modify backskin for higher impermeability	(Task 15)
m-2.1.6	Complete Gemini hot zone redesign and order parts	(Task 14)
m-2.1.7	14% cells on Gemini ribbon	(Task 14)

### Milestones due no later than September 30, 2003

m-2.2.1	Establish hot zone redesign	(Task 10)
m-2.2.2	Demonstrate growth of oxide free ribbon	(Task 11)
m-2.2.4	Develop method to modify backskin	(Task 15)
m-2.2.5	Complete design of backskin modification machine	(Task 16)
m-2.2.6	Complete identification of pick and place robot	(Task 18)
m-2.2.7	Complete testing of redesigned hot zone	(Task 14)
m-2.2.8	Gemini yield and uptimes equivalent to single ribbon	(Task 14)

### Milestones due no later than December 31, 2003

m-2.3.1	Complete design and implementation of vibration damping	(Task 10)
m-2.3.2	Complete design and deployment of boat for double sided passivation	(Task 12)
m-2.3.3	Demonstrate adequate firing through of Al paste	(Task 12)
m-2.3.4	Decal application machine developed and tested	(Task 13)
m-2.3.6	Identify method to form backskin edge	(Task 15)
m-2.3.7	Complete development of backskin modification machine	(Task 16)
m-2.3.8	Decision on monolithic module manufacturing method	(Task 17)
m-2.3.9	Complete design of pick and place machine	(Task 18)
m-2.3.10	Complete design for automatic bulk resistivity measurement	(Task 19)
m-2.3.11	Complete tests on elimination of inside surface oxide stripe	(Task 14)
m-2.3.12	Demonstrate reduced variation in front to back thickness	(Task 14)
m-2.3.13	Installation and running of full cluster of 20 retrofit machines	(Task 14)

### Milestones due no later than March 31, 2004

m-2.4.1	Complete dislocation maps	(Task 10)
m-2.4.2	Demonstrate fabrication of 13% cells	(Task 12)
m-2.4.3	Establish data processing for decal application machine	(Task 13)
m-2.4.4	Develop method to form backskin edge	(Task 15)
m-2.4.5	Complete design of machine to form sealed leads	(Task 16)
m-2.4.6	Complete development of machine to form sealed leads	(Task 16)
m-2.4.7	Complete development of monolithic module manufacturing method	(Task 17)

- m-2.4.8 Complete development of automatic bulk resistivity measurement (Task 19)
- m-2.4.9 Complete incorporation of RS View in module machine designs (Task 19)
- m-2.4.10 Installation and running of 100 new Gemini machines (Task 14)
- m-2.4.11 In-line diagnostics implemented on all Gemini machines (Task 14)

### PHASE III

#### Milestones due no later than June 30, 2004

- m-3.1.1 Complete debug of robotic pick and place machine (Task 25)

#### Milestones due no later than September 30, 2004

- m-3.2.1 Complete debug of wrap-around decal application machine (Task 22)
- m-3.2.2 Demonstrate viability of laser cutting small cells from large cells (Task 23)
- m-3.2.3 Complete running of robotic pick and place machine (Task 25)
- m-3.2.4 Complete demonstration of positional accuracy and repeatability (Task 25)

#### Milestones due no later than December 31, 2004

- m-3.3.1 Demonstrate impurity reduction on production machine (Task 20)
- m-3.3.2 Demonstrate dislocation reduction on production machine (Task 20)
- m-3.3.3 Complete reliability studies on high-voltage small modules (Task 23)
- m-3.3.4 Complete automation for high-voltage small modules (Task 23)
- m-3.3.5 Complete speed and quality demonstration for manufacture of frameless, monolithic module (Task 24)

#### Milestones due no later than March 31, 2005

- m-3.4.1 Demonstrate starting lifetimes of 5 to >10 microseconds (Task 20)
- m-3.4.2 Advances made in Tasks 12 and 20 brought together (Task 21)
- m-3.4.3 Demonstrate 14% wrap-around contact cells (Task 21)
- m-3.4.4 Complete testing of wrap-around decal application machine (Task 22)
- m-3.4.5 Complete yield demonstration for manufacture of frameless, monolithic module (Task 24)
- m-3.4.6 Complete development of RS View on all automated machines for modules (Task 26)
- m-3.4.7 Complete integration of all inputs into a central collection point (Task 26)
- m-3.4.8 Complete demonstration of manufacturing capability (Task 27)
- m-3.4.9 Demonstrate capability to make 100 modules at a yield 99% (Task 27)

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

EVERGREEN shall prepare and submit reports and deliverables in accordance with the following Sections. EVERGREEN shall also supply NREL with samples of EVERGREEN cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, EVERGREEN shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. EVERGREEN shall provide deliverables according to the following schedule:

#### PHASE I

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant. (Task 1)	2	October 31, 2002
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2. (Task 1)	1	October 31, 2002
D-1.1.3	Report on a suitable solvent drying procedure. (Task 1)		October 31, 2002
D-1.1.4	Report on suitable transport of doped feedstock in feeder. (Task 1)		October 31, 2002
D-1.1.5	Report on chemical and optical characterization of surface oxide. (Task 2)		October 31, 2002
D-1.1.6	Report on feasibility of a simple optical method for oxide determination. (Task 2)		October 31, 2002
D-1.1.7	Ribbon sample grown without any surface oxide. (Task 2)	1	October 31, 2002
D-1.1.8	Report describing concept for prototype decal application machine. (Task 6)		October 31, 2002
D-1.1.9	Report describing design for prototype machine. (Task 6)		October 31, 2002
D-1.1.10	Example of thinner backskin sheets. (Task 8)		October 31, 2002
D-1.2.1	Report on installation of mixing equipment. (Task 1)		October 31, 2002

D-1.2.2	One sample of 3" wide doped ribbon. (Task 1)	1	October 31, 2002
D-1.2.3	Two 12% cells made with feedstock doped with new doping process. (Task 1)	2	October 31, 2002
D-1.2.4	Report on finger cross section through screen-printing. (Task 5)		October 31, 2002
D-1.2.5	Report on decision to study alternative printing methods. (Task 5)		October 31, 2002
D-1.2.6	Report on dielectric layers selected. (Task 5)		October 31, 2002
D-1.2.7	Report on development and testing of prototype machine. (Task 6)		October 31, 2002
D-1.2.8	One cell from prototype machine. (Task 6)	1	October 31, 2002
D-1.2.9	Example of cross-linked thinner backskin . (Task 8)		October 31, 2002
D-1.2.10	Report on ink choice. (Task 9)		October 31, 2002
D-1.2.11	One sample of printed conductive material on backskin. (Task 9)		October 31, 2002
D-1.3.1	Report on coating with reduced permeability. (Task 3)		January 31, 2003
D-1.3.2	Report on establishment of network for new crystal growth machines. (Task 7)		January 31, 2003
D-1.3.3	Report on resistivity and laser cutting data added to the network. (Task 7)		January 31, 2003
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests. (Task 8)		January 31, 2003
D-1.3.5	One backskin sample. (Task 8)	1	January 31, 2003
D-1.3.6	Report on performance under thermal cycling and humidity freeze. (Task 9)		January 31, 2003
D-1.3.7	Report on completed accelerated tests. (Task 9)		January 31, 2003
D-1.4.1	Report on tests of improved purification graphite parts. (Task 3)		March 31, 2003
D-1.4.2	Report on novel hot zone parts' configurations. (Task 3)		March 31, 2003
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3.		March 31, 2003

	(Task 3)		
D-1.4.4	One >15% R&D cell. (Task 3)	1	March 31, 2003
D-1.4.5	Report on optimization of plasma nitride process. (Task 4)		March 31, 2003
D-1.4.6	Report on optimization of metallization firing process. (Task 4)		March 31, 2003
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data. (Task 4)	1	March 31, 2003
D-1.4.8	Report on reduced series and shunt resistance. (Task 5)		March 31, 2003
D-1.4.9	One cell demonstrating device improvements due to contact improvements. (Task 5)	1	March 31, 2003
D-1.4.10	Report on real time process monitoring using SPC charts. (Task 7)		March 31, 2003
D-1.4.11	One sample of printed conductive material on backskin. (Task 9)	1	March 31, 2003

## PHASE II

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-2.1.1	Report on reduced oxygen in hot zone. (Task 11)		June 30, 2003
D-2.1.2	Report on design for alternate method to introduce Ar. (Task 11)		June 30, 2003
D-2.1.3	Report on design of production-worthy decal application machine. (Task 13)		June 30, 2003
D-2.1.5	Report on choice of method to modify backskin. (Task 15)		June 30, 2003
D-2.1.6	Report on Gemini hot zone redesign (Task 14)		June 30, 2003
D-2.1.7	14% full area cell made on Gemini ribbon (Task 14)		June 30, 2003
D-2.2.1	Report on hot zone redesign. (Task 10)		September 30, 2003
D-2.2.2	Report on redesign of ambient gas flow pattern. (Task 11)		September 30, 2003
D-2.2.3	One oxide free ribbon sample. (Task 12)	1	September 30, 2003
D-2.2.5	Report on method to modify backskin. (Task 15)		September 30, 2003

D-2.2.6	Report on design of backskin modification machine. (Task 16)		September 30, 2003
D-2.2.7	Report on identification of pick and place robot. (Task 18)		September 30, 2003
D-2.2.8	Report on testing of redesigned hot zone (Task 14)		September 30, 2003
D-2.2.9	Report of comparison to single ribbon of Gemini yield and uptime (Task 14)		September 30, 2003
D-2.3.1	Report on design and implementation of vibration damping. (Task 10)		December 31, 2003
D-2.3.2	Report on design and deployment of boat for double sided passivation. (Task 12)		December 31, 2003
D-2.3.3	Report on adequate firing through of Al paste. (Task 12)		December 31, 2003
D-2.3.4	Report on development and testing of decal application machine. (Task 13)		December 31, 2003
D-2.3.7	Report on choice of method to form backskin edge. (Task 15)		December 31, 2003
D-2.3.8	Report on development of backskin modification machine. (Task 16)		December 31, 2003
→ D-2.3.9	Report on design of a machine to form sealed leads. (Task 16)		December 31, 2003 05/31/04
→ D-2.3.10	Report on decision for monolithic module manufacturing method. (Task 17)		December 31, 2003 05/31/04
→ D-2.3.11	Report on pick and place machine design. (Task 18)		December 31, 2003 05/31/04
D-2.3.12	Report on design of automatic bulk resistivity measurement. (Task 19)		December 31, 2003
D-2.3.13	Report on elimination of inside surface oxide stripe (Task 14)		December 31, 2003
D-2.3.14	Report on reduced variation in front to back thickness (Task 14)		December 31, 2003
D-2.3.15	Report on running of full cluster of 20 retrofit machines (Task 14)		December 31, 2003
D-2.4.1	Report on improved lifetimes and dislocation maps. (Task 10)		March 31, 2004
D-2.4.2	One 13% wrap-around cell. (Task 12)	1	March 31, 2004
D-2.4.3	One sample from and report on decal application machine with data		March 31, 2004

	processing. (Task 13)		
D-2.4.4	One sample from and report on decal application machine with data processing. (Task 13)	1	March 31, 2004
D-2.4.5	Report on process to make frameless modules. (Task 15)		March 31, 2004
D-2.4.6	Report on manufacturing equipment for frameless modules. (Task 16)		March 31, 2004
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control. (Task 17)		March 31, 2004
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control. (Task 17)	1	March 31, 2004
D-2.4.9	Report on development of automatic bulk resistivity measurement. (Task 19)		March 31, 2004
D-2.4.10	Report on incorporation of RS View in module machine designs. (Task 19)		March 31, 2004
D-2.4.11	Report on running of 100 new Gemini machines (Task 14)		March 31, 2004
D-2.4.12	Report on implementation of in-line diagnostics on all Gemini machines (Task 14)		March 31, 2004

### PHASE III

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-3.1.1	Report on debug of robotic pick and place machine. (Task 25)		June 30, 2004
D-3.2.1	Report on debug of wrap-around decal application machine. (Task 22)		September 30, 2004
D-3.2.2	Small cells cut from larger cell with laser. (Task 23)	6	September 30, 2004
D-3.2.3	Report on running of robotic pick and place machine. (Task 25)		September 30, 2004
D-3.2.4	Report on demonstration of positional accuracy and repeatability. (Task 25)		September 30, 2004
D-3.3.1	Report on impurity reduction on production machine. (Task 20)		December 31, 2004
D-3.3.2	Report on dislocation reduction on production machine. (Task 20)		December 31, 2004

D-3.3.3	Report on reliability of high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Report on completion of automation for high-voltage small modules. (Task 23)		December 31, 2004
D-3.3.4	Two prototype high-voltage small modules. (Task 23)	2	December 31, 2004
D-3.3.5	Report on speed and quality demonstration. (Task 24)		December 31, 2004
D-3.4.1	Report on starting material lifetimes of 5 to >10 microseconds. (Task 20)		March 31, 2005
D-3.4.1	One sample of starting material with lifetimes of 5 to >10 microseconds. (Task 20)	1	March 31, 2005
D-3.4.2	Report on advances made in Tasks 12 and 20 brought together. (Task 21)		March 31, 2005
D-3.4.3	Report on 14% wrap-around contact cells. (Task 21)		March 31, 2005
D-3.4.3	Two typical cells characterizing efforts for 14% wrap-around cells. (Task 21)	2	March 31, 2005
D-3.4.4	Report on testing (yield and throughput) of wrap-around decal application machine. (Task 22)		March 31, 2005
D-3.4.5	Report on yield demonstration. (Task 24)		March 31, 2005
D-3.4.6	Report on development of RS View on all automated machines for modules. (Task 26)		March 31, 2005
D-3.4.7	Report on integration of all inputs into a central collection point. (Task 26)		March 31, 2005
D-3.4.8	Report on demonstration of manufacturing capability. (Task 27)		March 31, 2005
D-3.4.9	Report on module fabrication yield. (Task 27)		March 31, 2005
D-3.4.10	Two monolithic modules typical of 100 module run sent to NREL. (Task 27)	2	March 31, 2005

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered as one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### **5.3 REPORTING REQUIREMENTS**

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: David Mooney, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

### **5.4 REQUIRED REPORTS**

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting

purposes: whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

#### **A. MONTHLY TECHNICAL STATUS REPORT:**

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

#### **B. ANNUAL TECHNICAL PROGRESS REPORT**

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see B1 Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

## C. FINAL TECHNICAL REPORT

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

### 6.0 Electronic Reporting Requirements for Subcontract Report Deliverables:

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the deliverable schedule of this Statement of Work in accordance with the following electronic reporting requirements:

- a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document. The electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

- b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).
- c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:
- Microsoft Word (v.6.0 or newer for PC or MAC)
  - WordPerfect (v.6.1 or newer for PC)
  - Microsoft PowerPoint
  - Microsoft Excel
- d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files\*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:
- QuarkXPress (.qxd)
  - Pagemaker (.pm)
  - Photoshop (.psd)
  - Illustrator (.ai)
  - Freehand (.fh)
  - Corel Draw (.cdr)
  - Framemaker (.fm)
  - Microsoft Publisher(.pub)

\*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.

- e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.
- f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are

permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.

- g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.
- h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

## 7.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**MODIFICATION NO. 3  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
TOTAL:	\$2,998,203.00	\$2,998,203.00	\$5,996,406.00

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

<b>FUNDED AMOUNT AND TASK CHARGE NUMBER:</b>	LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
	DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
	MOD. 1:	\$ 500,000.00 - PVP36282
	MOD. 2:	\$ 80,000.00 - PVP36282
	MOD. 3:	<u>\$ 170,000.00</u> - PVP46112
	TOTAL:	\$1,750,000.00

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to continue the Phase II work effort under Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs under this subcontract by "\$170,000.00" from "\$1,580,000.00" to "\$1,750,000.00". It is estimated that the allotted amount will cover work under this subcontract through 01/31/04.
2. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: Christie Johnson  
TITLE: Sr. Contract Administrator  
DATE: 11/24/03

**MODIFICATION NO. 4  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 03/31/04  
PHASE III: 04/01/04 THROUGH 05/31/05

<b>SUBCONTRACT AMOUNT:</b>	NREL'S <u>COST SHARE</u>	SUBCONTRACTOR'S <u>COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
<b>TOTAL:</b>	<b>\$2,998,203.00</b>	<b>\$2,998,203.00</b>	<b>\$5,996,406.00</b>

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:**

LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
MOD. 1:	\$ 500,000.00 - PVP36282
MOD. 2:	\$ 80,000.00 - PVP36282
MOD. 3:	\$ 170,000.00 - PVP46112
MOD. 4:	<u>\$ 248,638.00 - PVP46112</u>
<b>TOTAL:</b>	<b>\$1,998,638.00</b>

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to complete the Phase II work effort under Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs under this subcontract by "\$248,638.00" from "\$1,750,000.00" to "\$1,998,638.00. It is estimated that the allotted amount will cover work under this subcontract through March 31, 2004.
2. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: *Christi Johnson*  
TITLE: *Sr. Contract Administrator*  
DATE: *01/12/04*

**MODIFICATION NO. 5  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 05/31/04  
PHASE III: 06/01/04 THROUGH 07/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
ORIGINAL	\$2,998,203.00 - 50%	\$2,998,203.00 - 50%	\$5,996,406.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	0.00	0.00	0.00
MOD. 5:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
<b>TOTAL:</b>	<u>\$2,998,203.00</u>	<u>\$2,998,203.00</u>	<u>\$5,996,406.00</u>

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

<b>FUNDED AMOUNT AND TASK CHARGE NUMBER:</b>	LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
	DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
	MOD. 1:	\$ 500,000.00 - PVP36282
	MOD. 2:	\$ 80,000.00 - PVP36282
	MOD. 3:	\$ 170,000.00 - PVP46112
	MOD. 4:	\$ 248,638.00 - PVP46112
	MOD. 5:	<u>\$ 0.00</u>
	<b>TOTAL:</b>	<b>\$1,998,638.00</b>

**REVISION:**

Subcontract No. ZDO-2-30628-09 is hereby modified as follows:

1. The Subcontract Cover Page is hereby modified to extend the Phase II period of performance by deleting the period of performance in its entirety and replacing it with the following:  
  
"PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 05/31/04  
PHASE III: 06/01/04 THROUGH 07/31/05"
  
2. **ARTICLE 2 - THE PERIOD OF PERFORMANCE** is hereby deleted in its entirety and replaced with the following:  
  
**"ARTICLE 2 - THE PERIOD OF PERFORMANCE**  
  
A. The period of performance under this subcontract shall be as follows:  
  
Phase I: 09/27/02 through 03/31/03  
Phase II: 04/01/03 through 05/31/04  
Phase III: 06/01/04 through 07/31/05  
  
B. Each of these periods may be extended by mutual written agreement of the parties. NREL will make a decision, based on its sole judgement, whether or not to continue and incrementally fund each Phase prior to the completion date of each Phase. If all Phases are authorized by NREL, the total period of performance for the subcontract would be thirty-four (34) months. If NREL should decide not to authorize a Phase, the subcontract shall be considered complete upon submittal of the final version of the Annual Technical Report, with corrections as specified by NREL, if any."
  
3. **ARTICLE 3 - ESTIMATED COSTS, COST SHARING, OBLIGATION OF FUNDS AND FINANCIAL LIMITATIONS**, Paragraph D is hereby modified to extend the period that the allotted amount will cover work under this subcontract through by deleting "March 31, 2004" and substituting "May 31, 2004".
  
4. **ARTICLE 11 SUBCONTRACT ADMINISTRATION RESPONSIBILITIES**, Paragraph C is hereby modified to delete "Dave Mooney, (303) 384-6782" as the NREL designated Technical Monitor for this subcontract, and substitute "Katie Brown, (303) 384-6576".
  
5. **ARTICLE 14 - NEGOTIATED AND CEILING INDIRECT RATES**, Paragraphs A and B are hereby modified to extend the "Subcontract Period Covered" by deleting "05/31/05" and substituting "07/31/05".
  
6. Appendix A-1, Statement of Work, dated August 19, 2003 is hereby modified to extend the deliverable due date for deliverables numbered D-2.3.9, D-2.3.10 and D-2.3.11 by deleting "December 31, 2003" and substituting May 31, 2004".

7. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: Christie Johnson  
TITLE: SI. Contract Administrator  
DATE: 03/22/04

**MODIFICATION NO. 6  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 05/31/04  
PHASE III: 06/01/04 THROUGH 07/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
PHASE I:	\$999,833.00 - 50%	\$999,834.00 - 50%	\$1,999,667.00
PHASE II:	\$998,805.00 - 50%	\$998,804.00 - 50%	\$1,997,609.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	0.00	0.00	0.00
MOD. 5:	0.00	0.00	0.00
PHASE III:	\$999,565.00 - 50%	\$999,565.00 - 50%	\$1,999,130.00
MOD. 6:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
<b>TOTAL:</b>	<b>\$2,998,203.00</b>	<b>\$2,998,203.00</b>	<b>\$5,996,406.00</b>

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:**

LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
MOD. 1:	\$ 500,000.00 - PVP36282
MOD. 2:	\$ 80,000.00 - PVP36282
MOD. 3:	\$ 170,000.00 - PVP46112
MOD. 4:	\$ 248,638.00 - PVP46112
MOD. 5:	\$ 0.00
MOD. 6:	<u>\$ 450,000.00 - PVP46112</u>
<b>TOTAL:</b>	<b>\$2,448,638.00</b>

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to proceed with Phase III under Definitized Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D is hereby modified to increase the amount that has been allotted and is available for payment of NREL's estimated share of allowable costs under this subcontract by "\$450,000.00" from "\$1,998,638.00" to "\$2,448,638.00". It is estimated that the allotted amount will cover work under this subcontract through September 31, 2004.
2. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost or the cost sharing ratio of the parties hereto for each phase and for the entire subcontract.

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: *Christie Hanson*  
TITLE: *Sr. Contract Administrator*  
DATE: *06/04/04*

**MODIFICATION NO. 7  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 05/31/04  
PHASE III: 06/01/04 THROUGH 03/31/05

<b>SUBCONTRACT AMOUNT:</b>	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
PHASE I:	\$ 999,833.00 - 50%	\$ 999,834.00 - 50%	\$1,999,667.00
MOD. 7:	(\$ 77,271.00)	(\$ 76,340.40)	(\$ 153,611.40)
PHASE II:	\$ 998,805.00 - 50%	\$ 998,804.00 - 50%	\$1,997,609.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	0.00	0.00	0.00
MOD. 5:	0.00	0.00	0.00
MOD. 7:	\$ 75,364.85	\$ 75,365.85	\$ 150,730.70
PHASE III:	\$ 999,565.00 - 50%	\$ 999,565.00 - 50%	\$1,999,130.00
MOD. 6:	0.00	0.00	0.00
MOD. 7:	(\$ 2,212.36)	(\$ 1,279.22)	(\$ 3,491.58)
<b>TOTAL:</b>	<b>\$2,994,084.49</b>	<b>\$2,995,949.23</b>	<b>\$5,990,033.72</b>

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:**

LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
MOD. 1:	\$ 500,000.00 - PVP36282
MOD. 2:	\$ 80,000.00 - PVP36282
MOD. 3:	\$ 170,000.00 - PVP46112
MOD. 4:	\$ 248,638.00 - PVP46112
MOD. 5:	\$ 0.00
MOD. 6:	\$ 450,000.00 - PVP46112
MOD. 7:	<u>\$ 545,446.49 - PVP46112</u>
<b>TOTAL:</b>	<b>\$2,994,084.49</b>

**REVISION:**

In accordance with Article 2 - The Period of Performance, Paragraphs A and B, and Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations, Paragraph D, the Subcontractor is hereby authorized to complete the Phase III work effort under Definitized Subcontract No. ZDO-2-30628-09. By reason of this authorization, the allotted amount available for payment by NREL and the obligated amount are hereby increased and the following changes are hereby made to this subcontract:

1. The Subcontract Cover Page is hereby modified to reduce the Phase III performance period by deleting "07/31/05" and substituting "03/31/05".
2. Article 2 - The Period of Performance, Paragraphs A and B are hereby modified as follows:
  - a. Paragraph A is hereby modified to reduce the Phase III performance period by deleting "07/31/05" and substituting "03/31/05".
  - b. Paragraph B is hereby modified to reduce the Phase III performance period by deleting "thirty-four (34) months" and substituting "thirty (30) months".
3. Article 3 - Estimated Cost, Cost Sharing, Obligation of Funds And Financial Limitations is hereby deleted in its entirety and replaced with the following:

**"ARTICLE 3 - ESTIMATED COST, COST SHARING, OBLIGATION OF FUNDS AND FINANCIAL LIMITATIONS**

A. Estimated Cost -- The estimated cost for the performance of the work conducted under this subcontract is \$5,990,033.72. It is agreed by the parties hereto that said total cost shall be shared as follows:

Estimated NREL Share:	\$2,994,084.49	- 50%
Estimated Subcontractor Share:	<u>\$2,995,949.23</u>	- <u>50%</u>
Total:	\$5,990,033.72	- 100%

This cost sharing formula shall also apply (on the percentage basis shown above) to any increase or decrease in the estimated total cost of subcontract performance, changes under the "Changes" clause and/or terminations under the "Terminations" clause contained in Appendix B.

B. The estimated cost specified in A above is broken down as follows for this subcontract:

	Estimated NREL Share		Estimated Subcontractor Share		Total Cost
Phase I:	\$ 922,562.00	-- 50%	\$ 923,493.60	-- 50%	\$1,846,055.60
Phase II:	\$1,074,169.85	-- 50%	\$1,074,169.85	-- 50%	\$2,148,339.70
Phase III:	<u>\$ 997,352.64</u>	-- 50%	<u>\$ 998,285.78</u>	-- 50%	<u>\$1,995,638.42</u>
Total:	\$2,994,084.49	-- 50%	\$2,995,949.23	-- 50%	\$5,990,033.72

This cost sharing formula for each phase shall also apply (on the percentage basis shown above) to any increase or decrease in the estimated total cost of each phase of subcontract performance, changes under the "Changes" clause and/or terminations under the "Termination" clause contained in Appendix B.

- C. The Subcontractor shall be paid for the work conducted under this subcontract in accordance with the clauses entitled "Allowable Cost and Payment" and "Cost Sharing Subcontract - No Fee" in Appendix B, and the article entitled "Invoices" in this schedule.
  - D. Pursuant to the "Limitation of Funds" clause in Appendix B, the amount of \$2,994,084.49 has been allotted and is available for payment of NREL's estimated share of allowable costs for a portion of the work under this subcontract. It is estimated that the allotted amount will cover work under this subcontract through 03/31/05. This allotted amount presently obligated by NREL with respect to this subcontract, may be unilaterally increased by NREL by written notice to the Subcontractor, and may be increased or decreased by written agreement of the parties by formal modification of this subcontract.
  - E. The Subcontractor is authorized by NREL's execution of this subcontract to perform that portion of Phase I work for which funds have been allotted in Paragraph D above.
  - F. The Subcontractor is cautioned that, subject to the provisions of the clauses entitled "Limitation of Funds" and "Limitation of Cost" contained in Appendix B, NREL (i) is not presently obligated to reimburse the Subcontractor for costs incurred in excess of NREL's share of funds allotted in Paragraph D above for portions of authorized work under the subcontract, and (ii) shall not be obligated to reimburse the Subcontractor for costs incurred in excess of NREL's share of the total estimated costs in paragraph B above for full performance under the subcontract.
  - G. The giving of any notice by either party under this article, the article entitled "The Period of Performance" in this Schedule or the clauses entitled "Limitation of Funds" and "Limitation of Cost" in Appendix B, as applicable, shall not be construed to waive or impair any rights of NREL to terminate this subcontract under the provisions of the termination clause(s) contained in Appendix B."
- 4. Article 8 - Applicable Documentation, Paragraph E is hereby modified to add "and technical proposal dated August 11, 2004" after "technical proposal dated October 6, 2000".
  - 5. Article 10 - Rights to Proposal Data is hereby modified to add "and Subcontractor's proposal dated August 11, 2004" after "Subcontractor's proposal dated October 6, 2000"
  - 6. Article 14 - Negotiated and Ceiling Indirect Rates, Paragraphs A and B are hereby modified to reduce the "Subcontract Period Covered" by deleting "07/31/05" and substituting "03/31/05".
  - 7. Appendix A-1, Statement of Work, dated August 19, 2003 is hereby deleted in its entirety and replaced with the attached Appendix A-2, Statement of Work, dated August 11, 2004. In accordance with this change, all references in the subcontract schedule to "Appendix A-1, Statement of Work, dated August 19, 2003" are hereby replaced with "Appendix A-2, Statement of Work, dated August 11, 2004".

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

ACCEPTED: EVERGREEN SOLAR, INC.

BY: Richard Yelloni

TITLE: Vice President

DATE: 08/31/04

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: Austin Johnson

TITLE: Jr. Contract Administrator

DATE: 08/31/04

**Appendix A-2**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module  
Manufacturing of String Ribbon Si PV Modules**  
ZDO-2-30628-09

August 11, 2004

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for

optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, Evergreen will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 -1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. Evergreen will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of Evergreen's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. Evergreen shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, Evergreen shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. Evergreen shall design and develop a prototype machine to apply wrap-around decals.

They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Scale-Up Of A Production Worthy Doping Method**

Evergreen shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

Evergreen shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

Evergreen shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

Evergreen shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cell.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

Evergreen shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

Evergreen shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

Evergreen shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

Evergreen shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing. This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

Evergreen shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

## **PHASE II**

During Phase II, Evergreen shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

Evergreen shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and

more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

Evergreen shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

Evergreen shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

Evergreen shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Implementation of Multiple Ribbon Growth**

During Phase I of this program, project Gemini was launched and pilot production initiated. Gemini allows for the growth of two ribbons from a single crucible and represents an opportunity to lower significantly many of the costs of producing a ribbon substrate. In Phase II, the pilot line will continue and expand to the point where a significant fraction of the Subcontractor's crystal growth machines will be Gemini machines. In addition, during Phase II, considerable R&D work will continue on

improvements in the hot zone to increase production metrics such as yield and uptime. Also, in-line diagnostics will be continually upgraded to assist in reaching the production goals. Given the successful implementation of Gemini, the next platform for multiple ribbon growth – Quad – the growth of four ribbons from a single crucible- will be investigated with a view to bringing it to the stage of pre-implementation into production. This would not occur before the third year of this project, i.e. Phase 3.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

Evergreen shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

Evergreen shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

Evergreen shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

Evergreen shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or

minus 0.005".

### **3.19 Task 19 In-Line Diagnostics-2**

Evergreen shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSView into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

#### **PHASE III**

During Phase III, Evergreen shall continue to perform R&D needed to effect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on Gemini II cells leading to 14.2% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall: design and develop an improved 120-W, Gemini II module; debug, test, and fine-tune module manufacturing equipment used for such modules; debug, test, and fine-tune a diffusion machine for automated in-line diffusion using the no-etch process; and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. Finally, Evergreen shall demonstrate their state of the art manufacturing capability to make 120-W Gemini II modules at high yield and at a rate of 10-14 MW/year. Evergreen shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

Evergreen shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14.2% Efficient Gemini II Cells**

Evergreen shall combine advances made in Task 20 to routinely make 14.2% cells on Gemini II ribbon. These advances shall include: improvements in starting lifetime (Task 20); continued control of surface oxide layers such the the no-etch process can continue to be utilized; and further, tighter control of the oxide layer on the as-grown ribbon surface allowing for higher sheet resistivities in the diffusion process. The latter should help in producing an improved blue response, and this, in turn, will result in a high short-circuit current ( $J_{sc}$ ) value. At present, sheet resistivities are in the low to mid-40  $\Omega$ /square. The aim here would be to achieve values closer to 50  $\Omega$ /square. This work effort will be connected with Task 25 activities as well. In addition, a further advance will be in the decal formation and application processes, some of which will build on results from Task 22 activities.

The result of this task shall be a 14.2% efficient cell made from Gemini II string ribbon technology.

### **3.22 Task 22 Fine-Tune And Test Multi-Lane Decal Application Machine**

Evergreen shall demonstrate, fine-tune, and test a production-worthy multi-lane decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their multi-lane decal application machine at high volume, demonstrating multi-lane capability.

This task is expected to result in a complete debugging of the decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Develop 120-W Gemini II Module**

Evergreen shall produce 120-W modules based on Gemini II ribbon technology based on the results of Tasks 20 and 21. At present, Evergreen manufactures a 115-W module using Gemini I and single ribbon cells. The 120-W modules will undergo accelerated environmental testing to be certain the modules meet all standard qualification requirements. In addition, Evergreen will target yields above 98% in module lamination.

This task is expected to result in the fabrication of 120-W, Gemini II modules with high module-lamination yields.

### **3.24 Task 24 Debug And Run Crystal Growth Furnaces for Gemini II**

Evergreen shall procure additional Gemini II machines and retrofit earlier Gemini I machines or single ribbon machines following the completion of Tasks 14 and 23. The expected result for this task will be year-end yield and uptimes at least 10% absolute high than for Gemini I or single-ribbon furnaces at a volume rate between 10 and 14 MW/yr.

The expected result of this task will be the debugging of the Gemini II furnace technology in the form of new machines as well as retrofitted applications.

### **3.25 Task 25 High-Volume, Streamlined No-Etch/Diffusion Process**

Evergreen shall streamline the existing machine sequence for the no-etch/diffusion process in order to achieve continuous material flow throughout this processing step. The no-etch process, developed at Evergreen, involves wafers going directly from crystal growth into diffusion without any etching or wet chemistry. Following the belt-furnace diffusion step, the diffusant glass is removed in a continuous, belt-like process where the wafers are always horizontal and never placed in carriers. Also, this process eliminates the need for any edge isolation. Evergreen now has the entire machine sequence to perform this process in a line with an ultimate capacity of 8-10 MW/yr. To reach these production rates, it will be necessary to run 10 cells across the full width of the 38"-wide belt. Furthermore, a successful belt-to-belt transfer to the diffusant-glass-removal machine will need to be devised. A considerable amount of debugging of this equipment and process optimization will be needed before this machine sequence is fully functional as a production line.

The expected result of this task is the development of production sequence to enable continuous material flow throughout the no-etch/diffusion process at an 8-10MW/yr rate.

### **3.26 Task 26 Develop and Implement In-Line Diagnostics for Gemini II**

Evergreen shall continue to improve in-line diagnostics for Gemini II production. In-line diagnostic procedures that will be important for the Gemini II technology, particularly with the hot zone configuration labeled #6, include: 1) an improved thickness scanner; 2) an algorithm that automatically adjusts for melt-height changes; and 3) a central, computerized data collection system that will allow for analysis of the reasons for machine downtime.

The expected result of this task shall be the development and implementation of these diagnostic tools.

### **3.27 Task 27 Demonstrate Manufacturing Capability to Produce 120-W, Gemini II Modules with High Yields throughout Factory**

Evergreen shall demonstrate its manufacturing capabilities through the production of 120-W, Gemini II modules with high yields throughout the manufacturing facility. This task will be the culmination of the complete work effort under this PV Manufacturing R&D subcontract, combining the results of Tasks 20 through 26. This task shall combine the results of: 1) developing a 14.2% efficiency cell; 2) realizing the manufacturing benefits of dual-ribbon growth through Gemini II furnaces; 3) a well-controlled diffusion process; 4) improvements in decal application and formation; and 5) greater control in module assembly and yields. The success of this task will have important implications for Evergreen — laying the foundation for the further expansion beyond the goal of year-end 2004 of a production capacity of 10-14 MW/yr.

The expected result of this task is a demonstration of an overall production yield improvement of 10%.

#### 4.0 PROGRAM PLAN

The subcontracted research shall be conducted at Evergreen. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by Evergreen according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. Evergreen shall perform these tasks according to the following phased schedules:

##### PHASE I

Evergreen shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	△	X	X	X	X				
Task 2	△	X	X	X					
Task 3	△	X	X	X	X	X	▽		
Task 4					△	X	▽		
Task 5	△	X	X	X	X	X	▽		
Task 6	△	X	X	X	X	X			
Task 7	△	X	X	X	X	X	▽		
Task 8	△	X	X	X	X	X	▽		
Task 9	△	X	X	X	X	X	▽		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

Evergreen shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	△	X	X	X	X	X	X	X	X	X	X	▽		
Task 11	△	X	X	X	X	X								
Task 12						△	X	X	X	X	X	▽		
Task 13	△	X	X	X	X	X	X	X	X	X	X	▽		
Task 14	△	X	X	X	X	X	X	X	X	X	X			
Task 15			△	X	X	X	X	X	X	X	X			
Task 16					△	X	X	X	X	X	X	▽		
Task 17						△	X	X	X	X	X			
Task 18				△	X	X	X	X	X					
Task 19							△	X	X	X	X	▽		
Monthly Reports	15th													
Annual Report													Draft 15th	Final 30th

**Phase III**

Evergreen shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	J	J	A	S	O	N	D	J	F	M
Task 20			△	X	X	X	▽			
Task 21				△	X	X	▽			
Task 22					△	X	▽			
Task 23					△	X	▽			
Task 24	△	X	X	X	X	X	▽			
Task 25	△	X	X	▽						
Task 26	△	X	X	X	X	X	▽			
Task 27						△	▽			
Monthly Reports	15th									
Annual Report								Draft 15th		Final 31st

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. Evergreen shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

**PHASE II**

Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	Task 11
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	Task 11
m-2.1.3	Production-worthy decal application machine designed	Task 13
m-2.1.5	Identify method to modify backskin for higher impermeability	Task 15
m-2.1.6	Complete Gemini hot zone redesign and order parts	Task 14
m-2.1.7	14% cells on Gemini ribbon	Task 14

Milestones due no later than September 30, 2003

m-2.2.1	Establish hot zone redesign	Task 10
m-2.2.2	Demonstrate growth of oxide free ribbon	Task 11
m-2.2.3	<i>Eliminated from scope of work</i>	
m-2.2.4	Develop method to modify backskin	Task 15
m-2.2.5	Complete design of backskin modification machine	Task 16
m-2.2.6	Complete identification of pick and place robot	Task 18
m-2.2.7	Complete testing of redesigned hot zone	Task 14
m-2.2.8	Gemini yield and uptimes equivalent to single ribbon	Task 14

Milestones due no later than December 31, 2003

m-2.3.1	Complete design and implementation of vibration damping	Task 10
m-2.3.2	Complete design and deployment of boat for double sided passivation	Task 12
m-2.3.3	Demonstrate adequate firing through of Al paste	Task 12
m-2.3.4	Decal application machine developed and tested	Task 13
m-2.3.5	<i>Eliminated from scope of work</i>	
m-2.3.6	Identify method to form backskin edge	Task 15
m-2.3.7	Complete development of backskin modification machine	Task 16
m-2.3.8	Decision on monolithic module manufacturing method	Task 17
m-2.3.9	Complete design of pick and place machine	Task 18
m-2.3.10	Complete design for automatic bulk resistivity measurement	Task 19
m-2.3.11	Complete tests on elimination of inside surface oxide stripe	Task 14
m-2.3.12	Demonstrate reduced variation in front to back thickness	Task 14
m-2.3.13	Installation and running of full cluster of 20 retrofit machines	Task 14

Milestones due no later than March 31, 2004

m-2.4.1	Complete dislocation maps	Task 10
m-2.4.2	Demonstrate fabrication of 13% cells	Task 12
m-2.4.3	Establish data processing for decal application machine	Task 13
m-2.4.4	Develop method to form backskin edge	Task 15
m-2.4.5	Complete design of machine to form sealed leads	Task 16
m-2.4.6	Complete development of machine to form sealed leads	Task 16
m-2.4.7	Complete development of monolithic module manufacturing method	Task 17

m-2.4.8	Complete development of automatic bulk resistivity measurement	Task 19
m-2.4.9	Complete incorporation of RS View in module machine designs	Task 19
m-2.4.10	Installation and running of 100 new Gemini machines	Task 14
m-2.4.11	In-line diagnostics implemented on all Gemini machines	Task 14

### PHASE III

#### Milestones due no later than September 30, 2004

m-3.1.1	Complete debug of multi-lane decal application machine	Task 22
m-3.1.2	Demonstrate diffusion uniformity across the ten-cell span	Task 25
m-3.1.3	Demonstrate diffusant glass etching uniformity across the ten-cell span	Task 25
m-3.1.4	Show thickness scanner accuracy of >5x	Task 26
m-3.1.5	Build and test prototype in laboratory	Task 26
m-3.1.6	Develop algorithm in laboratory	Task 26

#### Milestones due no later than November 15, 2004

m-3.2.1	Yield 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.2	Uptimes 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.3	Show belt speeds compatible with 8-10 MW/yr rate	Task 25
m-3.2.4	Demonstration of production worthiness by running for three shifts/day for a month	Task 25
m-3.2.5	Build and test in-line diagnostics in pilot	Task 26
m-3.2.6	Test in-line diagnostic algorithm in pilot	Task 26

#### Milestones due no later than December 31, 2004

m-3.3.1	Demonstrate impurity reduction on Gemini II machine	Task 20
m-3.3.2	Demonstrate dislocation reduction on production machine	Task 20
m-3.3.3	Complete running of multi-lane decal application machine	Task 22
m-3.3.4	Form modules from Gemini II wafers that are 120W in pilot	Task 23
m-3.3.5	Demonstrate lamination yields of >98% in pilot	Task 23
m-3.3.6	Demonstrate qualification requirements met	Task 23
m-3.3.7	Demonstrate starting lifetimes of 5 to >10 microseconds	Task 20
m-3.3.8	14.2% Efficient Gemini II cells	Task 21

m-3.3.9	Advances made in Task 20 brought together	Task 21
m-3.3.10	Deploy in manufacturing	Task 23
m-3.3.11	Demonstrate lamination yields >98% in manufacturing	Task 23
m-3.3.12	Yield 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.13	Uptime 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.14	Production capacity of at least 10 MW/yr.	Task 24
m-3.3.15	Deploy algorithm in production	Task 26
m-3.3.16	Deploy in production	Task 26
	Demonstrate high yields in crystal growth with manufacturing	Task 27
m-3.3.17	capability	
	Demonstrate high yields in cell making with manufacturing	Task 27
m-3.3.18	capability	
	Demonstrate high yields in module making with manufacturing	Task 27
m-3.3.19	capability	
m-3.3.20	Combine M-3.27.1, 2, and 3 to reach capacity of 10-14 MW/yr.	Task 27

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

Evergreen shall prepare and submit reports and deliverables in accordance with the following Sections. Evergreen shall also supply NREL with samples of Evergreen cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, Evergreen shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. Evergreen shall provide deliverables according to the following schedule:

#### PHASE I Deliverables

Deliverables due no later than October 31, 2002

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant	2	Task 1
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2	1	Task 1
D-1.1.3	Report on a suitable solvent drying procedure		Task 1
D-1.1.4	Report on suitable transport of doped feedstock in feeder		Task 1
D-1.1.5	Report on chemical and optical characterization of surface oxide		Task 2
D-1.1.6	Report on feasibility of a simple optical method for oxide determination		Task 2
D-1.1.7	Ribbon sample grown without any surface oxide	1	Task 2
D-1.1.8	Report describing concept for prototype decal application machine		Task 6
D-1.1.9	Report describing design for prototype machine		Task 6
D-1.1.10	Example of thinner backskin sheets		Task 8

Deliverables due no later than October 31, 2002

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.2.1	Report on installation of mixing equipment		Task 1

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.2.2	One sample of 3" wide doped ribbon	1	Task 1
D-1.2.3	Two 12% cells made with feedstock doped with new doping process	2	Task 1
D-1.2.4	Report on finger cross section through screen-printing		Task 5
D-1.2.5	Report on decision to study alternative printing methods		Task 5
D-1.2.6	Report on dielectric layers selected		Task 5
D-1.2.7	Report on development and testing of prototype machine		Task 6
D-1.2.8	One cell from prototype machine	1	Task 6
D-1.2.9	Example of cross-linked thinner backskin		Task 8
D-1.2.10	Report on ink choice		Task 9
D-1.2.11	One sample of printed conductive material on backskin		Task 9

Deliverables due no later than January 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.3.1	Report on coating with reduced permeability		Task 3
D-1.3.2	Report on establishment of network for new crystal growth machines		Task 7
D-1.3.3	Report on resistivity and laser cutting data added to the network		Task 7
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests		Task 8
D-1.3.5	One backskin sample	1	Task 8
D-1.3.6	Report on performance under thermal cycling and humidity freeze		Task 9
D-1.3.7	Report on completed accelerated tests		Task 9

Deliverables due no later than March 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.4.1	Report on tests of improved purification graphite parts		Task 3
D-1.4.2	Report on novel hot zone parts' configurations		Task 3

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3		Task 3
D-1.4.4	One >15% R&D cell	1	Task 3
D-1.4.5	Report on optimization of plasma nitride process		Task 4
D-1.4.6	Report on optimization of metallization firing process		Task 4
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data	1	Task 4
D-1.4.8	Report on reduced series and shunt resistance		Task 5
D-1.4.9	One cell demonstrating device improvements due to contact improvements	1	Task 5
D-1.4.10	Report on real time process monitoring using SPC charts		Task 7
D-1.4.11	One sample of printed conductive material on backskin	1	Task 9

## **PHASE II Deliverables**

### Deliverables due no later than June 30, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.1.1	Report on reduced oxygen in hot zone.		Task 11
D-2.1.2	Report on design for alternate method to introduce Ar.		Task 11
D-2.1.3	Report on design of production-worthy decal application machine.		Task 13
D-2.1.5	Report on choice of method to modify backskin.		Task 15
D-2.1.6	Report on Gemini hot zone redesign		Task 14
D-2.1.7	14% full area cell made on Gemini ribbon	1	Task 14

### Deliverables due no later than September 30, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.2.1	Report on hot zone redesign.		Task 10
D-2.2.2	Report on redesign of ambient gas flow pattern		Task 11
D-2.2.3	One oxide free ribbon sample	1	Task 12

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.2.4	<i>Eliminated from scope of work</i>		
D-2.2.5	Report on method to modify backskin		Task 15
D-2.2.6	Report on design of backskin modification machine		Task 16
D-2.2.7	Report on identification of pick and place robot		Task 18
D-2.2.8	Report on testing of redesigned hot zone		Task 14
D-2.2.9	Report of comparison to single ribbon of Gemini yield and uptime		Task 14

Deliverables due no later than December 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.3.1	Report on design and implementation of vibration damping		Task 10
D-2.3.2	Report on design and deployment of boat for double sided passivation		Task 12
D-2.3.3	Report on adequate firing through of Al paste		Task 12
D-2.3.4	Report on development and testing of decal application machine		Task 13
D-2.3.5	<i>Eliminated from scope of work</i>		
D-2.3.6	<i>Eliminated from scope of work</i>		
D-2.3.7	Report on choice of method to form backskin edge		Task 15
D-2.3.8	Report on development of backskin modification machine		Task 16
D-2.3.9	Report on design of a machine to form sealed leads		Task 16
D-2.3.10	Report on decision for monolithic module manufacturing method		Task 17
D-2.3.11	Report on pick and place machine design		Task 18
D-2.3.12	Report on design of automatic bulk resistivity measurement		Task 19
D-2.3.13	Report on elimination of inside surface oxide stripe		Task 14
D-2.3.14	Report on reduced variation in front to back thickness		Task 14
D-2.3.15	Report on running of full cluster of 20 retrofit machines		Task 14

Deliverables due no later than March 31, 2004

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.4.1	Report on improved lifetimes and dislocation maps		Task 10
D-2.4.2	One 13% wrap-around cell	1	Task 12
D-2.4.3	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.4	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.5	Report on process to make frameless modules		Task 15
D-2.4.6	Report on manufacturing equipment for frameless modules		Task 16
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control		Task 17
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control	1	Task 17
D-2.4.9	Report on development of automatic bulk resistivity measurement		Task 19
D-2.4.10	Report on incorporation of RS View in module machine designs		Task 19
D-2.4.11	Report on running of 100 new Gemini machines		Task 14
D-2.4.12	Report on implementation of in-line diagnostics on all Gemini machines		Task 14

**Phase III Deliverables**

Deliverables due no later than September 30, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.1.1	Report on debug of multi-lane decal application machine		Task 22
D-3.1.2	Report on diffusion uniformity across the ten cell span		Task 25
D-3.1.3	Report on diffusant glass etching uniformity across the ten cell span		Task 25
D-3.1.4	Report on thickness scanner accuracy of >5x		Task 26
D-3.1.5	Report on building and testing prototype in lab		Task 26

D-3.1.6 Report on lab development of algorithm for melt height Task 26

Deliverables due no later than November 15, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.2.1	Report on yield 10% higher than for Gemini I		Task 24
D-3.2.2	Report on Uptimes 10% higher than for Gemini I		Task 24
D-3.2.3	Report on belt speeds compatible with 8-10 MW/yr rate		Task 25
D-3.2.4	Report on production worthiness by running for 3 shifts/day for a month		Task 25
D-3.2.5	Report on building and testing prototypes in pilot		Task 26
D-3.2.6	Report on testing of algorithm for melt height in pilot		Task 26
D-3.2.7	Report on development of centralized computer data of do downtime reasons		Task 26

Deliverables due no later than December 31, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.3.1	Report on impurity reduction on Gemini II machine		Task 20
D-3.3.2	Report on dislocation reduction on production machine		Task 20
D-3.3.3	Report on deployment of algorithm in production		Task 26
D-3.3.4	Report on deployment in production of centralized computer data		Task 26
D-3.3.5	Report on deployment in manufacturing of thickness scanner		Task 26
D-3.3.6	Report on running of multi-lane decal application machine		Task 22
D-3.3.7	Report on demonstration of lamination yields of >98% in pilot		Task 23
D-3.3.8	Report on demonstration of meeting qualification requirements		Task 23
D-3.3.9	Report on starting lifetimes of 5 to >10 microseconds		Task 20
D-3.3.10	Report on advances made in Task 20		Task 21
D-3.3.11	Report on 14.2% Efficient Gemini II cells		Task 21
D-3.3.12	14.2% Efficient Gemini II cells	2	Task 21
D-3.3.13	Report on deployment in manufacturing		Task 23
D-3.3.14	Report on lamination yields >98% in manufacturing		Task 23
D-3.3.15	120 W module sent to NREL	2	Task 23
D-3.3.16	Report on yields for retrofit machines		Task 24
D-3.3.17	Report on uptimes for retrofit machines		Task 24

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.3.18	Report on production capacity of at least 10 MW/yr.		Task 24
D-3.3.19	Report on high yields in crystal growth with manufacturing capability		Task 27
D-3.3.20	Report on high yields in cell making with manufacturing capability		Task 27
D-3.3.21	Report on high yields in module making with manufacturing capability		Task 27

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: Katie Brown, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered as one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### **5.3 REPORTING REQUIREMENTS**

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: Katie Brown, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

## 5.4 REQUIRED REPORTS

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes; whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

### A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

### B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see B1 Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1)**

**reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

## C. FINAL TECHNICAL REPORT

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

### 6.0 Electronic Reporting Requirements for Subcontract Report Deliverables:

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the deliverable schedule of this Statement of Work in accordance with the following electronic reporting requirements:

- a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document. The electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

- b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).
- c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:
- Microsoft Word (v.6.0 or newer for PC or MAC)
  - WordPerfect (v.6.1 or newer for PC)
  - Microsoft PowerPoint
  - Microsoft Excel
- d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files\*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:
- QuarkXPress (.qxd)
  - Pagemaker (.pm)
  - Photoshop (.psd)
  - Illustrator (.ai)
  - Freehand (.fh)
  - Corel Draw (.cdr)
  - Framemaker (.fm)
  - Microsoft Publisher(.pub)
- \*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.
- e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.
- f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are

permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.

- g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.
- h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

## 7.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**MODIFICATION NO. 8  
TO  
DEFINITIZED SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY  
DIVISION

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.

**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE  
MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING - PHASED

**PERIOD OF PERFORMANCE:** PHASE I: 09/27/02 THROUGH 03/31/03  
PHASE II: 04/01/03 THROUGH 05/31/04  
PHASE III: 06/01/04 THROUGH 05/15/05

**SUBCONTRACT AMOUNT:**

	<u>NREL'S COST SHARE</u>	<u>SUBCONTRACTOR'S COST SHARE</u>	<u>TOTAL</u>
PHASE I:	\$ 999,833.00 - 50%	\$ 999,834.00 - 50%	\$1,999,667.00
MOD. 7:	(\$ 77,271.00)	(\$ 76,340.40)	(\$ 153,611.40)
PHASE II:	\$ 998,805.00 - 50%	\$ 998,804.00 - 50%	\$1,997,609.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	0.00	0.00	0.00
MOD. 5:	0.00	0.00	0.00
MOD. 7:	\$ 75,364.85	\$ 75,365.85	\$ 150,730.70
PHASE III:	\$ 999,565.00 - 50%	\$ 999,565.00 - 50%	\$1,999,130.00
MOD. 6:	0.00	0.00	0.00
MOD. 7:	(\$ 2,212.36)	(\$ 1,279.22)	(\$ 3,491.58)
MOD. 8:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
TOTAL:	\$2,994,084.49	\$2,995,949.23	\$5,990,033.72

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S  
REMITTANCE NAME  
AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

**FUNDED AMOUNT AND  
TASK CHARGE NUMBER:**

LETTER SUBCONTRACT:	\$ 750,000.00 - PVP26282
DEFINITIZED SUBCONTRACT:	\$ 250,000.00 - PVP26282
MOD. 1:	\$ 500,000.00 - PVP36282
MOD. 2:	\$ 80,000.00 - PVP36282
MOD. 3:	\$ 170,000.00 - PVP46112
MOD. 4:	\$ 248,638.00 - PVP46112
MOD. 5:	\$ 0.00
MOD. 6:	\$ 450,000.00 - PVP46112
MOD. 7:	\$ 545,446.49 - PVP46112
MOD. 8:	<u>\$ 0.00</u>
TOTAL:	\$2,994,084.49

**REVISION:**

Subcontract No. ZDO-2-30628-09 is hereby modified as follows:

1. The Subcontract Cover Page is hereby modified to extend the subcontract completion date by deleting "03/31/05" and substituting "05/15/05".
2. Article 2 - The Period of Performance, Paragraph A and B are hereby modified as follows:
  - a. Paragraph A is hereby modified to extend the Phase III performance period by deleting "03/31/05" and substituting "05/15/05".
  - b. Paragraph B is hereby modified to extend the Phase III performance period by deleting "thirty (30) months" and substituting "thirty-one and one half (31 ½) months".
3. Article 14 - Negotiated and Ceiling Indirect Rates, Paragraphs A and B are hereby modified to reduce the "Subcontract Period Covered" by deleting "03/31/05" and substituting "05/15/05".
4. Appendix A-2, Statement of Work, dated 08/11/04 is hereby deleted in its entirety and replaced with the attached "Appendix A-3, Statement of Work, dated 03/23/05".

Except as provided herein, all other terms and conditions of this subcontract remain in full force and effect.

AUTHORIZED: MIDWEST RESEARCH INSTITUTE  
NATIONAL RENEWABLE ENERGY LABORATORY DIVISION

BY: Christa Johnson  
TITLE: Sr. Contract Administrator  
DATE: 04/12/05

**Appendix A-3**  
Statement of Work for Evergreen Solar, Inc.  
**Innovative Approaches to Low Cost Module  
Manufacturing of String Ribbon Si PV Modules**  
ZDO-2-30628-09

March 23, 2005

## **1.0 BACKGROUND**

The U.S. Department of Energy (DOE), in cooperation with the U.S. Photovoltaics (PV) Industry, has the objective of retaining and enhancing U.S. leadership in the world market. To further this objective, the Photovoltaic Manufacturing Technology (PVMaT) project was initiated in FY 1990 to form a partnership between DOE and the U.S. PV industry, assisting in the improvement of module manufacturing processes and in the substantial reduction of module manufacturing cost. The goals of the project were to improve PV manufacturing processes and products for terrestrial applications, accelerate PV manufacturing cost reduction, lay the foundation for significantly increased production capacity, and assist the U.S. industry in retaining and enhancing its world leadership role in the commercial development and manufacture of terrestrial PV systems. The focus of the program emphasized research and development (R&D) manufacturing process issues.

Four solicitations have been completed since inception of the PVMaT Project and a fifth solicitation is near completion. These solicitations addressed, respectively: (1) process-specific R&D on PV module manufacturing (open only to companies that completed successfully a preliminary problem-definition phase; (2) generic research on problems of interest to all, or to a large portion of the PV industry; (3) process-specific R&D on PV module manufacturing; (4) product-driven PV manufacturing R&D addressing process-specific problems, as well as manufacturing improvements for balance-of-systems (BOS) components and system design improvements; and (5) PV module manufacturing technology and PV system and component technology.

The FY2000 solicitation, "PV Manufacturing R&D — In-Line Diagnostics and Intelligent Processing in Manufacturing Scale-Up," was a continuation of the PV Manufacturing R&D Project that focused on further accelerating the PVMaT achievements and was designed to be impartial to various PV technologies and manufacturing approaches. The goals are to improve PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up (100-MW level). Letters of Interest under this solicitation were to address areas of work that could include, but were not be limited to, issues such as improvement of module manufacturing processes; system and system component packaging, system integration, manufacturing and assembly; product manufacturing flexibility; and balance-of-system development including storage and quality control. The primary emphasis was on new and improved in-line diagnostics and monitoring with real-time feedback for

optimal process control and increased yield in the fabrication of PV modules, systems, and other system components.

During this subcontract, Evergreen Solar, Inc. (hereafter referred to as "Evergreen" in this document) will address the goals of improved PV manufacturing processes and products while reducing costs and providing a technology foundation that supports significant manufacturing scale-up. To accomplish these goals, Evergreen will focus their efforts on their second-generation technology. These advances would be: further cost reduction in the production of wafers by the String Ribbon technique; high efficiency wrap-around contact solar cells; development and deployment of the manufacturing technology to make frameless modules based on polymers developed in Evergreen Solar's first PVMaT contract (1995 -1997); and the culmination of all these developments- monolithic modules. These developments will be accompanied with extensive use of manufacturing science techniques especially in the areas of diagnostics and statistical process control. Evergreen will also work toward PVMaT goals by developing quality assurance and ES&H programs in keeping with local, State, and Federal regulations as applicable.

## **2.0 OBJECTIVE**

The objective of this subcontract over its three-phase duration is to continue the development of Evergreen's String Ribbon Si PV technology resulting in an advanced generation of crystalline silicon PV module manufacturing technology applied to a virtually continuous fully integrated manufacturing line. The final goal of this line will be the production of frameless modules using wrap-around contacts on String Ribbon solar cells and made in a monolithic module configuration. Specific objectives include methods for improving surface and bulk quality of as-grown ribbon, techniques for wrap-around solar cell efficiency improvement, extensive reliability testing under accelerated conditions, developing low cost manufacturing to make frameless modules in general and monolithic modules in particular, and in line diagnostics throughout the production line. To further the high efficiency work, close interaction with Prof. Rohatgi's group at Georgia Tech will be pursued.

## **3.0 SCOPE OF WORK**

The subcontract shall consist of three phases and will be incrementally funded. Evergreen shall complete the investigations described in the following tasks and provide a detailed summary of this work in its reports and deliverables.

### **PHASE I**

During Phase I, Evergreen shall perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. These efforts shall address the scale-up of a previously developed laboratory scale technique to a production worthy doping method, growth of surface oxide free ribbon, improved starting lifetime of as-grown string ribbon, 12% efficient wrap-around cells, and device improvements on wrap-around cells. Evergreen shall design and develop a prototype machine to apply wrap-around decals.

They shall develop necessary in-line diagnostics to support crystal growth. Evergreen shall also perform work leading to backskin materials cost reduction and develop and use methods for accelerated testing of monolithic modules to demonstrate desired stability. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase I task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.1 Task 1 Scale-Up Of A Production Worthy Doping Method**

Evergreen shall scale-up the laboratory scale technique already developed to a scale suitable for manufacturing feedstock silicon using liquid spin-on dopants. To accomplish this task, Evergreen shall demonstrate a mixing method with satisfactory uniformity, develop a suitable solvent drying procedure and develop equipment which will not contaminate the feedstock silicon. This task is expected to result in a production worthy doping method and apparatus that produces satisfactory ribbon growth and cell efficiencies.

### **3.2 Task 2 Growth Of Surface Oxide Free Ribbon-1**

Evergreen shall find a simple optical method to detect surface oxide on Si ribbon as it grows and develop an easily implementable method that provides data needed for in-situ correction. To accomplish this task, Evergreen shall develop a detailed characterization of surface oxide layers and develop a simple method for optical detection. This task is expected to result in the development of an optical method for collecting data needed to implement real-time corrective action during crystal growth (see task 11 in Phase II) that can eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.3 Task 3 Improve Starting Lifetime Of As-Grown String Ribbon -1**

Evergreen shall improve the starting lifetime of as-grown string ribbon through better purification of hot zone component materials to reduce transition metals and the development of coatings that are more impermeable for hot zone components. DLTS shall be used to verify the lifetime improvements. To accomplish this task, Evergreen shall investigate coatings to reduce permeability, investigate improved purification methods for graphite parts, investigate new configurations in hot zone parts, perform in-house lifetime measurements, obtain DLTS results through university contacts, and obtain string ribbon characterization through interaction with Georgia Tech. This task is expected to result in improvement in starting lifetime through reduced transition metals in string ribbon.

### **3.4 Task 4 12% Efficient Wrap-around Cell**

Evergreen shall improve cell-processing leading to a 12% efficient wrap-around cell. Evergreen will achieve the efficiency gains in this task by both improvements in starting lifetime (Task 3) and advances in cell processing, especially plasma nitride passivation and firing through contacts. To accomplish this task, Evergreen shall perform cell processing of higher lifetime material, optimization of plasma nitride processes, and optimization of metallization firing processes. This task is expected to result in 12% wrap-around cell.

### **3.5 Task 5 Improve Devices Through Lowered Series Resistance And Increased Shunt Resistance**

Evergreen shall develop techniques to improve their wrap-around cell by achieving lowered series resistance through changes in finger cross section and increased shunt resistance through materials science studies on pastes and dielectric layers. To accomplish this task, Evergreen will develop methods to improve finger cross section, perform Ag paste studies to improve wrap around ribbon edge, investigate appropriate dielectric layers, and develop methods for reduction of edge leakage. This task is expected to result in improved fill factors for 120 sq. cm. wrap-around contact cells

### **3.6 Task 6 Design And Develop A Prototype Machine To Apply Wrap-around Decals**

Evergreen shall develop a concept and prototype machine for applying wrap-around solar cells that will lead higher manufacturing line volume and yield. To accomplish this task, Evergreen shall develop a concept for prototype machine, design a prototype machine, develop the prototype machine, and test the prototype machine. This task is expected to result in the testing of a prototype decal application machine that will be the basis for development of a high volume production machine.

### **3.7 Task 7 In-Line Diagnostics-1**

Evergreen shall develop a central database for in-line diagnostics in the crystal growth area to automatically generate SPC charts using the software package called RS View 32. To accomplish this task, Evergreen shall develop a data network for all new crystal growth machines, add bulk resistivity and laser cutter data to the network, and develop real time process monitoring using SPC charts. This task is expected to result in improved process control in the crystal growth area.

### **3.8 Task 8 Backskin Materials Cost Reduction**

Evergreen shall develop processes to reduce cost of the backskin material by formulating thinner sheets of this material and then apply appropriate qualification tests, as well as in house accelerated tests, to the thinner sheets. To accomplish this task, Evergreen shall formulate thinner backskin, cross-link thinner backskin sheets, conduct qualification tests with thinner material, and perform in-house accelerated testing. This task is expected to result in the development of a process to reduced backskin cost.

### **3.9 Task 9 Accelerated Testing Of Monolithic Modules**

Evergreen shall study appropriate inks and printing properties and perform accelerated testing to establish the long term stability of the electrical bonds for material used in adhesive and conducting bars. To accomplish this task, Evergreen shall study various conductive inks, establish suitable printing properties for conductive material, and conduct accelerated testing of conductive material contacts. This task is expected to result in the development of practical printing method for the conductive material chosen, the demonstration of long term stability for contacts, and the demonstration of long term viability by the monolithic module.

### **PHASE II**

During Phase II, Evergreen shall continue to perform R&D needed to affect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase II efforts shall address further improvement in the starting lifetime of as-grown string ribbon, continued work on growth of surface oxide free ribbon, continued improvements on wrap-around cells leading to 13% efficiency, the design, development, and initial testing of a machine to apply wrap-around decals, development of a continuous lamination process, design and development of manufacturing processes and equipment to make frameless modules, development of a manufacturing process to make monolithic modules, and the design of a robotic pick and place machine. In addition, Evergreen shall continue improving their in-line diagnostics capability through completion of the design for automating the collection and analysis of bulk resistivity measurements and the monitoring of module making machines. For all of these efforts Evergreen shall develop the quality assurance and ES&H programs required in keeping with local, state, and federal regulations as applicable. Evergreen shall report all progress from this Phase II task-oriented research through reporting requirements detailed in sections 4, 5, and 6.

### **3.10 Task 10 Improve Starting Lifetime Of As-Grown String Ribbon -2**

Evergreen shall continue to improve the starting lifetime of as-grown string ribbon through better control of thermal and mechanical perturbations to minimize dislocation formation. To accomplish this task, Evergreen shall make use of vibration control and

more uniform thermal environment to obtain lower dislocation content. Evergreen shall redesign their crystal growth hot zone to improve the thermal uniformity, design and develop techniques for vibration damping during growth, and perform dislocation density mapping to guide other efforts in this task. This task is expected to result in higher starting lifetimes through reduced dislocation density.

### **3.11 Task 11 Growth Of Surface Oxide Free Ribbon-2**

Evergreen shall develop a better understanding of oxygen ingress from the exit slits and convection in the region around the hot zone through a better understanding of convection in the hot zone. In addition, Evergreen shall design new techniques to utilize the improved understanding of oxygen ingress and reduce the oxygen available that creates undesired oxide on newly grown ribbon. To accomplish this task, Evergreen shall redesign their Ar introduction techniques and develop methods to reduce convection in the hot zone region. This task is expected to result in oxide free ribbon and eliminate all etch steps between growth and diffusion for Si ribbon.

### **3.12 Task 12 13 % Wrap-around Cells**

Evergreen shall improve efficiency through optimized nitride passivation for both front and rear surfaces and development of a method to form a good back contact. To accomplish this task, Evergreen shall develop, deploy, and test a boat for double sided passivation and develop and test Al paste that can fire through nitride. This task is expected to result in 13 % wrap-around cells.

### **3.13 Task 13 Design, Develop, and Test a Production-worthy Machine to Apply Wrap-around Decals**

Evergreen shall design, develop, and test a machine to apply wrap-around decals for high volume production rates on the order of 1000 cells/hr. The design shall make use of an Allen Bradley PLC that will feed process data into a central computer. This task is expected to result in the development of a production-worthy machine that automates the application of wrap-around decals.

### **3.14 Task 14 Implementation of Multiple Ribbon Growth**

During Phase I of this program, project Gemini was launched and pilot production initiated. Gemini allows for the growth of two ribbons from a single crucible and represents an opportunity to lower significantly many of the costs of producing a ribbon substrate. In Phase II, the pilot line will continue and expand to the point where a significant fraction of the Subcontractor's crystal growth machines will be Gemini machines. In addition, during Phase II, considerable R&D work will continue on

improvements in the hot zone to increase production metrics such as yield and uptime. Also, in-line diagnostics will be continually upgraded to assist in reaching the production goals. Given the successful implementation of Gemini, the next platform for multiple ribbon growth – Quad – the growth of four ribbons from a single crucible- will be investigated with a view to bringing it to the stage of pre-implementation into production. This would not occur before the third year of this project, i.e. Phase 3.

### **3.15 Task 15 Develop a Manufacturing Process to Make Frameless Modules**

Evergreen shall develop a low-cost, manufacturable technique to make frameless modules through close interaction with vendors and manufacturing personnel. To accomplish this task, Evergreen shall study alternative methods to modify their backskin for higher impermeability and study alternative methods to form a backskin edge. This task is expected to result in the development of a viable manufacturing process for frameless modules.

### **3.16 Task 16 Design Manufacturing Equipment to Make Frameless Modules**

Evergreen shall design, develop and test low-capital cost equipment for high volume manufacturing of frameless modules. To accomplish this task, Evergreen shall design a suitable backskin modification machine for improved impermeability backskin, test the backskin modification machine for output with improved impermeability, design a machine to form sealed leads from the module, and test the machine to form the sealed leads. This task is expected to result in the design, development and testing of a backskin modification machine and design, development, and testing of a machine to form sealed electrical leads from the module.

### **3.17 Task 17 Develop a Manufacturing Process to Make Monolithic Modules**

Evergreen shall develop a cost-effective, manufacturing method to control backskin shrinkage. To accomplish this task, Evergreen shall explore possible methods to control shrinkage, identify and select a promising method, and develop and test this method for adequacy in a manufacturing process. This task is expected to result in a method to control backskin shrinkage suitable for manufacturing.

### **3.18 Task 18 Design a Robotic Pick and Place Machine**

Evergreen shall design a robotic pick and place machine that can accurately position a wrap-around cell on the printed backskin. To accomplish this task, Evergreen shall identify a robot with desired properties and design a machine with that robot to perform the required pick and place activities needed to position the cell on the backskin. This task is expected to result in a pick and place machine with positional accuracy of plus or

minus 0.005".

### **3.19 Task 19 In-Line Diagnostics-2**

Evergreen shall develop the necessary processes and equipment to incorporate bulk resistivity measurement into the automatic laser cutting station. Such equipment to perform the measurements, done manually during the Phase I, shall be designed to automatically perform the required measurements on the as grown wafers. In the module area, processes and equipment necessary to incorporate RSView into the machine designs shall also be developed and tested. This task is expected to result in in-line diagnostics for bulk resistivity measurement and automated monitoring of module making machines.

### **PHASE III**

During Phase III, Evergreen shall continue to perform R&D needed to effect improvements in ribbon growth and cell and module manufacture. Evergreen's Phase III efforts shall address the demonstration of improved starting lifetime of as-grown string ribbon from a production-capable system, continued improvements on Gemini II cells leading to 14.2% efficiency, continued testing and fine tuning to demonstrate manufacturing line worthiness for a decal application machine. Evergreen shall: design and develop an improved 120-W, Gemini II module; debug, test, and fine-tune module manufacturing equipment used for such modules; debug, test, and fine-tune a diffusion machine for automated in-line diffusion using the no-etch process; and continue improved automation of their manufacturing line with design, development, and testing of a network for collection of all data at a central point for advanced in-line diagnostics. Finally, Evergreen shall demonstrate their state of the art manufacturing capability to make 120-W Gemini II modules at high yield and at a rate of 10-14 MW/year. Evergreen shall report all progress from this Phase III task-oriented research through reporting requirements detailed in Sections 4, 5, and 6.

### **3.20 Task 20 Demonstrate Improved Starting Lifetime On Production-Capable System**

Evergreen shall demonstrate the results of the work on impurity reduction (Task 3) and dislocation reduction (Task 10) on a production crystal growth system so as to produce a higher average and tighter distribution of starting lifetime. Presently the lifetimes vary from <1 to >10 microseconds. The goal here will be to eliminate the lower end of the distribution. This task is expected to result in starting lifetimes of 5 to >10 microseconds.

### **3.21 Task 21 14.2% Efficient Gemini II Cells**

Evergreen shall combine advances made in Task 20 to routinely make 14.2% cells on Gemini II ribbon. These advances shall include: improvements in starting lifetime (Task 20); continued control of surface oxide layers such that the no-etch process can continue to be utilized; and further, tighter control of the oxide layer on the as-grown ribbon surface allowing for higher sheet resistivities in the diffusion process. The latter should help in producing an improved blue response, and this, in turn, will result in a high short-circuit current ( $J_{sc}$ ) value. At present, sheet resistivities are in the low to mid-40  $\Omega$ /square. The aim here would be to achieve values closer to 50  $\Omega$ /square. This work effort will be connected with Task 25 activities as well. In addition, a further advance will be in the decal formation and application processes, some of which will build on results from Task 22 activities.

The result of this task shall be a 14.2% efficient cell made from Gemini II string ribbon technology.

### **3.22 Task 22 Fine-Tune And Test Multi-Lane Decal Application Machine**

Evergreen shall demonstrate, fine-tune, and test a production-worthy multi-lane decal application machine with a goal of achieving throughput of 1000 cells/hr at > 95% yield. To accomplish this task, Evergreen shall execute an iterative process of fine-tuning and testing their multi-lane decal application machine at high volume, demonstrating multi-lane capability.

This task is expected to result in a complete debugging of the decal application machine and a demonstration of production-worthiness.

### **3.23 Task 23 Develop 120-W Gemini II Module**

Evergreen shall produce 120-W modules based on Gemini II ribbon technology based on the results of Tasks 20 and 21. At present, Evergreen manufactures a 115-W module using Gemini I and single ribbon cells. The 120-W modules will undergo accelerated environmental testing to be certain the modules meet all standard qualification requirements. In addition, Evergreen will target yields above 98% in module lamination.

This task is expected to result in the fabrication of 120-W, Gemini II modules with high module-lamination yields.

### **3.24 Task 24 Debug And Run Crystal Growth Furnaces for Gemini II**

Evergreen shall procure additional Gemini II machines and retrofit earlier Gemini I machines or single ribbon machines following the completion of Tasks 14 and 23. The expected result for this task will be year-end yield and uptimes at least 10% absolute high than for Gemini I or single-ribbon furnaces at a volume rate between 10 and 14 MW/yr.

The expected result of this task will be the debugging of the Gemini II furnace technology in the form of new machines as well as retrofitted applications.

### **3.25 Task 25 High-Volume, Streamlined No-Etch/Diffusion Process**

Evergreen shall streamline the existing machine sequence for the no-etch/diffusion process in order to achieve continuous material flow throughout this processing step. The no-etch process, developed at Evergreen, involves wafers going directly from crystal growth into diffusion without any etching or wet chemistry. Following the belt-furnace diffusion step, the diffusant glass is removed in a continuous, belt-like process where the wafers are always horizontal and never placed in carriers. Also, this process eliminates the need for any edge isolation. Evergreen now has the entire machine sequence to perform this process in a line with an ultimate capacity of 8-10 MW/yr. To reach these production rates, it will be necessary to run 10 cells across the full width of the 38"-wide belt. Furthermore, a successful belt-to-belt transfer to the diffusant-glass-removal machine will need to be devised. A considerable amount of debugging of this equipment and process optimization will be needed before this machine sequence is fully functional as a production line.

The expected result of this task is the development of production sequence to enable continuous material flow throughout the no-etch/diffusion process at an 8-10MW/yr rate.

### **3.26 Task 26 Develop and Implement In-Line Diagnostics for Gemini II**

Evergreen shall continue to improve in-line diagnostics for Gemini II production. In-line diagnostic procedures that will be important for the Gemini II technology, particularly with the hot zone configuration labeled #6, include: 1) an improved thickness scanner; 2) an algorithm that automatically adjusts for melt-height changes; and 3) a central, computerized data collection system that will allow for analysis of the reasons for machine downtime.

The expected result of this task shall be the development and implementation of these diagnostic tools.

### **3.27 Task 27 Demonstrate Manufacturing Capability to Produce 120-W, Gemini II Modules with High Yields throughout Factory**

Evergreen shall demonstrate its manufacturing capabilities through the production of 120-W, Gemini II modules with high yields throughout the manufacturing facility. This task will be the culmination of the complete work effort under this PV Manufacturing R&D subcontract, combining the results of Tasks 20 through 26. This task shall combine the results of: 1) developing a 14.2% efficiency cell; 2) realizing the manufacturing benefits of dual-ribbon growth through Gemini II furnaces; 3) a well-controlled diffusion process; 4) improvements in decal application and formation; and 5) greater control in module assembly and yields. The success of this task will have important implications for Evergreen — laying the foundation for the further expansion beyond the goal of year-end 2004 of a production capacity of 10-14 MW/yr.

The expected result of this task is a demonstration of an overall production yield improvement of 10%.

#### 4.0 PROGRAM PLAN

The subcontracted research shall be conducted at Evergreen. The research shall be carried out according to the Task Schedule outlined below. All Milestones, Deliverables, and Reporting Requirements shall be met by Evergreen according to the schedules detailed in the appropriate sections that follow.

#### 4.1 TASK SCHEDULE

Task Schedules are broken down into separate Phase I, Phase II, and Phase III efforts to correspond to the three phases of the subcontract. Evergreen shall perform these tasks according to the following phased schedules:

##### PHASE I

Evergreen shall perform and complete Tasks 1 through 9 during Phase I of this subcontract according to the following schedule:

Months	S	O	N	D	J	F	M	A	M
Task 1	△	X	X	X	X				
Task 2	△	X	X	X					
Task 3	△	X	X	X	X	X	▽		
Task 4					△	X	▽		
Task 5	△	X	X	X	X	X	▽		
Task 6	△	X	X	X	X	X			
Task 7	△	X	X	X	X	X	▽		
Task 8	△	X	X	X	X	X	▽		
Task 9	△	X	X	X	X	X	▽		
Monthly Reports		15th	15th	15th	15th	15th	15th		
Annual Report							draft 15 <sup>th</sup>		Final 30 <sup>th</sup>

**PHASE II**

Evergreen shall perform and complete Tasks 10 through 19 during Phase II of this subcontract according to the following schedule:

Months	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Task 10	△	X	X	X	X	X	X	X	X	X	X	▽		
Task 11	△	X	X	X	X	X								
Task 12						△	X	X	X	X	X	▽		
Task 13	△	X	X	X	X	X	X	X	X	X	X	▽		
Task 14	△	X	X	X	X	X	X	X	X	X	X			
Task 15			△	X	X	X	X	X	X	X	X			
Task 16					△	X	X	X	X	X	X	▽		
Task 17						△	X	X	X	X	X			
Task 18				△	X	X	X	X	X					
Task 19							△	X	X	X	X	▽		
Monthly Reports	15th													
Annual Report													Draft 15th	Final 30th

**Phase III**

Evergreen shall perform and complete Tasks 20 through 27 during Phase III of this subcontract according to the following schedule:

Months	J	J	A	S	O	N	D	J	F	M	A	M
Task 20			△	X	X	X	▽					
Task 21				△	X	X	▽					
Task 22					△	X	▽					
Task 23					△	X	▽					
Task 24	△	X	X	X	X	X	▽					
Task 25	△	X	X	▽								
Task 26	△	X	X	X	X	X	▽					
Task 27						△	▽					
Monthly Reports	15th											
Annual Report											Draft 30th	Final 15th

## 4.2 MILESTONES

Milestones are broken down into Phase I, Phase II, and Phase III milestones to correspond to the three phases of the subcontract. Evergreen shall perform tasks 1 through 27 in order to meet milestones and deliverables according to the below schedule. Although Milestones are shown as due by the end of three month periods, Evergreen shall regularly report on Milestone progress in its Monthly Reports due on the 15<sup>th</sup> of each month.

### PHASE I

#### Milestones due no later than October 31, 2002

m-1.1.1	Demonstrate process steps for uniform mixing of dopant	(Task 1)
m-1.1.2	Grow ribbon with doped feedstock using demonstrated mixing procedure	(Task 1)
m-1.1.3	Demonstrate a suitable solvent drying procedure	(Task 1)
m-1.1.4	Show suitable transport in feeder	(Task 1)
m-1.1.5	Complete chemical and optical characterization of surface oxide	(Task 2)
m-1.1.6	Demonstrate feasibility of a simple optical method for oxide determination	(Task 2)
m-1.1.7	Concept for prototype decal application machine completed	(Task 6)
m-1.1.8	Design for prototype machine completed	(Task 6)
m-1.1.9	Thinner backskin sheets formulated	(Task 8)

#### Milestones due no later than October 31, 2002

m-1.2.1	Install mixing equipment	(Task 1)
m-1.2.2	Grow ribbon using feedstock mixed in new equipment	(Task 1)
m-1.2.3	Show no negative impact on efficiency from new doping process	(Task 1)
m-1.2.4	Identify contact cross section changes for screen printing	(Task 5)
m-1.2.5	Decision on whether or not to study alternative printing method	(Task 5)
m-1.2.6	Dielectric layers selected	(Task 5)
m-1.2.7	Prototype machine developed and tested	(Task 6)
m-1.2.8	Demonstrate cross-linked thinner backskin sheets	(Task 8)
m-1.2.9	Choose conductive ink for printing onto backskin	(Task 9)
m-1.2.10	Demonstrate ease of printing of conductive material	(Task 9)

### Milestones due no later than January 31, 2003

m-1.3.1	Demonstrate coating with reduced permeability	(Task 3)
m-1.3.2	Network for all new crystal growth machines established	(Task 7)
m-1.3.3	Bulk resistivity and laser cutting data connected to the network	(Task 7)
m-1.3.4	Initiate qualification tests	(Task 8)
m-1.3.5	Initiate in-house accelerated testing	(Task 8)
m-1.3.6	Demonstrate adequate performance under thermal cycling	(Task 9)
m-1.3.7	Demonstrate adequate performance under humidity freeze	(Task 9)

### Milestones due no later than, March 31, 2003

m-1.4.1	Test graphite parts for improved purification	(Task 3)
m-1.4.2	Test novel hot zone parts' configurations	(Task 3)
m-1.4.3	Demonstrate lifetime gains from M-1.3.1-M-1.3.3	(Task 3)
m-1.4.4	Verify M-1.3.4 with DLTS	(Task 3)
m-1.4.5	R and D cells from Ga. Tech with efficiency > 15.5%	(Task 3)
m-1.4.6	Optimize plasma nitride process	(Task 4)
m-1.4.7	Optimize metallization firing process	(Task 4)
m-1.4.8	Demonstrate fabrication of 120 sq. cm., 12% wrap-around cells	(Task 4)
m-1.4.9	Demonstrate reduced series resistance	(Task 5)
m-1.4.10	Demonstrate increased shunt resistance	(Task 5)
m-1.4.11	Demonstrate process monitoring using SPC charts	(Task 7)
m-1.4.12	Complete accelerated testing	(Task 8)
m-1.4.13	Complete accelerated tests	(Task 9)

## **PHASE II**

### Milestones due no later than June 30, 2003

m-2.1.1	Demonstrate reduced oxygen in hot zone	Task 11
m-2.1.2	Design for alternate method to introduce Ar into the hot zone	Task 11
m-2.1.3	Production-worthy decal application machine designed	Task 13
m-2.1.5	Identify method to modify backskin for higher impermeability	Task 15
m-2.1.6	Complete Gemini hot zone redesign and order parts	Task 14
m-2.1.7	14% cells on Gemini ribbon	Task 14

Milestones due no later than September 30, 2003

m-2.2.1	Establish hot zone redesign	Task 10
m-2.2.2	Demonstrate growth of oxide free ribbon	Task 11
<i>m-2.2.3</i>	<i>Eliminated from scope of work</i>	
m-2.2.4	Develop method to modify backskin	Task 15
m-2.2.5	Complete design of backskin modification machine	Task 16
m-2.2.6	Complete identification of pick and place robot	Task 18
m-2.2.7	Complete testing of redesigned hot zone	Task 14
m-2.2.8	Gemini yield and uptimes equivalent to single ribbon	Task 14

Milestones due no later than December 31, 2003

m-2.3.1	Complete design and implementation of vibration damping	Task 10
	Complete design and deployment of boat for double sided	
m-2.3.2	passivation	Task 12
m-2.3.3	Demonstrate adequate firing through of Al paste	Task 12
m-2.3.4	Decal application machine developed and tested	Task 13
<i>m-2.3.5</i>	<i>Eliminated from scope of work</i>	
m-2.3.6	Identify method to form backskin edge	Task 15
m-2.3.7	Complete development of backskin modification machine	Task 16
m-2.3.8	Decision on monolithic module manufacturing method	Task 17
m-2.3.9	Complete design of pick and place machine	Task 18
m-2.3.10	Complete design for automatic bulk resistivity measurement	Task 19
m-2.3.11	Complete tests on elimination of inside surface oxide stripe	Task 14
m-2.3.12	Demonstrate reduced variation in front to back thickness	Task 14
m-2.3.13	Installation and running of full cluster of 20 retrofit machines	Task 14

Milestones due no later than March 31, 2004

m-2.4.1	Complete dislocation maps	Task 10
m-2.4.2	Demonstrate fabrication of 13% cells	Task 12
m-2.4.3	Establish data processing for decal application machine	Task 13
m-2.4.4	Develop method to form backskin edge	Task 15
m-2.4.5	Complete design of machine to form sealed leads	Task 16
m-2.4.6	Complete development of machine to form sealed leads	Task 16
m-2.4.7	Complete development of monolithic module manufacturing method	Task 17

m-2.4.8	Complete development of automatic bulk resistivity measurement	Task 19
m-2.4.9	Complete incorporation of RS View in module machine designs	Task 19
m-2.4.10	Installation and running of 100 new Gemini machines	Task 14
m-2.4.11	In-line diagnostics implemented on all Gemini machines	Task 14

### PHASE III

#### Milestones due no later than September 30, 2004

m-3.1.1	Complete debug of multi-lane decal application machine	Task 22
m-3.1.2	Demonstrate diffusion uniformity across the ten-cell span	Task 25
m-3.1.3	Demonstrate diffusant glass etching uniformity across the ten-cell span	Task 25
m-3.1.4	Show thickness scanner accuracy of >5x	Task 26
m-3.1.5	Build and test prototype in laboratory	Task 26
m-3.1.6	Develop algorithm in laboratory	Task 26

#### Milestones due no later than November 15, 2004

m-3.2.1	Yield 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.2	Uptimes 10% higher than for Gemini I for two quarters on new furnaces	Task 24
m-3.2.3	Show belt speeds compatible with 8-10 MW/yr rate	Task 25
m-3.2.4	Demonstration of production worthiness by running for three shifts/day for a month	Task 25
m-3.2.5	Build and test in-line diagnostics in pilot	Task 26
m-3.2.6	Test in-line diagnostic algorithm in pilot	Task 26

#### Milestones due no later than December 31, 2004

m-3.3.1	Demonstrate impurity reduction on Gemini II machine	Task 20
m-3.3.2	Demonstrate dislocation reduction on production machine	Task 20
m-3.3.3	Complete running of multi-lane decal application machine	Task 22
m-3.3.4	Form modules from Gemini II wafers that are 120W in pilot	Task 23
m-3.3.5	Demonstrate lamination yields of >98% in pilot	Task 23
m-3.3.6	Demonstrate qualification requirements met	Task 23
m-3.3.7	Demonstrate starting lifetimes of 5 to >10 microseconds	Task 20
m-3.3.8	14.2% Efficient Gemini II cells	Task 21

m-3.3.9	Advances made in Task 20 brought together	Task 21
m-3.3.10	Deploy in manufacturing	Task 23
m-3.3.11	Demonstrate lamination yields >98% in manufacturing	Task 23
m-3.3.12	Yield 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.13	Uptime 10% higher than for Gemini I for two quarters on retrofits	Task 24
m-3.3.14	Production capacity of at least 10 MW/yr.	Task 24
m-3.3.15	Deploy algorithm in production	Task 26
m-3.3.16	Deploy in production	Task 26
m-3.3.17	Demonstrate high yields in crystal growth with manufacturing capability	Task 27
m-3.3.18	Demonstrate high yields in cell making with manufacturing capability	Task 27
m-3.3.19	Demonstrate high yields in module making with manufacturing capability	Task 27
m-3.3.20	Combine M-3.27.1, 2, and 3 to reach capacity of 10-14 MW/yr.	Task 27

## 5.0 DELIVERABLES/REPORTING REQUIREMENTS

Evergreen shall prepare and submit reports and deliverables in accordance with the following Sections. Evergreen shall also supply NREL with samples of Evergreen cells and modules for collaborative and analytical efforts with NREL as directed by the technical monitor. In addition, Evergreen shall supply, according to the schedule indicated, the following representative samples of the current best device/material design and fabrication procedures:

### 5.1 DELIVERABLES

The Deliverables under this subcontract are divided into Phase I, Phase II, and Phase III deliverables to correspond to the three phases of the subcontract. Evergreen shall provide deliverables according to the following schedule:

#### PHASE I Deliverables

##### Deliverables due no later than October 31, 2002

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Due Date</u>
D-1.1.1	Report on results for scaling up process for uniform mixing of dopant	2	Task 1
D-1.1.2	One sample of 3" wide ribbon grown per M-1.1.2	1	Task 1
D-1.1.3	Report on a suitable solvent drying procedure		Task 1
D-1.1.4	Report on suitable transport of doped feedstock in feeder		Task 1
D-1.1.5	Report on chemical and optical characterization of surface oxide		Task 2
D-1.1.6	Report on feasibility of a simple optical method for oxide determination		Task 2
D-1.1.7	Ribbon sample grown without any surface oxide	1	Task 2
D-1.1.8	Report describing concept for prototype decal application machine		Task 6
D-1.1.9	Report describing design for prototype machine		Task 6
D-1.1.10	Example of thinner backskin sheets		Task 8

##### Deliverables due no later than October 31, 2002

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.2.1	Report on installation of mixing equipment		Task 1

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.2.2	One sample of 3" wide doped ribbon	1	Task 1
D-1.2.3	Two 12% cells made with feedstock doped with new doping process	2	Task 1
D-1.2.4	Report on finger cross section through screen-printing		Task 5
D-1.2.5	Report on decision to study alternative printing methods		Task 5
D-1.2.6	Report on dielectric layers selected		Task 5
D-1.2.7	Report on development and testing of prototype machine		Task 6
D-1.2.8	One cell from prototype machine	1	Task 6
D-1.2.9	Example of cross-linked thinner backskin		Task 8
D-1.2.10	Report on ink choice		Task 9
D-1.2.11	One sample of printed conductive material on backskin		Task 9

Deliverables due no later than January 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.3.1	Report on coating with reduced permeability		Task 3
D-1.3.2	Report on establishment of network for new crystal growth machines		Task 7
D-1.3.3	Report on resistivity and laser cutting data added to the network		Task 7
D-1.3.4	Report on initiation of in-house accelerated tests and qualification tests		Task 8
D-1.3.5	One backskin sample	1	Task 8
D-1.3.6	Report on performance under thermal cycling and humidity freeze		Task 9
D-1.3.7	Report on completed accelerated tests		Task 9

Deliverables due no later than March 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.4.1	Report on tests of improved purification graphite parts		Task 3
D-1.4.2	Report on novel hot zone parts' configurations		Task 3

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-1.4.3	Report on lifetime gains (and DLTS verification) from M-1.3.1-M-1.3.3		Task 3
D-1.4.4	One >15% R&D cell	1	Task 3
D-1.4.5	Report on optimization of plasma nitride process		Task 4
D-1.4.6	Report on optimization of metallization firing process		Task 4
D-1.4.7	One 120 sq. cm., 12% wrap-around cell and I-V Data	1	Task 4
D-1.4.8	Report on reduced series and shunt resistance		Task 5
D-1.4.9	One cell demonstrating device improvements due to contact improvements	1	Task 5
D-1.4.10	Report on real time process monitoring using SPC charts		Task 7
D-1.4.11	One sample of printed conductive material on backskin	1	Task 9

## **PHASE II Deliverables**

### Deliverables due no later than June 30, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.1.1	Report on reduced oxygen in hot zone.		Task 11
D-2.1.2	Report on design for alternate method to introduce Ar.		Task 11
D-2.1.3	Report on design of production-worthy decal application machine.		Task 13
D-2.1.5	Report on choice of method to modify backskin.		Task 15
D-2.1.6	Report on Gemini hot zone redesign		Task 14
D-2.1.7	14% full area cell made on Gemini ribbon	1	Task 14

### Deliverables due no later than September 30, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.2.1	Report on hot zone redesign.		Task 10
D-2.2.2	Report on redesign of ambient gas flow pattern		Task 11
D-2.2.3	One oxide free ribbon sample	1	Task 12

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.2.4	<i>Eliminated from scope of work</i>		
D-2.2.5	Report on method to modify backskin		Task 15
D-2.2.6	Report on design of backskin modification machine		Task 16
D-2.2.7	Report on identification of pick and place robot		Task 18
D-2.2.8	Report on testing of redesigned hot zone		Task 14
D-2.2.9	Report of comparison to single ribbon of Gemini yield and uptime		Task 14

Deliverables due no later than December 31, 2003

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.3.1	Report on design and implementation of vibration damping		Task 10
D-2.3.2	Report on design and deployment of boat for double sided passivation		Task 12
D-2.3.3	Report on adequate firing through of Al paste		Task 12
D-2.3.4	Report on development and testing of decal application machine		Task 13
D-2.3.5	<i>Eliminated from scope of work</i>		
D-2.3.6	<i>Eliminated from scope of work</i>		
D-2.3.7	Report on choice of method to form backskin edge		Task 15
D-2.3.8	Report on development of backskin modification machine		Task 16
D-2.3.9	Report on design of a machine to form sealed leads		Task 16
D-2.3.10	Report on decision for monolithic module manufacturing method		Task 17
D-2.3.11	Report on pick and place machine design		Task 18
D-2.3.12	Report on design of automatic bulk resistivity measurement		Task 19
D-2.3.13	Report on elimination of inside surface oxide stripe		Task 14
D-2.3.14	Report on reduced variation in front to back thickness		Task 14
D-2.3.15	Report on running of full cluster of 20 retrofit machines		Task 14

Deliverables due no later than March 31, 2004

<u>No.</u>	<u>Deliverable Description</u>	<u>Quantity</u>	<u>Task #</u>
D-2.4.1	Report on improved lifetimes and dislocation maps		Task 10
D-2.4.2	One 13% wrap-around cell	1	Task 12
D-2.4.3	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.4	One sample from and report on decal application machine with data processing	1	Task 13
D-2.4.5	Report on process to make frameless modules		Task 15
D-2.4.6	Report on manufacturing equipment for frameless modules		Task 16
D-2.4.7	Report on development of monolithic module manufacturing method for shrinkage control		Task 17
D-2.4.8	One sample demonstrating monolithic module manufacturing method for shrinkage control	1	Task 17
D-2.4.9	Report on development of automatic bulk resistivity measurement		Task 19
D-2.4.10	Report on incorporation of RS View in module machine designs		Task 19
D-2.4.11	Report on running of 100 new Gemini machines		Task 14
D-2.4.12	Report on implementation of in-line diagnostics on all Gemini machines		Task 14

**Phase III Deliverables**

Deliverables due no later than September 30, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.1.1	Report on debug of multi-lane decal application machine		Task 22
D-3.1.2	Report on diffusion uniformity across the ten cell span Report on diffusant glass etching uniformity across the ten cell span		Task 25
D-3.1.3	span		Task 25
D-3.1.4	Report on thickness scanner accuracy of >5x		Task 26
D-3.1.5	Report on building and testing prototype in lab		Task 26

D-3.1.6 Report on lab development of algorithm for melt height Task 26

Deliverables due no later than November 15, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.2.1	Report on yield 10% higher than for Gemini I		Task 24
D-3.2.2	Report on Uptimes 10% higher than for Gemini I		Task 24
D-3.2.3	Report on belt speeds compatible with 8-10 MW/yr rate		Task 25
D-3.2.4	Report on production worthiness by running for 3 shifts/day for a month		Task 25
D-3.2.5	Report on building and testing prototypes in pilot		Task 26
D-3.2.6	Report on testing of algorithm for melt height in pilot		Task 26
D-3.2.7	Report on development of centralized computer data of do downtime reasons		Task 26

Deliverables due no later than December 31, 2004

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.3.1	Report on impurity reduction on Gemini II machine		Task 20
D-3.3.2	Report on dislocation reduction on production machine		Task 20
D-3.3.3	Report on deployment of algorithm in production		Task 26
D-3.3.4	Report on deployment in production of centralized computer data		Task 26
D-3.3.5	Report on deployment in manufacturing of thickness scanner		Task 26
D-3.3.6	Report on running of multi-lane decal application machine		Task 22
D-3.3.7	Report on demonstration of lamination yields of >98% in pilot		Task 23
D-3.3.8	Report on demonstration of meeting qualification requirements		Task 23
D-3.3.9	Report on starting lifetimes of 5 to >10 microseconds		Task 20
D-3.3.10	Report on advances made in Task 20		Task 21
D-3.3.11	Report on 14.2% Efficient Gemini II cells		Task 21
D-3.3.12	14.2% Efficient Gemini II cells	2	Task 21
D-3.3.13	Report on deployment in manufacturing		Task 23
D-3.3.14	Report on lamination yields >98% in manufacturing		Task 23
D-3.3.15	120 W module sent to NREL	2	Task 23
D-3.3.16	Report on yields for retrofit machines		Task 24
D-3.3.17	Report on uptimes for retrofit machines		Task 24

<u>Number</u>	<u>Description</u>	<u>Quantity</u>	<u>Task #</u>
D-3.3.18	Report on production capacity of at least 10 MW/yr. Report on high yields in crystal growth with manufacturing		Task 24
D-3.3.19	capability Report on high yields in cell making with manufacturing		Task 27
D-3.3.20	capability Report on high yields in module making with manufacturing		Task 27
D-3.3.21	capability		Task 27

Deliverables that are not reports shall be sent to the Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: Katie Brown, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with a copy of the transmittal letter sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Deliverables identified as reports in the above schedule in this section may be delivered as attachments to the Monthly Technical Status Report (MTSR) corresponding to the final month for the quarter in which that report deliverable is due. If an MTSR is not due in the final month of the quarter (as is the case at the end of each phase when an annual or the final report is due), the deliverable reports due at that time shall be delivered as one item with separate sections. In any of these cases, each deliverable report shall be clearly identifiable as a distinct section.

## 5.2 PRESENTATIONS AND PUBLICATIONS

Evergreen Solar, Inc. shall attend NREL Subcontractor Annual Review Meetings to be held at a place and time specified by NREL. Evergreen Solar, Inc. shall present a complete discussion of work performed under this subcontract at such meetings and submit one reproducible master copy of the presentation material prior to this review, as specified by the NREL Technical Monitor.

Presentations at scientific meetings and publications of research results in scientific journals are encouraged by the PV Manufacturing R&D Project, but must be approved in advance by the NREL Subcontract Administrator. Any costs to NREL that are to be incurred as a result of such presentations/publications must be included in the negotiated cost of the subcontract. The subcontractor is responsible for obtaining NREL's technical approval. Before a representative of Evergreen Solar, Inc. submits or presents a publication concerning the research effort under this subcontract (e.g., abstract, reprint of manuscript, etc.), Evergreen Solar, Inc. shall **submit two (2) copies to the NREL Technical Monitor, one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the Contract Administrator.**

Evergreen Solar, Inc. is reminded that the **technical approval** requirements, as specified above, also apply to reports requiring distribution outside of NREL.

Evergreen Solar, Inc. shall also be prepared to respond to requests for written information in summary form as required by the Technical Monitor to meet obligations to DOE. Such requests include, but are not limited to, Program Summaries (annually, 1-2 pages) and Summary Annual Reports (2-3 pages). These are the usual requested annually, and NREL does not at this time expect any others during the contract. They are in addition to other reporting requirements (below).

### **5.3 REPORTING REQUIREMENTS**

Evergreen Solar, Inc. shall furnish reports in accordance with the "Required Reports," Section 5.4. These reports shall be sent to the NREL Technical Monitor at the following address:

National Renewable Energy Laboratory  
ATTENTION: Katie Brown, MS#3214  
1617 Cole Boulevard  
Golden, Colorado 80401

with one copy of the report, and a copy of the transmittal letter to the Technical Monitor, being sent to the Contract Administrator at:

National Renewable Energy Laboratory  
ATTENTION: Christie Johnson, MS#2713  
1617 Cole Boulevard  
Golden, Colorado 80401

Technical monitoring will be performed by NREL/Sandia Personnel and will be in compliance with DOE PV Manufacturing R&D project and NREL Procurement requirements. One copy of these reports shall also be sent to the Technical Monitoring Team Members as described in Section 5.4, with a copy of their transmittal letters sent to the Technical Monitor.

## 5.4 REQUIRED REPORTS

Evergreen Solar, Inc. shall be required to prepare and submit the following reports indicated below. If the period of performance for this subcontract begins during the first through the fifteenth of a month, then that month is considered the first full month of the subcontract for reporting purposes. If the period of performance for this subcontract begins during the sixteenth through the end of the month, then the first full month of the subcontract for reporting purposes is the following month. For example, if the period of performance start date is January 10, then January is the first full month for reporting purposes; whereas, if the period of performance start date is January 20, then February is the first full month for reporting purposes.

### A. MONTHLY TECHNICAL STATUS REPORT:

The Monthly Technical Status Report shall be formatted to communicate to NREL an assessment of subcontract status, explain variances and problems, report on the accomplishment of performance milestones and/or program deliverables, and discuss any other achievements or areas of concern. This report should be three to six pages written in a letter format with emphasis placed on the status rather than a description of the progress. An introductory paragraph will be included in each monthly report that provides a highlight of the month's activities. **Copies of this report are due on or before fifteen (15) days after completion of each month** [two (2) copies to the NREL Technical Monitor (TM), one (1) copy to each of the Technical Monitoring Team (TMT) members, and one (1) copy to the NREL Contract Administrator].

### B. ANNUAL TECHNICAL PROGRESS REPORT

The Annual Technical Progress Reports shall be structured as formal technical reports, both in draft and final version, which describe all significant work performed during each phase of the subcontract. **Copies of the draft Annual Technical Progress Report are due on or before fifteen (15) days prior to the completion date for each phase's research effort under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team (TMT) members, one (1) copy for the NREL TMT member, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make these corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Annual Technical Progress Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site, see B1 Guidelines below), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1)**

**reproducible copy for the NREL Contract Administrator.** If the subcontracted effort in the following phase is not authorized and funded by NREL, then that phase's Annual Technical Progress Report shall be designated as the Final Technical Report (see description below) and the period of performance for that phase shall be extended by three months to allow for the completion of this report as the Final Technical Report.

## C. FINAL TECHNICAL REPORT

The Final Technical Report is to be structured as a formal technical report, both in draft and final version, which describes all significant work performed during the entire subcontract's period of performance. **Copies of the draft Final Technical Report are due on or before fifteen (15) days after the final phase's completion date for active research under this subcontract** [two (2) copies for the NREL Technical Monitor (TM), one (1) copy for each of the Technical Monitoring Team members, and one (1) copy for the NREL Contract Administrator]. The subcontractor shall make any corrections or revisions per NREL direction, which may include technical or editorial comments. The subcontractor shall be allowed fifteen (15) days after receipt of NREL's recommendations and/or comments to make corrections and submit copies of the final version to NREL. The final version shall consist of **three (3) copies of the Final Technical Report** [one (1) master copy with original graphics, one (1) electronic copy with graphics (for posting on NREL's web site), and one (1) reproducible copy] **for the NREL Technical Monitor (TM), and one (1) reproducible copy for the NREL Contract Administrator.** The subcontractor shall follow one of the formats (listed above in Section B1, Annual Technical Progress Report) for the electronic copies of the final version of this report.

### 6.0 Electronic Reporting Requirements for Subcontract Report Deliverables:

As set forth in Department of Energy Order 241.1A, NREL is required to submit in an electronic format all scientific and technical information, including subcontract report deliverables intended for public distribution, to the DOE Office of Scientific and Technical Information (OSTI). In addition, it is NREL's intention to post subcontract report deliverables containing publicly available information (e.g. non-confidential, non-protected, non-proprietary information) for distribution on the NREL Intranet or the Internet.

The Subcontractor shall provide the final approved version of report deliverables intended for public distribution as specified in the deliverable schedule of this Statement of Work in accordance with the following electronic reporting requirements:

- a. The Subcontractor shall submit all report deliverables intended for public distribution (including status, annual, or final reports) as electronic files, preferably with all graphics and images embedded within the document. The electronic files shall be submitted along with an accompanying hard (printed) copy(ies) of the report. Limited exceptions allowing some graphics and images to be submitted as hard copies only may be granted on a case-by-case basis. The exceptions process for graphics and images is described in Paragraph E below. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.

- b. All final approved version submissions shall be delivered to NREL on PC or MAC-formatted media (3.5 inch disks, Zip and Jaz cartridges, or CD-ROM). Files of 1 Mb or less can be sent via e-mail to the 1) NREL technical monitor, 2) the NREL Subcontract Administrator or Associate (as specified in the Statement of Work).
- c. The preferred format is a single electronic file that includes all of the text, figures, illustrations, and high-resolution digital photographs (or photographs should be scanned and incorporated in the text). Acceptable file formats are:
- Microsoft Word (v.6.0 or newer for PC or MAC)
  - WordPerfect (v.6.1 or newer for PC)
  - Microsoft PowerPoint
  - Microsoft Excel
- d. If it is not possible to include all of the graphics and images (figures, illustrations, and photographs) in the same file as the text, NREL will accept the text in one of the above formats and the graphics and images as separate electronic graphic or image files\*. The native files for any page layout formats submitted shall be supplied. The following software is supported on both Mac and PC platforms:
- |                      |                             |
|----------------------|-----------------------------|
| • QuarkXPress (.qxd) | • Pagemaker (.pm)           |
| • Photoshop (.psd)   | • Illustrator (.ai)         |
| • Freehand (.fh)     | • Corel Draw (.cdr)         |
| • Framemaker (.fm)   | • Microsoft Publisher(.pub) |

\*The acceptable graphic or image file formats are: .eps, .tif, .gif, .jpg, .wpg, .wmf, .pct, .png, .bmp, .psd, .ai, .fh, .cdr. The preferred resolution for graphics or images is 150 to 300 dpi. Include all fonts that were used in creating the file.

- e. In the rare case that the graphics or images cannot be supplied electronically, either incorporated within the text or as a separate electronic file, original hard copies will be accepted. The Subcontractor shall obtain prior approval from the Subcontract Administrator before submitting graphics or images in hard copies. It shall be made clear in the deliverable transmittal letter that certain graphics and images are supplied in hard copy only.
- f. For all calculations in support of subcontract reports that are conducted in ASPEN+, an electronic copy of INPUT, REPORT and BACKUP (if Model Manager is used) must be submitted with all reports. Additionally, if costing or sizing calculations are conducted in a spreadsheet [no process calculations (heat and material balances) in spreadsheet format are

permitted], a copy of the fully documented MS Excel file shall be supplied. Note that vendor quotes and other non-original material can be supplied in hard copy.

- g. A fully executed release shall be supplied to NREL with all photographs, regardless of whether such photographs are delivered to NREL electronically or in hard copy. Such release shall certify that the National Renewable Energy Laboratory and the United States Government is granted a non-exclusive, paid-up, irrevocable, worldwide license to publish such photographs in any medium or reproduce such photographs or allow others to do so for United States Government purposes.
- h. The Subcontractor may contact NREL Publication Services at (303) 275-3644 with questions regarding technical guidance concerning the submission of subcontract report deliverables as electronic files or exceptions to electronic files for graphics and images.

## 7.0 PERFORMANCE EVALUATION

The performance of Evergreen Solar, Inc. will be monitored and evaluated by the following means:

- i) Monthly Technical Status Reports consisting of a report of program status relative to milestone and program schedules (3-6 pages);
- ii) Annual Technical Progress Reports;
- iii) A Final Technical Report covering work done under the subcontract;
- iv) Up to two On-Site Visits by a PV Manufacturing R&D project selected evaluation team to Evergreen Solar, Inc. per phase – these visits shall entail presentations and demonstrations by Evergreen Solar, Inc.; and
- v) Participation by Evergreen Solar, Inc. in up to two contractor Program Review Meetings per Phase as designated by PV Manufacturing R&D project management personnel.

During the subcontract, on-site presentations and demonstration reviews will be conducted by a PV Manufacturing R&D project review committee consisting of members selected by PV Manufacturing R&D project management staff. These meetings will be critical program evaluation points. The progress of Evergreen Solar, Inc. will be assessed at this time by reviewing past accomplishments and future program plans.

The progress of Evergreen Solar, Inc. will also be monitored by telephone conversations and by possible additional on-site visits by the NREL technical evaluation team at the discretion of the NREL technical monitor for the subcontract.

**MODIFICATION NO. 9 - CLOSEOUT**

TO

**SUBCONTRACT NO. ZDO-2-30628-09**

**CONTRACTING PARTY:** ALLIANCE FOR SUSTAINABLE ENERGY, LLC  
MANAGEMENT AND OPERATING CONTRACTOR FOR  
THE NATIONAL RENEWABLE ENERGY LABORATORY (NREL)

**SUBCONTRACTOR:** EVERGREEN SOLAR, INC.  
**ADDRESS:** 259 CEDAR HILL STREET  
MARLBORO, MA 01752

**SUBCONTRACT TITLE:** "INNOVATIVE APPROACHES TO LOW COST MODULE MANUFACTURING OF STRING RIBBON Si PV MODULES"

**SUBCONTRACT TYPE:** COST SHARING -- PHASED

**PERIOD OF PERFORMANCE:** 9/27/02 THROUGH 5/15/05

	NREL'S	SUBCONTRACTOR'S	TOTAL COST
	<u>COST SHARE</u>	<u>COST SHARE</u>	<u>TOTAL COST</u>
PHASE I:	\$ 999,833.00	\$ 999,834.00	\$ 1,999,667.00
MOD. 7:	<77,271.00>	<76,340.40>	<153,611.40>
PHASE II:	998,805.00	998,804.00	1,997,609.00
MOD. 1:	0.00	0.00	0.00
MOD. 2:	0.00	0.00	0.00
MOD. 3:	0.00	0.00	0.00
MOD. 4:	0.00	0.00	0.00
MOD. 5:	0.00	0.00	0.00
MOD. 7:	75,364.85	75,365.85	150,730.70
PHASE III:	999,565.00	999,565.00	1,999,130.00
MOD. 6:	0.00	0.00	0.00
MOD. 7:	<2,212.36>	<1,279.22>	<3,491.58>
MOD. 8:	0.00	0.00	0.00
MOD. 9:	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
<b>TOTAL:</b>	<b>\$ 2,994,084.49</b>	<b>\$ 2,995,949.23</b>	<b>\$ 5,990,033.72</b>

**PAYMENT TERMS:** NET 30

**SUBCONTRACTOR'S REMITTANCE NAME AND ADDRESS:** EVERGREEN SOLAR, INC.  
259 CEDAR HILL STREET  
MARLBORO, MA 01752

<b>FUNDED AMOUNT AND</b>	LETTER SUBCONTRACT:	\$ 750,000.00
<b>TASK CHARGE NUMBER:</b>	DEFINITIZED SUBCONTRACT:	250,000.00
	MOD. 1:	500,000.00
	MOD. 2:	80,000.00
	MOD. 3:	170,000.00
	MOD. 4:	248,638.00
	MOD. 5:	0.00
	MOD. 6:	450,000.00
	MOD. 7:	545,446.49
	MOD. 8:	0.00
	MOD. 9:	<u>0.00</u>
	<b>TOTAL:</b>	<b>\$ 2,994,084.49</b>

**REVISION:**

WHEREAS, NREL and the Subcontractor entered into Subcontract No. ZDO-2-30628-09 to perform work generally described as "Innovative Approaches to Low Cost Module Manufacturing Of String Ribbon Si PV Modules";

WHEREAS, performance under Subcontract No. ZDO-2-30628-09 has been completed and all deliverables have been received and accepted by NREL;

WHEREAS, the Subcontractor has reported all costs which were incurred during subcontract performance; and

WHEREAS, the parties hereto desire to establish the final dollar amount of the subcontract on the basis of the reported, audited, and negotiated costs.

NOW, THEREFORE, in consideration of the premises hereinabove set forth it is hereby mutually agreed between the parties that:

1. Article 3 – Estimated Cost, Cost Sharing, Obligation of Funds, and Financial Limitations is hereby modified as follows:

a. The final amount of this subcontract is \$5,990,033.72 which is cost shared as follows:

NREL's Cost Share:	\$	2,994,084.49	--	50%
Subcontractor's Cost Share:		<u>2,995,949.23</u>	--	50%
Total Cost:	\$	5,990,033.72		

b. By reason of the foregoing, there is neither an increase nor a decrease in the total estimated cost of this subcontract or the cost share of the parties hereto.

2. Release of Claims.

In consideration of the payment of the sum of Two Million Nine Hundred Sixty Six Thousand Six Hundred Forty Three and 60/100 Dollars (\$2,966,643.60) which has already been paid under Subcontract No. ZDO-2-30628-09, together with the sum of Twenty Seven Thousand Four Hundred Forty and 89/100 Dollars (\$27,440.89) which is to be paid by NREL under this subcontract to the Subcontractor, the Subcontractor does, and by receipt of said sum, for itself, its successors and assigns, remise, release and forever discharge NREL and the Government, acting by and through the Department of Energy, their respective officers, agents, and employees, of and from all manner of debts, dues, liabilities, obligations, accounts, claims, and demands whatsoever, including interest, fees, and expenses, in law and in equity, under or arising out of or in any manner relating to this subcontract, except:

a. Specified claims in stated amounts or in estimated amounts where the amounts are not susceptible to exact statement by the Subcontractor, as follows:

NONE

b. Claims, together with reasonable expenses incidental thereto, based upon the liabilities of the Subcontractor to third parties arising out of the performance of this subcontract, which are not known to the Subcontractor on the date of the execution of this release and of which the Subcontractor gives notice in writing to the Subcontract Administrator within the period specified in Subcontract No. ZDO-2-30628-09.

c. Claims for reimbursement of costs (other than expenses of the Subcontractor by reason of its indemnification of NREL against patent liability), including reasonable expenses incidental thereto, incurred by the Subcontractor under the provisions of the subcontract relating to patents.

The Subcontractor agrees, in connection with claims which are not released as set forth above, that final payment under this subcontract does not modify the requirements and limitations imposed on the Subcontractor by this subcontract, including without limitation those provisions relating to notification to the Subcontract Administrator and relating to the defense or prosecution of litigation.

3. Assignment of Refunds, Rebates, Credits and Other Amounts

The Subcontractor does hereby:

- a. Assign, transfer, set over and release to NREL, all right, title, and interest to all refunds, rebates, credits or other amounts (including any interest thereon) arising out of the performance of this subcontract, together with all the rights of action accrued or which may hereafter accrue thereunder.
- b. Agree to take whatever action may be necessary to effect prompt collection of all refunds, rebates, credits or other amounts (including any interest thereon) due or which may become due, and to promptly forward to NREL checks (made payable to the National Renewable Energy Laboratory) for any proceeds so collected. The reasonable costs of any such action to effect collection shall constitute allowable costs when approved by the Subcontract Administrator as stated in this subcontract and may be applied to reduce any amounts otherwise payable to NREL under the terms hereof.
- c. Agree to cooperate fully with NREL as to any claim of suit in connection with refunds, rebates credits or other amounts due (including any interest thereon); to execute any protest, pleading, application, power of attorney or other papers in connection therewith; and to permit NREL to represent it at any hearing, trial or other proceeding arising out of such claim or suit.

This modification constitutes full, complete and final accord and satisfaction of any and all right to equitable adjustment, arising under the "Changes" clause or any other provision of this subcontract.

Except as provided herein, all other terms and conditions remain unchanged and shall continue in full force and effect.

IN WITNESS WHEREOF, the parties hereto have executed this modification as of the date fully executed below.

ACCEPTED: EVERGREEN SOLAR, INC.

AUTHORIZED: ALLIANCE FOR SUSTAINABLE ENERGY, LLC

BY: Ronald C. [Signature]

BY: [Signature]

TITLE: Vice President

TITLE: Closeout Specialist

DATE: 25 February 2010

DATE: 2-18-16