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# Results of the Systems-Driven Approach to Solar Workshop

## December 17-18, 2002

Sponsored by:

Solar Energy Technologies Program

Utilizing the sun's natural energy
to generate electricity and provide
water and space heating

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# 1. Executive Summary

On December 17th and 18th 2002 a group of over 70 people concerned with solar energy development convened at the Maritime Institute of Technology and Graduate Studies in Linthicum, Maryland to discuss a new concept: a systems-driven approach to Solar Program management.

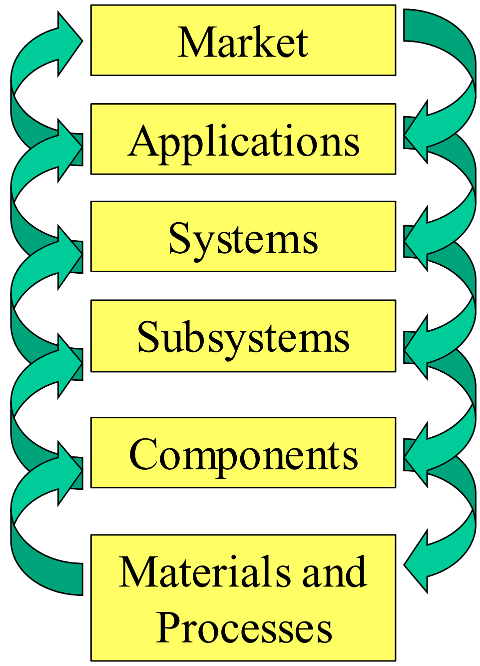


**Figure 1: Systems-Driven Approach Analysis Framework**

The concept was based on the experience of the former Office of Advanced Automotive Technologies (OAAT). OAAT had structured its program to be driven by markets, i.e., the technologies that OAAT developed needed to satisfy real marketplace needs. OAAT identified appropriate applications for the technologies that it was developing. At the same time it recognized that detailed attention must be given to the systems that enabled those applications, the subsystems within those systems, the components that were the building blocks of the subsystems, and the materials and processes that went into the manufacturing of the components. Activities at each level affected outcomes at every other level. This interaction is graphically presented in Figure 1. OAAT has been using this systems-driven approach with great success within its programs, and the new Solar Energy Technologies Program (SETP) Manager expressed the desire to develop a similar approach for SETP.

A small group of DOE and National Laboratory staff had spent the previous three months discussing how a systems-driven approach could be developed for the Solar Program. This December 2002 workshop was the first step in introducing the concept to the broader solar community. The group of over 70 stakeholders invited to the workshop included members of the solar industry representing photovoltaics, solar thermal systems, concentrating solar power, and solar researchers from the National Laboratories, universities, and DOE managers. For most, the systems-driven approach was a new concept.

## 1.1. Recommendations

The group's broadest recommendation was to continue meetings on the systems-driven approach to address the technology, analysis and program management issues involved in more detail. They also emphasized that it is important to carefully study the results of this first meeting to identify issues and problems before proceeding. The group emphasized that the systems driven approach has great potential to help clarify and rigorously test the technical and economic rationale of the solar program, to sharply focus program research on issues that will have the most impact, and help build support for the program by making it more transparent and well-defined for industry, the public, researchers and DOE management.

The group also recommended a scoping study of what a systems driven approach for the solar program should include, how to proceed, and to set priorities. This means defining holes in current approaches to analysis, identifying the best modeling practices that should be used, and agreeing on metrics and boundaries for what the systems-driven approach should encompass. The effort should focus on harvesting "low-hanging" fruit first. It is important to make progress and have some early successes before tackling more challenging issues. It would be a mistake to try to implement a comprehensive approach all at once.

To help with this scoping analysis the group also recommended chartering an analysis team that could begin the process of organizing the work required to establish a systems-driven approach, determine data/modeling needs, assess current data and models, and establish benchmarks and milestones for developing and implementing a systems-driven approach to solar program management.

Third, the group recommended collaborating with and engaging industry and other outside stakeholders as much as possible. The solar program needs to benchmark the decision making process they are constructing with standards and approaches used in other industries, like pharmaceuticals. DOE needs to identify what industry is doing in R&D from the early stages, and invite collaboration from the very beginning of the process.

DOE has already begun to implement many of these recommendations. The information and recommendations that resulted from the Systems-Driven Approach to Solar Workshop have shaped the April 2003 Draft Multiyear Technology Plan, and the core of an analysis team has already been assembled and is involved in the multiyear plan process. Another Systems-Driven Approach Workshop was held in April to focus on Inverter R&D. The Solar Program will continue to seek broader industry review and collaboration as tools and models develop--including a solar model like ADVISOR (Advanced Vehicle Simulator) in the near future.

### 1.2. Reactions to Systems-Driven Approach

These recommendations were the product of a workshop that generated a great deal of interest and discussion. The first day included presentations on current solar modeling and analysis activities that might be useful in developing a systems-driven approach to managing the Solar Program. Many of the participants were surprised at the amount of work in progress, and at the advances in modeling and analysis in technology areas outside their specialties. The participants expressed an interest in how analytical approaches and data developed for PV might be useful in concentrating solar power or solar thermal development, and vice-versa.

Also included in the first day's presentations on modeling was an OAAT-developed computer model named ADVISOR. ADVISOR is a key tool in executing OAAT's system-driven approach to its programs. ADVISOR is capable of simulating market requirements and impacts for advanced vehicles, vehicle applications, major vehicle systems and subsystems, and even the current and potential performance of components, materials and processes. The model not only deals with each of these elements of the technology development process, it also simulates the implications of changes at any stage of the process. For example, a new battery system affects the other stages of technology development. Change your choice of battery and the model will simulate what that battery implies for the development of related components, materials and processes as well as how that battery would perform in different vehicle electric systems. The ADVISOR model will also assess the battery's impact on related issues affecting the vehicle's market potential such as the overall weight, performance and cost. The presentation described and demonstrated this capability.

The presentation also showed how ADVISOR provides program managers, researchers and industry with the capability to explore pathways for technology development. ADVISOR calculates the energy, economic and environmental implications of new developments, and identifies critical research pathways necessary in achieving economic and performance goals for new vehicle technologies. While ADVISOR itself is an impressive tool, its potential to improve research program management and explain the logic and value of research investments is even more important. ADVISOR is a tool that can be used to document assumptions and inject logic and structure into research planning. The model cannot make research allocation decisions, but it can illuminate the risks, benefits and alternative approaches to accomplishing research objectives. This type of information is valuable to research program managers who must make decisions and be able to defend them.

It was also clear to the participants that while these modeling and analysis activities were very useful for their specific application, each model was using its own assumptions about solar markets, costs, system definitions, applications and other modeling parameters. The models probably used valid assumptions, but there was no easy way to tell. There were no mechanisms to identify standard assumptions or to red-flag deviations from standard assumptions. Interest in a solar ADVISOR model that could help with coordinating analysis grew. The participants supported the notion of a solar ADVISOR that could translate isolated modeling and analysis into program metrics and data to help guide solar research across technologies, while providing credible justification for continuing specific solar research.

Concerns were raised about how much it would cost to develop a solar ADVISOR model and how much time and other resources would be required. Questions were raised about the dangers of relying exclusively on a model in making research planning decisions. However, these remarks were made in the context of how to develop a systems-driven approach rather than not pursuing it.

### 1.3. Workshop Discussions

The second day was primarily discussion. The participants were divided into four groups focused on solar applications for distributed generation, off-grid, utility-scale and building applications. The groups were then asked to discuss how the systems-driven approach might be applied in each of these application areas. The details of their discussions are captured in the notes that follow this Executive Summary.

### *1.3.1. Emphasis on Understanding Solar Markets*

Great emphasis was placed on improving the understanding of solar markets and using those insights to guide research. This focus on markets is a function of the great diversity of solar technologies, and their multiple potential markets and applications. While solar has a great advantage in its flexibility and modularity, being capable of so many applications -- from central station power to building-integrated energy systems -- makes focusing more difficult. A systems-driven approach could help illuminate common issues in different markets and applications, and help account for these significant differences and commonalities in the technologies' development process.

### *1.3.2. Management and Coordination*

Discussions emphasized the importance of a process for managing and coordinating the development of a systems-driven approach for solar. As the lists of factors to model and issues to consider in developing a systems-driven approach to solar expanded, it was clear that developing a solar ADVISOR model would be a major, complex undertaking. There had to be a place to start the effort, resources, a framework for deciding what to do, and people responsible for moving the effort ahead and reaching milestones in its development.

### *1.3.3. Practical Application*

These discussions highlighted the participant's determination that a systems-driven approach should have practical applications and industry should be involved in its development. Measures of success would include industry's willingness to incorporate their data into a solar ADVISOR model (with strong protections for proprietary information), and to use the models and analysis tools themselves. It should also guide DOE decisions on resource allocation, assist program management, and generate credible program justification; otherwise, it will not be useful.

### *1.3.4. Coordination and Information Sharing*

There was a clear interest in using a systems-driven approach to improve coordination and information sharing between the different solar technologies. There were many areas, especially in market analysis and resource characterization, where the solar technologies should have common assumptions and should be collaborating on common solutions. There are also distinct differences in the technologies that justify separate and distinct research efforts. A systems-driven approach can help clarify both the common interests among the technologies and their differences.

### *1.3.5. Concerns*

While the discussion was mostly positive, there were concerns and cautions expressed by the group as well. Participants recognized that there was a risk that implementing a systems-driven approach to solar program management could spin out of control if it is not carefully planned, monitored and evaluated as it progresses. There are so many possible starting points and such a diversity of interests in markets, applications, systems and subsystems that it seems impossible to try to encompass all of solar into a single solar ADVISOR model. It was suggested that priorities need to be set to determine which elements of a solar ADVISOR model should be developed first, who will be responsible, and how the entire program will be kept abreast of developments.

There were also comments that similar efforts were done before, especially in the early 1980s, and more recently, on a smaller scale within parts of the program. There are existing models and analysis tools that any new approach should work to incorporate and expand.

There were concerns that the value of a systems-driven approach for Solar Program management could be diminished if it is not given support and credibility by Energy Efficiency and Renewable Energy's (EERE) upper management and other organizations like the Energy Information Administration, OMB and Congress. Decision makers outside the solar program will have to believe in the validity of the systems-driven approach and its results for it to be effective at a program level.

A related concern focused on how a systems-driven approach might be used to make resource allocation decisions. Many participants believed that the model had to play a role in resource decisions if it were to be perceived as a credible, valid tool for understanding the technical and economic issues involved in solar development. So, if the Solar Program is unwilling to use the model, why would others give it credibility? On the other hand, some participants were concerned that a systems-driven approach still under development and focused on quantitative outputs could be misleading. Managers could fail to understand that the numbers coming out of the analysis have their limitations. It may be difficult to quantify some factors and to include all factors in the model. Models developed for the systems-driven approach could then be misused. There was no resolution to these concerns, but they were noted.

## 1.4. Follow-Up

The December workshop proved to be the beginning of the effort to create a systems-driven approach for Solar Program management. Immediately after the meeting a group involved in international solar activities convened at the Maritime Institute to discuss the future of international activities. A significant part of their discussion focused on how the systems-driven approach considered for the Solar Program could be used to improve international activities. The group is currently working on a near-term strategy for international activities.

In January a task force of DOE and national laboratory personnel met for a week to begin developing a detailed multi-year program plan for the Solar Program. One of the key elements in the draft plan became implementation of the systems-driven approach. The draft plan discusses resources, mechanisms for coordinating the effort within DOE, and milestones and deliverables required to start development. At DOE headquarters, the task of coordinating development of the systems-driven approach has been assigned to a solar staff person, and the effort is proceeding.

In February the National Center for Photovoltaics (NCPV) Advisory Board was briefed on the workshop and the SETP plans to develop and implement a systems-driven approach, including the development of a solar ADVISOR model. The Board expressed unanimous support for this effort.

In March the results of the workshop and plans for implementing a systems-driven approach were presented at the annual Solar Program Review in Denver. The audience included more representatives from industry, laboratories, and universities. The response from industry was very positive. There was great interest in tools and processes that can make sense of the complex technical and economic issues involved in developing solar energy, and for their potential to be used by industry to accelerate solar development. Some industry representatives openly expressed surprise that a government program was adopting a research planning process that was more typical of industry, and offered to provide information and advice to help in its development.

In April a follow-on workshop was held to focus on the issue of inverter development using the systems-driven approach. The workshop attracted over 60 participants for two days of in-depth discussion of critical issues facing inverter development, and approaches to modeling and understanding the issues to guide research. Further workshops are being planned to focus on energy storage and solar water heating issues.

In conclusion, the concept of a systems-driven approach has sparked a great deal of positive discussion and support. While there are concerns about implementation, cost and timing, these questions are more focused on how a systems-driven approach can be developed rather than on whether it is worth pursuing.

## 2. Day One: Background on Systems Analysis Approach and Existing Tools

### 2.1. Opening Presentation, Raymond Sutula

Dr. Raymond A. Sutula, Program Manager, STEP, opened the Systems-Driven Approach to Solar Workshop by introducing the workshop schedule, objectives, and framework for the systems analysis. The analysis framework involves understanding the relationships and variables that impact solar technology markets, applications, systems, subsystems, components, and materials and processes. Dr. Sutula urged workshop participants to start developing the requirements and specifications for the solar systems framework. He also asked the participants to establish logical steps to achieve measured progress toward a functional systems analysis addressing each element of the framework. Sample inputs, outputs, direct and indirect benefits, and queries that should be answered by the models were discussed. In closing, Dr. Sutula gave a summary of the workshop task at hand: reach consensus on expectations for what a systems approach can/should deliver; develop a basic framework and elements of an effective systems approach; schedule next steps/assignments for starting the process and creating near-term, mid-term and final deliverables.

## 2.2. The ADVISOR Model, Terry Penney

Terry Penney, Technology Manager for the National Renewable Energy Laboratory, followed with his presentation on the systems approach used in the Vehicle Technologies Program. The program's ADVISOR software has 6,000 users and its growth has contributed to its application in component optimization. Early manufacturing design decisions that cause the greatest impact have been improved thanks to the ADVISOR modeling software. Examples of how ADVISOR has been used to troubleshoot issues included: analyzing the effect of auto battery temperatures on air conditioning; SUV tire trouble; and thermal comfort/fuel use predictions. Mr. Penney underlined the importance of validating data. To conclude, he discussed several potential uses of systems analysis in solar/renewable applications including: How does our nation's total solar generation increase over time? Where are the solar collectors? What is the daily variability in those collector areas? Which States are leaders in renewable energy? How can DOE give incentives to States to build more renewable/solar resources?

## 2.3. Concentrating Solar Power Systems Analysis, Henry Price

Henry Price of SunLab (Sandia and NREL partnership), parabolic trough division, gave a presentation on "Concentrating Solar Power Systems Analysis and Implications" in which he discussed the results of a due diligence study that had been conducted on SunLab's CSP program. CSP includes power troughs, power towers, dish engines systems, and concentrator PV. However, the study focused on the parabolic trough power market. The following points were raised: A lot of flat land and good beam radiation is needed for the troughs. Areas in the Southwest would provide the greatest resource potential at 7.0-7.5 kWh/m$^2$/day. Cost reduction of electricity and increased solar value is needed to provide competition with fossil fuel costs (natural gas and coal). This trend can be assisted by CSP's ability to meet peak load requirements. Storage capability and trough/concentrator/receiver improvements were also mentioned as key factors to competitive parabolic trough technology pricing.

Platts Research and Consulting conducted studies of the Southwest natural gas forecast for the due diligence study. Their findings included "strong demand growth for natural gas in the electric power sector." Platts predicted competition from coal prices will be stiff, due to further price drops caused by: "mining productivity enhancements, no growth in coal demand, and air quality constraints that limit developments of new coal power plants."

Mr. Price stressed the need to identify the essential requirements and understand the integrated analysis tools in order to grasp the metrics on which we are basing our decisions. Design optimization and project development with laboratory and industry collaboration is going to be important as will understanding the market and the value of power. A driver for the green power market for renewable energy is technology R&D incentives.

Other economic analysis questions that were raised included: How much are you paying for green power? Although developing countries don't have the money to pay for competitive costs for CSP projects, ESKOM in South Africa, for example, cannot meet their peak load with any other type of power and they may now be the first developer of CSP technologies. Currently, customer payments are based on energy + capacity payments, which might be .02-.03¢/kWh off peak and .06¢/kWh during peak. To be competitive with fossil fuels, .04-.06¢/kWh is the necessary price range. For current trough plants, capacity payments are now based on summer on-peak, added to full capacity payment (+ avg. revenue price) to arrive at .08-.12¢/kWh. In terms of operating costs, they are paying off energy costs, debts, extra return on investment ROI or equity before they see any income.

## 2.4. Zero Energy Buildings, Lew Pratsch

Lew Pratsch of the Department of Energy talked about Zero Energy Buildings and Systems Integration. He said the challenge is to put a package together, lobby Capitol Hill, and engage the building industry. SHEA Homes is marketing houses with solar packages in California; consumers rate solar energy one of the top three reasons they bought their home. SHEA Homes' main concern is their liability because they must make 16 rooftop holes to install the solar panels. Most customers are concerned about any holes in their roofs. Also, in order for major market penetration there must be a positive cash flow on the mortgages.

Mr. Pratsch stressed that marketing is important and industry should try to make solar an "I-have-arrived" status symbol. Since solar is an unusual option that most homes won't have, ZEB can help sell solar in general. Another user-friendlier feature is a new meter that does not spin but is a simple digital meter. Mr. Pratsch emphasized that so far market research is inconclusive; so the industry must be creative. We can't just rely on market research because it only measures attitudes before we have done anything to influence perceptions. For example, helping to place articles in housekeeping magazines and any other influencing outlets could change consumers' views.

## 2.5. PV Models and Tools, Eldon Boes

Eldon Boes spoke about "PV Models and Tools." He stated that good existing models can be asked what is the theoretical maximum efficiency of a structure or device…? Depending on the answer, 2% is not pursued but predictions up to as high as 40% are pursued. Given the material structure, what are the possible costs/$m^2$? Mr. Boes mentioned the importance of having the correct data entered into the model or else output would be incorrect. Discussion of models such as DesignPro and HOMER followed. Market penetration analysis includes three broad areas: On-Grid Large-Scale, On-Grid Small-Scale Distributed-Power, and Off-grid Remote/High-Value.

## 2.6. Solar Thermal Electric Models and Tools, Scott Jones

Scott Jones spoke about "Solar Thermal Electric Models and Tools." He mentioned the potential for impacting energy security with thermo-chemically generated fuels.
Mr. Jones stated that some high risk is alright if a high payoff is of some value to society. Mr. Jones went on to say that to validate the model, you must spend resources at the component system level and be realistic about where you are. Some metrics are hard to quantify like aesthetics, but you still have to keep them in mind. He discussed annual systems performance models and cost models, which are sometimes proprietary (price

information is easier to get). He offered an interesting perspective on the cost of renewable energy plants. He suggested that because of their capital intensive nature they are actually taxed at a higher rate than fossil fuel plants even though fuel is taxed. A level playing field (without incentives) would help renewable energy in this respect.

### 2.7. Solar Systems in Buildings, Craig Christensen

Craig Christensen discussed "Optimizing and Integrating Solar Systems in Buildings." He said that historically, systems analysis meant simple parameters, how systems size affects performance, climate considerations. He looked at TRNSYS and Dview modeling software. He pointed out that they provided a convenient way to switch variables and they have a whole range of formats available. Customers can also scroll through monthly, hourly, daily, yearly projections. For the HVAC system, a PV marginal cost is the optimum goal. Among the questions that were raised from the discussion was if some buildings don't go to zero, what do we do then?

### 2.8. Energy Market Trends, Brandon Owens and Robert Annan

Power, Natural Gas and Coal Market Trends and Industry Issues presentations from Brandon Owens of Platts Research & Consulting and Robert Annan wrapped up the first day of the Systems Analysis Approach to Solar Workshop.

## 3. Day Two: Workshop Breakout Groups

Terry Penney's discussion of the Vehicle Technologies Program underlined the importance of the systems analysis prior to production. Problems can be seen before production and allow early decisions to be changed or improved to ensure their great impact is a favorable one. Bearing this in mind, working groups asked if their modeling and analysis framework is made up of key markets/applications, systems, subsystems, components and materials, how can it improve program management?

### 3.1. Questions a Systems-Driven Approach Should Answer

Participants were divided into four break-out groups. The categories, following market segmentation used in the recent Photovoltaic Industry Roadmap, were Distributed Generation (DG), Off-Grid, Utility-Scale, and Buildings. The working groups responded to the question "What kinds of questions should a systems approach to this sector answer?" Recurring themes for answers given by all the groups included define cost, evaluate performance, locate markets, and plan systems. There were many common issues and themes raised across the subsystem, off-grid, utility-scale and buildings groups. One of the most apparent was an interest in a systems-driven approach capable of answering questions about specific markets and applications – how they are influenced by climate, by competition, and by the value-added benefits of solar. In the utility-scale and distributed generation discussions this translated into defining how solar would compete with wholesale, baseload, intermediate, peaking, firm, non-firm and green power options. Much of the interest was in how the system-driven approach might help in identifying the most promising markets/applications in terms of energy and national priorities, and in turn define the level of costs and performance needed to penetrate the most promising markets. This was one aspect of risk/reward in which people were interested. The more significant the application, the more demanding the requirements; but the greater the reward. There was also interest in both projections and better characterization of current markets and applications.

A common interest across groups was in having a systems-driven approach that could identify the high leverage technical advances needed to expand into key markets. This included gaining an understanding of the intrinsic performance and cost limits to the technology. What would be the theoretical limits of what different technologies can do, as well as the probability of achieving different levels of real performance?

### 3.1.1. Group 1: Distributed Generation

(This section intentionally left blank due to incomplete group input.)

### 3.1.2. Group 2: Off-Grid

Beyond these common themes, the different groups went into much different levels of detail, much of it specific to the sectors they were representing. The off-grid group did the most work on questions for the systems-driven approach, apparently driven by the enormous diversity of the markets and applications grouped together under this heading. The broadest questions were "what are our markets?," and "where will our systems be installed?" The group then raised a number of specific issues:

- Differences in international versus domestic markets;
- The impacts of incentives and "donor-made" markets and how to analyze their implications for achieving sustainable markets;
- Infrastructure required to sustain markets;
- Economic and institutional issues.

Technical aspects of the questions they raised included:

- Low-cost storage;
- Inverter and overall system reliability;
- Backup system configurations;
- How to gather data on all of the diverse applications to explore lessons learned.

They also went a step beyond some of the other groups by considering whether a systems-driven approach should be able to identify what types of resources DOE should be able to provide to support this market. This ability has implications for government's role in technology and market development.

### 3.1.3. Group 3: Utility-Scale

The utility-scale group posed questions with an emphasis on problems of integration with the grid at different levels of penetration. The group was also concerned with complementary storage and control technologies. There was interest in being able to explore the boundaries between distributed generation and large-scale central station generation to determine the potential mix of the two. The group showed interest in the difference in economic drivers for distributed generation versus traditional utility-owned central station configurations as well.

### *3.1.4. Group 4: Buildings*

The buildings group also hoped the systems-driven approach would address some government role issues, particularly how to integrate R&D with deployment and market transformation.  Related questions included what marketing activities are needed to enhance the opportunities for solar and how businesses can make profits from solar systems.

Questions concerning technology integration with building systems and between solar thermal and solar thermal electric systems were also prominent in this group.  In turn those questions were related to the group's interest in getting answers to questions concerning how building applications interact with utility needs, utility pricing of energy, and the importance of educating consumers on the real costs of conventional energy, particularly during peak demand periods.

## 3.2. Key Factors for Markets

Since markets are the first element in the systems analysis framework shown in Figure 1, each working group was asked: "What are the key factors that need to be modeled for markets?" All of the groups emphasized some variation of defining economic value and competitive costs specific to targeted market segments and variations in incentives, market regulation and competition. Most of the groups also mentioned the need to define other values, such as reduced environmental impact, security values, or local economic development. In the discussions the comments were connecting these values to the kinds of information needed to relate solar research and development to national needs.

Another recurring theme was the need for examining which technologies can serve different markets, and under what conditions. These discussions seemed focused on better defining how much the distinct characteristics of concentrator systems, trackers, flat-plate systems, etc… influence their suitability to different applications. Clearly the groups recognized that different solar technologies compete with each other in some markets, and that different characteristics give some technologies a potential advantage in specific markets.

In the context of the systems-driven approach, the groups also suggested factors that in one way or another would connect market conditions to research priorities.

### *3.2.1. Group 1: Distributed Generation*

In addition to the common themes mentioned above, the distributed generation group felt characterizing the situation for central station power plant development was important in defining their markets. The mix of conservation measures, fuels, and availability of power all impact the potential for distributed generation. In addition to mentioning non-economic values that need to be considered, the distributed generation group also emphasized that approaches to motivate and make use of these values to deploy solar will be important factors.

### *3.2.2. Group 2: Off-Grid*

The off-grid group emphasized the need to understand both domestic and international market factors, since a majority of off-grid solar systems are installed overseas. This makes issues such as solar resource availability, market infrastructure, and the geographic location of markets important. Reliability was also identified as an important market factor. By nature, off-grid systems are usually unattended and challenging to service. Financing was also identified as a key factor. Historically the small scale of off-grid systems and the demand for power among the poorest people in the world have made financing mechanisms a very significant issue. Surprisingly, none of the other groups mentioned financing mechanisms as a specific factor, although it is certainly important to the cost and deployment issues raised by all four groups. Off-grid markets have some unique factors, such as the role of solar in humanitarian aid and how illiteracy and poverty influence the ability of target consumers to take advantage of solar.

#### *3.2.3. Group 3: Utility-Scale*

Regulatory issues, including technical standards to deal with islanding, utility restructuring, and how distributed generation is treated were important for the utility-scale group. Utility restructuring has created ambiguities in the electricity market and has changed some of the likely customers for solar technology and their reasons for purchasing it. Separation of transmission, distribution and generation creates three very different potential customers, while markets that are opening to distributed generation are adding end-users as potential customers for utility-scale generation.

There was a lot of discussion of the need to understand distributed generation and its implications for the utility market in terms of how different penetration rates might impact system stability, the relationships between customer-sited and utility-sited systems, and the results of the competition among so many competing distributed generation options. There was also concern with incentives. First, understanding how effective different incentives might be, and second, understanding whether or how much different incentives eventually lead to sustainable markets without subsidies. Regional variations, and even variations from one utility to another within a single state, are important for understanding utility-sector markets.

#### *3.2.4. Group 4: Buildings*

In the buildings sector there was more focus on the factors that impact solar value. Cost is a more complex issue, since many homebuyers have little concept of what levelized energy costs are, or what they should be. There has been so little experience that there is still debate over what cost metric is most important for market penetration -- $/W, payback period, cents/kWh, first cost, etc… Aesthetics, consumer acceptance (for both initial sales and resale) and maintenance were also identified as significant factors. Variations in climate and in regional building preferences also need to be factored into market analyses. While individual building systems tend to be small-scale, when considering a builder or a subdivision the number of systems multiplies. For buildings it is important to factor in how scale and volume affect installed costs.

### 3.3. Key Factors for Applications of Solar Technology

The second element in the systems analysis framework is applications, so the groups were asked: "What are the key factors that need to be modeled for the applications of solar technology in each market?" Recurring themes given by the four groups included the ability to plan and configure systems to match market needs, determining how policies, regulations and consumer interests interact in determining supply and demand, and factors for managing system costs for applications.

#### *3.3.1. Group 1: Distributed Generation*

Much of the discussion focused on aspects of cost and marketing that would impact solar distributed generation – for example understanding levelized energy cost, internal rate of return, capacity factor and other elements that will make distributed solar competitive without incentives. Beyond economic costs, what are the other value characteristics of CSP and PV, separately or combined, which can support solar applications in the U.S.

market? For example, how important is dispatchable, firm power for the U.S. market? Since political decisions (i.e., incentives and regulatory policies) are currently driving wider deployment, how can they be maximized to aid technology development and deployment? From another perspective, the group was concerned with what is needed to "level" the playing field between solar and conventional technologies –what are the most important issues in the current energy system that work against solar applications?

There are also different investors and customers for distributed generation, so it is important to understand cost, capacity, dispatchability, reliability and financing from their different viewpoints. These issues have different significance for different customers/stakeholders. There are also significant differences between investor-owned utilities, public utilities, rural cooperatives, and independent power producers on the utility side of the meter. For a utility, understanding the connection between their generating dispatch and solar's impact on the demand curve they serve is important. The subprogram needs to understand the conditions required for solar energy to serve peaking needs, intermediate and even bulk power requirements. Residential consumers may be more driven by the potential for uninterruptible power, reducing electric bills, or a combination of factors. There are differences between urban and rural utilities and the consumers that impact the potential for different solar distributed generation applications. Basically, there needs to be analysis that shows which factors and application are most important in order for solar to penetrate U.S. markets in a significant way.

Distributed generation is also an international market, and understanding factors such as the solar resource and the value of reliability and freedom from the grid need to be evaluated to determine the potential for different applications. It was suggested that there needs to be a mapping of solar applications against non-kWh values and resource characteristics to focus on the most promising applications and locations.

From an investor point of view, the group discussed what level of demonstration and technical assurance is necessary to reduce their perceived risk and encourage investment in both applications of solar and the solar industry. Different financing vehicles need to be understood and analyzed as well, including state and municipal bonds, private debt financing, utility debt financing, and loans from agencies like the Rural Utility Service. For applications, there was also concern with examining where new module manufacturing capacity will come from – besides Japan. This conversation was mainly focused on recognizing that manufacturing will locate closer to markets over time, which will probably mean production expansion in the developing countries.

There was considerable discussion of how to model and understand the chicken-and-egg dilemma facing solar technology – how much capacity/volume will be needed to bring down costs, and in turn how much do costs have to come down to generate the levels of demand needed to support expanded capacity and volume?

The group was also interested in factors that would help define technical issues and focus R&D investments. This starts with defining the current state of the technology in terms of performance, cost, reliability and operation and maintenance. Then it is necessary to project into the future to understand what factors are required to penetrate U.S. markets. Technical factors related to the impacts of large-scale market penetration are also important, including implications for transmission constraints, resource characteristics in relation to utility dispatch and operating plans, utility control, and other utility integration issues.

System characteristics and how they impact applications and markets was another focus. System sizes may vary considerably depending on whether systems are located on the customer side of the meter, or on the utility side. Utilities can justify megawatts of power. Consumer applications can range from watts to kW to MW depending on the nature of their demand. Water availability is important for some solar thermal systems. Land area, available rooftop space, and other siting factors are important to defining the potential for different solar applications. Looking to the future, there are characteristics of cost, location and operation that will influence the potential for solar to generate hydrogen, become integrated into building structures, operate as a hybrid with other technologies, for desalination, or to improve non-energy values such as security enhancement.

### *3.3.2. Group 2: Off-Grid*

The off-grid group started by listing some of the applications that need to be modeled, including:

- Telecommunications;
- Water Pumping;
- Signals;
- Sensors;
- Lights;
- Consumer Home Power;
- Village Power;
- Education;
- Refrigeration;
- Water Purification;
- Water Heating;
- Cooking;
- Entertainment;
- Irrigation, Cathodic Protection, Remote Signs; and
- Environmental Monitoring.

Factors to be modeled included:

- Siting and Meteorology (including solar resources relative to market location);
- Reliability;
- Funding Mechanisms;
- System Sizing;
- Lifetime;
- Usage Patterns, Typical Load Profiles;

- Special Characteristics (e.g. reliability, voltage, ac/dc);
- Characteristics of Productive Users, including National Parks, Military, etc.
- Size of Application Area.

### 3.3.3. Group 3: Utility-Scale

For the Utility-Scale group, the application of solar in distributed generation was a key factor because it is necessary to understand the combination of distributed generation and large-scale applications. A systems-driven approach also needs to focus on defining the application features that customers value most. This includes cost-competitiveness for different customers and applications as well as whether it is retail versus wholesale.

Other very basic information is needed on the solar resource and the cost and performance of different solar technologies by applications. In some applications storage could be a factor, and/or load management strategies that can deliver some of the same value as storage. Tradeoffs between standardization versus customization of systems for applications should be something a systems-driven approach can explore. Just how standardized can equipment be for different applications, and what is the optimum level of customization in equipment and settings?

From a utility perspective, optimization of applications with the grid will be important. The potential for stand-alone systems was also mentioned in cases where a utility might want to supply solar as an independent source of power as an alternative to grid connection.

Finally, the group mentioned understanding policy drivers as an important factor.

### 3.3.4. Group 4: Buildings

The buildings group focused on many factors unique to the buildings sector: energy usage in buildings by location; architectural and building trends; regional economic and population growth; building types, size, climates, and operating practices; aesthetics; housing/building turnover rates; variability in the solar resource in relation to housing stocks; new versus retrofit opportunities in the buildings sector; and the diversity of the housing market.

Like many other groups they also noted that there are both international and domestic applications that have different characteristics.

Compared to other groups there was a lot of emphasis on financing, regulatory and other barriers. Tax incentives and financing in building applications is very different because they are part of financing and building a home or building which has its own practices and its own expectations as far as first costs, return on investment, and other financial indicators. Building applications are also constrained by building codes, zoning, insurance requirements, and safety requirements. There is little experience with insurance claims and risks surrounding solar applications in buildings, that technology developers, builders and consumers will need to understand.

Building-integrated solar applications also become part of building systems, so understanding the costs/benefits of different combinations of energy efficiency and solar energy applications is important. Maximizing less expensive efficiency measures can help downsize solar systems, thus reducing first costs, for example.

Solar has made limited inroads into buildings, so there is still much analysis to perform on the impact consumer awareness and marketing might have on solar applications. This includes what really motivates customers to want solar energy. Cost is only one element, and levelized energy cost may not be as important as first cost. Other factors that should be looked at include consumer sensitivity to loss of power, security, environmentalism, prestige, and other values. The point was made that it is hard to gauge potential demand because to some extent decision makers in the buildings market hardly know solar energy exists, so it is hard to tell how much they may want it once they are informed.

Different types of buildings and building owners also have different capabilities/ infrastructure for service and maintenance that should influence technology and the design of applications in the buildings sector. A related issue is the degree to which technology is really ready for different applications in the buildings sector, and the key factors that will influence acceptance by both builders and consumers. Different approaches to service, maintenance and payment need to be examined.

## 3.4. Key Factors in Modeling Systems

The third element of the framework is the systems that make the technology work. The groups were asked: "what are the key factors that need to be modeled for these systems?" Common themes were cost variables, system lifetime and reliability, O&M, tradeoffs between cost and performance, and the need for information to help in systems planning (sizing, interactions with other systems, simulation).

### *3.4.1. Group 1: Distributed Generation*

The group began by discussing factors that would help define what could be expected of systems – is it reasonable to expect a 3 kW system with a 10-year lifetime? What are the tradeoffs in reliability, cost, lifetime, and system size? Dispatchability is also related to cost and size.

Another set of modeling factors focused on efficiency. What are the losses/issues raised by putting components into systems? Could the DC output from fuel cells/PV be complementary? Could both complement DC transmission?

For different systems, there also needs to be an examination of the factors that make up the critical path for reaching competitiveness. In addition to knowing which components need to be analyzed, there needs to be a way to identify which are the most critical elements. Then the variations need to be characterized by their influence on annual system performance, seasonal and daily variations in performance, capital and operation and maintenance costs, scheduled and unscheduled outages, reliability and lifetime, today and in the future.

There also needs to be more detail on cost factors, for example, how they might be influenced by system size, standardization of components, the impacts of variations in local labor rates, and transportation costs.

Finally, systems need to be examined for vulnerabilities. For example, how vulnerable are they to attack, theft or vandalism and to events on the system grid?

#### *3.4.2. Group 2: Off-Grid*

This group emphasized the need to understand and meet changing user needs. There is a need to explore what the next generation of systems should be. This includes modeling the application-specific performance characteristics of systems – efficiency, reliability, life-cycle costs, and maintenance under the conditions they will face in current and emerging applications.

Second, systems need to be serviced so factors such as replacement part availability, service procedures, maintenance contracts, and training are important.

Off-grid applications often involve integration with other equipment such as water pumps, stills, crop dryers, hot water systems, and electrical storage that need to be understood to predict the reliability and performance of PV as part of the system. Consumers are interested in these solutions more than they are in the PV system which is only the power supply for the equipment. There are tradeoffs in module selection, system design, tracking and control all of which need to be understood in order to determine whether solar is even the best solution. In some cases solar needs to be considered in the context of a hybrid system to determine what is the optimal/holistic best design solution.

The impact of standardization of packaging, of codes and standards, and even the business infrastructure used to finance, sell, deliver and service systems is an important factor. There are also institutional issues in the way such as aid agencies, governments, and how different markets operate that need to be understood in order to optimize design.

Finally there needs to be data and metrics to identify successful configurations and applications, and to provide information on field reliability and performance to guide innovation. The use of satellite/internet communication with remote areas is both a potentially attractive application and a means to improve data collection and service of systems in the field.

#### *3.4.3. Group 3: Utility-Scale*

System interactions/synergies with the utility grid and with systems that provide heat and power, HVAC and other services to customers are important to understand, particularly to identify added benefits of solar. Basic information is also needed on cost, size, efficiency, lifetime, power quality and reliability in real applications. Both current and futuristic ideas like using solar to generate hydrogen for fuel cell cars, or supplying power back to the grid.

The factors that are modeled need to be able to provide sensitivity analyses of system performance and applications – for example what is the potential to reduce energy consumption in a building to make applications of solar more affordable on a first-cost basis? There should also be an exploration of how solar thermal systems could displace electricity. How are they similar or complementary to distributed generation? Are there advantages to solar thermal generation in particular applications; for example, the fact that they don't need inverters? What is the value of solar modularity and scale in a utility setting?

#### *3.4.4. Group 4: Buildings*

The emphasis in the buildings groups was on factors that define solar's role as part of a building system. They were interested in tradeoffs between solar and alternative or conventional technologies. They wanted to be able to explore options for simplifying systems, increasing reliability, and understanding aesthetics. They also believed that system efficiencies needed to be understood in the context of specific applications in a building, and how solar could impact building responses to changes in the utility grid or other energy supplies brought to the building. Whole building simulation programs are needed to facilitate modeling of all reasonable combinations of systems, and determine the levelized cost of energy, operation and maintenance, and other economic indicators for solar systems in building applications. They should also help with design, analysis of functionality, performance and safety.

### 3.5. Key Factors for Subsystems

The fourth element in the framework for the systems driven approach is subsystems. Each of the groups was asked: "What are the key factors that need to be modeled for the subsystems that make the technology work?" The majority of participants in all four groups mentioned loads, storage and maintenance, costs, subsystem integration, control systems and mean-time-between-failures (MTBF) as key factors.

#### *3.5.1. Group 1: Distributed Generation*

The distributed generation group felt there needed to be a definition of subsystems. Especially subsystems common to different systems and applications in order to investigate the implications of standardization/scale, performance versus costs, different materials, component design; equipment degradation/loss of performance, and interchangeability. Component interaction and off-design performance are also important in helping to identify weak links in subsystems, understand failure modes, examine which components can be certified to what levels of performance, and MTBF for components.

#### *3.5.2. Group 2: Off-Grid*

The off-grid group was also interested in interactions among subsystems, and particularly compatability between different subsystems because of the importance of modularity and matching with other equipment found in off-grid markets. Reliability is a top concern, and therefore understanding the durability of subsystems relative to the location of the installation (far or near to service). Off-grid subsystems also need to be understood in terms of how they affect installation, respond to load situations, interact with storage, and impact maintenance and monitoring.

It is important to understand the value and characterization of trouble-free and autonomous operation. When interacting with loads and other equipment, efficiency needs to be understood as overall energy efficiency when in use. Key subsystems to understand are:

- Solar Thermal Collectors/ Pumps and Heat Exchangers;
- Integrated Battery/Charge Controllers;
- Hydrogen Production, and Other Forms of Potentially Low-Cost storage;
- Pumps;
- Vaccine Refrigerators;
- Lights; and
- Signs.

Because storage is common with off-grid systems, understanding storage service and maintenance is essential. Service is also problematic, so analysis of failure modes and MTBF are especially valuable, along with availability of local components and service infrastructure.

Ideally a systems-driven approach should help identify potential opportunities, quantify the value and benefits of cross-technology subsystem collaborative development, and help characterize reliability and cost so that intelligent R&D decisions can be made concerning costs, cost tradeoffs, and certification of systems.

#### *3.5.3. Group 3: Utility-Scale*

The utility-scale group emphasized the following factors:

- Reliability;
- Durability;
- Cost;
- Manufacturability;
- Aesthetics;
- Material minimization;
- Structural loads;
- Definition of Appropriate Storage; and
- Characterization/Rank Value of Subsystem, Performance/Optimal Characteristics.

There are a number of applications/markets that more advanced computer and communications systems could support, including control systems/functions, combined generation, monitoring of system efficiency, and systems integration with other applications.

#### *3.5.4. Group 4: Buildings*

The buildings group emphasized the need for subsystem integration, understanding implications for utility interconnection, and the need for control systems (programmable and smart). Buildings also involve mounting subsystems for building integration, and interconnection of PV modules. There needs to be adequate data to determine the cost impact of each subsystem, intelligent systems that can communicate and possibly even diagnose their own faults, good installation guidelines, and an improved interface/integration with conventional systems.

## 3.6. Key Factors for Components

The fifth element of the systems analysis framework is components. Each group was asked: "What are the key factors that need to be modeled for the key components that comprise systems?" The recurring themes in the answers from the four groups were cost, reliability, failure mode analysis, and inverter and battery dynamics.

### *3.6.1. Group 1: Distributed Generation*

The distributed generation group started with a question as to whether it is reasonable to expect a design environment where all components survive 10 years before failure. This raised the issue of being able to factor in disposable/reprogrammable components and how to analyze this complexity in terms of its implications for performance, cost and reliability. Component performance is also a function of irradiance, spectrum, temperature, tracking mode, location, weather/climate, and wind speed.

Technology projections for thin-films, crystalline silicon and III-V materials are also important. To understand implications for market growth, factors such as lead time for construction or manufacture need to be analyzed.

Reliability indicators may need to be more complex than MTBF, exploring concepts such as mean time to repair, failure modes, effects on other components, and the impact of redundancy. What are the tradeoffs in cost versus reliability for different design approaches? Not all components simply fail. There needs to be an understanding of the difference between ultimate wear-out and replacement, versus partial failure/degradation, and the impacts on other components. Understanding these factors will influence the design of warranties, certification, performance validation, failure mode analysis, financing, cost to repair, and the degree to which industry adopts built-in redundancy.

Understanding the manufacturing inputs, transportation issues (for moving by truck or rail) versus manufacturing on site is important in defining the optimal production situation for components. In manufacturing there are also issues of safety, energy consumption, water use, and environmental emissions.

### *3.6.2. Group 2: Off-Grid*

The off-grid group focused first on the components they thought were most important to analyze:

- Inverters (performance, certification);
- Water pumps;
- Components for village power systems;
- Storage/controllers;

- Monitoring and diagnostic systems;
- Battery chargers;
- Module packaging;
- Distributed Generation-seals;
- Substrates (glass and glass substitutes);
- Cell and module interconnects (particularly for thin-films);
- Power electronics components;
- Max power trackers;
- Blocking diodes; and
- Glazing/frames.

Key factors to analyze are inverter performance, reliability, costs of components, the potential for cross-technology component application and collaborative development, and appropriate codes and standards. There are also tradeoffs in component quality versus availability in off-grid applications. For example, what is the tradeoff between the benefit of having a local supplier of batteries or other components, versus having higher quality components from sources that are less accessible? Components also need to be considered in terms of whether they are appropriate to the application and level of service that is available. A programmable component may not be desirable if there is no one available to program or service it.

### *3.6.3. Group 3: Utility-Scale*

The utility group noted that most of the factors mentioned for subsystems also applied to components. They did add that temperature, voltage/current stress, and mechanical stress are factors that could be important to model. The potential for technology cross-pollination with off-the-shelf technologies used in other applications (industrial, distributed generation, appliances) should be explored. There should also be an examination of "failure links" for applications – what series of events tend to trigger failures, particularly in the area of inverter dynamics, interconnects, and component cycling. There should be an ability to model subsystem-specific characteristics, failure rates, ways to bundle and reduce the number of components, and analyze the interactions among size, cost, and manufacturability, particularly for the power conversion unit.

### *3.6.4. Group 4: Buildings*

The buildings group was the only group to mention developing a complete model of solar radiance and its influence on solar equipment performance. They also listed the components they thought were most important to analyze:

- PV converters;
- Mounting;
- Power conditioners;
- Solar thermal heat exchangers, and
- Solar lighting.

They were interested in understanding the economies of scale involved in component manufacture, as well as specific details on operating processes and materials, components and the building interface with solar energy systems, including how it affects aesthetics.

## 3.7. Key Factors in Materials and Processes

The sixth element of the framework is the materials and processes that produce components. Each group was asked: "What are the key factors that need to be modeled for these materials and processes?" Common responses were thin-film production, improved PV materials, solar system performance prediction, and process mapping.

### *3.7.1. Group 1: Distributed Generation*

The distributed generation group ran out of time before they could address these factors.

### *3.7.2. Group 2: Off-Grid*

This group was interested in examining standardization of processes, and standardization of design and installation. Other materials and processes of concern were solar cell materials (crystalline silicon, polycrystalline silicon, amorphous silicon cadmium-telluride, copper-indium diselenide, organic cells and other novel materials); and materials in electronic devices used in solar systems.

Other factors of interest were the quality of systems manufacturing, thin-film deposition techniques, thin-film cell design, and thin-film manufacturing. Semiconductor opto-electronic properties and ranges of acceptable properties were also discussed. Other factors include improved manufacturing to reduce costs, improved battery charge controllers, longer material lifetime and reliability, improved battery chemistry, expanded module options, and the adaptability of different processes and materials to local support and local supply.

### *3.7.3. Group 3: Utility-Scale*

The utility-scale group ran out of time before it could address materials and processes.

### *3.7.4. Group 4: Buildings*

The materials group was concerned with information on the durability and reliability of materials in the built environment. They were also interested in better resources for industry (tools and resources in industry that will lower cost of materials), better access to lab resources, in order for them to adopt new materials, and provide feedback to research and development.

For the buildings group it was important to understand the physics of materials, the energy required to produce the materials/run the processes, environmental factors, material availability, recyclability, and the fire resistance of the final materials. Modeling should include individual process steps, the ability to project long-term performance from short-term tests/modeling considerations, and the integration of all models through objective function/tradeoff analysis (models should be able to deal with multiple constraints). Materials and processes also need to be examined in the context of building codes and standards, basic material costs, and tradeoffs between performance and cost.

## 3.8. Existing Models

The next questions asked were: "What existing models address some or all of these factors? How much and what types of data will be needed? What is the best approach to modeling this sector? What element should receive the highest priority?" In summary, each working group was able to name an existing model or models for their particular market. Every group mentioned the importance of validated data in using the models as well as the customer's willingness to pay the data costs. There was no single best approach or model identified and the highest priority was given to the information the models would provide about the markets.

### *3.8.1. Group 1: Distributed Generation*

Models:

- EPRI TAG
- HOMER (under development);
- Utility system models with renewable energy capability:
  - PROMOD,
  - Power World,
  - Dynastore,
  - IV Tracer,
  - Design PRO.

*How much and what types of data will be needed?*

Disposal costs, green power data—willingness to pay, externalities—monetization resource assessment, better idea of performance data—components, characterizations—especially materials, validated data—real world terrestrial, O&M data.

### *3.8.2. Group 2: Off-Grid*

Models:

- HOMER,
- PVFORM,
- PV Design Pro,
- PV Grid,
- TRANSYS,
- F-CHART,
- PVWatts,
- IVCURVETRACER,
- NSOL,
- SIZE PV,
- ENERGYGAUGE USA (Building Model),
- RAPS (PV-CAD, Sizing tools, Design Optimization, Experts)

The group recommended that the approach should be to attack system integration issues, and build models on surveying field results and lessons learned. Long-term modeling requires better market analysis (including understanding the current and future competition); understanding international regulations and standards/challenges, and analyzing international programs. The effort should incorporate the results of European studies, and take advantage of information from the Global Village Energy Partnership (GVEP).

### 3.8.3. Group 3: Utility-Scale

Models:

- REPI,
- Clean Power Estimator;
- Grid-Interaction Models at the System level.

*How much and what types of data will be needed?*

Solar resource/weather, demographics/preferences, financials, comp inverter efficiency Reliability/O+N Data (detailed), workforce housing stock, geographic distribution of power loads.

*What element should receive the highest priority?*

Markets. There need to be links between systems and markets and technology requirements. Industry can't afford to build the models, or invest in a total system for examining markets and testing sensitivities like understanding differences among technologies. The model(s) need to illuminate how technologies develop in markets. They also need to support decision making tools, examine the implications of decisions, and perform risk analysis. To do that they need to incorporate an understanding of how companies invest in technology. To start, the models need to address the present, then move into mid- and long-term projection.

### 3.8.4. Group 4: Buildings

Over 200 Existing Models:

- Energy 10,
- Energy USA,
- LEEDS,
- Building performance models,
- TRNSYS,
- EnergyPlus

*How much and what types of data will be needed?*

Information that will be needed includes interface of design tools, validated real world data for performance O&M and lifetime, market preference data, weather data (TMY) detailed, energy use patterns by buildings: including type, size and climate, databases/capitalization opportunities, validation data for our models, failure rate data, component cost data (raw material versus manufacturer's costs), whole building systems integration data, and data on size of Green and Early adopter market. We'll also need to know who wants the data, who is the end user of model and for what purpose? Likewise, end user and cost effectiveness of R&D data as well as occupant satisfaction data will be useful.

*What is the best approach to modeling this sector?*

No single model is adequate for all needs. The best approach should address all factors. Important issues include establishing the size of particular market niches, being able to handle technical parameters to generate measures of:

- Cost effectiveness,
- Risk and reliability,
- Aesthetics/features,
- Estimates of penetration and impact.

The model(s) should link market factors, environmental issues and other elements to create a broad scope diffusion model. The issue is what is the best system model we can create for the least amount of money. Design tools are needed for performance analysis, economics, energy and financial savings. To succeed the models will need builder input and involvement. There also needs to be high level model/decision tools that interface with system and component models. Models need to be validated by data (market information), and account for policy issues. The models will need flexible inputs and outputs for multilevel materials and manufacturer optimization.

*What element should receive the highest priority?*
The most important element is the ability to rank R&D by energy savings, time and cost to complete. The systems driven approach should be able to move from the market to materials and integrate each element, using knowledge of markets and opportunities within those markets for development of a solar ADVISOR model and integrated tool kit for the program and industry.

## 3.9. Most Important Technology Pathways to Start Modeling

| Response Group→ | Distributed Generation | Off-Grid | Utility-Scale | Buildings |
|---|---|---|---|---|
| | | | | |
| Distributed Generation | Quantified/Modeled benefits of Distributed Generation (DG)—also impacts Utility rate modeling and the use of them by customer Unintended islanding issue—Technical and marketing barrier- Impacts of benefit in energy security<br>Is net metering really of any value?—Other incentives DG T&D costs—better handle on future- What is value of DG on that?—DG benefits—Business model to get pay for those validating and quantifying—No NIMBY Financial models for DG-Virtual utility Coordinated Who pays for benefits Storage technology & value (also utility) Makes solar dispatchable DG in homeland security and grid reliability Intermittency—what are real issues/impacts?—Wind example (see Amory Louins) More work on peak shaving value | Develop a 10% model for cost reduction @500MW ($.060/W)[Applies to all technology pathways for PV), Customer Value [Applies to all], Cost competitions (for DG: regulatory issues) [Applies to all], System Reliability[Applies to all], Grid Topology/islanding, Systems model, High-penetration and grid stability, System Reliability, Market infrastructure readiness, System integration and design, Grid optimization through DG, Grid and generation options, Lifetime cost of PV energy, Zero energy community (productive). | Most important part to start modeling? Business model investors? Utility actors BK DG-look Utility-Scale, Hybrids, Markets and how they change, Configurations, Combine value streams?, Utility/consumer Transmission deferral Resource assessment Grid interactions Continuity of RPSs (policy env.), Load center opps. (city centers), hi value power opps, interactions with other techs (ie transportation) | -Systems cost as a function of subsystems interconnections and control<br>-Cost, etc. versus time metrics with benchmarks |
| Off-Grid | Storage Performance modeling is totally different Very detailed reliability and O&M cost New applications/ expanded—hydrogen, urban, water pumping, PC lighting Hybrids, Village power Wireless 3rd world, Installer education | Develop a 10% model for cost reduction @500MW ($.060/W) [Applies to all technology pathways for PV), Customer Value [Applies to all], Cost competitions (for DG: regulatory issues) [Applies to all], System Reliability [Applies to all], System Optimization/ integration, High-penetration and grid stability, Market analysis, Village power / hybrids, Local Business infrastructure, Suitability of design versus load, Direct drive issues, Financing value chain Sizing of systems, ID Markets Standardized or prepackaged systems (turnkey operations) | | -Systems performance including reliability<br>-Cost, etc. versus time metric with benchmarks |
| Utility-Scale | Develop advisor equivalent to point out weakest link<br>Identify the targets of opportunity w/ positive C/B Use model to identify<br>Road blocks to performance & cost Tech. Pathway—have we optimized systems & components for utility systems First-cost/Lec Model Market—value, not just cost Connection of market to tech. Pathway Technology—BOS issues inverters/trackers Validating performance, validating | Develop a 10% model for cost reduction @500MW ($.060/W)[Applies to all technology pathways for PV),<br>Customer Value [Applies to all],<br>Cost competitions (for DG: regulatory issues) [Applies to all], System Reliability [Applies to all] Life cycle costing (levelized energy costs), System integration, Codes and standards, Subsidies and financing, Load demand matching, >100MW systems, PV use in existing models, Performance vs load vs | CSP technology (conc pv) versus flatplate PV models trade-off, Hybrids, Business models (tax/finance/etc.), Utility involvement, Interaction with the grid (real grids), Storage, Utility rate structure, GIS/ transmission grids, Environ benefits, Business risk, Distributed versus central, If distributed takes off, capacity left for central plants? | -Levelized energy costs as an ftn. of the system (business decisions)<br>-How addition of opportunities will improve service<br>-Cost versus time metrics with benchmarks<br>-Contributions to RPS, net revenue neutral or profit centered<br>-Financing |

| Response Group→ | Distributed Generation | Off-Grid | Utility-Scale | Buildings |
|---|---|---|---|---|
| | | | | |
| Utility-Scale cont'd | reliability Lack of uniform approaches in components Degree of penetration to impact real benefits—tipping points- jobs/env. System Establish what are the tech. Characteristics to impact utility, as a guide to R & D Minimum—R & D $ impacts—on mkt, benefits, probability of success, timeline Balance among, near, mid, long-term—systems approach adaptable to each benefits/costs—for example PV produced without vacuum All areas Basic power system model Off ramps Find out WAAT utilities need to do renewables. Inverter reliability Solar thermal focus on utility markets | cost, Value and benefits of Utility-Scale vs DG, Shareholder Value, Storage, Islanding, Storage, Reliability, Performance Indexing, Grid impact | | |
| Buildings | Replacement of building parties, Building-integration of components Certs, codes, practitioner certs Rate modeling Optimize EE and PV in DG Market modeling<br>Totally different benefits to quantify Non-quantif. Benefits —hesthetics The near-zero energy building Trade offs between solar and albedo. Orientation of PV/ Solar thermal—what is population of useable roofs Modeling development of infrastructure—analyze size of apps and the businesses/trades they impact<br>For solar thermal—CHP—How big, will solar be accepted | Develop a 10% model for cost reduction @500MW ($.060/W)[Applies to all technology pathways for PV), Customer Value [Applies to all], Cost competitions (for DG: regulatory issues) [Applies to all], System Reliability [Applies to all] Life cycle costing (levelized energy costs), Friendly integrated systems design, Overall building system model, Cost benefit, Outreach to building industry (marketing tools), Retrofit, Demographics (types, location), Resource modeling, Policy zoning issues, Integration, Green pricing/ financing, Smart building (automated), UPS for building (Uninterruptible power supply),<br>Utility peaking effects,<br>Enhanced models to include all value attributes, Education models, Models for low cost solar, Code compliance and certification | Buildings Most imp.? Craig Christensen stuff… continue Model the building as a system whole building approach, Retrofit options, Market size (retrofit cycle) analysis-new and retrofits, Land-use planning, Aesthetic codes, Passive arch mods, DOE integration, Interaction with tech and R&D models | Building element, Energy cost and social benefits, Perceived benefit market barriers, SHW, Incorporating existing energy modeling software, Cost, etc. and metric with benchmark |

## 3.10. Obstacles to System-Driven Approach

All of the groups were asked: "What is the biggest obstacle to developing an effective systems analysis approach to managing the solar program?" The recurring theme in the answers included setting priorities, risk analysis, and impact considerations.

### *3.10.1. Group 1: Distributed Generation*

The distributed generation group was concerned that there is a lack of consensus on assumptions/data. Behind some of those issues are proprietary concerns involved in industry actually sharing data and information. Establishing the systems-driven approach will also take time, money, and especially for distributed generation, utility interest. The technology stove pipes – PV, CSP and Solar Buildings are an impediment, because there are real differences in the technology, and organizationally they have operated separately. There is a real risk of information overload – it is easy to try and become too detailed. For example, CSP needs detailed resource data for project development, which could involve adaptation of satellite data, improving resolution—the problem is how detailed can you get? How detailed do you want to? National impacts? Local impacts? Design?

There is also the problem of modelling intangibles—how can the approach deal with issues like public perception and aesthetics. There is also difficulty in developing market/ customer models, in applications that are new and consumers have little information to provide feedback. Implementing the approach could also be threatening because there is a zero sum game for funds—the implications of model results for budget means there will be political concerns and responses. Based on this, industry reaction could be a problem – the PV and CSP industries are quite different, and then there are many other players in distributed generation as well in fuel cells and microturbines.

### *3.10.2. Group 2: Off-Grid*

The off-grid groups first concern was how to prioritize the elements of the systems-driven approach. Basically, where should it start? DOE will need to make a long-term commitment of resources, something that is always difficult to sustain. Whatever is implemented should avoid re-inventing the wheel – it should use analysis and information that has already been developed.

There is inertia in existing efforts. Assignment of lead roles/responsibilities have been made and to the extent this might change that status quo there will be friction. Managers will need to be made accountable for results of implementing the approach, and the approach has implications for producing metrics that could make managers uncomfortable because their performance will be reflected in the analysis. There is also a conflict in balancing public will, which supports solar energy, versus Administration concerns which consider solar energy as just one element of the entire energy strategy. Building expectations too high needs to be avoided, because there is a level of intractable uncertainty that analysis will not be able to completely overcome, particularly in trying to understand the market with a technology and applications that have a short track record. Stakeholders will have to learn to accept the output of analysis, good and bad. The approach will need to balance long-term research versus immediate needs. It is important to avoid optimistic analysis that leads to premature commercialization. It will be a challenge to balance all of these factors and produce alignment with private sector, some definition of acceptable risk levels, arrive at optimized solutions, and in the process create credible metrics and data.

### *3.10.3. Group 3: Utility-Scale*

Politics was the first item on the list of obstacles from the utility-scale group. There is also a lack of hard data in many areas, and stovepiping that impedes communication and collaboration between technologies. Funding for the analysis will be a problem because research funds are limited. Funding and other obstacles will be even more formidable if the system-driven approach lacks a compelling business case, or fails to win buy-in and credibility from industry and other stakeholders. Getting the model started is one challenge, but then continuing to improve and update it as situations change will be a hurdle. It will need to produce compelling and effective risk analysis, and show that it is a reliable model capable of reducing uncertainty. The other big challenge is in how the process will be used – will management be willing to use it to take an honest, hard look at costs, reliability and technology data and make decisions about good and bad technology investments?

### *3.10.4. Group 4: Buildings*

The buildings group saw developing reliable and realistic impact parameters while technology is still in the R&D stages as the first obstacle – can the process help identify and avoid over-optimism? Development will be challenged by a lack of validated O&M data, by the diversity of systems and markets that need to be considered, and the time required to develop and implement a credible analysis framework. It will also be facing a set of existing program beneficiaries who will resist change. In PV there is a lack of system-level cost models for PV that deal with both its up sides and down sides. DOE should beware of publishing cost expectations—prices are not costs, and DOE can create consumer expectations that manufacturers cannot meet. There is also a basic lack of technology characterizations (cost performance versus time) for technologies. There will need to be a critical mass of funding support for the effort, and a consensus on what modeling approach to use. Identifying industry needs will be a hurdle, as well as identifying mechanical and electrical systems of the future – the technology that solar will integrate with in buildings is changing as quickly as solar technology. The approach also has no way of dealing with the lack of a stimulating policy/vision for where solar should go in buildings, which could change the status quo of consumer and business expectations. Does the systems-driven approach fix: Residential, Commercial, New Construction, Retrofits? What is most important? The approach also needs to incorporate risk management -- an understanding of the time, risk, cost constraints in directing R&D programs that meet your needs.

## 3.11. Most Important Questions a Systems-Driven Approach Should Answer

Next, the four groups were asked what are the three most important questions a systems approach should be able to answer for the solar program?

### *3.11.1. Group 1: Distributed Generation*

(This page intentionally left blank due to incomplete group input.)

#### *3.11.2. Group 2: Off-Grid*
The off-grid group started with these basic questions, ranked in this order:

- What are the most important market drivers?/ What are the cost drivers (values)?[29 votes]
- What is the value to the U.S.A.? To U.S. Consumers/stakeholders?[17 votes],
- What program areas deserve enhancement?[12]
- What are the research/program priorities?[11],
- What is the best path to mainstream PV?[10],
- How to integrate PV systems successfully?[7],
- Why (solar)?[6],
- Where? (markets) [2],
- How Much? (will it cost – both in the market and in terms of investment – how much can be sold) [1],
- Where to dis-invest?[1],

#### *3.11.3. Group 3: Utility-Scale*
The utility-scale group settled on these three questions/issues:

- Optimize tech pathways to achieve biggest bang for buck and measure progress.,
- Why should program budget be doubled/justification?,
- What is solar's role in a diversified energy mix?

#### *3.11.4. Group 4: Buildings*
The buildings group developed these items:

- What market driven R&D paths should be pursued?
- Markets, Technologies;
- Costs/Risks/Rewards

### 3.12. Next Step Recommendations
Finally, each group was asked: What would you recommend as the next step to start developing a systems approach and modeling capability for the solar program?

#### *3.12.1. Group 1: Distributed Generation*
The distributed generation group recommended:

- prioritizing,
- defining holes in current approaches,
- identifying best modeling practices,
- finding what is left of low-hanging fruit to work on,
- agreeing on metrics for benefits, boundaries, for example near-term versus long-term, establishing a base line for where we are.

#### *3.12.2. Group 2: Off-Grid*
The off-grid group recommened digesting the information from this meeting and identifying what is already in place to address these priorities.

### *3.12.3. Group 3: Utility-Scale*

The utility-scale group made these recommendations:

- Assess current data and models (does this approach make sense?),
- Determine data/modeling needs,
- Determine arrangement of models (1 for CSP, OG, DG),
- Establish benchmarks /milestones,
- Charter mission analysis team

### *3.12.4. Group 4: Buildings*

The buildings group recommendations were:

- Identify what industries are doing in R&D (opening dialogue with industry),
- Find opportunities for collaboration on decision making process from step one,
- Fund scoping study on implementing systems approach, benchmarking this decision making process against something like the approach used by the pharmaceutical/biotech industries,
- Define the markets and market characteristics.

## 4. Next Steps

The information and recommendations that resulted from the Systems-Driven Approach to Solar Workshop have shaped the April 2003 Multiyear Program Plan. Another Systems-Driven Approach Workshop held to focus on Inverter R&D in April, benefited from the SDA framework analysis in determining how to best impact the manufacturing process to yield the greatest ROI and enhance solar technology reliability and marketability. The Solar Program will continue to seek broader industry review and collaboration as tools and models develop--including a solar ADVISOR model in the near future.