APPENDIX 6.1. TECHNICAL DESCRIPTION OF THE REVERSE ENGINEERING COST ESTIMATION METHODOLOGY

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APPENDIX 6.1. TECHNICAL DESCRIPTION OF THE REVERSE ENGINEERING COST ESTIMATION METHODOLOGY

6.1.1 INTRODUCTION

The manufacturing cost estimation methodology—"reverse engineering"—is a detailed, component-focused, activity-based technique for rigorously estimating the manufacturing cost of a product. It considers direct materials, direct labor, and plant overhead costs.

This appendix describes the technical aspects of the approach as applied to residential furnaces and boilers. Refer to Chapter 6 of the Technical Support Document (TSD) for more information on assumptions and context.

6.1.2 TEAR-DOWNS

The first step in the reverse engineering process was to perform tear-downs on equipment samples that are typical of today's furnaces and boilers. A tear-down is a thorough disassembly of the equipment followed by a detailed inspection of the parts and subassemblies. The level of resources allocated to different product classes and the unit selection process are described in Chapter 6.

6.1.2.1 General Tear-Down Practice

Representative minimum, medium, and high-efficiency units were disassembled for many product classes, as discussed in Chapter 6. The Department made every attempt to perform the disassembly in reverse of the actual assembly process; the bill of materials (BOM) reflects the order of these operations. From observations of industry practices, DOE assumed that major sub-assemblies arrive pre-assembled at the final assembly line.

There were a few cases where individual manufacturer practices differed from industry-wide practices, but the cost impact of these differences is within the tolerances of the analysis. First, sub-assembly allocation practices varies between manufacturers—for example, some stage sub-assemblies elsewhere and then add them to the final assembly line, while others build all assemblies directly on the final assembly line. A reasonable middle ground was taken, and the extremes assessed; assembly times varied on the order of minutes, well within the tolerances of the analysis. Second, manufacturing out-sourcing practices vary between manufacturers. A similar middle ground was taken, and extreme points evaluated; these variations again fell within the tolerances of the analysis.

6.1.2.2 Specific Product Class Features

Each product class presented some specific features that differ from the general tear-down practice that the Department performed. Specific features for each product class are indicated in Table 6.1.2.1.

Table 6.1.2.1 Specific Features for Each Product Class

Product Class	***Variation***
Gas Furnace	Clamshell and tubular constructions evaluated separately and averaged.
Gas Boiler	Cast iron heat exchangers are in-sourced at a sister plant for one major manufacturer. The Department assumed the transfer price would be equivalent to the open market value, and a high level of automation is applicable.
Oil Furnace	None
Oil Boiler	Based on bills of materials of gas boilers and oil furnaces.
Mobile Home Furnaces	None
Weatherized (Packaged) Furnaces	A/C coil model used rather than furnace/boiler model. This is fully described in the Technical Support Document for the Residential Air-Conditioning Rulemaking.[1]

6.1.2.3 Weight Confirmation of Tear-down Results

The Department confirmed the cost and weight predictions using a number of methods. Initially, DOE compared shipping weight predictions with published shipping weights. Since cost and weight tend to be highly correlated in manufactured goods, the ability to accurately predict weight is usually an important indication of the accuracy of the cost model. However, DOE discovered that at least one equipment manufacturer had published erroneous weight data. Since it could not verify all the published weights, DOE could not place confidence in the weight verification.

6.1.2.4 Final Confirmation of Tear-down Results

For further confirmation of tear-down results, DOE solicited feedback and comments on the cost analysis directly from the manufacturers of units that were torn down. As a disinterested third party, DOE modeled their factory conditions and assumed production volumes, and calibrated the model assumptions and results for their particular units. Final results, as discussed in Chapter 6 of this TSD, were generated using a set of industry-wide aggregate assumptions to avoid disclosure of company-specific sensitive cost data.

6.1.2.5 General Tear-down Practice of "Hypothetical" Units

Although DOE had detailed information on a number of units physically torn down, it needed many more samples to span a broad range of efficiency levels in each of the product classes. To cost these samples, DOE created "hypothetical" units. For these units, DOE started from a calibrated tear-down BOM, and then modified the BOM to obtain the desired efficiency level. Typically, for any change in efficiency level, there are numerous paths to take and a variety of hardware changes that can be made to obtain a particular efficiency level. According to existing literature, three options appear to be the most promising for gas furnaces—increased heat exchanger area, improved heat transfer coefficient, and derating (see discussion in Chapter 6).

Aside from the two design options selected for non-weatherized gas furnaces, a few others were considered for other product classes. These include:

1. Electronic ignition for boilers.

2. Two-stage Modulation. Efficiency gains ascribed to modulation varied from 0 percent to 2.5 percent, dependent on unit and operating conditions. A conservative 1 percent gain was applied.

3. Insulation. For weatherized furnaces only, additional insulation can improve AFUE ratings.

In addition, design options that affect fuel and electricity consumption were costed. These include:

1. Two-stage Modulation—Uses a two-speed combustion air fan, a dual flow rate gas valve, a multi-speed blower, and associated electronic controls.

2. Continuous Modulation—Uses a continuously variable combustion air fan and gas valve, a multi-speed blower, and associated sensors and controls.

3. Interrupted Ignition (Oil-Fired equipment only)—Uses interrupted firing of the burner rather than continuous, and associated controls.

4. Fan Atomized Burner (Oil-Fired equipment only) with modulation—Uses a fan and ECM motor to atomize the oil. Prototypes exist; conservative costs have been used to reflect the relatively undeveloped nature of this technology.

For each hypothetical tear-down, DOE modified the BOM hardware to reflect applicable design options from the list above, costed each design option path, and averaged the results.

6.1.3 CREATING THE TEAR-DOWN BILL OF MATERIALS

The Department used the tear-down process to create a complete and structured BOM for each torn-down and hypothetical unit. In the process of completely dismantling each piece of the unit, DOE characterized every part according to weight, dimensions, material, quantity, and the manufacturing processes used to fabricate and assemble it.

The BOMs incorporate all materials, components, and fasteners with estimates of raw materials and purchased parts and sub-assemblies. The Department based its sourcing assumptions on previous industry experience, recent information in trade publications, and discussions with high- and low-volume original equipment manufacturers (OEMs). To augment its understanding of the industry's manufacturing practices, DOE also visited several manufacturing plants. These visits focused on observing and characterizing current manufacturing practices.

Figure 6.1.3.1 illustrates a small section of a structured bill of materials. It shows:

- **Serial Number:** Assigned during disassembly.
- **Part Number:** Assigned during disassembly.
- **Description:** A description of the part. Subassemblies are grouped.
- **Quantity:** Number of parts assembled in a given step for a given subassembly.
- **Extended Quantity**: Flat bill-of-materials.
- **V**: This entry denotes whether a part is a purchased component or fabricated in-house.
- **Material**: Material type or component number
- **OD, Length, Width, Depth, Thickness:** Physical parameters that describe the finished part.
- **Extended Weight:** Final weight of the part, in grams.
- **Extended Material Cost**: Final material cost of the part (calculated), accounting for scrap losses but excluding required assembly, painting, fabrication, or joining costs.
- **Extended Assembly Time:** The manual labor (in seconds) required to handle all parts and assemble them into the unit.

Serial #	Part #	Description	Qty	Ext Qty	V?	Material	OD (cm)	Length (cm)	Width /ID (cm)	Depth (cm)	Wall t (cm)	Ext Weight (g)	Ext Mat Cost (USD)	Ext Assy Time (s)
6000	0.0	Model 2 Assembly	1	1				110	79.5	69		XX.XX	XX.XX	XX.XX
6001	1.1	Packaging SubAssy	*1*	*1*								*11417*	*$56.37*	*111*
6002	1.1.1	Banding	1	1	Y	Band		340	1			17	$0.11	35
6003	1.1.2	Box End	2	2	Y	CardBd					0.4	1622	$11.99	11
6004	1.1.3	Cardboard Corners	4	4	Y	CardBd		104	8	8	0.18	2002	$14.35	43
6005	1.1.4	Cardboard Body	1	1	Y	CardBd						2738	$19.63	11
6006	1.1.5	Pallet	1	1	Y	Comp#90		122	122			5039	$10.30	12
6007	1.2	Label SubAssy	*1*	*1*								*30*	*$0.17*	*88.8*
6008	1.2.1	Efficiency Label	1	1	Y	Paper		19	14		0.013	4	$0.01	17.8
6009	1.2.2	UPC Label	1	1	Y	Paper		10	6		0.016	1	$0.01	17.8
6010	1.2.3	Energy Star Label	1	1	Y	Mylar		8	5		0.016	1	$0.05	17.8
6011	1.2.4	CA Warning Label	1	1	Y	Mylar		20	5		0.016	1	$0.05	17.8
6012	1.2.5	Model Label	1	1	Y	Mylar		18	10		0.036	8	$0.50	17.8

Figure 6.1.3.1 Bill of Materials Sample

6.1.4 ADDITIONAL PRODUCTION COST DATA

The tear-down process and the development of the structured BOMs provided the starting points for estimating production costs, but DOE still needed information on manufacturing operations, part and material prices, wages, plant equipment amortization, and plant overhead. Chapter 6 describes the assumptions and data sources. This section briefly describes the processes DOE used to gather the data and how it used them.

6.1.4.1 Labor and Factory Overhead

The Department obtained information on equipment and tooling costs, typical process cycle times, and materials used for fabrication from the proprietary TIAX manufacturing databases. Plant equipment suppliers provided details concerning equipment capabilities and processing parameters (cycle times, scrap rates, etc.). Fabrication cycle rates are directly entered into the cost model and depend on part complexity and processes used.

6.1.4.2 Depreciation

Depreciation, or amortization, is the accounting process by which capital costs are allocated to production volume. Amortization occurs over the whole period of time that it takes to produce a product, so that at the end of that time, all capital costs are accounted for in the full cost of producing the product. For example, if a manufacturer produces one million furnaces over ten years and amortizes a $10 million investment over the same ten years, each furnace produced during that time would include $10 in amortization charges.

The methodology DOE used to allocate depreciation depended on whether it is assumed that the plant machinery is dedicated or non-dedicated to the production of the sample product. Dedicated machinery is tied solely to the production of the sample product. During times when a piece of dedicated machinery is not needed for that product, it sits idle. The entire capital cost of a piece of dedicated machinery is amortized across the annual volume of the sample product. Conversely, non-dedicated machinery may be used to produce another product when it is not needed for the sample product. Only a fraction of the capital cost of non-dedicated machinery is allocated to the sample product, based on the time the machinery was used to produce the sample product. For example, a non-dedicated press that was used 55 percent of the time to produce the sample product would allocate 55 percent of its depreciation charges to the sample product and 45 percent to the other products with which it is associated. A dedicated press, on the other hand, would allocate 100 percent of its depreciation to the sample product, even if its utilization was 55 percent, since the press is not used for any other production.

The Department assumed that all fabrication machinery is non-dedicated, unless it is part of an assembly line (welding, or bending, directly on the line). Due to the seasonal nature of the furnace and boiler business, some manufacturers have off-season uses for their fabrication machinery (e.g., to make air conditioners).

The Department also allocated labor to operate a piece of machinery based on whether the machinery is dedicated or non-dedicated.

As equipment utilization rates approach 100 percent, the costs associated with dedicated versus non-dedicated equipment costs become equal. However, few dedicated pieces of equipment ever achieve 100 percent utilization due to lack of demand, capacity mismatches between process steps, scheduled downtime, etc. Thus, non-dedicated equipment results in lower overall costs per part, as depreciation, maintenance, and other costs are only assessed on the basis of how much time each part uses a piece of equipment. As equipment types vary, so do the manufacturing equipment and labor requirements. Depreciation charges therefore also vary across equipment types.

6.1.4.3 Parts and Materials

Cost estimates for raw materials and purchased components were drawn from TIAX manufacturing databases and supplemented with information obtained from manufacturer and supplier sources. The Department adjusted the cost estimates as appropriate to include price discounts typically seen in the industry as the result of high-volume purchases.

As purchased components make up much of the unit costs, DOE paid special attention to establishing accurate OEM-level price data. Through manufacturer submissions, industry literature, and active research, DOE was able to ascertain the exact specifications for the majority of components used in the units under investigation. For the relatively few purchased components DOE could not identify, it substituted parts from comparable equipment. For example, a manufacturer's technical data sheet may report that a sample furnace uses a certain type of motor supplied by a particular company, but may not state the precise size or part number. In the cases when distributors could not positively identify the part, industry experts would compare the known attributes of similar units (such as horse power, voltage, etc.) with those of the sample equipment. The Department would then select a specific motor size and type based on an interpolation of the available data.

The Department then consulted with local distributors, wholesalers, parts suppliers, and OEMs to determine high-volume pricing. The Department applied a discount to the prices received from each of those sources based on their place in the distribution chain. These discounts were based on markup data and DOE's previous experience in the industry. The many different data sources and the large purchased parts list also allowed DOE to do some cross-checking of price data and discounts. The Department selected those that, most likely reflected actual prices to OEMs. The discounts on each component are a function of the total dollar volume of a typical OEM's account with a typical supplier. Since DOE is modeled high volume OEMs who deal with one supplier for each component, this resulted in substantial discounts relative to retail or wholesale prices. In addition, OEM manufacturers commented on assumed OEM pricing, as detailed in section 6.1.2.4 of this appendix.

6.1.5 STRUCTURE OF THE COST MODELS

Once the Department had collected all of the information required to estimate production costs for each sample, DOE used Excel spreadsheet models to perform the required calculations. In addition, DOE used Boothroyd-Dewhurst, Inc. (BDI) Design for Assembly software to calculate assembly times, and BDI's Concurrent Costing software to estimate casting and machining processes.[2] Figure 6.1.5.1 illustrates the structure and relationship of the spreadsheets and software used to make the estimates.

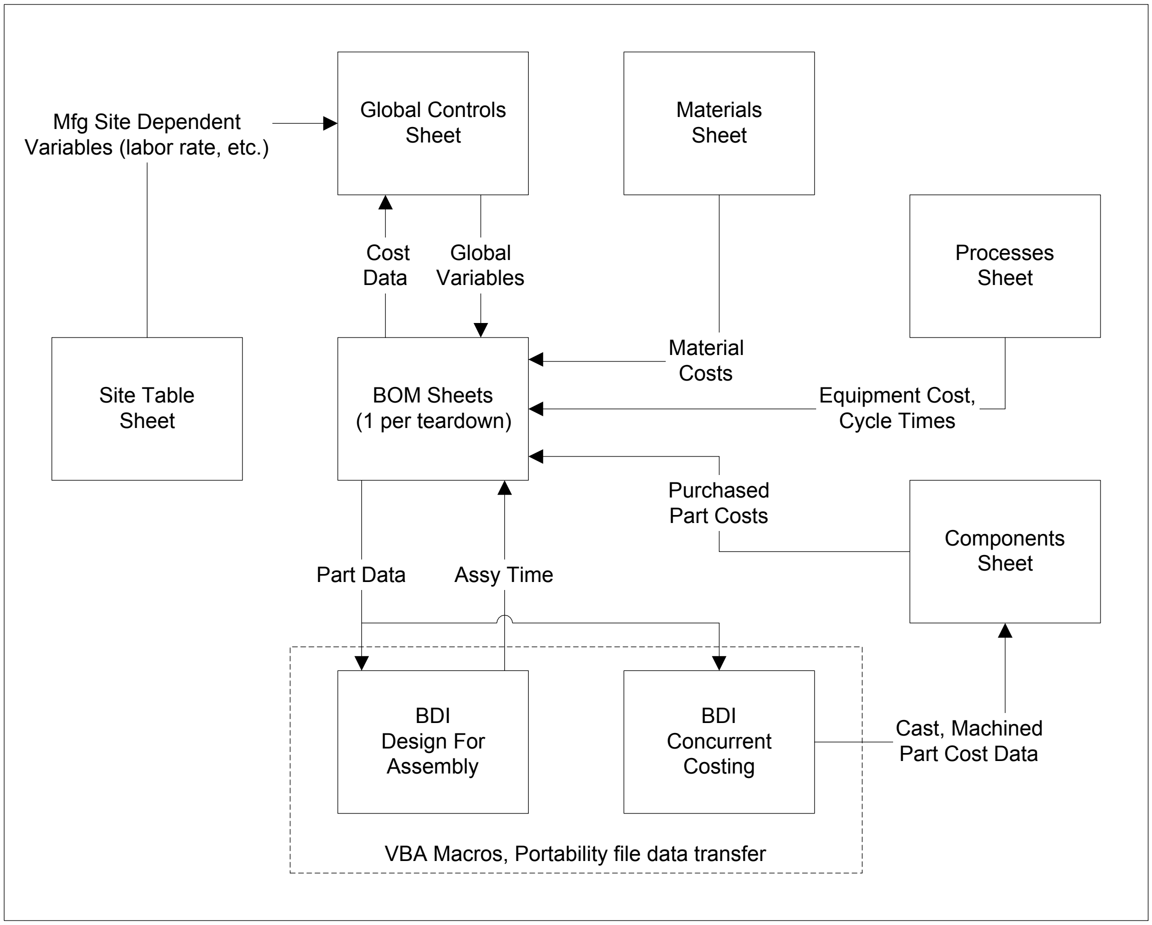

Figure 6.1.5.1 Cost Model Structure

6.1.5.1 Main Cost Model

The main model serves to hold data and perform the calculations that determine the production cost of the final assembled equipment. It contains a number of worksheets that perform different functions.

Global Controls Sheet. This worksheet sets parameters such as production volume and wages; it also displays the cost results by sub-assembly. The basic parameters (e.g., days available per year) of the Global Controls sheet are linked to multiple BOM sheets, one for each tear-down. A sample section of those controls is shown in Figure 6.1.5.2. Shaded fields are also varied in the sensitivity analysis.

Designed Fabrication Work Days per Year:	240
Designed Assembly Work Days per Year:	240
Runtime per Shift (hrs):	8
Equipment Uptime (%):	90%
Designed Assembly Worker Downtime (%):	20%
Auxiliary Equipment + Installation Cost:	60%
Building Depreciation Life (Years):	25
Tooling Depreciation (Years):	7
Ratio of Walkways to Fabrication + Storage:	20%
Yearly Maintenance Ratio (as % of Equipment Cost)	4%
Utility Cost (% of factory cost)	3.0%
Invest. Relativity Factor (%)	1
Avg Depreciation Life (%)	1
Freight Factor:	3%
Freight Cost($/cu ft):	$1.66
Benefits	40%
Building Cost ($/sf)	120

Figure 6.1.5.2 Sample of Global Controls Sheet

The Global Controls sheet also shows costs broken down by sub-assembly and cost category. The results are shown in tables 6.1.5.2 and 6.1.5.3. Figure 6.1.5.3 features costs by major sub-assembly and cost type. Cost breakdowns to this fine level allowed DOE to zero in on the differences between equipment across efficiency levels and facilitated the calibration and industry review processes.

YY Class			
XX% AFUE	Material	Labor	Overhead
Blower			
Casing			
Circulator			
Electrical/Controls			
Exterior Components			
Fuel Control			
Heat Exchanger			
Inducer			
Packaging			
Total			
Grand Total			

Figure 6.1.5.3 Subassembly Breakdown

Site Table Sheet. Variables that vary from manufacturing site to manufacturing site were isolated on the Site Table sheet. These include labor rates, purchasing power (effective production volumes for components shared across many product families), and a number of other variables. (see Figure 6.1.5.4). After individual manufacturer data was gathered, an industry average were generated, along with two sub-group averages—large and small manufacturers. To avoid disclosure of manufacturing site-specific information, the industry average column was used to generate all numbers in this TSD. The ranges found from individual manufacturers were used in the sensitivity analysis.

	Industry Avg	Small Mfg.	Large Mfg.	Mfg A	Mfg B	Mfg C	…
Assembly Factor							
assy shifts / day							
Design vs. Actual Capacity Ratio							
Direct Labor Rate							
fab shifts / day							
Ind:Dir Labor Ratio							
Management Span (people/manager)							
Pay Difference Manager to Line worker							
Production Volume							
Purchasing Power							
rework rate (all repaired)							
Lot size (days of inventory)							
JIT ratio							

Figure 6.1.5.4 Site Table Spreadsheet

Components Sheet. The Components sheet contains two types of data: major purchased components unique to each model; and minor, common purchased components used by every model.

Major Purchased Components. The Components sheet represents the output of the TIAX manufacturing component database, which logs multiple quotations at a variety of production volumes to build a production volume versus cost curve. These outputs are shown in the Q1 to Q1000000 columns in Figure 6.1.5.5. Depending on quantity per model and production volumes, the component cost is fed to the BOM sheet through the CompCostX column, which queries the result by unit number. These tables determine at least 45 percent of total cost.

Component ID	Comp Class Name	Comp SubClass Name	Name	Manufacturer Part Number	Cost Model ID Number	Q1	Q1000	Q10000	Q100000	Q1000000	TotQty1	CompCost1
1	0	0	Dummy									
2	Electronic	PCB	Control Board, Damper									
3	Electronic	PCB	Control Board, Mfg A									
4	Electronic	PCB	Control Board, Mfg B									
5	Mechanical	Motor	Blower Motor									
6	Mechanical	Motor	Blower Motor									
7	Mechanical	Motor	Blower Motor									
8	Mechanical	Fan	Blower Wheel									
9	Mechanical	Fan	Blower Wheel									
10	Mechanical	Fan	Blower Wheel									
11	Mechanical	Pump	Circulator with gaskets									
12	Mechanical	Motor	Blower Motor									
13	Mechanical	Motor	Blower Motor									
14	Electronic	Switch	Dual Pressure Switch SubAssy									
15	Mechanical	Fan	Blower Wheel									
16	Mechanical	Fan	Blower Wheel									
17	Fuel System	Valve	Gas valve									
18	Fuel System	Valve	Gas Valve Assy									
19	Fuel System	Valve	Gas Valve Assy									
20	…	…	…									

Figure 6.1.5.5 Components Sheet

Minor, Common Purchased Components. These include items such as connectors, wire, fasteners, board transformers, and other smaller parts that OEMs are likely to purchase from outside suppliers. From the TIAX manufacturing component database, DOE gathered price quotations from multiple sources (suppliers, distributors, prior experience) in quantities throughout the price versus volume curve. In the same fashion as for major purchased components, minor component costs are passed to the BOM sheets.

Figure 6.1.5.6 shows modeled fabrication processes; material cost in these cases is determined by the part weight times a cost per gram as detailed on the Raw Materials sheet, Figure 6.1.5.7. For out-sourced parts, DOE applied a vendor profit markup of 1.2. The Department assumed that even in cases of a sister company manufacturing sub-components, this markup will capture the transfer price and the profit of the sister unit.

Process ID	Class Name	SubClass Name	Machine Name	Capacity	Capacity Units	Capacity Rate	Capacity Rate Units	Cycle Time (minutes)	Depreciation Life (Years)	Q1	Capital Cost ($)
1	None	None	Dummy Process								
2	Material Handling	Convey	Conveyor								
3	Material Removal	Tube	Tube Cut								
4	Deformation Forming	Tube	Tube Bend								
5	Deformation Forming	Tube	Roll Form								
6	Deformation Forming	Tube	Tube Coil								
7	Sheet Metal	Stamp	Large Press								
8	Sheet Metal	Stamp	Med Press								
9	Sheet Metal	Stamp	Sm Press								
10	Sheet Metal	Bend	Press Brake								
11	Sheet Metal	Blank	Blanking								
12	Sheet Metal	Stamp	Turret Punch								
13	Material Removal	Machine	Machining Center								
14	Casting	Plastic	Injection Mold								
15	Casting	Metal	Sand Cast								
16	Casting	Metal	Investment Cast								
17	Finishing	Powder Coat	Paint								
18	Material Removal	Stamp	Plasma								
19	Assembly	Adhesive	Adhesive Bonding								
20	Assembly	Weld	Seam Welding								
21	…	…	…								

Figure 6.1.5.6 In-house Fabrication Process

Class Name	SubClass Name	Material Full Name	Physical Form Name	Density (g/cc)	Q1	Q1000	Q10000	Q100000	Q1000000	TotWt1 (g)	MatCost1 ($/g)
Polymer	Thermoplastic	ABS	Pellet	1.06							
Metal	Commodity Metal	Aluminum	Sheet	2.70							
Metal	Commodity Metal	Alumized Steel	Sheet	7.87							
Metal	Commodity Metal	Aluminum Tube	Tube	2.70							
Polymer	Commodity Metal	Strap Band	N/A	N/A							
…	…	…	…	…							

Figure 6.1.5.7 Raw Materials Sheet

Bill-of-Materials Sheet. The Bill-of-Materials sheet (as illustrated in Figure 6.1.3.1 and discussed in section 6.1.3) serves as a structured assembly tree, summarizes fabrication and assembly tool data, and calculates production costs based on the price of the part or material and the labor and machinery required to fabricate or assemble it. The BOM sheet also adjusts many other costs in response to changes in physical parameters. For example, the model adjusts baseline sheet metal sizes to incorporate different enclosure sizes. Also, the size of the fiberglass insulation is a function of the sheet metal it has to cover and the efficiency level of the unit (insulation is thicker at higher efficiencies). Many fastener quantities and labor costs are also a function of the sheet metal walls they have to secure. The result is that every unit cost estimate is unique, using the initial BOM as a starting point.

Labor, parts, materials, and depreciation costs are aggregated by sub-assembly and linked back to the Global Controls page.

Processes Sheet. This sheet, from the TIAX manufacturing database, is a list of process costs for all the plant machinery involved in the production of furnaces and boilers. An implicit assumption is that the plant equipment required to produce lower-efficiency samples is also able to produce higher-efficiency samples without any modification. The process data show installed equipment costs, equipment capacity, depreciation life, whether equipment is dedicated, cycle times, labor requirements per station, consumables costs, etc. The installed costs include price quotations for the equipment plus markups to account for installation labor and auxiliary equipment (e.g., electrical service to the equipment).

6.1.6 SENSITIVITY ANALYSIS RESULTS

Chapter 6 of the TSD described the Monte Carlo analysis process. The results are presented in Figure 6.1.6.1 in the form of standard deviation values. These results are used as an input for the LCC analysis. Confidence intervals are easily calculated using standard deviation values.

	Material	Labor	Overhead	Shipping	Total
Non-weatherized Gas-fired Furnaces					
Baseline	$5	$3	$2	$1	$6
80% AFUE	$4	$2	$1	$1	$5
81% - 83% AFUE	$5	$3	$2	$1	$6
Non-condensing Furnaces with Modulation	$8	$3	$2	$1	$9
90% AFUE	$3	$3	$4	$1	$6
92% AFUE	$10	$3	$6	$1	$12
92% with Modulation	$15	$3	$6	$1	$16
96% AFUE	$35	$3	$6	$1	$36
Weatherized Gas-fired Furnaces			Same as Non-weatherized		
Mobile Home Furnaces					
75% AFUE	$5	$2	$1	$1	$5
80% AFUE	$6	$2	$1	$1	$6
90% AFUE	$30	$10	$3	$1	$32
Oil-fired Furnaces					
Baseline	$6	$10	$6	$1	$14
Other Options	$10	$10	$6	$1	$15
Gas Boilers					
Baseline	$4	$4	$3	$1	$7
81% - 84% AFUE	$4	$4	$3	$1	$6
Gas Boiler with Modulation	$10	$4	$3	$1	$11
88% AFUE	$30	$10	$3	$1	$32
91% AFUE	$75	$15	$5	$1	$77
99% AFUE	$100	$20	$10	$1	$102
Oil-fired Boilers					
Baseline	$10	$4	$3	$1	$11
81%-86% AFUE	$10	$4	$3	$1	$11
Oil Boiler with Other Options	$10	$10	$6	$1	$15
90% AFUE	$75	$15	$5	$1	$77
95% AFUE	$100	$20	$10	$1	$102

Figure 6.1.6.1 Standard Deviations of Manufacturing Costs

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1. U.S. Department of Energy-Office of Building Research and Standards, *Technical Support Document: Energy Efficiency Standards for Consumer Products: Residential Central Air Conditioners and Heat Pumps*, 2000, U.S. Department of Energy. Washington, DC. <http://www.eere.energy.gov/buildings/appliance_standards/residential/ac_central.html>

2. Boothroyd Dewhurst, *Design for Manufacture and Assembly (DFMA),* (Last accessed December 17, 2000, <http://www.dfma.com/software/dfaben.html>