

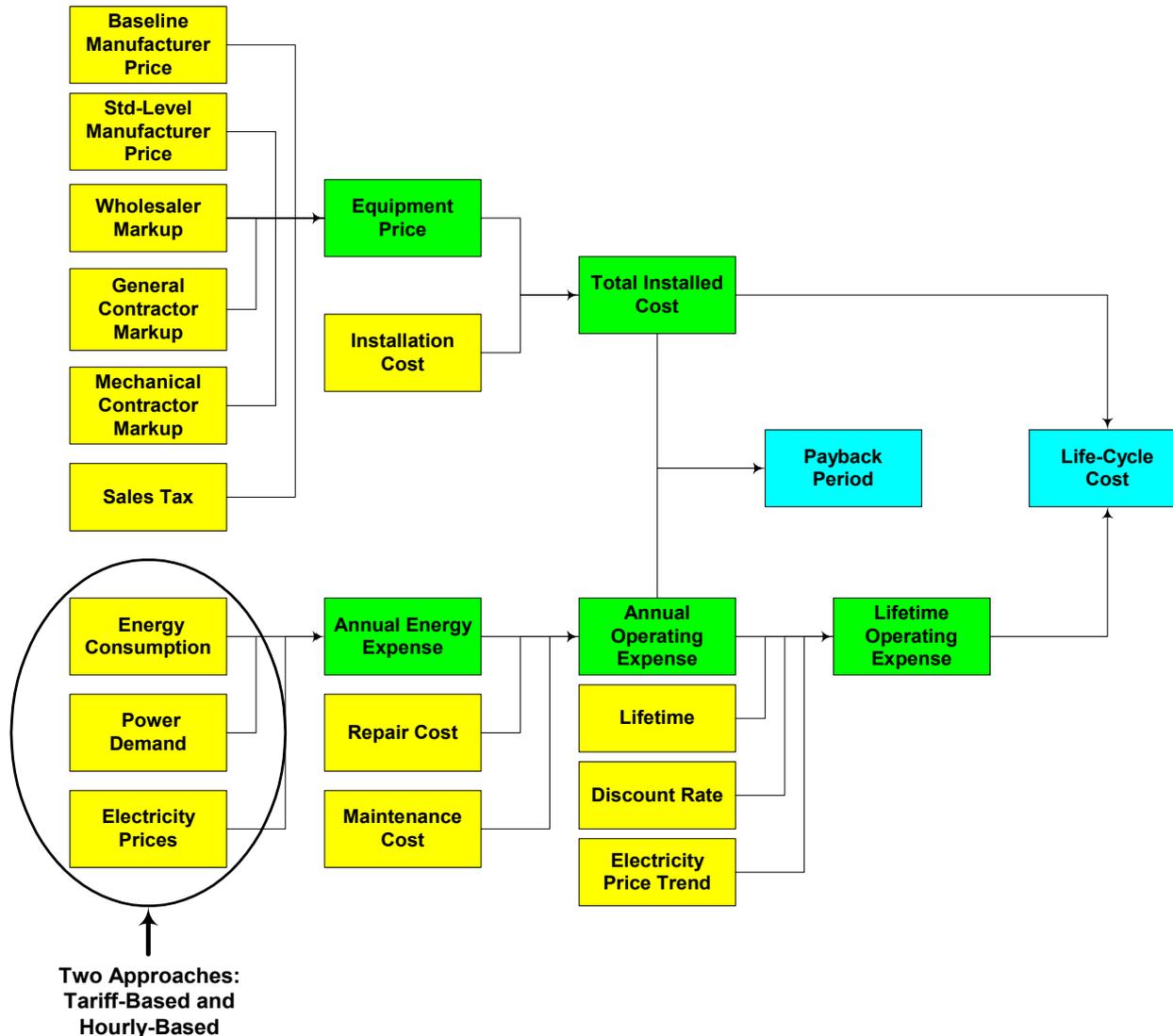
# Commercial Unitary Air Conditioner & Heat Pump

## Life-Cycle Cost Analysis: Inputs and Results

Lawrence Berkeley National Laboratory

July 2003

# Life-Cycle Cost Inputs



# Revisions to LCC inputs: September 2002 – December 2002

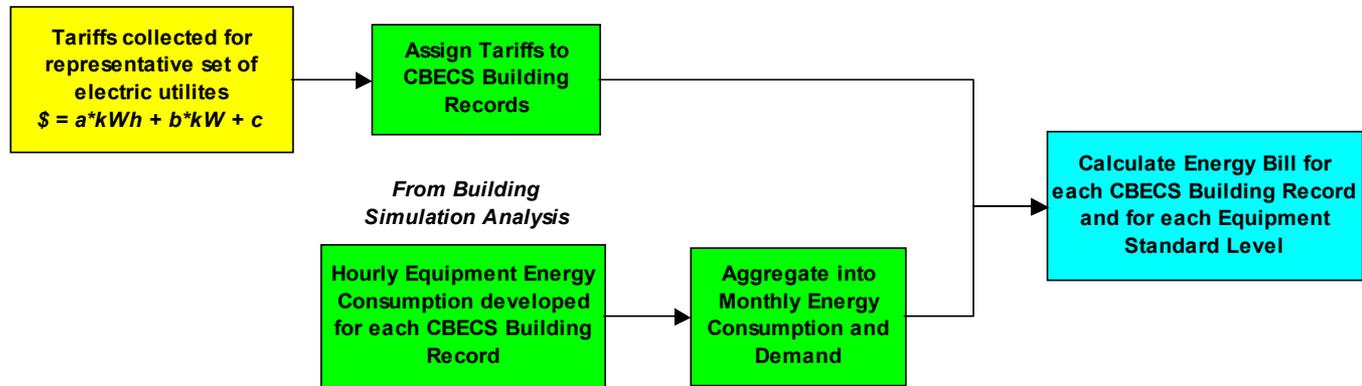
- Mechanical Contractor Markups
  - Before: Disaggregated by size of contractor (large and small)
  - Now: Disaggregated by size and market served
    - Large Contractor, New Construction
    - Large Contractor, Replacement
    - Small Contractor, New Construction
    - Small Contractor, Replacement
- Electricity Prices
  - Annual energy expenses based on new building simulation data
- Equipment Lifetime
  - Before: Shape of survival function based on residential heat pumps
  - Now: Weibull probability distribution used
- Maintenance Costs
  - Before: Based on costs developed for residential central a/c
  - Now: Based on RS Means data specific to commercial unitary a/c

# Revisions to LCC inputs since December 2002

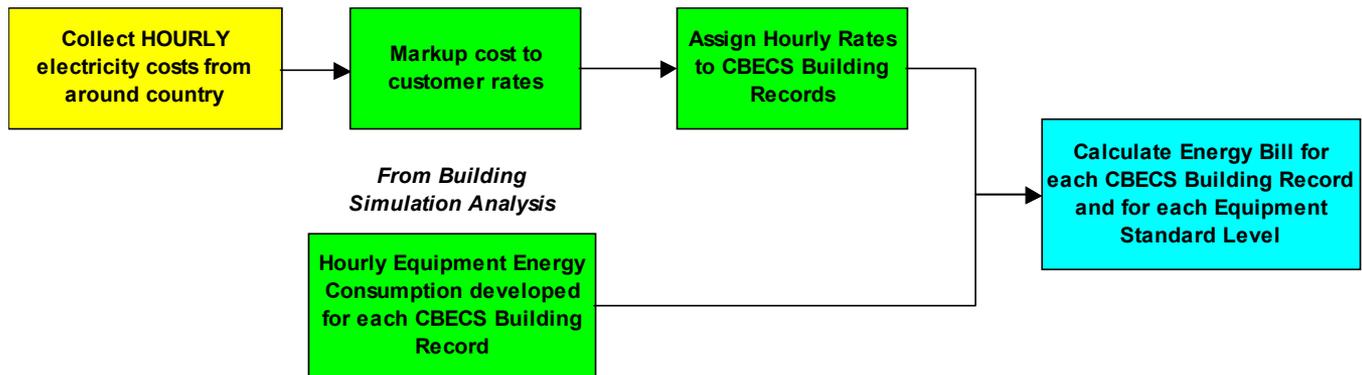
- Typical Distribution Channels
  - Reordering of Mechanical and General Contractors – no impact to resulting markups
- Replacement of AEO 2002 electricity price forecasts with AEO 2003 price forecasts
- LCC analysis re-run with AEO 2003 price forecasts

# Two approaches to energy expenses

## Tariff-Based Approach

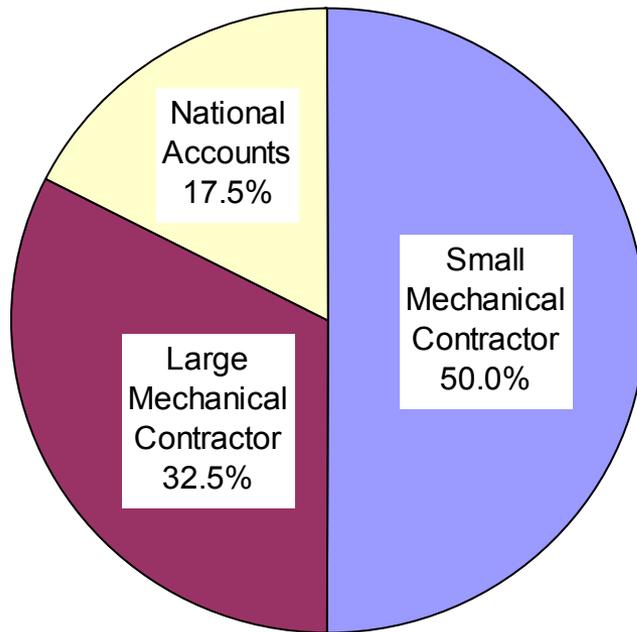


## Hourly-Based Approach

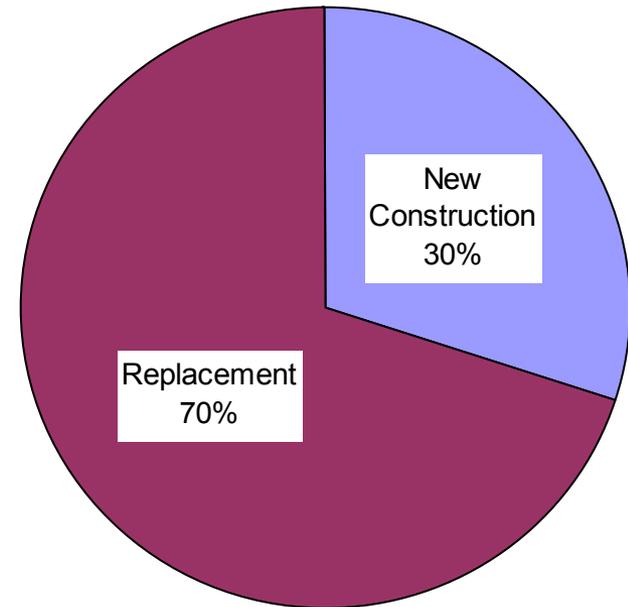


# Equipment Markups

# Markups depend on distribution channels and construction markets



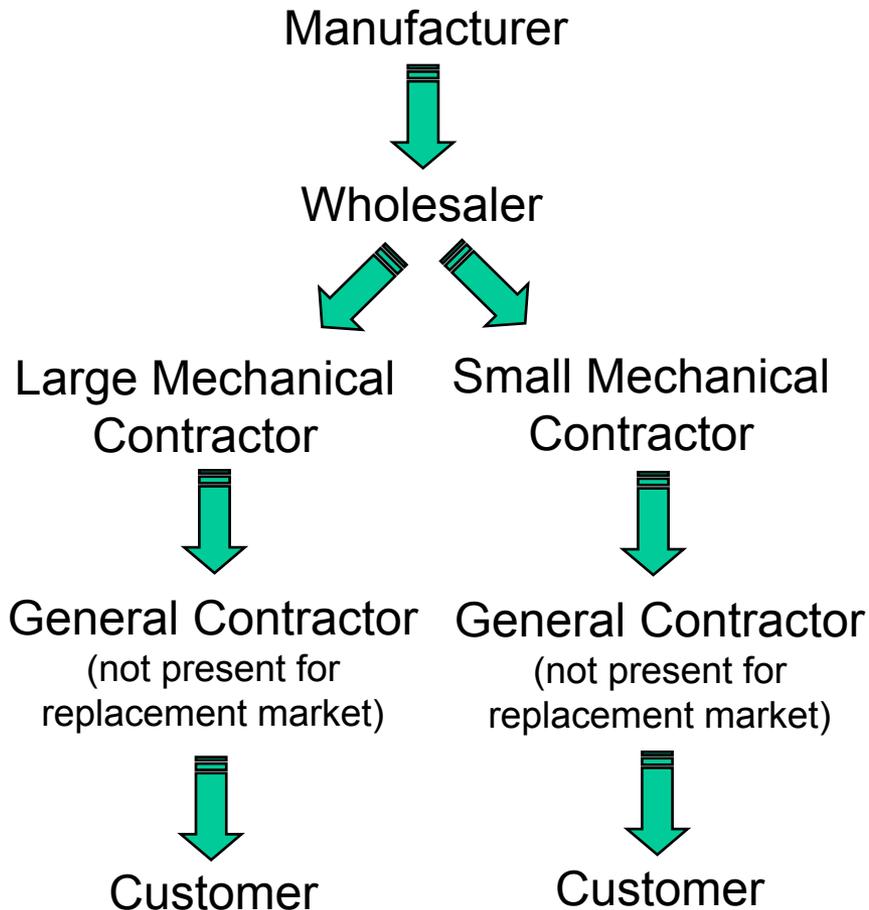
Distribution channel depends on size of mechanical contractor and whether the customer purchases directly from the manufacturer (i.e., national account)



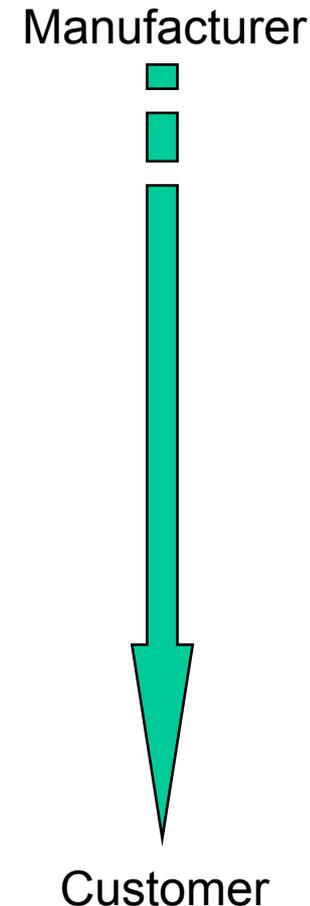
Two construction markets: replacement & new construction

# Distribution Channel assumed to consist of Several Parties

## Distribution Channels 1 & 2



## Distribution Channel 3 (Nat'l Acct)



# Two types of Markups developed – Baseline and Incremental

- Markups relate customer price to cost of goods sold (CGS)
- Baseline markups relate price to cost prior to a change in efficiency
  - Baseline markups indicate a customer price that covers all of a Wholesaler's or Contractor's expenses plus profit
  - Direct labor costs are included
- Incremental markups relate the incremental change in customer price to the incremental change in CGS
  - Incremental markups cover only expenses that vary with CGS
  - Direct labor costs do not vary with changes in CGS

# Wholesaler Markups

	Item	Fraction	Per Dollar Sales Revenue	Per Dollar Cost of Goods Sold
	<b>Cost of Goods Sold</b>	<b>73.60%</b>	<b>\$0.736</b>	<b>\$1.000</b>
	Gross Margin	26.40%	\$0.264	\$0.359
Scales with Direct Labor	<b>Payroll Expenses</b>			
	Executive Salaries & Bonuses	2.70%	\$0.027	\$0.037
	Inside Sales Salaries/Wages	3.20%	\$0.032	\$0.043
	Outside Sales Salaries/Commissions	2.20%	\$0.022	\$0.030
	Warehouse & Delivery Salaries/Wages	2.30%	\$0.023	\$0.031
	All Other Salaries/Wages & Bonuses	2.10%	\$0.021	\$0.029
	Payroll Taxes	1.10%	\$0.011	\$0.015
	Group Insurance	0.70%	\$0.007	\$0.010
	Benefit Plans	0.50%	\$0.005	\$0.007
	<b>Total Payroll Expenses</b>	<b>14.80%</b>	<b>\$0.148</b>	<b>\$0.201</b>
	<b>Occupancy Expenses</b>			
	Utilities: Heat, Light, Power, Water	0.40%	\$0.004	\$0.005
	Telephone	0.60%	\$0.006	\$0.008
	Building Repairs & Maintenance	0.20%	\$0.002	\$0.003
Rent or Ownership in Real Estate	2.40%	\$0.024	\$0.033	
<b>Total Occupancy Expenses</b>	<b>3.60%</b>	<b>\$0.036</b>	<b>\$0.049</b>	
Scales with All Direct Costs	<b>Other Operating Expenses</b>			
	Advertising and Promotion	0.90%	\$0.009	\$0.012
	Insurance	0.40%	\$0.004	\$0.005
	Depreciation	0.70%	\$0.007	\$0.010
	Bad Debt Losses	0.30%	\$0.003	\$0.004
	All Other Operating Expenses	3.20%	\$0.032	\$0.043
	<b>Total Other Operating Expenses</b>	<b>5.40%</b>	<b>\$0.054</b>	<b>\$0.073</b>
<b>Operating Profit</b>	<b>2.70%</b>	<b>\$0.027</b>	<b>\$0.037</b>	
<b>Baseline Markup</b>				<b>1.36</b>
<b>Incremental Markup</b>				<b>1.11</b>

Source: Source: Air-conditioning & Refrigeration Wholesalers Association (ARW), *1998 Wholesaler PROFIT Survey Report, Based on 1997 Wholesaler Operations, 1998.*

Baseline Markup covers all expenses = 1.36

Incremental Markup (no change in direct labor costs) = 1.11

# Mechanical Contractor Markups

	Item	Fraction	Per Dollar Sales Revenue	Per Dollar of Direct Sale Costs
	<b>Cost of Sales</b>			
	Direct Materials	22.70%	\$0.227	\$0.347
	Equipment Installed	14.22%	\$0.142	\$0.217
	Direct Labor	19.01%	\$0.190	\$0.290
	Direct Subcontract	5.55%	\$0.056	\$0.085
	Direct Other	3.97%	\$0.040	\$0.061
	<b>Total Cost of Sales</b>	<b>65.45%</b>	<b>\$0.655</b>	<b>\$1.000</b>
	Gross Margin	34.55%	\$0.346	\$0.528
	<b>Operating Expenses</b>			
Scales with Direct Labor	Occupancy Costs	1.24%	\$0.012	\$0.019
	Payroll Taxes/Fringe Benefits	4.02%	\$0.040	\$0.061
	Officer Salaries	3.80%	\$0.038	\$0.058
	Sales and Estimating Salaries	2.69%	\$0.027	\$0.041
	Administration Salaries	3.18%	\$0.032	\$0.049
	Warehouse Salaries	0.46%	\$0.005	\$0.007
	Unapplied Labor	1.04%	\$0.010	\$0.016
	<b>Total Labor Operating Expenses</b>	<b>16.43%</b>	<b>\$0.164</b>	<b>\$0.251</b>
Scales with All Direct Costs	Advertising	1.10%	\$0.011	\$0.017
	Bad Debts	0.16%	\$0.002	\$0.002
	Depreciation	1.02%	\$0.010	\$0.016
	Interest Expenses	0.33%	\$0.003	\$0.005
	Liability Insurance	1.12%	\$0.011	\$0.017
	Other Insurance	1.36%	\$0.014	\$0.021
	Selling Expense	1.49%	\$0.015	\$0.023
	Vehicle/Maintenance Repairs	1.82%	\$0.018	\$0.028
	Other Operating Expenses	5.13%	\$0.051	\$0.078
	<b>Total "All Direct Cost" Operating Expenses</b>	<b>13.53%</b>	<b>\$0.135</b>	<b>\$0.207</b>
	<b>Profit</b>			
Net Operating Profit	4.59%	\$0.046	\$0.070	
Other Income	0.79%	\$0.008	\$0.012	
Other Expenses	-0.49%	-\$0.005	-\$0.007	
<b>Net Profit Before Income Taxes</b>	<b>4.89%</b>	<b>\$0.049</b>	<b>\$0.075</b>	
	<b>Baseline Markup</b>			<b>1.53</b>
	<b>Incremental Markup</b>			<b>1.28</b>

Source: Air Conditioning Contractors of America (ACCA), *Financial Analysis for the HVACR Contracting Industry, 1995 Edition, 1995.*

Baseline Markup covers all expenses = 1.53  
 Incremental Markup (no change in direct labor costs) = 1.28

Baseline and Incremental Markups vary depending on Contractor Size (i.e., revenues) and Market Served (i.e., new construction and replacement)

Small Contractor (< \$2 million), New Construction:

Baseline Markup = 1.48

Incremental Markup = 1.26

Small Contractor (< \$2 million), Replacement:

Baseline Markup = 1.70

Incremental Markup = 1.37

Large Contractor (> \$2 million), New Construction:

Baseline Markup = 1.35

Incremental Markup = 1.18

Large Contractor (> \$2 million), Replacement:

Baseline Markup = 1.55

Incremental Markup = 1.29

# General Contractor Markups

	Item	Total Dollar Value	Fraction	Per Dollar Sales Revenue	Per Dollar of Direct Sale Costs
	<b>Cost of Sales</b>				
	<b>Direct Materials and Equipment Installed:</b> Cost of materials, components, and supplies	\$28,087,296	16.03%	\$0.160	\$0.198
	<b>Direct Labor:</b> Payroll, construction workers	\$10,797,116	6.16%	\$0.062	\$0.076
	<b>Direct Subcontract:</b> Cost of construction work subcontracted out to others	\$101,952,864	58.18%	\$0.582	\$0.720
	<b>Direct Other:</b> Cost of selected power, fuels, and lubricants	\$827,160	0.47%	\$0.005	\$0.006
	<b>Total Cost of Sales</b>	<b>\$141,664,436</b>	<b>80.84%</b>	<b>\$0.808</b>	<b>\$1.000</b>
	Gross Margin	\$33,566,396	19.16%	\$0.192	\$0.237
	<b>Operating Expenses</b>				
Scales with Direct Labor	<b>Occupancy Costs:</b> Rental cost for machinery, equipment, and buildings + Purchased communication services	\$1,657,257	0.95%	\$0.010	\$0.012
	<b>Payroll Taxes/Fringe Benefits:</b> Fringe benefits, all employees	\$4,524,436	2.58%	\$0.026	\$0.032
	<b>Non-Construction Worker Salaries:</b> Payroll, other employees	\$8,379,046	4.78%	\$0.048	\$0.059
	<b>Total Labor Operating Expenses</b>	<b>\$14,560,739</b>	<b>8.31%</b>	<b>\$0.083</b>	<b>\$0.103</b>
Scales with All Direct Costs	<b>Depreciation:</b> Depreciation charges during year	\$808,477	0.46%	\$0.005	\$0.006
	<b>Vehicle/Maintenance Repairs:</b> Cost of repairs to buildings and other structures + Cost of repairs to machinery and equipment	\$558,930	0.32%	\$0.003	\$0.004
	<b>Total "All Direct Cost" Expenses</b>	<b>\$1,367,407</b>	<b>0.78%</b>	<b>\$0.008</b>	<b>\$0.010</b>
	<b>Operating Profit</b>	<b>\$17,638,250</b>	<b>10.07%</b>	<b>\$0.101</b>	<b>\$0.125</b>
<b>Baseline Markup</b>					<b>1.24</b>
<b>Incremental Markup</b>					<b>1.13</b>

Source: U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau, *Commercial and Institutional Building Construction, 1997 Economic Census, Construction, Industry Series*, January, 2000, Washington, DC. Report No. EC97C-2333B.

Baseline Markup covers all expenses = 1.24

Incremental Markup (no change in direct labor costs) = 1.13

# National Accounts

- Large customers that are able to negotiate prices directly with the manufacturer
- “National Account” markup is expected to be lower than other markups because of fewer “middle men,” but how much less is uncertain.
- We take the “National Account” markup to be  $\frac{1}{2}$  of the product of the wholesaler, general contractor, and mechanical contractor markups.
- Comments providing additional information are welcome.

# Converting Baseline and Standard Level Manufacturer Prices to Customer Prices

		Small Mech. Contractor Market Share=50%		Large Mech. Contractor Market Share=32.5%		National Accounts Market Share=17.5%		Weighted-Average New & Replacement		Weighted-Average All	
		Baseline	Incremental	Baseline	Incremental	Baseline	Incremental	Baseline	Incremental	Baseline	Incremental
New Construction Market Share=30%	Wholesaler	1.36	1.11	1.36	1.11	1.69	1.27	2.43	1.60	2.31	1.56
	Mechanical Contractor	1.48	1.26	1.35	1.18						
	General Contractor	1.24	1.13	1.24	1.13						
	Sales Taxes	1.07	1.07	1.07	1.07						
	Overall	2.66	1.68	2.42	1.59						
Replacement Market Share=70%	Wholesaler	1.36	1.11	1.36	1.11	1.60	1.24	2.27	1.54	2.31	1.56
	Mechanical Contractor	1.70	1.37	1.55	1.29						
	General Contractor	NA	NA	NA	NA						
	Sales Taxes	1.07	1.07	1.07	1.07						
	Overall	2.47	1.63	2.24	1.53						

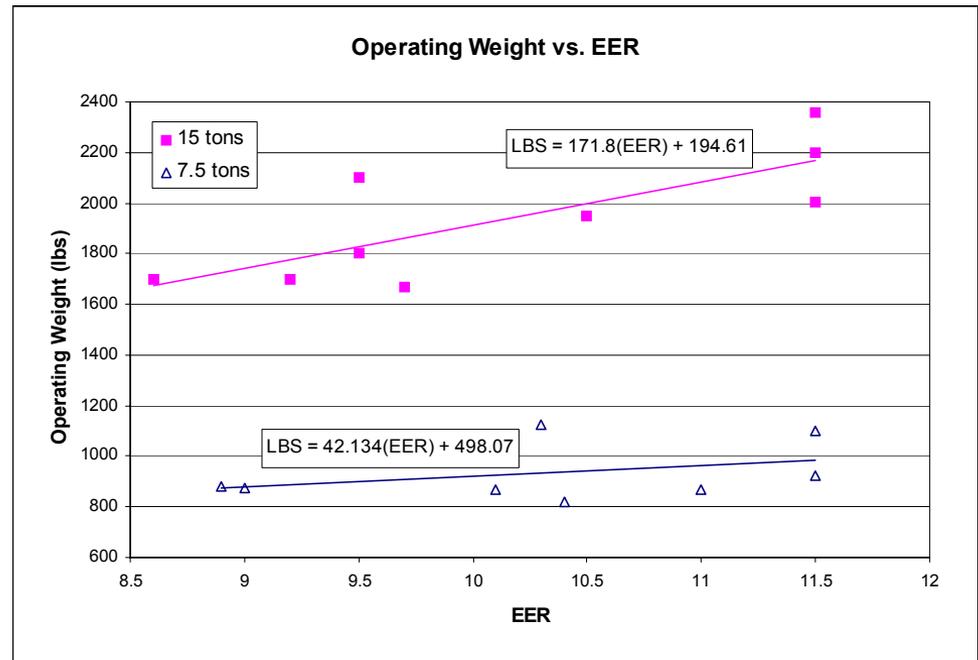
## Example Calculation

	Manufacturing Price		Customer Price		Deduced Markups
	Incremental	Total	Incremental	Total	
Baseline	-	\$2,000	-	\$4,630	2.31
Standard Level 1	\$300	\$2,300	\$468	\$5,098	2.22

# Total Installed Cost of Equipment

# Installation Costs

- Based on RS Means Mechanical Cost Data
  - 7.5 ton baseline (10.1 EER) installation cost = \$1585
  - 15 ton baseline (9.5 EER) installation cost = \$2142
  - Installation cost varies by State
- Assumed to increase in direct proportion to equipment weight
  - Weight is a function of equipment efficiency



# Average Values: Manufacturer Price, Customer Equipment Price, Installation Cost, and Total Installed Cost

## AC 65 - 134.9 kBtu/h

EER	Manufacturer Price		Equipment Price	Installation Cost	Total Installed Cost
	Increase	Total			
10.1	-	\$2,098	\$4,855	\$1,585	\$6,440
10.5	\$47	\$2,145	\$4,928	\$1,614	\$6,542
11.0	\$139	\$2,237	\$5,072	\$1,650	\$6,722
11.5	\$292	\$2,390	\$5,309	\$1,686	\$6,995
11.8	\$427	\$2,525	\$5,520	\$1,708	\$7,228
12.0	\$543	\$2,641	\$5,700	\$1,722	\$7,422

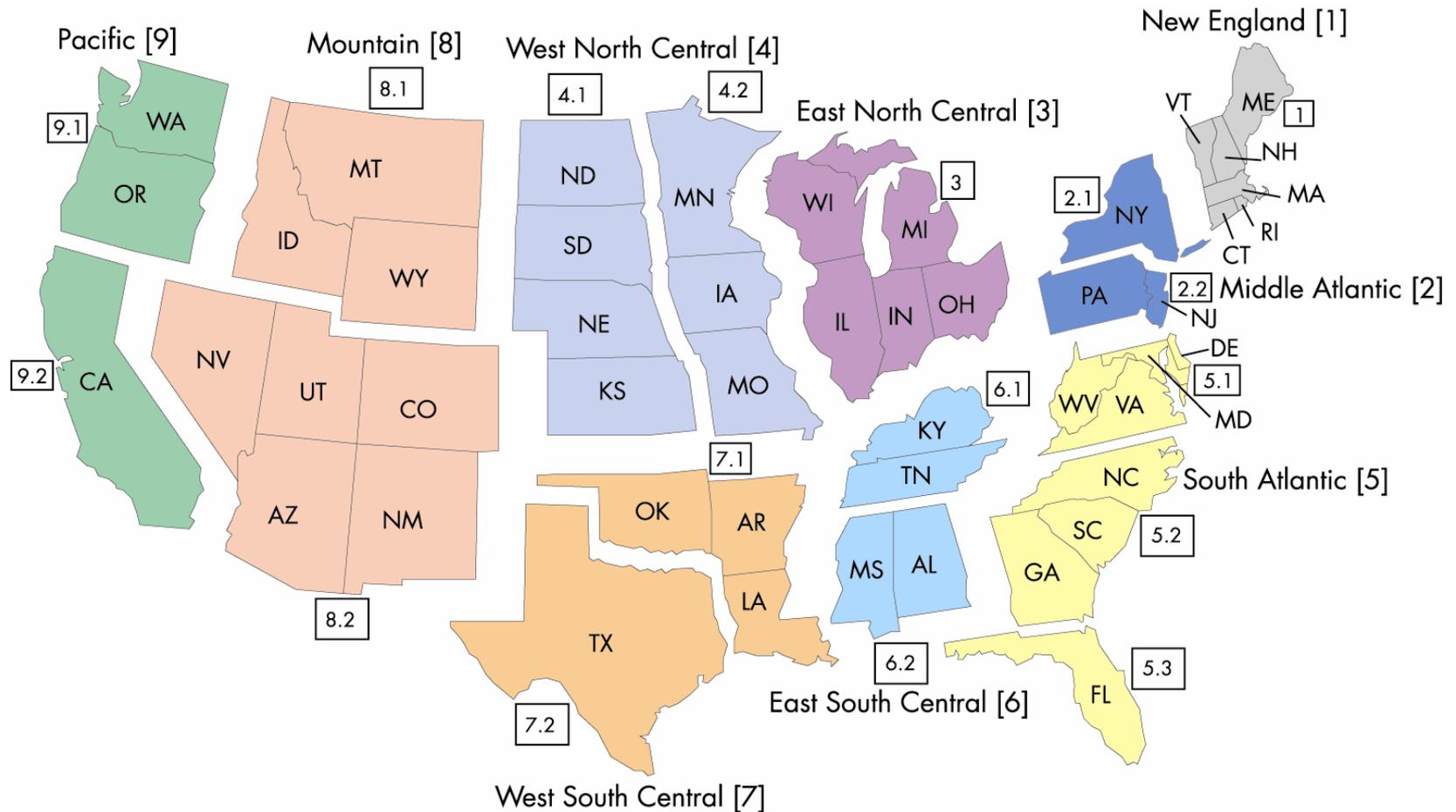
## AC 135-239.9 kBtu/h

EER	Manufacturer Price		Equipment Price	Installation Cost	Total Installed Cost
	Increase	Total			
9.5	-	\$3,957	\$9,157	\$2,142	\$11,299
10.0	\$62	\$4,019	\$9,254	\$2,243	\$11,497
10.1	\$82	\$4,039	\$9,285	\$2,263	\$11,548
10.5	\$165	\$4,122	\$9,414	\$2,343	\$11,757
11.0	\$334	\$4,291	\$9,677	\$2,444	\$12,121
11.5	\$613	\$4,570	\$10,111	\$2,545	\$12,656
11.8	\$866	\$4,823	\$10,506	\$2,605	\$13,111
12.0	\$1,072	\$5,029	\$10,826	\$2,646	\$13,472



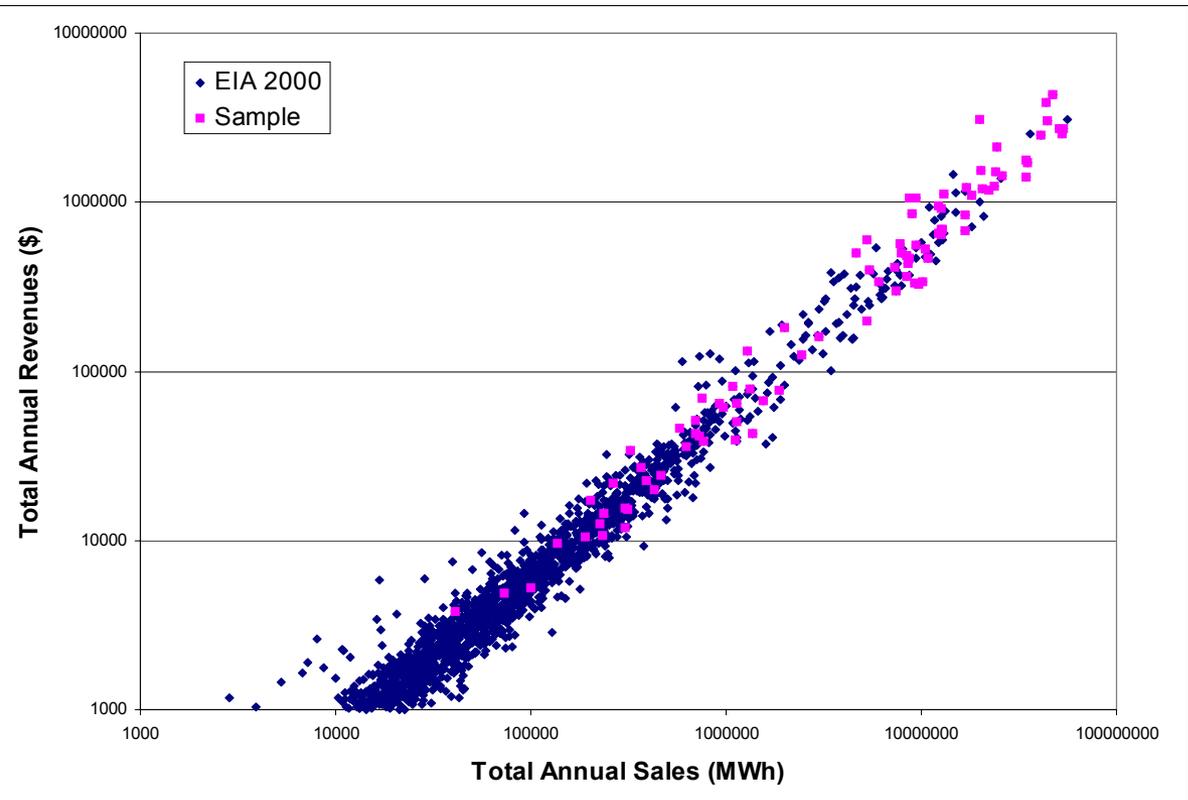
# Tariff-based Electricity Prices

# 17 Subdivisions based on Census Division, Climate Region, Grid Structure



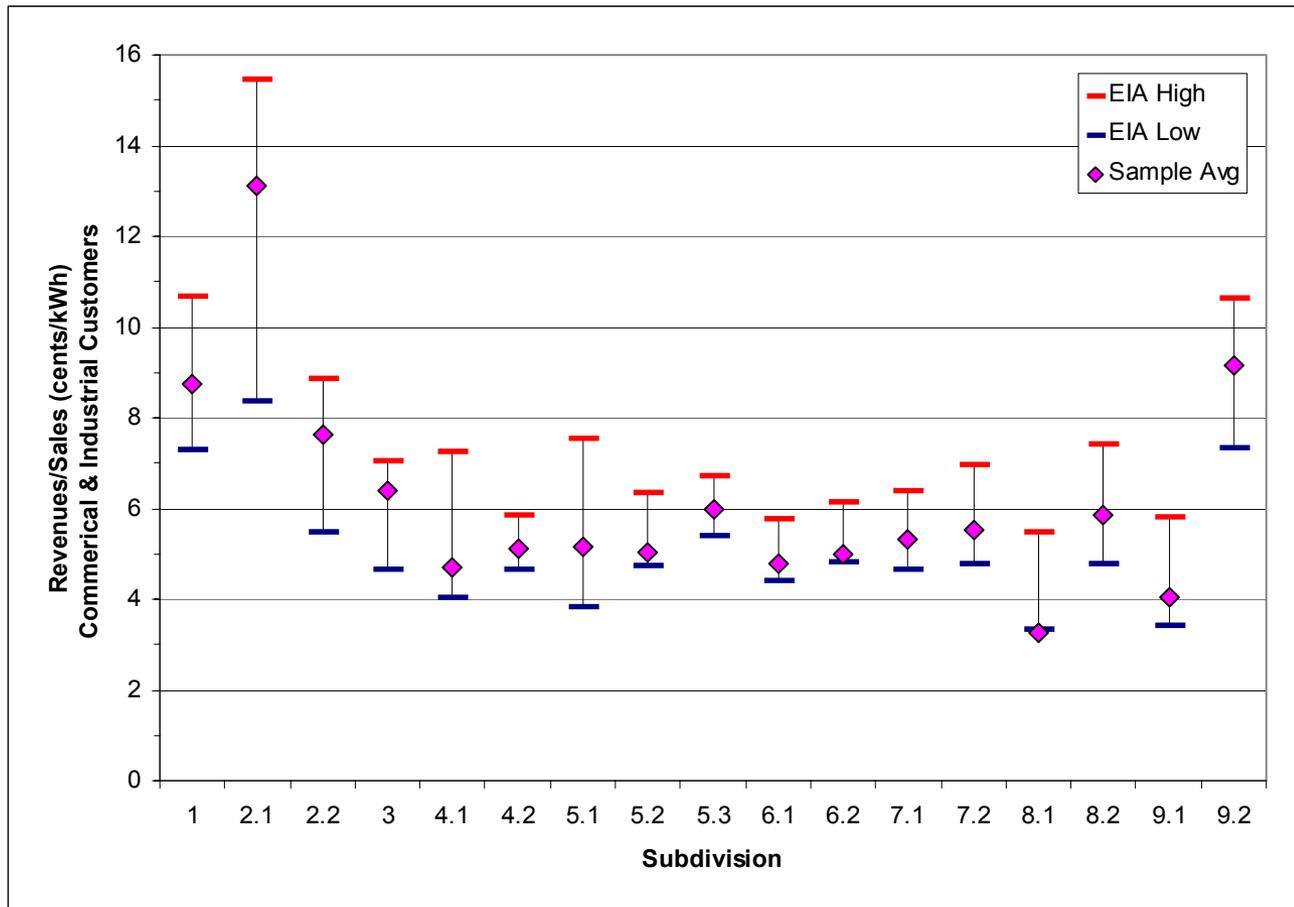
- Tariffs have been collected at the subdivision level

# Sample utilities selected on the basis of obtaining high coverage of U.S. sales and customers



CUSTOMER COVERAGE BY SUBDIVISION					
No.	Subdivision	States	Customers		
			Total	Private	Public
1	New England	CT,MA,ME,NH,RI,VT	39%	43%	4%
2.1	New York	NY	75%	73%	88%
2.2	Mid Atlantic	NJ,PA	47%	48%	8%
3	EN Central	IL,IN,MI,OH,WI	39%	44%	8%
4.1	W-WN Central	KS,ND,NE,SD	12%	27%	5%
4.2	E-WN Central	IA,MO,MN	46%	59%	10%
5.1	N-S Atlantic	DE,MD,VA,WV	67%	73%	13%
5.2	Mid-S Atlantic	GA,NC,SC	64%	89%	12%
5.3	Florida	FL	58%	72%	15%
6.1	N-ES Central	KY,TN	21%	47%	11%
6.2	S-ES Central	AL,MS	43%	69%	10%
7.1	N-WS Central	AR,LA,OK	44%	60%	3%
7.2	Texas	TX	22%	24%	19%
8.1	N-Mountain	ID,MT,WY	40%	53%	10%
8.2	S-Mountain	AZ,CO,NM,NV,UT	46%	72%	6%
9.1	N-Pacific	OR,WA	38%	48%	17%
9.2	California	CA	66%	81%	20%
9.3	Alaska	AK	21%	0%	23%
9.4	Hawaii	HI	63%	63%	NA
<b>USA</b>			<b>48%</b>	<b>59%</b>	<b>14%</b>

# Sample utilities have average *Revenue/Sales* values within range of Energy Information Administration (EIA) listed utilities



# Utilities generally have several tariffs

Example: Commercial/Industrial Tariffs from  
Boston Edison Company, Boston MA

Tariff	Tariff Limits (kW)	
	Min	Max
General Service G-1 w/o Demand Meters	0	10
General Service G-2 w/ Demand	10	150
Time of Use Rate T-2	150	99999999

# Each tariff is a combination of fixed, energy, and demand charges

Example: Boston Edison Company, Boston MA  
General Service Tariff G-2 w/ Demand

Charge Description	Summer Rates	Winter Rates
<b>Fixed Charges (\$)</b>	18.19	18.19
<b>Energy Charges</b>		
first 200 kWh (\$/kWh)	0.1117	0.0449
next 150 hours of billing demand (\$/kWh)	0.0245	0.0116
for all additional kWh (\$/kWh)	0.0050	0.0045
<b>Demand Charges</b>		
in excess of 10kW (\$/kW)	23.51	10.97

# Calculate annual electricity bill from the tariff and the building's energy & demand characteristics

Example: Boston Edison Company, Boston MA  
General Service Tariff G-2 w/ Demand  
Season – Summer; Month – July  
C&I Revenue/Sales = 9.63 cents/kWh

<b>CBECS Bldg ID</b>	<b>Bldg Type</b>	<b>Area sq. ft.</b>	<b>Consumption kWh</b>	<b>Demand kW</b>	<b>Marginal Rate cents/kWh</b>
7273	Small Office	3000	3329	10.27	5.75
6274	Small Office	5001	5468	17.77	12.13
41	Restaurant	900	22024	50.90	8.43
5650	Small Office	23750	27455	86.08	11.42
4054	Warehouse	55000	33703	125.48	13.92

Bill Calculator and Tariffs are available at:  
<http://eetd.lbl.gov/ea/ees/tariffs/index.php>

# Marginal electricity rates for package a/c customers are a function of building load factor

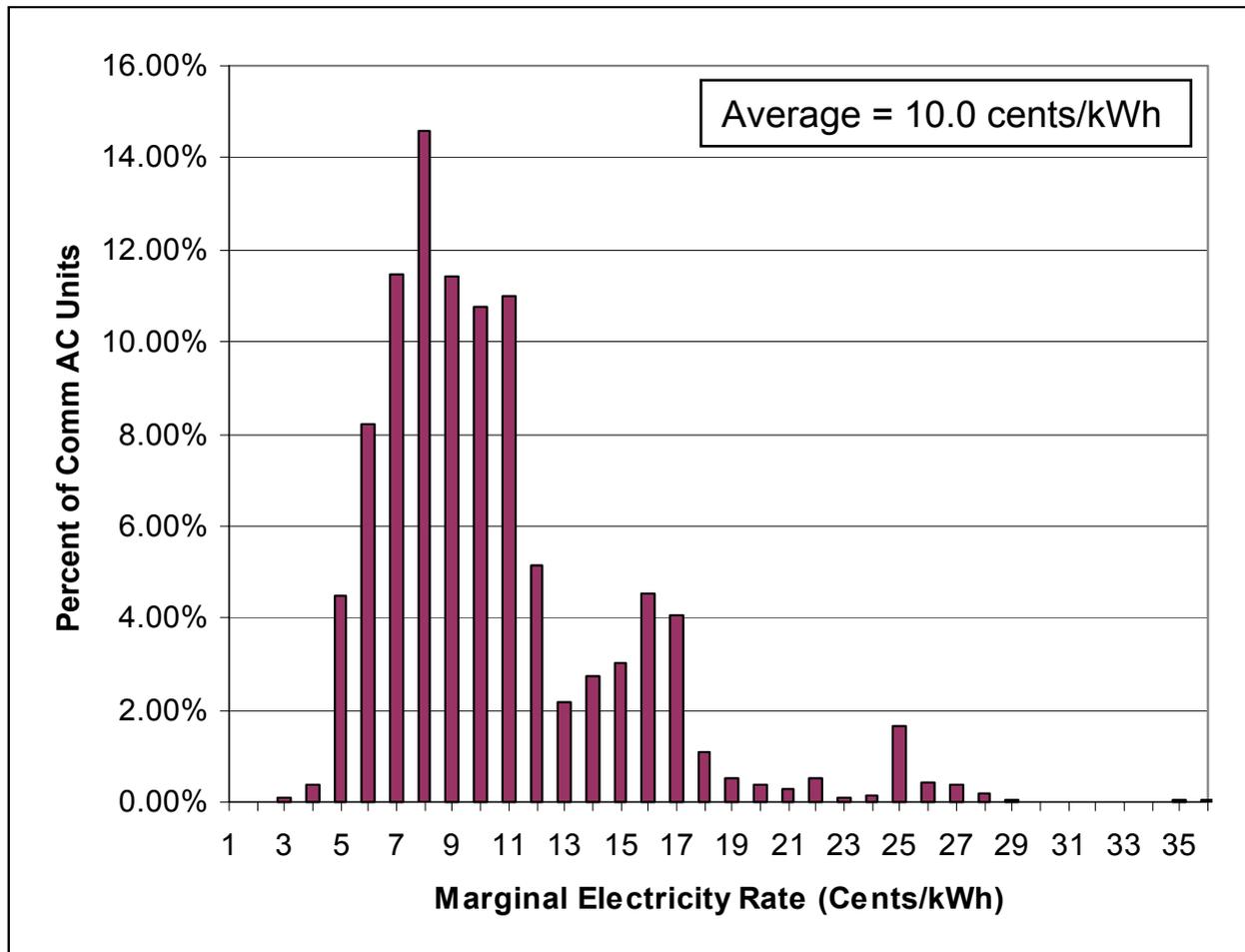
- Building load factor indicates the relative significance of peak demand use
  - The higher the load factor the lower peak demand is to overall energy consumption
  - Bldg load factor = Annual energy use (kWh) ÷ [Peak demand (kW) • 8760 hours]

MARGINAL ELECTRICITY RATES BY SUBDIVISION (cents/kWh)					
No.	Subdivision	States	Building Load Factor		
			< 30%	30% to 50%	> 50%
1	New England	CT,MA,ME,NH,RI,VT	9.1	7.6	6.7
2.1	New York	NY	13.1	13.4	10.4
2.2	Mid Atlantic	NJ,PA	11.8	10.7	8.5
3	EN Central	IL,IN,MI,OH,WI	11.1	9.4	8.0
4.1	W-WN Central	KS,ND,NE,SD	6.1	5.9	5.3
4.2	E-WN Central	IA,MO,MN	6.1	6.0	5.4
5.1	N-S Atlantic	DE,MD,VA,WV	9.1	7.4	6.3
5.2	Mid-S Atlantic	GA,NC,SC	7.5	7.4	5.2
5.3	Florida	FL	7.7	7.8	7.3
6.1	N-ES Central	KY,TN	6.7	6.2	5.8
6.2	S-ES Central	AL,MS	6.7	6.3	5.2
7.1	N-WS Central	AR,LA,OK	6.1	5.9	5.4
7.2	Texas	TX	10.2	9.3	7.0
8.1	N-Mountain	ID,MT,WY	NA	6.1	5.8
8.2	S-Mountain	AZ,CO,NM,NV,UT	9.1	8.1	7.5
9.1	N-Pacific	OR,WA	NA	4.4	3.1
9.2	California	CA	19.6	18.4	18.2
<b>USA</b>			<b>11.3</b>	<b>10.1</b>	<b>7.3</b>

92% of building sample has a load factor less than 50%.

As a result, most of building sample has relatively high marginal electricity rates.

# Marginal electricity rates vary over a wide range of values



# Hourly-based Electricity Prices

# Motivation for Hourly Approach

- Restructuring of electricity markets may change pricing, creating a need for more precise analysis of system costs and benefits
- Loads and electricity costs vary hourly
- Strong correlation between high temperatures, air-conditioning use, high system loads and high marginal electricity prices
- Determine whether utility tariff structures accurately reflect the real costs of serving peaky loads

# Hourly electricity prices: Approach

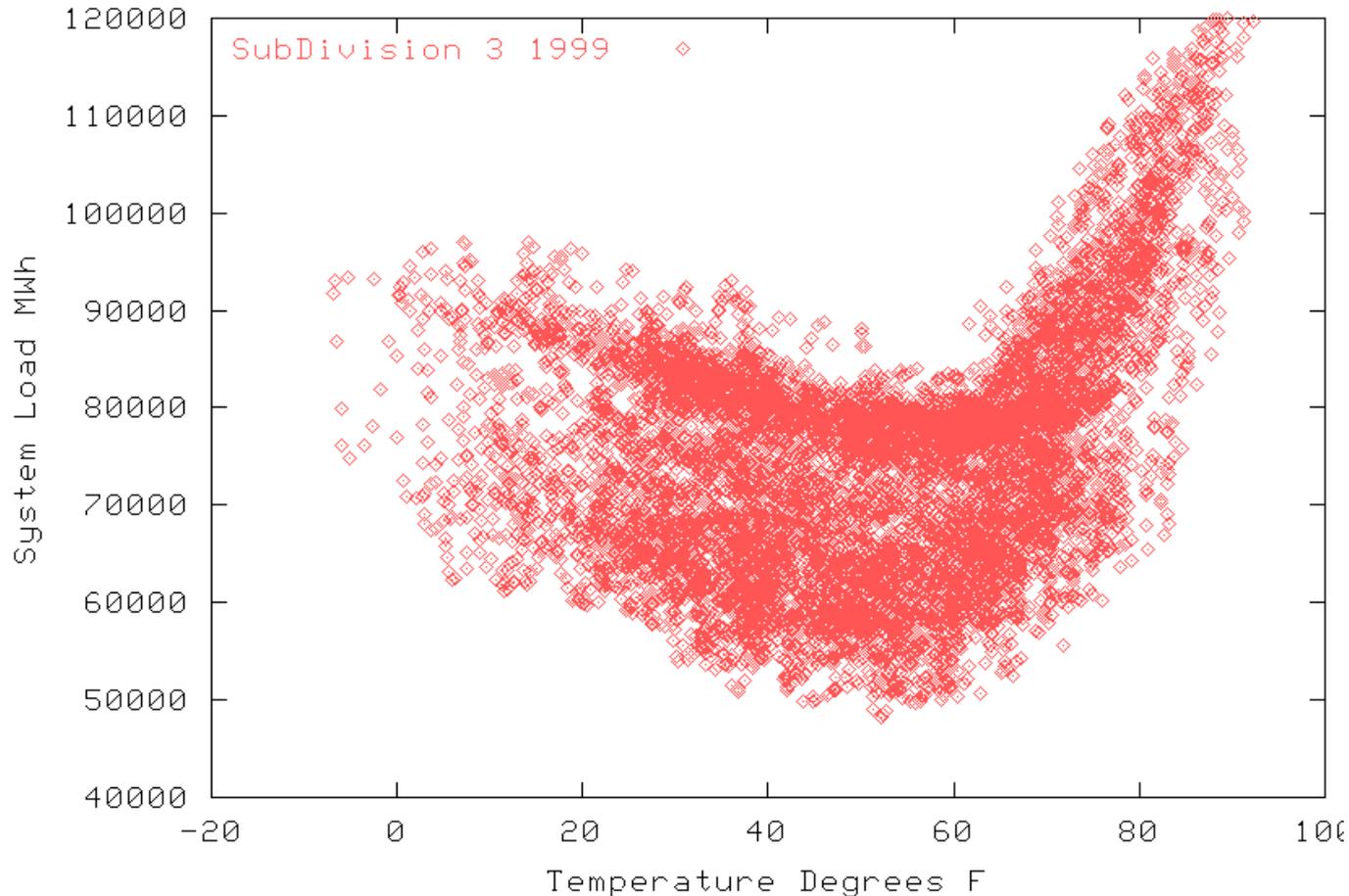
- *Why do we need a model?*
  - Building simulations use Typical Meteorological Year (TMY) weather data, so we need to create corresponding “TMY prices” by modeling the relationship between actual prices and actual weather
- *Step 1: Relate system load to temperature*
  - Data sources: Hourly temperature data for 1999, 2000 and the TMY year from NCDC. Hourly system loads for all utilities with peak loads > 200 MW from FERC Form 714.
- *Step 2: Relate system marginal price to load*
  - Data sources: Hourly “system lambda” (marginal production cost) data for every control area from FERC Form 714. Hourly market clearing prices for 1999 and 2000 from NY, NE, CA and PJM.

# Load is a function of Temperature, Time of Day, and Day-Type

- Use historical data to establish Load-Temperature relationships in each of the 17 subdivisions
- First sort the data into bins, according to the hour of the day, the day type (weekday or weekend) and natural light (day or night).
- Within each bin, fit the load-temperature relationship to a polynomial
- Compute a frequency distribution for the difference between the actual load and the fitted value
- Use this model to construct TMY loads as a function of temperature, including random fluctuations

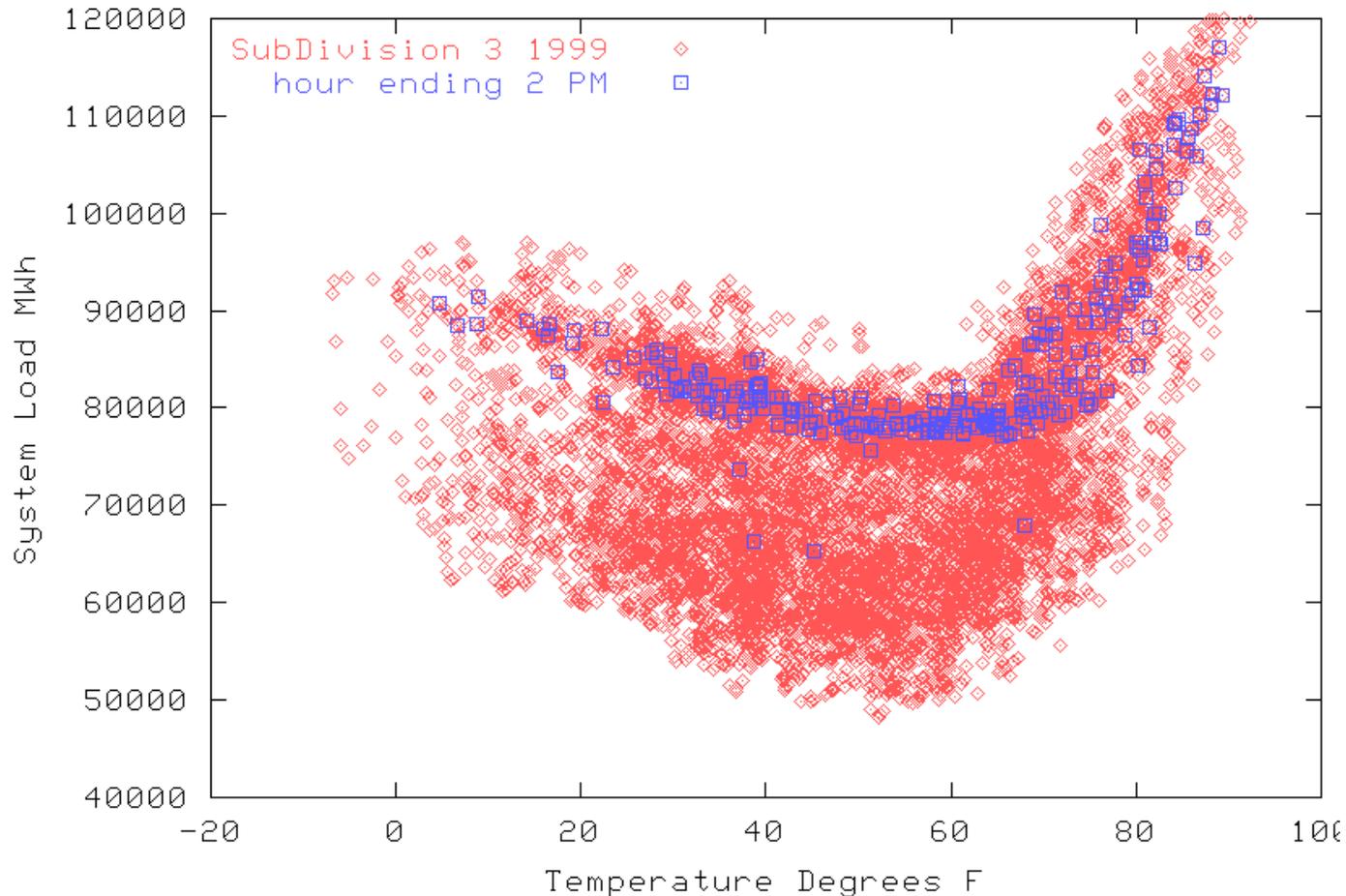
# Load as a function of temperature varies over a broad range

## Example: Subdivision 3



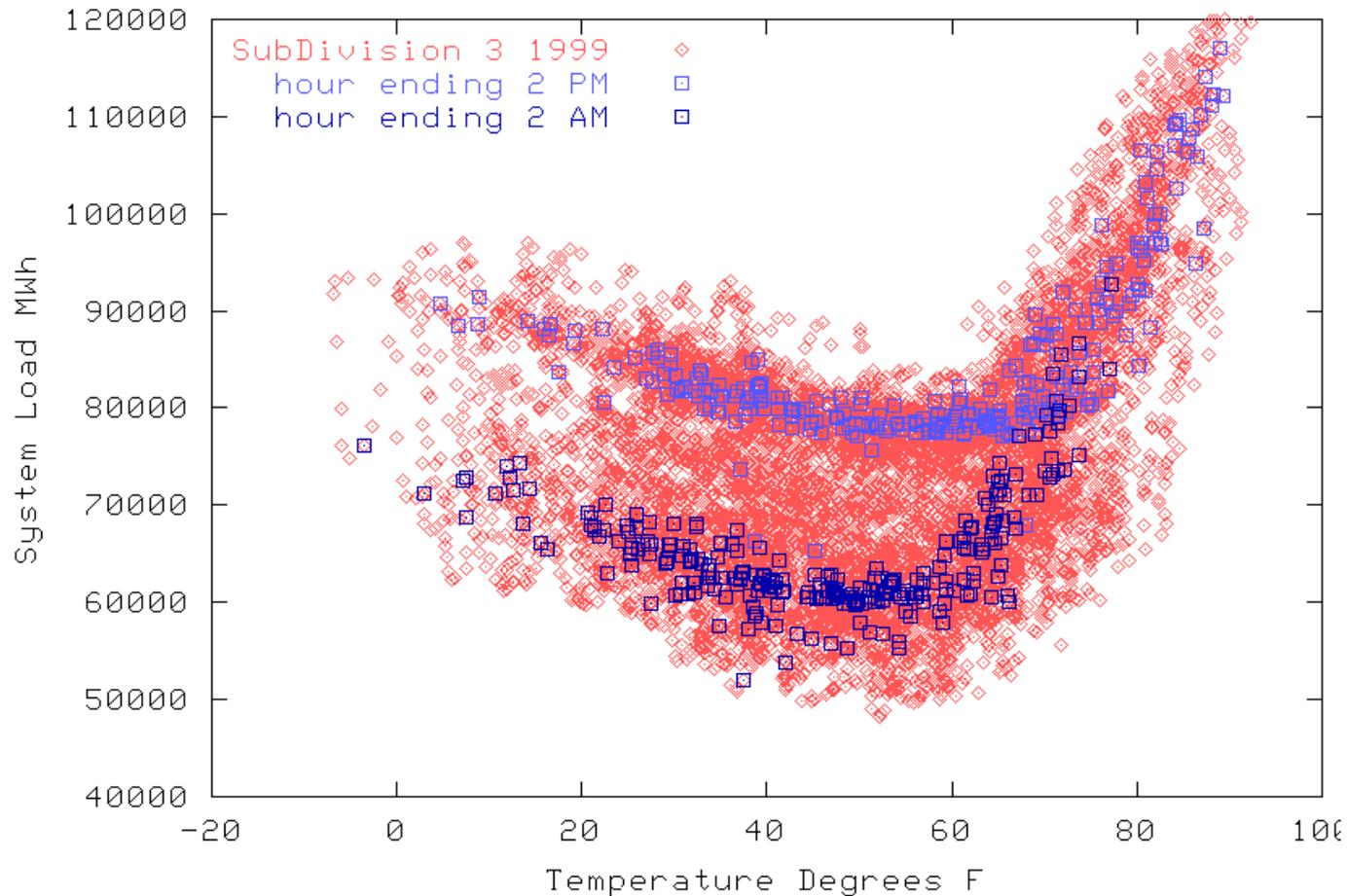
# Sorting on hour of day reduces the variability of the data

## Example: Subdivision 3

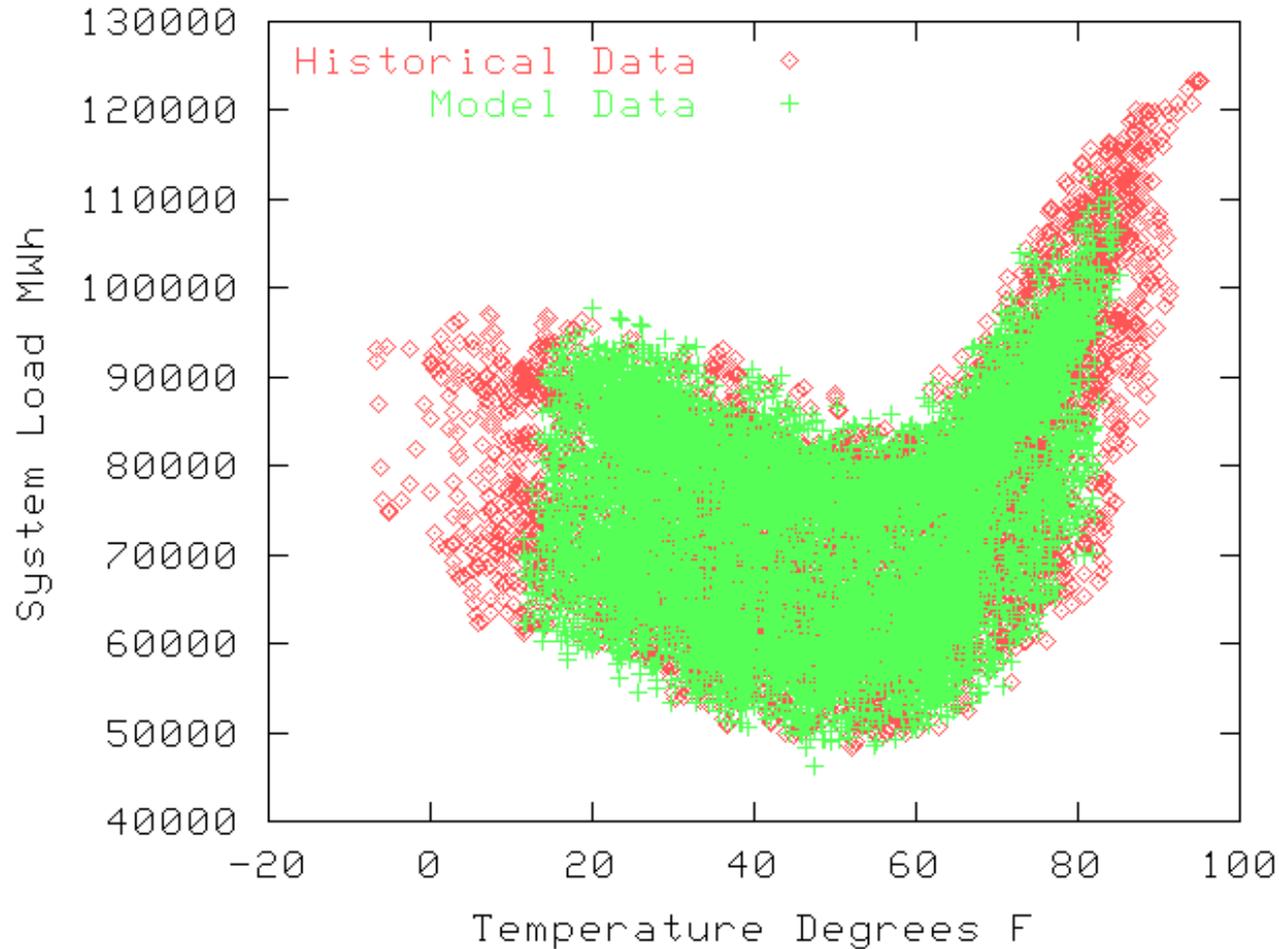


# Different hours of the day show different relationships to temperature

## Example: Subdivision 3



# Hourly Load-Temperature Model Output for TMY: Comparison to actual (1999) for Subdivision 3

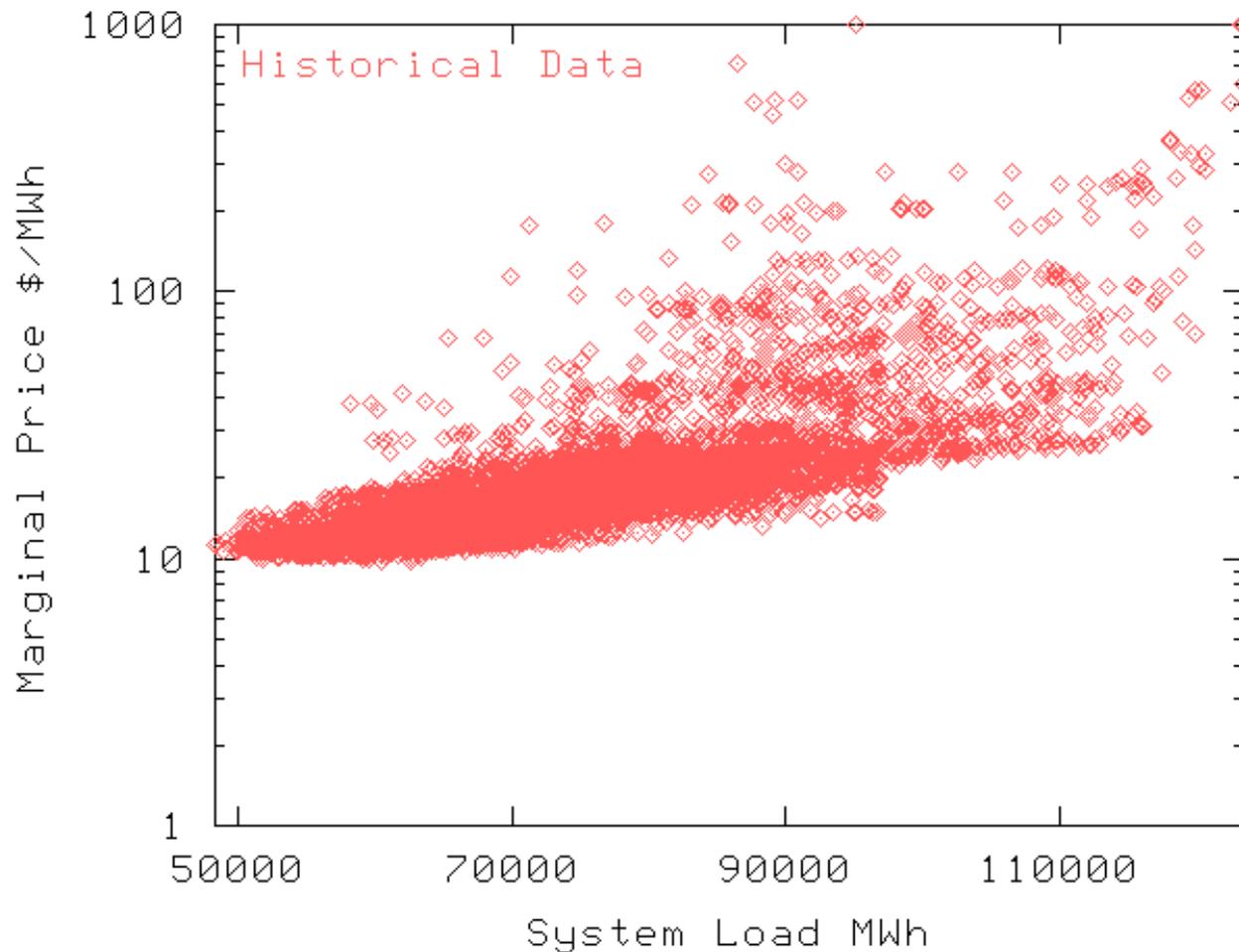


# Price is a function of Load, Season and Hour-Type

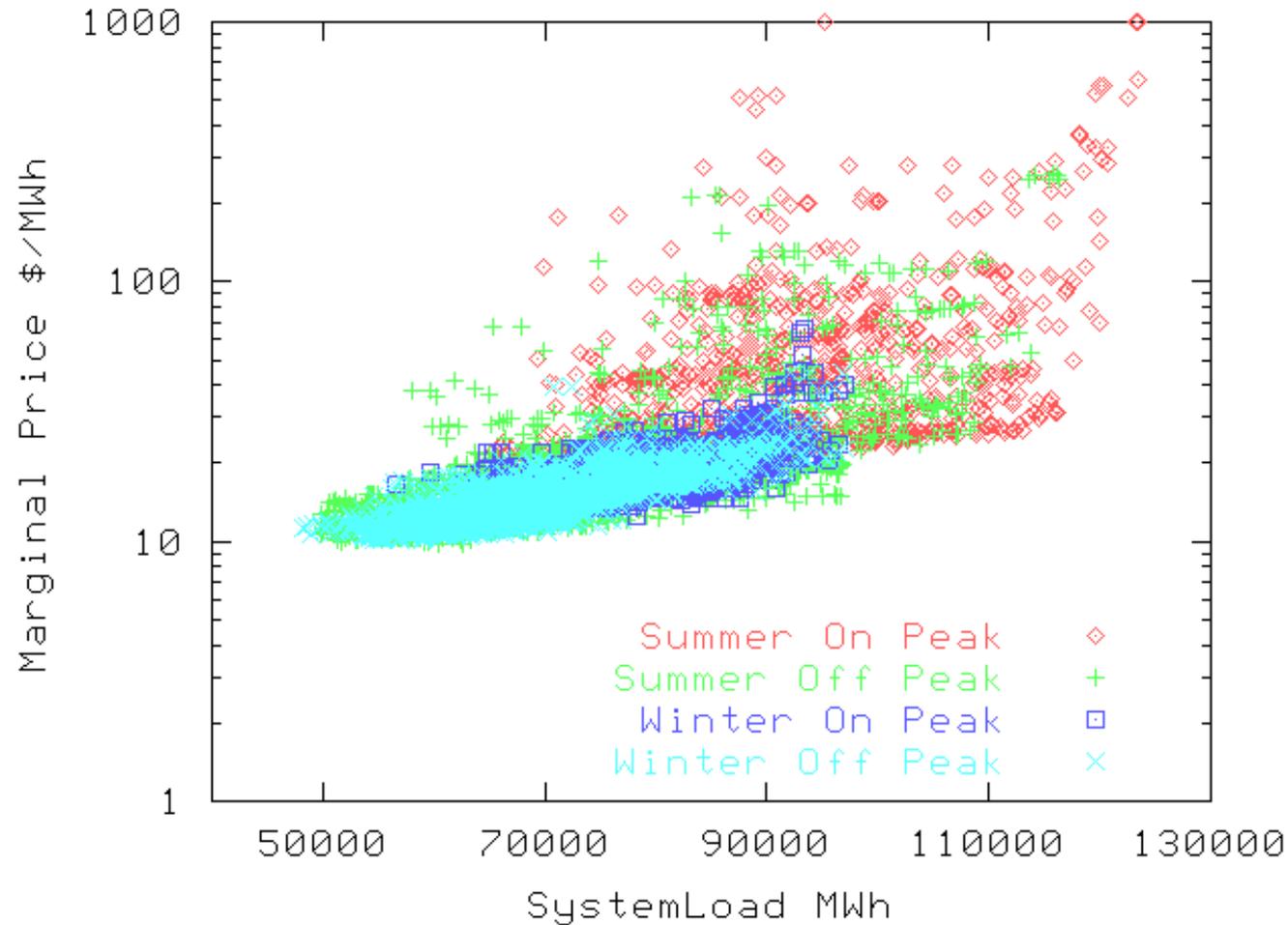
- In general, the price-load relationship is much more random than the load-temperature relationship
- Important variables are season (summer, winter) and hour-type (peak, off-peak)
- Volatility and price spikes occur primarily for summer, peak hours
- Model computes an average Price vs. Load relationship and adds random variations

# Price vs. Load varies over two orders of magnitude

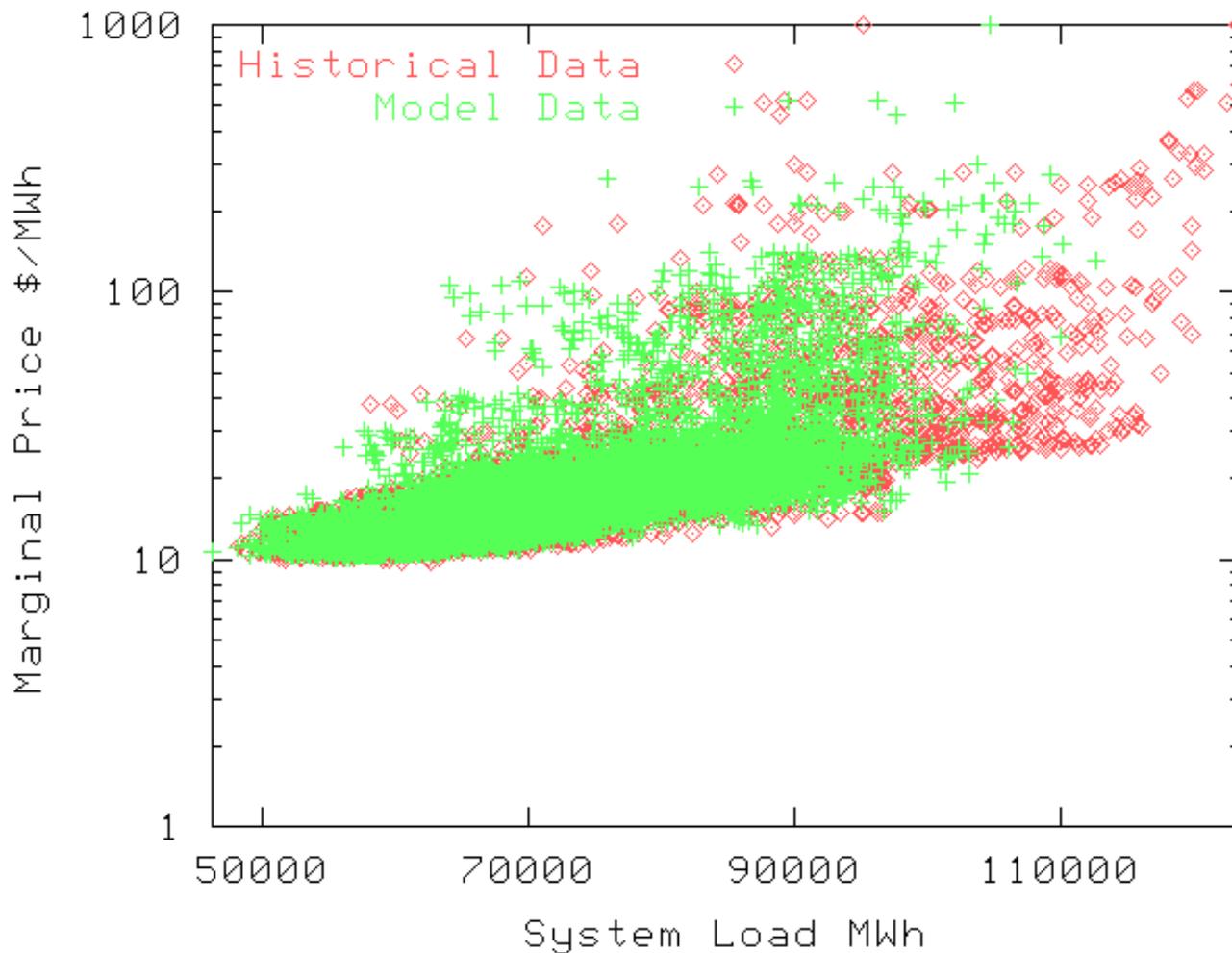
## Example: Subdivision 3



# Price vs. Load for Summer/Winter Peak/Off-Peak Example: Subdivision 3



# Hourly Price-Load Model Output for TMY: Comparison to actual (1999) for Subdivision 3



# Customer Hourly Price Model

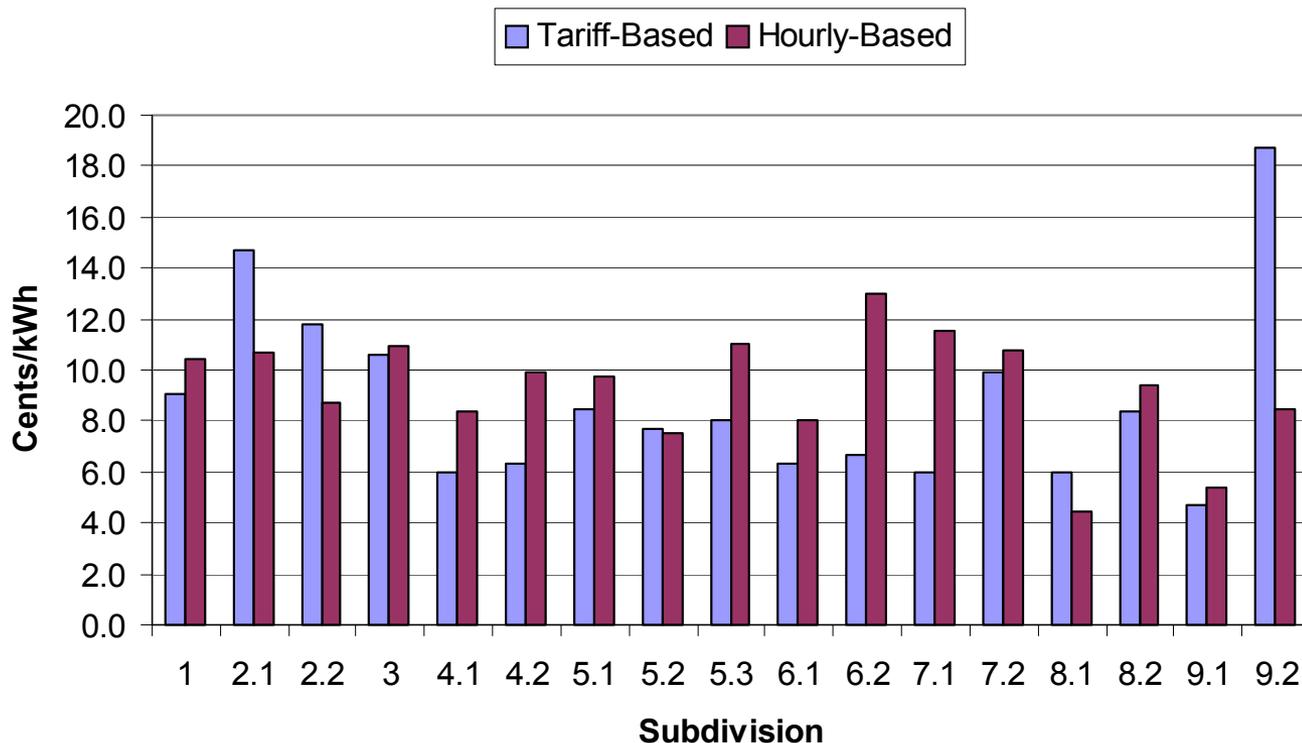
- **Total Cost Savings** = **(Generation Cost Savings) + (Coincident Peak Load Reduction)\*(Total Capacity Cost)**
- **Generation Cost Savings** = sum over all hours of marginal price times energy savings, multiplied by an additional *Cost Recovery Factor*
- **Coincident Peak Load Reduction** = reduction in a customer's load during the hour of the system peak
- **Total Capacity Cost** includes generation, transmission and distribution capacity, reserve margins, and losses, expressed as \$/kW. *Utility Fixed Charge Rates* are used to convert these to the annual revenue stream required to cover all investment costs.

# Marginal Electricity Prices by Subdivision

Tariff-based  
Average 10.0 ¢/kWh

Hourly-based  
Average 9.9 ¢/kWh

Commercial AC Marginal Electricity Price

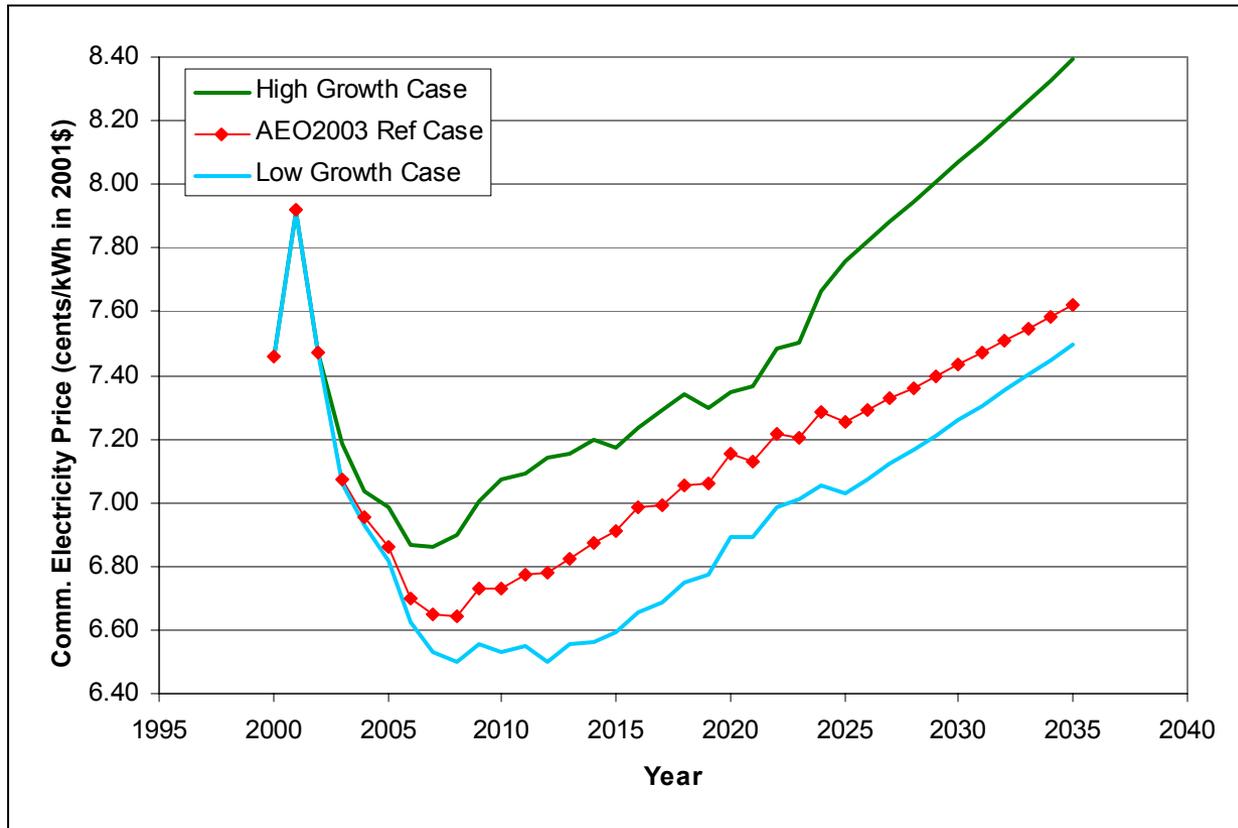


# Marginal Electricity Prices by Subdivision

No.	Subdivision	States	Unit Weighting	Tariff-based Marginal Price		Hourly-based Marginal Price	
				Cents/kWh	% demand	Cents/kWh	% capacity
1	New England	CT,MA,ME,NH,RI,VT	4.7	9.5	53%	10.7	43%
2.1	New York	NY	7.4	14.6	53%	10.5	35%
2.2	Mid Atlantic	NJ,PA	5.6	10.5	27%	8.7	48%
3	EN Central	IL,IN,MI,OH,WI	13.7	10.8	46%	11.0	65%
4.1	W-WN Central	KS,ND,NE,SD	0.8	6.2	44%	8.4	60%
4.2	E-WN Central	IA,MO,MN	4.7	7.1	30%	9.8	60%
5.1	N-S Atlantic	DE,MD,VA,WV	5.6	7.9	41%	9.9	63%
5.2	Mid-S Atlantic	GA,NC,SC	7.9	7.3	22%	7.4	68%
5.3	Florida	FL	6.6	8.0	36%	11.0	66%
6.1	N-ES Central	KY,TN	5.1	6.5	38%	8.0	68%
6.2	S-ES Central	AL,MS	5.4	6.1	39%	12.8	70%
7.1	N-WS Central	AR,LA,OK	5.3	5.8	26%	11.6	76%
7.2	Texas	TX	9.5	10.0	23%	10.8	75%
8.1	N-Mountain	ID,MT,WY	0.6	6.1	20%	4.5	43%
8.2	S-Mountain	AZ,CO,NM,NV,UT	4.2	8.8	35%	9.5	69%
9.1	N-Pacific	OR,WA	1.7	4.5	33%	5.4	24%
9.2	California	CA	11.2	18.5	21%	8.5	46%
<b>USA</b>			100.0	<b>10.0</b>	<b>35%</b>	<b>9.9</b>	<b>60%</b>

# Electricity Price Forecasts

# Future Trends: Average Electricity Price for U.S. Commercial Customers



Source: Energy Information Administration, Annual Energy Outlook, 2003

# Discount Rates

# Discount Rates based on Cost of Capital

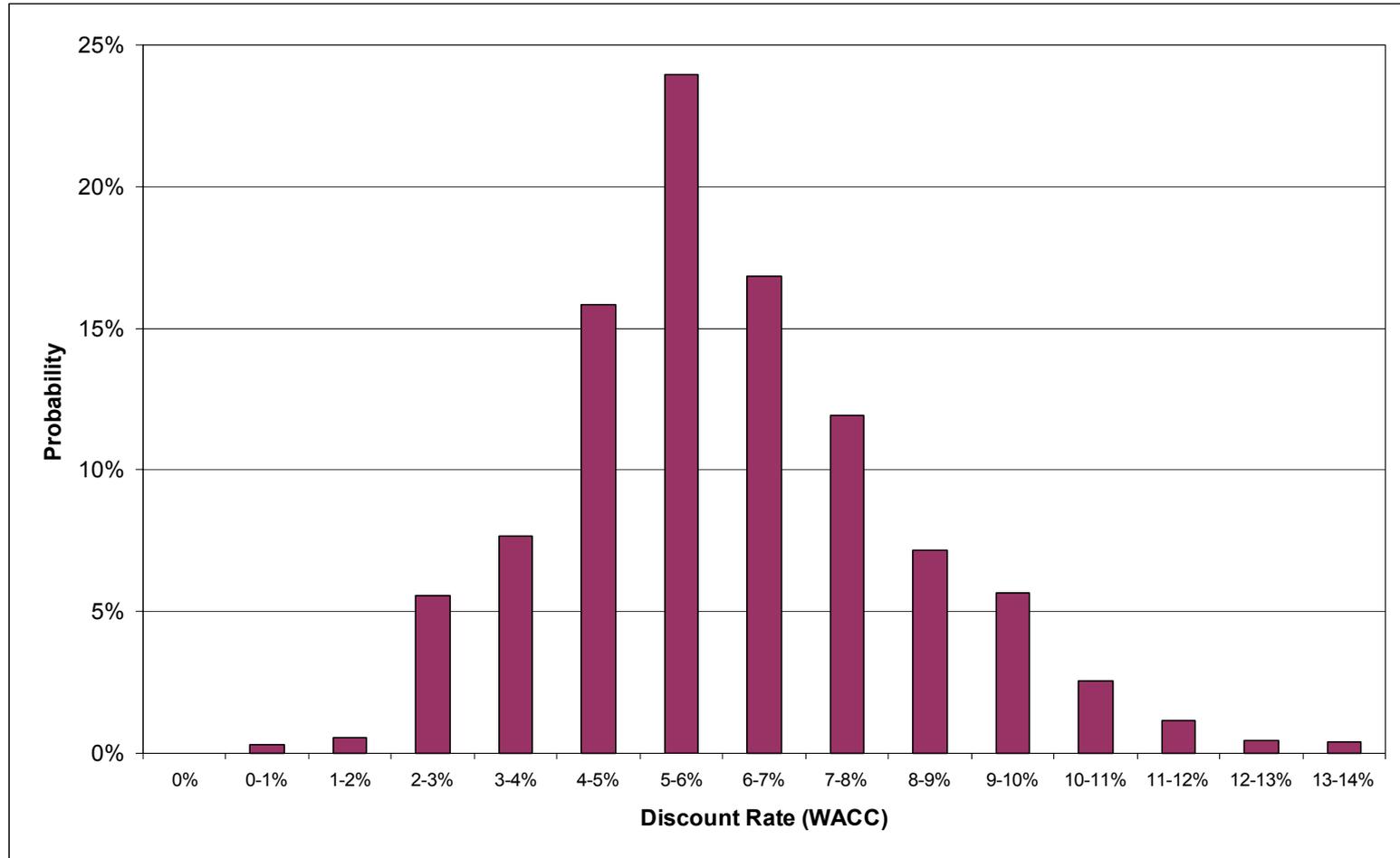
- Discount rates are used to reduce the future value of cash flows to be derived from a typical company project or investment
- Discount rates are derived from estimates of the cost of capital of companies that purchase commercial air conditioners
- Costs of capital is calculated from the weighted-average cost to the firm (WACC) to obtain equity and debt financing
  - Cost of equity financing ( $k_e$ ) is estimated using the capital asset pricing model (CAPM)
  - Cost of debt financing ( $k_d$ ) is the yield or interest rate paid on money borrowed by a company

# Discount rates for LCC analysis based on WACC for various ownership categories

- Sample of companies drawn for each ownership category from Value Line investment survey and listed on the Damodaran Online site
- Ownership category shares based on Commercial Building Energy Consumption Survey (CBECS) 1999 cooled floor space area

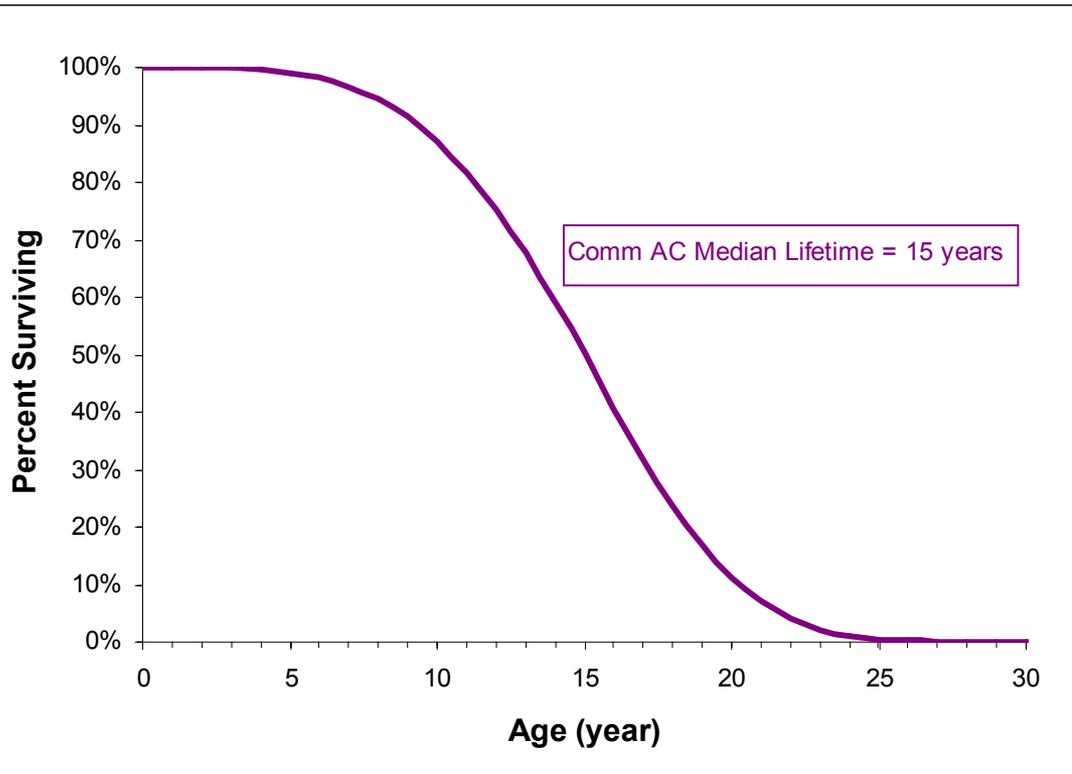
Ownership Category	SIC Code	Ownership Shares	Mean Real Discount Rate (WACC)	Standard Deviation	Number Observations
<b>Retail stores</b>	53, 54, 56	16%	7.1%	2.1%	218
<b>Property owners</b>	6720	21%	5.2%	0.7%	11
<b>Medical services</b>	8000	7%	7.0%	1.7%	115
<b>Industrial</b>	1000-4000	5%	6.9%	3.2%	253
<b>Hotels</b>	7000	4%	5.6%	1.5%	51
<b>Food Service</b>	5812, 5400	5%	6.1%	1.4%	88
<b>Office Service</b>	5910-9913	19%	6.9%	2.1%	128
<b>Public non-profit</b>	N.A.	11%	3.0%	0.7%	41
<b>Public for profit</b>	7950, 8299	11%	7.3%	1.8%	68
<b>Weighted Average</b>		N.A.	<b>6.1%</b>	1.59%	N.A.

# Distribution of real discount rates (WACC) for commercial air conditioner customers



# Other LCC Inputs

# Equipment Lifetime



- Median age of 15 years based on 1999 ASHRAE HVAC Applications Handbook
- Survival function based on Weibull probability distribution
  - 5% of population retired by 8<sup>th</sup> year
  - 90% of population retired by 21<sup>st</sup> year

# Repair Costs

- Annual Cost for repairing or replacing component failures
- Baseline annual repair cost assumed to equal  $\frac{1}{2}$  equipment price divided by average equipment lifetime
  - 7.5 ton baseline (10.1 EER) annual repair cost = \$158
  - 15 ton baseline (9.5 EER) annual repair cost = \$291
- Assumed to increase in direct proportion to equipment manufacturing price
  - 7.5 ton baseline (11 EER) annual repair cost = \$169
  - 15 ton baseline (11 EER) annual repair cost = \$316

# Maintenance Costs

- Maintenance Cost is the cost for maintaining equipment operation (e.g., checking refrigerant charge, cleaning coils)
- Based on RS Means Facilities Maintenance & Repair Cost Data
  - Specific to roof top air conditioners ranging in cooling capacity from 3 to 24 tons
- Stays constant as efficiency increases
- Annual maintenance cost equals \$200
  - Includes labor and materials with overhead and profit

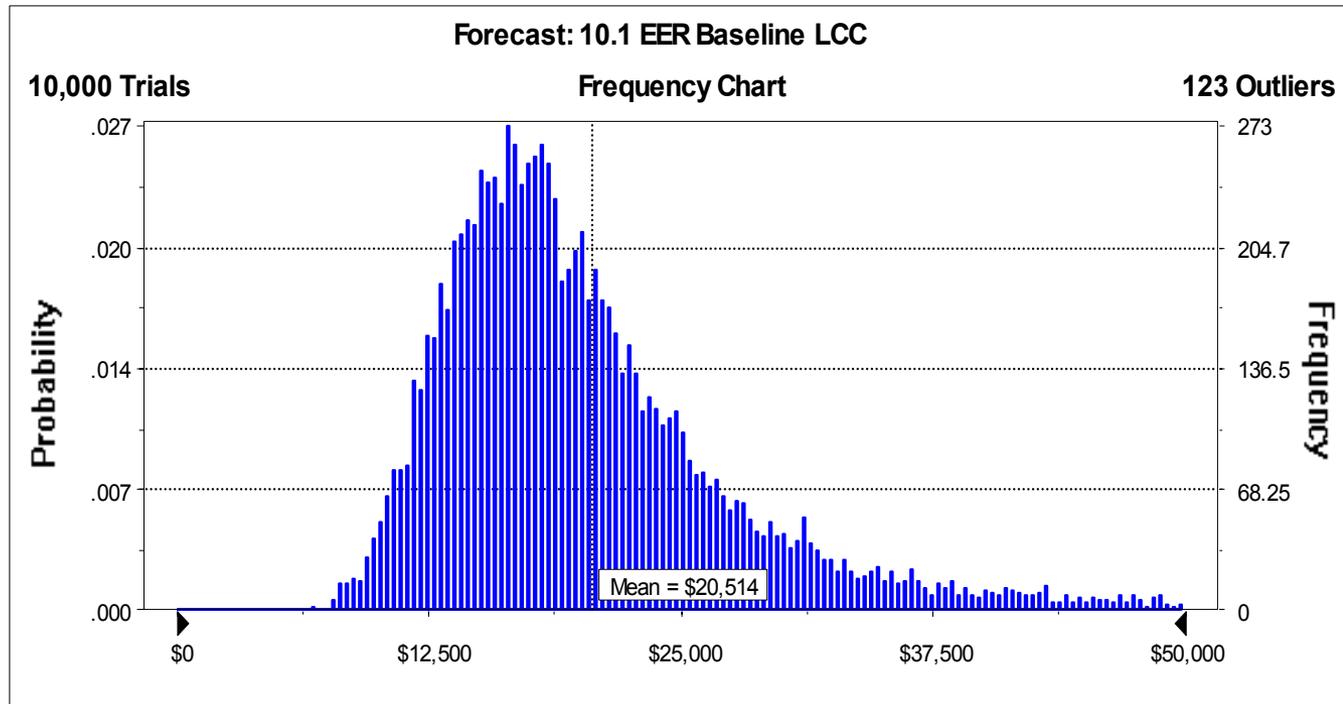
# LCC Results: Tariff-based Electricity Prices

# Analysis generates a distribution of LCC results

- LCC calculation performed on the representative set of units to generate a distribution of LCC results
- LCC calculations performed using a spreadsheet with a commercially available “add-in” for statistical sampling
- The spreadsheet plus “add-in” uses a Monte Carlo simulation analysis to sample from the representative set of units and the other input distributions

# Baseline LCC varies over a wide range of values

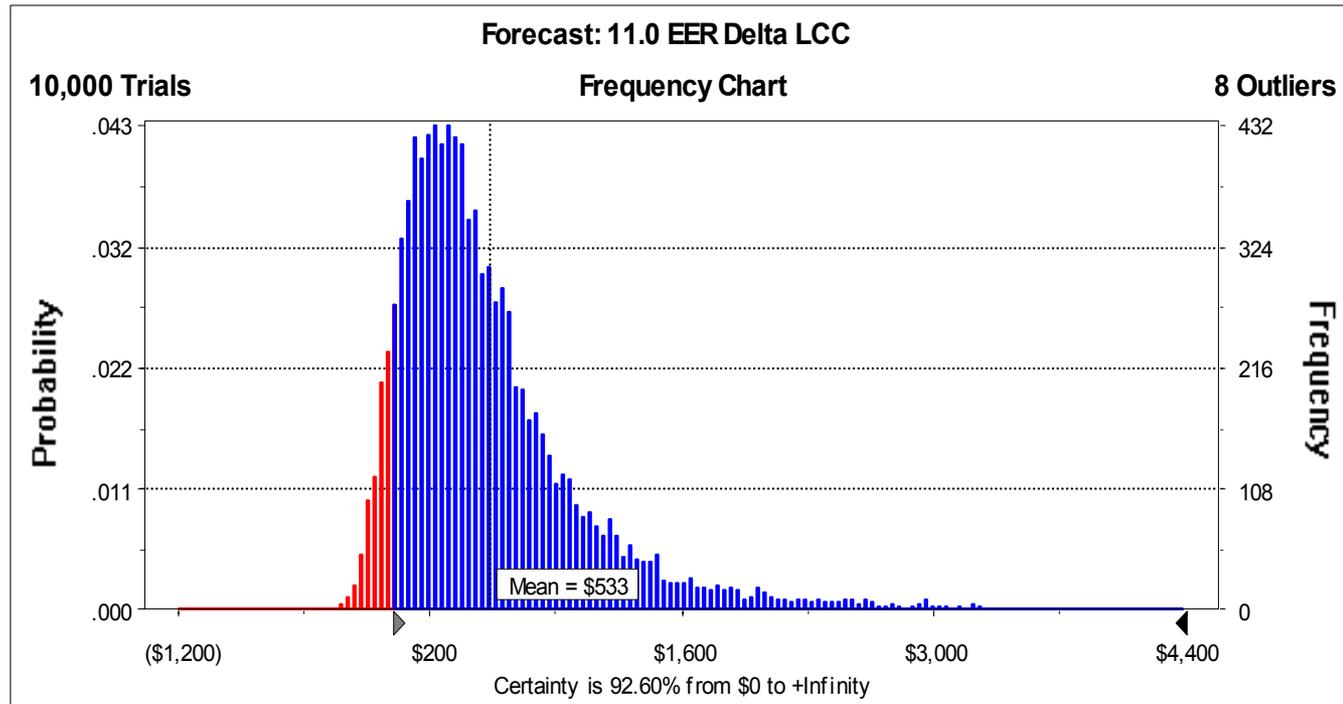
Product Class: A/C, 65-134.9 kBtu/h



- Mean LCC = \$20,514; Minimum LCC = \$6667; Maximum LCC = \$93,747
- Approximately 30% of LCC due to Total Installed Cost of Equipment (~\$6400)
- Outliers due to units with high marginal elec prices (> 25 cents/kWh)

# At 11 EER, most users have LCC savings

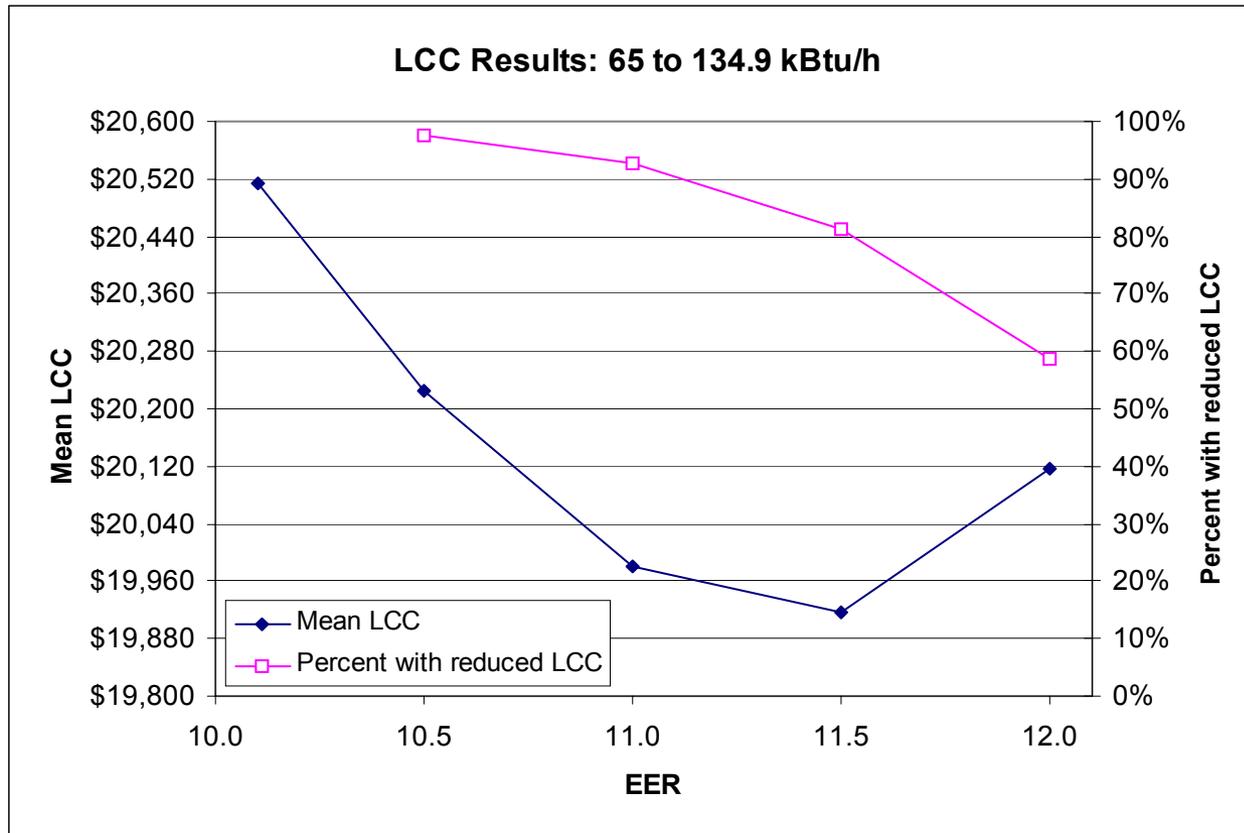
Product Class: A/C, 65-134.9 kBtu/h



- Mean impact is LCC savings of \$533
- 93% of sample have net savings
- Range is from net savings of \$5764 to net cost of \$333

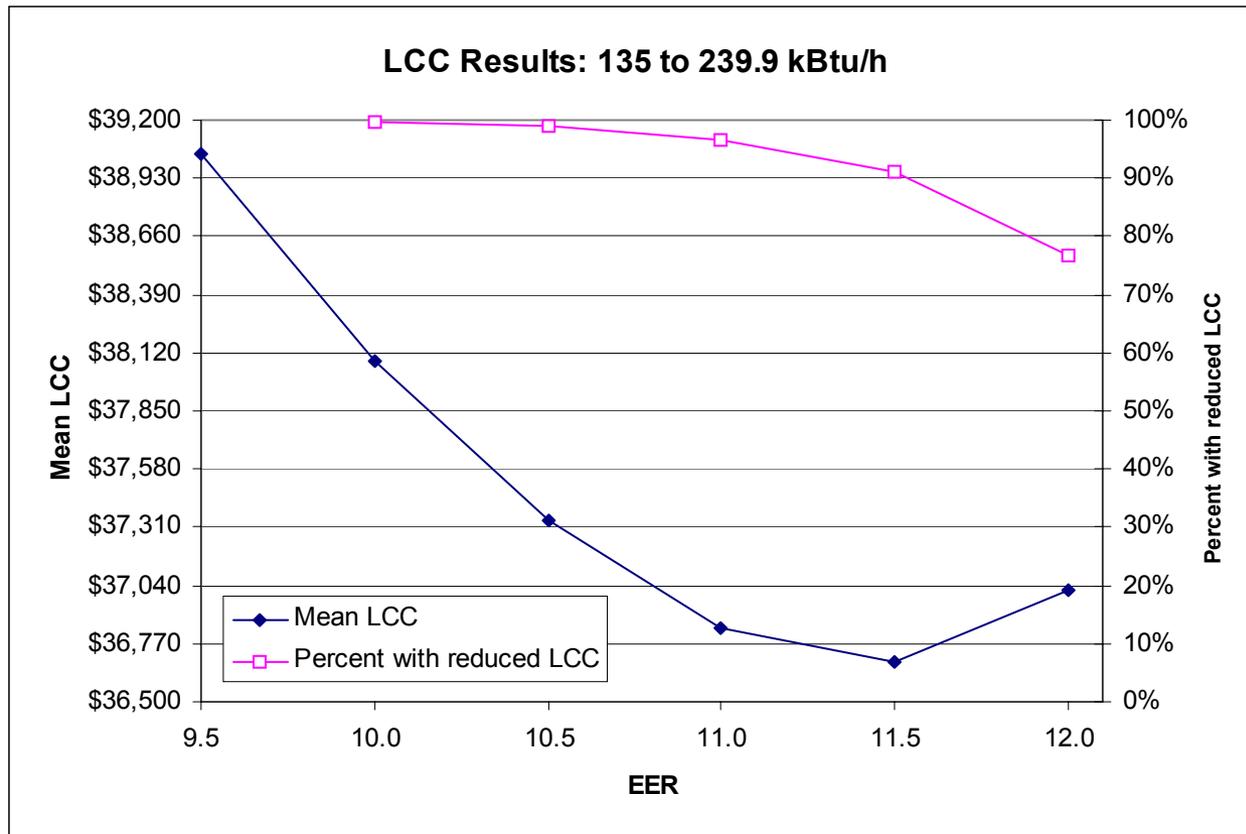
# Results: Mean LCC and Percent with Reduced LCC

Product Class: A/C, 65-134.9 kBtu/h



# Results: Mean LCC and Percent with Reduced LCC

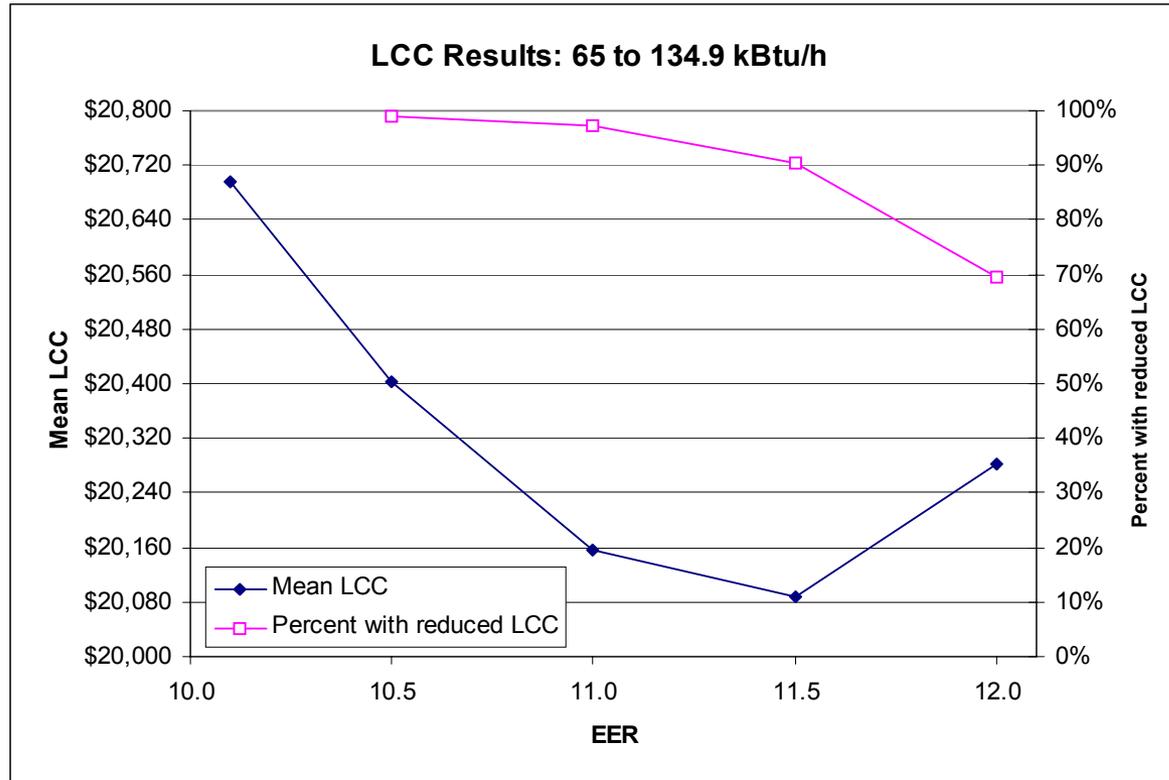
Product Class: A/C, 135-239.9 kBtu/h



# LCC Results: Hourly-based Electricity Prices

# Results: Mean LCC and Percent with Reduced LCC

Product Class: A/C, 65-134.9 kBtu/h



- Mean LCC results are similar to tariff-based analysis
- Range of hourly-based electricity prices less than that of tariff-based prices – eliminates extremes resulting in greater percentage of units with reduced LCC

# Results: Mean LCC and Percent with Reduced LCC

Product Class: A/C, 135-239.9 kBtu/h

