U.S. Department of Energy
Energy Efficiency and Renewable Energy

Energy Conservation Standards for Commercial Refrigeration Equipment

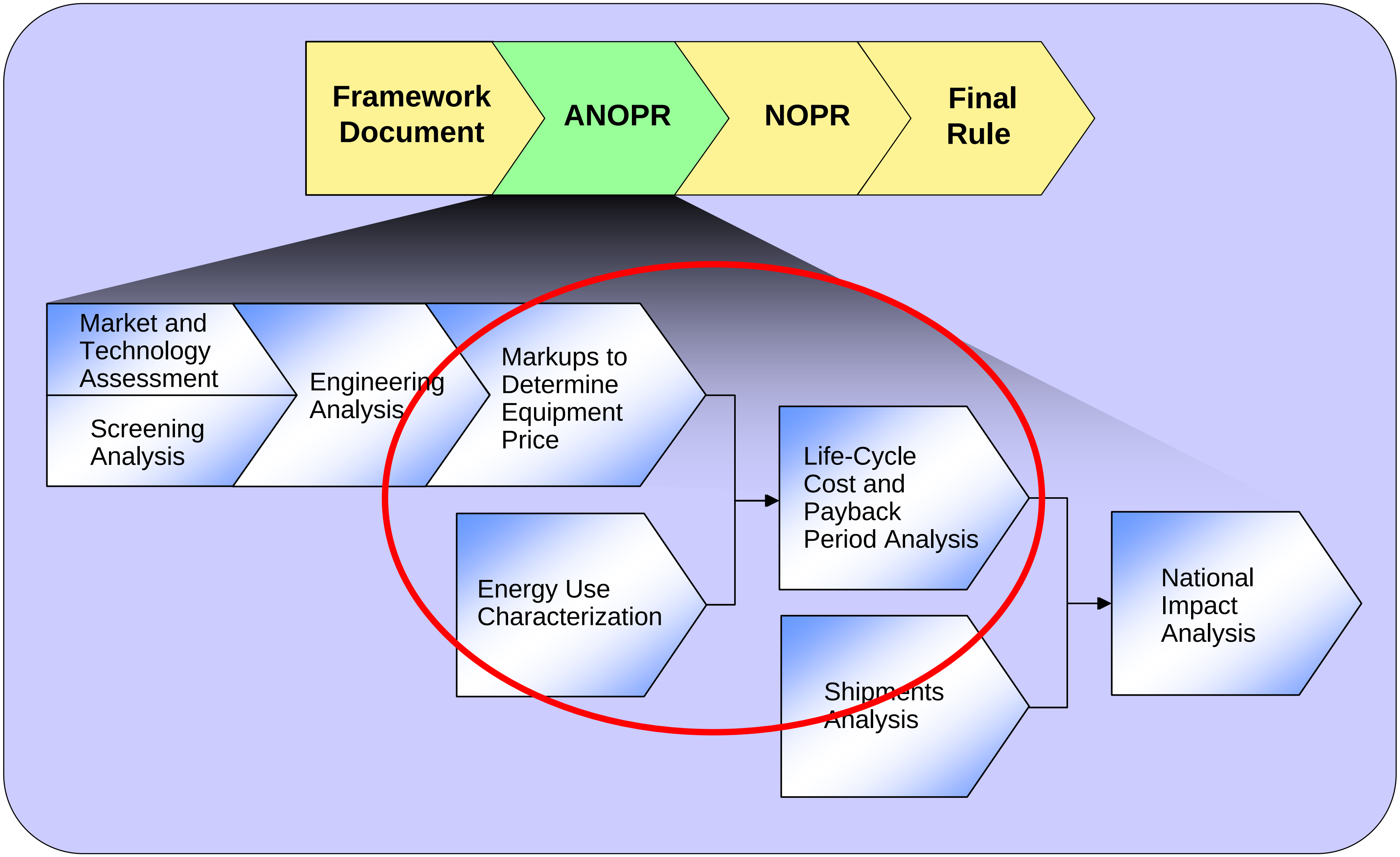
ANOPR Public Meeting

Life-Cycle Cost Analysis

Building Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

August 23, 2007

ANOPR Analyses Flow Diagram



Purpose

- **Energy Use Characterization**
  - To develop electrical energy consumption savings estimates for selected equipment efficiency levels.
  - To validate the energy savings estimates from the engineering analysis using refrigerant system and whole building modeling for a diverse set of climates.
- **Markups to Determine Equipment Price**
  - To characterize the channels for how equipment is distributed from the manufacturer to the customer.
  - To determine prices paid by customers based on manufacturer selling prices for baseline and higher efficiency equipment.
- **Life-Cycle Cost and Payback Period Analyses**
  - To develop the customer life-cycle cost savings and payback period for higher efficiency equipment.

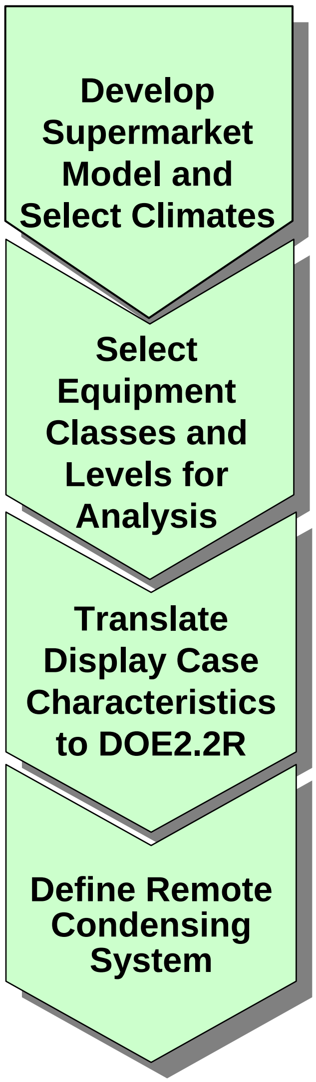
ANOPR Issues for Public Comment

- **Display Case Lighting Operating Hours (Issue #6)**
- **Operation and Maintenance Practices (Issue #7)**
- **Equipment Lifetime (Issue #8)**
- **Life-Cycle Cost Baseline Level (Issue #9)**

Energy Use Characterization

- **DOE used the engineering estimates of energy consumption based on the ARI 1200 Test Procedure "Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets, 2006"**
- **ARI 1200 Test Procedure accounts for**
  - *Direct energy consumption* (evaporator fan motors, lighting, anti-sweat heaters, defrost and drain heaters, and condensate pan heaters in all equipment and compressor energy consumption) in self-contained equipment.
  - *Indirect energy consumption* (compressor energy consumption) in remote condensing equipment.
- **ARI 1200 does not account for**
  - Variation in building temperature or humidity from rating conditions
  - The impact of outdoor air temperature on remote compressor/condensers
  - Subsequent building HVAC impacts of improved CRE efficiency.
- **DOE validated the engineering estimates using whole-building annual energy simulation incorporating interactive refrigeration system modeling (DOE 2.2R) for seven classes of remote condensing equipment.**

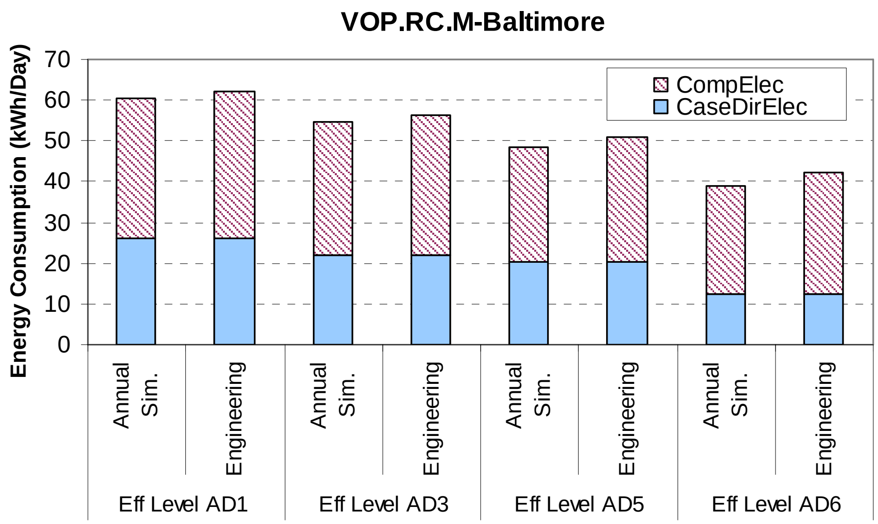
Whole Building Simulation Approach

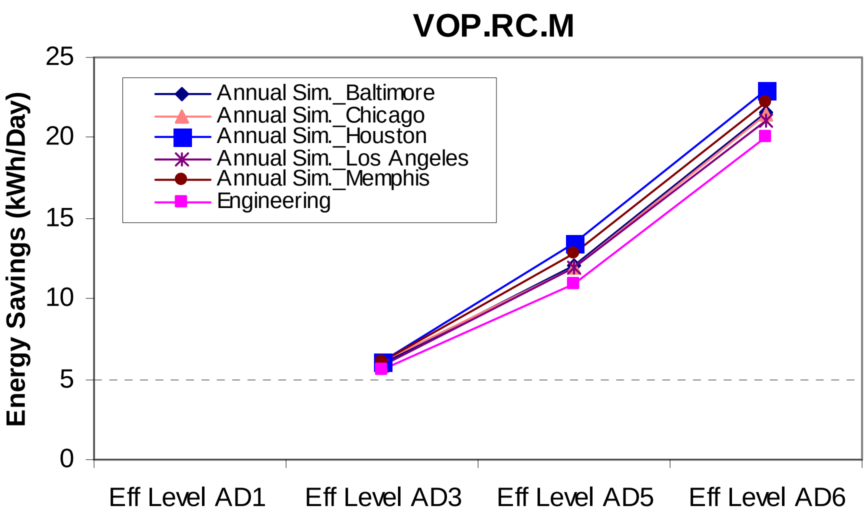


- Single 45,000 ft^2 supermarket. 16 hour/day operating schedule. HVAC: Unitary AC/ gas heat. Lighting: 1.5 W/sf. Misc: 0.4 W/sf. Five U.S. Climates (Baltimore, Chicago, Houston, Los Angeles and Memphis)
- Seven equipment classes analyzed: VOP.RC.M, SVO.RC.M, VCT.RC.M, HZO.RC.M, SOC.RC.M, VOP.RC.L, VCT.RC.L]. Four analytically derived efficiency levels per class.
- Equipment characteristics derived from engineering analysis.
- Refrigeration rack compressors were based on same model and performance used for ARI 1200. Air-cooled condenser with floating- head pressure presumed. Separate compressor racks by equipment class were used

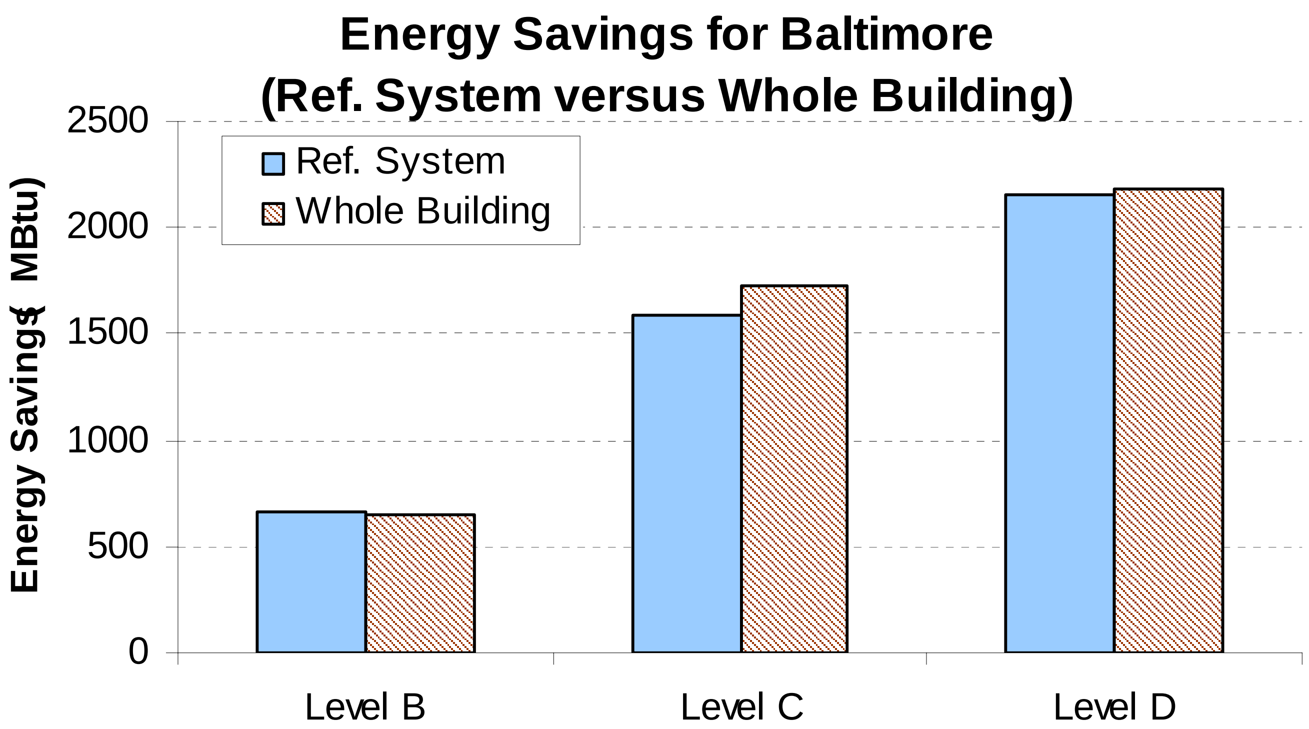
Sample Results (VOP.RC.M)

- **Case refrigeration load, overall energy consumption (direct and indirect), overall refrigeration energy savings from baseline, and overall building energy savings from baseline.**





Comparison of Refrigeration System Savings to Whole-Building Savings



Key Observations

- **Simulated case refrigeration loads are less than the case refrigeration loads calculated in the engineering analysis--believed due to simulated building humidity being less on average during the year than that used in the rating condition.**

- **While simulated refrigeration loads are lower but compressor energy use is approximately the same as calculated by ARI 1200 for most equipment classes.**
    - Note: Simulation program accounts for additional refrigerant superheat occurring in the supermarket refrigeration piping to provide the presumed suction gas temperature (65°F) to the compressors.

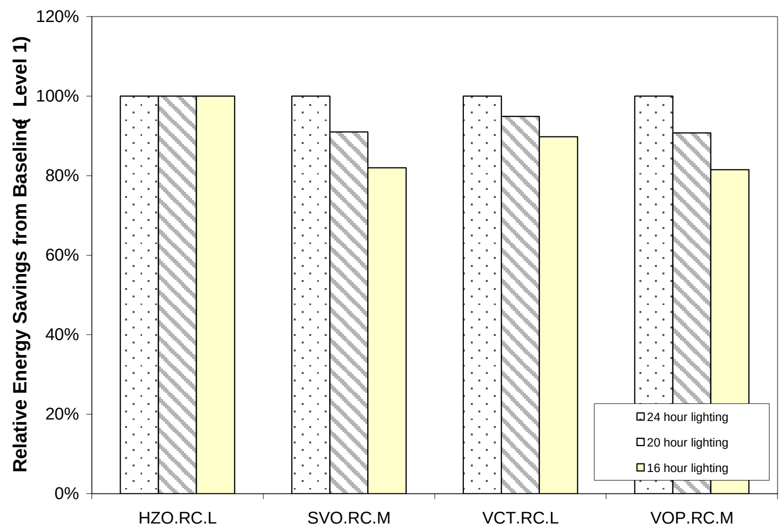
- **Reductions in case heat load reduce total refrigerant mass flow needed in the case, which generally results in less total "additional superheat" load on the compressor and lead to greater energy savings benefits to a design change then not taking this additional superheat load into account.**

Key Observations (cont.)

- Averaged over the five climates, the simulated refrigeration system energy savings was between 4% and 9% higher at the highest efficiency level analyzed than was determined by the engineering analysis
- Warm and humid climates (Houston and Memphis) have slightly greater energy savings than relatively cooler and drier climates (Baltimore, Chicago and Los Angeles).
- The difference in energy savings, between the refrigeration system only and the whole building, is less than 10% at all levels and is a function of the design option analyzed. When the highest efficiency levels were considered, the difference was on the order of 1%.
- The interaction between the display case modifications and the building HVAC system is small. Whole-building energy savings are mostly attributable to the energy savings of the CRE system.

Case Lighting Operating Hours (Issue #6)

- **The engineering analysis assumed a 24-hour operation of the display-case lighting.**
- **DOE conducted a lighting sensitivity study of the relative energy savings as a function of display-case lighting operating hours per day**



DOE invites comments on the assumption of 24-hours for display-case lighting operation.

Operation and Maintenance Practices (Issue #7)

DOE invites comments on operation and maintenance practices.

- Additional O&M practices for CRE or buildings using CRE that may differ from standardized conditions, such as those represented in a test procedure
- The frequency that such factors come in to play in energy use in the field
- Whether and how DOE might account for these factors in assessing the overall impacts of the candidate standards levels for CRE

Markups to Determine Equipment Price
Purpose, Inputs, and Output

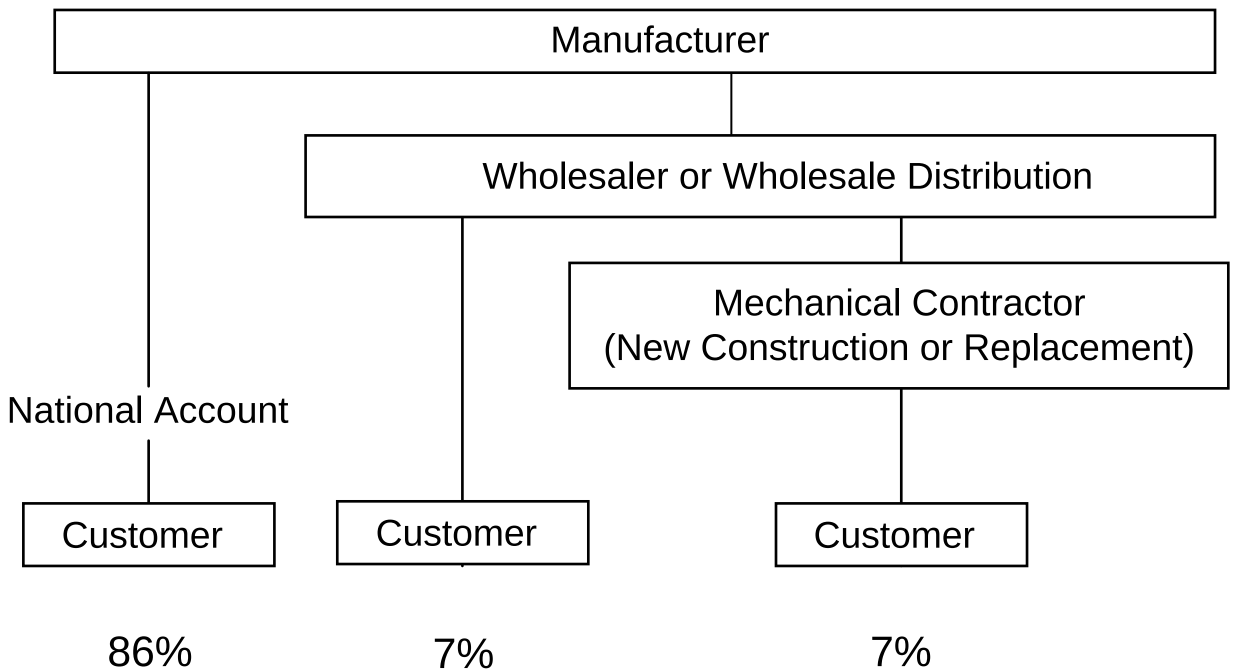
- **Purpose**
  - To determine customer prices under a standards scenario based on manufacturer costs
  - Characterize equipment distribution channels and market segments
  - Describe equipment distributing company direct costs, expenses, and profits

- **Inputs**
  - Firm balance sheets
    - Wholesalers: *HARDI's 2005 Profit Planning Report*
    - Mechanical Contractors: *U.S. Census Bureau Financial Data for Plumbing, Heating, and Air-Conditioning Contractors, 2002*

- **Output**
  - Baseline and incremental markups

Distribution Channels

- **Estimated Fraction of Equipment Shipments by Distribution Channels**



• DOE assumed the same market shares by distribution channel for replacement and new construction

Baseline and Incremental Markups

- ***Markups* relate customer price to cost of goods sold (COGS)**
- ***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 (salaries, payroll, rental and occupancy) are included
- ***Incremental markups* relate the incremental change in customer price to the incremental change in COGS beyond baseline**
  - Some distribution costs remain constant with COGS increases
  - Incremental markups cover only expenses that vary with COGS – in this case, expenses that increase due to an increase in equipment efficiency
    - For example, direct labor costs (salaries, payroll, rental and occupancy) do not vary with efficiency-induced changes in COGS
  - DOE assumes other operating costs and profit will scale proportionally with COGS

Distribution Expenses and Markups (cont.)

- **Wholesaler markup estimated from HARDI Financial Data**
- **National Account Markups**
  - DOE derived an average national account markup, assuming that the resulting equipment price increase was one half of that realized from a distribution through the wholesaler channel (before application of sales tax).
- **Mechanical contractor markup indices were developed based on State level census data and applied to average mechanical contractor markups.**
- **Sales tax is applied based on each specific State's tax data.**
- **National average estimates for sales tax and mechanical contractor markup require estimates of relative shipments of commercial refrigeration equipment by State.**
- **Since relative shipments at a State level are unknown, DOE used census data for refrigerated and frozen food sales by State as a proxy for equipment shipment.**

Distribution Expenses and Markups (cont.)

- **Resulting Average Baseline Markups**

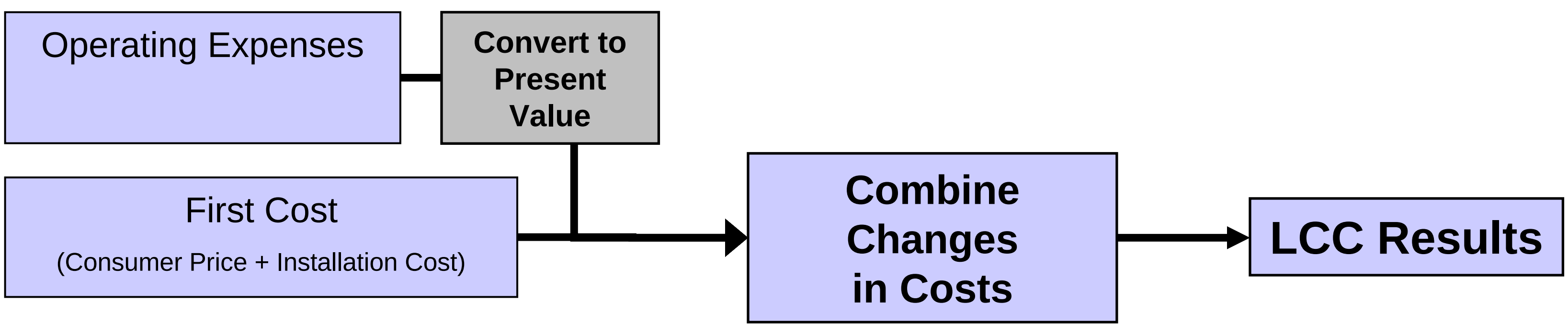
	Wholesaler	Mechanical Contractor (Includes Wholesaler)	National Account (Mfg Direct)	Overall Weighted Average Markup
Distributor(s) Markup	1.436	2.182	1.218	1.301
Sales Tax Multiplier	1.068	1.068	1.068	1.068
Overall Markup	1.533	2.330	1.300	1.389

- **Resulting Average Incremental Markups**

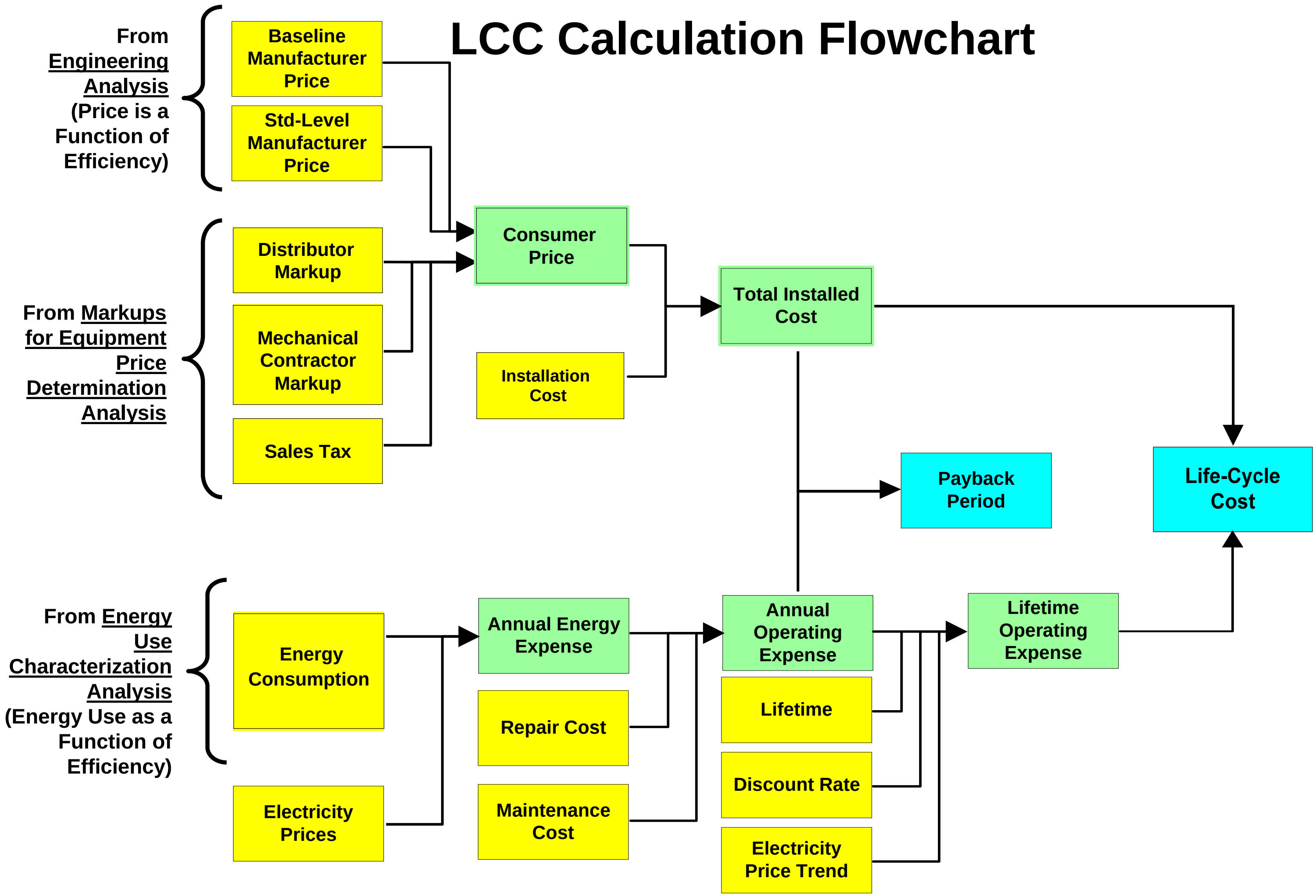
	Wholesaler	Mechanical Contractor (Includes Wholesaler)	National Account (Mfg Direct)	Overall
Distributor(s) Markup	1.107	1.362	1.054	1.079
Sales Tax Multiplier	1.068	1.068	1.068	1.068
Overall Markup	1.182	1.454	1.125	1.152

Life-Cycle Cost Analysis

- **Life-Cycle Cost (LCC) equals customer price plus the sum of annual operating costs discounted to a particular base year**
- **Economic evaluation from the customer perspective**
- **Analysis implemented in an Excel® spreadsheet**
- **Results are expressed as LCC difference (baseline minus standard level)**
- **Simple payback (in years) is also calculated and reported in this analysis**



LCC Calculation Flowchart



Selection of Efficiency Levels for Analysis

- **Up to 11 efficiency levels were examined for equipment in the engineering analysis; only up to 8 efficiency levels selected for the LCC analysis to reduce analysis complexity.**

- **Where 8 or fewer efficiency levels existed in the engineering analysis, all were included in the LCC analysis.**

- **Where more than 8 efficiency levels ~~were~~ examined in the engineering analysis, 8 levels were selected, spanning the breadth of efficiency levels from the engineering analysis (removing levels that were at approximately the same cost-efficiency point or that appeared less cost-effective than adjacent levels).**

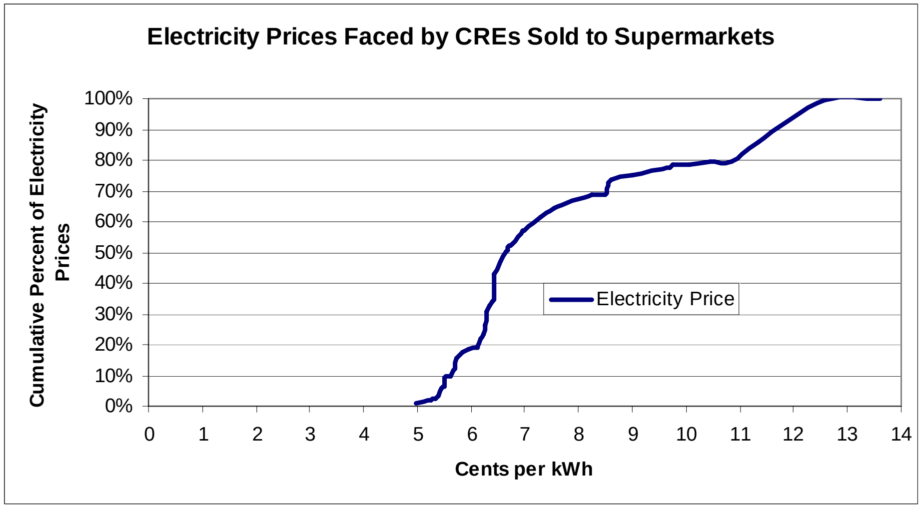
Electricity Prices

- **Analysis was based on State-by-State average electricity prices paid by four business classes using CRE equipment.**
- **Electricity prices by business class were developed using the ratio of average price in 2003 CBECS by business class to commercial average price.**
- **These ratios are then applied to the State-by-State average electricity prices projected for 2012 and out years by EIA.**

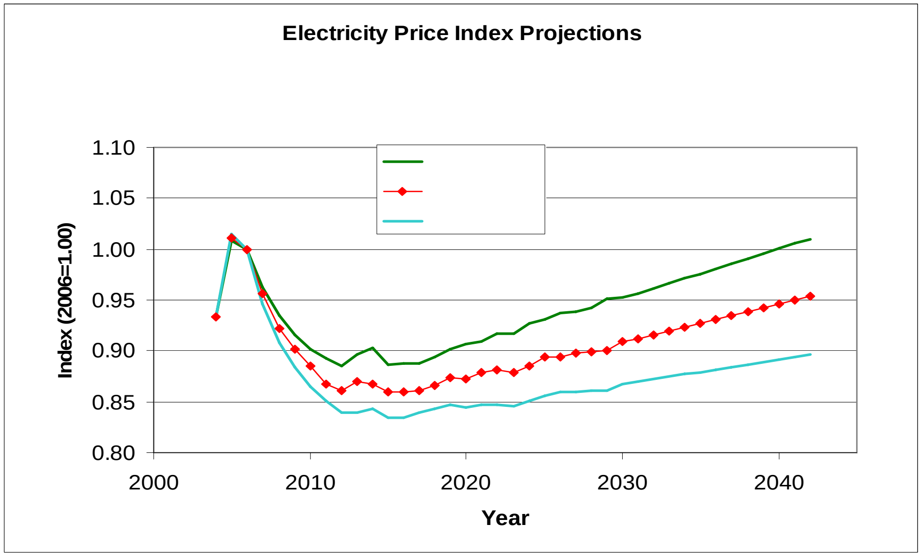
Business Type	Grocery Store/Food Market	Convenience Store	Convenience Store with Gas Station	Multi-line Retailers and Other Food Sales	All Commercial Buildings
Ratio of Electricity Price to Average Price for all Commercial Buildings	0.928	1.109	0.993	1.057	1.00

Electricity Prices (cont.)

- **Example distribution of electricity prices (2006$) for supermarkets/large grocery stores.**



- **Electricity price projections based on EIA/AEO reference case for commercial sector.**
- **AEO High Growth and Low Growth cases can be run as a sensitivity.**



Other Inputs

- **Installation Costs**
  - Based on RS Means data: $295 for remote condensing equipment classes, $227 for self-contained equipment classes.
  - Installation costs assumed not to vary with equipment price or efficiency level
- **Discount Rates**
  - Derived from estimates of the cost of capital of companies that purchase commercial refrigeration equipment by business class.
  - Cost of capital is calculated from the weighted-average cost of capital (WACC) to the firm to obtain equity and debt financing.
  - Weighted-average value equals 4.76% (real) for large grocery retailers, 5.66% for multi-line retailers, and 7.26% for small grocery and convenience stores (with and without gasoline stations).

Other Inputs (con't)

- **Equipment Lifetime**
  - Used average age of 10 years based upon literature survey and industry input for average age at replacement.
  - Used-equipment market not considered in analysis.
- **Repair Costs**
  - Annualized repair costs based on fraction (0.5) of customer equipment price divided by equipment lifetime.
  - Repair costs were not assumed to increase with costs of design options.
- **Maintenance Costs**
  - Based on RS Means data (2006) for commercial refrigeration equipment.
  - DOE used a flat $156/yr for preventative maintenance activities for all equipment classes and efficiency levels.
  - Lighting maintenance costs calculated separately based on 2-year replacement cycle for fluorescent bulbs, ballast replacement once over the 10-year equipment life, and LED fixture replacement once over the 10-year equipment life.

Equipment Lifetime (Issue #8)

DOE invites comments on the lifetime of CRE and whether, in fact, this is a significant issue and whether DOE should perform a sensitivity analysis of this variable in the LCC and NES analysis.

- How long these units are typically maintained in service, on average, either for all equipment covered under this rulemaking or by equipment class and store type
- The existence and significance of a used equipment market for CRE and the importance of considering such a market in its analysis

Life-Cycle Cost Baseline Level (Issue #9)

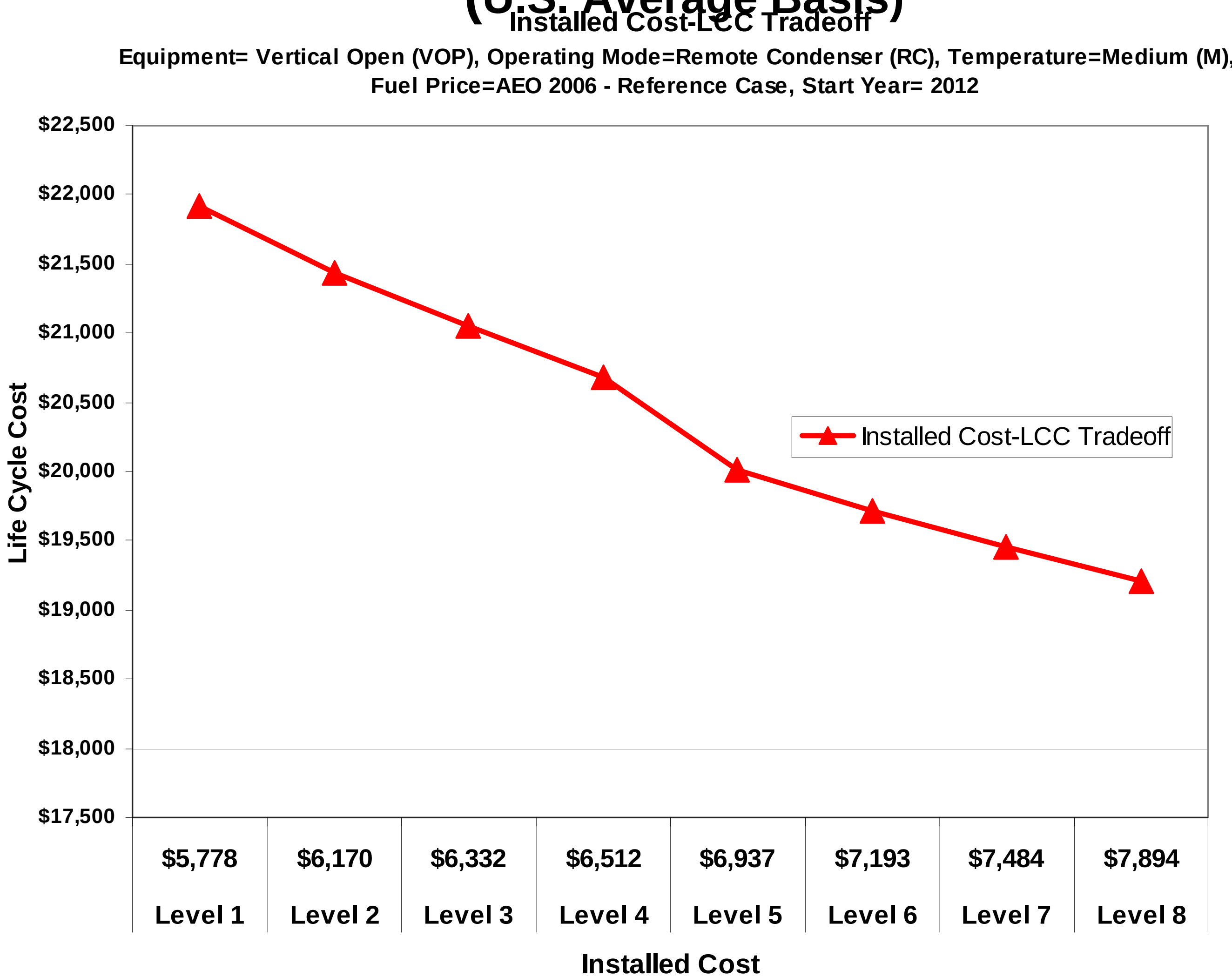
- **DOE did not receive data from industry concerning the average energy efficiency of CRE currently being shipped or historical shipments, nor were these data provided in further discussion with manufacturers.**
- **An analysis of the literature suggests little data on the energy characteristics of display cases in the general market is available.**
- **DOE used the Level 1 (minimum energy efficiency level) established in the engineering analysis as the baseline for the LCC analysis.**

DOE invites comments on the selection of Level 1 as the baseline in the LCC analysis.

- Whether a distribution of efficiencies should be used in the LCC analysis baseline (instead of a single efficiency level), and if so, what data could be used to populate this distribution
- If more detailed data to develop a distribution of efficiencies in the baseline cannot be provided, DOE seeks input on how a sensitivity analysis to alternative baselines could best be used to inform the LCC and NES analyses

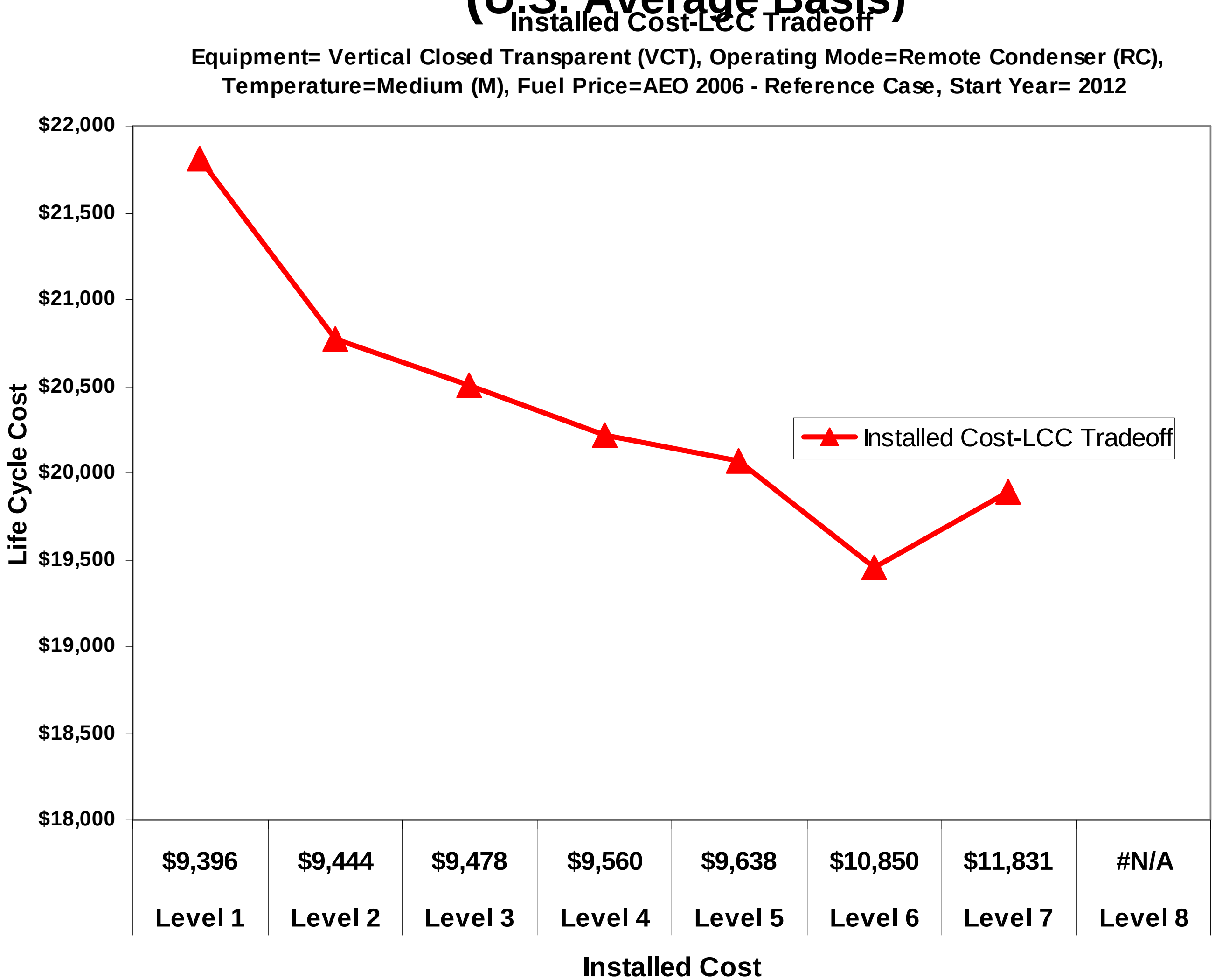
Example of LCC Results for VOP.RC.M

(U.S. Average Basis)

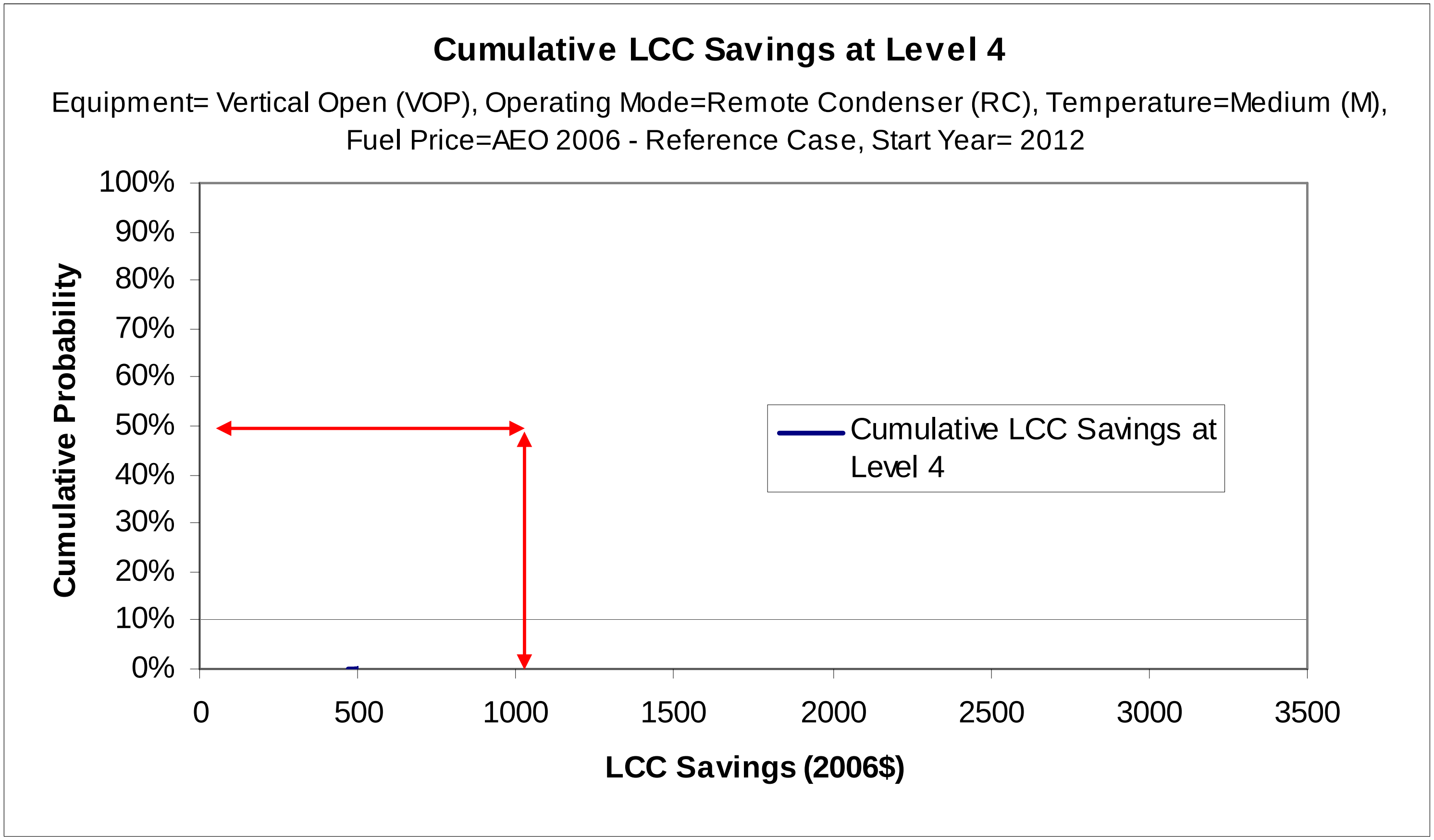


Example of LCC Results for VCT.RC.M

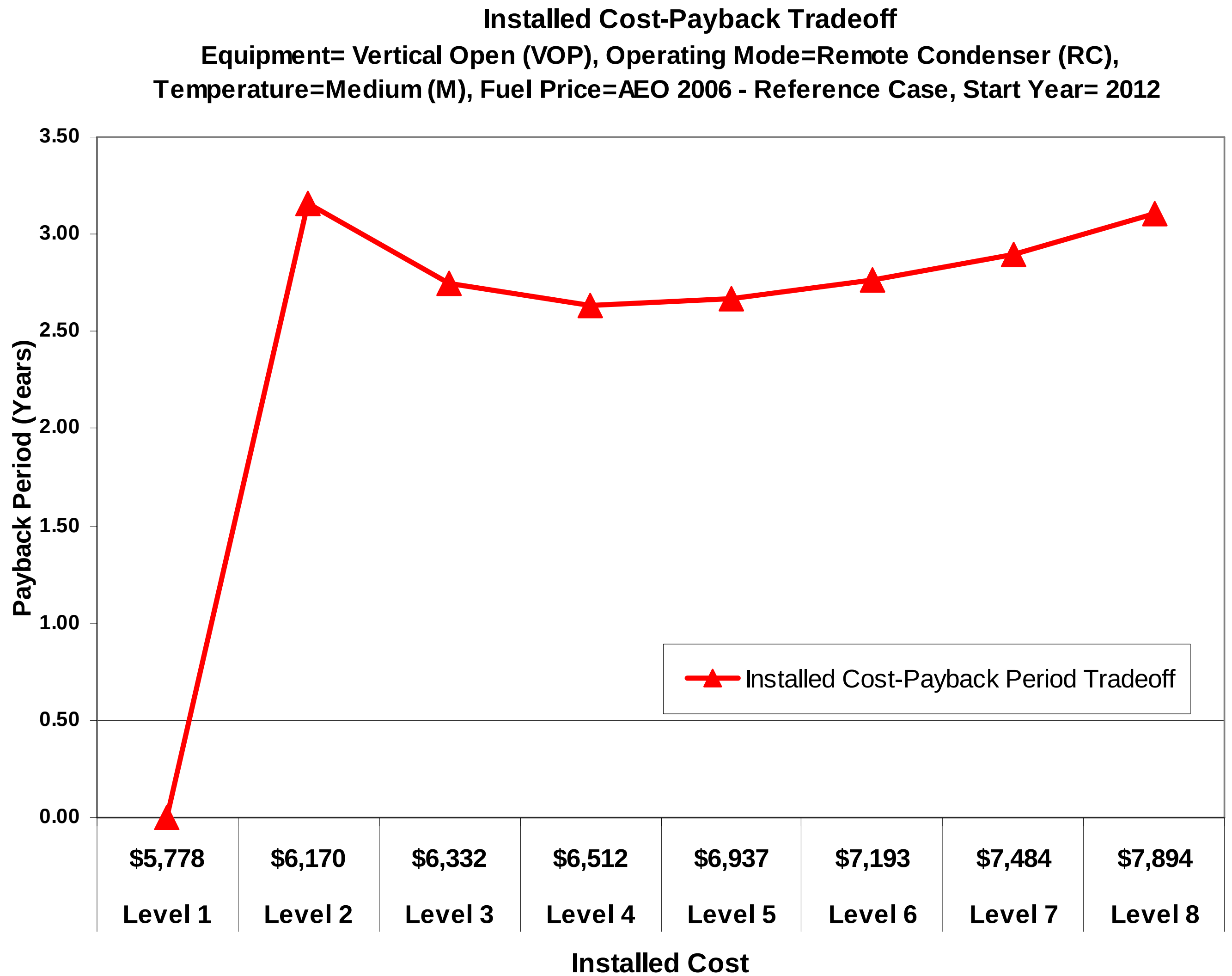
(U.S. Average Basis)



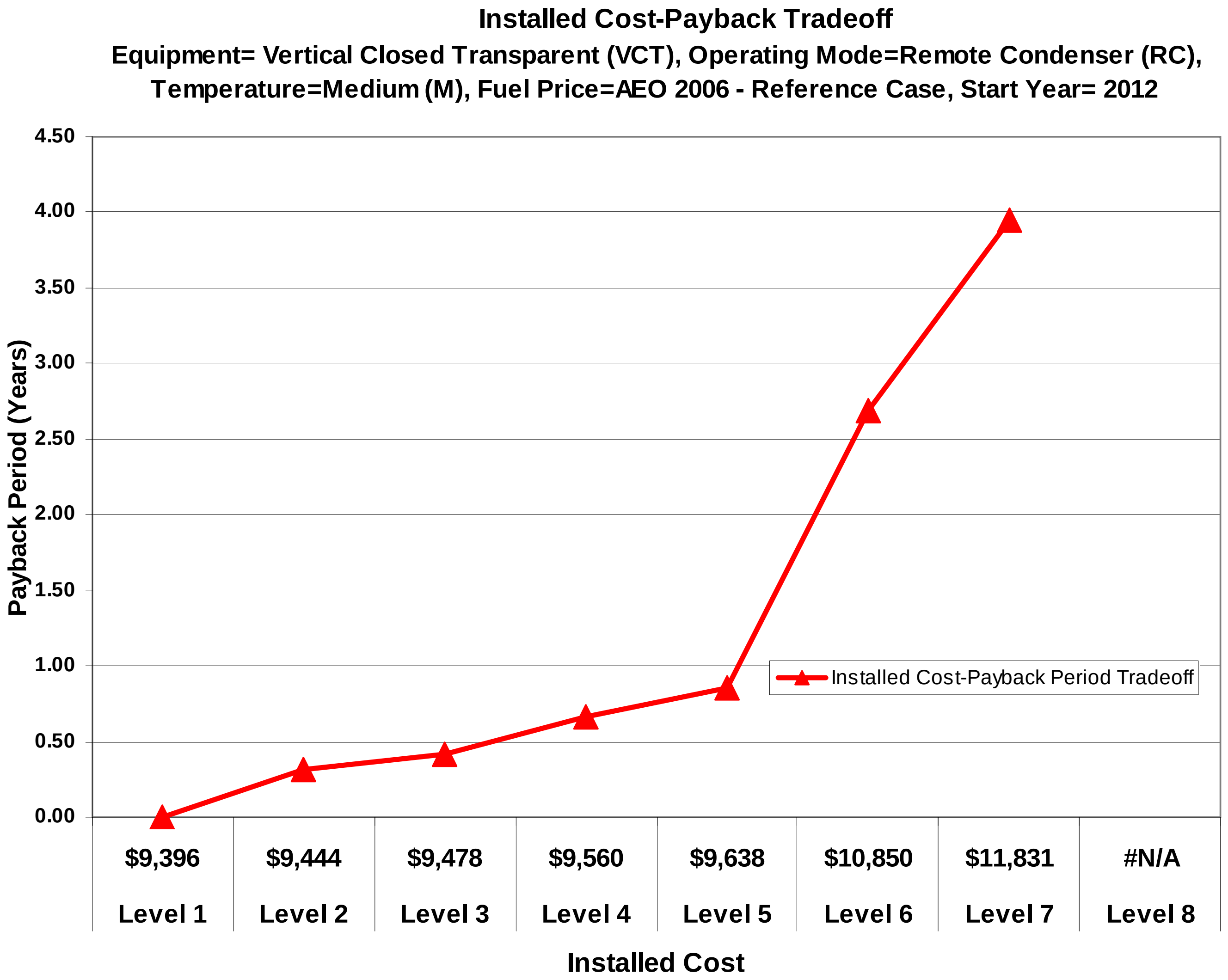
Example of LCC Savings Results -VOP.RC.M



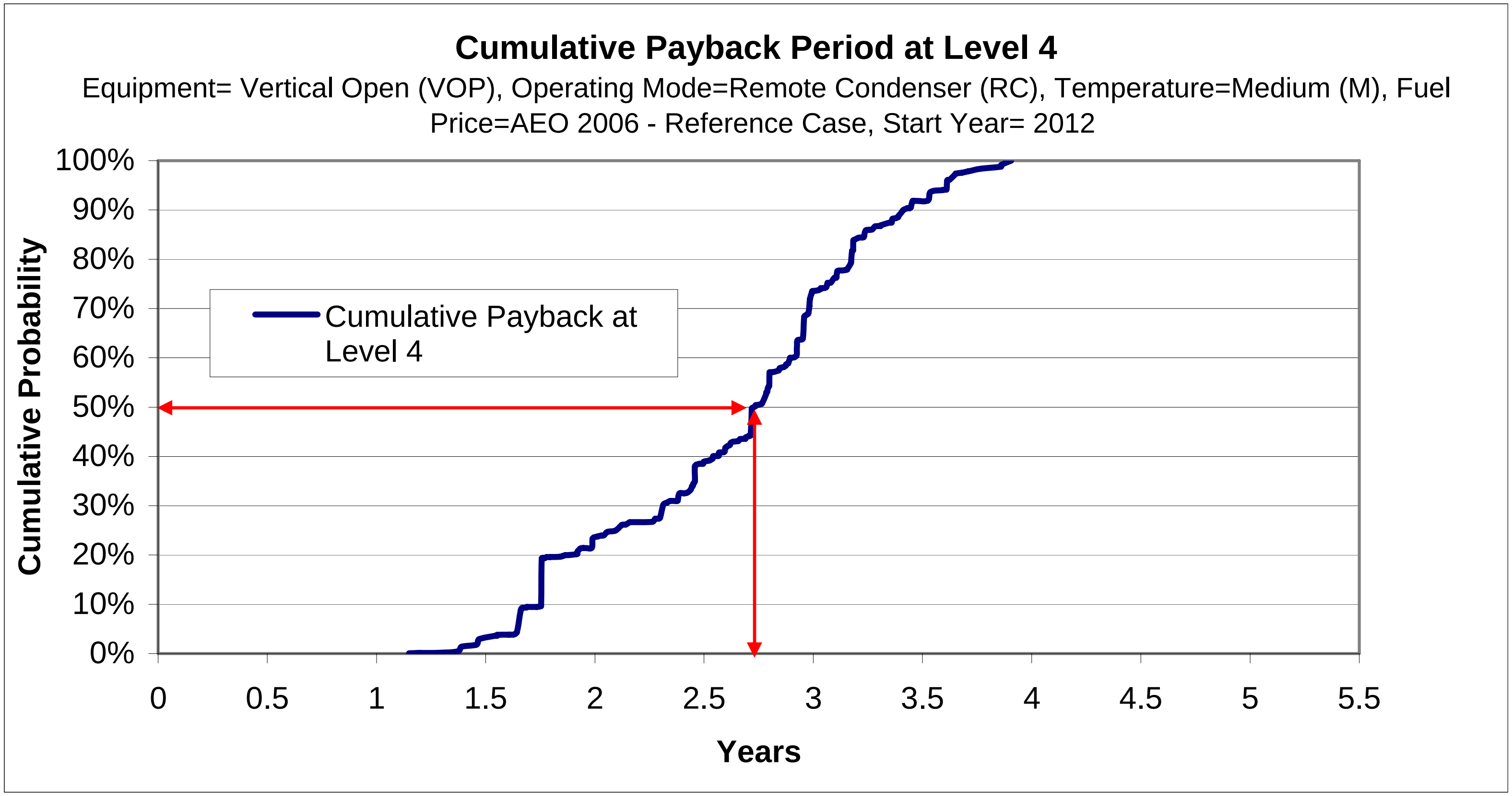
Example of Payback Period Results – VOP.RC.M



Example of Payback Period Results – VCT.RC.M



Example of Payback Period Results
(VOP.RC.M)



National Average LCC Savings by Equipment Class

Equipment Class	National Average LCC Savings (2006$)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0	485	871	1239	1910	2203	2459	2707
VOP.RC.L	0	1209	2604	3512	3470	3443	NA	NA
VOP.SC.M	0	759	883	1006	1265	1328	1487	1482
VCT.RC.M	0	1046	1309	1596	1750	2362	1925	NA
VCT.RC.L	0	1179	1650	2105	2949	3333	3684	4272
VCT.SC.I	0	1371	2581	3020	3285	5313	5613	5398
VCS.SC.I	0	398	961	1383	1451	1559	1619	1609
SVO.RC.M	0	227	500	758	1000	1223	1458	NA
SVO.SC.M	0	552	588	644	824	841	1200	1186
SOC.RC.M	0	835	1779	1718	1901	1868	1540	NA
HZO.RC.M	0	208	435	490	NA	NA	NA	NA
HZO.RC.L	0	234	591	935	1267	1459	NA	NA
HZO.SC.M	0	66	286	354	381	445	466	543
HZO.SC.L	0	68	555	1071	1136	1155	1448	1457
HCT.SC.I	0	250	315	731	809	835	NA	NA

National Average Payback Period by Equipment Class

Equipment Type	National Average Payback Period (Years)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	NA	3.2	2.8	2.6	2.7	2.8	2.9	3.1
VOP.RC.L	NA	0.5	0.8	1.1	1.2	2.0	NA	NA
VOP.SC.M	NA	0.7	0.7	0.8	1.1	1.4	2.0	3.1
VCT.RC.M	NA	0.3	0.4	0.7	0.9	2.7	3.9	NA
VCT.RC.L	NA	1.4	1.6	1.8	2.1	2.2	2.3	2.7
VCT.SC.I	NA	0.3	0.4	0.5	0.6	1.3	1.5	2.1
VCS.SC.I	NA	0.3	0.6	0.6	0.7	0.7	0.8	1.2
SVO.RC.M	NA	3.2	2.8	2.7	2.8	2.9	3.0	NA
SVO.SC.M	NA	0.8	0.8	0.9	1.1	1.3	1.8	2.4
SOC.RC.M	NA	0.6	1.0	1.2	1.4	3.1	3.9	NA
HZO.RC.M	NA	0.8	1.2	1.5	NA	NA	NA	NA
HZO.RC.L	NA	1.2	1.6	1.7	1.8	1.9	NA	NA
HZO.SC.M	NA	0.7	1.0	1.1	1.1	1.2	1.4	1.8
HZO.SC.L	NA	0.6	0.6	0.8	0.8	0.9	1.3	1.3
HCT.SC.I	NA	0.7	0.7	1.3	1.4	1.4	NA	NA

Life-Cycle Cost Baseline Level Sensitivity Analysis

- **LCC sensitivity analyses were performed for AEO High Growth and Low Growth fuel escalation rate scenarios.**
  - The choice of fuel escalation rate scenario impacted the life-cycle cost for all equipment classes.
  - The minimum life-cycle cost efficiency level (maximum life-cycle cost savings level) differed from the AEO reference case for only two equipment classes, VOP.SC.M and SOC.RC.M and only when the High-Growth scenario was examined.
- **Sensitivity of the LCC Savings and Payback Period to assumed baseline level was also examined.**
  - The minimum life-cycle-cost level is unaffected by choice of baseline efficiency level, but the magnitude of the savings is affected.
  - PBP is affected, with PBP generally increasing when higher baseline efficiency levels are assumed.

Other Issues

DOE invites comments and recommendations from stakeholders on any other aspects related to the Life-Cycle Cost Analysis.