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

Energy Conservation Standards for Commercial Unitary Air Conditioners and Heat Pumps

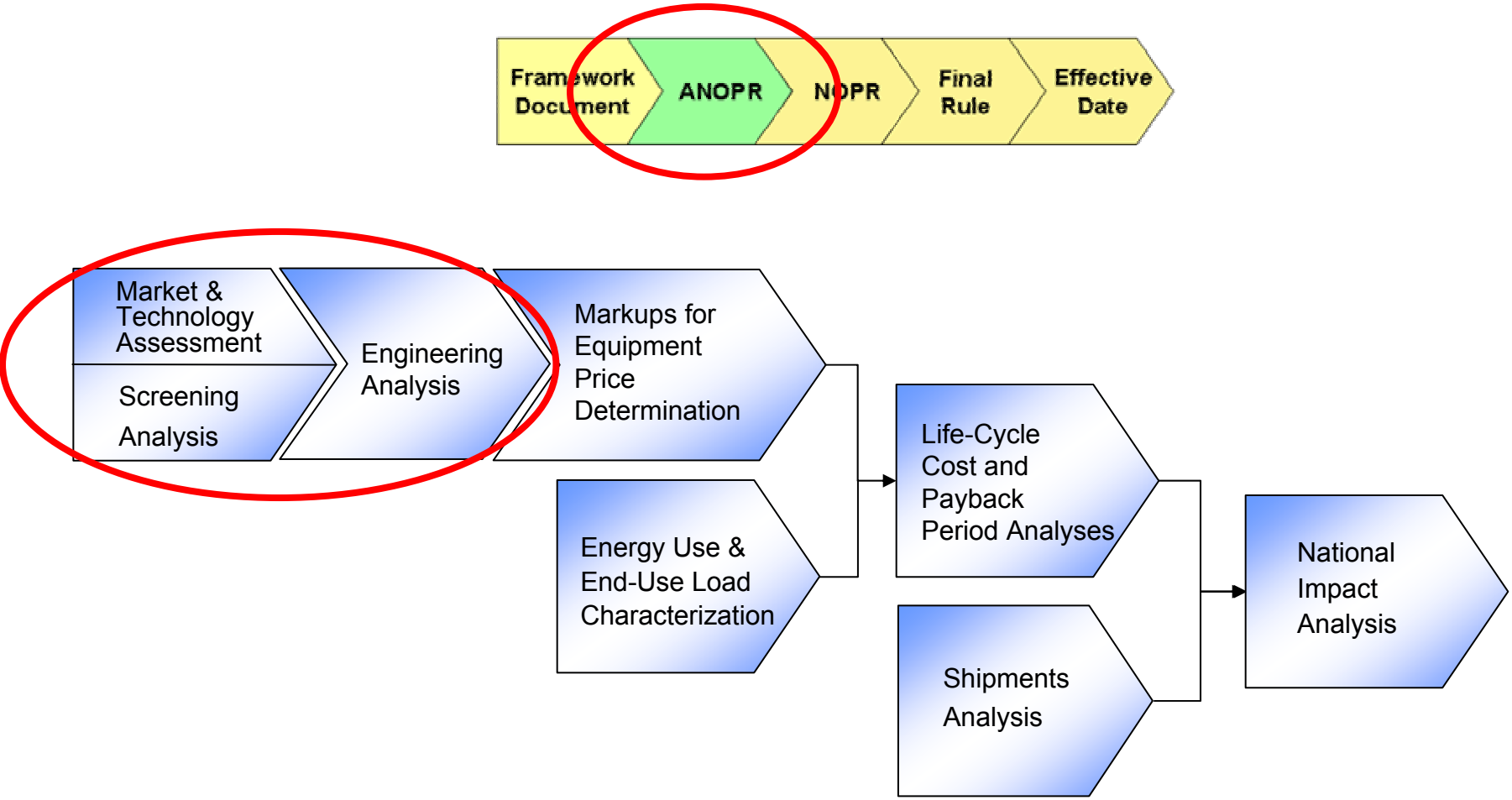
ANOPR Public Meeting

Engineering Analysis

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

September 30, 2004

ANOPR Analyses Flow Diagram



Purpose

- **Market & Technology Assessment**
  - To characterize the commercial unitary AC and HP market to determine available equipment efficiencies and shipments by product class
- **Screening Analysis**
  - To identify design options that increase efficiency and to apply screening criteria established by DOE to determine which design options to evaluate and which to screen out
- **Engineering Analysis**
  - To characterize manufacturer cost-efficiency relationships for higher efficiency equipment
  - To evaluate design options that improve efficiency relative to the baseline units

ANOPR Issues for Public Comment

- Approaches to Analyses for Split Systems, Heat Pumps, and Niche Equipment (ANOPR Issue #1)
- Alternative Refrigerant Analysis (ANOPR Issue #2)
- Design-Option Analysis and Maximum Energy Efficiency Levels (ANOPR Issue #4)
- Technologies that Affect Full- or Part-Load Performance (ANOPR Issue #18)

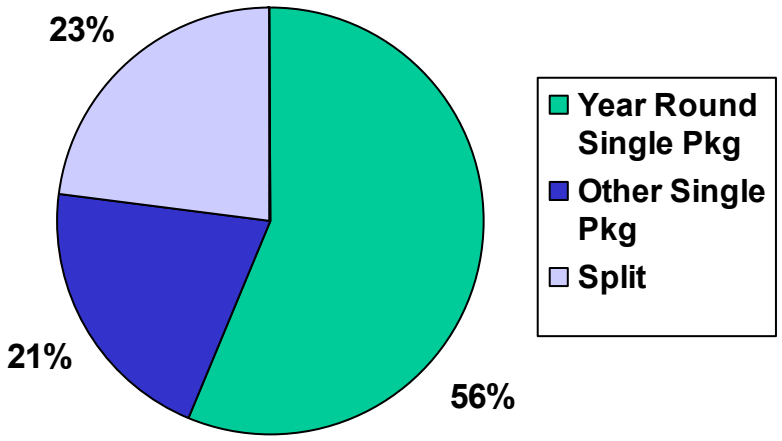
Product Classes

- **Air-cooled unitary air conditioners and air-source unitary heat pumps between 65,000 Btu/h and 240,000 Btu/h, including:**
  - Single package air conditioners and heat pumps
  - Split system air conditioners and heat pumps

ASHRAE Standard 90.1-1999 Minimum Efficiency (EER) Levels (Assumed as Baseline Efficiency)		
Equipment Type	**≥65,000 to <135,000 Btu/h cooling capacity**	**≥135,000 to <240,000 Btu/h cooling capacity**
Single Package: Air Conditioner	10.3	9.7
Single Package: Year-round Air Conditioner	10.1	9.5
Split System: Condensing Unit, Coil with Blower	10.3	9.7
Single Package: Heat Pump	10.1	9.3
Split System: Heat Pump with Remote Outdoor Unit	10.1	9.3

Market Shares and Unit Shipments

- Approximately 300,000 units covered by this rulemaking were shipped in year 2000 (2001 U.S. Census data).
- Air conditioners account for about 90% of the covered market, while heat pumps account for the remaining 10%.
- Majority of market share is held by four manufacturers.
- Significant portions of the market are held by two other manufacturers.
- Year-round (units with gas heating) single package units are the most common configuration.



Screening Analysis Method

- **Design options screened using the following criteria:**
  - Technological feasibility
  - Practicability to manufacture, install and service
  - Adverse impacts on product utility or product availability
  - Adverse impacts on health or safety

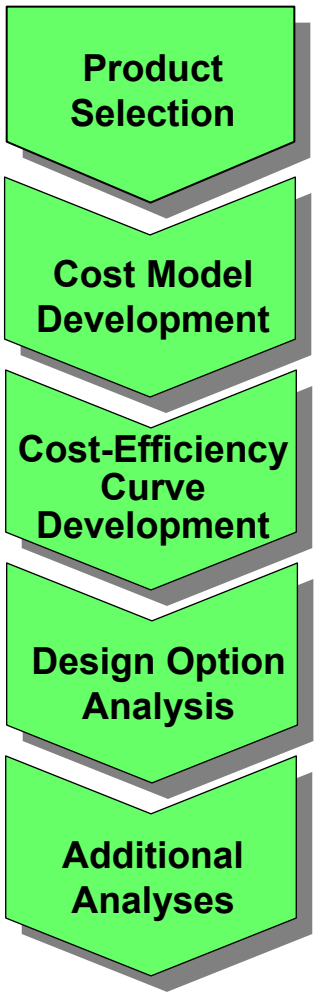
Design Options Selected for Further Consideration

Technologies that enhance EER
■ Increase evaporator or condenser coil area
■ Change the number of coil rows
■ High-efficiency fan motors or compressors
■ Micro-channel heat exchangers
■ Deep coil heat exchangers
■ Air-foil or backward-curved centrifugal fans
■ Increase evaporator or condenser fan diameters
■ Synchronous (toothed) belts
■ Direct drive fans
■ High-efficiency propeller condenser fans
■ Low pressure loss filter
■ Reduce air leakage paths within unit

Technologies that Affect Full- or Part-Load Performance (ANOPR Issue #18)

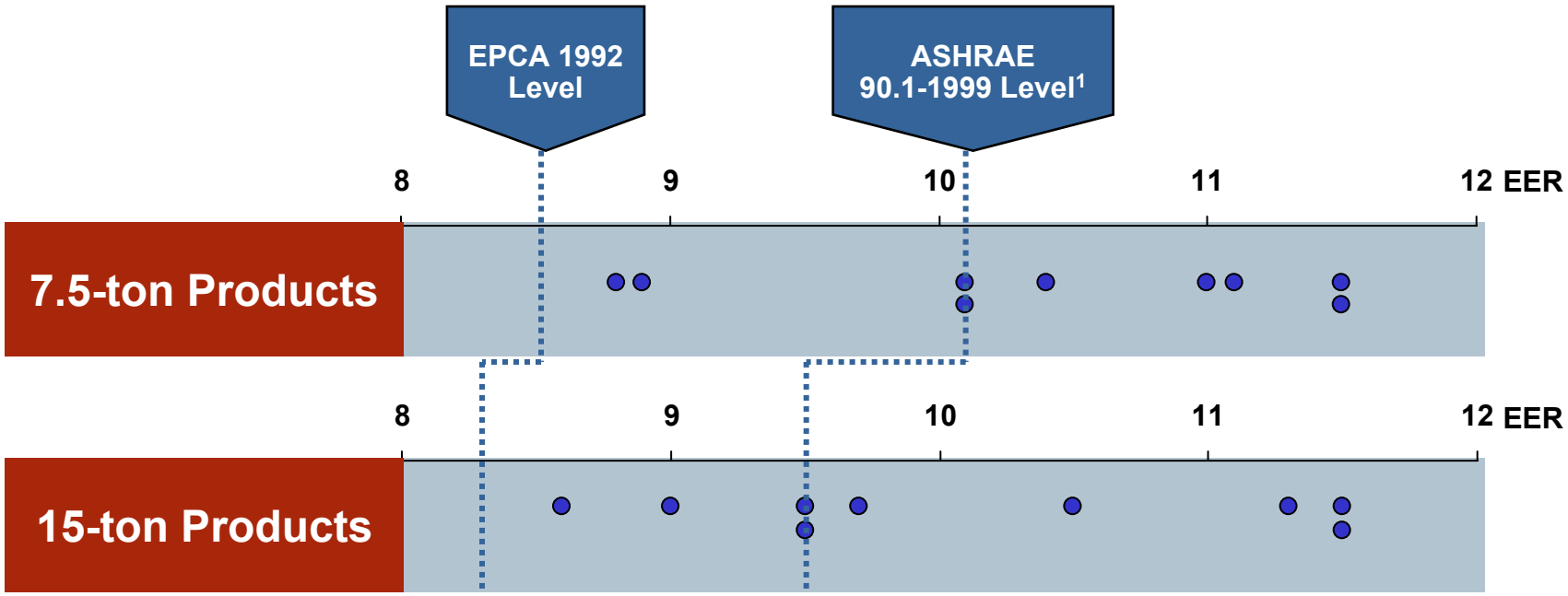
The Department invites comment on analyzing the effects of technologies that can reduce EER, or are EER-neutral but can reduce annual energy consumption, and the implications both on national energy savings and consumer life-cycle costs.

Engineering Analysis Process



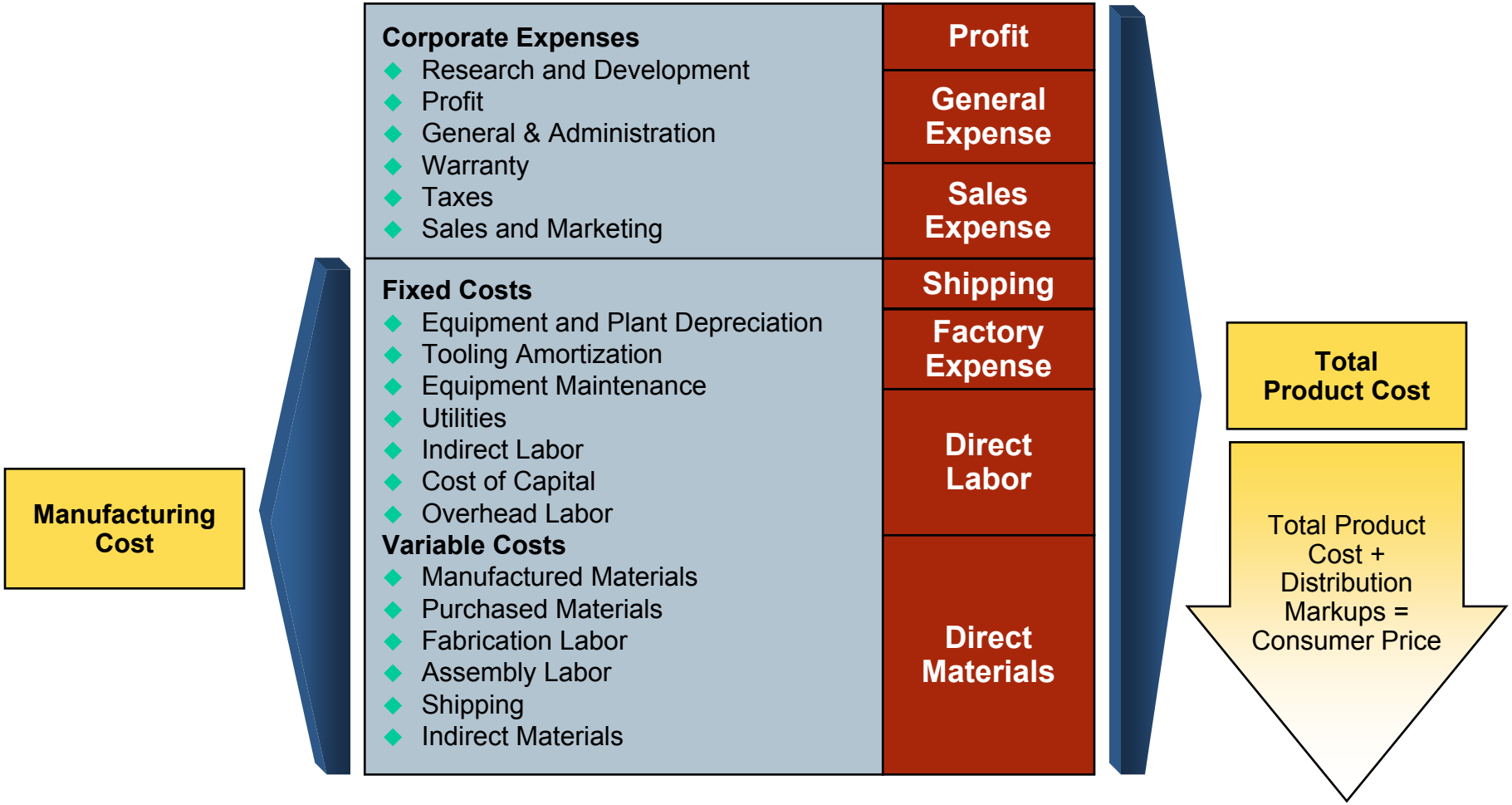
- Define Equipment Classes and Baseline Units
- Select Teardown Units, Perform Teardowns, Develop Bill of Materials, Develop Cost Model, Validate Cost Model
- Develop Manufacturers' Cost-Efficiency Curves, Normalize Curves, Aggregate Curves to an Industry Curve
- Identify Design Options, Develop Performance Model, Apply Cost Model to Design Options, Validate Cost-Efficiency Relationship
- Conduct R-410A Analysis, Incorporate Stakeholder Feedback

Product Selection



[1] Based on ASHRAE 90.1-1999 Mandatory Minimum EER, including a reduction of 0.2 for units having a heating section other than electric resistance heat.

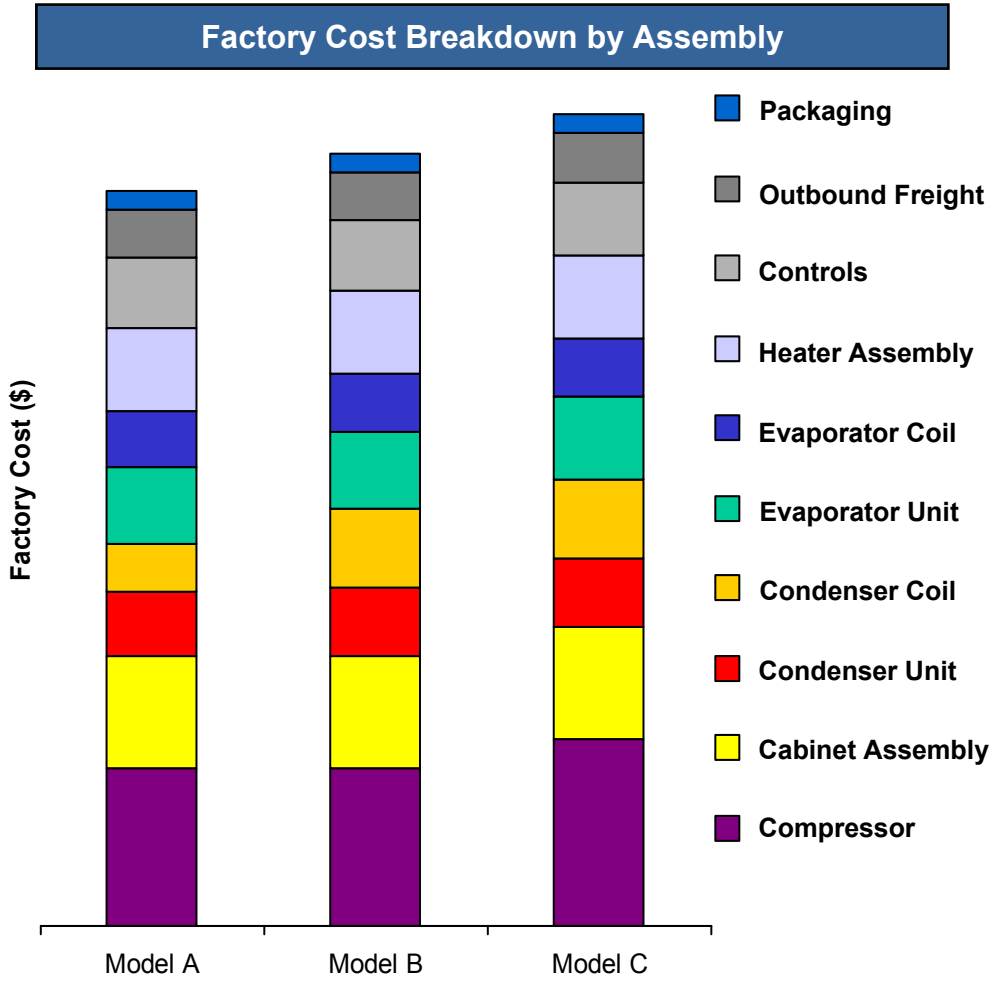
Manufacturing Cost Components



Cost Model Validation

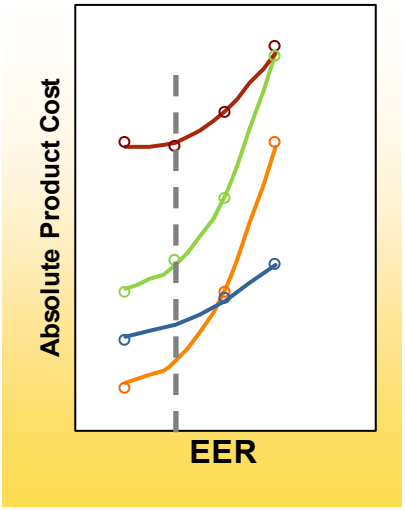
Factory Cost Breakdown			
	Model A	Model B	Model C
Labor	$	$	$
Material	$	$	$
Overhead & Ship	$	$	$
Depreciation	$	$	$
TOTAL factory cost	**$**	**$**	**$**

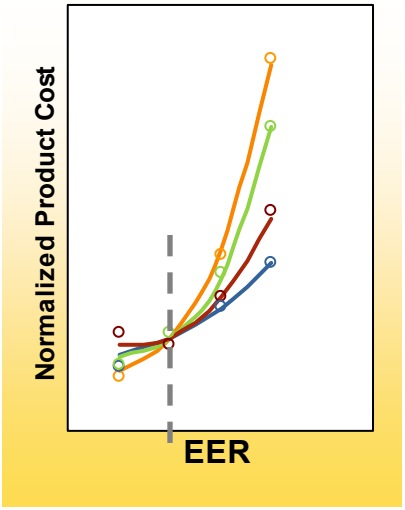
ILLUSTRATIVE EXAMPLE

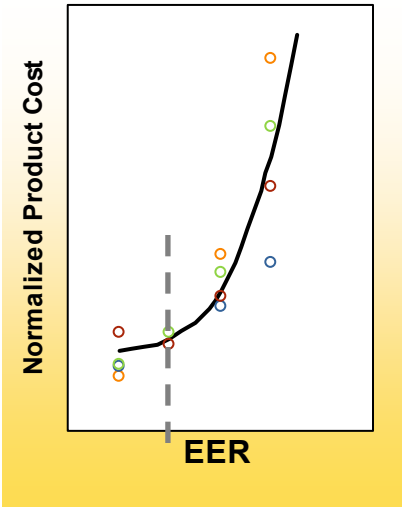


Cost Efficiency Curve Development

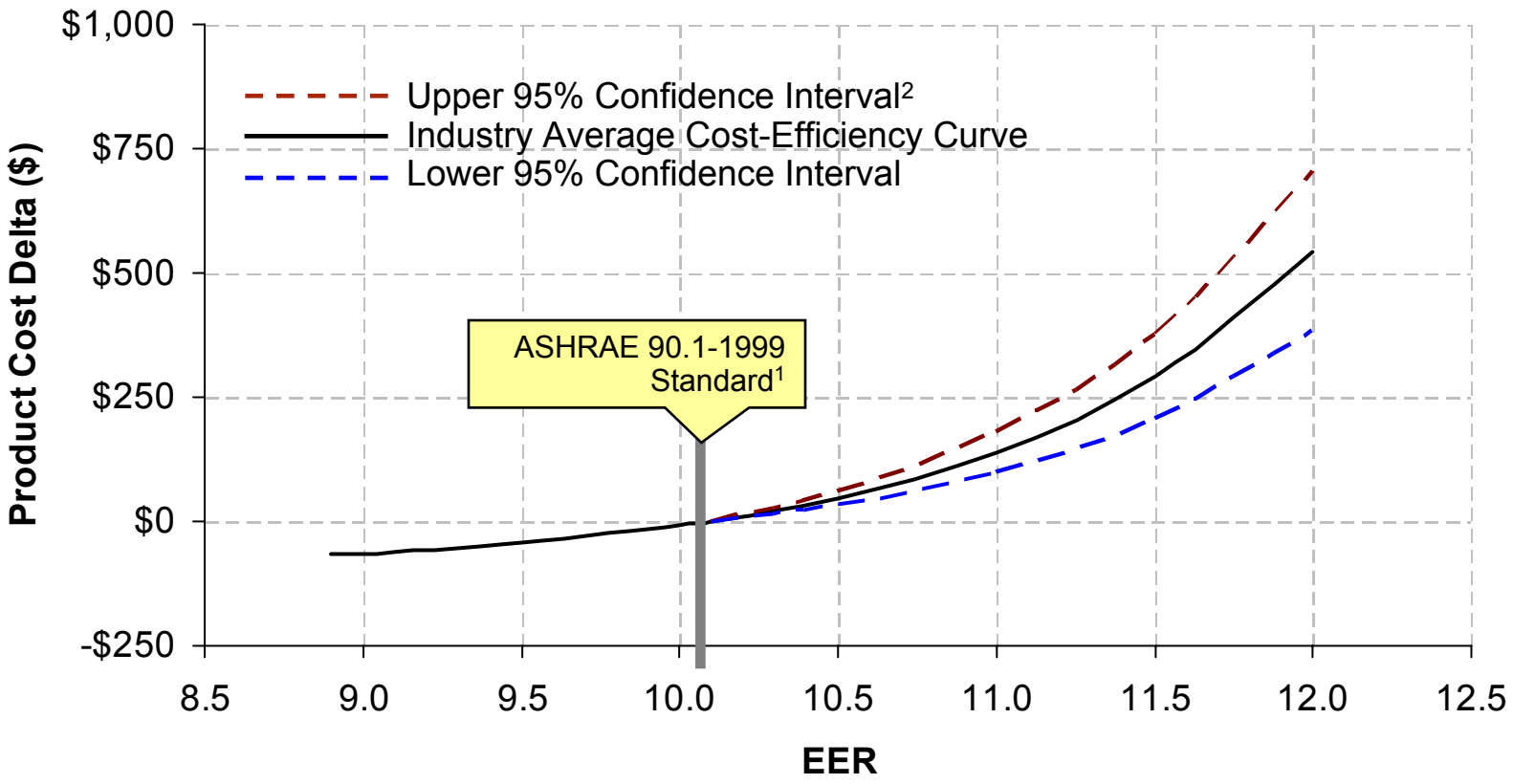
1. An exponential curve was fit to each manufacturer's cost-efficiency points individually.
2. The data points were then normalized so that each manufacturer curve intersected at the ASHRAE 90.1-1999 EER level.
3. Next, an exponential curve was fit to the normalized data points (all manufacturers), extrapolating the curve slightly to 12 EER.





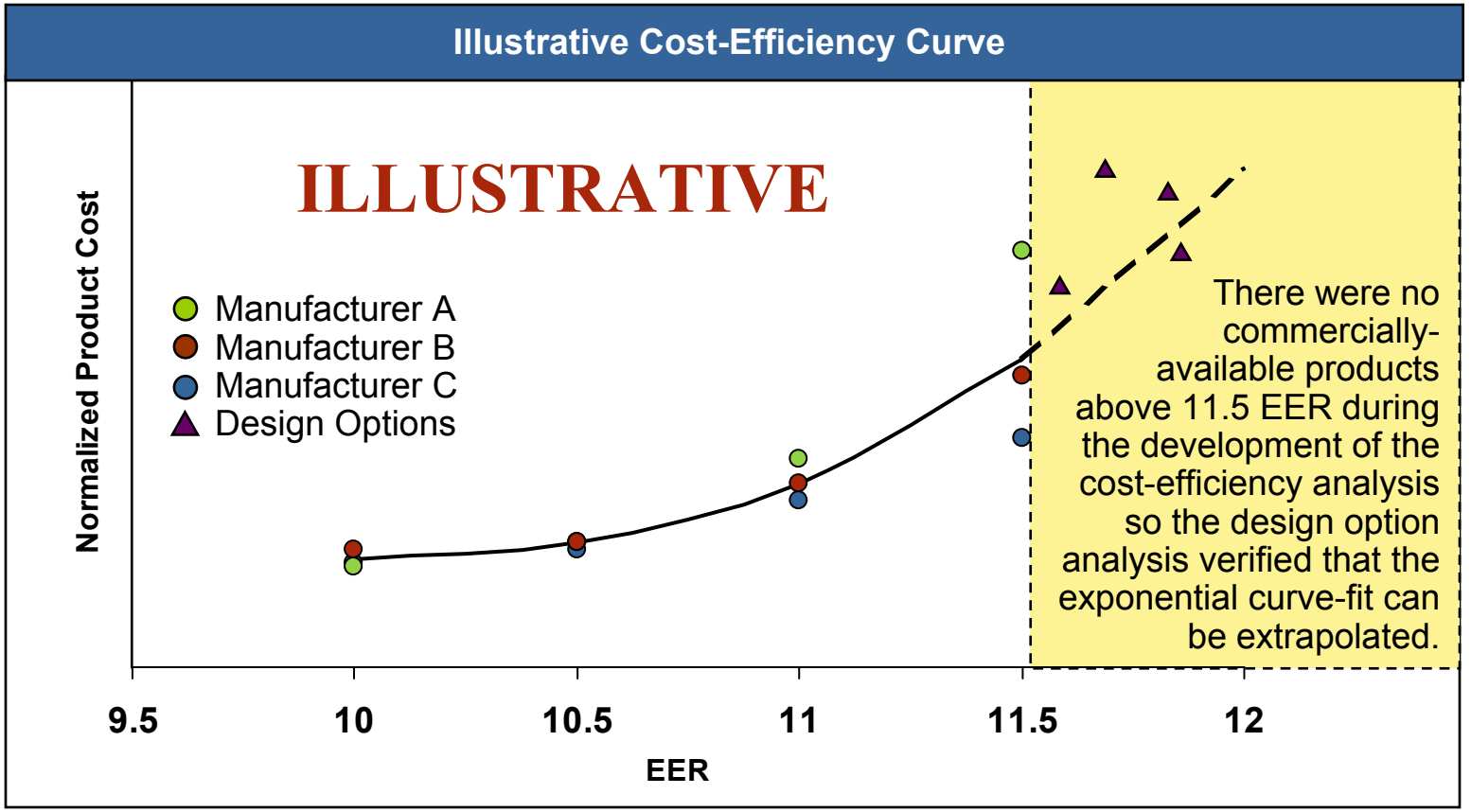


7.5 Ton Cost-Efficiency Results



[1] Based on ASHRAE 90.1-1999 Mandatory Minimum EER, including a reduction of 0.2 for units having a heating section other than electric resistance heat.
[2] Confidence Interval represents the accuracy of the mean regression curve-fit (i.e., There is a 95% probability that the mean cost of a sample of products at a given EER level would fall within the confidence interval).

Design Option Analysis



Design Option Analysis Approach

BASELINE | APPROACH | DESCRIPTION

An existing product is the starting point for the design process

1. **Condenser Coil** → Increases either condenser area or depth while adjusting fan size, number of fans, motor size, subcool, and/or compressor capacity.

2. **Evaporator Coil** → Increases either evaporator area or depth while adjusting blower size, number of blowers, subcool, and/or compressor capacity.

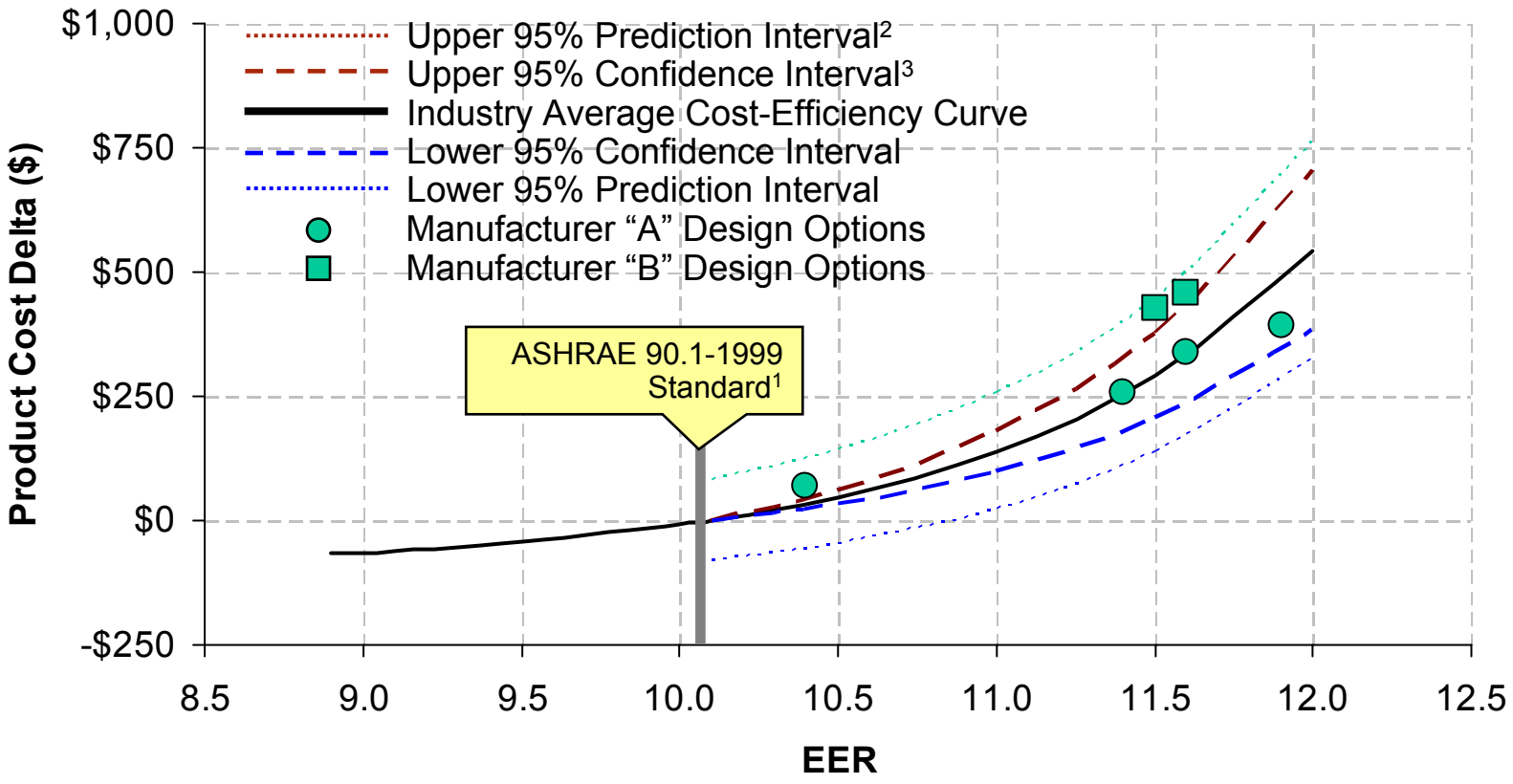
EER Design Targets
7.5-ton ≯ 10.5-EER and 12.0-EER
15-ton ≯ 11.0-EER and 12.0-EER

Modeling Parameters

- Evaporator temperature
- SHR
- Condensing temperature
- Condenser exit temperature
- Condenser refrigerant ΔP
- Condenser face velocity
- Blower motor efficiency
- Condenser fan motor efficiency
- System capacity vs. baseline

The design options were combined to reach the EER design targets while satisfying various modeling guidelines suggested by the manufacturers

Validation of Cost-Efficiency Curves



1 Based on ASHRAE 90.1-1999 Mandatory Minimum EER, including a reduction of 0.2 for units having a heating section other than electric resistance heat.
2 Prediction Interval represents the accuracy of predicting the cost of any single unit given its EER.
3 Confidence Interval represents the accuracy of the mean regression curve-fit (i.e., There is a 95% probability that the mean cost of a sample of products at a given EER level would fall within the confidence interval).

Design-Option Analysis and Maximum Energy Efficiency Levels (ANOPR Issue #4)

The Department invites comments on the approach used to conduct design-option modeling for verifying the manufacturing cost and efficiency relationship.

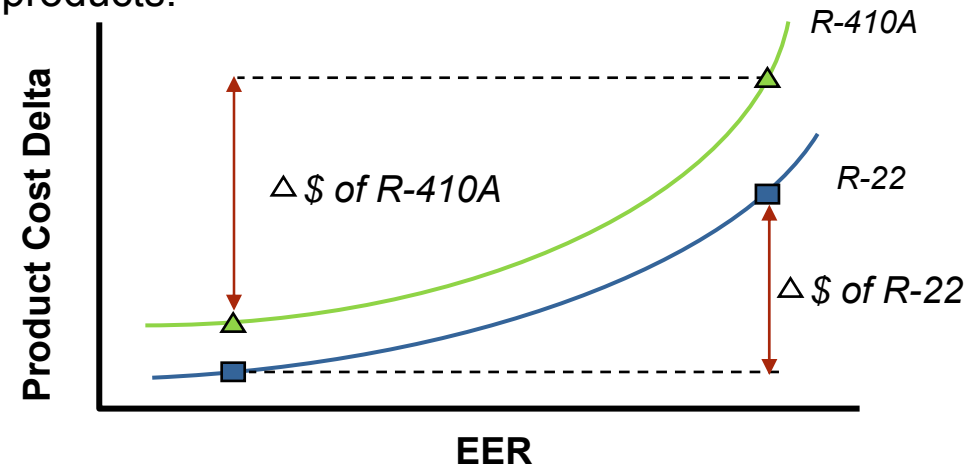
The Department invites comments on the design options selected for estimating the manufacturing cost and efficiency relationships beyond 11.5 EER.

The Department invites comments on other design options that the Department should consider.

The Department invites comments on assumptions for evaluating a maximum technologically feasible design.

R-410A Analysis

- Because of the phaseout of CFC refrigerants, the engineering analysis considers how the cost-efficiency relationship of R-410A systems differs from R-22.
- The properties of R-410A are different from those of R-22 (higher operating pressures, requires modification of existing refrigeration components).
- The critical parameters in the analysis are the cost differential between baseline and high efficiency units (rather than absolute cost) and whether this cost delta differs for R-410A vs. R-22 products.



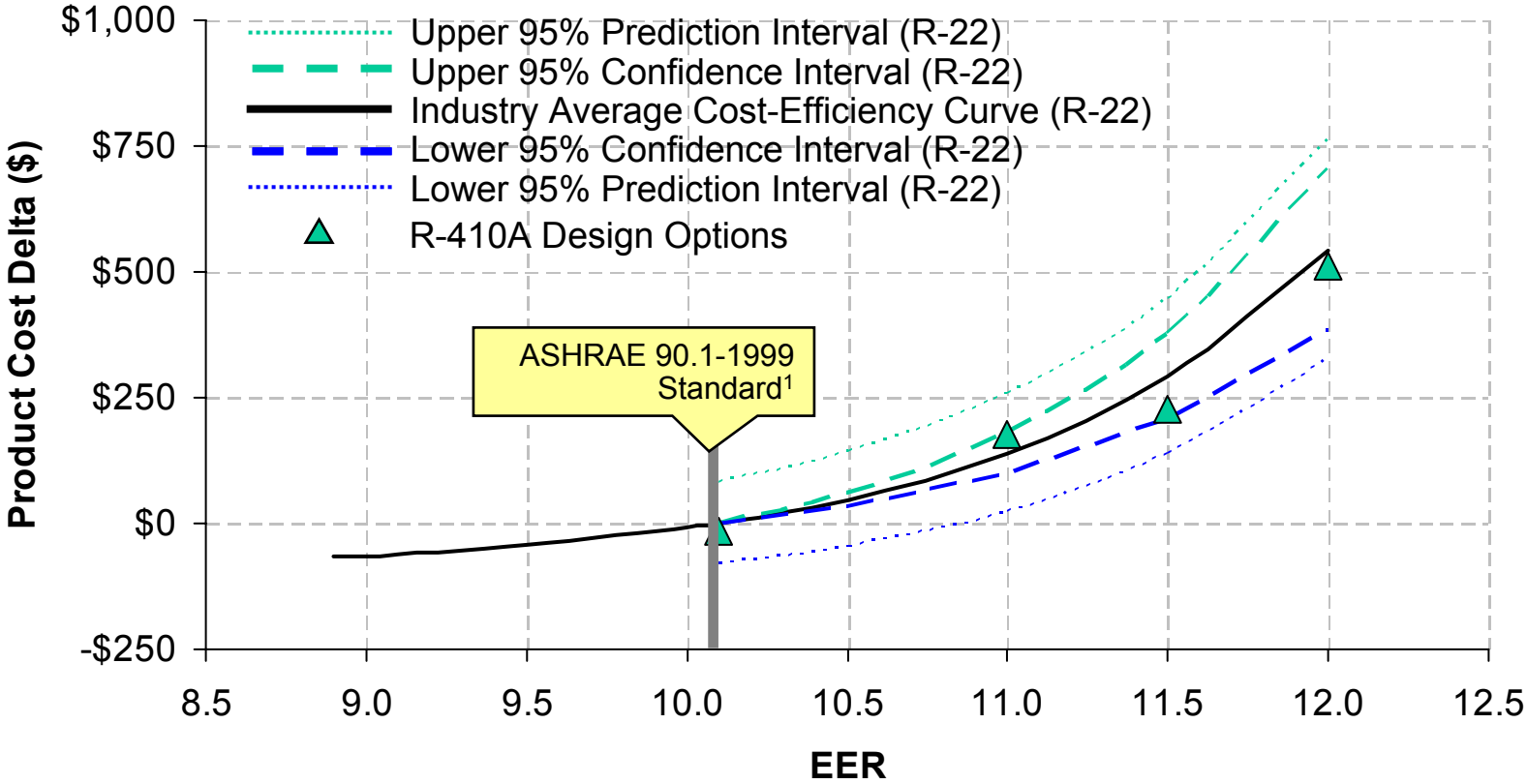
- The 7.5-ton R-410A design option points based on a representative design appear to follow a trend that is similar to the R-22 cost-efficiency curve. This trend will be validated in the post ANOPR phase.

R-410A Analysis Preliminary Assumptions

- Although design pressures are higher, the diameter and thickness of the copper tubing remains the same.
- R-410A scroll compressors are less efficient than comparable R-22 scroll compressors, but more efficient than low-efficiency R-22 reciprocating compressors.
- The higher heat-transfer coefficients of R-410A provide for slightly lower condensing temperatures than R-22 for similar coil designs.
- The evaporating temperature limits for the R-410A system are the same as the R-22 system.

7.5 Ton R-410A Analysis Results

- The R-410A points fall within the prediction interval of the R-22 curve.



[1] Based on ASHRAE 90.1-1999 Mandatory Minimum EER, including a reduction of 0.2 for units having a heating section other than electric resistance heat.

Alternative Refrigerant Analysis (ANOPR Issue #2)

The Department seeks comments or data that can refine or verify the incremental cost-efficiency relationship associated with R-410A systems.

The Department seeks comments on alternative refrigerants, other than R-410A, that the Department should consider.

Approaches to Analyses for Split Systems, Heat Pumps, and Niche Equipment (ANOPR Issue #1)

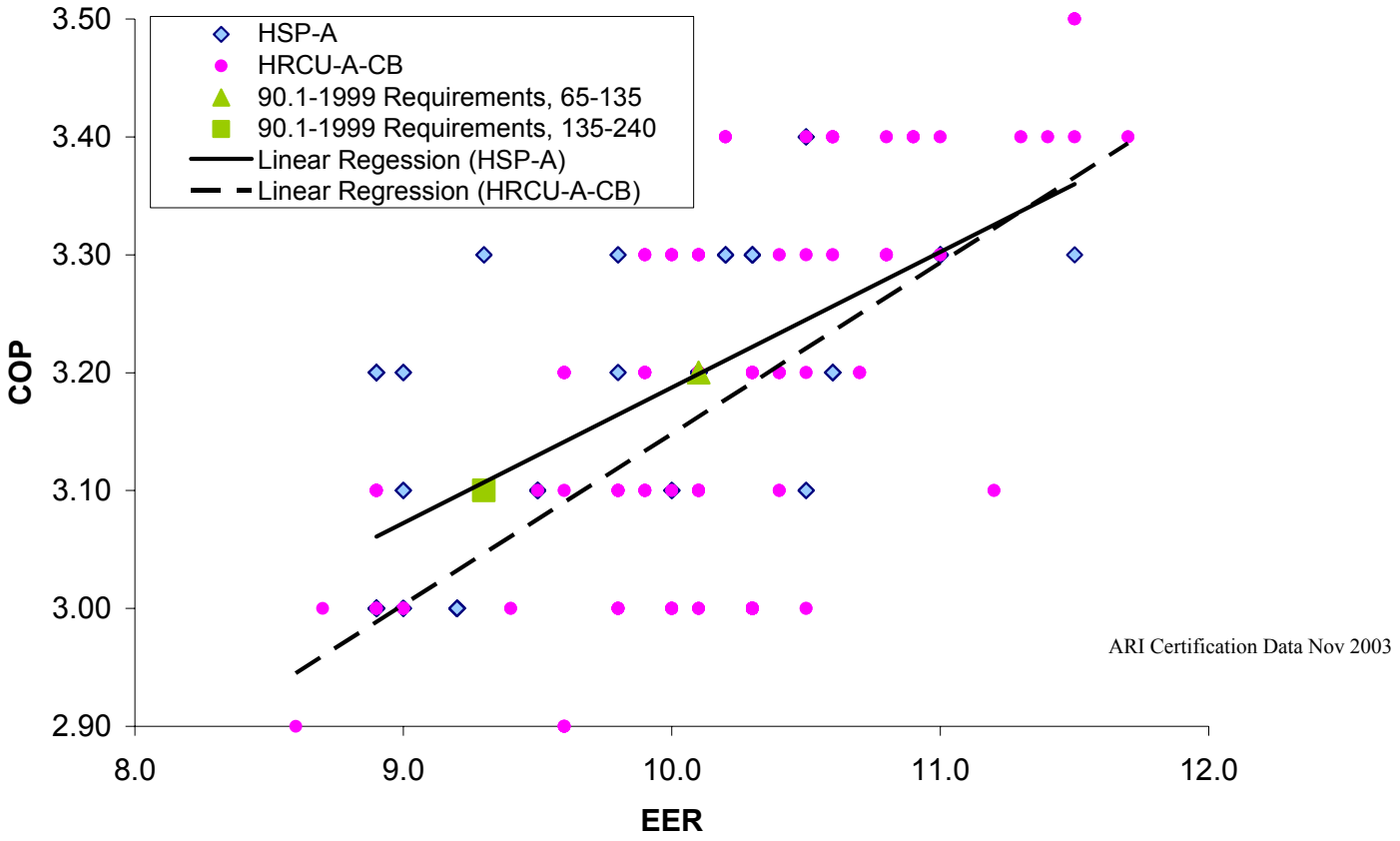
The Department invites comments on applying the cost/efficiency relationships developed for single package air conditioners to split AC systems.

The Department invites comments on the approach to address niche equipment classes, such as portable units and explosion-proof/hazardous duty units.

The Department invites comments on addressing energy efficiency standards for commercial unitary heat pumps in a way that is consistent with the ASHRAE methodology used to set the ASHRAE/IESNA Standard 90.1-1999 levels.

Approaches to Analyses for Split Systems, Heat Pumps, and Niche Equipment (continued) (ANOPR Issue #1)

DOE proposes to develop heating COP (47° F) requirements based on relationship between EER and COP as determined from market data, as used by ASHRAE.



Other Issues

The Department seeks comments and recommendations from stakeholders on any other aspects related to the Engineering Analysis.