DOE Residential Air-Conditioner Rulemaking
December 13, 2002

Small Duct, High Velocity (SDHV) System Standards
and
Central Air-Conditioner Test Procedure

Public Workshop

Agenda

1 Introduction and Welcome

2 SDHV Standards

- Engineering Analysis
- Life Cycle Cost Analysis

3 Central Air-Conditioner Test Procedure

4 Workshop Conclusion

The Department of Energy (DOE) set several goals for today's workshop.

-Present DOE engineering and life-cycle cost analyses for small duct, high velocity (SDHV) standard.

-Discuss additional revisions to DOE's test procedure for central air-conditioners and heat pumps.

-Listen to interested parties present oral views, data, and arguments on the specific topics described in the agenda.

-Solicit stakeholder comments on outstanding issues.

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1. Introduction and Welcome
2. **SDHV Standards**
   - Engineering Analysis
   - Life Cycle Cost Analysis
3. Central Air-Conditioner Test Procedure
4. Workshop Conclusion

Seven factors need to be considered, according to the National Appliance Energy Conservation Act (NAECA).

- Economic impact on manufacturers and consumers
- Life cycle cost savings *
- Total projected energy savings
- Lessening of utility *
- Lessening of competition
- Need for national energy conservation
- Other factors the Secretary deems relevant

*** Focus of today's workshop**

During the last years, SDHV has emerged as a separate product class.

- DOE identified "niche products" as serving applications with severe space constraints.

- Space constrained products excluded from January 22, 2001 rule.

- SDHV systems were not excluded but to be given special treatment in the test procedure.

- ARI supported separate product class for SDHV.

- Separate product class for SDHV adopted in May 23, 2002 final rule.

- DOE began limited analysis to develop standards for SDHV systems in February, 2002.

DOE has a specific definition of small duct, high velocity (SDHV) systems.

The term "small duct, high velocity (SDHV) system" indicates a blower and indoor coil combination that:

(1) Is designed for, and produces, at least 1.2 inches of external static pressure when operated at the certified air volume rate of 220-350 CFM per rated ton of cooling; and

(2) When applied in the field, uses high velocity room outlets generally greater than 1000 fpm which have less than 6.0 square inches of free area.

The Department prescribed new minimum standard levels for central air conditioners and central air conditioning heat pumps, with the exception of SDHV systems.

	SEER	HSPF
Split System Air-Conditioners	12	-
Split System Heat Pumps	12	7.4
Single Package Air-Conditioners	12	-
Single Package Heat Pumps	12	7.4
Through-the-wall Air Conditioners and Heat Pumps – Split System	10.9	7.1
Through-the-wall Air Conditioners and Heat Pumps – Single Package	10.6	7.0
Small Ducts, High Velocity Systems	10.0[1]	6.8[1]

[1] NAECA prescribed value – subject to amendment

The scope of today's workshop is to present key assumptions and results of analyses that will support DOE in establishing a new standard level for SDHV systems.

– **Engineering Analysis, which develops a relationship between consumer cost and SDHV system efficiency.**

– **Life-Cycle Cost Analysis, which estimates the economic impact of higher efficiency SDHV systems on consumers over the life of the equipment.**

- **Public workshop, 12/13/02**
- **Deadline for submitting comments to DOE, 01/08/03**
- **Supplemental NOPR, proposed for April 2003**
- **Final Rule, proposed for October 2003**

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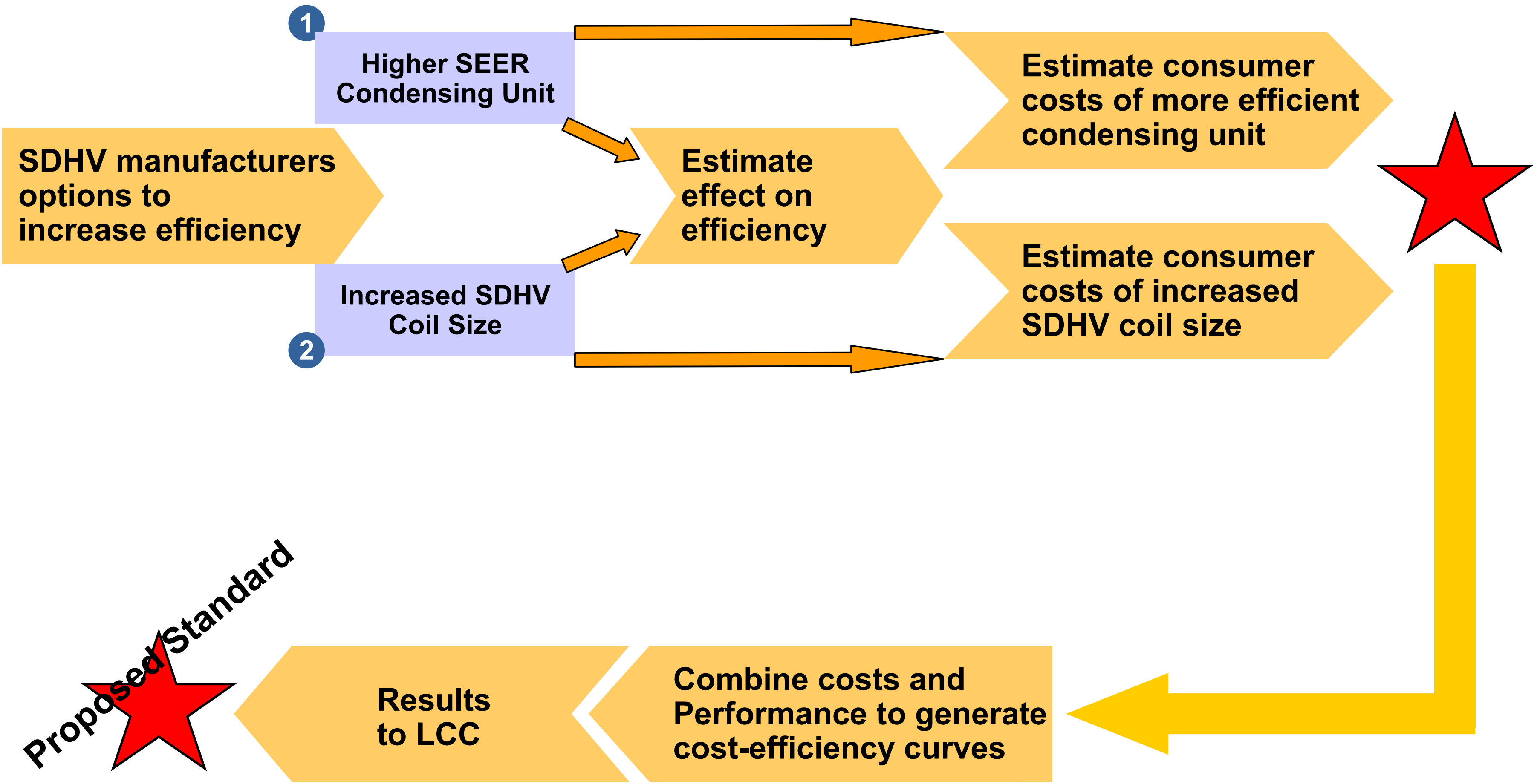
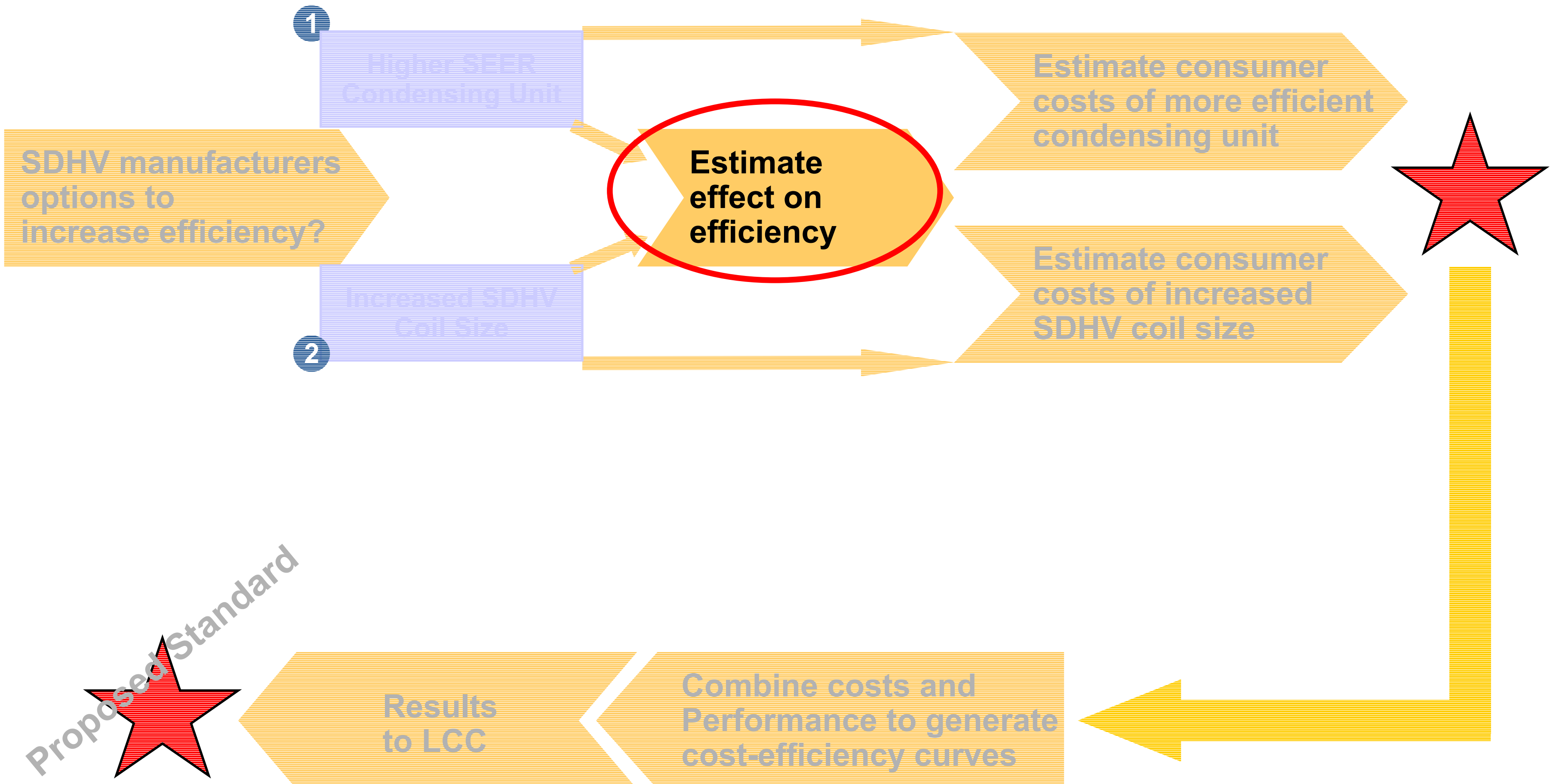
DOE identified two possible paths to increase SDHV system efficiency.

1) Pair the SDHV system with a more efficient condensing unit

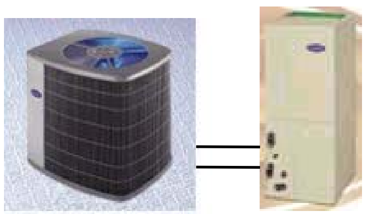
2) Increase SDHV coil size


SDHV manufacturers options to increase efficiency
1
Higher SEER Condensing Unit
Increased SDHV Coil Size
2
Estimate effect on efficiency
Estimate consumer costs of more efficient condensing unit
Estimate consumer costs of increased SDHV coil size
Combine costs and Performance to generate cost-efficiency curves
Results to LCC
Proposed Standard

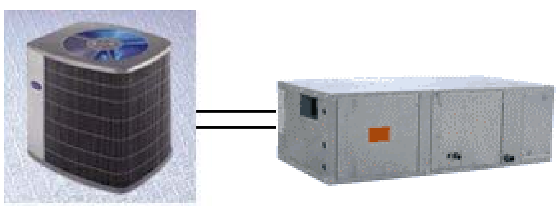
Engineering Analysis Estimating Efficiency



To estimate SDHV equipment performance, the Department used an available rating methodology*, specifically tailored to account for SDHV special features.



Manufacturers must test the highest sales volume air-conditioning system** combination in each product line. This is a **MATCHED SYSTEM**.



Without any additional testing, manufacturers can rate a system that has a different indoor unit (or an SDHV indoor blower-coil), by using an alternative rating method (ARM).
This is a **MIXED SYSTEM**.

* This methodology was originally developed by the National Institute of Standards and Technology (NIST).
** For the purpose of our analysis, an *air-conditioning system* is comprised of a condensing unit (or "outdoor unit" because it's typically installed out-of-doors) and a blower-coil unit (or "indoor unit").

The Department is seeking input from interested parties on several assumptions.

Two formulas are significant:

- **Formula to calculate SDHV fan power**

$$P_{F,x} = P_{F,m} \times \frac{\eta_m}{\eta_x} \times \frac{CFM_x \times (ESP_x + CPD_x)}{CFM_m \times (ESP_m + CPD_m)}$$

- **Formula to calculate coil capacity ratio**

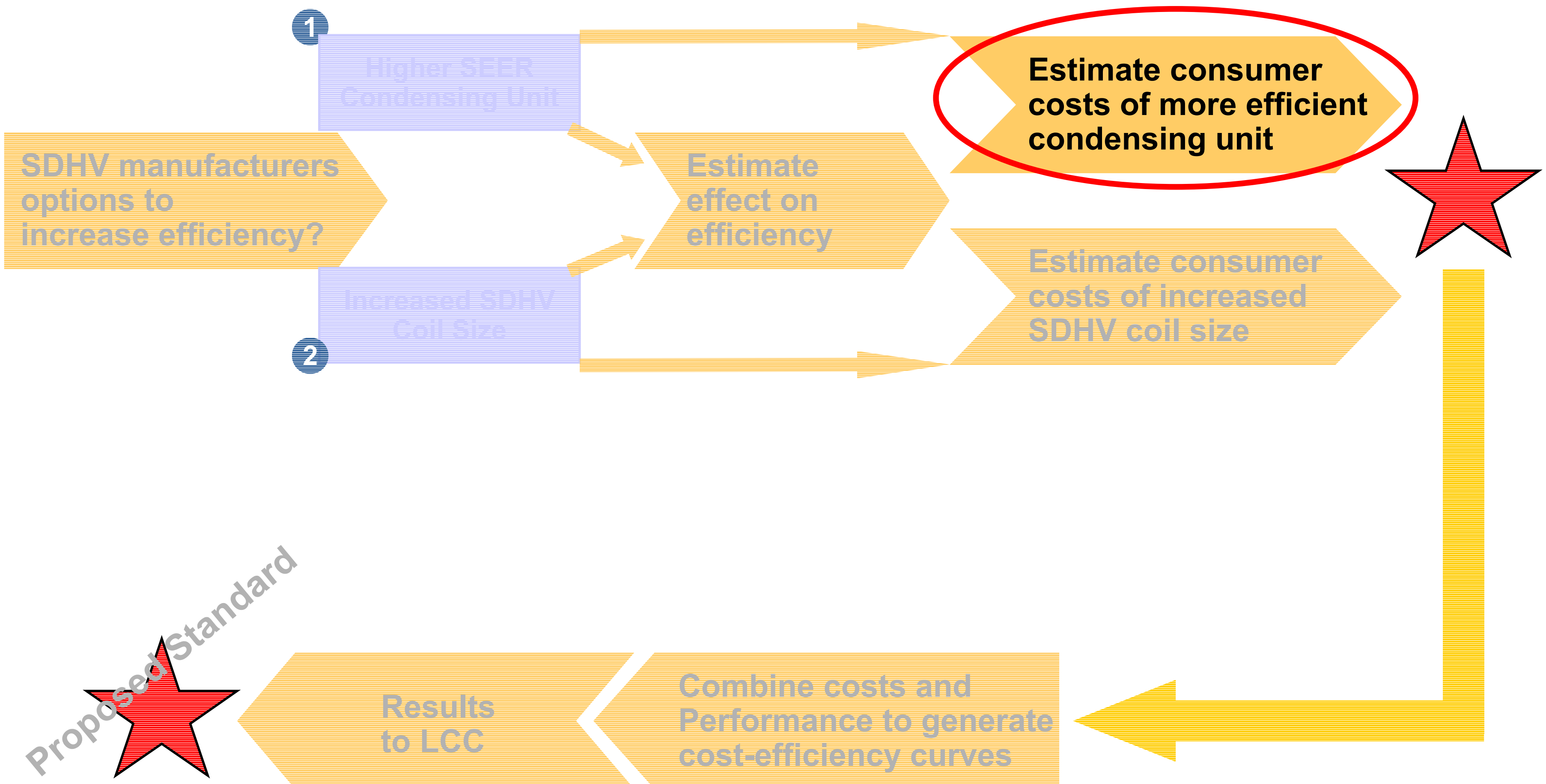
$$F_c = \sqrt{\frac{CFM_x}{CFM_m} \times \frac{(FA \times Rows)_x}{(FA \times Rows)_m}}$$

Nomenclature:

η_x	SDHV Blower Motor Efficiency (=0.65)
η_m	Matched Blower Motor Efficiency (=0.45)
FA	Coil Face Area
Rows	Number of Rows in Coil
CFM	Air Flow Rate (in cubic feet per minute)
ESP	External Static Pressure
CPD	Coil Pressure Drop
F_C	Coil Capacity Ratio
P_F	Indoor Fan Power

Note: The subscript “m” refers to the matched system and “x” to the mixed system.

Engineering Analysis Estimating Costs

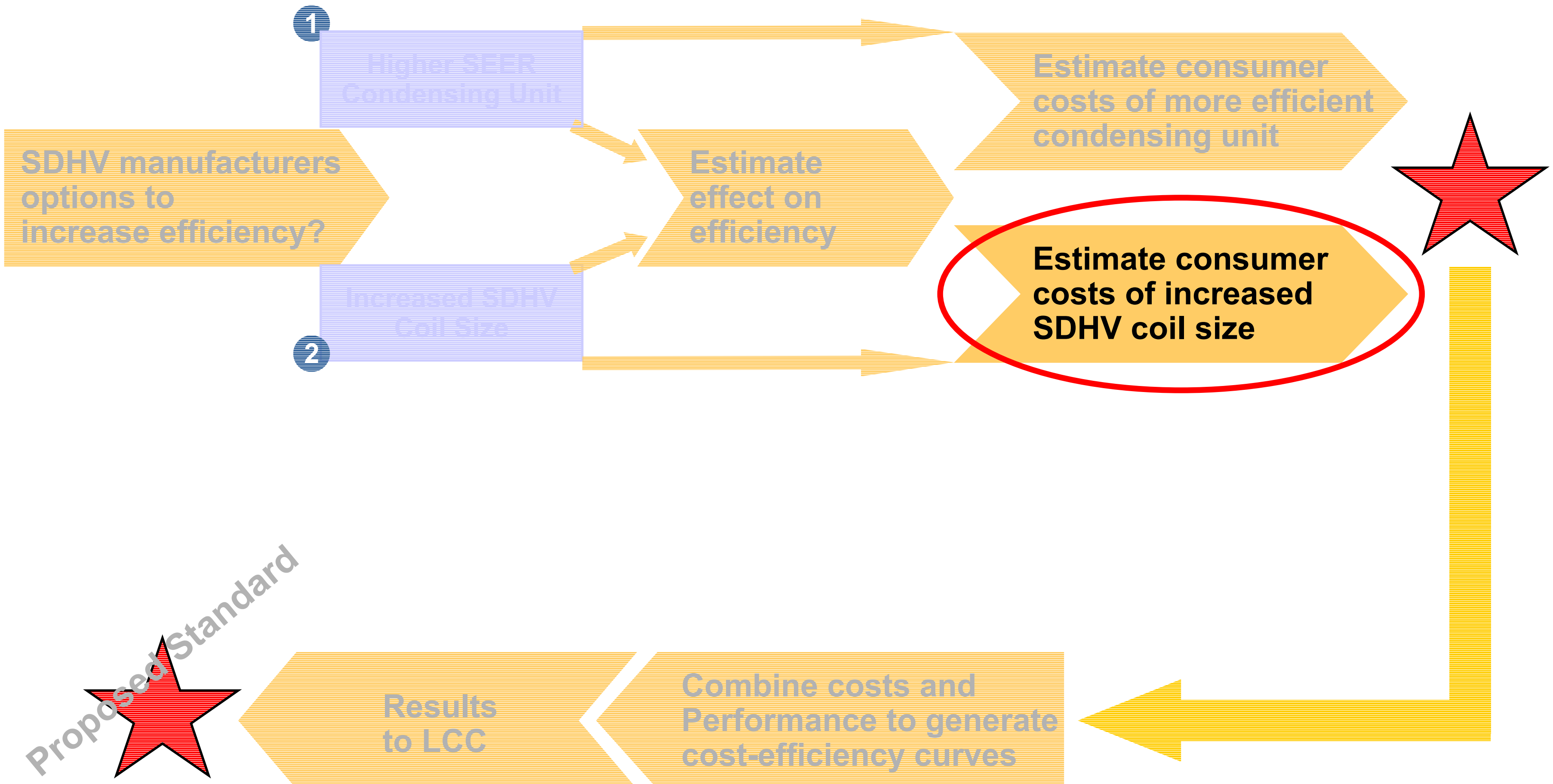


DOE used the residential air-conditioner rulemaking cost estimates as a basis to estimate cost of more efficient condensing units.

DOE added correction factors to convert “standard” cost estimates into “market” cost estimates.

CONDENSING UNIT EFFICIENCY ------------------->	12	13	14
Production cost for high volume production rates	$406.80	$462.91	$500.49
Adjustment for actual production rates	1.00	1.05	1.10
Adjusted production cost	$406.80	$486.06	$550.54
Manufacturer's Markup	1.18	1.33	1.54
Selling Price to Distributor	$478.59	$648.07	$846.98
Distributor Markup	1.27	1.27	1.27
Selling Price to Dealer	$607.81	$823.05	$1,075.67
Dealer Markup	1.30	1.30	1.30
Dealer Selling Price	$790.15	$1,069.97	$1,398.37
Sales Tax	1.07	1.07	1.07
Consumer Cost	**$845.5**	**$1,144.9**	**$1,496.3**

Engineering Analysis Estimating Costs

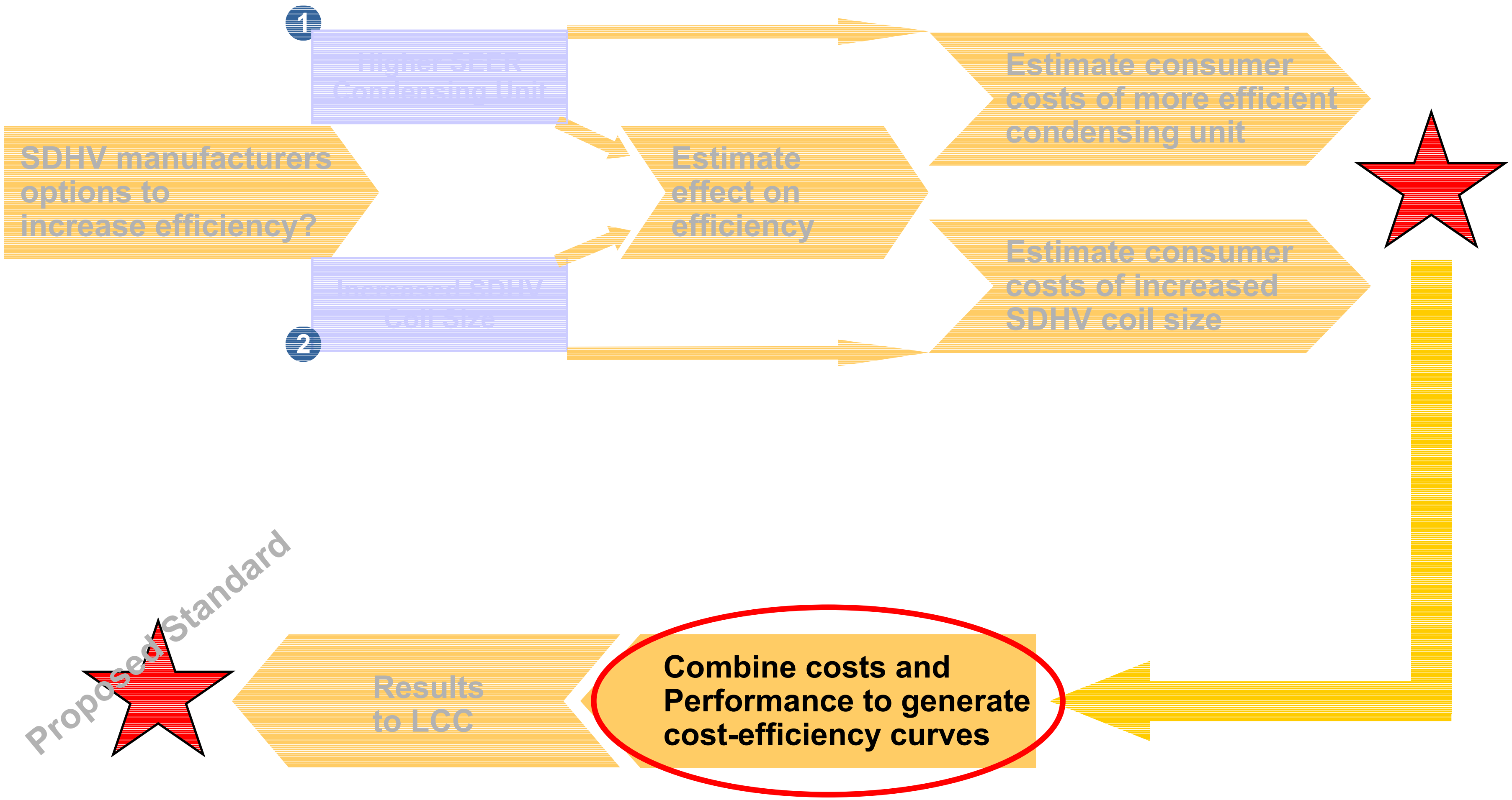


Baseline blower coil cost to consumer is about $1200.

- SDHV coil sizes range from 8 to 20.

- Consumer costs, which include SDHV specific markups, SDHV blower-coil costs and condensing unit costs, are available for review on the DOE web site.*

* (http://www.eren.doe.gov/buildings/codes_standards/applbrf/central_air_conditioner.html)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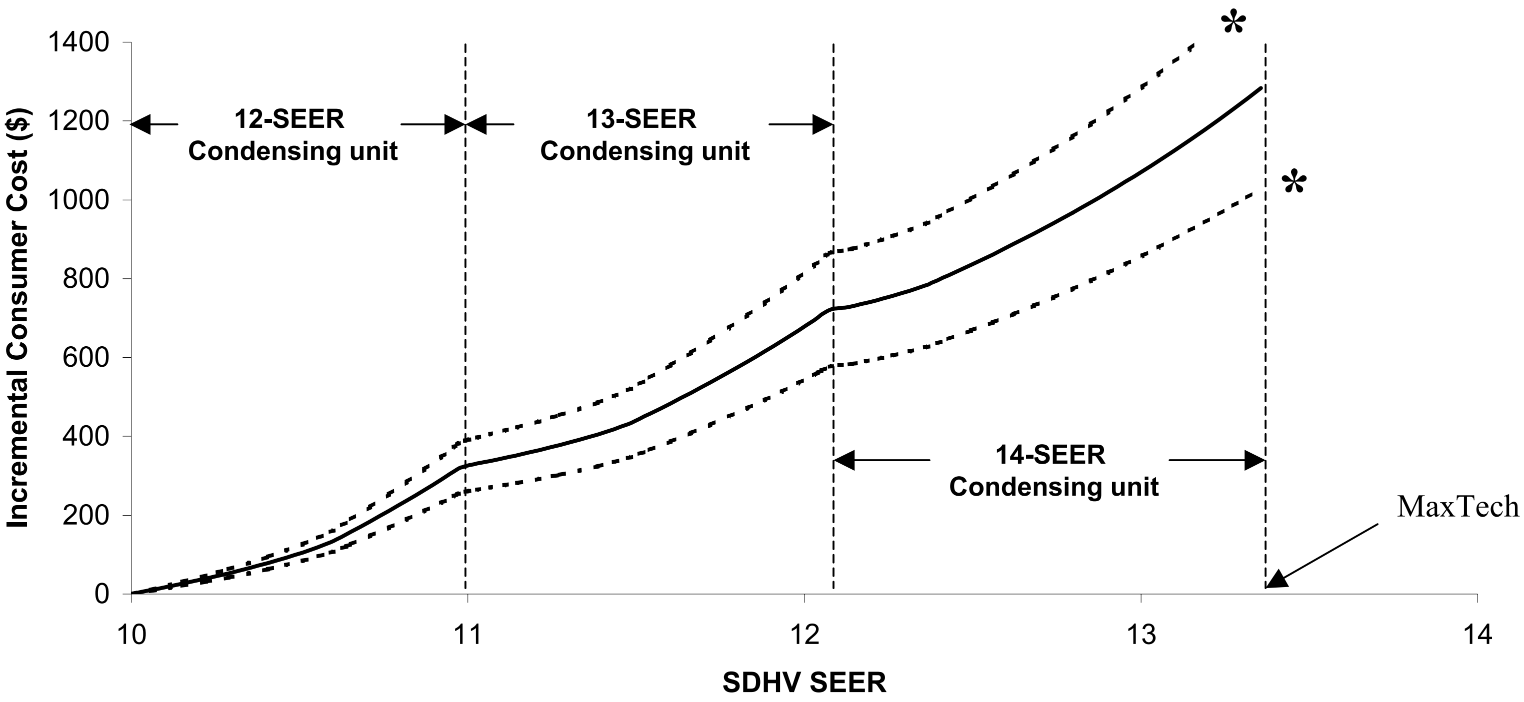
DOE is required to estimate SDHV system efficiency ranging from baseline to max tech.

- **Baseline system, which assumes a small-size SDHV coil and a 12-SEER condensing unit, has a 10 SEER rating.**

- **MaxTech system, which assumes the largest SDHV blower coil size currently on the market and a 14-SEER condensing unit, has a 13.4 SEER rating.**

Engineering Analysis Preliminary Results



*** A sensitivity analysis was performed on the assumptions to establish the upper and lower bounds.**

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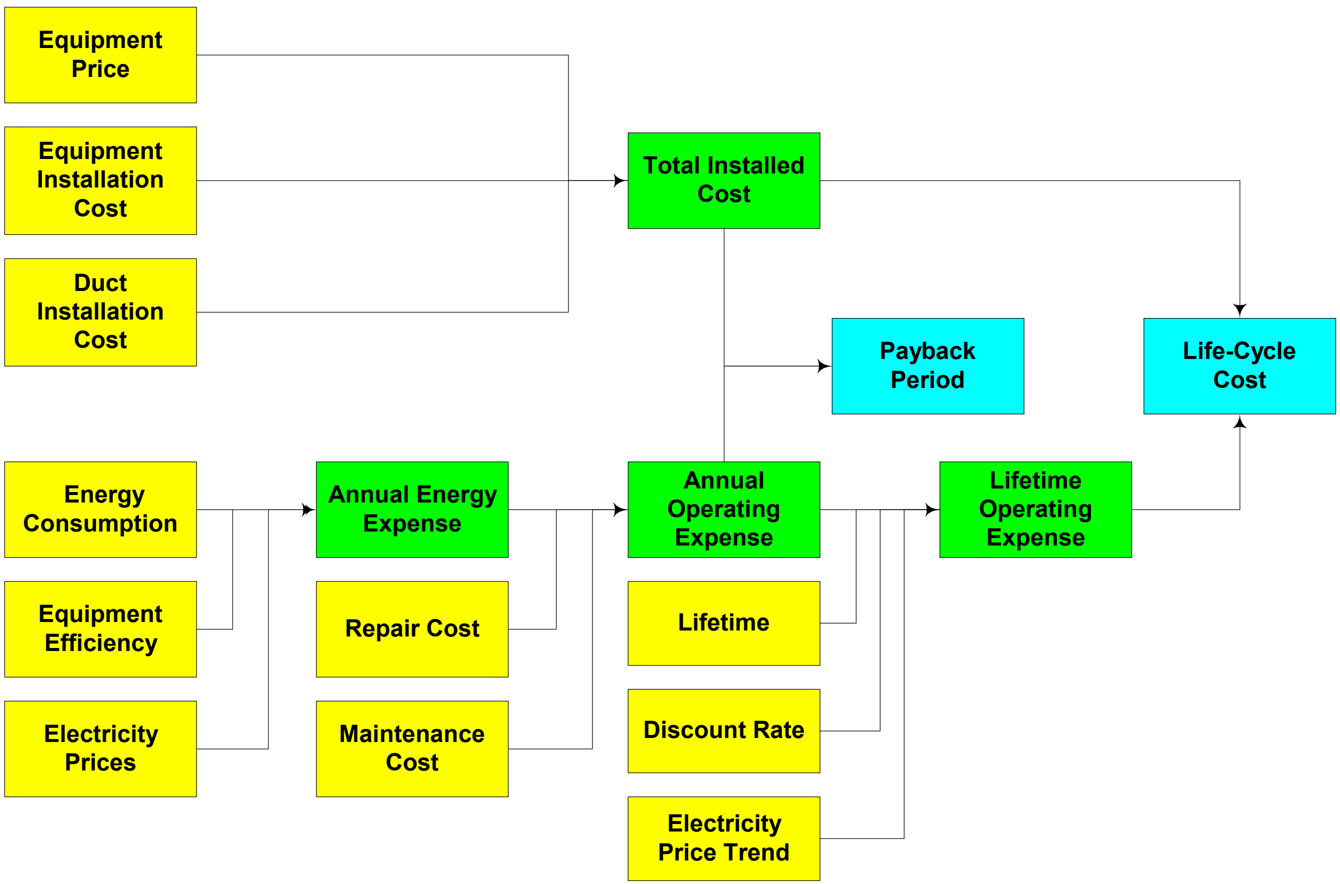
The LCC analysis approach is the same as for conventional products.

- **Representative set of residential and commercial buildings – same as those used in conventional CAC analysis**
  - Representative residential bldgs from 1997 RECS
  - Non-residential bldgs based on ASHRAE 90.1 analysis

- **LCC calculation performed on representative set of buildings**
  - Monte Carlo simulation approach using Crystal Ball

Life Cycle Cost Analysis Inputs



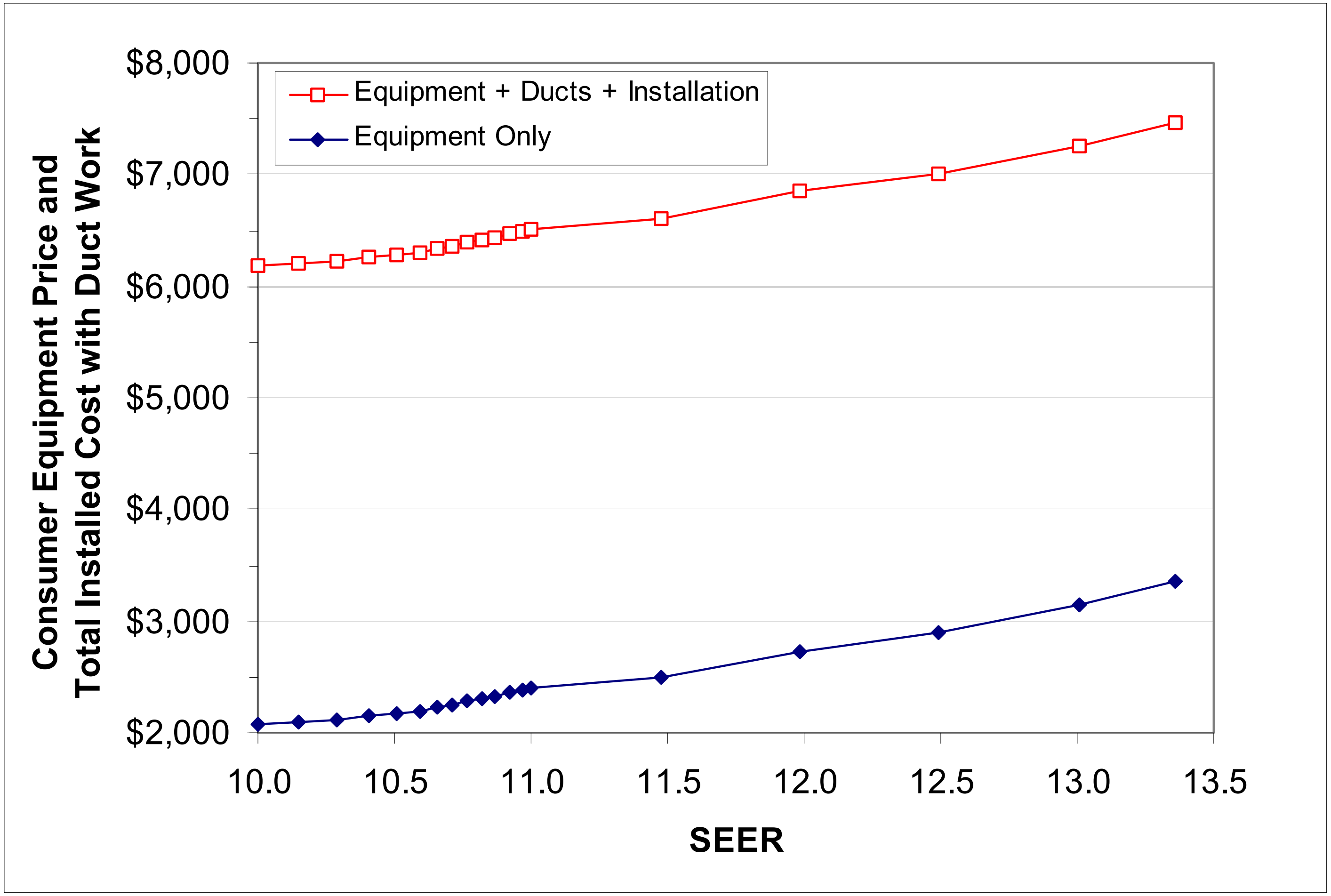
Most of the LCC inputs come from the conventional air-conditioner analysis.

- Exceptions to conventional CAC analysis
  - Consumer Equipment Prices
  - Additional Consumer Installed Cost for Duct Work = $2720 (includes Ducts, other Materials, and Labor for installation)
    - Note: Consumer Installation Cost for Equipment = $1390 (from conventional CAC analysis)
  - Electricity Price Trends from *Annual Energy Outlook 2002*
  - Repair Costs based on SDHV Consumer Equipment Prices

Summary of LCC inputs from the conventional air-conditioner analysis.

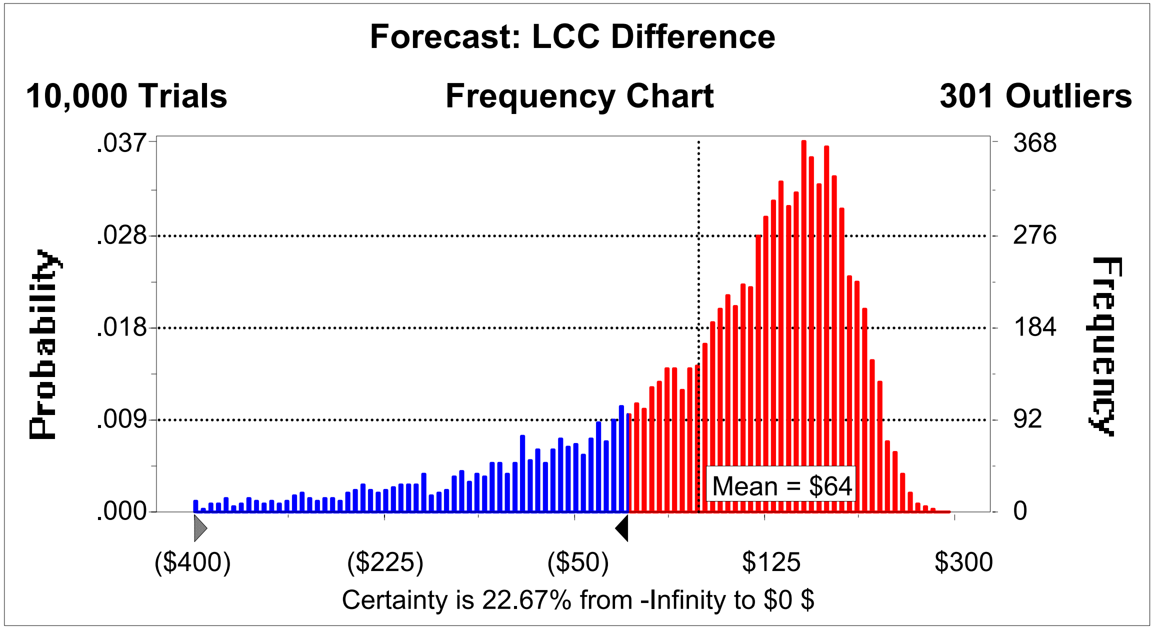
LCC Input	Weighted-Average Value	Source
Percent of units used in comm. applications	10%	CAC TSD, Section 5.1.4
Equipment Installation Cost	$1390	CAC TSD, Section 5.2.2.8
Baseline (10 SEER) Energy Use (kWh/yr)	Residential = 1947; Commercial = 5824; Combined = 2305	CAC TSD, Section 5.2.3.1
Average Electricity Price (cents/kWh)	Residential = 9.46; Commercial = 8.49; Combined = 9.36	CAC TSD, Section 5.2.3.5
Marginal Electricity Price (cents/kWh)	Residential = 9.16; Commercial = 8.64; Combined = 9.11	CAC TSD, Section 5.2.3.6
Maintenance Cost	$40	CAC TSD, Section 5.2.3.9
Lifetime (years)	18.4	CAC TSD, Section 5.2.3.10
Compressor Replacement Cost	10-10.99 SEER = $363 11-12.13 SEER = $391 >12.13 SEER = $498	CAC TSD, Section 5.2.3.10
Discount Rate	5.6%	CAC TSD, Section 5.2.3.11

Life Cycle Cost Analysis Equipment Prices with Duct Work



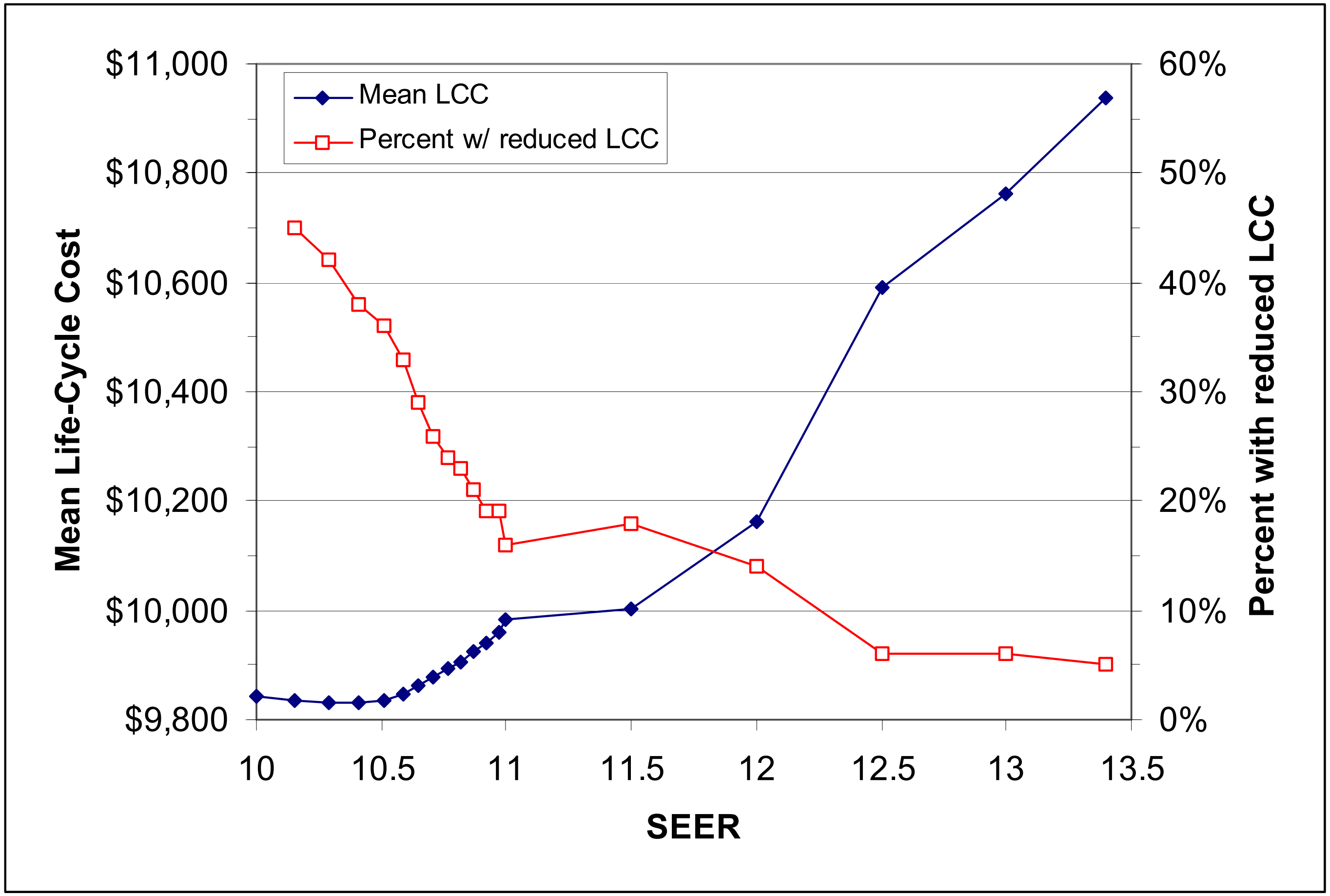
LCC results show percent of consumers benefiting from an efficiency increase.

SDHV Efficiency = 10.82 SEER



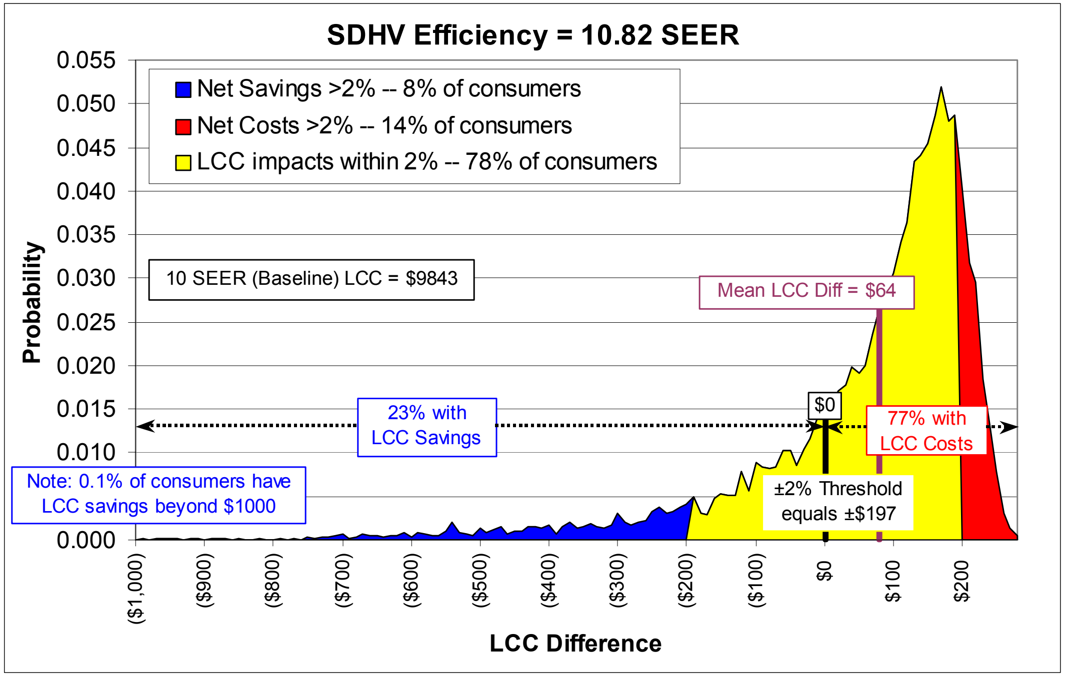
- Mean impact is LCC <u>cost</u> of $64
- 22.67% of sample have net savings
- Range is from savings of $1622 to $282 cost

Mean life-cycle cost and percentage with reduced life-cycle cost.

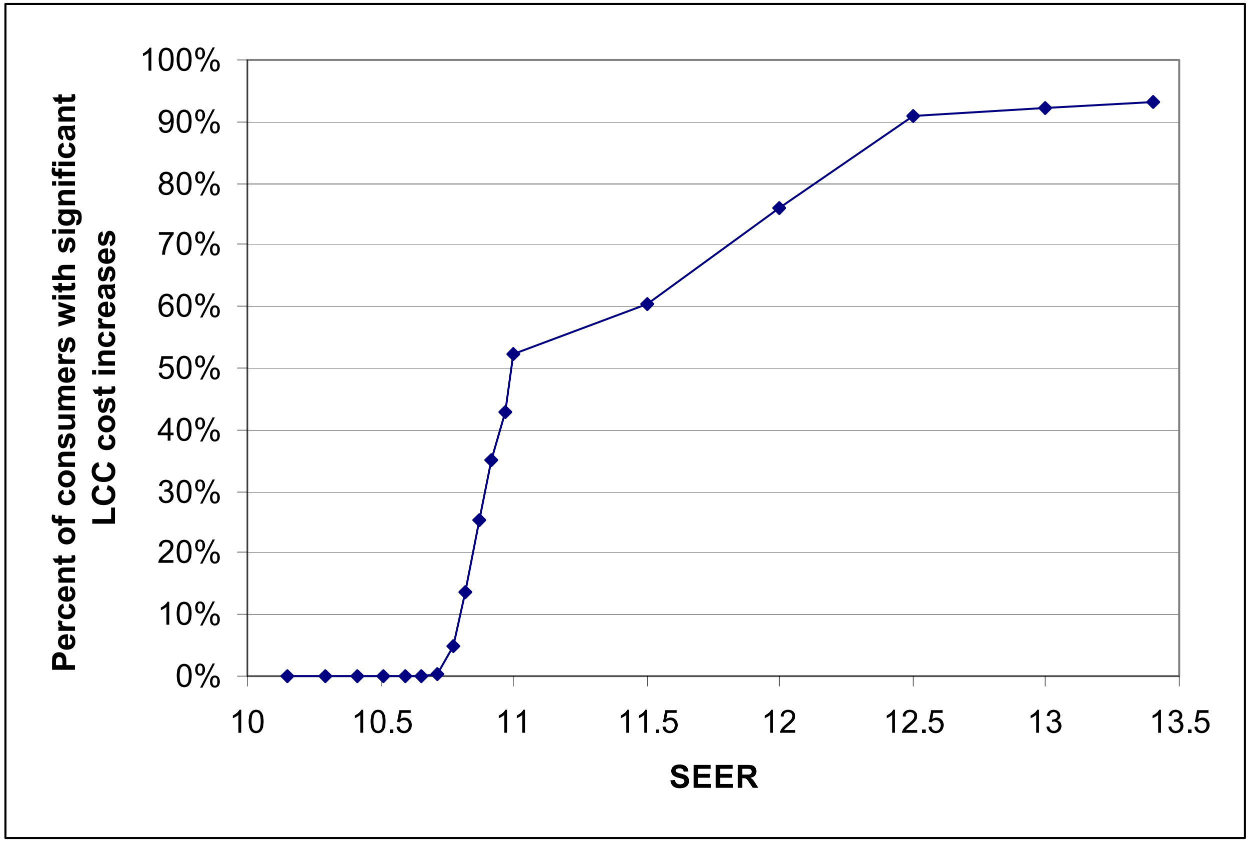


LCC results are viewed differently based upon ±2% threshold concept.

- Percent of consumers categorized as follows:
  - Significant net savings: Consumers with LCC savings >2% of 10 SEER LCC
  - Significant net costs: Consumers with LCC costs >2% of 10 SEER LCC
  - No Significant impacts: Consumers within ±2% of 10 SEER LCC



"±2%" LCC results show percent of consumers with significant impacts.



DOE seeks comments on the following items in the draft report.

- **Efficiency methodology**
  - Equation for SDHV Fan power (eq 2.3)
    assumed fan motor efficiencies
  - Equation for Fc (eq. 2.4)
    implicit assumption of coil technologies
  - Baseline SDHV system (table 1)
  - SDHV options in Section 2.4
  - Other design options not discussed in Section 2.4
  - Max Tech assumptions in Section 2.4.5
  - Heat pumps relation to AC in section 2.9

- **Cost methodology**
  - Derivation of condensing unit costs in section 2.6.2
  - Manufacturer markups for 13 and 14 SEER units
  - Installation costs in Section 2.10

- **Other**
  - Spreadsheet comments
  - Resulting cost-efficiency relationship

- **Appropriateness of using inputs from conventional CAC analysis**
  - If not appropriate, what specifically should be used?
- **LCC results based on "±2% threshold" concept**
  - Should consumer impacts be defined in this manner?

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3 **Central Air-Conditioner Test Procedure**

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Background

- Comprehensive test procedure revision final rule – Spring 2003

- New C^C_D defaults have not been proposed

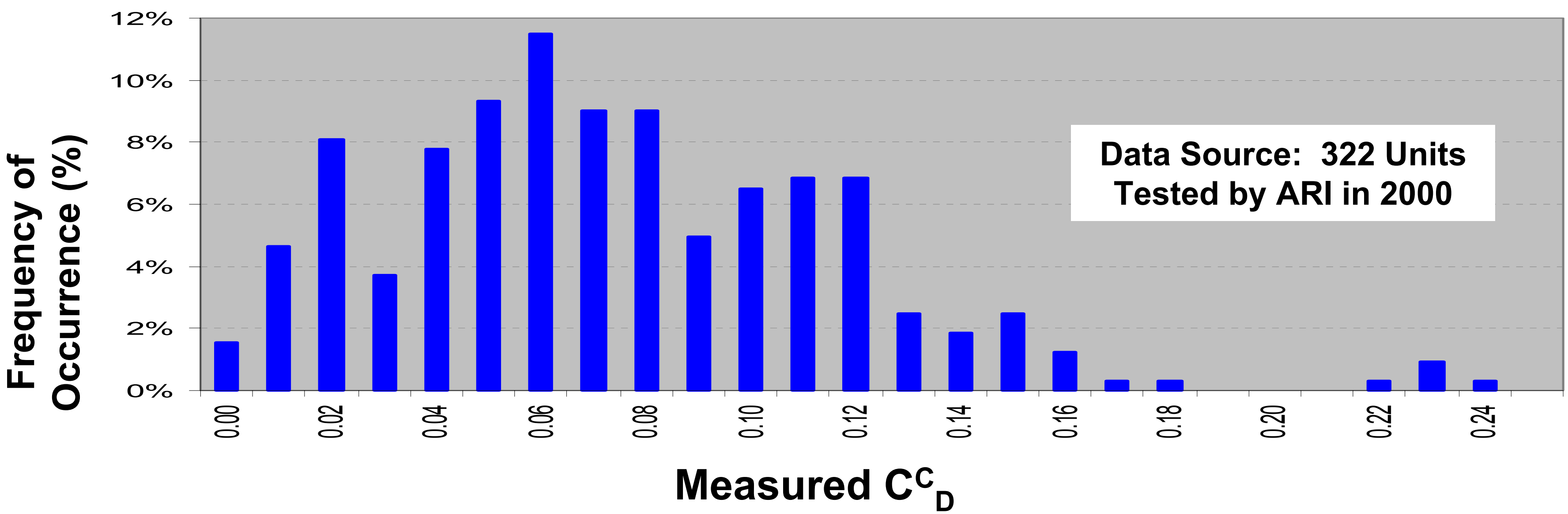
- A separate notice of proposed rulemaking for new C^C_D defaults, a change to the SDHV static pressure requirement and other changes will also be issued in the Spring of 2003.

Question

What Parts of the DOE AC&HP Test Procedure and Related CFR Sections Should Be (Re-)Evaluated As Part of a Limited-Scope Proposed Rulemaking?

Consider New C^C_D Defaults

- Present C^C_D default of 0.25 dates back to the late 1970's.
- Equipment improvements have led to lower tested C^C_D's.
- The default C^C_D is used less and the two optional tests used to determine C^C_D are more frequently conducted.



- Pros and cons of lowering the C^C_D default values
- Pros
  - ✓ Reduce testing burden on manufacturers
  - ✓ More accurate default values
  - ✓ May encourage use of non-bleed TXV's and time delay relays on the indoor blower
- Cons
  - ✓ May trigger SEER standard adjustment – EPCA 323(e)

Changing the C^C_D Defaults

Section 323(e) of EPCA states:

- (e) Amendment of standard
- (1) In the case of any amended test procedure which is prescribed pursuant to this section, the Secretary shall determine, in the rulemaking carried out with respect to prescribing such procedure, to what extent, if any, the proposed test procedure would alter the measured energy efficiency, measured energy use, or measured water use of any covered product as determined under the existing test procedure.
- (2) If the Secretary determines that the amended test procedure will alter the measured efficiency or measured use, the Secretary shall amend the applicable energy conservation standard during the rulemaking carried out with respect to such test procedure. In determining the amended energy conservation standard, the Secretary shall measure, pursuant to the amended test procedure, the energy efficiency, energy use, or water use of a representative sample of covered products that minimally comply with the existing standard. The average of such energy efficiency, energy use, or water use levels determined under the amended test procedure shall constitute the amended energy conservation standard for the applicable covered products.
- (3) Models of covered products in use before the date on which the amended energy conservation standard becomes effective (or revisions of such models that come into use after such date and have the same energy efficiency, energy use, or water use characteristics) that comply with the energy conservation standard applicable to such covered products on the day before such date shall be deemed to comply with the amended energy conservation standard.

- **Difficulties with 323 (e) Standard Amendment:**

  It may be impossible to construct a "representative sample" of products that minimally comply (10 SEER units). The SEER adjustment could range from zero to roughly 6%, depending on the makeup of the sample. The statute offers no guidance in constructing the sample.

Higher Minimum External Static Requirements for SDHV Systems

- **The forthcoming test procedure final rule includes a definition for a small-duct, high velocity (SDHV) system.**

  "... a system that contains a blower and indoor coil combination that is designed for, and produces, at least 1.2 inches (of water) of external static pressure when operated at the certified air volume rate of 220-350 CFM per rated ton of cooling. When applied in the field, small-duct products use high-velocity room outlets (i.e., generally greater than 1000 fpm) having less than 6.0 square inches of free area."

- **Proposed test procedure change is to specify a higher minimum external static pressure requirement (i.e., 1.2 inches of H_2O) when testing such units.**

- **Proposed change acts to verify that the product is a SDHV system.**

Optional Testing for Two-Capacity Units

- **Forthcoming test procedure final rule does not include the option of testing to determine the cyclic degradation coefficient at high capacity, $(C_D)^{k=2}$**
- **$(C_D)^{k=2}$ needed in some SEER/HSPF calculations for units that limit low-capacity operation to certain temperature ranges.**
- **Propose to permit the option of conducting the extra tests required to determine the cooling and heating mode cyclic degradation coefficients at high capacity.**
- **Possible default options:**
  - ✓ **Assign $(C_D)^{k=2}$ = Normal C_D default value (0.25)**
  - ✓ **Assign as: $(C_D)^{k=2} = (C_D)^{k=1}$**

- **Running a Frost Accumulation Test on a two-capacity heat pump that is operating at low-capacity can be difficult.**
  - ✓ **Often little frosting of the outdoor unit**
  - ✓ **Demand defrost units may not initiate a defrost cycle**
  - ✓ **Possibility of having to run test for 12 hours; hard to achieve test condition tolerances over that long an interval.**

- **Options for changing the test procedure:**
  - ✓ **Reduce the 12-hour limit to 6 hours**
  - ✓ **Allow test to end with a manual defrost that is initiated after a manufacturer-specified time interval**
  - ✓ **Develop a default equation**

- **Two Questions:**
  1. **When testing multi-split systems, should they be allowed to cycle off one or more indoor units for tests at low capacity, minimum speed, or the intermediate speed?**
  2. **Do tests at maximum speed, minimum speed, and the intermediate speed provide a representative performance map from which to determine SEER and HSPF?**

- **Presently, multi-evaporator units are tested with all indoor units operating.**

- **Seek comment on whether and how the DOE test procedure could be changed to better cover multi-split units.**

1. **Do some smaller manufacturers need an alternative to the presently stated requirement?**

   10 CFR, Pt. 430, Subpart B, Section 430.24(m)(6)(iii), ". . .test data for two coils from two different coil families for two different condensing units. The tested capacities for the matched systems for the two condensing units shall differ by at least a factor of two."

   If the above criteria can not be met, can the manufacturer submit data on two indoor units, each tested with two different outdoor units (see example)?

2. **Should manufacturers be able to use a previously tested combination for verification if the indoor coil design has changed?**

   i. **If the new design creates a new coil family?**

   ii. **Any limit on age of test data?**

Test Set-up Requirements for Split Systems

- **Question asked by a user of the DOE test procedure: Are there any limits on the elevation difference between the indoor and outdoor coils?**

- **Answer:**
  - ✓ **Follow the manufacturer installation instructions**
  - ✓ **Nothing presently specified from a laboratory setup standpoint (includes ASHRAE Std 37)**

- **Seek Comment:**
  - ✓ **Should some height differential be specified, with the intent of adding test repeatability**
  - ✓ **If yes, what should be the limit?**

Duct Loss Correction

- A duct loss correction was added in the forthcoming test procedure final rule (Section 3.11).
  - ✓ The duct loss correction was added so that the DOE test procedure was consistent with industry practice.
  - ✓ Unfortunately, the correction is incorrectly applied: correction for duct losses on the indoor-side is used to correct the secondary measurement of capacity.
  - ✓ Plan to change the correction so that duct losses on the indoor side are used to adjust the primary capacity measurement.

Note: The magnitude of the duct loss correction is minimized due to the required duct insulation requirement of R-19 when testing.

- Question: should the DOE central air conditioner and heat pump test procedure reference sample calculations in ASHRAE Standard 116?

- ASHRAE Standard 116, Appendix A
  - ✓ Cooling mode examples: 1-speed, 2-speed, variable-speed
  - ✓ Heating mode examples: 1-speed, 2-speed, variable-speed

- Options:
  - ✓ Reference Appendix A of Std 116
  - ✓ Rather than reference, add sample calculations to the DOE test procedure
  - ✓ Do neither – stay as we are

Other Suggestions or Comments

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