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# Summary

Efficiency of air conditioners is rated by Seasonal Energy Efficiency Ratio (SEER)/Energy Efficiency Ratio (EER) as a ratio of cooling output in British thermal unit (Btu) divided by total energy used to create the output. SEER ratings differ from EER as they are measured and compiled over seasonal changes and necessary cooling output, whereas EER is based upon fixed conditions. To project future savings for households, we need to establish the SEER/EER rating of a current piece of equipment based upon age collected from the consumer and survey the SEER/EER ratings for replacement equipment purchases that are currently available. With this information, determine a relationship to be able to specify the projected household savings for the upgraded equipment.

# Applicable Areas

Heat Pumps (Air Source), Central Air Conditioners (Packaged & Split system), Gas Pack, Room (Window) Air Conditioners

# Background

The gas pack category, since it is the combination of a central air conditioner and a gas furnace will be assumed to be a central air system for air conditioning.

## Energy Regulations

Since 1992, the U.S. Department of Energy (DOE) has imposed regulations on air conditioning equipment manufacturers to drive energy conservation based upon the Energy Policy and Conservation Act. The DOE has twice established the following standards on manufacturers of Air Source Heat Pumps and Central Air Conditioners:

|  |  |
| --- | --- |
| Year | Federal SEER rating |
| 1992[[1]](#footnote-1) | 10 SEER |
| 2002 | 12 SEER |
| 2006 | 13 SEER |

Table 1: Air Source Heat Pump & Central Air Conditioners SEER Requirements[[2]](#footnote-2)

Based on DOE regulations imposed on manufacturers, below standard stock could still be purchased and installed until depleted, so not necessary all appliances bought after 1992 or 2006 met these standards.

Since no regulation existed before 1992, to determine the SEER rating of older equipment, looking at the shipped units’ average SEER rating will paint the best picture possible. In Table 2, the average SEER for select years going back to 1981 to 1990 was used (up to 30 years old or twice the life expectancy of a cooling system), amounting to an average of 8.6 SEER ≈ 9 SEER.

|  |  |
| --- | --- |
| Survey Year | Average SEER of Central Air-Conditioning Units Sold During the Year |
| 1981 | 7.78 SEER |
| 1982 | 8.31 SEER |
| 1984 | 8.66 SEER |
| 1987 | 8.97 SEER |
| 1990 | 9.31 SEER |

Table 2: 1981-1990 Unit Sold SEER Rating[[3]](#footnote-3)

Applying the historical shipped average SEER ratings and regulations the following assumed SEER rating can be associated with the SE3D equipment year groupings.

|  |  |  |
| --- | --- | --- |
| Year(s) | SE3D equipment year groupings | Assumed SEER rating |
| <=1991 | >= 20 Years | 9 SEER |
| 1992-1996 | 15-19 Years | 10 SEER |
| 1996-2000 | 11-15 Years | 10 SEER |
| 2001-2005 | 6-10 Years | 10 SEER |
| 2006-2009 | 2-5 Years | 13 SEER |
| 2010-2011 | 1 Year | 13 SEER |

Table 3: SE3D Year Group SEER ratings for Air Source Heat Pumps and Central Air Conditioning Units

Separate Federal standards have been established for Room (Window) Air Conditioners based upon additional device factors originally in 1990.

|  |  |  |
| --- | --- | --- |
| Capacity  (Btu/Hr) | Federal Standard EER,  with louvered sides | Federal Standard EER,  without louvered sides |
| < 6,000 | >= 8.0 | >= 8.0 |
| 6,000 to 7,999 | >= 8.5 | >= 8.5 |
| 8,000 to 13,999 | >= 9.0 | >= 8.5 |
| 14,000 to 19,999 | >= 8.8 | >= 8.5 |
| >= 20,000 | >= 8.2 | >= 8.2 |
| REVERSE CYCLE | | |
| Capacity (Btu/Hr) | Federal Standard EER,  with louvered sides | Federal Standard EER,  without louvered sides |
| < 14,000 | n/a | >= 8.0 |
| >= 14,000 |
| < 20,000 | >= 8.5 | n/a |
| >=20,000 |

Table 4: Room (Window) Air Conditioners 1990 Manufacturer Standards[[4]](#footnote-4)

The current manufacturing standards were begun in 2000.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Capacity  (Btu/Hr) | Federal Standard EER,  with louvered sides | ENERGY STAR EER,  with louvered sides | Federal Standard EER,  without louvered sides | ENERGY STAR EER, without louvered  sides |
| < 6,000 | >= 9.7 | >= 10.7 | >= 9.0 | >= 9.9 |
| 6,000 to 7,999 |
| 8,000 to 13,999 | >= 9.8 | >=10.8 | >=8.5 | >9.4 |
| 14,000 to 19,999 | >= 9.7 | >= 10.7 |
| >= 20,000 | >= 8.5 | >= 9.4 |
| Casement | Federal EER | | ENERGY STAR EER | |
| Casement-only | >= 8.7 | | >= 9.6 | |
| Casement-slider | >= 9.5 | | >= 10.5 | |
| REVERSE CYCLE | | | | |
| Capacity (Btu/Hr) | Federal Standard EER,  with louvered sides | ENERGY STAR EER,  with louvered sides | Federal Standard EER,  without louvered sides | ENERGY STAR EER, without louvered  sides |
| < 14,000 | n/a | n/a | >= 8.5 | >= 9.4 |
| >= 14,000 | >= 8.0 | > 8.8 |
| < 20,000 | >= 9.0 | >= 9.9 | n/a | n/a |
| >=20,000 | >= 8.5 | >= 9.4 |

Table 5: Room (Window) Air Conditioners 2000 Manufacturer Standards[[5]](#footnote-5)

There is a new ENERGY STAR specification regarding the Room (Window) Air Conditioners efficiency standard that is being revised. This specification will not be used in the calculations since it is expected to be effective in January 2013[[6]](#footnote-6).

## ENERGY STAR® Standards

ENERGY STAR current standard is 14 SEER for packaged systems and 14.5 SEER for split systems.[[7]](#footnote-7) ENERGY STAR ratings for Window Air Conditioners require 10% lower energy consumption versus conventional models, but the exact EER rating will vary based upon unit Btu output and construction, though the range will fall between 8.8 EER and 10.8 EER as provided in Table 5.

## Market Household Data

The age distribution of Central Air Systems (Conditioners and Heat Pumps) and Room (Window) Air Conditioners was surveyed as part of the 2005 Residential Energy Consumption Survey (RECS)[[8]](#footnote-8). In summer of 2011, the RECS will be providing update to this 2005 survey data based upon the 2009 RECS.

|  |  |  |
| --- | --- | --- |
| Equipment Age | Housing Units (millions) | % of Housing Units |
| Less than 2 Years | 9.0 | 15% |
| 2 to 4 Years | 11.0 | 18% |
| 5 to 9 Years | 16.3 | 27% |
| 10 to 19 Years | 16.8 | 28% |
| 20 Years or More | 6.5 | 11% |

Table 6: Central Air-Conditioning - Age of Central Air-Conditioner Used by One Housing Unit

|  |  |  |
| --- | --- | --- |
| Equipment Age | Housing Units (Millions) | % of Housing Units |
| Less than 2 Years | 6.4 | 24% |
| 2 to 4 Years | 7.8 | 29% |
| 5 to 9 Years | 7 | 26% |
| 10 to 19 Years | 3.7 | 14% |
| 20 Years or More | 2.1 | 8% |

Table 7: Window/Wall Unit Air-Conditioning - Age of Most-Used Unit

ENERGY STAR provides a table that can be used to roughly estimate the size of the Room Air Conditioning required based on the square footage of the space to be conditioned and some basic characteristics. The table is provided below:

|  |  |
| --- | --- |
| Area to be cooled (square feet) | Capacity Needed (BTUs per hour) |
| 100 up to 150 | 5,000 |
| 150 up to 250 | 6,000 |
| 250 up to 300 | 7,000 |
| 300 up to 350 | 8,000 |
| 350 up to 400 | 9,000 |
| 400 up to 450 | 10,000 |
| 450 up to 550 | 12,000 |
| 550 up to 700 | 14,000 |
| 700 up to 1,000 | 18,000 |
| 1,000 up to 1,200 | 21,000 |
| 1,200 up to 1,400 | 23,000 |
| 1,400 up to 1,500 | 24,000 |
| 1,500 up to 2,000 | 30,000 |
| 2,000 up to 2,500 | 34,000 |

Table : Room (Window) Air Conditioner square footage vs. cooling capacity[[9]](#footnote-9)

## Equipment Availability

Air Conditioner/Heat Pump installers, including American Standard, Bryant, Carrier, Lennox, and Trane, have top line equipment in the 20-21 SEER range down to the minimum 13 SEER.[[10]](#footnote-10)

Window Air conditioners, including Friedrich, Frigidaire, Haier, GE, LG and Kenmore, top out around 11.7 EER – 12 EER down to varying Federal standards based on construction.[[11]](#footnote-11)

# Unit Energy Consumption

## Energy Use Factors

The main factors that affect energy usage of cooling systems are climate zone, cooling degree days, cooling square footage, type of system, usage of a programmable thermostat, and the age of the system. The types of systems included here are Central Air (CAC), heat pumps (Pump), room air conditioners (window), and geothermal.

## Consumer Provided Factors

Based on customer feedback, the surveys will provide the cooling square footage, usage of a programmable thermostat, type of system, and the age of their system. The climate zone and cooling degree days will be found based on the weather data we receive based on the customer’s location.

## Assumed Factors

If the customers is not sure or omits a question, there must be assumed answers to fill in the blanks.

* Cooling Square footage- 2,036 sqft[[12]](#footnote-12). For the cases where there are Room (Window) Air Conditioners present, the cooling square footage per unit, if not provided in the survey, will be estimated based upon the 2009 Room (Window) Air Conditioners shipment-weighted average capacity per unit, which equals 9,287 BTU/Hr[[13]](#footnote-13). From Table 8: Room (Window) Air Conditioner square footage vs. cooling capacity, a unit with this capacity can be used in any room with a square footage between 350 and 400 square feet. The upper limit of the range, 400 square feet, will be used in the calculations.
* Type of cooling system- If climate is warmer than 2,000 CDD=Heat Pump. If cooler than 2,000 CDD=Central Air[[14]](#footnote-14)
* Age of system- If Central Air, Heat Pump, or Geothermal- 6-10 years, If window unit- 2-5 years (Using Table 6 & Table 7)
* Set afternoon temperature during summer or cooling months- Assume national average of 74[[15]](#footnote-15). This value is found using a weighted average of the data in Table 9.

|  |  |  |  |
| --- | --- | --- | --- |
| Summertime Daytime Temperature Ranges | Assumed Summer Daytime Set Temperature ( | Population With Equivalent Setting (%) | Weighted Average Temperature ( |
| 69 Degrees or Less | 68 | 11.4 | 74 |
| 70 Degrees | 70 | 14.8 |
| 71 to 73 Degrees | 72 | 19 |
| 74 to 76 Degrees | 75 | 25.6 |
| 77 to 79 Degrees | 78 | 17.8 |
| 80 or More Degrees | 80 | 11.6 |

**Table 9: Average Summer Afternoon Set Temperatures in the United States**

## Annual Operating Use

### Calculation

Unit energy consumption is calculated for cooling systems using a regression-derived formula[[16]](#footnote-16) created by Go Sustainable Energy combined with customer input data and depending on the type of cooling system.

|  |  |
| --- | --- |
|  | Equation 1 |

|  |  |
| --- | --- |
|  | Equation 2 |

|  |  |
| --- | --- |
|  | **Equation 3** |

Where CDD is cooling degree days, CSF is cooling square footage, is the programmable thermostat effect, Age efficiency % is the effect of age on SEER efficiency, and # of units is the number of window units in the home. For an example, a home with 2,200 CDD, 2,700 square feet cooled (for CAC and Geothermal), a summer afternoon temperature setting of 74 thus making equal to 1, and an age of 8 years will be tested through the energy consumption equations for all three types of cooling systems. Sample 1 shows the average annual energy usage for Central Air systems and Heat Pumps, Sample 2 shows the average annual energy usage for window units (379 square feet per Room Air Conditioner unit), and Sample 3 shows the average annual energy usage for a geothermal system that is 3 years old. The CSF for the window A/C unit is 400 square feet because the average window A/C unit has capacity for 379 square feet. Therefore, 1 window unit will be assumed.

|  |  |
| --- | --- |
|  | Sample 1 |
|  | Sample 2 |
|  | Sample 3 |

### Input(s)

Customer inputs will provide afternoon set temperature (T), cooling square footage (CSF), type of system, and age of system. CDD values, representing the weather experienced over a twelve month period based on the customer’s zip code, will be found using Weather Source.

In the CAC/Pump and geothermal equations, the “T” input is found by relating the set afternoon temperature of customers with thermostats to the national average set afternoon temperature, as seen in Equation 4. The customer Inputs their afternoon set temperature on their thermostats, shown as “T” in Equation 4.

|  |  |
| --- | --- |
|  | Equation 4 |

The thermostat T for a system set at 76 in the afternoons and 2,200 CDD is found in Sample 4.

|  |  |
| --- | --- |
|  | Sample 4 |

Age Efficiency % is based on an equation that relates the age of a system to the average SEER numbers for a system of that age. Table 10 shows the age to SEER comparison.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Age of System | SEER CAC | SEER Pump | EER Window | Geothermal Heat Pump EER**[[17]](#footnote-17)** |
| **Base (Constant for calculation)** | 11.5 | 11.5 | 9.49 | 14.1 |
| **1 year** | 13 | 13 | 10.35 | 16.1 |
| **2-5 years** | 12.94 | 12.99 | 10.35 | 14.1 |
| **6-10 years** | 12.95 | 12.95 | 10.34 | 14.1 |
| **11-15 years** | 12.92 | 12.92 | 10.29 | 13 |
| **16-20 years** | 11.04 | 11.25 | 9.24 | 13 |
| **20+ years** | 7.67 | 7.14 | 6.54 | 13 |

**Table 10: SEER numbers for ages of cooling systems (EER for window units and Heat Pumps[[18]](#footnote-18))[[19]](#footnote-19)**

Since the first part of the overall energy equations were made under the assumption of base SEER numbers, we must find the consumption reduction percentage for that difference using Equation 5.

|  |  |
| --- | --- |
|  | Equation 5 |

If a home had a CAC system that was 8 years old, Equation 5 can be used, as seen in Sample 5.

|  |  |
| --- | --- |
|  | Sample 5 |

### Output(s)

Equation 1, Equation 2, and Equation 3 produce the average annual energy usage for Central Air or Heat Pumps, window units, and geothermal cooling systems, respectively. Equation 4 and Equation 5 explain the inputs that go into Equation 1, Equation 2, and Equation 3.

## Efficiency Gains & Consumption Reduction

Since SEER/EER are a measure of equipment efficiency, increases in SEER/EER of new equipment can provide projected cost savings given that all other factors(in home temperature, outdoor temperature, etc.) stay the same. This process needs to have the SEER or EER ratings for the current equipment within a home and the upgrade equipment.

|  |  |
| --- | --- |
|  | Equation 6 |
|  | Equation 7 |

So if a home was upgrading their Central Air Conditioning system from a 10 SEER system to a 13 SEER system, their consumption reduction would be 23%.

|  |  |
| --- | --- |
|  | Sample 6 |
|  | Sample 7 |

Below are some Consumption Reduction percentages based upon expected SEER & EER ratings for both central and room based systems.

|  |  |  |  |
| --- | --- | --- | --- |
| **Current**  **SEER** | **Upgraded**  **SEER** | **Efficiency**  **Gain** | **Consumption Reduction** |
| 9 SEER | 13 SEER | 144% | 31% |
| 9 SEER | 14 SEER | 156% | 36% |
| 9 SEER | 16 SEER | 178% | 44% |
| 9 SEER | 20 SEER | 222% | 55% |
| 10 SEER | 13 SEER | 130% | 23% |
| 10 SEER | 14 SEER | 140% | 29% |
| 10 SEER | 16 SEER | 160% | 38% |
| 10 SEER | 20 SEER | 200% | 50% |
| 13 SEER | 13 SEER | 100% | 0% |
| 13 SEER | 14 SEER | 108% | 7% |
| 13 SEER | 16 SEER | 123% | 19% |
| 13 SEER | 20 SEER | 154% | 35% |

Table 11: SEER Upgrade Consumption Reductions ratings for Air Source Heat Pumps and Central Air Conditioning Units

|  |  |  |  |
| --- | --- | --- | --- |
| **Current**  **SEER** | **Upgraded**  **SEER** | **Efficiency**  **Gain** | **Consumption Reduction** |
| 8 SEER | 11 SEER | 138% | 27% |
| 8 SEER | 12 SEER | 150% | 33% |
| 9 SEER | 11 SEER | 122% | 18% |
| 9 SEER | 12 SEER | 133% | 25% |

Table 12: SEER Upgrade Consumption Reductions ratings Room (Window) Air Conditioners

# Recommendations

There is a new ENERGY STAR specification regarding the Room (Window) Air Conditioners efficiency standard that is being revised. This specification will not be used in the calculations since it is expected to be effective in January 2013[[20]](#footnote-20).

1. DOE, “Final Rule” document, page 3 under rulemaking history. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/cac_finalrule.pdf> [↑](#footnote-ref-1)
2. DOE, “Residential Central Air Conditioners and Heat Pumps (CAC).” (For 2002 and 2006 standards)

   <http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html> [↑](#footnote-ref-2)
3. EIA, “Trends in Residential Air-Conditioning Usage from 1978 to 1997”, 2000. <http://www.eia.doe.gov/emeu/consumptionbriefs/recs/actrends/recs_ac_trends.html> [↑](#footnote-ref-3)
4. EERE, “Energy Conservation Program for Consumer Products; Conservation Standards for Room Air Conditioners; Final Rule”. Federal Register Vol. 62, No. 185 [Wednesday, September 24, 1997]. <http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/racrlbod.pdf> [↑](#footnote-ref-4)
5. ENERGY STAR, “Room Air Conditioners Key Product Criteria.” <http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac> [↑](#footnote-ref-5)
6. ENERGY STAR, “Room Air Conditioners Specification.” <http://www.energystar.gov/index.cfm?c=revisions.room_air_conditioners_spec> [↑](#footnote-ref-6)
7. ENERGY STAR, “Air-Source Heat Pumps and Central Air Conditioners Key Product Criteria.” <http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_crit_as_heat_pumps> [↑](#footnote-ref-7)
8. EIA, “Table HC2.6 Air Conditioning Characteristics by Type of Housing Unit, 2005”. RECS 2005. <http://www.eia.gov/emeu/recs/recs2005/hc2005_tables/hc6airconditioningchar/excel/tablehc2.6.xls> [↑](#footnote-ref-8)
9. ENERGY STAR, “Properly Sized Room Air Conditioners.” <http://www.energystar.gov/index.cfm?c=roomac.pr_properly_sized> [↑](#footnote-ref-9)
10. ENERGY STAR, “Qualified Air Conditioning, Central.” <http://www.energystar.gov/ia/products/prod_lists/cac_ashp_prod_list.pdf> [↑](#footnote-ref-10)
11. ENERGY STAR. “Qualified Air Conditioning, Room”. <http://downloads.energystar.gov/bi/qplist/Room%20Air%20Conditioners%20Product%20List.pdf> [↑](#footnote-ref-11)
12. EIA, “Residential Energy Consumption Survey.” <http://www.eia.gov/consumption/residential/> [↑](#footnote-ref-12)
13. Association of Home Appliance Manufacturers. “Trends in Energy Efficiency 2009”. U:\ Direct Options\ Energy Information\ Research Sources\ Association of Home Appliance Manufacturers (AHAM)\ Trends in Energy Efficiency 2009.pdf [↑](#footnote-ref-13)
14. EIA, “Residential Energy Consumption Survey.” <http://www.eia.gov/consumption/residential/> [↑](#footnote-ref-14)
15. EIA, “Residential Energy Consumption Survey.” <http://www.eia.gov/consumption/residential/> [↑](#footnote-ref-15)
16. Go Sustainable Energy, “Energy End-Use Breakdown – Temperature Set-forward Revisions.” [↑](#footnote-ref-16)
17. ENERGY STAR. ”Geothermal Heat Pumps Key Product Criteria.” <http://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps> [↑](#footnote-ref-17)
18. Oregon Institute of Technology. “Survival Kit for the Prospective Geothermal Heat Pump Owner.” <http://geoheat.oit.edu/ghp/survival.pdf> [↑](#footnote-ref-18)
19. Residential Energy Databook, shipswef.xls [↑](#footnote-ref-19)
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