CHAPTER 2. MARKET ASSESSMENT

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CHAPTER 2. MARKET ASSESSMENT

2.1 INTRODUCTION

This market assessment summarizes the market for those equipment classes for which American National Standards Institute (ANSI)/ American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)/Illuminating Engineering Society of North America (IESNA) Standard 90.1 (hereafter referred to as ASHRAE Standard 90.1-2010) increased its efficiency levels. This chapter describes each of the equipment classes affected by this rule, the existing standards that apply to any equipment classes, and breaks down each equipment classes by number of models on the market and efficiency distribution.

For the analysis, DOE only examined the equipment classes for which ASHRAE Standard 90.1-2010 increased its efficiency levels in comparison to the existing Federal standards that would apply: water-cooled and evaporatively-cooled air conditioner equipment classes with cooling capacities greater than or equal to 65,000 Btu/h, water-source VRF heat pumps with a cooling capacity <17,000 Btu/h, water-source VRF systems with a cooling capacity ≥135,000 Btu/h, and computer room air conditioners.

2.2 EQUIPMENT CLASSES

ASHRAE Standard 90.1-2010 contained increased efficiency levels for water-cooled and evaporatively-cooled commercial package air conditioners with a cooling capacity ≥65,000 Btu/h. ASHRAE Standard 90.1-2010 also created a new subclass of commercial package air-conditioning and heating equipment called variable refrigerant flow (VRF) multi-split systems and increased the efficiency levels for certain classes of water-source VRF heat pumps in comparison to the existing Federal standards that would apply. Lastly, ASHRAE Standard 90.1-2010 created a new equipment class for computer room air conditioners with new efficiency levels.

2.2.1 Water-cooled and Evaporatively-cooled Air Conditioners

Water-cooled and evaporatively-cooled air conditioners are part of a subset of commercial package air conditioning and heating equipment. EPCA defines a "commercial package air conditioning and heating equipment" as an "air-cooled, water-cooled, evaporatively-cooled, or water-source (not including ground water-source) electrically operated, unitary central air conditioners and central air conditioning heat pumps for commercial application." (42 U.S.C. 6311(8)(A))

Air conditioners use a refrigeration cycle to cool an indoor space by moving heat from the cold location to a hotter location by means of evaporating and condensing a fluid, typically a refrigerant. An air conditioner typically has four major components: a compressor, condensing coil, expansion valve, and an evaporator coil. The compressor turns the refrigerant from a low pressure gas into a high pressure gas and raises the temperature of the refrigerant. At the next step, the condensing coil convects the heat from the hot refrigerant, which condenses into a liquid, still at a high temperature and high pressure. This liquid refrigerant then goes through an expansion valve that lowers the refrigerant's pressure and temperature before entering the evaporator coil. The evaporator coil cools the indoor air by transferring heat from the warmer indoor air to the low temperature refrigerant.

Commercial-size water-cooled and evaporatively-cooled air conditioners cool commercial facilities and utilize water instead of ambient air (as is used in air-cooled equipment) to cool the condensing coil. In the case of a water-cooled air conditioner, the condensing coil is submerged in circulating water; whereas, in the case of evaporatively-cooled air conditioner, the condensing coil is sprayed with water that evaporates as air passes over the coil. Both systems utilize the high heat capacity of water to increase the heat transfer from the refrigerant in the condensing coil. Water-cooled air conditioners can be used effectively in any type of environment, while evaporatively-cooled air conditioners are most effective in hot-dry climate regions (*i.e.*, the southwestern United States).

DOE currently combines both water-cooled and evaporatively-cooled air conditioners into one equipment class with subclasses based on cooling capacity (<65,000 Btu/h; ≥65,000 Btu/h and <135,000 Btu/h; ≥135,000 Btu/h and <240,000 Btu/h; and ≥240,000 Btu/h and <760,000 Btu/h) and type of electric heating (electric/no heating or any other type of heating). In ASHRAE Standard 90.1-2010, ASHRAE specified different efficiency levels for water-cooled air conditioners and evaporatively-cooled air conditioners, while retaining the same cooling capacity ranges: <65,000 Btu/h, ≥65,000 and <135,000 Btu/h, ≥135,000 and <240,000 Btu/h, and ≥240,000 and <760,000 Btu/h.[1] ASHRAE Standard 90.1-2010 further divides each of these size categories based on whether the equipment has electric resistance/no heating or any other kind of heating. ASHRAE Standard 90.1-2010 increased the efficiency levels for all size categories except for those classes with a cooling capacity <65,000 Btu/h.

[1] ASHRAE Standard 90.1 does not specify an upper limit on the cooling capacity for the largest capacity equipment class (i.e., ≥240,000 Btu/h). However, EPCA limits the size of very large commercial package air conditioning and heating equipment to cooling capacities below 760,000 Btu/h.

2.2.2 Variable Refrigerant Flow Commercial Package Air Conditioning and Heating Equipment

Variable refrigerant flow systems are newly defined in ASHRAE 90.1-2010 and are also a subset of commercial package air conditioning and heating equipment, defined above. VRF systems are most commonly used in hotels, schools, and office buildings where different zones have different heating and cooling load requirements depending on occupancy and time of day. VRF systems typically have one outdoor condensing unit that is connected to multiple indoor evaporator coils, as opposed to the single indoor evaporator coil typically found in conventional air conditioners and heat pumps. Each evaporator coil in a VRF system can be individually controlled, and VRF systems are capable of monitoring and adjusting the refrigerant flow to each evaporator to meet the requirements of heating and cooling loads in specific zones. Some VRF heat pumps have a heat recovery option, which allows the system to move heat between zones within a building via a third refrigerant line that connects indoor evaporator coils. The heat recovery feature allows a zone requiring heat to be warmed using the heat extracted from a zone requiring cooling, and vice versa. However, if all zones need to be heated at the same time, then the heat would need to be provided by other means (*e.g.* the reverse refrigeration cycle).

Water-source VRF systems utilize a condensing unit that transfers heat to or from circulating water depending on whether the system is in cooling or heating mode. These systems allow the condensing unit of the system to be placed indoors, such as in a mechanical closet or a basement. Having the condensing unit indoors decreases the amount of refrigerant piping to the individual evaporator coils, which is especially useful for equipment installed in high rise office buildings.

Neither EPCA nor DOE’s regulations in the Code of Federal Regulations (CFR) define variable refrigerant flow systems. ASHRAE Standard 90.1-2010 defines a variable refrigerant flow system as:

> “an engineered direct expansion (DX) multi-split system incorporating at least one variable capacity compressor distributing refrigerant through a piping network to multiple indoor fan coil units each capable of individual zone temperature control, through integral zone temperature control devices and common communications network. Variable refrigerant flow utilizes three or more steps of control on common, interconnecting piping.”

AHRI Standard 1230-2010, the ASHRAE Standard 90.1-2010 test procedure for this equipment, uses the term “variable refrigerant flow multi-split system” and defines it as:

> “a split system air-conditioner or heat pump incorporating a single refrigerant circuit, with one or more outdoor units, at least one variable speed compressor or an alternative compressor combination for varying the capacity of the system by three or more steps, multiple indoor fan

coils units, each of which is individually metered and individually controlled by a proprietary control device and common communications network. The system shall be capable of operating as an air conditioner or a heat pump. Variable refrigerant flow implies three or more steps of control on common, inter-connecting piping."

AHRI Standard 1230 and ASHRAE Standard 90.1-2010 use the term "multi-split" for VRF systems because they have multiple indoor units controlled by separate thermostats, as distinct from "mini split" systems, the indoor units of which can only be controlled by one thermostat. Since DOE believes that it is important to distinguish VRF systems as multi-split systems, DOE is adopting definitions for this equipment class based on the definitions above and defines "variable refrigerant flow multi-split air conditioner" and "variable refrigerant flow multi-split heat pump" in section III.F of the final rule. The definitions DOE adopted clearly delineate VRF air conditioners and heat pumps as a sub-category of commercial package air conditioning and heating equipment and are structured in such a way to ensure that there are no overlaps with any other covered equipment class. The definition also incorporates all of the unique features of this equipment, such as the individually-controlled indoor units and an integral control device for monitoring the system. There is also a subcategory of VRF heat pumps that have "heat recovery," which DOE also defines in section III.F of the final rule.

ASHRAE Standard 90.1-2010 also created new equipment classes for VRF systems. ASHRAE divides air-cooled VRF systems into 4 size categories: <65,000 Btu/h, ≥65,000 and <135,000 Btu/h, ≥135,000 and <240,000 Btu/h, and ≥240,000 and < 760,000 Btu/h.[1] ASHRAE 90.1-2010 also divides water-source VRF heat pumps into 3 size categories, <65,000 Btu/h, ≥65,000 and <135,000 Btu/h, and ≥135,000 and <760,000 Btu/h.[1] ASHRAE also further divides the size categories for VRF heat pumps based on whether or not a heat recovery system is present. ASHRAE Standard 90.1-2010 raised the efficiency level above the Federal standard for water-source VRF heat pumps with a cooling capacity <17,000 Btu/h and water-source VRF heat pumps with a cooling capacity ≥135,000 Btu/h (for which no Federal standard exists).

2.2.3 Computer Room Air Conditioners

"Air conditioners and condensing units serving computer rooms" is a new equipment class established in ASHRAE Standard 90.1-2010. ASHRAE Standard 90.1-2010 modified its scope to cover air conditioning equipment used for industrial and process cooling and specified the efficiency metric for this equipment class as sensible coefficient of performance (SCOP) as measured by ASHRAE 127-2007, *Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners*. Because of this expansion of scope, DOE concluded that it has the authority to regulate and set standards for this equipment. Thus, DOE must define computer room air conditioners so that this equipment class is clearly differentiated from other commercial packaged air conditioners and heat pumps used for comfort cooling. ASHRAE Standard 90.1-

2010 does not contain a definition for "air conditioners and condensing units serving computer rooms," but does define a "computer room" as:

> "a room whose primary function is to house equipment for the processing and storage of electronic data and that had a design electronic data equipment power density exceeding 20 watts/ft^2 of conditioned floor area."

ASHRAE Standard 127-2007 defines a "computer and data processing room (CDPR) unitary air conditioner" as a system:

> "consisting of one or more factory-made assemblies, which include a direct expansion evaporator or chilled-water cooling coil, an air-moving device, and air-filtering devices. The air conditioner may include a compressor, condenser, humidifier, or reheating function. Where direct expansion equipment is provided in more than one assembly and the separate assemblies are to be used together, the requirements of rating outlined in this standard are based upon the use of matched assemblies. The functions of a CDPR air conditioner, either alone or in combination with a cooling and heating plant, are to provide air filtration, circulation, cooling, reheating, and humidity control."

Neither of these definitions gives any unique physical characteristics that would always differentiate computer room air conditioners from other commercial packaged unitary air conditioners.

Computer room air conditioners operate in the same manner as other commercial packaged unitary air conditioners in that they provide space conditioning by means of a direct expansion system. However, cooling computer rooms, server rooms, and data centers present unique challenges because these areas contain valuable equipment that are sensitive to small changes in temperature and humidity. Too much humidity can lead to water condensing on electronic components, and too little humidity may cause static discharges. Computer equipment are also continuously producing dynamic, high density heating loads; thus, the air conditioning equipment needs to be running constantly and needs to be able to cool any "hot spots" within the computer room. Server rooms and data centers are typically located in the center of buildings away from windows and often have limited floor space, which limits the size and positioning of the air conditioner and causes design issues related to removing the heat from the computer room.

Because of these challenges, computer room air conditioners have different design requirements than standard air conditioners, even though they use the same process and components as conventional air conditioners (*i.e.*, a refrigeration cycle with a compressor, condensing coil, expansion valve, and evaporator coil). Computer room air conditioners have to maintain the temperature in a narrow range and maintain a specific relative humidity (usually between 40 and 55 percent); so in addition to cooling, these equipment are usually capable of both humidifying and dehumidifying the air. These air conditioners are often called "precision air conditioners" because of this control requirement. These units can be installed in various configurations, including floor mounted, ceiling mounted, or portable units for moving around the room. The condensing units can be cooled by air, water, or a glycol-water mixture. However, even though humidity control is an essential feature for conditioning computer rooms, humidity control is typically an optional feature for computer room air conditioners since most of the system is custom built for a specific application. Some data centers could have a separate system of humidifiers and dehumidifiers for controlling the humidity in the room.

Because DOE is not aware of any physical features unique to computer room air conditioners and because computer room air conditioners are typically described by their application, DOE is adopting a definition for computer room air conditioners based on the application of the equipment and which test standard and metric are used to rate its performance. In the final rule DOE defined a "computer room air conditioner" as:

> "a basic model of commercial package air-conditioning and heating equipment (packaged or split) that is: (1) used in computer rooms, data processing rooms, or other information technology cooling applications; (2) rated for sensible coefficient of performance (SCOP) and tested in accordance with 10 CFR 431.96, and (3) is not a covered consumer product under 42 U.S.C. 6291(1)-(2) and 6292. A computer room air conditioner may be provided with, or have as available options, an integrated humidifier, temperature, and/or humidity control of the supplied air, and reheating function."

ASHRAE first divides air conditioners and condensing units serving computer rooms into 5 classes depending on cooling mechanism: air-cooled, water-cooled, water-cooled with a fluid economizer, glycol-cooled (rated at 40% propylene glycol), and glycol-cooled with a fluid economizer. ASHRAE further divides these classes into 3 size categories based on <u>sensible</u> cooling capacity (<65,000 Btu/h, ≥65,000 and <240,000 Btu/h, and ≥240,000 Btu/h and <760,000 Btu/h) and orientation categories (upflow and downflow) to make up a total of 30 unique efficiency levels for this equipment class. ASHRAE Standard 90.1-2010 uses sensible cooling capacity as opposed to total cooling capacity because computer rooms typically only produce sensible heat, which causes a change in a room's dry-bulb temperature. DOE adopted these classifications in the final rule.

2.3 EXISTING STANDARDS

2.3.1 Current Federal Energy Conservation Standards

On January 12, 2001, DOE published in the *Federal Register* a final rule promulgating the current standards for 5 equipment classes of small (*i.e.*, cooling capacity <135,000 Btu/h) and large (*i.e.*, cooling capacity ≥135,000 Btu/h and <240,000 Btu/h) water-cooled and evaporatively-cooled air conditioners. 66 FR 3336. This final rule adopted the efficiency levels set by ASHRAE Standard 90.1-1999. On July 22, 2009, DOE published in the *Federal Register* a final rule setting the standards for very large water-cooled and evaporatively-cooled equipment with a cooling capacity ≥240,000 and <760,000 Btu/h. 74 FR 36312. In the July 2009 final rule, DOE adopted the efficiency levels for these products as specified in ASHRAE Standard 90.1-2007.

As noted previously, VRF systems are new classes of equipment in ASHRAE Standard 90.1-2010. However, these equipment classes are currently covered by DOE under the more broad Federal equipment classes of commercial package air conditioning and heating equipment. ASHRAE Standard 90.1-2010 generally set the efficiency levels for all classes of VRF systems equal to the existing Federal energy conservation standards for commercial package air conditioning and heating equipment, except for the equipment class of water-source VRF heat pumps with a cooling capacity <17,000 Btu/h. Therefore, with the exception of water-source VRF heat pumps with a cooling capacity <17,000 Btu/h, DOE was not required to perform an analysis of those equipment classes. In addition, ASHRAE Standard 90.1-2010 includes efficiency levels for water-source VRF heat pumps with cooling capacity ≥135,000 Btu/h, which are not currently regulated by Federal energy conservation standards. Thus, DOE performed an analysis for that equipment class in this rulemaking. The current Federal energy conservation standard for water-source heat pumps with a cooling capacity <135,000 Btu/h was set by the January 2001 final rule, which adopted the ASHRAE Standard 90.1-1999 levels. 66 FR 3336. The Energy Policy Act of 2005 (EPACT 2005) set the current Federal standard for the remaining classes of commercial package air conditioners and heating equipment with the exception of air-cooled heat pumps with a cooling capacity less than 65,000 Btu/h, which were included in EISA 2007.

Table 2.1.1 shows the current Federal energy conservation levels for equipment classes where ASHRAE Standard 90.1-2010 increased the efficiency levels in comparison to the Federal levels. Note that computer room air conditioners are not included in this table since they were not previously covered by DOE and water-cooled and evaporatively-cooled air conditioners were combined into their own separate equipment class.

Table 2.1.1 Current Federal Energy Conservation Standards for Commercial Package Air Conditioning and Heating Equipment Classes with Increased Efficiency Levels in ASHRAE Standard 90.1-2010

Equipment Type	Cooling Capacity	Subcategory	Federal Standard
Small Commercial Package Air Conditioning Equipment, Water-cooled and Evaporatively-cooled	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance or no heating	11.5 EER
		All other	11.3 EER
Large Commercial Package Air Conditioning and Heating Equipment, Water-cooled and Evaporatively-cooled	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance or no heating	11.0 EER
		All other	11.0 EER
Very Large Commercial Package Air Conditioning and Heating Equipment, Water-cooled and Evaporatively-cooled	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance or no heating	11.0 EER
		All other	10.8 EER
Small Commercial Package Air Conditioning and Heating Equipment, Water-source*	<17,000 Btu/h	HP	11.2 EER 4.2 COP
Large Commercial Package Air Conditioning and Heating Equipment, Water-source*	≥135,000 Btu/h	HP	None

* This equipment class includes VRF systems, for which ASHRAE Standard 90.1-2010 updated its standard levels.

2.3.2 ASHRAE Standard 90.1-2010 Equipment Classes and Efficiency Levels

The previous version of ASHRAE Standard 90.1 (ASHRAE Standard 90.1-2007) specified the efficiency levels for water-cooled and evaporatively-cooled air conditioners as a single equipment class including both types of equipment. ASHRAE Standard 90.1-2010 splits water-cooled and evaporatively-cooled air conditioners into two equipment classes. ASHRAE Standard 90.1-2010 also introduced a new equipment class for VRF systems and for computer room air conditioners.

Table 2.1.2 below shows the ASHRAE Standard 90.1-2010 efficiency level for the updated equipment classes along with the currently applicable Federal minimum efficiency standards for comparison. In summary, ASHRAE Standard 90.1-2010 raised the efficiency level in comparison to the current Federal minimum energy conservation standards for six water-cooled air conditioner equipment classes, six evaporatively-cooled air conditioner equipment classes, and one water-source VRF heat pump equipment classes. In addition, ASHRAE Standard 90.1-2010 created new efficiency levels for one water-source VRF heat pump equipment class and for thirty classes of air conditioners serving computer rooms that were not previously covered by DOE's regulations. DOE assessed the current market and performed a potential energy savings analysis for each equipment class where DOE found models on the market. The market assessment is described in the next section.

Table 2.1.2 Updated ASHRAE Standard 90.1-2010 Efficiency Levels in Comparison to the Current Federal Minimum Conservation Standards

ASHRAE Equipment Type	Cooling Capacity	Subcategories		Federal Minimum Energy Conservation Standards	ASHRAE Standard 90.1-2010
Water-cooled Air Conditioner	≥65,000 and <135,000Btu/h	Electric Resistance or No Heating	Split System and Single Package	11.5 EER	12.1 EER (as of 6/1/11)
		All Others	Split System and Single Package	11.3 EER	11.9 EER (as of 6/1/11)
	≥135,000 and <240,000Btu/h	Electric Resistance or No Heating	Split System and Single Package	11.0 EER	12.5 EER (as of 6/1/11)
		All Others	Split System and Single Package		12.3 EER (as of 6/1/11)
	≥240,000 and <760,000Btu/h	Electric Resistance or No Heating	Split System and Single Package	11.0 EER	12.4 EER (as of 6/1/11)
		All Others	Split System and Single Package	10.8 EER	12.2 EER (as of 6/1/11)
Evaporatively-cooled Air Conditioner	≥65,000 and <135,000Btu/h	Electric Resistance or No Heating	Split System and Single Package	11.5 EER	12.1 EER (as of 6/1/11)
		All Others	Split System and Single Package	11.3 EER	11.9 EER (as of 6/1/11)
	≥135,000 and <240,000Btu/h	Electric Resistance or No Heating	Split System and Single Package	11.0 EER	12.0 EER (as of 6/1/11)
		All Others	Split System and Single Package		11.8 EER (as of 6/1/11)
	≥240,000 and <760,000Btu/h	Electric Resistance or No Heating	Split System and Single Package	11.0 EER	11.9 EER (as of 6/1/11)
		All Others	Split System and Single Package	10.8 EER	12.2 EER * (as of 6/1/11)

ASHRAE Equipment Type	Cooling Capacity	Subcategories		Federal Minimum Energy Conservation Standards	ASHRAE Standard 90.1-2010
Variable Refrigerant Flow, Water-source	<17,000 Btu/h	All heating types	Multi-split system	11.2 EER 4.2 COP	12.0 EER 4.2 COP
			Multi-split system with Heat Recovery	11.2 EER 4.2 COP	11.8 EER 4.2 COP
	≥135,000 Btu/h	All heating types	Multi-split system	None	10.0 EER 3.9 COP
			Multi-split system with Heat Recovery		9.8 EER 3.9 COP
Air Conditioners Serving Computer Rooms, Air-cooled	<65,000 Btu/h	-	Downflow	None	2.20 SCOP
			Upflow		2.09 SCOP
	≥65,000 Btu/h and <240,000 Btu/h	-	Downflow		2.10 SCOP
			Upflow		1.99 SCOP
	≥240,000 Btu/h and <760,000 Btu/h	-	Downflow		1.90 SCOP
			Upflow		1.79 SCOP
Air Conditioners Serving Computer Rooms, Water-cooled	<65,000 Btu/h	-	Downflow	None	2.60 SCOP
			Upflow		2.49 SCOP
	≥65,000 Btu/h and <240,000 Btu/h	-	Downflow		2.50 SCOP
			Upflow		2.39 SCOP
	≥240,000 Btu/h and <760,000 Btu/h	-	Downflow		2.40 SCOP
			Upflow		2.29 SCOP
Air Conditioners Serving Computer Rooms, Water-cooled with Fluid Economizer	<65,000 Btu/h	-	Downflow	None	2.55 SCOP
			Upflow		2.44 SCOP
	≥65,000 Btu/h and <240,000 Btu/h	-	Downflow		2.45 SCOP
			Upflow		2.34 SCOP
	≥240,000 Btu/h and <760,000 Btu/h	-	Downflow		2.35 SCOP
			Upflow		2.24 SCOP
Air Conditioners Serving Computer Rooms, Glycol-cooled	<65,000 Btu/h	-	Downflow	None	2.50 SCOP
			Upflow		2.39 SCOP
	≥65,000 Btu/h and <240,000 Btu/h	-	Downflow		2.15 SCOP
			Upflow		2.04 SCOP
	≥240,000 Btu/h and <760,000 Btu/h	-	Downflow		2.10 SCOP
			Upflow		1.99 SCOP
Air Conditioners Serving Computer Rooms, Glycol-cooled with Fluid Economizer	<65,000 Btu/h	-	Downflow	None	2.45 SCOP
			Upflow		2.34 SCOP
	≥65,000 Btu/h and <240,000 Btu/h	-	Downflow		2.10 SCOP
			Upflow		1.99 SCOP
	≥240,000 Btu/h and <760,000 Btu/h	-	Downflow		2.05 SCOP
			Upflow		1.94 SCOP

*Given the historical approach of the ASHRAE committee to setting efficiency levels with for commercial air conditioning and heating equipment, this efficiency level appears to be a mistake in ASHRAE Standard 90.1-2010. DOE believes the intended level is 11.7 EER, and an addendum to lower the value to 11.7 EER is currently being considered by ASHRAE. Accordingly, DOE considered the value 11.7 EER as the ASHRAE Standard 90.1-2010 efficiency level in its potential energy savings analysis.

2.4 MARKET ASSESSMENT

The following market assessment identifies the manufacturer trade associations and domestic and international manufacturers of commercial water-cooled and evaporatively-cooled air conditioners, water-source VRF heat pumps, and computer room air conditioners. The market assessment also summarizes the relevant market performance data for each equipment class where such data was available.

2.4.1 Trade Associations

DOE researched various trade groups who represent manufacturers, distributors, and installers of the various types of equipment being analyzed this rulemaking. The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) is one of the largest trade associations for manufacturers of space heating and cooling equipment, representing over 90% of the residential and commercial air-conditioning, space-heating, water-heating, and commercial refrigeration equipment manufactured in the US.[1] AHRI also develops and publishes test standards for residential and commercial heating, ventilation, and air conditioning (HVAC) equipment and coordinates with the International Organization for Standardization (ISO) to help harmonize the US standards with international standards, if feasible. AHRI also maintains the AHRI Directory of Certified Product Performance that lists all the products and equipment that have been certified by AHRI. Water-cooled air conditioners can be found in the commercial unitary large equipment directory, and VRF systems can be found in the VRF multi-split air conditioning and heat pump equipment directory. There are no evaporatively-cooled air conditioners or computer room air conditioners listed in the AHRI directory. However, AHRI has commented that they are in the process of creating a Datacom Cooling Section to cover computer room air conditioners.

Heating, Airconditioning & Refrigeration Distributors International (HARDI) is a trade association that represents over 450 distributor members representing nearly 3,400 branch locations and close to 500 suppliers, manufacturer representatives, and service vendors.[2] Air Conditioning Contractors of America (ACCA) is another trade association whose members include over 4,000 businesses and 60,000 professionals. ACCA provides contractors technical, legal, and market resources.[3]

2.4.2 Manufacturers

DOE obtained the efficiency data for water-cooled and evaporatively-cooled air conditioners currently on the market by examining the AHRI Directory of Certified Product Performance[4] and the California Energy Commission (CEC) Appliance Efficiency Database.[5] To supplement the data in the AHRI and CEC databases, DOE gathered additional information from the websites of individual manufacturers of that equipment. For water-source VRF heat pumsp, DOE used the AHRI Directory of Certified Product Performance for VRF systems and gathered data from manufacturers' websites for this equipment. DOE gathered data on computer room air conditioners from the CEC database and from manufacturers' websites.

DOE identified eight manufacturers of water-cooled air conditioners, three manufacturers of evaporatively-cooled air conditioners, three manufactures of water-source variable refrigerant flow heat pumps, and five manufacturers of computer room air conditioners. The manufacturers for each equipment class are listed in Table 2.2.1 with their parent companies, if applicable, in parentheses.

Table 2.2.1 Manufacturers of the Commercial Equipment Included in this Rulemaking

Water-Cooled Air Conditioner Manufacturers	Evaporatively-Cooled Air Conditioner Manufacturers	Water-Source Variable Refrigerant Flow System Manufacturers	Computer Room Air Conditioners
Aaon, Inc.	Aaon, Inc.	Daikin	American Power Conversion
Allied Thermal Systems	Trane Inc. (Ingersoll Rand)	LG Electronics U.S.A., Inc.	CompuAire
Carrier Corp. (United Technologies Corporation)	York International Corp. (Johnson Controls, Inc.)	Mitsubishi Electric & Electronics USA, Inc.	Data Aire, Inc.
Lennox International, Inc.			Liebert (Emerson Network Power)
Engineered Air			Stulz Air Technology Systems
Thermoplus Air, Inc.			
Trane Inc. (Ingersoll Rand)			
York International Corp. (Johnson Controls, Inc.)			

2.4.3 Market Performance Data

For each equipment class analyzed, DOE began by gathering market data to characterize the efficiency and performance of models currently on the market. As noted earlier, DOE gathered information from the AHRI Directory of Certified Product Performance, as well as the CEC Appliance Efficiency Database. DOE also examined individual manufacturer's websites and product literature to compile a complete database of models for each equipment class.

2.4.3.1 Water-Cooled Air Conditioners

Using the AHRI and CEC directories as a starting point and augmenting the data with information from manufacturer websites, DOE compiled a database of water-cooled air conditioner models with efficiency data available and separated them into the appropriate size category classes. The subsections below describe the market DOE found for water-cooled air conditioners.

***Small (≥65,000 Btu/h and <135,000 Btu/h) Water-cooled Air Conditioners*.** Small water-cooled air conditioners have a cooling capacity greater than or equal to 65,000 Btu/h and less than 135,000 Btu/h and have their condensing coil completely submerged in water. Small water-cooled air conditioners are part of the water-cooled and evaporatively-cooled air conditioners equipment class, whose Federal energy conservation standard is 11.5 EER for systems with electric resistance or no heating and 11.3 EER for systems that use any other type of heating (66 FR 3336; 10 CFR 431.97). ASHRAE Standard 90.1-2010 changed the efficiency rating to 12.1 for systems with electric resistance or no heating and 11.9 for systems that use any other type of heating. DOE analyzed the distribution of energy efficiency ratios (EERs) for these products as well as the minimum, maximum, and average cooling input capacities and EER values. The average EER value for this equipment class is 13.9. Of the 16 models identified by DOE, three currently have EERs rated below the ASHRAE Standard 90.1-2010 levels. DOE performed a potential energy savings analysis in the NODA for this equipment class.

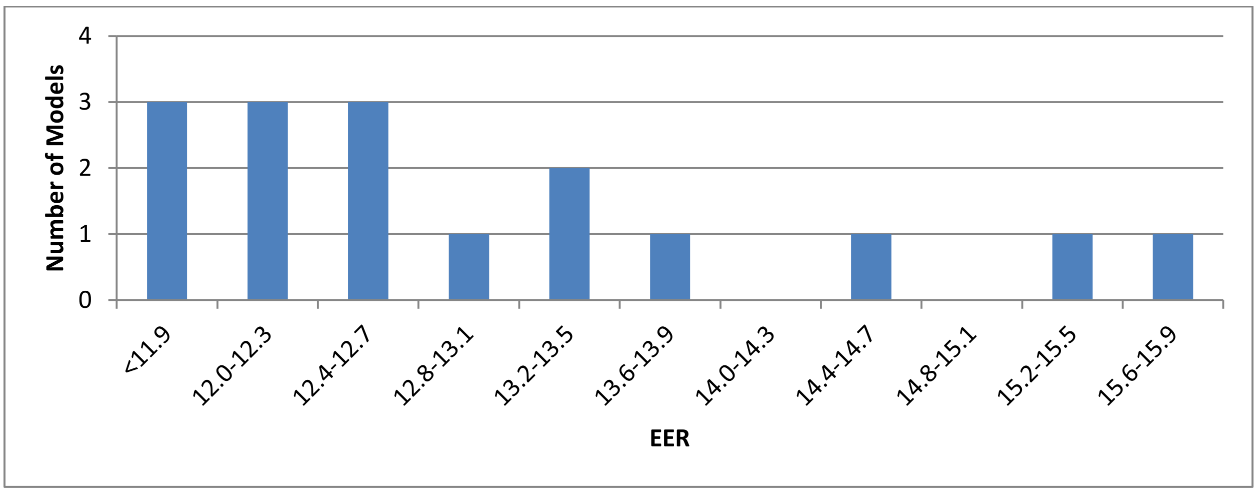

Figure 2.2.1 EER Histogram of Small Water-cooled Air Conditioners

***Large Water-cooled Air Conditioners*.** Large water-cooled air conditioners have a cooling capacity greater than or equal to 135,000 Btu/h and less than 240,000 Btu/h and have their condensing coil completely submerged in water. Large water-cooled air conditioners are part of the water-cooled and evaporatively-cooled air conditioners equipment class, whose Federal energy conservation standard is 11.0 EER regardless of what kind of heating is used (66 FR 3336; 10 CFR 431.97). ASHRAE Standard 90.1-2010 changes the efficiency rating to 12.5 for systems with electric resistance or no heating and 12.3 for systems that use any other type of heating. DOE analyzed the distribution of efficiencies for these products. The average EER for these units was 13.0. DOE identified 6 models (43 percent of the total models in this equipment class) that would fall below the ASHRAE Standard 90.1-2010 levels for this equipment class. DOE performed a potential energy savings analysis in the NODA for this equipment class.

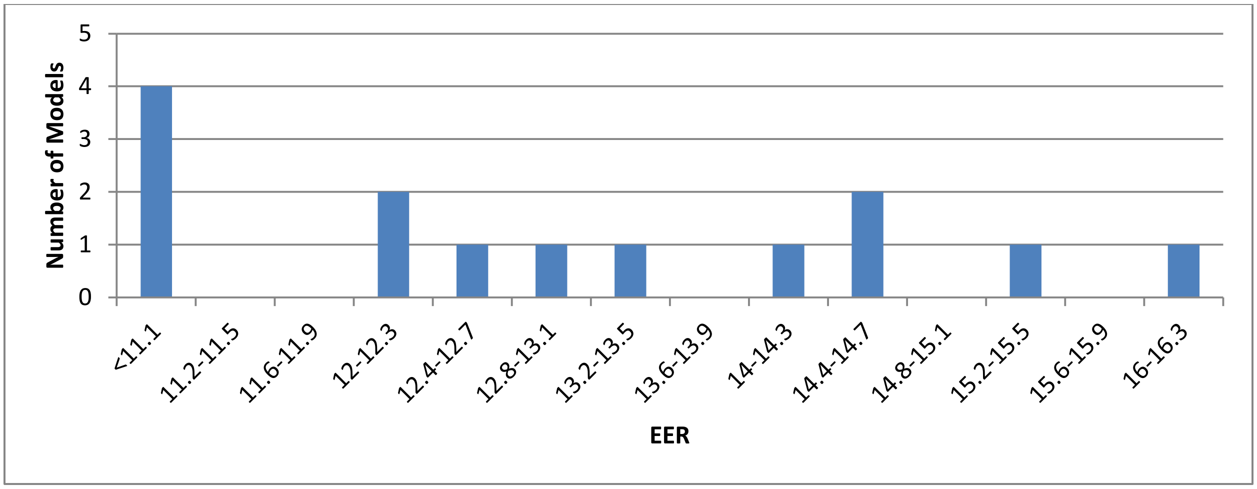

Figure 2.2.2 EER Histogram of Large Water-cooled Air Conditioners

Very Large Water-cooled Air Conditioners. Very large water-cooled air conditioners have a cooling capacity greater than or equal to 240,000 Btu/h and less than 760,000 Btu/h, and have their condensing coil completely submerged in water. Very large water-cooled air conditioners are part of the water-cooled and evaporatively-cooled air conditioners equipment class, whose Federal energy conservation standard is 11.0 EER for units with electric resistance or no heating and 10.8 for units with all other kinds of heating (74 FR 36312; 10 CFR 431.97). ASHRAE Standard 90.1-2010 changes the efficiency rating to 12.5 for systems with electric resistance or no heating and 12.3 for systems that use any other type of heating. DOE analyzed the distribution of efficiencies for these products. The average EER rating for these units is 13.0. DOE identified 6 models (20 percent of the total models identified) that would fall below the ASHRAE Standard 90.1-2010 efficiency level for this equipment class. DOE performed a potential energy savings analysis in the NODA for this equipment class.

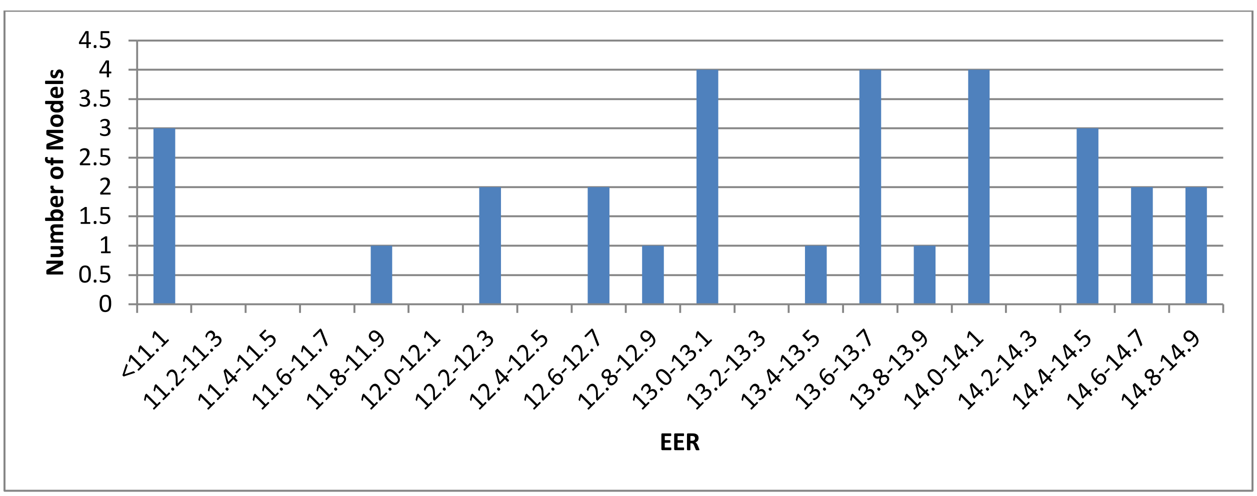

Figure 2.2.3 EER Histogram of Very Large Water-cooled Air Conditioners

2.4.3.2 Evaporatively-Cooled Air Conditioners

DOE found no evaporatively-cooled air conditioners in the AHRI and CEC directories but found a few evaporatively-cooled air conditioners on manufacturers' websites. DOE compiled a database of evaporatively-cooled air conditioner models with efficiency data available and separated them into the appropriate size category classes.

Small (≥65,000 Btu/h and <135,000 Btu/h) Evaporatively-cooled Air Conditioners. Small evaporatively-cooled air conditioners have a cooling capacity greater than or equal to 65,000 Btu/h and less than 135,000 Btu/h. Small evaporatively-cooled air conditioners are covered as part of the water-cooled and evaporatively-cooled air conditioners equipment class, whose Federal energy conservation standard is 11.5 EER for systems with electric resistance or no heating and 11.3 EER for systems that use any other type of heating (66 FR 3336; 10 CFR 431.97). ASHRAE Standard 90.1-2010 changes the efficiency rating to 12.1 EER for systems with electric resistance or no heating and 11.9 EER for systems that use any other type of heating. DOE surveyed the AHRI database and manufacturers' websites to find small evaporatively-cooled air conditioners with cooling capacities greater than or equal to 65,000 Btu/h and less than 135,000 Btu/h and did not find any on the market. Therefore, DOE did not perform a potential energy savings analysis in this rulemaking.

Large Evaporatively-cooled Air Conditioners. Large evaporatively-cooled air conditioners have a cooling capacity greater than or equal to 135,000 Btu/h and less than 240,000 Btu/h. Large evaporatively-cooled air conditioners are covered as part of the water-cooled and evaporatively-cooled air conditioners equipment class, whose Federal energy conservation standard is 11.0 EER regardless of what type of heating is used (66 FR 3336; 10 CFR 431.97). ASHRAE Standard 90.1-2010 changes the efficiency rating to 12.0 EER for systems with electric resistance or no heating and 11.8 EER for systems that use any other type of heating. DOE surveyed the AHRI database and manufacturers' websites to find large evaporatively-cooled air conditioners with cooling capacities greater than or equal to 135,000 Btu/h and less than 240,000 Btu/h and did not find any on the market. Therefore, DOE did not perform a potential energy savings analysis in this rulemaking.

Very Large Evaporatively-cooled Air Conditioners. Very large evaporatively-cooled air conditioners have an input capacity greater than or equal to 240,000 Btu/h and less than 760,000 Btu/h. Very large evaporatively-cooled air conditioners are covered as part of the water-cooled and evaporatively-cooled air conditioners equipment class, whose Federal energy conservation standard is 11.0 EER for systems with electric resistance or no heating and 10.8 EER for systems that use any other type of heating (74 FR 36312; 10 CFR 431.97). ASHRAE Standard 90.1-2010 changes the efficiency rating to 12.0 EER for systems with electric resistance or no heating and 11.8 EER for systems that use any other type of heating. During the market research, DOE identified several models from manufacturers that would be classified as very large evaporatively-cooled air conditioners. However, the efficiency rating for these models was not readily available, and DOE was unable to obtain it. DOE did perform a potential energy savings analysis in the NODA for the very large evaporatively-cooled air conditioners.

2.4.3.3 Variable Refrigerant Flow Water-source Heat Pumps

For the NODA, DOE used manufacturers' websites to compile a database of water-source VRF heat pumps with a cooling capacity <17,000 Btu/h and water-source VRF heat pumps with a cooling capacity ≥135,000 Btu/h. However, after the NODA was published, AHRI released a VRF multi-split air conditioning and heat pump database on September 16, 2011, as part of AHRI's Directory of Certified Product Performance. Thus, for the market assessment DOE used the AHRI database published on September 16 and supplemented that database with models found from manufacturer's websites that were not in the AHRI database.

Water-source VRF Heat Pumps with a Cooling Capacity less than 17,000 Btu/h. Water-source VRF heat pumps with a cooling capacity less than 17,000 Btu/h are covered as part of the small commercial package air conditioning and heating equipment class, which has a Federal energy conservation standard of 11.2 EER and 4.2 COP. ASHRAE Standard 90.1-2010 changed the efficiency rating for water-source VRF systems with a cooling capacity less than 17,000 Btu/h to 12.0 EER and 4.2 COP for those systems with no heat recovery technology and to 11.8 EER and 4.2 COP for those systems with heat recovery technology. DOE surveyed the AHRI database and VRF manufacturers' websites to find VRF water-source heat pumps with cooling capacities below 17,000 Btu/h and did not find any on the market. Therefore, DOE did not perform a potential energy savings analysis for this equipment class.

Water-source VRF Heat Pumps with a Cooling Capacity Greater than or Equal to 135,000 Btu/h. Water-source VRF heat pumps with a cooling capacity greater than or equal to 135,000 Btu/h currently do not have a Federal energy conservation standard. ASHRAE Standard 90.1-2010 set new efficiency levels for those systems with a cooling capacity greater than or equal to 135,000 Btu/h at 10.0 EER and 3.9 COP for systems without heat recovery devices and 9.8 EER and 3.9 COP for systems with heat recovery devices. From the AHRI directory published on September 16, 2011, and manufacturers' websites, DOE found 106 models with no heat recovery option and 58 models with a heat recovery add-on for a total of 164 unique units. The AHRI directory gave EER information as tested by AHRI 1230-2010: *Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment*, which is the test procedure as listed in ASHRAE Standard 90.1-2010 for this equipment. However, manufacturers' websites did not release any EER data as tested by AHRI 1230-2010, so DOE used only the models in the AHRI directory (published on September 16, 2011) for EER information (a total of 98 units). For water-source VRF heat pumps with a cooling capacity greater than or equal to 135,000 Btu/h, the average EER/COP is 11.3 for units without a heat recovery system and 11.4 for units with a heat recovery system. A histogram of EER for this equipment class is shown in Figure 2.2.4 and Figure 2.2.5. DOE did perform a potential energy savings analysis in the NODA for this equipment class. However, since the potential energy savings was minimal for this equipment class, DOE did not conduct any additional energy savings or economic analyses for this equipment class.

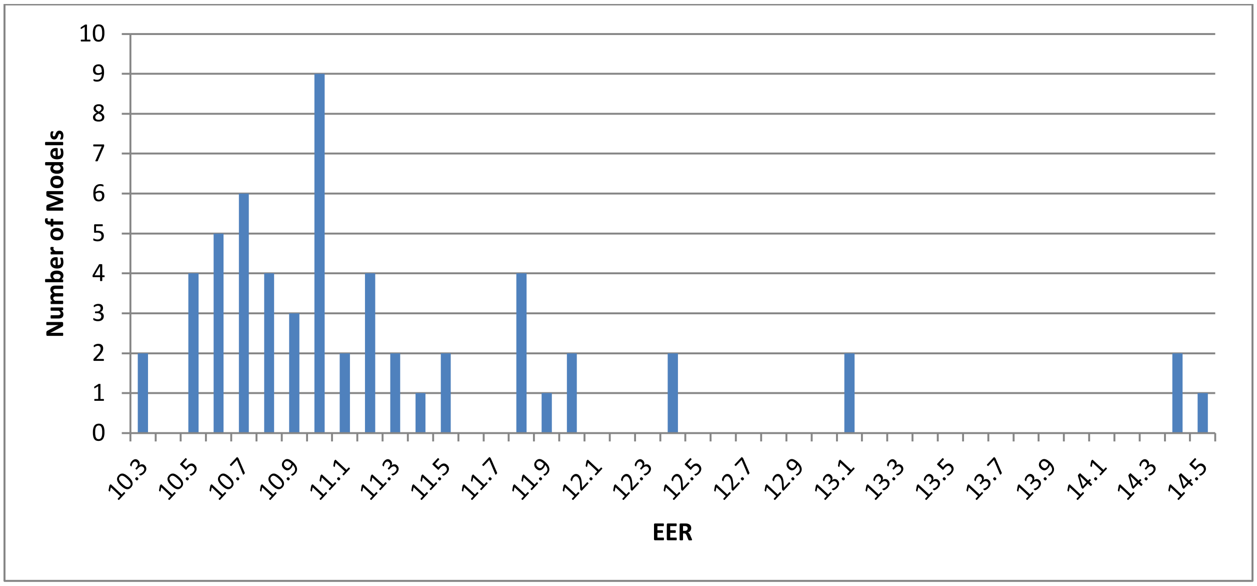

Figure 2.2.4 Histogram of Water-Source VRF Systems (≥135,000 Btu/h) with No Heat Recovery

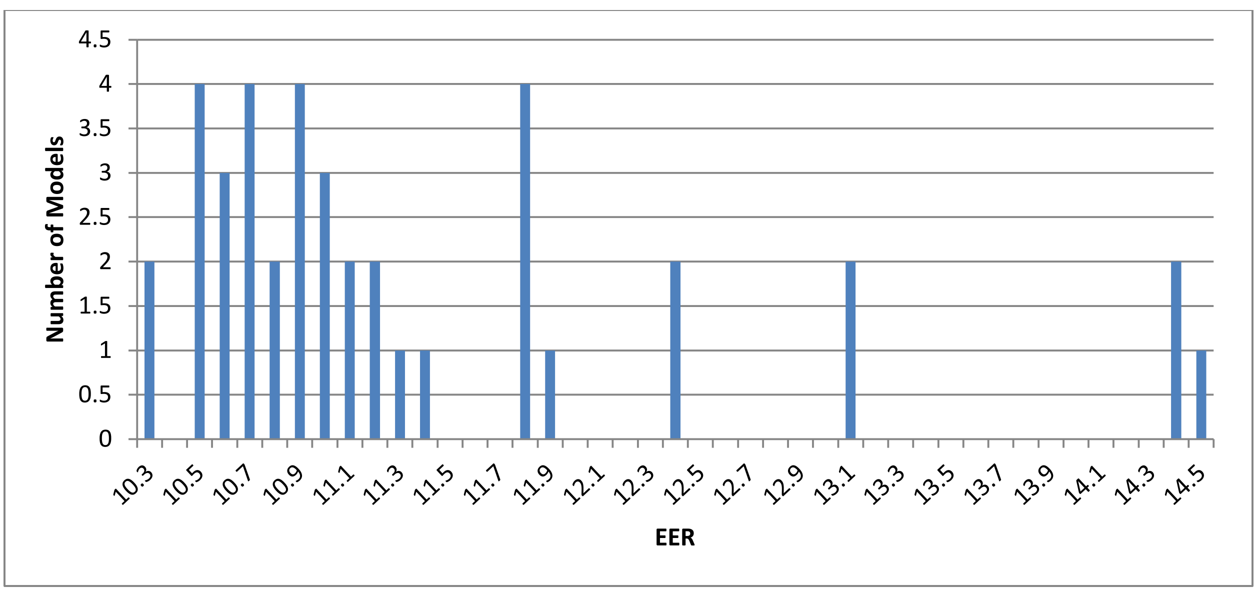

Figure 2.2.5 Histogram of Water-Source VRF Systems (≥135,000 Btu/h) with Heat Recovery

2.4.3.4 Computer Room Air Conditioners

Lastly, for computer room air conditioners, DOE compiled a database of available models using information from the CEC directory and from manufacturers' websites. AHRI did not have a database for computer room air conditioners in their Directory of Certified Product Performance. DOE took the information from its sources and then divided the computer room air conditioner models into 30 equipment classes as defined in section 2.2.3. DOE used this database as the starting point for its analysis of computer room air conditioners.

Prior to ASHRAE Standard 90.1-2010, computer room air conditioners were not considered covered equipment under EPCA, so there are currently no Federal energy conservation standards for these equipment. As a result of the lack of existing Federal standards (and as a result, lack of reporting requirements), manufacturers typically do not report the efficiency of their equipment. However, the CEC regulates the minimum efficiency of computer room air conditioners, requiring units installed in the state of California to be tested using ASHRAE 127-2001 and meet a minimum EER rating as listed in Table 2.2.2.

Table 2.2.2 CEC Computer Room Air Conditioners Minimum Efficiency Levels

CEC Equipment Type	Cooling Capacity (Btu/h)	Minimum Efficiency Level (ASHRAE 127-2001 EER)
Air-cooled computer room air conditioners	< 65,000	11.0 EER
	≥ 65,000 and < 135,000	10.4 EER
	≥ 135,000 and < 240,000	10.2 EER
Water-cooled, Glycol-cooled, and Evaporatively-cooled Computer Air Conditioners	< 65,000	11.1 EER
	≥ 65,000 and < 135,000	10.5 EER
	≥ 135,000 and < 240,000	10.0 EER

As noted previously, the CEC maintains a directory of "computer room air conditioners" in its Appliance Efficiency Database. DOE searched the CEC database for computer room air conditioners and supplemented that data with information from literature found on manufacturer websites. In total, DOE found 1364 models of computer room air conditioners, many of which are variations of the same base model. For example, a given model could have the same basic design and construction, but with multiple optional features, such as optional upflow or downflow configuration, and the option of adding a fluid economizer; thus from this single model, 4 different variations are possible, each variation with its own efficiency characteristics and each falling into a separate equipment class. From the 5 manufacturers identified, DOE found 22 model lines of computer room air conditioners, consisting of 120 base models and 1244 models that were optional variations of those models to make up the 1364 models in its database. DOE presents the models included in its database broken up by equipment class in Table 2.2.3.

Table 2.2.3 Computer Room Air Conditioner Database Breakdown

Equipment Class	Size Category	Number of Upflow Units	Number of Downflow Units
Air-Cooled	<65,000 Btu/h	63	140
	≥65,000 Btu/h and <240,000 Btu/h	99	126
	≥240,000 Btu/h and <760,000 Btu/h	13	11
Water-Cooled	<65,000 Btu/h	31	68
	≥65,000 Btu/h and <240,000 Btu/h	56	71
	≥240,000 Btu/h and <760,000 Btu/h	12	10
Water-Cooled with a Fluid Economizer	<65,000 Btu/h	17	44
	≥65,000 Btu/h and <240,000 Btu/h	47	58
	≥240,000 Btu/h and <760,000 Btu/h	4	4
Glycol Cooled	<65,000 Btu/h	28	63
	≥65,000 Btu/h and <240,000 Btu/h	57	71
	≥240,000 Btu/h and <760,000 Btu/h	10	8
Glycol Cooled with a Fluid Economizer	<65,000 Btu/h	32	60
	≥65,000 Btu/h and <240,000 Btu/h	66	79
	≥240,000 Btu/h and <760,000 Btu/h	9	7

DOE found efficiency information for three of the five computer room air conditioner manufacturers. The CEC database included EER information for two manufacturers, and one manufacturer included EER information in its product literature. In all cases the EER information was measured according to the procedures in ASHRAE 127-2001. However, DOE notes that ASHRAE Standard 90.1-2010 adopts an updated version of ASHRAE 127 (*i.e.*, ASHRAE 127-2007), which changes the efficiency metric from EER to SCOP. In addition, the standard rating conditions were changed between the 2001 and 2007 editions of the ASHRAE 127 test procedure, which adds to the difficulty of obtaining information about product efficiency as rated using the new SCOP rating metric. A footnote to Table D1 in Appendix D of ASHRAE 127-2007 contains a "rule-of-thumb" formula listed in equation 2.1 below that approximates the SCOP value using the old EER rating. The rule of thumb converts EER for air-cooled units into SCOP by multiplying the EER at the old rating condition (71.6°F dry-bulb (DB) return temperature and 50% relative humidity (RH)) with the sensible heat ratio[2] (SHR) at the new rating condition (75°F DB return temperature and 45% RH) and dividing by 3.5.

$$\frac{EER_{old} * SHR}{3.5} = SCOP$$

Eq. 2.1

[2] Sensible heat ratio (SHR) is the ratio of a unit's sensible cooling capacity divided by the total (i.e., sensible and latent) cooling capacity.

For fluid-cooled units the same rule-of-thumb formula can be used, with the electric power reduced by 3% to omit the heat-rejection equipment. That is, for water-cooled and glycol-cooled units, the rule-of-thumb takes the final result from the air-cooled calculation and divides by 0.97 to take into account of the 3% reduction in electric power from the heat-rejection equipment.

DOE found EER information for 208 models in DOE's compiled database (15.2% of the database) and used this rule of thumb conversion to convert this EER data into SCOP data. For the units in the CEC database, DOE found calculated the SHR at the new rating condition by dividing the sensible cooling capacity by the net cooling capacity provided in the manufacturer's product literature. For units not in the CEC database, SHR information was only available at the old rating condition. To approximate the SHR at the new rating condition, DOE increased the sensible cooling capacity at the old rating condition by 8.9% (the average percent increase in sensible cooling capacity from the old rating condition to the new rating condition for units in the CEC database) and increased the total cooling capacity at the old rating condition by 3.3% (the average percent increase in total cooling capacity from the old rating condition to the new rating condition for the rest of the models in the database). DOE used these newly calculated sensible and total cooling capacities to estimate the SHR at the new rating condition for these units. Thus, DOE was able to calculate estimated SCOP values for all of the units for which it had EER information.

DOE found that for units available optionally in either a downflow or upflow orientation only a single EER value was specified and the orientation in which the value was obtained was not specified. DOE assumed that the reported EER was tested in the downflow orientation because the EER value as tested in the downflow configuration would be higher than if the same unit was tested in the upflow configuration (and manufacturers would want to report the highest efficiency rating for their equipment). Then, in order to calculate the SCOP for the unit in the upflow orientation, DOE assumed that the upflow model would have a lower EER and SCOP due to the effects of additional static pressure that the blower must overcome. Thus, DOE reduced the corresponding downflow model's SCOP by 0.11, which is the reduction in ASHRAE Standard 90.1-2010 between the downflow and upflow equipment classes. The average SCOP for each equipment class is shown below in Table 2.2.4. For some equipment classes, DOE could not find any efficiency information from the CEC database or manufacturers' websites. Those equipment classes are shown as a blank in Table 2.2.4.

Table 2.2.4 Average SCOP for Computer Room Air Conditioners

Equipment Class	Size Category	Average Upflow SCOP	Average Downflow SCOP
Air-Cooled	<65,000 Btu/h	2.49	2.61
	≥65,000 Btu/h and <240,000 Btu/h	2.64	2.64
	≥240,000 Btu/h and <760,000 Btu/h	-	2.25
Water-Cooled	<65,000 Btu/h	2.76	2.90
	≥65,000 Btu/h and <240,000 Btu/h	2.76	2.78
	≥240,000 Btu/h and <760,000 Btu/h	-	2.45
Water-Cooled with a Fluid Economizer	<65,000 Btu/h	-	-
	≥65,000 Btu/h and <240,000 Btu/h	-	-
	≥240,000 Btu/h and <760,000 Btu/h	-	-
Glycol Cooled	<65,000 Btu/h	2.66	2.71
	≥65,000 Btu/h and <240,000 Btu/h	-	2.62
	≥240,000 Btu/h and <760,000 Btu/h	-	2.49
Glycol Cooled with a Fluid Economizer	<65,000 Btu/h	-	2.43
	≥65,000 Btu/h and <240,000 Btu/h	-	2.48
	≥240,000 Btu/h and <760,000 Btu/h	-	2.38

The following sections report for each equipment class the total number of models that DOE found on the market, the number of models for which DOE was able to obtain efficiency information, and information about the performance characteristics (such as the sensible cooling capacity and SCOP) of computer room air conditioners on the market.

Air-cooled Computer Room Air Conditioners (<65,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.2 SCOP for air-cooled computer room air conditioners with a cooling capacity less than 65,000 Btu/h. DOE found 203 total models in this class and 44 models with efficiency information (18 upflow models and 26 downflow models). The average sensible cooling capacity for this class is 34,848 Btu/h, and the average SCOP is 2.56. Figure 2.2.6 shows a histogram of the sensible cooling capacities, and Figure 2.2.7 shows a histogram of SCOP of the models on the market.

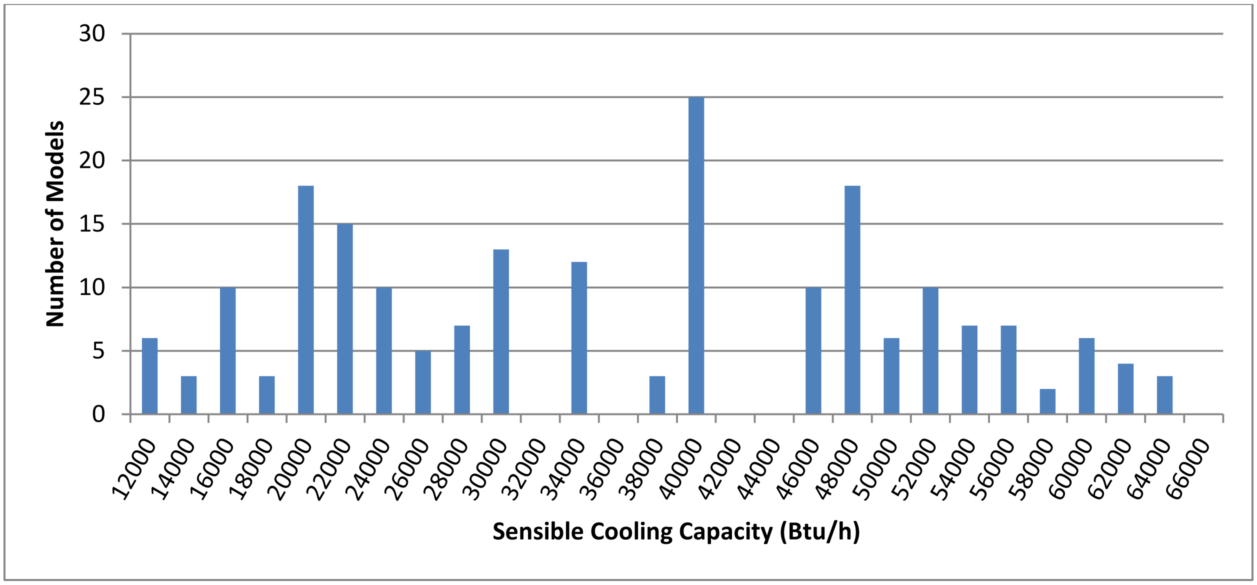

Figure 2.2.6 Air-Cooled Computer Room Air Conditioners (<65,000) Sensible Cooling Capacity Histogram

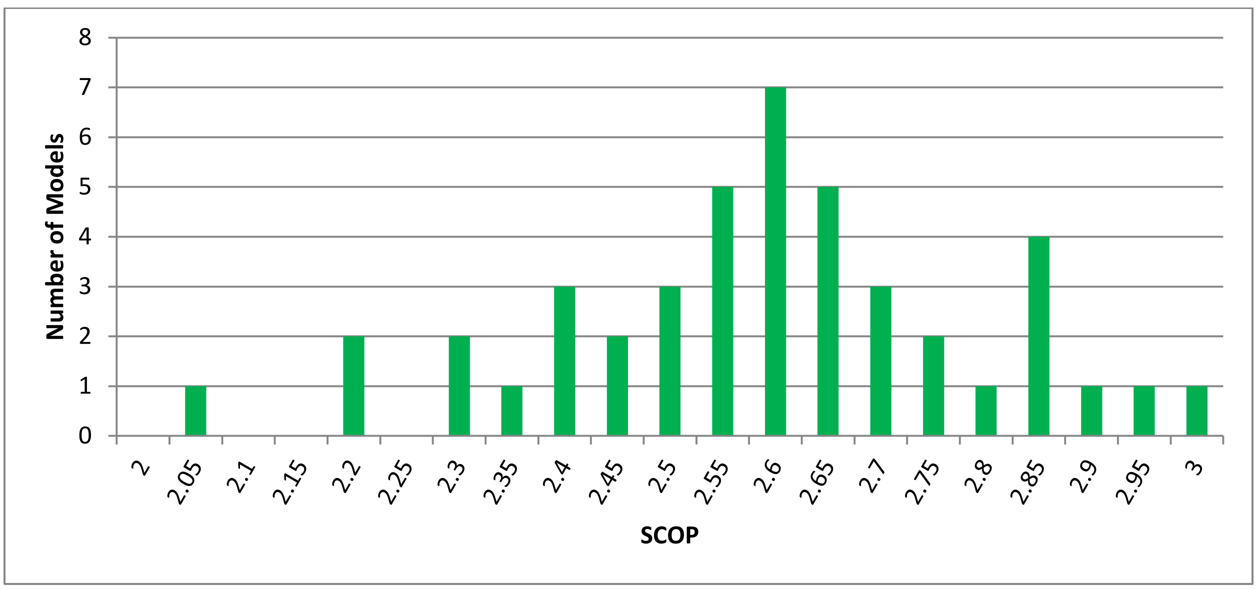

Figure 2.2.7 Air-Cooled Computer Room Air Conditioners (<65,000 Btu/h) SCOP Histogram

Air-cooled Computer Room Air Conditioners (≥ 65,000 Btu/h and <240,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.1 SCOP for air-cooled computer room air conditioners with a cooling capacity greater than or equal to 65,000 Btu/h and less than 240,000 Btu/h. DOE found 225 total models in this class and 51 models with efficiency information (21 upflow models and 30 downflow models). The average sensible cooling capacity for this class is 126,671 Btu/h, and the average SCOP is 2.64. Figure 2.2.8 shows a histogram of the sensible cooling capacities, and Figure 2.2.9 shows a histogram of SCOP of the models on the market.

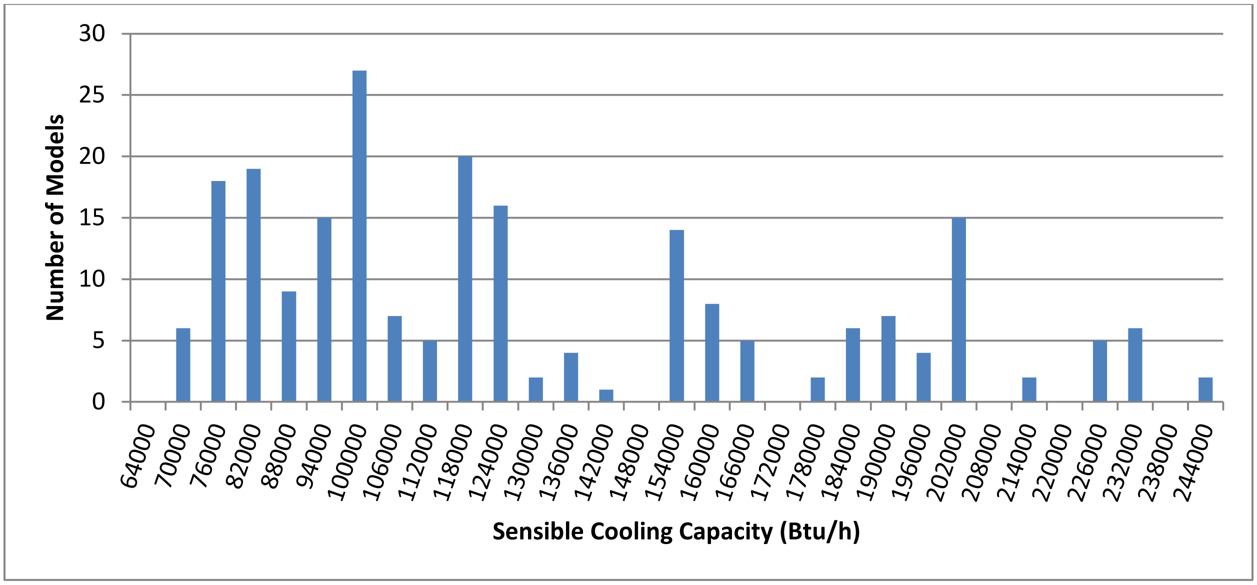

Figure 2.2.8 Air-Cooled Computer Room Air Conditioners (≥65,000 Btu/h and <240,000 Btu/h) Sensible Cooling Capacity Histogram

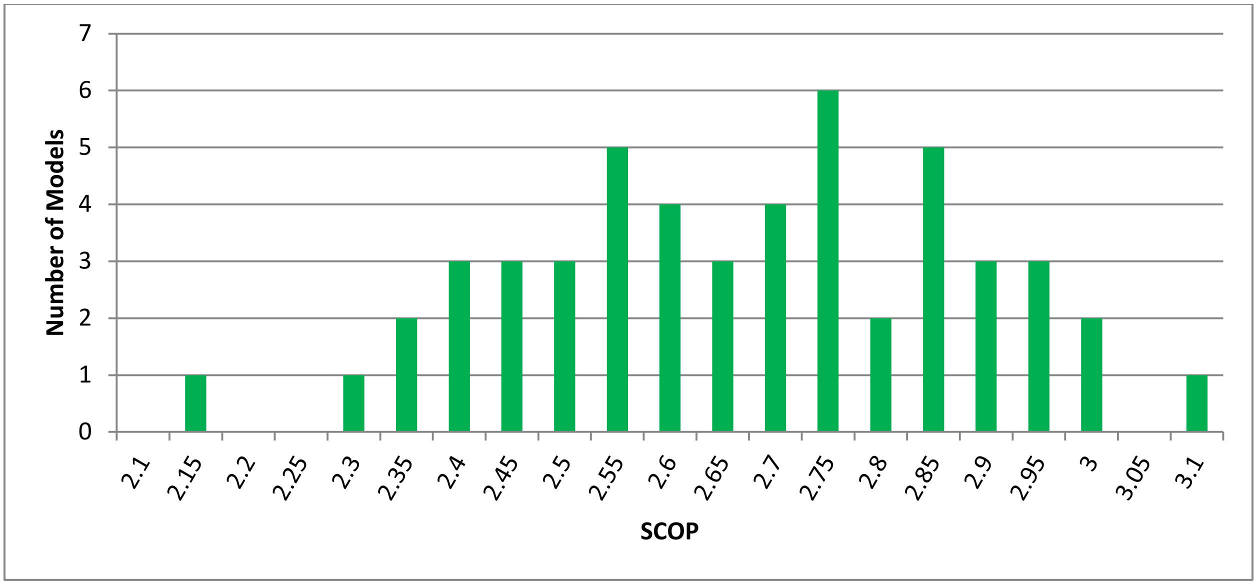

Figure 2.2.9 Air-Cooled Computer Room Air Conditioners (≥65,000 Btu/h and <240,000 Btu/h) SCOP Histogram

Air-cooled Computer Room Air Conditioners (≥240,000 Btu/h and <760,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 1.9 SCOP for air-cooled computer room air conditioners with a cooling capacity greater than or equal to 240,000 Btu/h and less than 760,000 Btu/h. DOE found 24 total models in this class and 1 model with efficiency information (only a downflow model with a 2.25 SCOP). The average sensible cooling capacity for this class is 286,015 Btu/h. Figure 2.2.10 shows a histogram of the sensible cooling capacities.

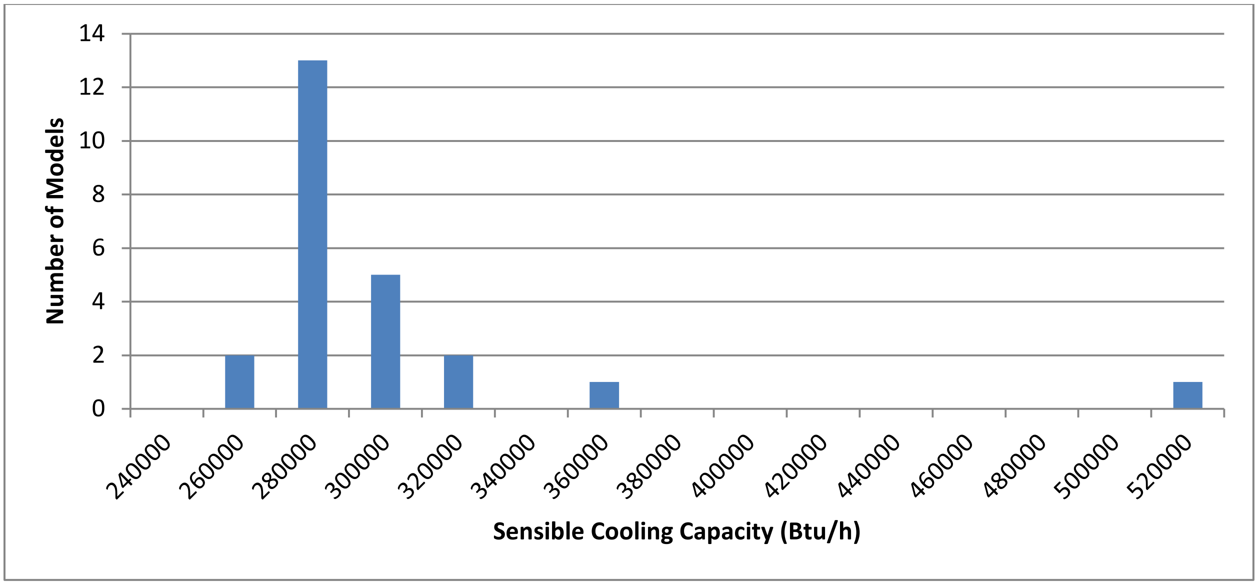

Figure 2.2.10 Air-Cooled Computer Room Air Conditioners (≥240,000 Btu/h and <760,000 Btu/h) Sensible Cooling Capacity Histogram

Water-cooled Computer Room Air Conditioners (<65,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.6 SCOP for water-cooled computer room air conditioners with a cooling capacity less than 65,000 Btu/h. DOE found 99 total models in this class and 39 models with efficiency information (14 upflow models and 25 downflow models). The average sensible cooling capacity for this class is 36,071 Btu/h, and the average SCOP is 2.85. Figure 2.2.11 shows a histogram of the sensible cooling capacities, and Figure 2.2.12 shows a histogram of SCOP of the models on the market.

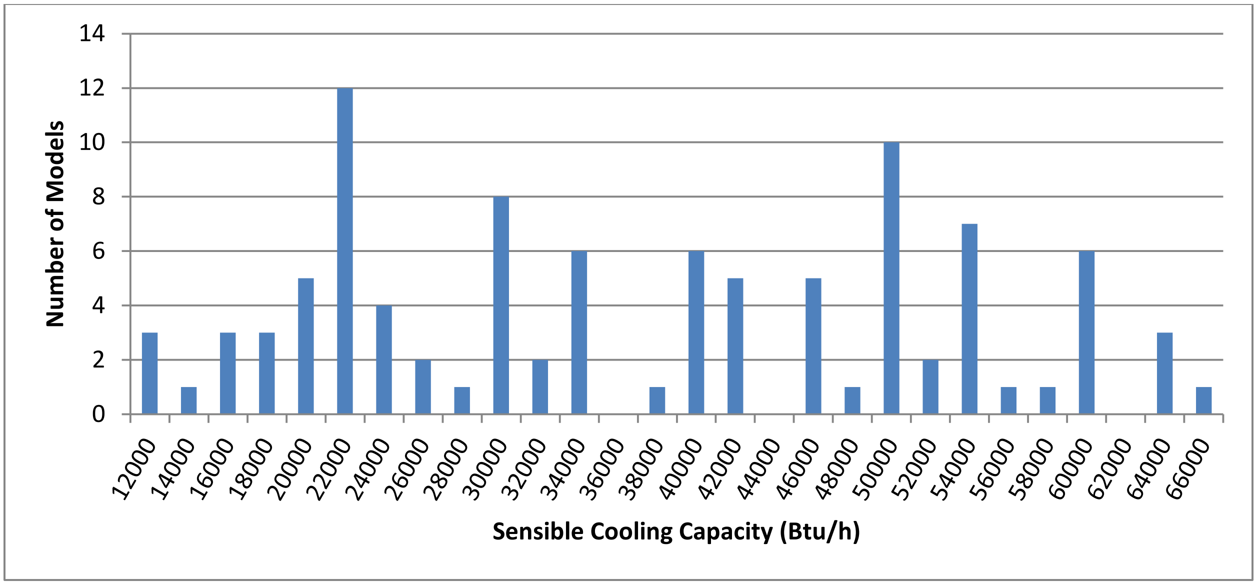

Figure 2.2.11 Water-Cooled Computer Room Air Conditioner (<65,000 Btu/h) Sensible Cooling Capacity Histogram

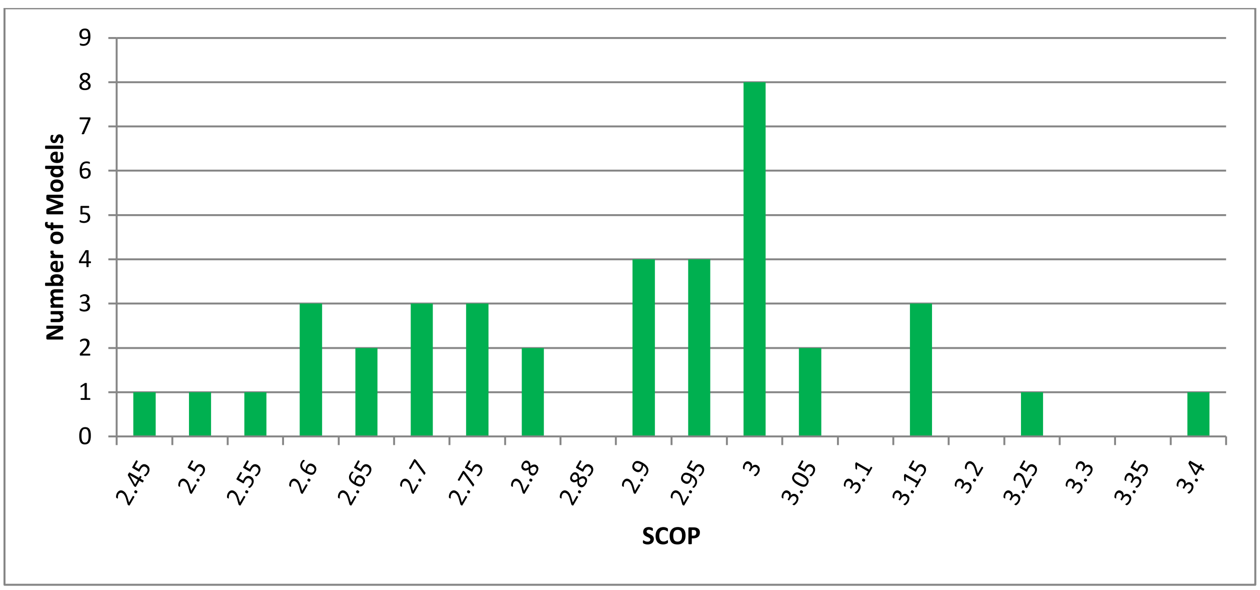

Figure 2.2.12 Water-Cooled Computer Room Air Conditioner (<65,000 Btu/h) SCOP Histogram

Water-cooled Computer Room Air Conditioners (≥ 65,000 Btu/h and <240,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.5 SCOP for water-cooled computer room air conditioners with a cooling capacity greater than or equal to 65,000 Btu/h and less than 240,000 Btu/h. DOE found 127 total models in this class and 50 models with efficiency information (20 upflow models and 30 downflow models). The average sensible cooling capacity for this class is 134,398 Btu/h, and the average SCOP is 2.77. Figure 2.2.13 shows a histogram of the sensible cooling capacities, and Figure 2.2.14 shows a histogram of SCOP of the models on the market.

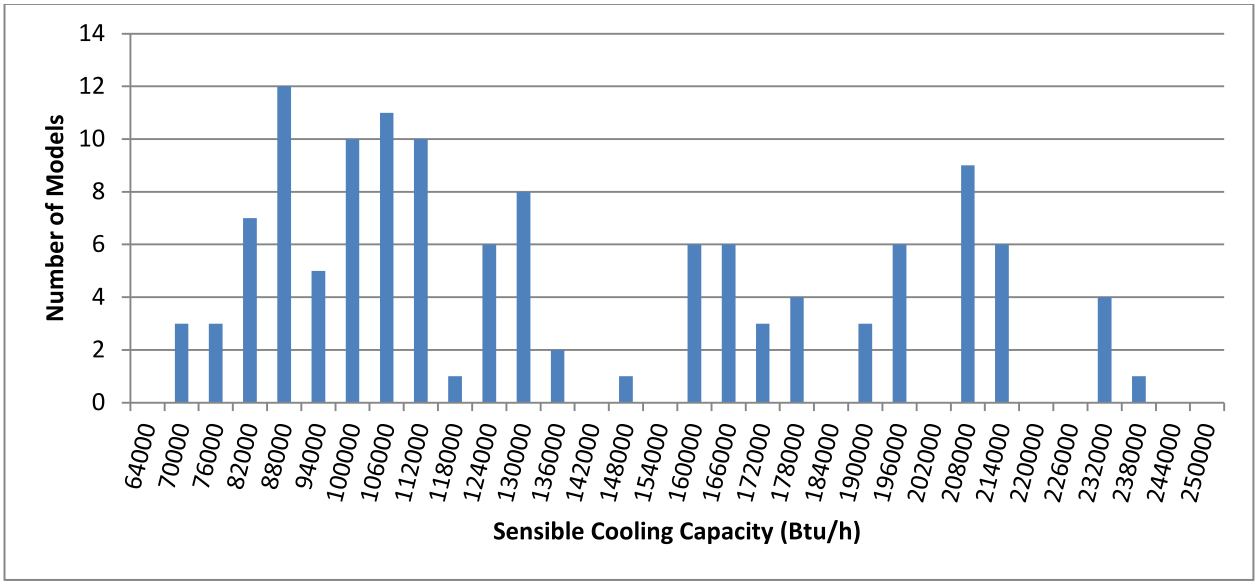

Figure 2.2.13 Water-Cooled Computer Room Air Conditioner (≥65,000 Btu/h and <240,000 Btu/h) Sensible Cooling Capacity Histogram

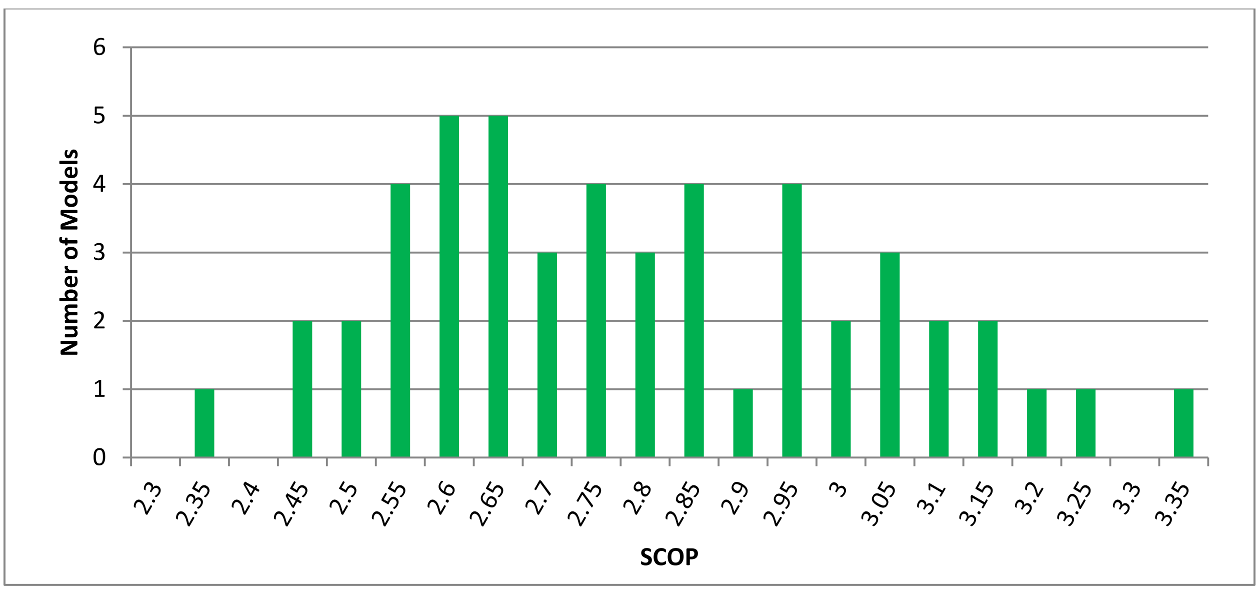

Figure 2.2.14 Water-Cooled Computer Room Air Conditioner (≥65,000 Btu/h and <240,000 Btu/h) SCOP Histogram

Water-cooled Computer Room Air Conditioners (≥240,000 Btu/h and <760,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.4 SCOP for water-cooled computer room air conditioners with a cooling capacity greater than or equal to 240,000 Btu/h and less than 760,000 Btu/h. DOE found 22 total models in this class and 1 model with efficiency information (only a downflow model with a 2.45 SCOP). The average sensible cooling capacity for this class is 292,245 Btu/h. Figure 2.2.15 shows a histogram of the sensible cooling capacities.

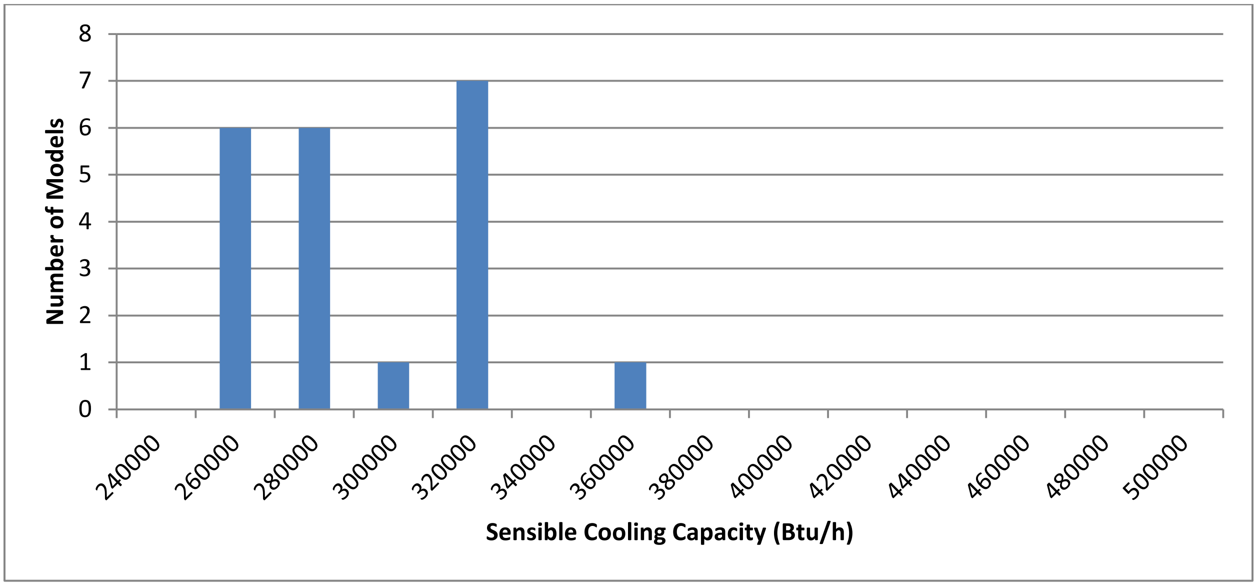

Figure 2.2.15 Water-Cooled Computer Room Air Conditioner (≥240,000 Btu/h and <760,000 Btu/h) Sensible Cooling Capacity Histogram

Water-cooled Computer Room Air Conditioners with a Fluid Economizer (<65,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.55 SCOP for water-cooled computer room air conditioners with a fluid economizer with a cooling capacity less than 65,000 Btu/h. DOE found 61 total models in this class and no models with efficiency information. The average sensible cooling capacity for this class is 37,301 Btu/h. Figure 2.2.16 shows a histogram of the sensible cooling capacities.

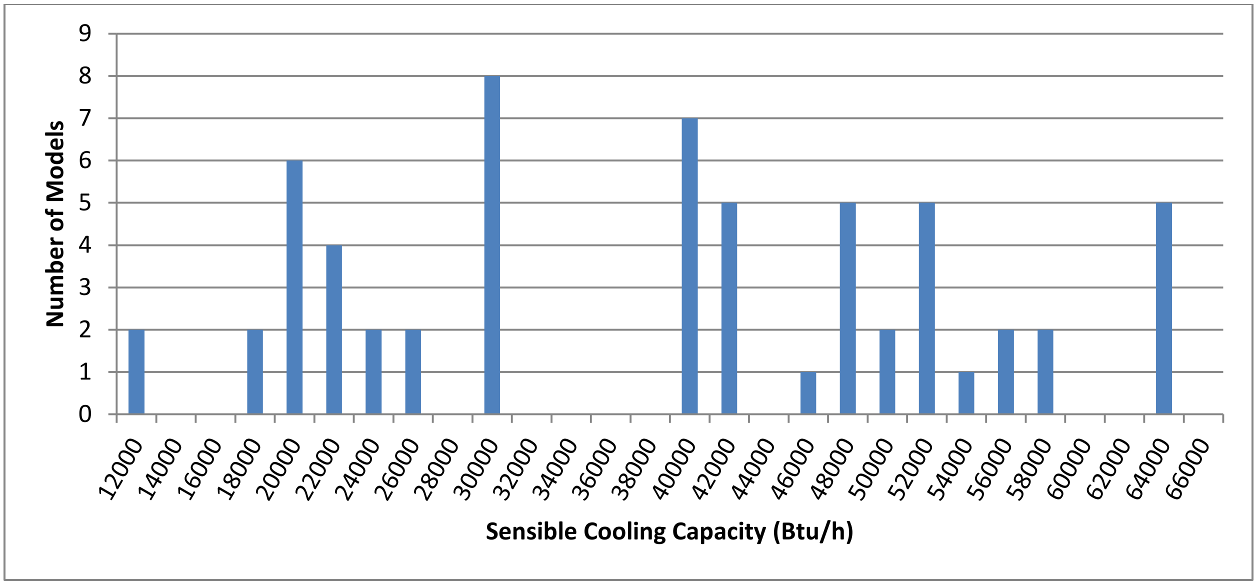

Figure 2.2.16 Water-Cooled Computer Room Air Conditioner (<65,000 Btu/h) With a Fluid Economizer Sensible Cooling Capacity Histogram

Water-cooled Computer Room Air Conditioners with a Fluid Economizer (≥65,000 Btu/h and <240,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.45 SCOP for water-cooled computer room air conditioners with a fluid economizer with a cooling capacity greater than or equal to 65,000 Btu/h and less than 240,000 Btu/h. DOE found 105 total models in this class and no models with efficiency information. The average sensible cooling capacity for this class is 129,602 Btu/h. Figure 2.2.17 shows a histogram of the sensible cooling capacities.

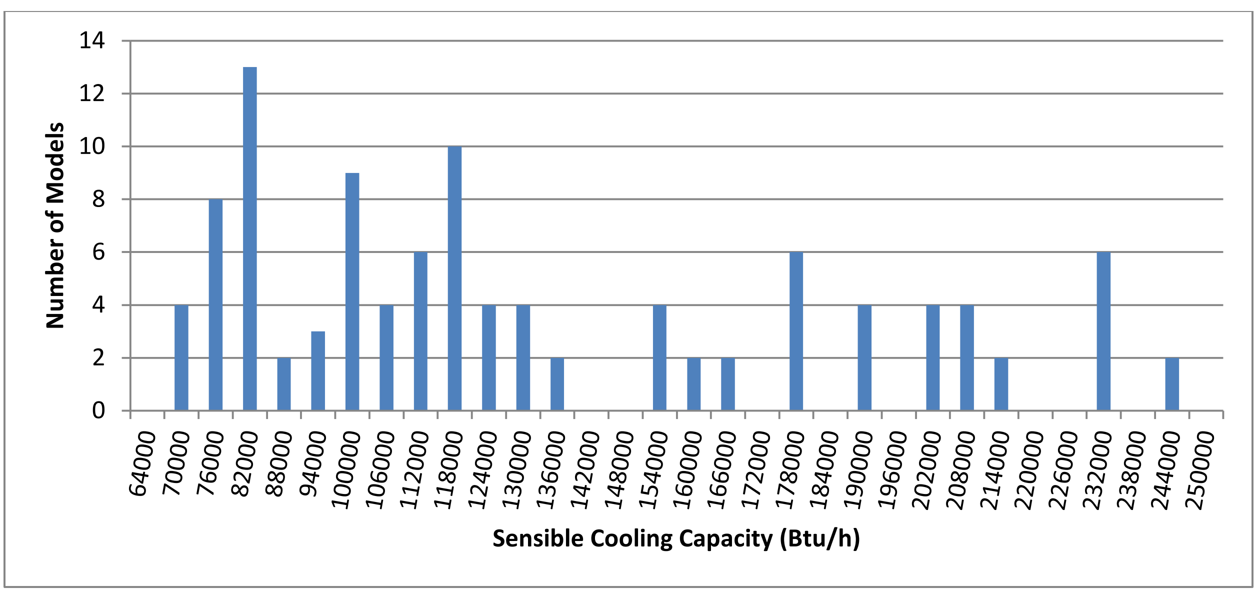

Figure 2.2.17 Water-Cooled Computer Room Air Conditioner (≥65,000 Btu/h and <240,000 Btu/h) with a Fluid Economizer Sensible Cooling Capacity Histogram

Water-cooled Computer Room Air Conditioners with a Fluid Economizer (≥240,000 Btu/h and < 760,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.35 SCOP for water-cooled computer room air conditioners with a fluid economizer with a cooling capacity greater than or equal to 240,000 Btu/h and less than 760,000 Btu/h. DOE found 8 total models in this class and no models with efficiency information. The average sensible cooling capacity for this class is 285,063 Btu/h. Figure 2.2.18 shows a histogram of the sensible cooling capacities.

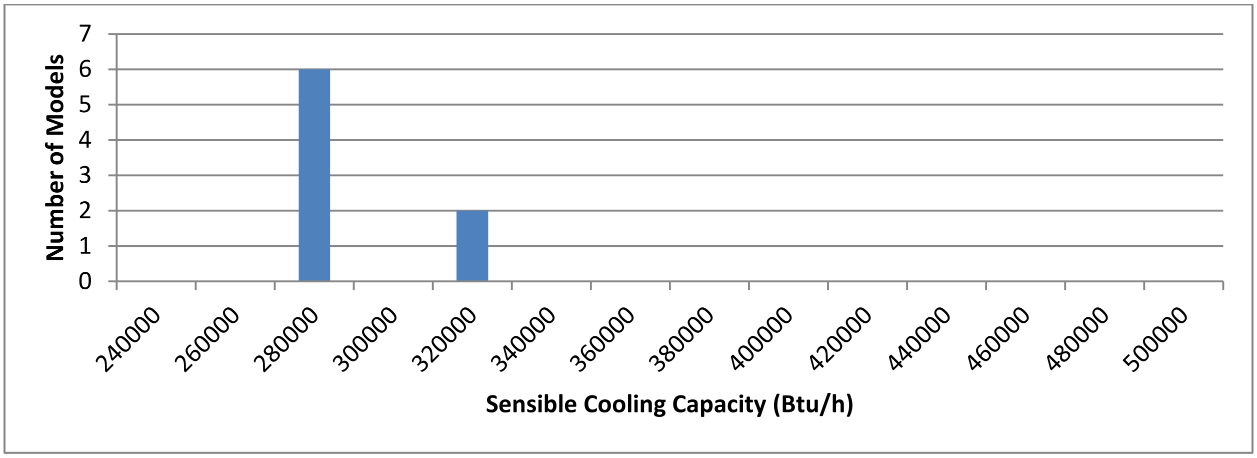

Figure 2.2.18 Water-Cooled Computer Room Air Conditioner (≥240,000 Btu/h and <760,000 Btu/h) with a Fluid Economizer Sensible Cooling Capacity Histogram

Glycol-cooled Computer Room Air Conditioners (<65,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.5 SCOP for glycol-cooled computer room air conditioners with a cooling capacity less than 65,000 Btu/h. DOE found 91 total models in this class and 9 models with efficiency information (4 upflow models and 5 downflow models). The average sensible cooling capacity for this class is 35,425 Btu/h, and the average SCOP is 2.66. Figure 2.2.19 shows a histogram of the sensible cooling capacities, and Figure 2.2.20 shows a histogram of SCOP of the models on the market.

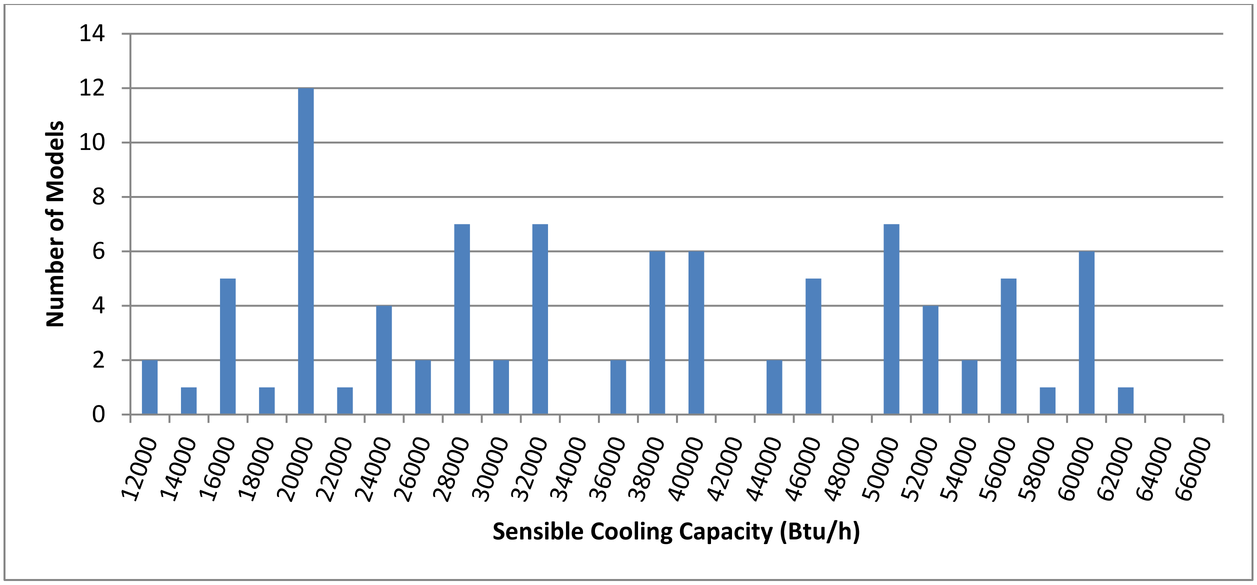

Figure 2.2.19 Glycol-Cooled Computer Room Air Conditioner (<65,000 Btu/h) Sensible Cooling Capacity Histogram

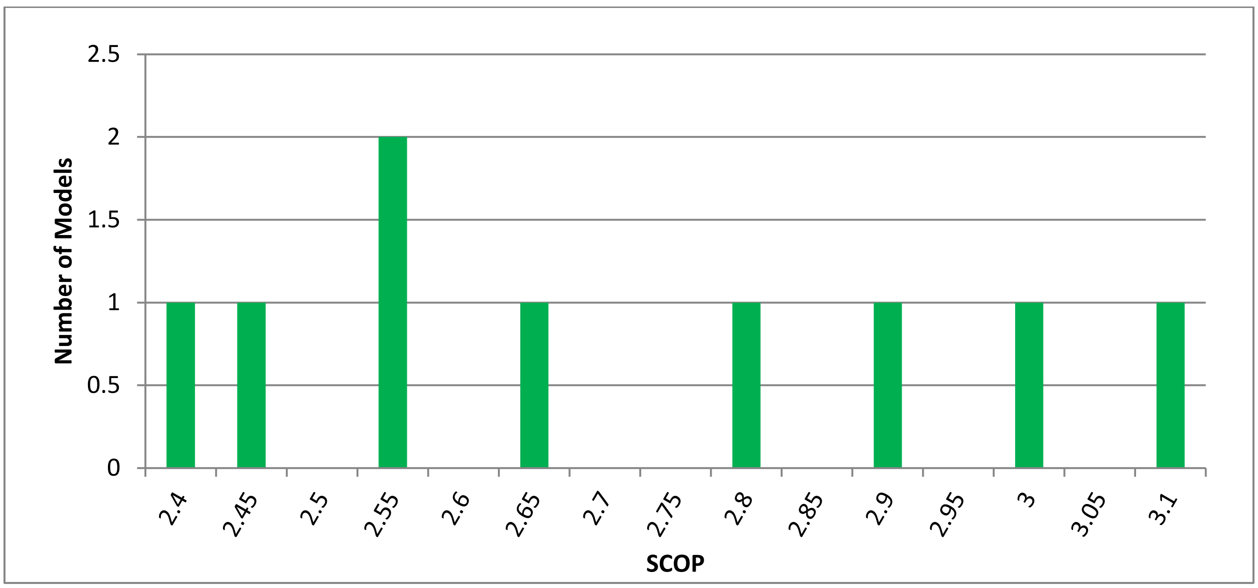

Figure 2.2.20 Glycol-Cooled Computer Room Air Conditioner (<65,000 Btu/h) SCOP Histogram

Glycol-cooled Computer Room Air Conditioners (≥65,000 Btu/h and <240,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.15 SCOP for glycol-cooled computer room air conditioners with a cooling capacity greater than or equal to 65,000 Btu/h and less than 240,000 Btu/h. DOE found 128 total models in this class and 5 models with efficiency information (only downflow models with SCOPs of 2.47, 2.55, 2.65, 2.68, and 2.74). The average sensible cooling capacity for this class is 129,309 Btu/h, and the average SCOP is 2.62. Figure 2.2.21 shows a histogram of the sensible cooling capacities.

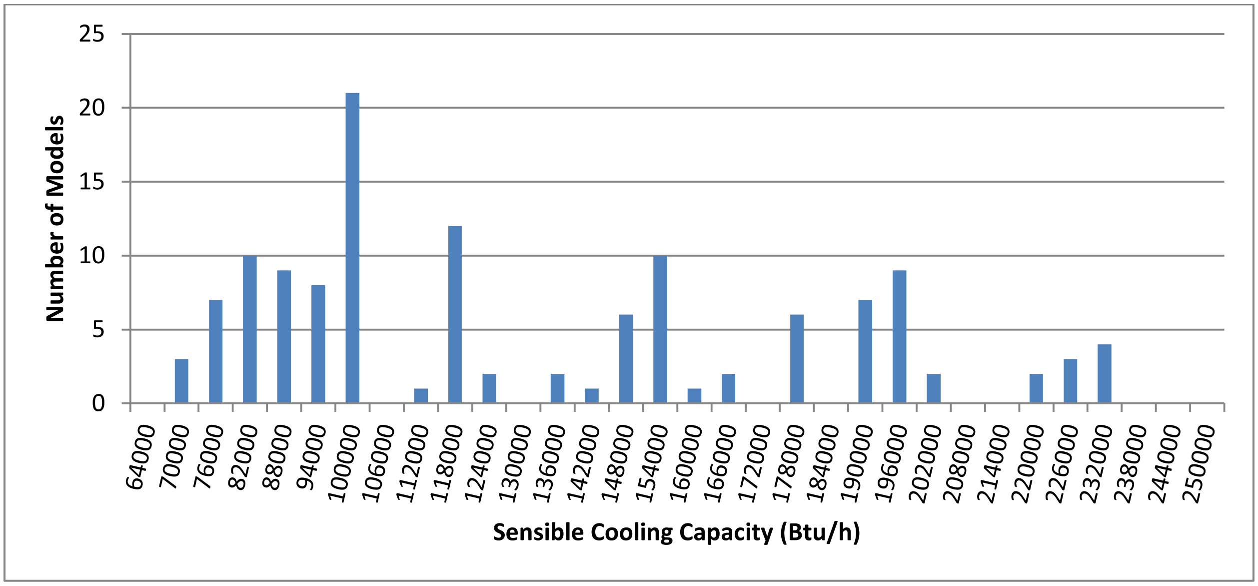

Figure 2.2.21 Glycol-Cooled Computer Room Air Conditioner (≥65,000 and <240,000 Btu/h) Sensible Cooling Capacity Histogram

Glycol-cooled Computer Room Air Conditioners (≥240,000 Btu/h and <760,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.1 SCOP for glycol-cooled computer room air conditioners with a cooling capacity greater than or equal to 240,000 Btu/h and less than 760,000 Btu/h. DOE found 18 total models in this class and 1 model with efficiency information (only a downflow model with a 2.49 SCOP). The average sensible cooling capacity for this class is 285,480 Btu/h. Figure 2.2.22 shows a histogram of the sensible cooling capacities.

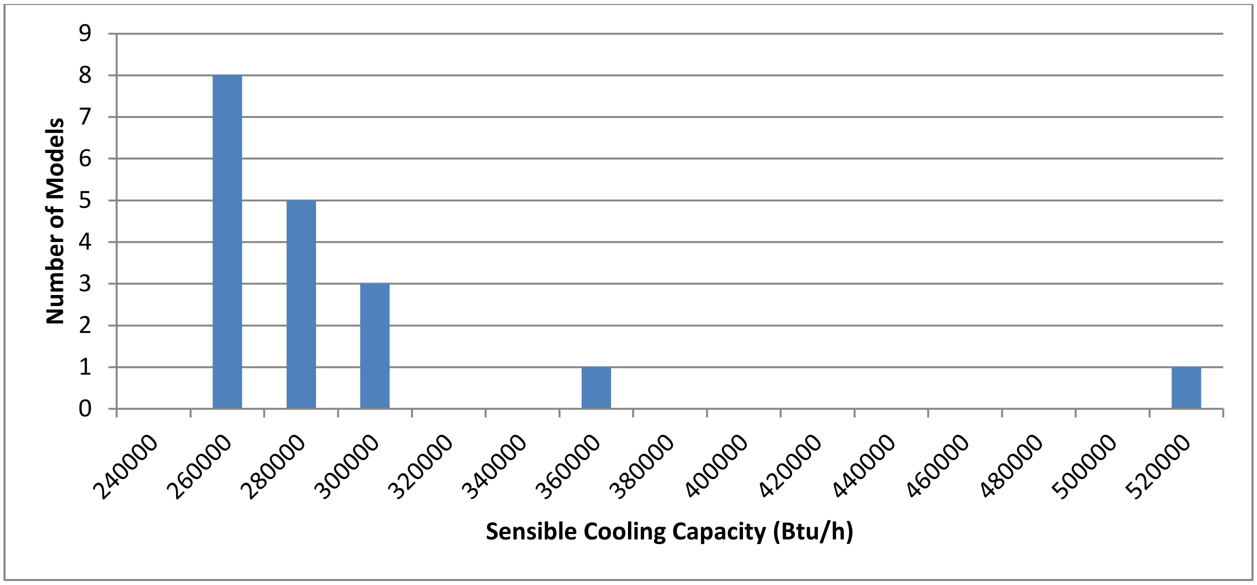

Figure 2.2.22 Glycol-Cooled Computer Room Air Conditioner (≥240,000 and <760,000 Btu/h) Sensible Cooling Capacity Histogram

Glycol-cooled Computer Room Air Conditioners with a Fluid Economizer (<65,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.45 SCOP for glycol-cooled computer room air conditioners with a fluid economizer with a cooling capacity less than 65,000 Btu/h. DOE found 92 total models in this class and 1 model with efficiency information (only a downflow model with a 2.43 SCOP). The average sensible cooling capacity for this class is 37,147 Btu/h. Figure 2.2.23 shows a histogram of the sensible cooling capacities.

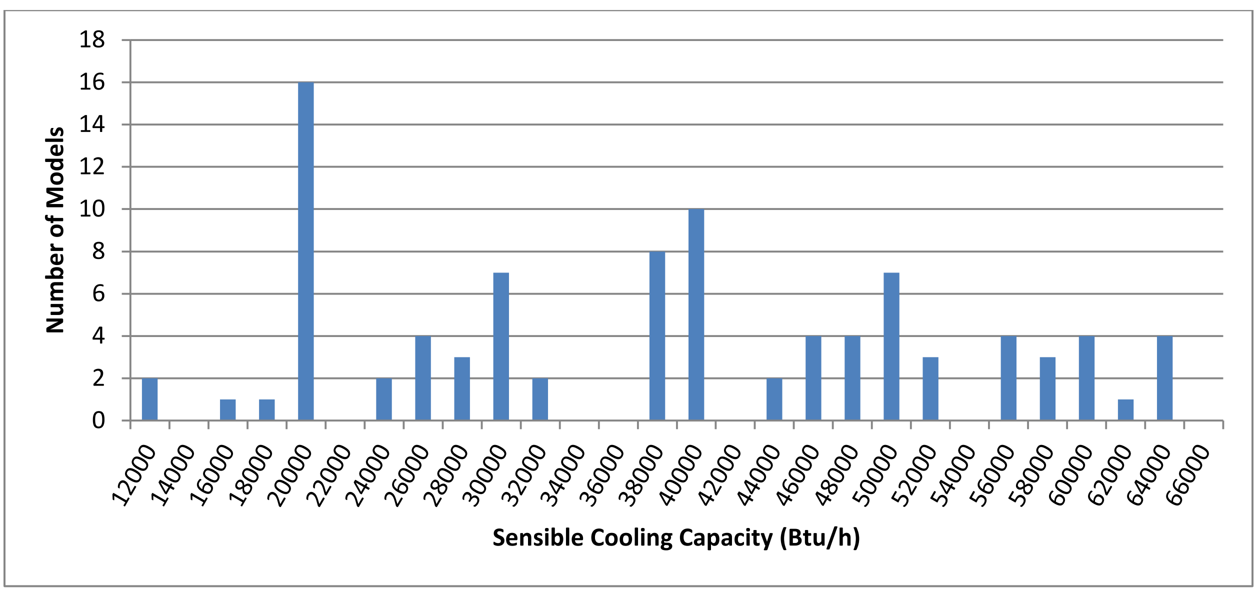

Figure 2.2.23 Glycol-Cooled Computer Room Air Conditioner (<65,000 Btu/h) with a Fluid Economizer Sensible Cooling Capacity Histogram

Glycol-cooled Computer Room Air Conditioners with a Fluid Economizer (≥65,000 Btu/h and <240,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.1 SCOP for glycol-cooled computer room air conditioners with a fluid economizer with a cooling capacity greater than or equal to 65,000 Btu/h and less than 240,000 Btu/h. DOE found 145 total models in this class and 5 models with efficiency information (only downflow models with SCOPs of 2.26, 2.45, 2.53, 2.56, and 2.62). The average sensible cooling capacity for this class is 129,380 Btu/h, and the average SCOP is 2.48. Figure 2.2.24 shows a histogram of the sensible cooling capacities.

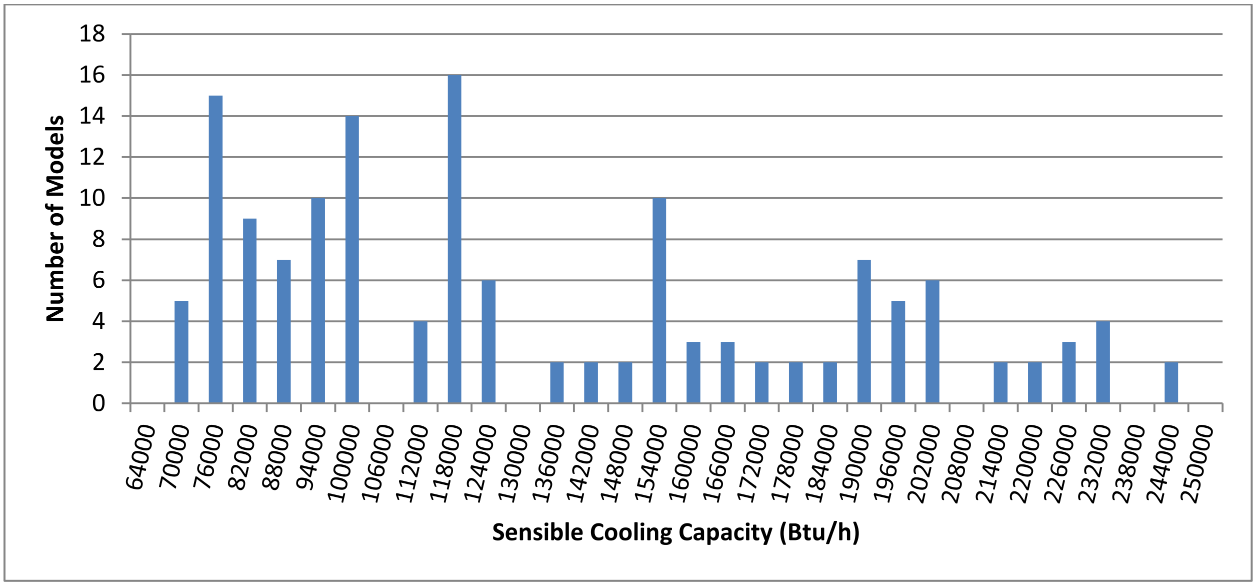

Figure 2.2.24 Glycol-Cooled Computer Room Air Conditioner (≥65,000 and <240,000 Btu/h) with a Fluid Economizer Sensible Cooling Capacity Histogram

Glycol-cooled Computer Room Air Conditioners with a Fluid Economizer (≥240,000 Btu/h and <760,000 Btu/h). ASHRAE Standard 90.1-2010 set the efficiency level at 2.05 SCOP for glycol-cooled computer room air conditioners with a fluid economizer with a cooling capacity greater than or equal to 240,000 Btu/h and less than 760,000 Btu/h. DOE found 16 total models in this class and 1 model with efficiency information (only a downflow model with a 2.38 SCOP). The average sensible cooling capacity for this class is 293,554 Btu/h. Figure 2.2.25 shows a histogram of the sensible cooling capacities.

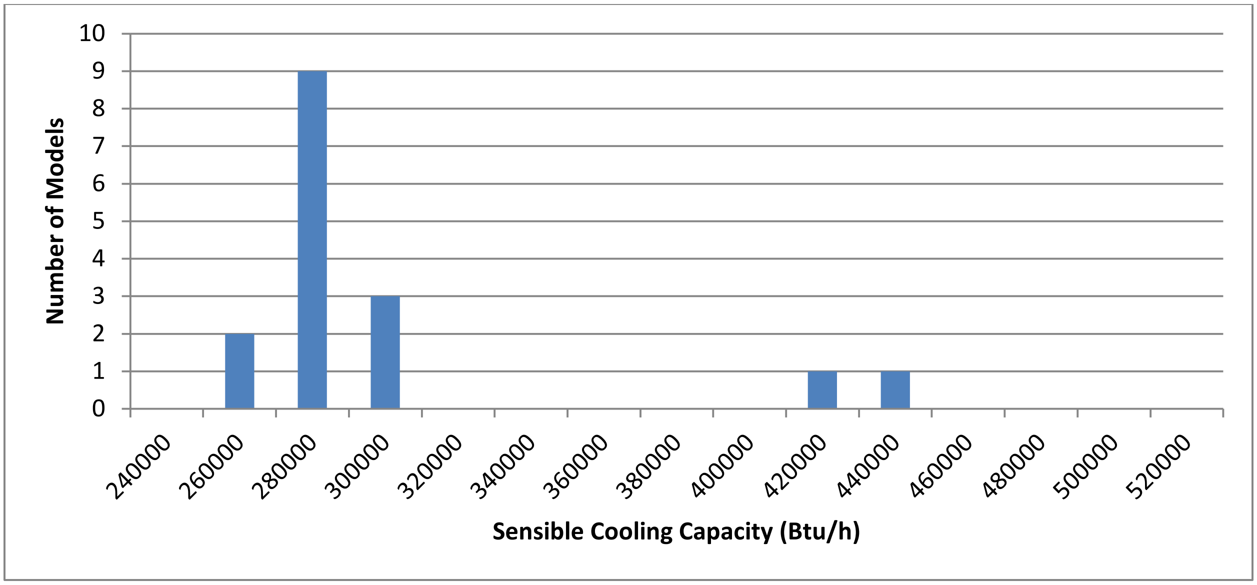

Figure 2.2.25 Glycol-Cooled Computer Room Air Conditioner (≥240,000 and <760,000 Btu/h) With a Fluid Economizer Sensible Cooling Capacity Histogram

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