ORNL/TM-2016/766

Commercial Integrated Heat Pump with Thermal Storage –Preliminary Market Assessment – FY17 1st Quarter Milestone Report

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12/29/2016

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Title

BTO Project 3.2.2.26
HVAC R&D
FY17 1st Quarter Milestone Report

Commercial Integrated Heat Pump with Thermal Storage (C-IHP-TS) - Preliminary Market Assessment

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Date: 12/29/2016

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UT-BATTELLE, LLC
for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

Preliminary Market Assessment

Executive Summary

The commercial integrated heat pump with thermal storage (AS-IHP) offers significant energy saving over a baseline heat pump with electric water heater. The saving potential is maximized when the AS-IHP serves coincident high water heating and high space cooling demands. A previous energy performance analysis showed that the AS-IHP provides the highest benefit in the hot-humid and hot-dry/mixed dry climate regions. Analysis of technical potential energy savings for these climate zones based on the BTO Market calculator indicated that the following commercial building market segments had the highest water heating loads relative to space cooling and heating loads – education, food service, health care, lodging, and mercantile/service. In this study, we focused on these building types to conservatively estimate the market potential of the AS-IHP. Our analysis estimates maximum annual shipments of ~522,000 units assuming 100% of the total market is captured. An "early" replacement market based on replacement of systems in target buildings between 15 and 35 years old was estimated at ~136,000 units. Technical potential energy savings are estimated at ~0.27 quad based on the maximum market estimate, equivalent to ~13.9 MM Ton CO_2 emissions reduction.

Introduction

Air source integrated heat pumps (AS-IHP) recover condenser rejected heat for water heating. It operates most efficiently in the simultaneous space cooling and water heating mode, when the indoor cooling energy is directly pumped to the condenser side for water heating. The commercial integrated heat pump with thermal storage (AS-IHP) achieves the highest utilization and in turn highest energy savings when it services coincident high demands for hot water and space cooling. The FY2016 4th quarter milestone report for this project [1] showed that the highest utilization occurs when the AS-IHP is located in the hot-humid and hot-dry/mixed-dry climate regions [2]. Climate regions are defined by the U.S. Department of Energy (DOE) Building America (BA) program as adopted by CBECS [3]. The hot-humid and hot-dry/mixed-dry regions comprise entirely or partially the following 18 states: California, Nevada, Arizona, Utah, New Mexico, Colorado, Texas, Oklahoma, Louisiana, Arkansas, Mississippi, Alabama, Georgia, Florida, South Carolina, North Carolina, Puerto Rico, and Hawaii. A graphical representation of climate regions is shown in Figure 1.

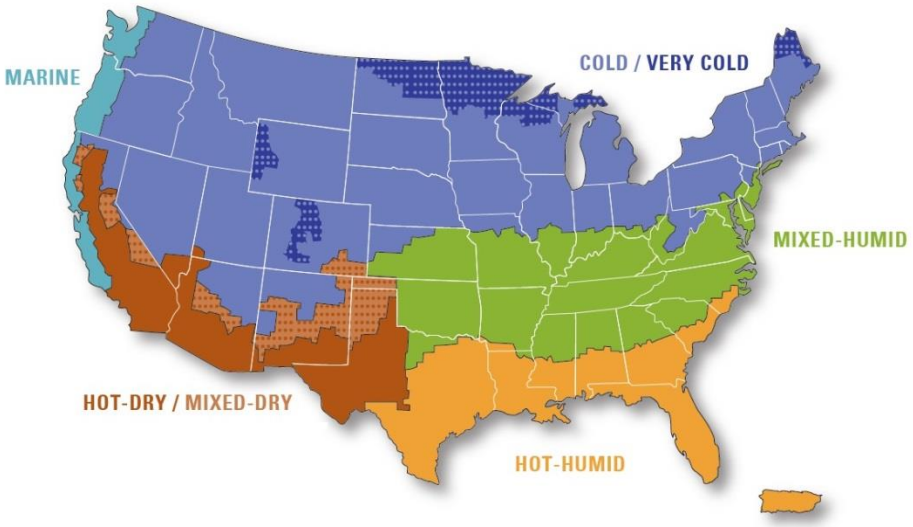

Figure 1. Climate regions designation as adopted by CBECS 2012.

U.S. commercial building electric energy markets for 2030 using the BTO Market calculator [4] were estimated for the two warmest climate zones. We did not consider gas energy markets in these estimates. Table 1 gives the building categories with the largest water heating energy markets relative to their space cooling and heating markets in the target climate regions - education, food service, health care, lodging, and mercantile/service. The food sales building category (including supermarkets, etc.) was not considered because it was assumed that all of the hot water needs for these buildings would be supplied by heat recovery from their large food refrigeration systems.

Table 1. Water heating and space cooling electric energy market estimates for 2030 for selected commercial building categories in the two warmest climate zones

Category	Water heating, TBtus	Space cooling, TBtus	Space heating, TBtus
Education	20.0	47.6	16.0
Food service	14.2	76.5	7.6
Health care	4.7	13.5	3.6
Lodging	12.9	17.7	8.6
Mercantile/service	57.6	140.7	46.5
Totals	109.4	296.0	82.3

The food service category (full service and quick service restaurants) may be the most logical initial end use application for the commercial AS-IHP technology. Figure 2 shows that food service buildings have the highest energy intensity among all the commercial building types [5]. Figure 3 [5] shows Annual Sector Hot Water Load in California measured in acre-foot hot water volume, which indicates that full service restaurants have much more hot water consumption the other building types.

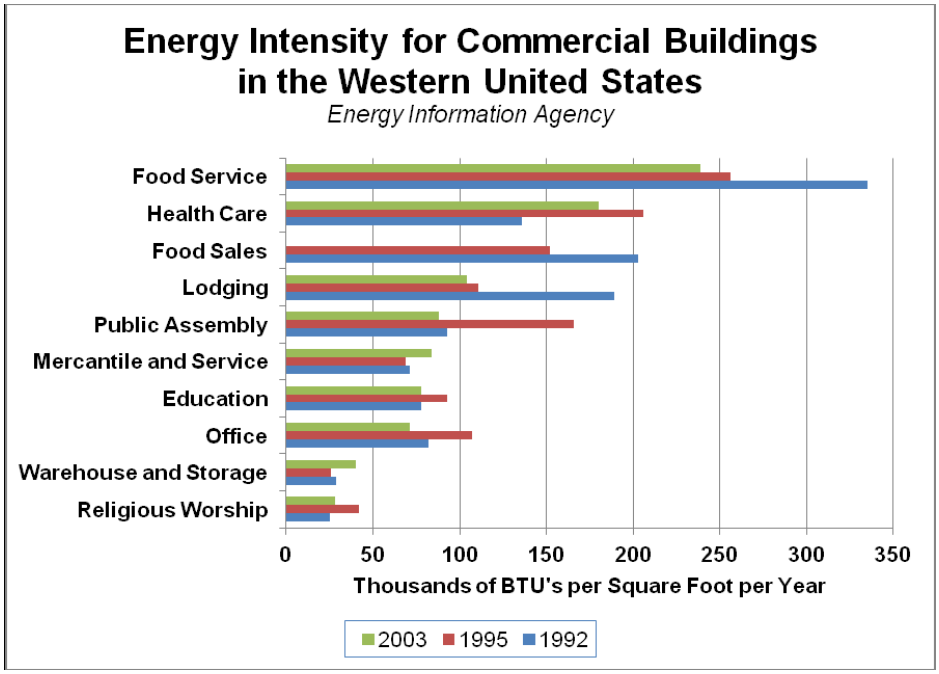

Figure 2. Energy Intensity for Commercial Buildings [5]

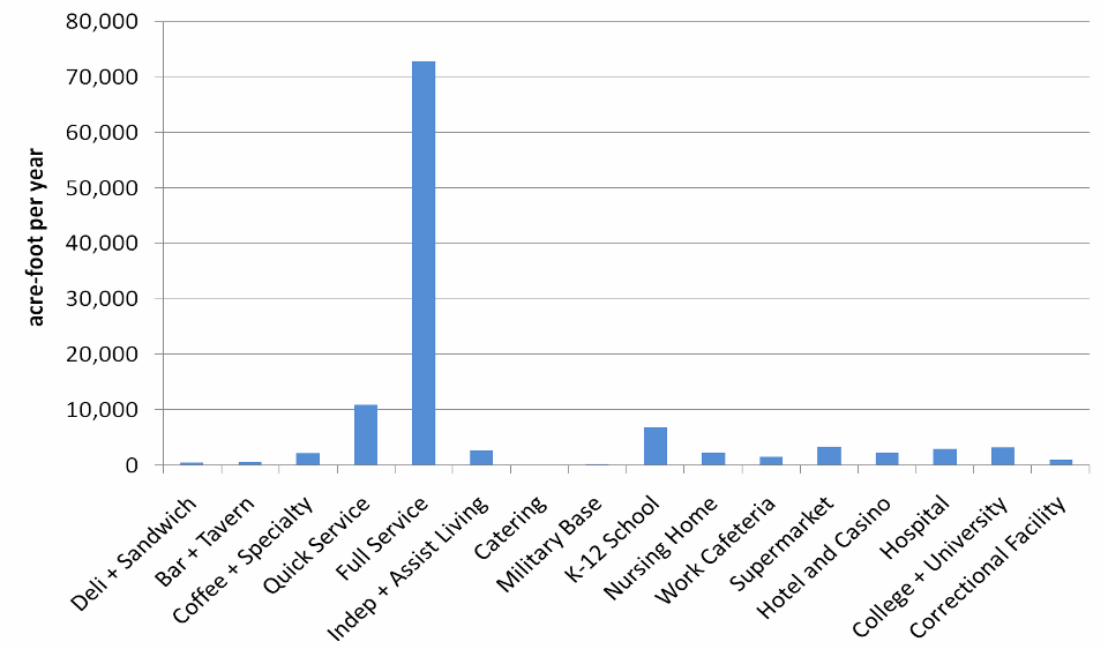

Figure 3. Annual Sector Hot Water Load in California (Y-axis means hot water use in volume of acre × foot) [5]

In food service, the hot water system is designed to deliver water at temperatures typically ranging between 120°F and 140°F to faucets and equipment. An exception is hand sinks where the water temperature may be reduced to 100°F. Figures 4 and 5 show costs of heating 1,000 gallons of water by 55°F and 120°F, respectively using gas or electricity at different rates [5]. Previous studies of AS-IHPs in residential applications in hot-dry or hot-humid locations have indicated they can reduce energy use for water heating by 72-76%. Assuming the commercial AS-IHP can reduce water heating energy use by 75% on average in these climate regions, the cost to heat 1000 gallons of water by 55F for a 26 cents/kWh rate would drop from ~$37 to ~$9.25.

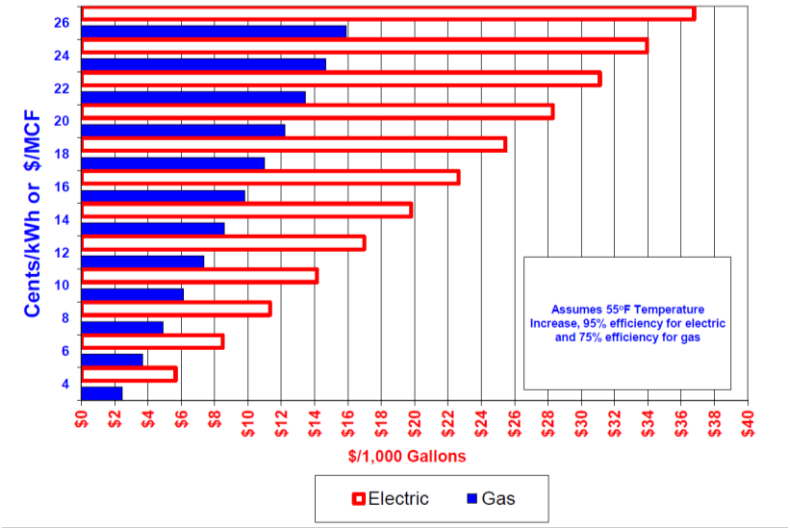

Figure 4. Costs of Heating 1,000 Gallons of Water by 55°F [5]

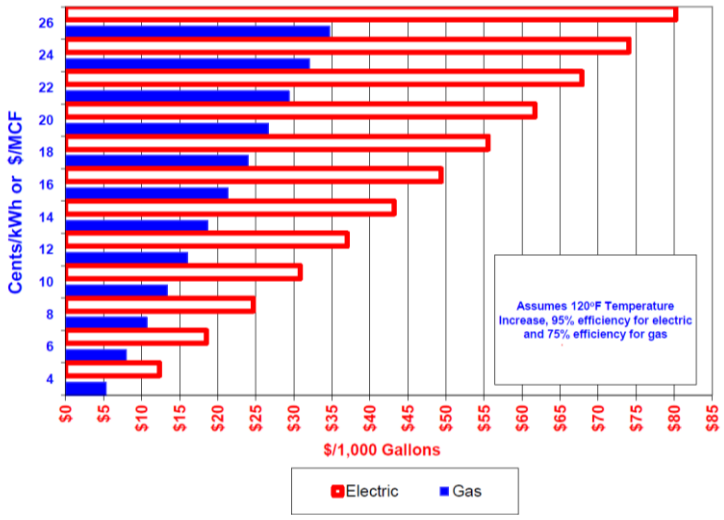

Figure 5. Costs of Heating 1,000 Gallons of Water by 120°F [5]

Table 2 presents hot water uses and utility costs in a typical quick service restaurant and full service restaurants [6]. Based on the information presented in Table 2 along with that in Figures 3-5, it may be assumed that the commercial AS-IHP would achieve the shortest payback periods and most noticeable energy savings in restaurants, especially full service types.

Table 2. Hot Water Uses and Utility Costs [6]

	Water Use (gal/d)	Gas Use (therms/yr)	Water/Sewer Cost*	Gas Cost**	Electricity Cost***	Annual Utility Cost
Quick Service	500	1400	$2,000	$1,500	-	$3,500
Full Service	2500	8800	$9,800	$9,700	$150	$19,650

California 2009 nominal utility rates: *$8.00/unit for water and sewer
**$1.10/therm for natural gas
***$0.15/kWh for electricity (recirculation pump)

Maximum Market Estimate for Target Climate Zones

According to the CBECS 2012 there were a total of 5.557 million commercial buildings in the U.S. of which 41.5% were in the five categories listed in Table 1 [3]. In the hot-humid region there were 799,000 buildings and in the mixed-dry/hot-dry region there were 837,000 buildings. Together these categories represent 29.4% of total commercial buildings. We used this number to estimate the number of suitable commercial buildings in these region sat ~678,000. According to CBECS 2012, 28% of commercial buildings used residential-type air conditioners, 13% used individual air conditioners, 34% used packaged air conditioners, and 2% used swamp coolers for space cooling. In total 77% of commercial buildings used their own dedicated space cooling equipment. Hence we estimate a maximum available market of ~522,000 units based on the number of buildings that use their own dedicated cooling equipment. This total includes ~87,000 food service buildings.

Competition

Historical Cooling Equipment Shipments

Cooling equipment shipment data on a national level is provided by various organizations. However, the publicly available data are not broken down by climate region. The project team estimated the distribution of cooling equipment shipment by climate region in order to provide a clearer idea of the total market

share for which the AS-IHP could compete. Total commercial AC shipments for 2010 through 2015 are shown in Figure 1. This shipment data was provided by the Air Conditioning, Heating, and Refrigeration Institute (AHRI) [7].

CBECS 2012 provides information on the number of surveyed buildings in each climate region that used individual air conditioners and packaged air conditioning units for space cooling [8]. The number of surveyed buildings that used this equipment in the hot-humid climate region was 411,000 buildings and in the hot-dry/mixed-dry region that number was 471,000 buildings. The total number of buildings that used this equipment in all climate regions was 2.696 million buildings. Thus we inferred that 32% of commercial AC shipments were directed to the hot-humid and hot-dry/mixed-dry climate regions. The estimated number of shipments to these climate regions was added to Figure 1.

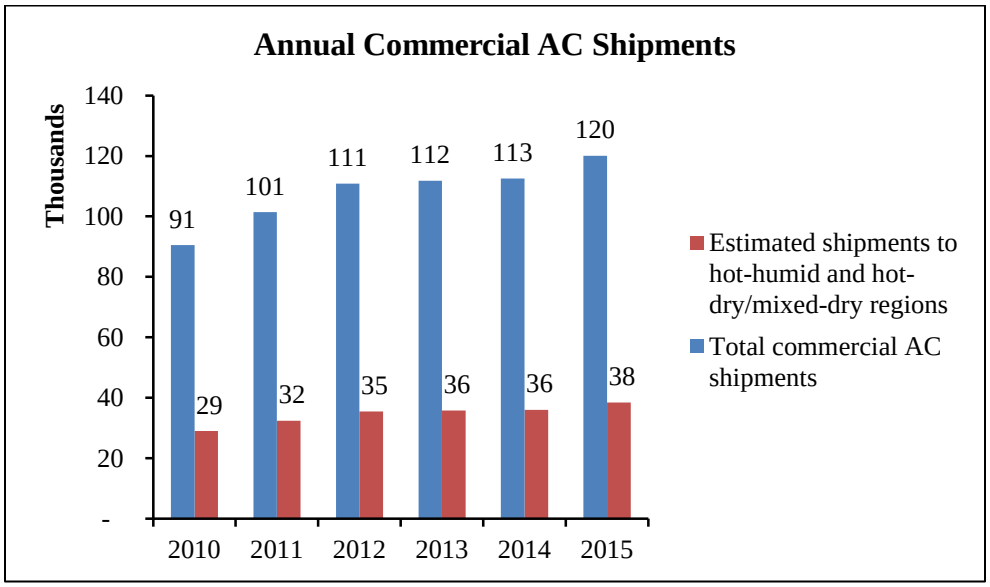

Figure 1. Annual commercial AC shipments, 2010-2015.

Water Heating Equipment Shipments

Water heating equipment shipment data was also obtained from AHRI historical shipments data [9]. Total commercial gas- and electric-water heaters shipments for 2010 through 2015 are shown in Figure 2. This data is not broken down by climate region. We tried to estimate the number of water heater shipments to the hot-humid and hot-dry/mixed-dry climate regions in a manner similar to the estimate of the commercial AC shipments above.

CBECS 2012 provides data on the number of surveyed buildings that used centralized water heating systems in each climate region [10]. In the hot-humid climate region 431 buildings used centralized water heating system and in the hot-dry/mixed-dry region 457 buildings did. The total number of buildings in all climate regions that used centralized water heating systems was 3,347 buildings. The combined number of buildings in the hot-humid and hot-dry/mixed-dry climate regions that used centralized water heating systems represents 27% of all buildings in all climate regions. Thus, we inferred that 27% of the water heater shipments were directed to the hot-humid and hot-dry/mixed-dry regions. The estimated number of shipments was added to Figure 2.

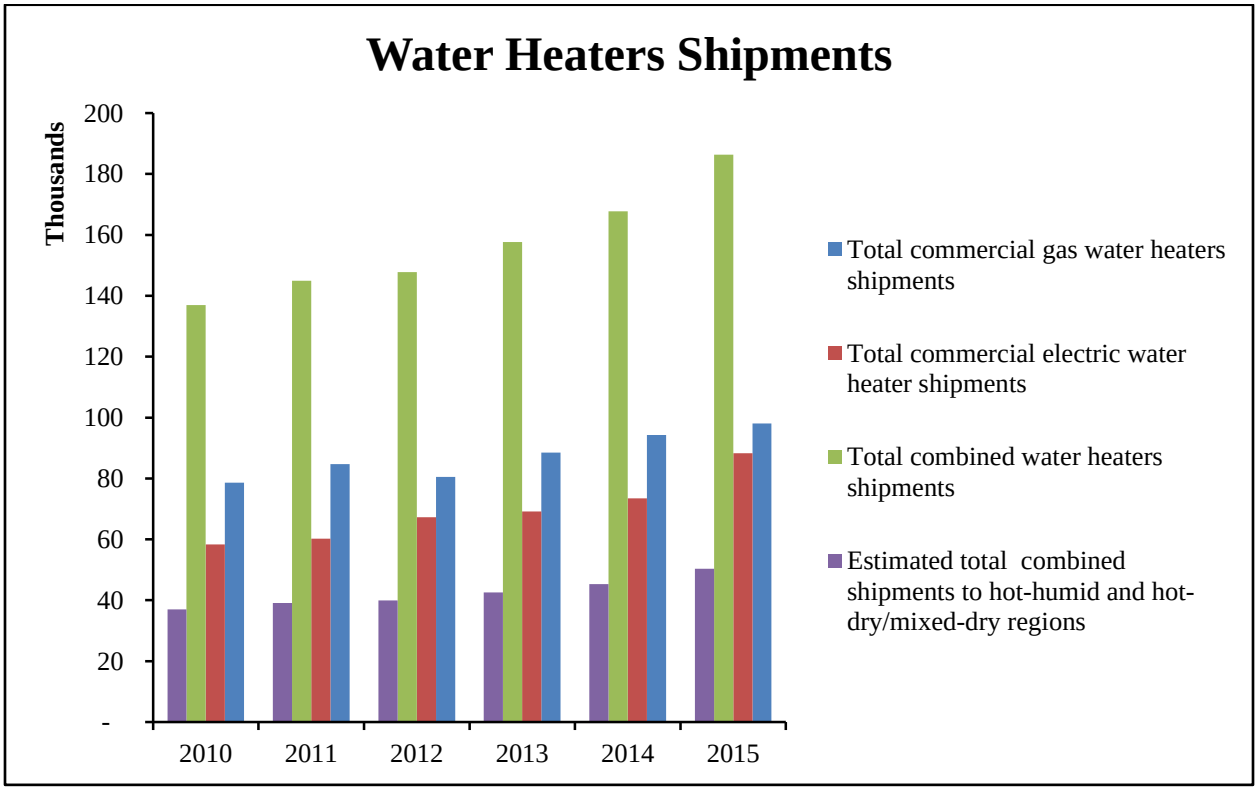

Figure 2. Historical water heater shipments – 2010-2015.

Potential Initial Market Estimate

To estimate a potential initial or "early" market for the AS-IHP, we considered the replacement ratio of the currently installed commercial AC and water heating equipment in food service buildings in the hot-humid and hot-dry/mixed-dry climate regions. According to the BTO Buildings Energy Data Book the median lifetime of commercial AC is 15 years, the median lifetime of hot-water boilers is 24 to 35 years and the median life of hot-water unit heaters is 20 years [11]. Since the AS-IHP replaces both the AC and the water heating equipment, we assume that the potential market is all buildings that are between 15 and 35 year-old. CBECS 2012 provides data on year of construction for commercial buildings - shown in Figure 3.

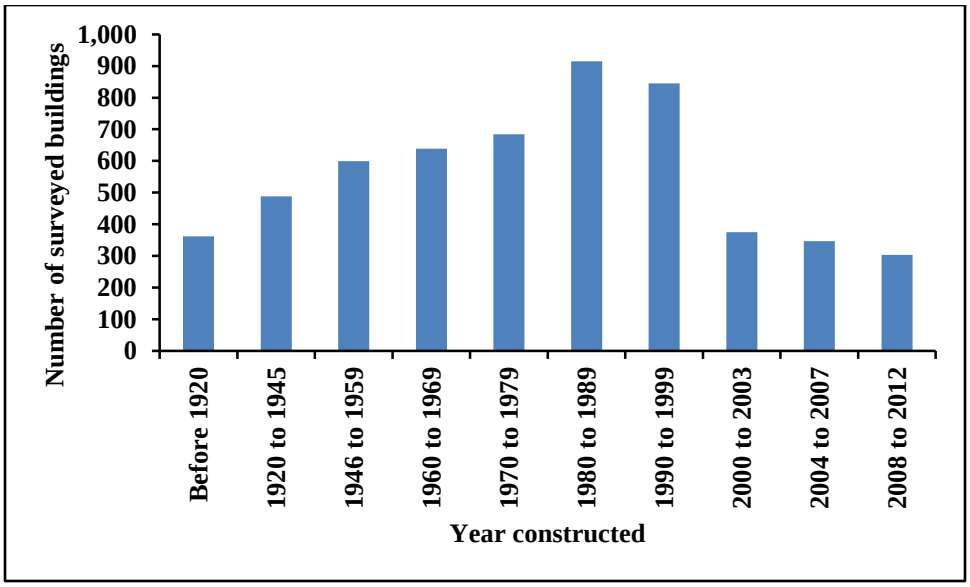

Figure 3 Number of buildings by time construction.

The ratio of buildings that were between 15 and 35 years old was calculated using this data as 26%. Therefore, we estimate that an early market for the AS-IHP could potentially be ~136,000 of the target building types including ~23,000 food service buildings.

Potential Energy & CO_2 Emissions Savings Estimate

Compared to baseline electric water heating equipment used in commercial buildings the AS-IHP is expected to provide 75% energy savings per unit. It is also expected to provide at least 50% savings for space heating and cooling on average compared to current electric HVAC systems. Based on these per unit savings and the energy markets identified in Table 1, the maximum technical potential savings for the commercial AS-IHP is ~270 TBtus (0.27 quads) annually, equivalent to ~13.9 MM Ton CO_2 emissions reduction. For the "early" replacement market the savings estimate is ~70 TBtus/y. For food service buildings only, the maximum and "early" replacement savings are ~53 TBtus/y and ~14 TBtus/y, respectively.

Conclusion

An analysis was presented to show the potential market size for the commercial air-source integrated heat pump with thermal storage (AS-IHP). The analysis focused on five target building types in the hot-humid and hot-dry/mixed-dry climate regions – education, food service, health care, lodging, and mercantile/service. The analysis estimated "early" potential annual shipments for initial replacement systems of ~136,000 to buildings constructed within the past 15 to 35 years. The maximum market potential was estimated at ~522,000 shipments. For food service buildings only, the shipment totals in the two categories are ~23,000 and ~87,000, respectively.

References

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