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US Heat Pump Market Overview–2020

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Abstract

This paper provides an overview of the US heat pump market in 2020; discusses the key drivers and challenges that have been shaping the market; and discusses the underlying factors that are setting the direction for the research, development, and commercialization of heat pumping technologies in the United States. Following the 2006–2007 housing market collapse, the US heat pump market has shown steady growth since 2010. Air-source heat pump shipments reached nearly 3 million in 2018, a 12.2% increase over 2017 versus the 7.1% estimated growth rate of the global heat pump market. Owing to the recovering economy, growing construction market, relatively stable electricity prices, numerous financial incentives, and technological advancements, the demand for heat pumps has been increasing. The current focus of heat pump research and development in the United States includes development of next-generation systems and components, lower global warming potential refrigerant alternatives, and reduced cost for premium-efficiency technologies. The future heat pump market and technologies will be highly influenced by increasingly stringent minimum efficiency standards, incentive programs, technological innovations, and the national and global economy.

Keywords: Heat pumps; shipments; US market; construction market; research and development; efficiency standard

1. Heat Pump Market

1.1. Market trend

The market for heat pumps in the United States has shown healthy growth since 2010 following the 2006–2007 housing market collapse. Figure 1 shows the new single-family heating system market combined annual penetration rate of air-source heat pumps (ASHPs) and ground-source heat pumps (GSHPs). The market share of the ASHP and GSHP systems hovered between 20–30% from 1978 to 2005; since then it has relatively steadily increased to 41% [1]. In the US space heating market, heat pumps primarily compete with natural gas furnaces in addition to other traditional heating appliances like boilers, direct electric heating, etc. Figure 2 shows the annual shipments of ASHPs, gas warm air furnaces, oil warm air furnaces, and unitary air conditioners. ASHP shipments have shown a general increasing trend since 1998. From 2000 to 2006, annual ASHP shipments increased nearly 60% to 2.1 million units, then dropped and leveled off to about 1.7 million units annually between 2007 and 2013 during the housing market crash and recovery. In 2014, annual ASHP shipments surpassed the 2006 peak and have steadily increased in the intervening years, reaching nearly 3 million in 2018, while gas warm air furnaces have yet to fully recover to their 2006 shipment levels. Gas furnace shipments still outnumber ASHP shipments but the gap is much narrower.

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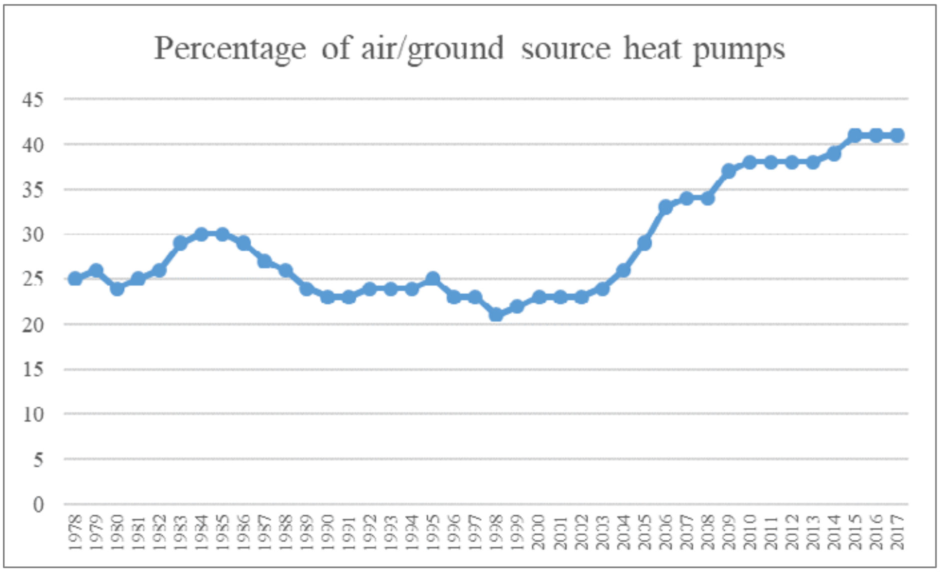

Figure 1 Penetration rate of heat pumps [1]

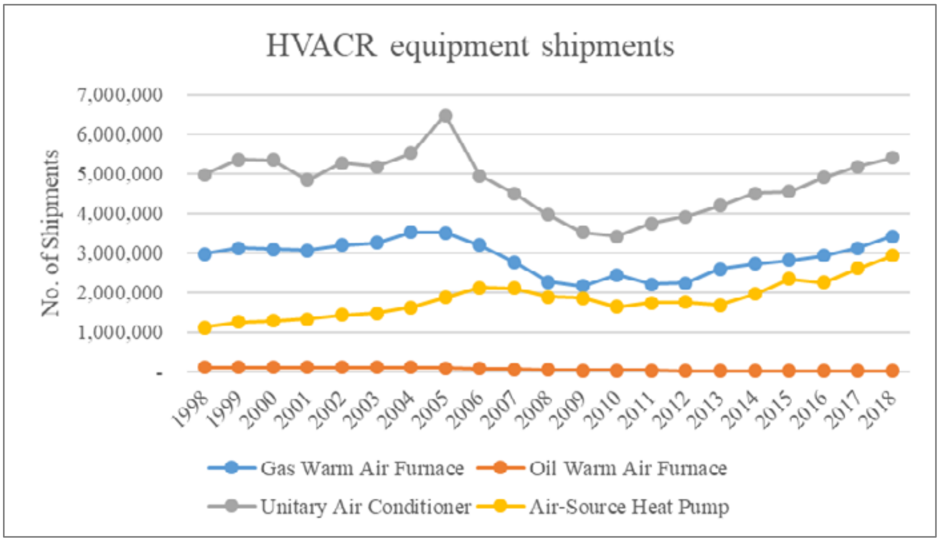

Figure 2 Heating, ventilation, air conditioning, and refrigeration (HVAC&R) equipment shipments [2]

Figure 3 illustrates the trend of annual shipments/installations of GSHPs based on 2003–2009 shipment data from the US Energy Information Administration (EIA) and 2010–2015 shipment estimates based on EnergyStar unit shipment and market penetration reports [3], [4]. Shipments of GSHPs have steadily increased since 2003, partly due to a 30% federal tax credit placed in service after 2008 and lasting through December 31, 2016. The federal tax credit was recently reinstated and will be available until 2021.

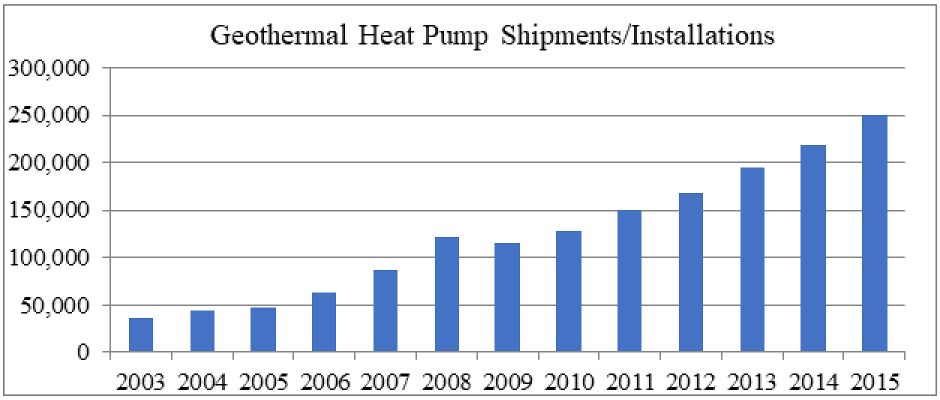

Figure 3 Geothermal heat pump shipments/installations [3], [4]

1.2. Market segments: residential, commercial, and industrial sectors

Despite the US housing market crisis in the late 2000s, heat pumps steadily increased their share of the new home market since 2004, reaching 41% in 2017 compared with only 25% in 1978 for single-family housing, as shown in Figure 1. As for multifamily housing, heat pump share was up to 48% in 2017, whereas competing technologies (forced-air furnace and hot water or steam heating) remained at 37% and 8%, respectively [1].

Similar to the residential market, commercial HP and air conditioner (AC) shipments (above 19.0 kW in capacity) in the United States have experienced some volatility over the past two decades due to economic conditions, fluctuating fuel prices, etc. Since the bottom of the market in 2009, total commercial HP and AC shipments have increased by 49% back up to slightly more than the 2006 level, approximately 312,000 units in 2017 and 2018 [2].

Total industrial HP installations in the United States was estimated at about 2,300 in 1994, growing to a conservatively estimated 5,000–7,000 by 2015/2016. Installations with lumber drying applications were responsible for about 75% of this total. Declining natural gas prices relative to electricity prices is the biggest impediment to this market, along with the 2006–2010 recession.

As mentioned previously, for building comfort cooling and space heating applications of ACs and HPs in the United States, the residential and commercial markets account for 96% and 4% of the total market, respectively; these percentages have varied only slightly (by 2%) over the past 18 years. The percentage distribution by capacity (Figure 4) has also stayed fairly consistent for decades as illustrated in [2].

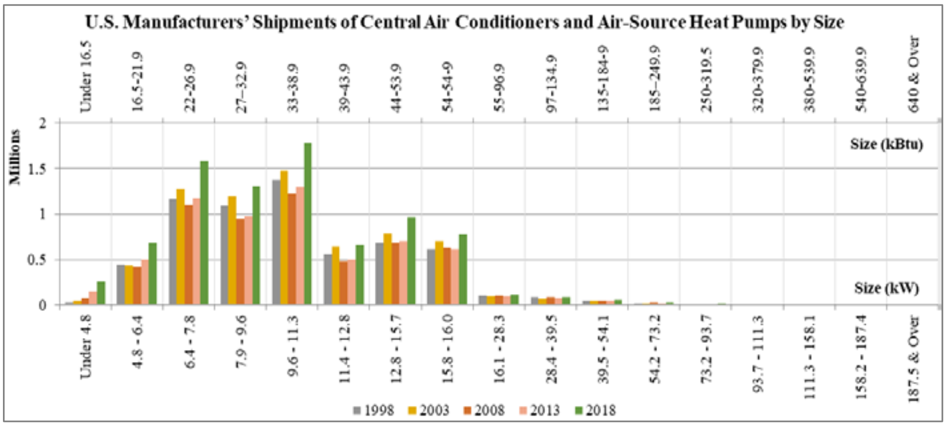

Figure 4 Central AC and ASHP shipment during 1998–2018 by system capacity [2]

2. Market Drivers

The primary appeal of heat pumps in the United States is the increased efficiency, which in turn saves energy and operating costs. Furthermore, it offers both heating and cooling functions, allowing consumers to potentially consolidate their equipment purchases. Also, the heat pump (electric) is the only option for some regions in the United States where natural gas is still not available to some residential and commercial building customers.

2.1. Electricity price

Electricity prices for residential building customers have gradually risen over the 2007–2018 period (Figure 5), whereas prices for other sectors (commercial buildings, transportation, and industry) remain relatively level or even slightly decreased. This trend is a barrier for the penetration of HP in residential sector. However, it drives the research and development (R&D) to improve the performance and efficiency.

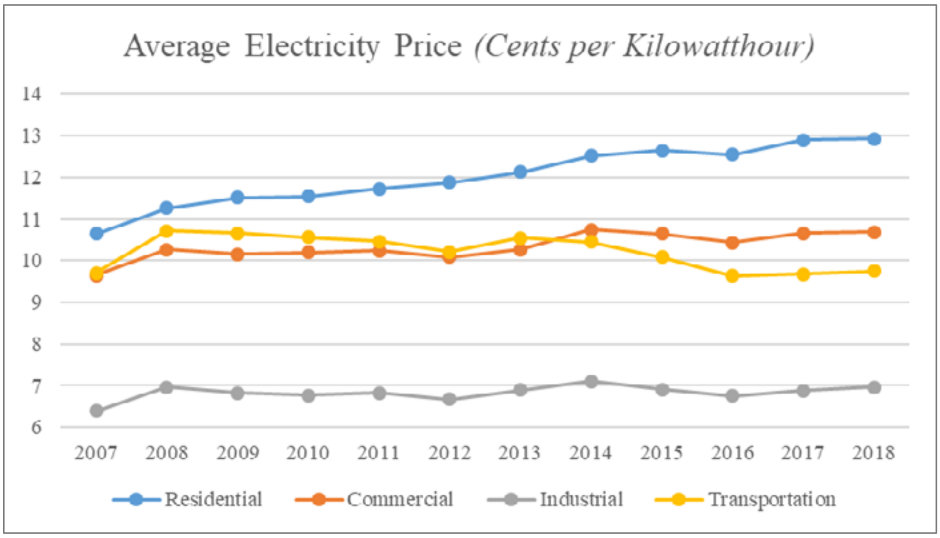

Figure 5 Average electricity price [5]

2.2. Installation cost

Comparisons of retail equipment cost, total installed cost, maintenance cost, and average life of HP technologies with other competing heating technologies for residential and commercial space heating and water heating (WH) are shown in Figure 7, respectively. These are obtained from the EIA's 2018 report on Technology Forecast Updates [6]. The underlying data is based on generic industry products from 2017 including government, R&D organizations, and manufacturers.

The cost comparison plots on the left side axes of the plots in the two figures show the min-max retail equipment cost ranges and total installed cost ranges (plotted along the primary vertical axis) for the typical capacity (plotted along the secondary vertical axis) of each technology type. Installed cost of the heat pump technologies are somewhat higher than those of most of the competing heating technologies. For the ground-source systems, the cost is driven by the drilling, trenching, and other activities required to install the ground loop heat exchanger. One significant advantage for the heat pumping options is that they can provide cooling in the summer as well while other space technologies require separate cooling system, which incur additional cost.

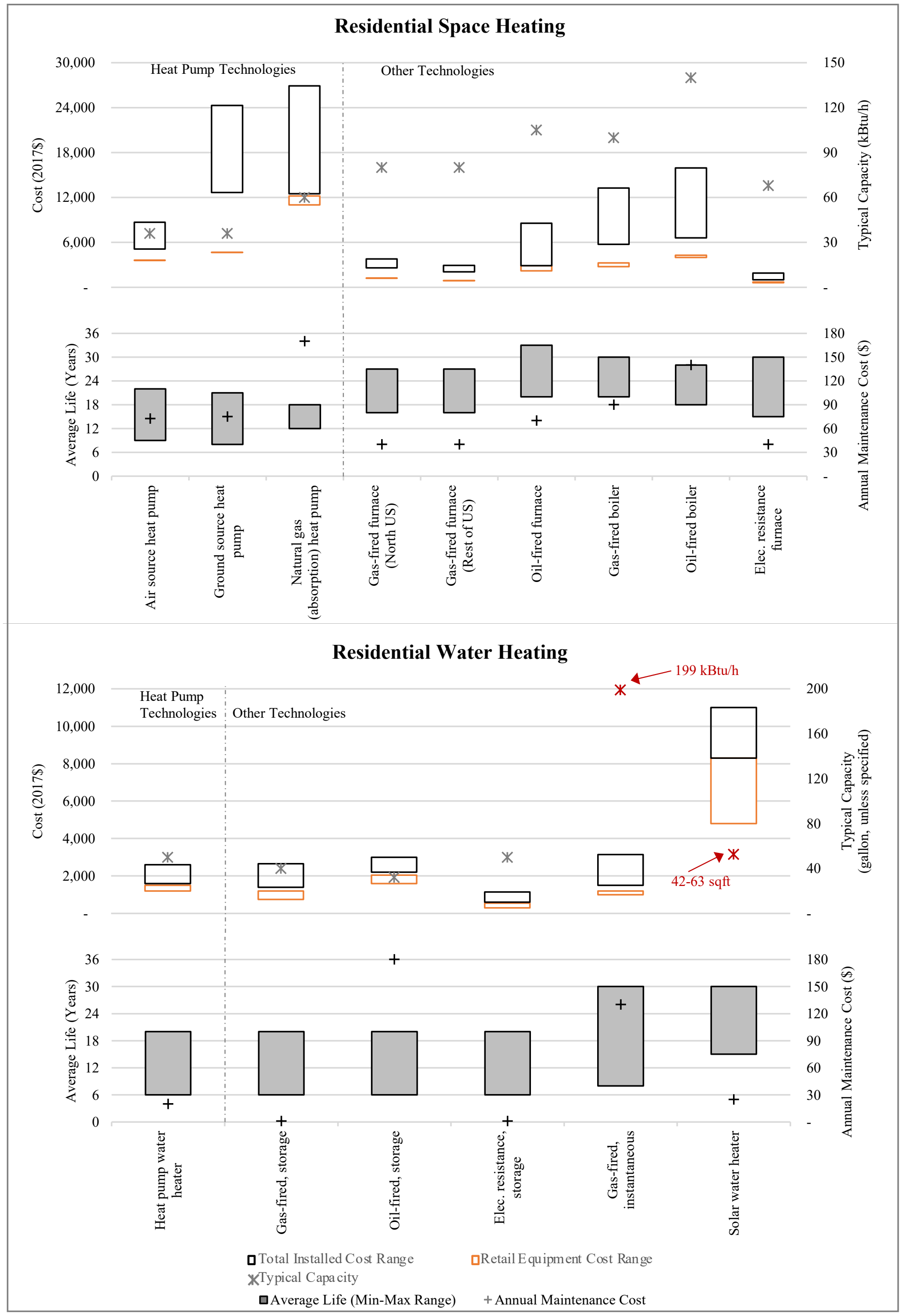

Figure 6 Comparison of heat pump technologies to other technologies: total installed costs with typical capacities and maintenance cost with average life for residential space heating (top) and water heating (bottom) [6].

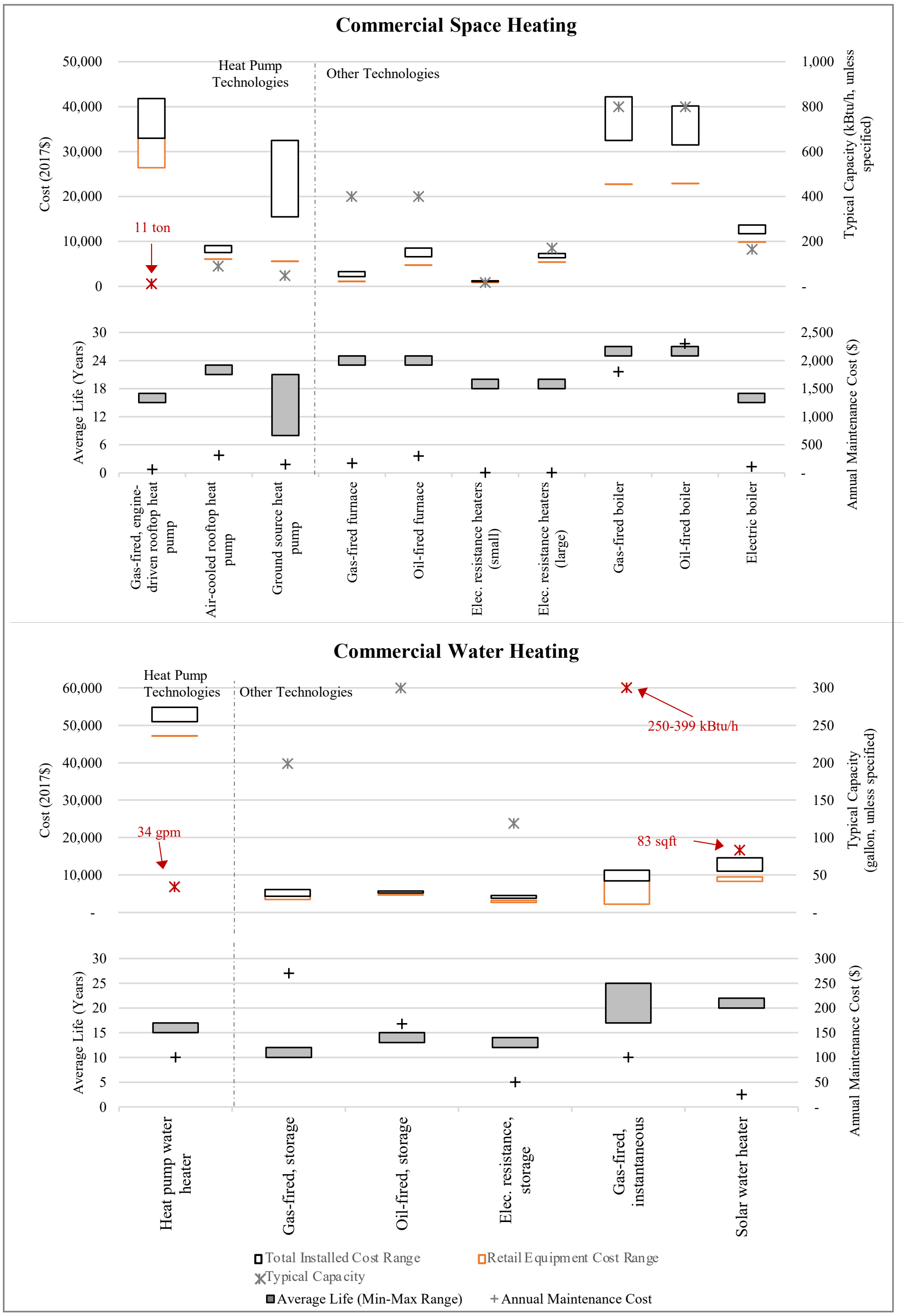

Figure 7 Comparison of heat pump technologies to other technologies: total installed costs with typical capacities and maintenance cost with average life for commercial space heating (top) and water heating (bottom) [6].

The lower plots in each section of the two figures show the min-max ranges of average life (plotted along the primary vertical axis) and average annual maintenance cost (plotted along the secondary vertical axis) for each technology type. Heat pump technologies have average life comparable to other competing technologies and are on the lower maintenance cost regime.

2.3. Financial incentives

HPs have grown in popularity over the past few decades and are now well known to the general public. This increase in awareness was supported by utility and state incentive programs that encouraged deployment of the technologies. Several federal and state-level financial incentives and utility programs for consumers and businesses are available that support HP technologies. Figure 8 shows the total currently active financial incentives and regulatory policies in the United States listed under the Database of State Incentives for Renewables & Efficiency (DSIRE) [7] for HPs including GSHPs. As shown, a large number of rebate and loan programs sponsored by states and utilities exist. Other common mechanisms include tax incentives and tax credits, financing, and grant programs.

Specific to HP technologies, GSHPs qualify for renewable energy tax incentives, whereas no explicit policies or incentives exist for fuel-driven HPs. Numerous appliance and home efficiency programs are in place, which do not specify a technology but support any system, equipment, or appliance that meets the minimum efficiency level (including HP systems). In addition, a few entities provide financial incentives for installers for business development [8].

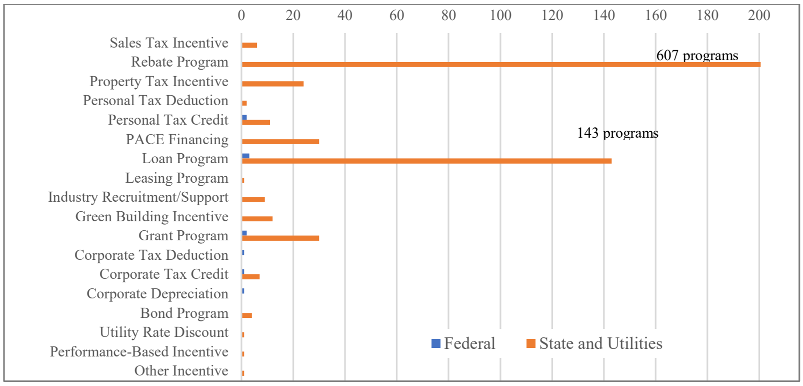

Figure 8 Financial incentives

2.4. Regulatory policy

Figure 9 shows the currently active regulatory policies listed under DSIRE [7] for HP technologies, most of which are enforced by states. On the federal level, the US Department of Energy (DOE) continues to push for elimination of lower efficiency products by implementing more stringent minimum performance regulations, legislation, and standards such as the "Energy Policy Act of 2005 (EPAct 2005)" and the "Energy Independence and Security Act of 2007" (EISA 2007). ENERGY STAR is a voluntary program managed by the US Environmental Protection Agency (EPA) and DOE to promote the eco-friendly industry and cost saving through energy-efficient products. Table 1 summarizes the status of minimum energy performance standards for different HP technologies. The minimum energy performance standards for each technology are provided in the Appendix.

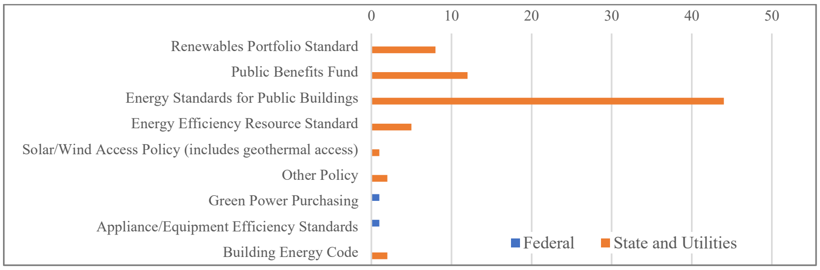

Figure 9 Regulatory policies

Table 1. Status of Minimum Energy Performance Standards for Different HP Technologies [9], [10]

HP Technology		**Federal Standard**	**ENERGY STAR Criteria**
Residential	ASHP	Current standards (for central systems) took effect in 2015. See Table A-1	More stringent requirements. See Table A-1
	GSHP	14.1 EER, 3.2 COPh; Current standards (for WSHP[a]) took effect in 2015	See Table A-2
	Air source absorption heat pump	Currently, not covered by NAECA[b]; CEC[c] Title 24 specifies cooling efficiency requirements	
	Heat pump water heater	See Table A-3	See Table A-3
Commercial	Gas-fired, engine-driven rooftop heat pump	Currently, none	
	Air-cooled rooftop heat pump (large ASHPs)	Amended standards in terms of IEER took effect in 2018. More stringent standards will take effect in 2023. See Table A-4	See Table A-4
	GSHP	14.1 EER, 3.2 COPh; Current standards (for WSHP) took effect in 2015	None; Criteria for GSHP apply only to residential applications
	HPWH	Currently, none	Under revision; the public final draft specifies 3.0 COPh

[a]WSHP = Water Source Heat Pump.
[b]NAECA = National Appliance Energy Conservation Act.
[c]CEC = California Energy Commission.

2.5. Technology deployment support

Several trade organizations exist in the United States to promote the deployment of HP technologies with high-quality installations and servicing with industry partners including distributors, vendors, and suppliers. Among these are the Geothermal Exchange Organization [11] and associations in different states, such as Louisiana [12], Minnesota [13], Virginia [14], Colorado, California, and New York [15], and NYSERDA [16]. The California Geothermal Heat Pump Association [17] strives for penetration of the HP into residential and commercial areas while collaborating with the California Energy Commission and the California Public Utility Commission for net zero energy building. There are several regional associations also promoting HP technologies. The Northeast Energy Efficiency Partnerships [18] has programs promoting cold climate ASHPs and HP water heaters (HPWHs) in the northeastern region of the United States. The Northwest Energy Efficiency Alliance has an active program promoting HPWHs [19]. The Electric Power Research Institute has developed an advanced HP specification featuring smart grid response requirements [20].

2.6. Workforce training and education

Some private companies provide classroom and online training for HVAC technicians on HP installation, operation, maintenance and troubleshooting [21][22]. International Ground Source Heat Pump Association (IGSHPA) runs a certification program for GSHP installers and designers [23]. The North American Technician Excellence organization is the largest in the United States for HVAC&R technician certification [24].

3. Overarching R&D in HP Technologies

3.1. Research infrastructure

Within DOE, R&D of HP technologies is supported by the DOE Building Technology Office's (BTO's) HVAC/WH/Appliances Subprogram. This subprogram engages with hundreds of internal and external partners including national laboratories, universities and institutes, industry, small businesses, building owners and operators, other DOE offices and federal agencies, state and local governments, nonprofits, international organizations, and other entities, as well as other subprograms within BTO, to reduce barriers to greater market adoption of premium efficiency technologies (see Figure 10).

DOE's national laboratories provide unique infrastructural support to R&D of HP technologies including modeling capabilities, test beds and simulation platforms, energy system integration facilities, as well as support to regulatory activities. Organizations such as ASHRAE and the Air-Conditioning, Heating, and Refrigeration Technology Institute (AHRTI) also contract R&D to universities, research institutes, and others in the United States and worldwide.

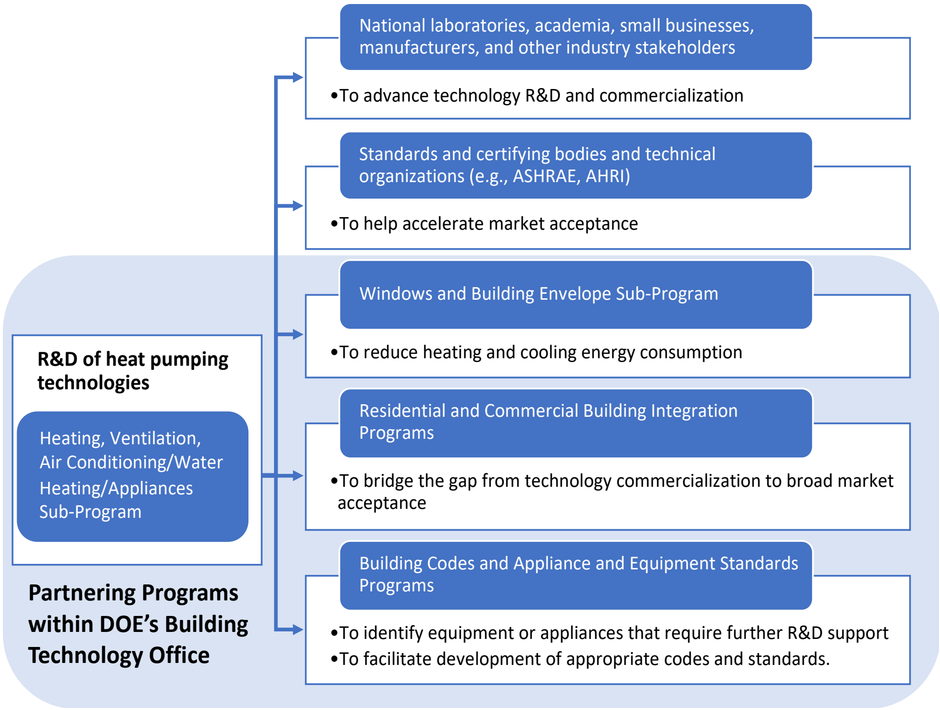

Figure 10 DOE's partners for heat pump R&D [25]

3.2. Research direction

DOE's Multi-Year Program Plan [25] identifies challenges and provides a roadmap for R&D and market simulation. The following are the key challenges for the HP in the R&D, demonstration, and adoption of current and developing HVAC and WH technologies:

- High cost and lack of sustained performance/reliability of high-efficiency systems compared with conventional systems.
- Unrealized design potential of the systems when built out of generic components. Opportunity exists for improved energy and nonenergy performance of many current systems via tailor-made components with advanced materials and designs, though at a higher cost.

- Increasing emphasis on advancing development of nontraditional and advanced vapor compression cycle technologies. Reducing the global environmental impacts of building HVAC&R and WH equipment and systems with advanced technology is extremely challenging.
- High manufacturing costs or lack of manufacturing methods for new components or technologies.

3.3. Research topics

Since 2017, the DOE focus for building energy efficiency R&D, including HPs and HP-related systems, has been increasingly toward advancement of technologies at lower technology readiness levels (TRLs) [25]. So there has been activity on nontraditional cooling and refrigeration technologies (magnetocaloric, elastocaloric, thermoelectric, etc.) and advanced compression technologies (e.g., electrochemical compression). R&D also continues on alternative lower global-warming potential (GWP) refrigerants as well as the low (or zero) GWP alternative technologies. Some work continues in collaboration with manufacturers on maximizing the efficiency of HPWH using lower-GWP refrigerants (moderate to higher TRLs).

The following specific research objectives/topics related to HP technology are being pursued by DOE [25]:

1. Develop and introduce next-generation, transformative technologies for the future such as nontraditional cooling cycles and advanced vapor compression system and component (compressors, heat exchangers, etc.) technologies.
2. Reduce barriers to greater market adoption of premium-efficiency technologies in the near term by refining and reducing the cost of available technologies, including HP technologies for space conditioning and WH.
3. Pursue system-oriented solutions to optimize whole-building energy use. R&D priorities include developing integrated systems that combine end uses, such as energy cascading, as in integrated HP technologies (including ASHPs, GSHPs, and multifunction natural gas–driven HPs).
4. Explore new or different next-generation components to find the best possible cost-effective combinations that have the potential to fully replace or be integrated with conventional technologies, often across end uses.
5. Advance regional solutions to improve the performance of HPs in cold and hot-humid climates (e.g., cold climate heat pump research).
6. Develop advanced vapor compression systems with low- or zero-GWP.
7. Develop HPWH technologies (e.g., electric HPWH with low-GWP; Absorption HPWH; non vapor compression HPWH units, low-GWP solutions).

4. Summary and Outlook

The US HP market has shown steady growth since 2010 following the 2006–2007 housing market collapse. HP shipments have been growing at a faster pace over the past several years relative to competing space heating technologies. The use of ASHPs in cold climates is becoming more feasible through promising R&D and market developments. Current R&D emphases are primarily on advancing development of (1) nontraditional cooling/refrigeration cycles and (2) alternative or advanced compression cycle technologies but also on (3) lower GWP refrigerant alternatives to cope with environmental concerns. Governmental actions, along with public and private-sector incentive programs, promote deploying more efficient HP systems. The future of HP technologies will be highly influenced by the stringent minimum efficiency standards, R&D for advancing nontraditional technologies and alternative lower GWP refrigerants, and tax credits and incentive programs.

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Appendix

Table A-1. Standard for Residential Air-Source Heat Pump [6]

Residential ASHP Product Class	Current Federal Minimum Efficiency Standards			Current ENERGY STAR Criteria		
	Min.SEER	Min.HSPF	Max. Off Mode Power (W)	Min.SEER	Min.EER	Min.HSPF
Split-System	14	8.2	33	15	12.5	8.5
Single-Package	14	8	33	15	12	8.2
Small-Duct, High Velocity	12	7.2	30	-	-	-
Space-Constrained	12	7.4	33	-	-	-

Note:

- Units for SEER, HSPF and EER are in Btu/Wh (divide by 3.412 to get equivalent dimensionless values).
- For split-system air conditioners (cooling only), the minimum SEER increased to 14 in southern climate regions, while the 13 SEER standard established in 2006 remained effective in the north. Whereas, for split-system ASHPs, the minimum SEER increased to 14 and the minimum HSPF increased to 8.2 in all climate regions.

Table A-2. ENERGY STAR Criteria for Water-to-air Ground Source Heat Pumps

Type	Heating COP	Cooling EER
Closed Loop	3.6	17.1
Open Loop	4.1	21.1
Direct Expansion	3.6	16

Table A-3. Federal Standard and ENERGY STAR Criteria for Residential Electric Storage and Heat Pump Water Heater

Volume Range	Draw Pattern	Federal Standard[1]	Federal minimum UEF for typical sizes	ENERGY STAR
≥ 20 gal and ≤ 55 gal	Very Small	UEF=0.8808-(0.0008*Gal)	No models on the market	2.0
	Low	UEF=0.9254-(0.0003*Gal)	0.91 for a 27-gallon water heater	2.0
	Medium	UEF=0.9307-(0.0002*Gal)	0.92 for a 36-gallon water heater	2.0
	High	UEF=0.9349-(0.0001*Gal)	0.93 for a 45-gallon water heater	2.0
> 55 gal and ≤ 120 gal	Very Small	UEF=1.9236-(0.0011*Gal)	No models on the market	2.2
	Low	UEF=2.0440-(0.0011*Gal)	No models on the market	2.2
	Medium	UEF=2.1171-(0.0011*Gal)	2.03 for a 77-gallon water heater	2.2
	High	UEF=2.2418-(0.0011*Gal)	2.15 for a 82-gallon water heater	2.2

Notes:

- Standards for residential electric storage WH also apply to integrated HPWH.
- Federal standards that came into effect in April 2015 effectively mandate heat pump technology for electric storage water heaters with storage volume > 55 gallons. Thus, the standards for the >55-gallon range and all ENERGY STAR levels are only achievable through heat pump technology.

Table A-4. Federal Standard and ENERGY STAR Criteria for Commercial Air-cooled Packaged Rooftop Heat Pump (large ASHPs) [6]

Cooling Capacity (kBtu/h)	Heating Type	Federal Standard (1/1/2010~)		ENERGY STAR version 2.2 (1/1/2011~)		
		Min. EER	Min. COP at 47°F	Min. EER	Min. IEER	Min. COP at 47°F
Small (≥ 65 and < 135)	Electric resistance or none	11.0	3.3	11.3	11.4	3.35
	Any other type	10.8	3.3	-	-	-
Large (≥ 135 and < 240)	Electric resistance or none	10.6	3.2	10.9	11.0	3.25
	Any other type	10.4	3.2	-	-	-

Note:

- This values in this table are for air-cooled commercial packaged rooftop heat pumps. There are different standards for many other types of commercial heat pumps.
- In 2018, the DOE-regulated metric switched from EER to IEER, and the minimum IEER for ASHPs with electric resistance or no heating system and any other type (e.g., heat pump) are set at 12.2 and 12.0, respectively, for small capacity systems and 11.6 and 11.4 for large capacity systems. They are effective until 2022.

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