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Heat pumps in the United States: Market potentials, challenges and opportunities, technology advances

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Abstract

The US heat pump market has been affected by the socioeconomic impacts of the COVID-19 pandemic. However, the Biden administration's goal of net-zero greenhouse gas emissions by 2050 through electrification and clean energy technologies is accelerating the research, development, and deployment of heat pumps in the United States for improved energy performance, reduced greenhouse gas emissions, and wider adoption. The US heat pump market has experienced steady growth since 2010. In 2020, heat pumps surpassed gas furnace shipments for the first time, and the trend maintains through 2022. The current priority is to improve the affordability of energy and equitable access to heat pump technologies through cost reductions and further accelerate this trend. In addition, current R&D includes emphases on alternative refrigeration technology and lower–global warming potential refrigerants to reduce direct emissions. Heat pump market share is expected to grow as regulatory policies and financial incentives steer the building sector toward decarbonization. This paper reviews policies and market trends, discusses the challenges and opportunities in the current policy landscape, and reviews current research in the United States.

Keywords: Heat pumps; US policy; shipments; heat pump market; research, development and deployment; electrification

1. Introduction

The halt in manufacturing and construction activities due to partial or complete lockdown during the COVID-19 pandemic severely impacted the global economy, including the heat pump market, in 2020 [1]. In 2021, global economy recovery began. However, the growth has been fragile because of the continued pandemic and geopolitical and economic uncertainties [2]. According to the United Nations [3], the economic impacts of the war in Ukraine has had both positive and negative effects on climate action. In particular, countries have an opportunity to address high prices and resource availability concerns by accelerating the adoption of clean energy, which also strengthens the fight against climate change [3]. Specifically, heat pump technologies are receiving unprecedented priority to reduce the use of fossil fuels and vulnerability to supply disruptions in response to the global energy crisis [4].

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2. US Policies and Programs

The Biden administration's affirmatory response to international climate change agreements, including Paris Climate Accord to limit and resist climate change [5], and the Kigali Amendment to Montreal Protocol to phase down the consumption and production of hydrofluorocarbons [6], confirms a commitment toward global clean energy economy. The United States has set forth the goals to reduce greenhouse gas (GHG) emissions by 50%–52% from 2005 levels in 2030, decarbonize the US power sector by 2035, and achieve a net-zero emissions economy by 2050 [7]. Minimizing the emissions from buildings has been a priority to accomplish these goals [8]. Federal investments have been allocated to modernizing and upgrading buildings to be affordable, resilient, accessible, energy-efficient, and electrified [9]. A number of policies have been implemented, and targeted actions are taken to support heat pump technology research, expand deployment, and address supply chain vulnerabilities. Figure 1 shows a timeline of policies since 2020 that have supported the development and adoption of heat pump–related technologies.

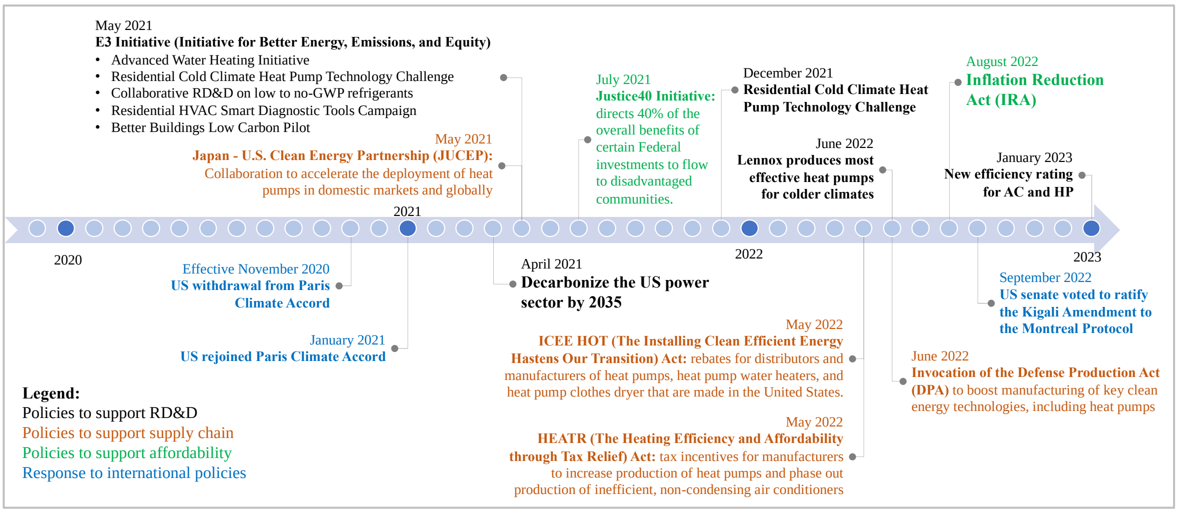

Fig. 1. Heat pump–related policies since 2020.

2.1. Policies and programs to support heat pump research, development, and deployment

In May 2021, the US Department of Energy (DOE) launched the E3 Initiative for improved energy, emissions, and equity to advance the research and adoption of clean energy technologies, including heat pumps. Initial actions under the E3 initiative included a nationwide Advanced Water Heating Initiative to increase market adoption of high-efficiency, grid-connected heat pump water heaters in residential and commercial buildings; the Residential Cold Climate Heat Pump Technology Challenge to accelerate the performance of cold climate heat pump technologies; and new collaborative research, development, and deployment efforts partnering national laboratories and manufacturers to accelerate the development of low– to no–global warming potential (GWP) refrigerants [10]. The focus of the E3 Initiative expanded to workforce solutions that ensure proper installation and maintenance through the Residential HVAC Smart Diagnostic Tools Campaign; and understanding implementation challenges through the Better Buildings Low Carbon Pilot [11].

2.2. Policies and programs to support heat pump supply chain

The United States has implemented international and domestic policies to respond to supply chain vulnerabilities and build up domestic manufacturing capacity. In May 2021, Japan and the United States collaborated under the Japan–US Clean Energy Partnership to accelerate the deployment of heat pumps in their respective domestic and global markets through support for manufacturing, training, and promotion [12]. On May 22, 2021, two bills—the ICEE HOT Act and HEATR Act—were introduced, which provide incentives for manufacturers and distributors of heat pumps [13]. In June 2022, the Defense Production Act was invoked to rapidly expand US manufacturing of five critical clean energy technologies, including heat pumps [14].

2.3. Policies and programs to increase affordability for heat pump technologies

To improve the affordability of energy and equitable access to heat pump technologies, the United States launched the Justice40 Initiative in January 2021, with the aim to direct 40% of the overall benefits of certain federal investments, including clean energy and energy efficiency, toward disadvantaged communities [15],[16]. These include R&D investments in the development of low-cost heat pump technology solutions and financial incentives for consumers. In August 2022, the Inflation Reduction Act was introduced, which offers tax credits and rebates for families to buy heat pumps and other energy-efficient home appliances, and rebates to low- to moderate-income households to electrify their homes [17].

3. Heat Pump Market

A review of the US heat pump market is presented in terms of prevalent heat pump technologies, market growth compared with competing heating and cooling technologies, and share in existing and new residential and commercial building sectors. Potential factors such as climate, energy price, efficiency standards, and financial incentives that impact the heat pump market are discussed.

3.1. Shipment

As shown in Figure 2, US heat pump market shipments predominantly comprises air source heat pumps. Heat pump water heaters, water loop heat pumps, and ground source heat pumps comprised a little over 7% of heat pump sales in 2022 [18]. More than 96% of air source heat pumps have a capacity of 19 kW or less [19].

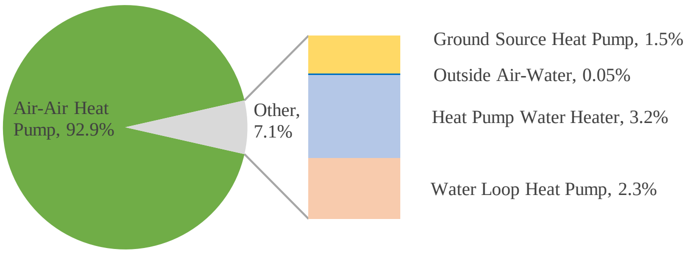

Fig. 2. 2022 market distribution of heat pump technologies.

Figure 3 shows the annual shipments of air source heat pumps (green) compared with gas and oil furnaces (orange and yellow, respectively) and central air conditioners (blue) since 2001. Despite the sharp drop in the shipments of all heating and cooling equipment during the 2006–2007 housing market collapse, the share of heat pumps (black dotted) has shown a relatively consistent increasing trend. In 2020, heat pumps surpassed gas furnace shipments for the first time and the trend maintains through 2022, reaching 52.6%. Meanwhile, the heat pump share in cooling equipment market reached 41.7% in 2022 [19].

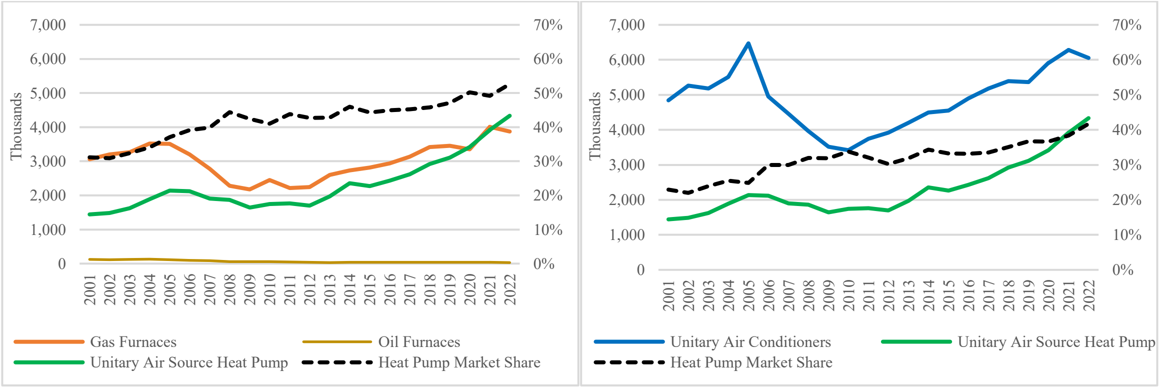

Fig. 3. Air source heat pump shipments compared with furnaces (left) and central air conditioners (right).

Figure 4 shows the sales of water loop heat pumps and heat pump water heaters since 2006 [18]. Water loop heat pumps are typically installed in multifamily buildings, hotels, dormitories, and so on, which may require simultaneous heating and cooling. Water loop heat pump shipments also saw a drop since 2007 due to the housing market collapse, and again, since 2019 as construction activities slowed down due to COVID-19 pandemic [18]. Heat pump water heaters have experienced a dramatic increase in sales due to the National Appliance Energy Conservation Act 2015 that requires higher energy factor ratings on all residential and some light-duty commercial products, and requires all electric water heaters of over 55 gal to use heat pump water heating technology [18].

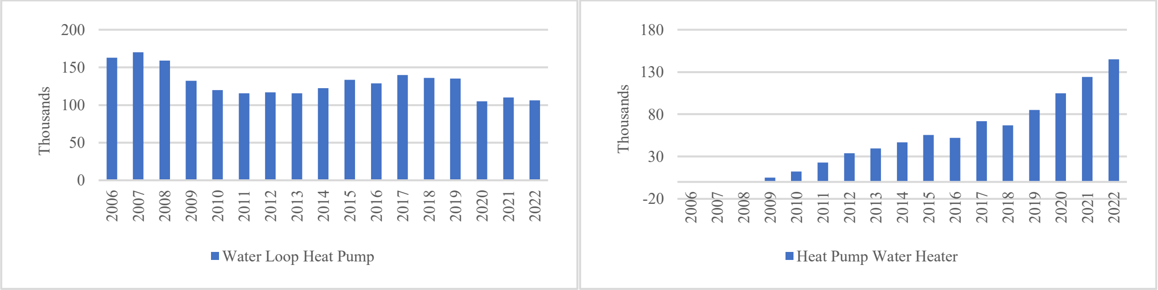

Fig. 4. Water loop heat pump and heat pump water heater sales.

Figure 5 shows the annual shipments of ground source heat pumps (GSHP) in the last 20 years [18]. It shows a steady increase from 2003 to 2011, first, due to increasing natural gas price, and since 2009, when the federal government started offering tax rebates for GSHP installation. GSHP shipments were apparently affected when tax credits expired in 2016, but jumped back in 2019 when tax credits were reinstated. The GSHP shipment dropped again in 2020 due to the COVID-19 pandemic and the resulting halt in construction activities and supply chain issues [18]. The low natural gas price during the pandemic may also have contributed to the staggering growth of GSHP applications in the United States.

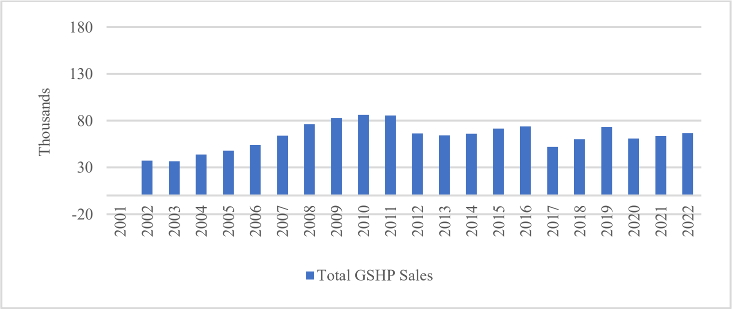

Fig. 5. GSHP sales.

3.2. Market share

The US Energy Information Administration's (EIA's) 2020 Residential Energy Consumption Survey estimates that approximately 15% of existing US homes use electric heat pumps as their primary heating source. The heat pump market share is higher in the South, where heat pumps serve one-third of existing homes [20]. The heat pump market share is smaller in the commercial building sector. According to EIA's 2018 Commercial Building Energy Consumption Survey, only 4.5% of existing US commercial building floorspace is served by electric heat pumps [21].

Based on the US Census Bureau's housing data [22], the market share of heat pumps in new single-family construction has stayed relatively constant since 2012. More than 39% of single-family homes completed in the United States in 2021 used a heat pump as their primary heating source (Figure 6, left). An estimated 59% of single-family homes completed in the South in 2021 used a heat pump for heating. The share has remained at 60% or more since 2011 (Figure 6, right). In the West, the installation of heat pumps has been ramping up, reaching 17% in 2021—the highest share since 1986. The housing construction, as well as the heat pump share, has declined in the Midwest. The heat pump market share has fluctuated in the Northeast, but stayed at a share of less than 10% [18].

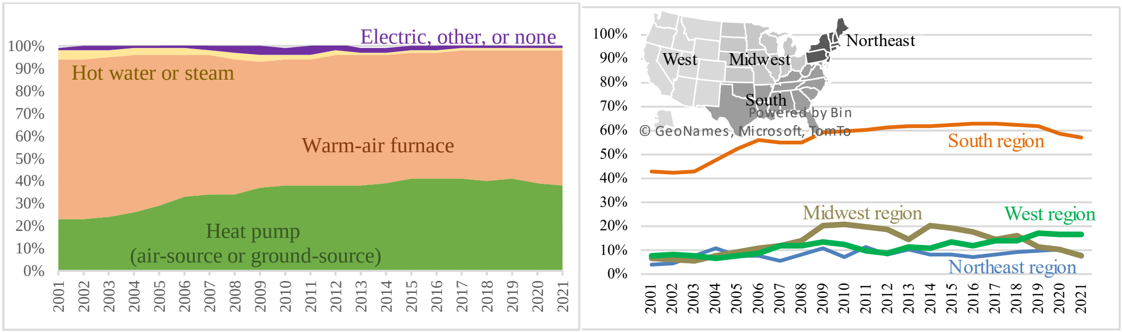

Fig. 6. Share of heat pumps in new single-family houses: (left) Comparison with other heating system types across the United States, and (right) heat pump share by US census region.

3.3. Energy price

Figure 7 shows the historical and projected prices of electricity and natural gas for residential sector in the United States [23],[24]. Both nominal and real prices[1] are shown to allow for a more accurate comparison between the past and predicted values. Over the 2007–2018 period, natural gas prices have decreased, and electricity prices gradually risen (or remained relatively level in terms of real price). Under nominal conditions[2], the prices are predicted to change with a 2022–2050 growth rate of 2.2% for electricity (-0.2%, considering real price) and 1.8% for natural gas (-0.5%, considering real price) [24].

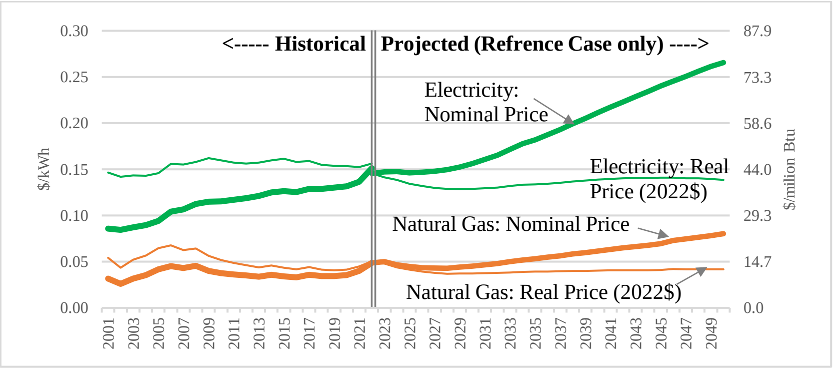

Fig. 7. US average historical and projected residential electricity and natural gas prices.

Figure 8 shows the 2021 natural gas and electricity prices by state [25],[26]. The regional differences in the heat pump market share, as noted in Figure 6 (right), can be attributed to the mild winter combined with lower electricity and higher natural gas prices in the southern states.

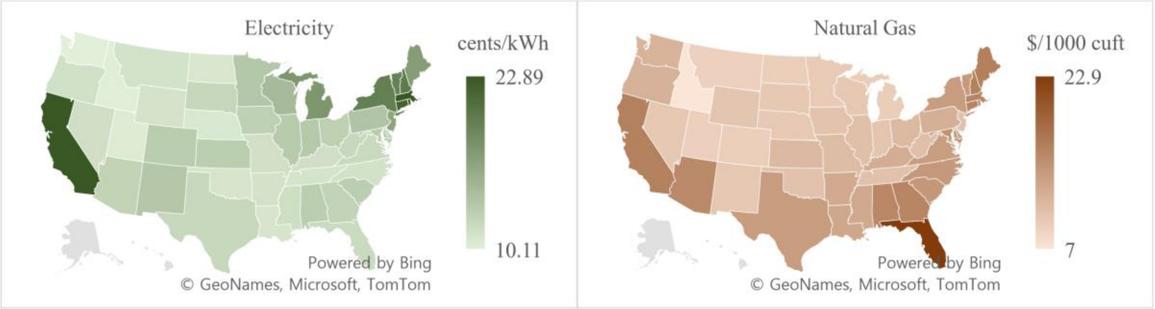

Fig. 8. 2021 residential energy prices by US state: (left) electricity and (right) natural gas.

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[1] Nominal price is the price paid for a product or service at the time of the transaction. Real price is a price that has been adjusted to remove the effect of changes in the purchasing power of the dollar, expressed in constant dollars relative to a base year.

[2] The EIA's Annual Energy Outlook modeled projections include cases with different assumptions about macroeconomic growth, world oil prices, and technological progress. The Reference Case represents projections under nominal conditions, which presumes no new policy or laws over the modeled time horizon.

3.4. Financial incentives

Heat pump installations in the United States have been in part driven by an array of tax credits. As part of the Inflation Reduction Act of 2022, federal tax credits have been extended through 2032 [27]. Equipment tax credits of $300 is available for installing air source heat pumps and heat pump water heaters in existing homes that meet specified efficiency criteria. Renewable energy tax credits are available for geothermal heat pump installation in existing homes and new construction, with a gradual step down in the credit value (i.e., 22%–30% of system cost) based on the year the system is placed in service. In addition, most states offer rebate programs for air source and geothermal heat pump installation [28]. Other common financial incentive mechanisms are available as loan programs, grant programs, and Property-Assessed Clean Energy financing [28]. The recent high natural gas prices and the uncertainties in natural gas supplies make the investment in GSHP systems more economically viable than during the pandemic. For example, New York and Massachusetts have invested in several pilot projects for district-scale GSHP systems [29].

Furthermore, under the High-Efficiency Electric Home Rebate Act, a part of the Inflation Reduction Act of 2022, point-of-sale consumer rebates are available for low- and moderate-income households to electrify their homes. The rebate covers 50%–100% of purchase and installation costs up to $14,000 on electrification measures, including heat pumps, heat pump water heaters, panel/service upgrades, electric stoves, clothes dryers, and insulation/air sealing measures [30].

These financial incentives help reduce the cost burden on consumers of heat pump technologies and support electrification.

3.5. Efficiency Standards

In the United States, the cooling and heating efficiency of central heat pumps is measured by seasonal energy efficiency ratio (SEER)[3] and heating seasonal performance factor (HSPF)[4]. The minimum efficiency standards for heat pumps were established in 1992 and were updated in 2006 and 2015 [31]. In 2017, DOE announced changes to the testing procedure and rating descriptor for central air conditioners and air source heat pumps. Effective January 2023, they will be rated by SEER2 and HSPF2 (as opposed to the current SEER and HSPF rating descriptors) following a more stringent testing procedure. The new testing procedure increases the systems' external static pressure by a factor of five to better reflect field conditions of installed equipment in a typical ducted system and results in a lower numerical rating value for the same product [32]. Thus, beginning in 2023, all new residential air source heat pump systems sold in the United States are required to meet or exceed 14.3 SEER2 and 7.5 HSPF2 (equivalent to 15 SEER and 8.8 HSPF) compared with 14 SEER and 8.2 HSPF required by the current standard that went into effect in 2015 [33]. The efficiency standards for other heat pump technologies are unchanged and are summarized in Joe *et al*. [34].

4. Challenges and Opportunities

The US government's decarbonization goal and the supporting policies and programs have presented an unprecedented opportunity for advancing the research, development, and deployment of heat pump technologies. Electrification of buildings and large-scale deployment of heat pumps are key to accomplishing this goal. A review of the heat pump market indicated areas and sectors that need dedicated solutions to encourage heat pump adoption. Solutions for increasing the supply chain capacity; workforce expansion, training, and education; affordability and accessibility for heat pump technologies; and a supporting grid infrastructure are needed. Key technological challenges include lack of regional solutions for cold climates, high upfront cost, complicated design and control of the components and system for hybrid heat pumps with multiple heat sources, compromised energy benefits due to installation challenges, and space constraints that potentially limit the installation of heat pumps.

Specific research topics to address these challenges include the following:

1. Improve efficiency and capacity of heat pumps for cold climates, and efficiency of systems for warm climates
2. Reduce installed cost and improve reliability of high-efficiency systems

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[3] The total heat removed from the conditioned space during the annual cooling season, expressed in Btu's, divided by the total electrical energy consumed by the central air conditioner or heat pump during the same season, expressed in watt-hours.

[4] The total space heating required during the heating season, expressed in Btu, divided by the total electrical energy consumed by the heat pump system during the same season, expressed in watt-hours.

3. Develop solutions for problematic heat pump installations, such as space and electrical panels, particularly for retrofit and renovation applications
4. Develop alternative refrigeration technologies and lower-GWP refrigerants to reduce direct emissions

Tackling these challenges requires technological, economic, social, and political innovations from all stakeholders by developing efficient systems with efficient components, smart monitoring, optimal control, innovative system integration, aggregation, and servicing.

5. Current R&D Focus

This section reviews recent research and developments in heat pump systems in the United States. The goals of R&D efforts are to increase the energy efficiency, reduce system cost, expand single-function equipment to be multi-function systems, and reduce environmental impacts. The focuses of these developments are depicted in Figure 9.

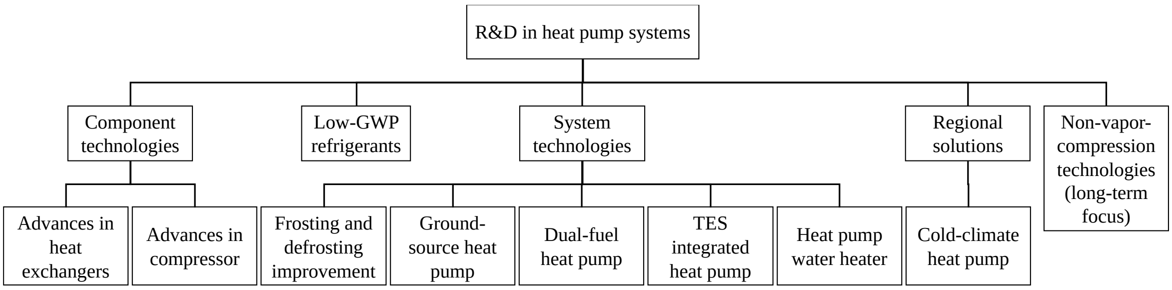

Fig. 9. Research and development focus for heat pump systems.

Advances in heat exchangers: The evolving simulation and manufacturing capabilities have given engineers new opportunities to pursue high-performance, cost-efficient heat exchanger designs. Figure 10 shows a topology optimized heat exchanger fabricated by additive manufacturing [35]. There has always been a great emphasis on understanding the underlying physics and improving the performance of these heat exchangers. Recently, researchers have been investigating the use of small hydraulic diameter flow channels and novel heat transfer surfaces based on topology optimization. The designs include shape-optimized tubes, as well as tube bundles with varying tube and fin geometries and refrigerant flow paths. The research interests for heat exchangers include mitigating the impact of airflow and refrigerant maldistribution, developing methods to reduce material/cost, developing advanced manufacturing techniques, and using technologies such as desiccant-coated, water-sorbing heat exchangers to reduce energy for dehumidification [36].

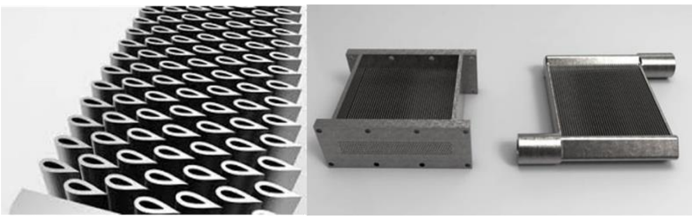

Fig. 10. Topology optimized heat exchanger fabricated by additive manufacturing [35].

Advances in compressors: The goal for new compressors is to reduce the power consumption, and one effective way is to keep compression temperature low. Most recently, several teams in US universities and national labs invest efforts to develop isothermal compressors that transfer heat out of the chamber during the compression process [37].

Low-GWP refrigerants: Natural refrigerants, HFO (hydrofluoroolefins), and HFO mixtures have significantly lower GWPs than traditional HFC (hydrofluorocarbons) refrigerants. Researchers have selected HFO refrigerants via drop-in testing and optimized heat pump components to achieve optimal solutions considering the trade-offs among low GWP, low flammability, and high system performance. Air-Conditioning, Heating, and Refrigeration Institute (AHRI) has established this industry-wide cooperative research program to identify and evaluate promising alternative refrigerants for major product categories. The

AHRI Low-GWP Alternative Refrigerants Evaluation Program (AREP) includes compressor calorimeter testing, system drop-in testing, soft-optimized system testing, and heat transfer testing [38]. For component soft optimization with goal of improving system performance with low-GWP refrigerants, the major efforts are on heat exchanger and compressor designs [39]. The IEA Annex 53 on advanced cooling/refrigeration technology development is exploring two directions on low-GWP refrigerants application: advanced vapor compression with low- or ultralow-GWP refrigerants, and nontraditional technologies such as zero-GWP refrigerants. McLinden *et al.* [40] identified 138 low-GWP refrigerants by screening more than 60 million chemical formulas. They filtered out the refrigerants according to several criteria. For instance, only molecules that consist of eight chemical elements were chosen, and the maximum number of atoms in a molecule was limited to 18. In addition, the critical temperature was limited to between 320K and 420 K. After filtering out highly toxic and unstable fluids, the screening identified 23 fluids with GWP values below 1000.

Frosting and defrosting improvements: Problems of frosting and defrosting are one of the biggest obstacles restricting the promotion of air source heat pumps. Research includes understanding the frosting and defrosting mechanism; comparing different defrosting technologies, including hot gas bypass, reverse cycle defrosting, electric heater, and dual hot gas bypass; thermal energy storage–based new reverse cycle defrosting to mitigate the indoor thermal discomfort during defrosting cycle; using frost-free air source heat pumps by different latent heat removal technologies to dehumidify the outdoor coil; and optimizing heat exchanger circuitry for uniform frost formation [41].

GSHPs: To enable wider adoption of GSHP systems, several recent projects have tried to reduce the cost of ground heat exchanger by developing shallow bore ground heat exchanger [42],[43] and advanced design tool for borehole field to minimize needed drilling [44],[45]. In addition, a web based GSHP screening tool has also be developed and released to public [46],[47]. This tool allows potential consumers of GSHP system to quickly evaluate the costs and benefits of retrofitting almost any existing commercial and residential buildings in the United States. To enable quick retrofit/replacement of existing conventional HVAC equipment, a dual-source heat pump (DSHP) has been prototyped and tested in an experimental house. DSHP can use the ambient air or the ground as heat sink or heat sources. It can switch between the two sources based on the available temperature of each. Therefore, it has potential to solve the performance degradation problem of ASHP in cold climate and cost less than conventional GSHP system by using a smaller ground heat exchanger. The DSHP system can also be integrated with thermal energy storage to shift electric demand from peak hours to off-peak hours or provide active demand side response according to control signals of electric grid operators [48]. DOE’s Geothermal Technologies Office released its roadmap for developing geothermal energy, including geothermal heat pump, in its GeoVision study [49]. One of the goals of Multi-Year Program Plan of the Geothermal Technologies Office is to implement geothermal heat pumps in 28 million homes by 2050.

Dual-fuel heat pumps (DFHPs): DFHPs, consisting of an electric heat pump and a natural gas furnace, are a promising compromise between economic and environmental impacts in the transition period toward zero emissions and eliminating the use of fossil fuels. Dual fuel heat pumps allow customers to adapt to changing temperatures and fuel prices, since they can easily alternate power or fuel sources. Plus, like other advanced electric technologies, many dual fuel heat pumps can be programmed to optimize economic or environmental impacts according to utility goals. Current research focuses on smart control of DFHPs to optimize their switching/mode of operation between furnace and heat pump modes in response to the outdoor temperature, gas and electricity prices, desired indoor temperature, and renewable energy generation to improve energy efficiency, minimize energy cost, and minimize carbon footprint [50].

Thermal energy storage (TES)-integrated heat pumps: Integrating heat pumps with a TES component to shift most of the electricity used for space cooling and heating from peak to off-peak periods is a popular research topic [51]. Commonly used phase change materials (PCMs) include paraffin wax, ice, and salt hydrates. Taking advantage of the thermal energy storage ability, several feasible PCM application schemes have been proposed. One of the recent research focuses is to develop a model-predictive control strategy to regulate the PCM tank charging and discharging mode switching based on weather, utility, and grid emission signals. Simulation based research have demonstrated the efficacy of TES-integrated heat pumps for electrification of space cooling and heating devices without overtaxing the grid [52]. Most recently, under the auspices of IEA Annex 55, the project “Comfort and Climate Box” develops nearly market-ready TES-integrated heat pump systems for cooling-dominated climate regions for 11 countries including the United States [53].

Heat pump water heaters: Potential research areas to improve heat pump water heater performance include incorporating defrost strategies to boost performance under low or extreme ambient conditions; considering suitable refrigerants for heat pump water heater applications; applying advanced materials and components to increase storage capacity; developing smart control strategies to optimize energy use, reduce operation cost, and reduce CO_2 emission; developing products with multi-function applications; and developing plug-in 120 V heat pump water heater units [54].

Cold-climate heat pumps (CCHPs): Driven by the building sector electrification policy in the United States, CCHPs are a popular research focus. For CCHPs, research challenges include the following: First, the maximum COP of the advanced system under low ambient temperature condition is relatively small in terms of primary energy ratio. Second, the heating capacity needs to be further enhanced to satisfy the building load, especially under extreme conditions. In addition, low-temperature start-up technology and year-round control strategy have potential to improve the reliability of CCHP systems. CCHPs can be classified into three categories: single-stage, dual-stage, and multi-stage compression systems [55]. For single-stage compression systems, employing an ejector and new refrigerant can improve the heating performance but cannot reduce the discharge temperature of the compressor. For dual-stage compression systems, various intermediate configurations, such as flash tank, sub-cooler, and ejector, are employed to enhance the heating performance to the maximum extent. For multi-stage compression systems, the theoretical COP increases with the number of compression stages. In general, CCHP technologies includes innovations on compressor technology, new system configuration, new cycle types such as vapor injection, defrosting technology and expansion loss recovery [56]. Long-term research, development, and deployment efforts have made heat pumps a viable option even in cold climates. DOE recently launched the Residential Cold Climate Heat Pump Technology Challenge to accelerate the deployment of technologies in very cold climates. Optimized heat pump solutions differentiated by climate needs could lower equipment costs.

Non-vapor compression technologies, as listed in Figure 11 [57], have also been developed to eliminate high GWP refrigerants, improve source energy efficiency, or expand operating conditions. Long-term R&D is still needed to improve performance, reliability, and cost effectiveness.

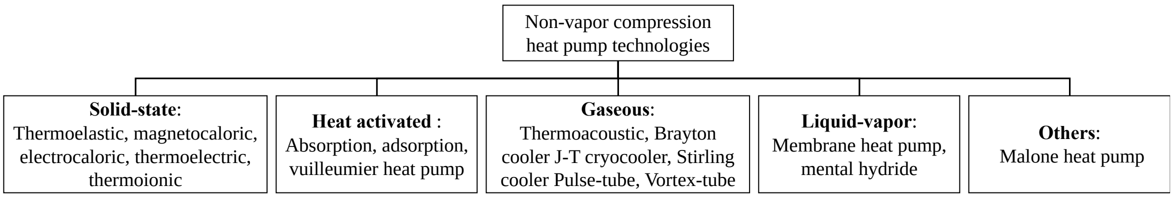

Fig. 11. Summary of non-vapor compression heat pump technologies

DOE's Building Technologies Office (BTO) characterized the non-vapor compression technologies based on their technical energy savings potential and development status as shown in Figure 12 [58]. The top favored technologies are thermoelastic, membrane heat pumps, evaporative liquid desiccant, magnetocaloric, and vuilleumier heat pump.

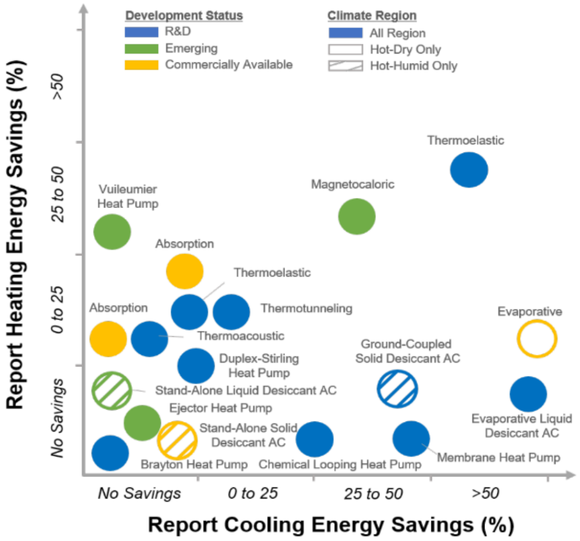

Fig. 12. Energy saving potential for different non-vapor compression technologies reorganized based on [58].

6. Summary and Outlook

This paper presents a review of the US policies, heat pump market potentials, identifies challenges and barriers facing large-scale deployment of heat pumps, and provides a brief review of recent developments in heat pump technologies.

The US government's decarbonization goal and the supporting policies and programs have presented an unprecedented opportunity for advancing the research, development, and deployment of heat pump technologies [59]. A large increase in heat pump policies and incentives, notably in the US Inflation Reduction Act, is set to accelerate their deployment [4]. Governmental actions, along with public and private sector incentive programs for heat pump and building electrification, promote deploying more efficient heat pump systems.

The US heat pump market has shown steady growth since 2010—faster relative to competing space heating technologies. However, the market growth is uneven geographically, with a very small market share in cold climates. The heat pump market share is also very small in the commercial sector. GSHP market trends show a direct and immediate influence of tax credits.

There are several hurdles to expanding heat pump deployment, including the relatively high cost of installation; high operational costs in cold climates; various supply chain constraints such as limited manufacturing capacity and shortages of skilled workers; and existing building stock with fossil fuel systems and constraints for fuel-switching.

DOE is investing heavily in heat pump technology. Research efforts have significantly improved the energy efficiency of heat pumps, as evidenced by the evolving efficiency standards. The development of component technologies effectively reduces the energy consumption, and the expansion of multi-functional equipment has enabled heat pumps to perform efficiently with wider applications. To further expand the usage of heat pumps, continuous efforts are needed to improve performance and reliability while discovering novel applications.

As the share of renewables in the energy mix increases, heat pumps can play an important role in electrifying the building sector. Heat pump technology is mature, and production and installation can, in principle, be scaled up quickly. Long-term solutions, including policy consistency, targeted action to strengthen supply chains, building the grid capacity, and expanding renewables, thermal storage, and smart technology (such as smart thermostats, zoning control, and auxiliary heat control) at lower costs, are needed to encourage further investment [4]. The future of heat pump technologies will be highly influenced by the evolving minimum standards, R&D, tax credits, and incentive programs.

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