Heat Pumps in the United States: Market Potentials, Challenges and Opportunities

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The US heat pump market has been affected by the socioeconomic impacts of the COVID-19 pandemic. However, the US administration's electrification goal accelerates the deployment of heat pumps, and 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 maintained through 2022. The heat pump market share is expected to grow as policies, and financial incentives steer the building sector toward decarbonization. This paper reviews the US heat pump market trends and discusses the challenges and opportunities in the current policy landscape.

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, the global economic 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 have 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].

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 the 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 have been 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.

US Heat Pump Shipments

As shown in Figure 2, US heat pump market shipments predominantly comprise air-source heat pumps. More than 96% of air-source heat pumps have a capacity of 19 kW or less [10]. Heat pump water heaters, water loop heat pumps, and ground source heat pumps comprised a little over 7% of heat pump sales in 2022 [11].

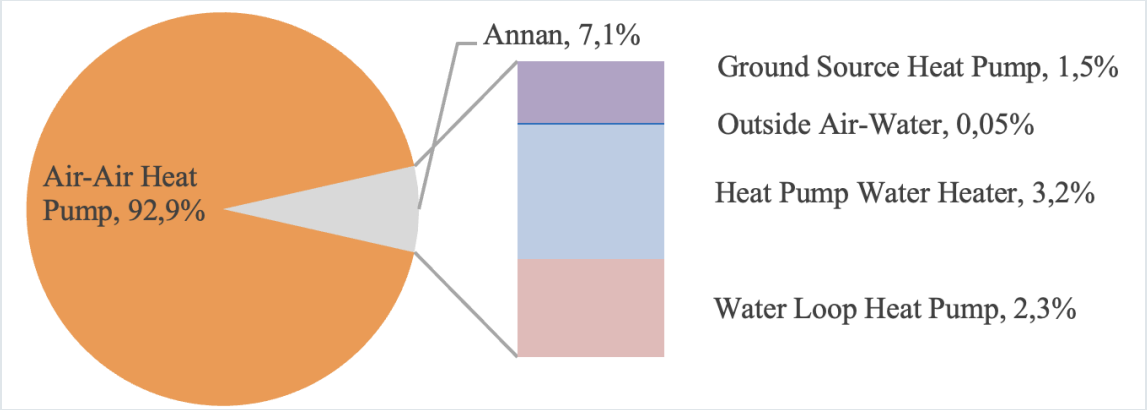

Figure. 2. 2022 market distribution of heat pump technologies.

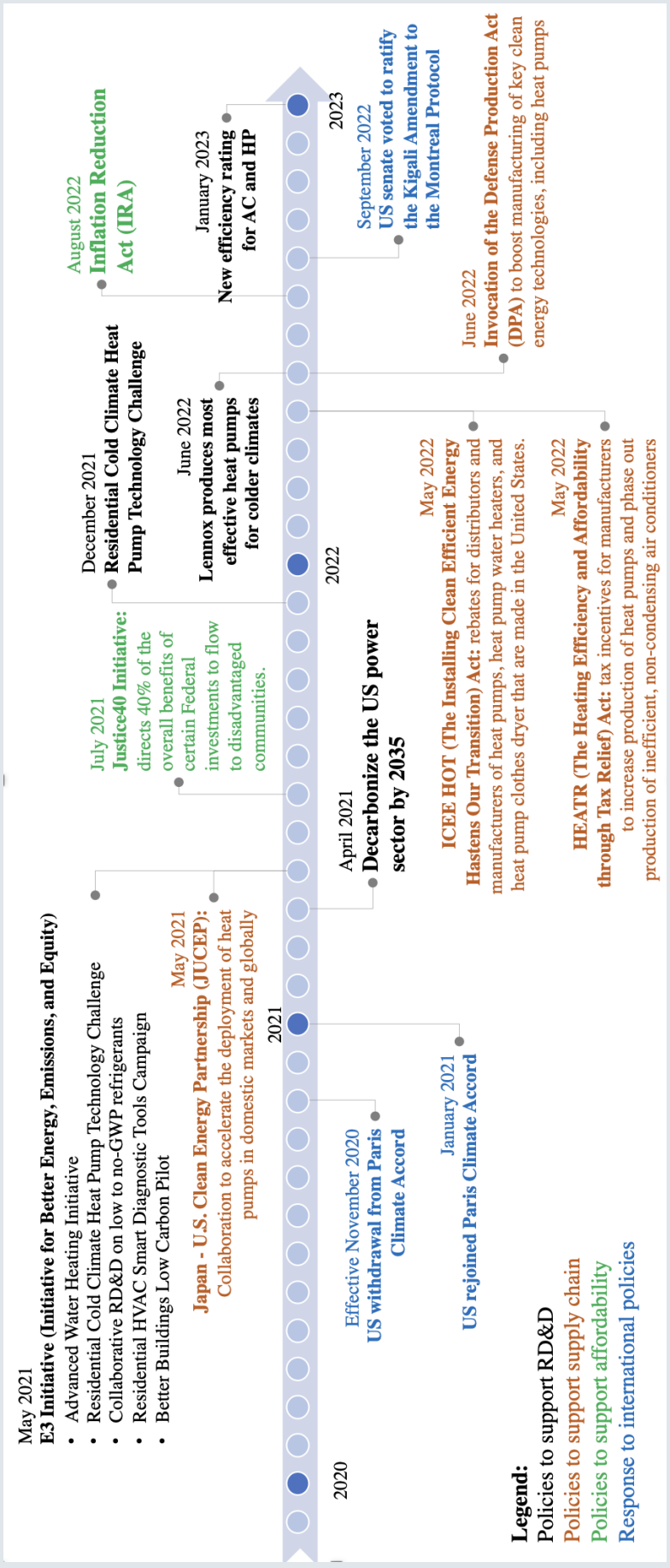

Figure. 1. Heat pump–related policies since 2020.

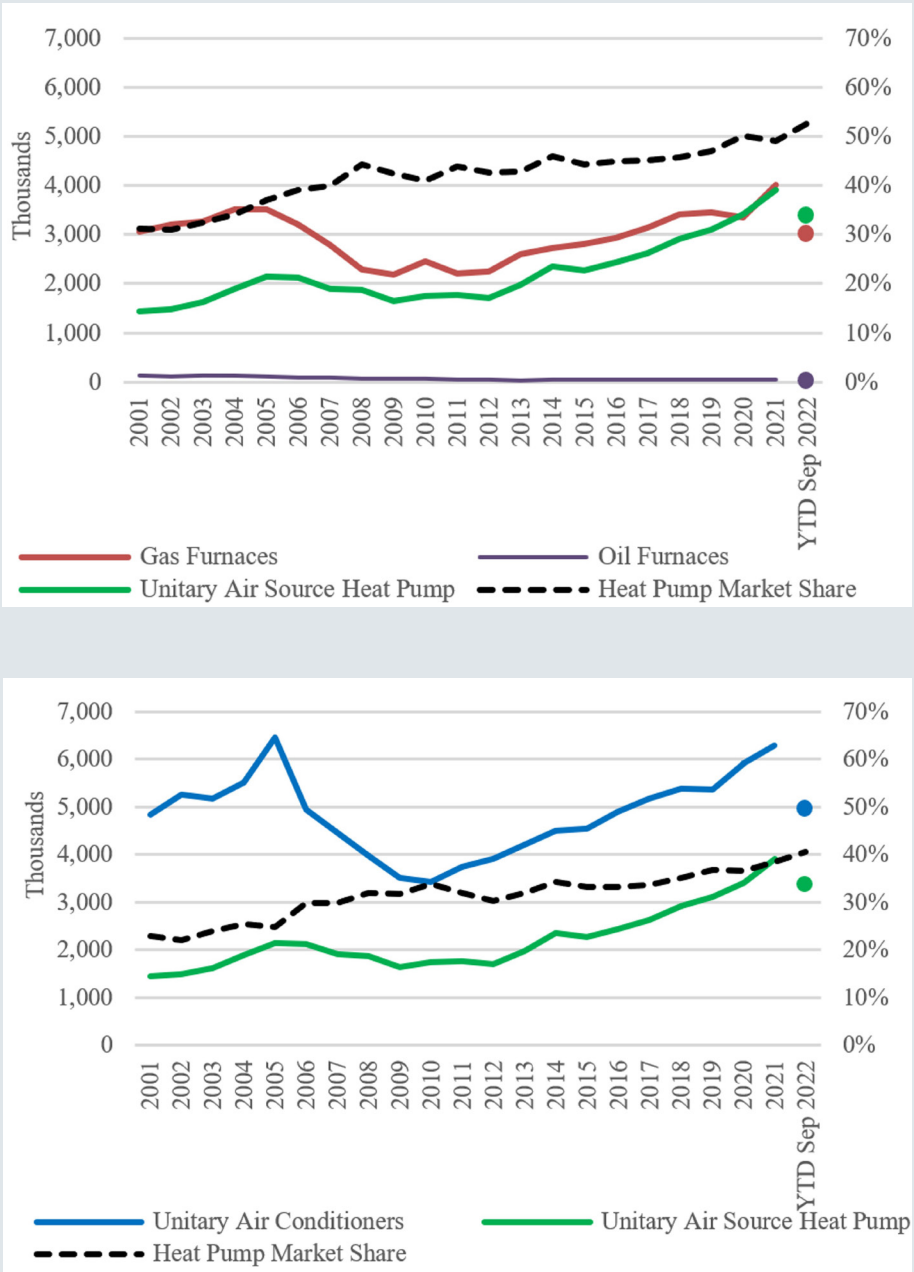

Figure. 3. Air source heat pump shipments compared with furnaces (top) and central air conditioners (bottom).

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 pump shipments surpassed that of gas furnaces for the first time, and the trend maintains through 2022, reaching 52.6% in September 2022 year-to-date (YTD). Meanwhile, the heat pump share in the cooling equipment market reached 40.6% in September 2022 YTD [10].

Heat pump water heaters have experienced a dramatic increase in sales due to the National Appliance Energy Conservation Act of 2015, which requires higher energy factor ratings on all residential and some light-duty commercial products, and requires all electric water heaters of over 208 L (55 gallons) to use heat pump water heat-

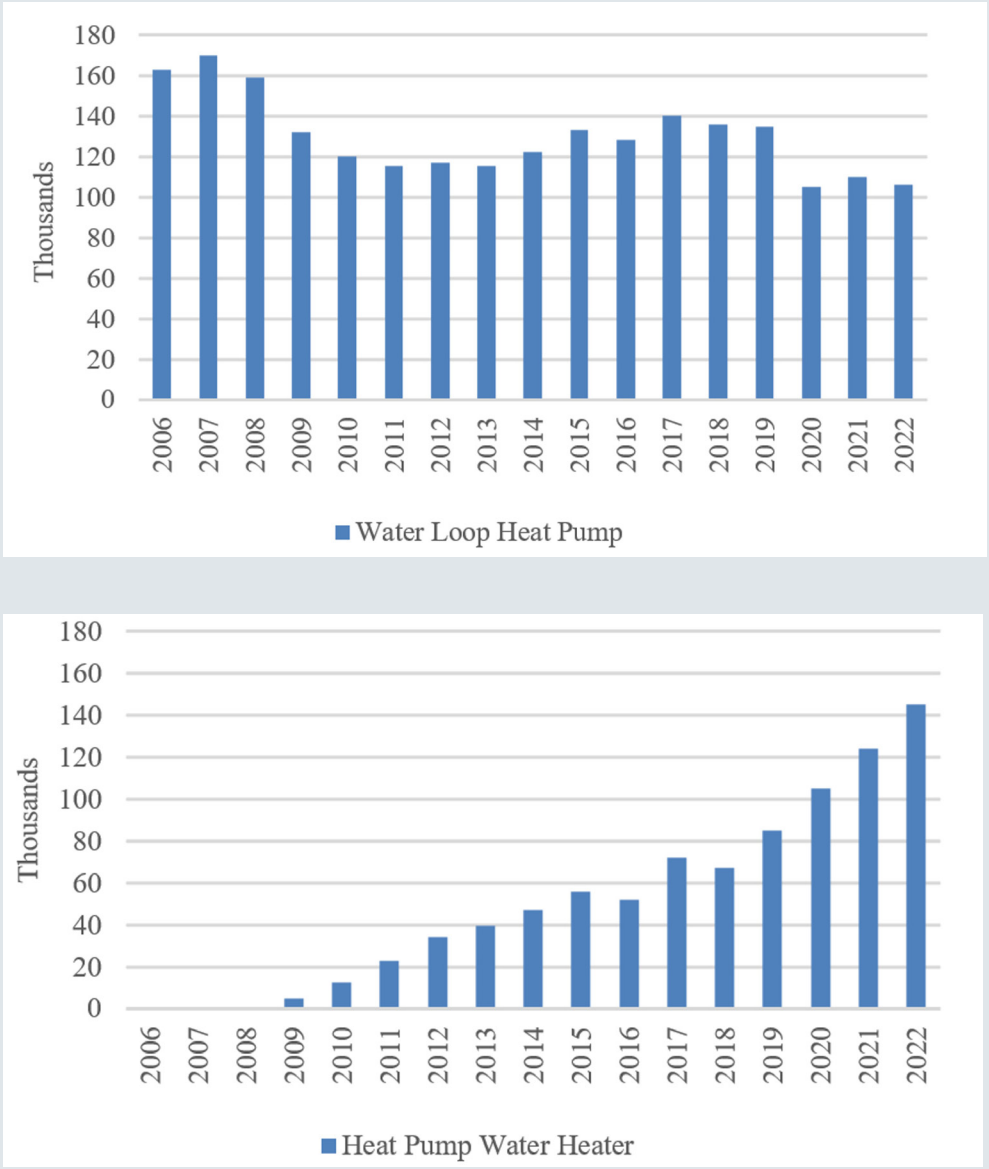

Figure. 4. Water loop heat pump (top) and heat pump water heater sales (bottom).

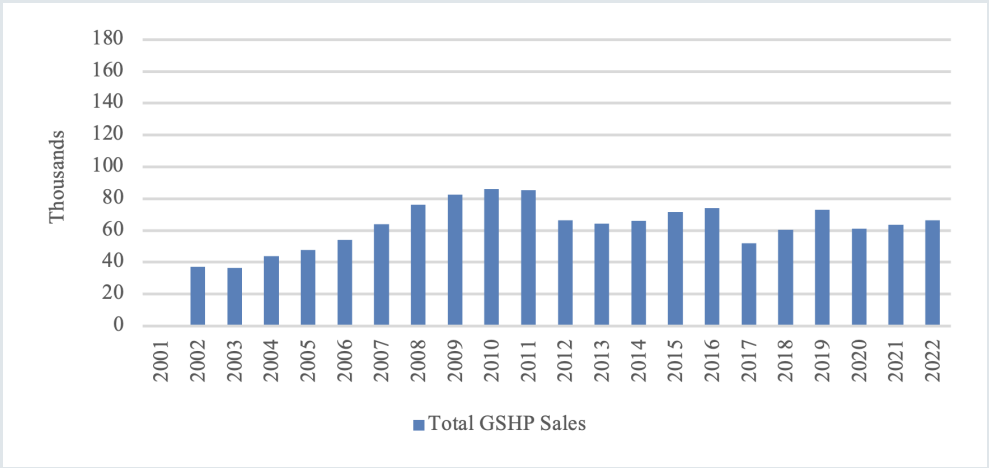

Figure. 5. GSHP sales.

ing technology. Figure 4 shows the sales of water loop heat pumps and heat pump water heaters since 2006 [11]. 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 the COVID-19 pandemic. Figure 5 shows the annual shipments of ground source heat pumps (GSHP) in the last 20 years [17]. It shows a steady increase from 2003 to 2011, first due to increasing natural gas prices and since 2009, when the federal government started offering tax rebates for GSHP installations. 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 [17]. The low natural gas price during the pandemic may also have contributed to the staggering growth of GSHP applications in the US.

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 [13]. 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 floor space is served by electric heat pumps [14].

The market share of heat pumps in new single-family construction has stayed relatively constant since 2012. More than 39% of single-family homes constructed in the United States in 2021 used a heat pump as their primary heating source (Figure 6 top) [15]. 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 bottom). 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% [11].

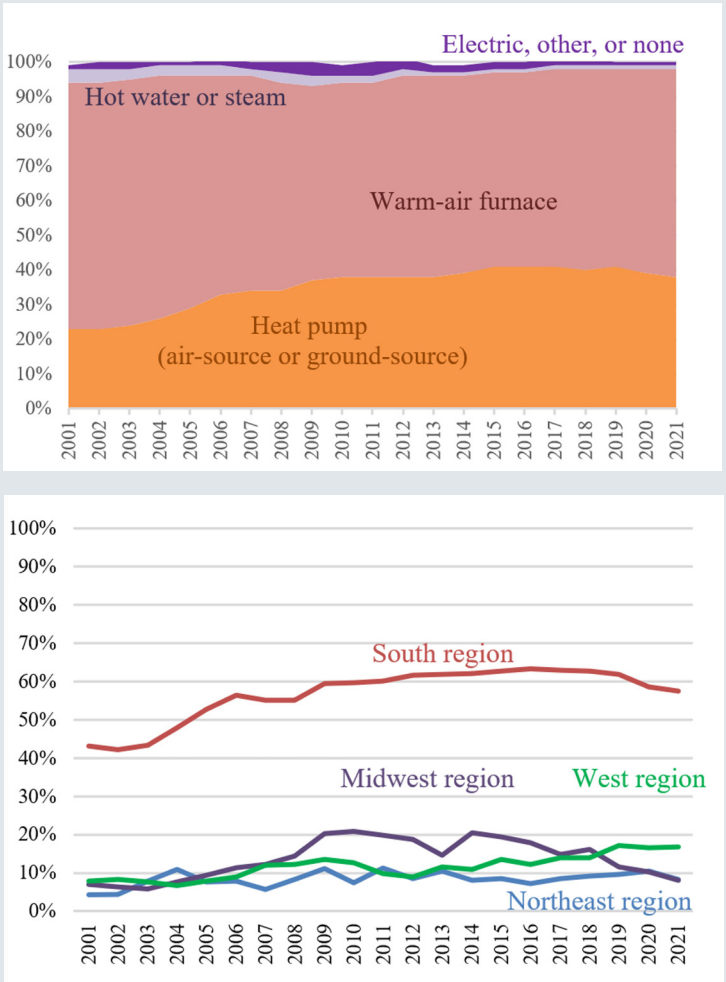

Figure. 6. Share of heat pumps in new single-family houses: (top) Comparison with other heating system types across the United States, and (bottom) heat pump share by US census region.

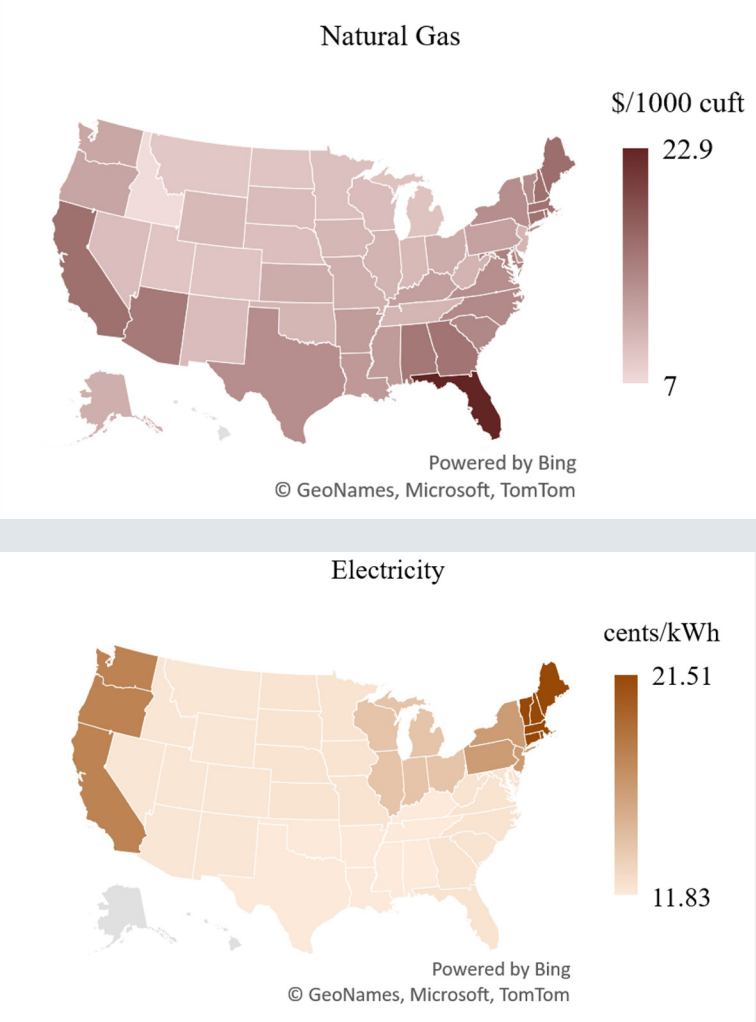

Figure. 7. 2021 regional fuel prices: (top) natural gas and (bottom) electricity.

Energy Price

The regional differences in the heat pump market share can be attributed to the mild winter and lower electricity and higher natural gas prices in the South, as shown in the 2021 regional natural gas and electricity prices in Figure 7 [16], [17].

Figure 8 shows the historical comparison of the electricity and national gas prices in the United States. For future prediction of energy prices, IEA publishes projected retail and residential energy prices for the United States through 2050 in the EIA Annual Energy Outlook [18]. The projections show very little change in retail and residential energy prices over that time frame. Natural gas prices are predicted to increase marginally, from $10.14 per million Btu in 2020 to $11.76 in 2050. Electricity rates are predicted to decrease marginally, from $35.77 per million Btu in 2020 to $34.96 in 2050.

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 [19]. 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 into service. In addition, most states offer rebate programs for air source and geothermal heat pump installations [20]. Other common financial incentive mechanisms are available as loan programs, grant programs, and Property-Assessed Clean Energy financing [20]. The recent high natural gas prices and the uncertainties in natural gas supplies make the investment in GSHP systems more economically viable now than during the pandemic. For example, New York and Massachusetts have invested in several pilot projects for district-scale GSHP systems [21].

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,

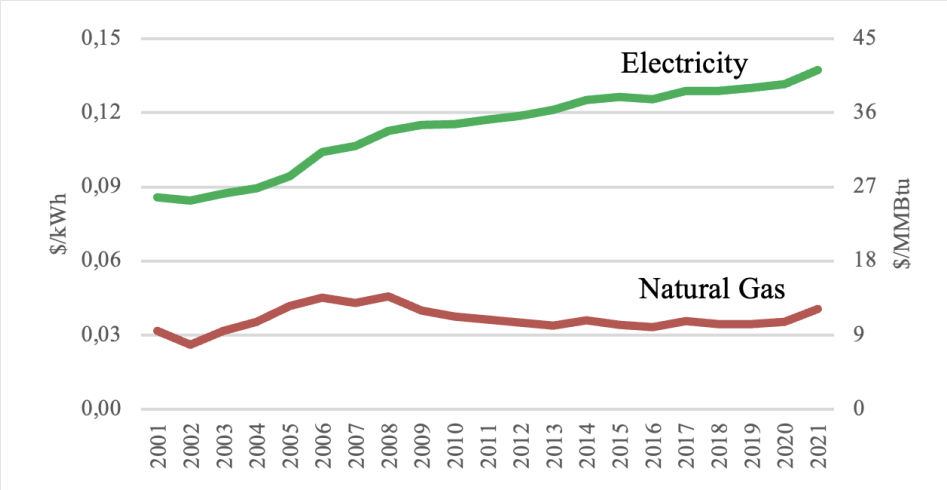

Figure. 8. US average electricity and natural gas prices.

panel/service upgrades, electric stoves, clothes dryers, and insulation/air sealing measures [22]. These financial incentives help reduce the cost burden on consumers of heat pump technologies and support electrification.

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. Key technological challenges include a lack of regional solutions for cold climates, high initial 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 the reliability of high-efficiency systems
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.

Conclusions

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. The US Department of Energy (DOE) is investing heavily in heat pump technology. Governmental actions, along with public and private sector incentive programs for heat pumps 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.

Heat pump technology is mature, and production and installation can, in principle, be scaled up quickly. 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. 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. 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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