ANALYSIS OF ELECTRIC AND GAS DECARBONIZATION OPTIONS FOR HOMES AND APARTMENTS

By Steven Nadel and Lyla Fadali

SUMMARY

As climate change intensifies, many states and utilities are making long-term commitments to reduce planet-warming emissions. With buildings responsible for about one-third of these emissions, some stakeholders advocate for full electrification of homes. Others tout opportunities to use clean fuels, such as biogas and hydrogen, or gas-driven heat pumps.

We recognize that electric heat pumps, which provide heat *and* air-conditioning, are a promising technology. They have improved substantially in recent decades, and newer cold-climate electric models can now operate efficiently at low temperatures. But what happens when it is super cold outside (below 5°F) for more than a few days per year, and electric heat pumps need backup heat?

Our research explores options. We analyzed several thousand homes across the United States, looking at decarbonization options for space and water heating beginning in 2030, under a scenario in which the electric grid and fuels are largely decarbonized. We estimate that switching to largely decarbonized fuels will more than triple fuel costs, and electrifying space and water heating will increase electricity costs in the north because of the costs to meet winter peak demand. For example, we estimate about a 30% electricity price increase in Minneapolis, with more to the north and less to the south.

OUR FINDINGS

For homes (detached and attached) with one to four units, **electric heat pumps** generally minimize average life-cycle equipment and energy costs for space heating and cooling in places warmer than Detroit. These places have fewer than 6000 heating degree days (HDD)—a measure of how much seasonal temperatures fall below 65°. In colder climates, electric heat pumps with an alternative fuel backup below 5°F generally minimize these costs.

These results assume use of **cold-climate electric heat pumps** in places with more than 4,000 HDDs (the recent climate in Maryland and points north). These cold-climate models can efficiently provide heat at temperatures down to about 5°F, because they have high-efficiency variable-speed compressors. Our analysis suggests we may minimize life-cycle costs by popularizing cold-climate electric models in places that are both cold (4,000 HDD to 6,000 HDD) and super cold (6,000-plus HDD).

For **multifamily buildings** with five or more units, energy use per housing unit is generally low and the costs of electrification are currently high. Based on limited data, we find that using alternative fuels in condensing boilers often minimizes life-cycle costs. This finding should be considered preliminary, with more data and analysis needed.

For **water heating** in one- to four-unit family homes, electric heat pump water heaters (HPWHs) have the lowest life-cycle costs in all parts of the United. States, followed by gas-driven HPWHs and then gas condensing tankless water heaters.

Energy efficiency often—but not always—reduces life-cycle costs as homes are decarbonized. For many homes, a moderately sized energy efficiency package (based on Home Performance with ENERGY STAR®) has the lowest life-cycle costs. For others, especially those in cold climates with oil or propane heat, or above-average energy bills, a deep retrofit at the time of building renovation often reduces life-cycle costs.

The above results, based on our **medium assumptions** for equipment costs and energy prices, change modestly at higher and lower prices. For example, where the above finding discusses 6,000 HDDs, other cost and price scenarios may change the pivot point to 5,500 or 5,000 HDDs.

Results vary by **region, household income, and building age**. Electric heat pumps are more likely to reduce life-cycle costs in the South and West than in the North Central region, with costs in other regions in between. As income increases and building age decreases, electric heat pumps are more likely to decrease life-cycle costs because of the presence of central air-conditioning, improved energy efficiency, and the increased prevalence of single-family (versus multifamily) homes. Given these financial realities, policymakers should prioritize assistance to low- and moderate-income households, whose homes are often the most challenging to decarbonize.

As we **transition to decarbonized homes**, electrification will play a crucial role. This transition will proceed slowly, though, as long as inexpensive fossil fuels are available. To accelerate this transition, we will need:

- Research and development of heat pumps and decarbonized fuels
- Minimum efficiency standards for heating equipment
- Incentives and grants
- Restructuring electric (and perhaps gas) rates
- Clean heat standards
- A price on carbon

OUR METHODOLOGY

We focused on approximately 3,000 homes now heated with fossil fuels in the 2015 Residential Energy Consumption Survey (RECS) compiled by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE). RECS contains detailed data on the building characteristics and energy use of a national sample chosen to represent the U.S. housing stock across regions and building types.[1] For each of the homes and apartments in RECS using natural gas, propane, or fuel oil furnaces or boilers in 2015, we analyzed several decarbonization options, including electric and gas heat pump options and alternative fuel options (as we describe in the body of the report). Our analysis assumes that equipment is installed in 2030 at the end of the service life of the existing equipment.[2]

We look at both space heat and water heat. In homes with central air conditioners, we look at installing an electric heat pump when the air conditioner needs replacement. In other homes, we look at installing heat pumps when the existing furnace or boiler needs replacement. For heat pumps, we consider air-source heat pumps that produce warm air, except in homes that have hot-water distribution systems, where we look at air-to-water heat pumps that provide hot water. For water heating, we look at electric and gas options when the existing equipment needs to be replaced. For both space and water heating, this new equipment will typically operate until nearly 2050. Figure 1 illustrates our approach, providing best-fit lines for the various decarbonization options for homes now heated with gas furnaces.

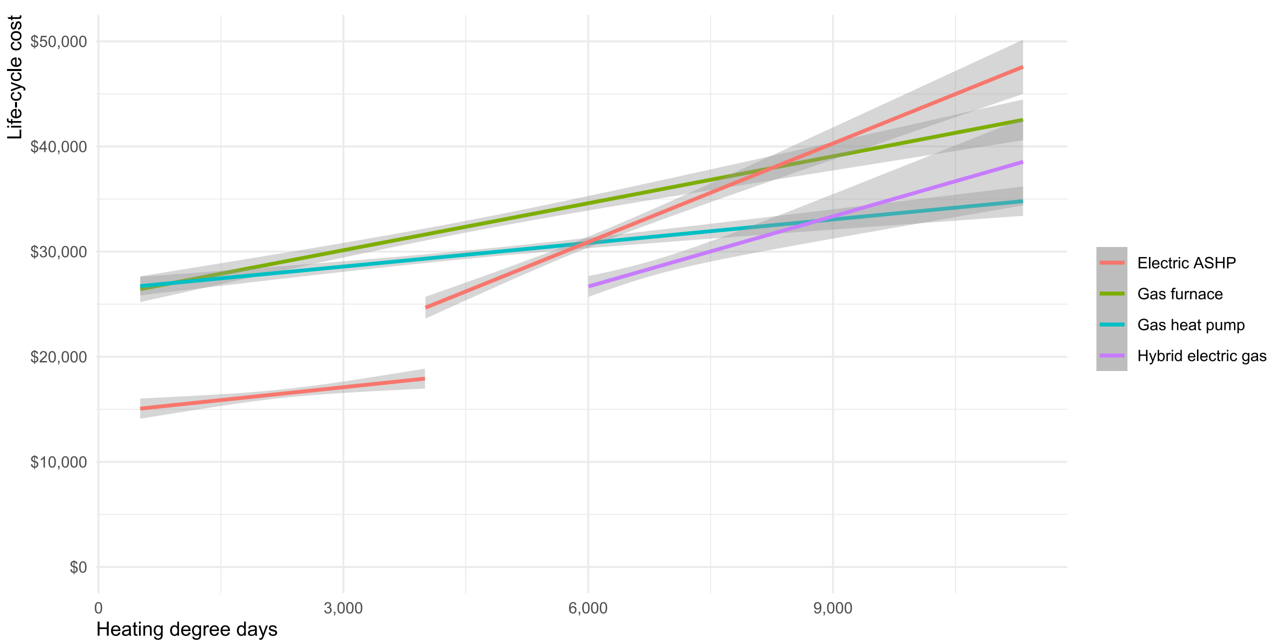

Figure 1: Life-cycle costs best-fit lines for electric heat pumps, condensing gas furnaces, gas heat pumps, and hybrid electric heat pump/condensing gas furnace systems for single-family homes now heated with natural gas. The gap in the electric heat pump line shows the impact of costs for cold-climate heat pumps for locations with 4,000 HDDs or more. Costs are in 2020 dollars.

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[1] EIA (Energy Information Administration), "Residential Energy Consumption Survey: 2015 RECS Survey Data" (2018). www.eia.gov/consumption/residential/data/2015/.

[2] We assume all replacements are in 2030, but, in actuality, the replacements will gradually occur as the existing equipment needs replacement. We do not model any early replacement (before the end of service life).

The 2015 RECS uses 1980–2010 climate data. It looks at the average heating degree days (HDD) for each home location based on 30-year averages. Due to climate change, most of the United Sates is warming and as a result HDDs are declining. To provide a more updated picture, ACEEE used U.S. government data to calculate 15-year (2006-2020) averages, as shown below in Figure 2. Philadelphia averages about 4,300 HDDs, while northern Minnesota often has more than 8,000.

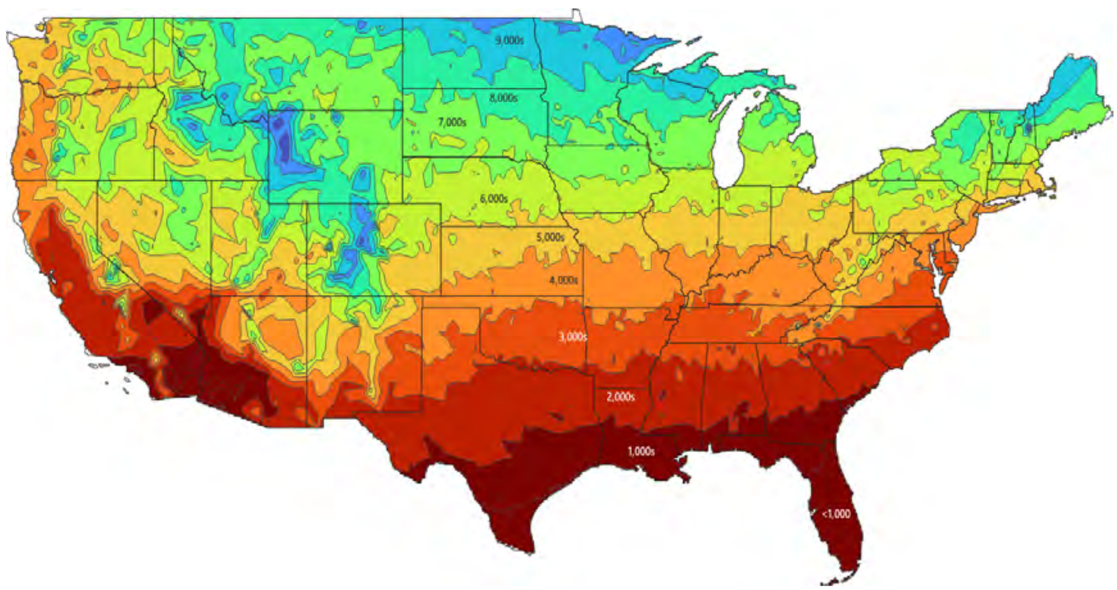

Figure 2. Average heating degree days (HDDs) at various locations in the United States based on averages over the 2006–2020 period. Lines between colors are approximate and not exact. Source: Map created by ACEEE based on data in NCEI 2021.[3]

HDDs will continue to decline because of climate change, particularly in the north, but the exact future patterns are unknown and will vary from region to region. We did not attempt to adjust HDDs for future warming. However, we note that the 4,000 and 6,000 HDD inflection points in our analysis will gradually move north, and fewer places will have more than 6,000 HDD. Instead, cooling needs will increase. Electric heat pumps can efficiently cool spaces in all climate regions.

[3] NCEI (National Centers for Environmental Information), "U.S. Climate Normals 2020: U.S. Annual/Seasonal Climate Normals (2006–2020)" (2022). www.ncei.noaa.gov/metadata/geoportal/rest/metadata/item/gov.noaa.ncdc:C01623/html.