CLIMATE CENTRAL SOLUTIONS BRIEF: CLIMATE-FRIENDLY HOMES



November 17, 2021

Research brief by Climate Central

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Part of the Climate Solutions series

INTRODUCTION

Trading in your gas-powered car for an electric vehicle isn't the only way individuals can help combat climate change. Swapping out your furnace and your gas stove at the end of their lives for efficient, electric versions can have a huge impact as well. As we switch our energy supply to renewable sources, electrifying our homes, businesses, and work spaces is a critical pathway for reaching <u>net zero emissions</u> and limiting climate warming.

According to the U.S. Environmental Protection Agency (EPA), commercial and residential buildings account for <u>13% of all</u> <u>greenhouse gas emissions</u> in the U.S. This comes from burning gas, propane, or oil in the buildings and from using electricity that in many places still comes from burning fossil fuels.

Electrification of buildings means changing over from burning fossil fuels to using electricity for things like cooking, clothes drying, and heating and cooling. Roughly one in four U.S. homes is already <u>all electric</u>. As electrification expands and more appliances and vehicles pull their energy from the grid, increasing **energy efficiency** can help to reduce the total amount of electricity needed to meet demand, while reducing emissions and lowering costs. Making homes more energy efficient and free of carbon emissions not only helps slow down climate change, but also offers health benefits and cost savings to homeowners and can grow local jobs.

Buildings, both residential and commercial, are meant to last for a long time. The median age of a U.S. home is <u>39 years</u>, meaning that many homes are not very energy efficient and rely on older appliances that burn fossil fuels for heating and cooking. Addressing the energy inefficiencies already locked into the nation's housing stock presents a significant opportunity for curbing greenhouse gas emissions. This brief primarily focuses on solutions for lowering emissions from single-family residences, since homeowners have a lot of say in the decision-making around how they heat and cool their homes and what types of appliances they install.

BUILDINGS AND THEIR CARBON FOOTPRINTS

In 2019, homes and businesses were the source of 13% of total heat-trapping emissions in the U.S. These emissions can vary from year-to-year due to weather conditions, but total on-site residential and commercial greenhouse gas emissions have <u>risen 8%</u> since 1990.

FIGURE 1. Where CO₂ emissions come from in residential buildings



Heating and cooling our homes <u>accounts</u> for 38% of carbon dioxide (CO2) emissions that come from the residential sector (see Figure 1). Another 24% comes from cooking meals, lighting our homes, running our electronic devices, and using other household appliances. Heating water for showers, baths, and washing dishes is the source of 15% of emissions. In addition, the waste we send to landfills, treatment of wastewater, and hydrofluorocarbons leaked from air conditioning and refrigeration also contribute to warming the planet. According to <u>Rewiring America</u>, a non-profit that advocates for electrification, U.S. households currently rely on fossil fuels to run 70 million furnaces, 60 million water heaters, 20 million clothes dryers, and 50 million gas stoves, ovens, and cooktops. That's a lot of appliances that can be electrified.

Sources: U.S. Energy Information Administration, Annual Energy Outlook 2018 (Washington, DC: Department of Energy, 2018), https://www.eia.gov/outlooks/aeo.

A <u>study of residential energy</u> use by researchers at the University of Michigan showed that local climate conditions and the age of homes contribute to a household's energy intensity—how much energy it uses. But the type of fuel that powers a state's energy infrastructure is what strongly influences a household's greenhouse gas emissions, or GHG intensity (see Figure 2 & 3).

Figure 2. Average household energy intensity



Household energy intensity is measured by kilowatt-hours per square meter. The average U.S. home consumed 147 kWh/m² of energy in 2015.



ousehold GHG intensity is measured by kilograms of CO₂ equivalents per square mete The average GHG intensity of a U.S. home was 45 kg CO₂e/m². Source: Goldstein, B., et al. 2020.

For example, Florida has low energy intensity (warm climate, newer homes) but ranks in the middle of states for its GHG intensity due to its grid being powered mostly by burning gas. Vermont has high energy intensity (cold climate, older homes) but lower GHG intensity because most of its electricity supply comes from hydroelectric and renewable sources. In states where most homeowners use carbon-intensive heating fuels (such as Maine, where about two-thirds of homes are heated with fuel oil), the benefits of a low-carbon electrical grid are diminished. The researchers also found that high-income households have more GHG intensive footprints, mostly due to larger homes. In wealthy suburbs, emissions can be 15 times greater than nearby less affluent neighborhoods.

CLIMATE ACTION AND THE ROLE OF BUILDINGS

The Paris Climate Agreement created goals to <u>limit</u> the increase in global temperatures to well below 2.0°C (3.6°F) above pre-industrial levels, with aims to curb the temperature increase to 1.5°C (2.7°F). In order to do this, global greenhouse gas emissions need to be cut in half by 2030, and reach "net zero" by mid-century for the 1.5°C degree target.

To align home energy use with these goals, all of our next major appliance purchases should be electric. Water heaters typically last 12-15 years, furnaces and other heaters can last 20 years. Most of our kitchen and laundry appliances make it 10 to 15 years. Upgrading to higher-performing electric machines (including <u>cars</u>) while increasing the share of clean renewable electricity supplies could bring us significantly closer to the global goal of limiting climate change to 2°C or less.

MAKING HOMES MORE EFFICIENT

Energy efficiency reduces greenhouse gas emissions in two ways. The energy not used reduces both direct emissions from burning fossil fuels at the source (like an old, inefficient gas furnace), and indirect emissions from electricity generation (like a coal- or gas-powered plant).

According to <u>research</u> from the National Renewable Energy Laboratory (NREL), 22% of electricity used by single-family homes could be saved—about 6% of all energy used nationwide—by adopting a number of efficiency measures that are also cost effective, profitable investments for the homeowner. The study assumed that efficiency upgrades would happen over 15-30 years, as homeowners' appliances wear out and are replaced.

The same study determined that implementing efficiency measures across households would reduce carbon emissions of single family homes by 24% (291 million metric tons CO₂e per year) annually, or about 4% of emissions coming from U.S. energy consumption. The amount of savings ranges by state, with some states seeing as much as 30% savings in homes' electricity use, including <u>North Carolina</u>, <u>South Carolina</u>, <u>Kentucky</u>, <u>Maryland</u>, and <u>Delaware</u> (see Figures 4 & 5 on page 5). Potential electricity savings were lower in New England due to increases in electricity usage following a switch from oil to electric home heating, for instance. But if the electricity supply is derived from renewable sources, then such upgrades would also reduce emissions.

FIVE in FIVE

FIVE UPGRADES THAT PAY HOMEOWNERS BACK WITHIN FIVE YEARS

Upgrade electric furnace/air conditioner to high-efficiency heat pump at wear out

Install smart thermostat (occupants not home during the day)

Install ENERGY STAR® clothes washer at wear out

Install ENERGY STAR refrigerators at wear out

Install light-emitting diode (LED) lighting

FIGURE 4. Annual carbon emissions reductions per household



If households were to invest in efficiency and electrification upgrades (under a 50% cleaner electricity grid scenario), it would reduce average household emissions by 2.63 tons of CO₂e per year. States in the Northeast could expect to see the greatest reductions in emissions.

FIGURE 5. Annual utility bill savings per household



Households across the U.S. would save an average of \$597 per year on their utility bills from efficiency and electrification upgrades. Source: <u>Wilson, E., et al. 2017.</u>

The NREL researchers identified a number of climate-friendly actions that paid for themselves within just five years through homeowners' cost savings from energy bills. Overall, replacing both an inefficient electric furnace and air conditioner with a single high-efficiency heat-pump provided the most savings. Other cost-saving actions were as simple as replacing major appliances when they wear out with high-efficiency <u>ENERGY STAR</u> rated products and installing light-emitting diodes (LED) in light fixtures. We'll go into greater detail on three of the most climate-friendly things you can do in your home: installing high-efficiency heat pumps and smart thermostats, and weatherizing your house.

FIGURE 6. Inefficient Home Energy Usage



FIGURE 7. Energy-efficient Home Upgrades



Sources: U.S. Department of Energy, Rewiring America

UPGRADE: High-Efficiency Heat Pumps

Most U.S. homes are currently heated through <u>furnaces or boilers</u> that generally use fossil fuels to heat air or water that is then distributed throughout a home via ductwork or radiators.

<u>Heat pumps</u> work differently; they can both heat and cool a home. Heat pumps draw heat into a house in the winter—they can do this even in very cold climates—and they can move heat out in the summer. A heat pump uses a small amount of energy to move heat from one location to another, by converting refrigerant between its liquid and gas forms. Already, about 1 in 10 American households have heat pumps installed, mostly in southern states.

There are two main types of heat pumps: air source and geothermal (also called ground source). When in heating mode, they collect heat from the air or ground outside your home and concentrate it for use inside.

The most commonly used is the air-source heat pump, which transfers heat between your house and the outside air. The U.S. Department of Energy (DOE) estimates that an air-source heat pump can help <u>reduce electricity use by 50%</u> on average, compared to furnaces and baseboard heaters (also known as electric resistance heating). High-efficiency heat pumps also dehumidify better than standard central air conditioners, resulting in less energy usage and more cooling comfort in summer months. A <u>geothermal heat pump</u> extracts the heat energy from the ground and soil and transfers it into a home. Because the ground temperature is almost always warmer than the air in the winter and cooler than the air in the summer (think of a cave), ground source heat pumps often use less energy than air-source heat pumps. Geothermal heat pumps can cost more to install, but have low operating costs because they take advantage of relatively constant ground temperatures.

Heat pumps aren't new. They've been around for decades, but have become more efficient in recent years, particularly for <u>cold climates</u>. Today's heat pumps can transfer heat effectively in subzero temperatures, although backup heat sources, such as electric resistance, might be required on the coldest days of the year. Studies have shown that heat pumps can be cost-effective even in cold climates like <u>Fargo, N.D.</u>. And a <u>study</u> of California homes showed that a new air-source heat pump can reduce greenhouse gas emissions by 46-54% compared to natural gas alternatives over its lifetime.

<u>Net Zero America (NZA)</u>, a research initiative by scientists and engineers at Princeton University, identified five pathways by which the U.S. could transform its energy system to get to net-zero emissions by 2050. Under a high electrification scenario, sales for heat pumps for space heating would have to grow from about 15% of the market currently to 64% in 2030 and 88% in 2050. But there are challenges to overcome. Heat pumps for space and water heating currently have small market share and consumer awareness of this technology is low. Many homes need additional electrical work to accommodate them, and local contractors and electricians are <u>often not up-to-date</u> on the latest technology.

UPGRADE: Smart Thermostats

Most household thermostats today are operated manually or through preset programming. <u>Smart thermostats</u> are internet-connected devices that automatically adjust heating and cooling temperature settings in your home for optimal performance. Smart thermostats use algorithms and sensors to gather and analyze data over time, remembering your choices and adapting to the household's routine—when you go to work, to sleep, or on vacation. Smart thermostats can eliminate the inefficiency of human behavior, such as when you forget to turn off the heat before you leave the house, thereby driving more predictable energy savings.

Besides tracking your behavior and temperature preferences, the newest models can interact with the energy grid, lowering consumption when energy use, prices, or emissions are at their peak. Homes with renewable energy or battery storage may also be able to send energy back to the grid when it's needed most. A <u>number of products</u> are already available and many more are on the way.

According to <u>analysis</u> by Project Drawdown, smart thermostats could grow from currently being in about 3% of U.S. households to about 60% of households with internet connection by 2050. That alone would reduce enough energy use to avoid 7.0–7.4 gigatons of carbon dioxide emissions. And there are cost savings to be had–<u>a study</u> by Nest of its consumers showed their average energy bills dropped by 10-12% on heating and 15% on cooling.



The benefits of a smart thermostat are more limited for consumers who are home all the time—cost savings are greater for those who are regularly away during the day. The initial purchase cost, perceived complexity, and distrust of smart technologies are some of the <u>barriers</u> to adoption of these new technologies. And the <u>digital divide</u> presents a challenge, with rural communities, older consumers, and people of color more likely to have limited or no internet access.

UPGRADE: Home Energy Audits and Weatherization

Unlike cars, there are no required energy performance or emissions standards for homes or buildings after they're constructed. As a result, homeowners may find themselves with larger energy bills and a larger carbon footprint due to inefficient building performance. Lack of insulation and efficient heating or cooling equipment can also leave residents exposed during extreme heat or cold weather events.

For low-income households, an uninsulated home and inefficient appliances can be particularly burdensome. According to the U.S. DOE, low-income households typically spend nearly <u>14% of their income</u> on energy costs, compared to 3% for others. Research shows that energy insecurity increased during the Covid-19 pandemic. Black and Hispanic households were more likely to be threatened by utility disconnection, as were households with young children, individuals who rely on electronic medical devices, and those who live in inefficient dwellings. When families are struggling economically, they may be forced to choose between paying for necessities like food or medicine or endure dangerous temperatures during an extreme heat or cold event.



"Weatherization" refers to both assessing buildings and their energy systems, as well as designing and implementing efficiency measures to make buildings use less energy while also providing comfort and cost savings for their occupants.

To start, energy auditors use advanced equipment to determine the most cost-effective measures appropriate for each home. Trained technicians use tools like a "blower door" to depressurize the house and check for air leaks. Infrared cameras can identify where heat losses occur and where more insulation is needed. They can also determine if your appliances are too energy intensive or inefficient. Testing and remediating for unhealthy things like gas leakage, lead, moisture damage, mold, asbestos, insects or pests, is also essential during an audit—you don't want to seal in anything that can lead to poor indoor air quality and trigger asthma or other health conditions.

In light of the widespread power outages in Texas during the winter storm in February 2021, a <u>study</u> by the American Council for an Energy-Efficient Economy (ACEEE) found that Texas could make its grid more resilient and avoid future blackouts by improving the energy efficiency of homes and shifting electricity use to off-peak times, rather than building expensive or fossil fuel-burning power plants. ACEEE found that a majority of Texan households use inefficient electric furnaces and half of single-family houses have inadequate attic insulation.

THE ULTIMATE GOAL: ZERO ENERGY BUILDINGS

Energy intensity in buildings is projected to <u>stabilize or decrease</u> by mid-century, even with population and economic growth, if cost-effective best practices and technologies that are already here today are instituted. Already, <u>zero energy buildings</u> (alternatively, <u>zero carbon buildings</u>) are being constructed that can produce enough renewable energy to power most or all of their annual energy consumption—including heating and cooling, appliances and devices, lighting and cooking. Energy efficiency and renewable energy are combined in a way that the building consumes only as much energy as can be produced onsite.

These "homes of the future" are actually already here. The U.S. DOE has a <u>database</u> of nearly 300 zero energy homes around the country in all types of climate zones that are designed to have most or all of their energy needs met with renewable energy. The homes range from a three-bedroom Colonial style in <u>Connecticut</u> that has energy bills of just \$7 a month to a Habitat for Humanity home in <u>Florida</u> that saves its owners \$700 a year on their utility bills.

In addition, a number of cities now require new homes to accommodate charging ports for electric vehicles. Building codes requiring electric vehicle-ready construction are already in place in Atlanta, Denver, Seattle, and the entire state of California.

BETTER HEALTH AND MORE JOBS

Besides reducing greenhouse gas emissions and saving energy costs, electrification and efficiency efforts also have potential health and local job growth benefits.

Electrifying appliances creates cleaner indoor and outdoor air. Gas furnaces and stoves can release some of the same <u>harmful emissions</u> as a car, but in your house. Burning gas produces nitrogen dioxide, or NO₂, and sometimes also carbon monoxide, formaldehyde, and other harmful pollutants into the air, which can be toxic to people and pets. A <u>2013 review</u> of 41 studies found that in homes with gas stoves, children had a 42% higher risk of experiencing asthma symptoms, and, over their lifetime, a 24% increase in the risk of being diagnosed with asthma. Another <u>study</u> showed that 70% of U.S. houses could reduce health damages from air pollutants by installing a heat pump. And indoor pollution disproportionately affects low-income households with smaller homes.

Low-income households would also gain health benefits from weatherization and the related home improvements. Some <u>30 million Americans</u> are considered to be below the poverty line. Many live in cramped, older homes with <u>structural</u> <u>deficiencies</u> like pest infestation, mold, lead paint and exposed wiring. Properly insulating a home and remediating these issues reduces heating and cooling costs, and also improves indoor air quality. This results in healthier environments and can decrease sick days and hospital visits for families.

And ramping up energy efficiency and electrification would create local, good-paying jobs. About <u>2 million Americans</u> currently work in energy efficiency, more than in any other energy sector—with the potential to grow. According to <u>Rewiring</u> <u>America</u>, electrification of household appliances would create about 460,000 installation jobs in the U.S. as well as 80,000 manufacturing jobs and 800,000 indirect and induced jobs.

CHALLENGES AND PROGRESS

Despite all the economic, health, and climate benefits of electrification and more efficient homes and appliances, there are still a number of barriers. The need for up-front capital to make energy upgrades in homes or purchase betterperforming appliances can be a major challenge for many families, and renters have little incentive to use their own money to invest in upgrades.

<u>Twenty-seven states</u> have established mandatory energy savings targets to drive investments in utility-sector energy efficiency programs. One such type of program, on-bill financing (OBF), allows homeowners to invest in energy efficiency upgrades and repay the initial investment over time through their utility bills, until they reach energy savings. According to ACEEE, <u>23 states have OBF programs</u>, but customers are often unaware of them. Low-income households may be eligible for the federal government's <u>weatherization assistance program</u>, which is run through states' local weatherization agencies, and each state has slightly different eligibility requirements. Local energy services teams can address energy-related health

and safety problems or perform incidental repairs. ACEEE has developed <u>state</u> and <u>city</u> scorecards and factsheets to show where there's been progress and where there's more potential for climate-friendly buildings and other clean energy policies. <u>California</u> and a number of its cities have long been leaders in clean energy and energy savings efforts, and the state has adopted net zero energy building codes and industry-leading appliance standards. But cities all over the country are making their buildings and transportation systems more energy efficient and investing in renewable energy. <u>Denver</u>, <u>Pittsburgh</u>, <u>Phoenix</u>, and <u>Minneapolis</u> all ranked in the top 20 clean energy cities in 2020.

State and local programs that encourage electrification of space heating in homes and buildings—primarily using high-efficiency heat pumps—are also growing rapidly. ACEEE identified 23 programs valued at nearly \$110 million across the U.S. in 2020. Maine has one of the most robust heat pump incentive programs. The state has set goals of reducing greenhouse gas emissions by 45% by 2030, and electrification of heating is essential, since 4 of 5 Maine households use oil, natural gas, or propane for heating, including 62% who use fuel oil, the highest of any other state. In early November 2021, the city council of Ithaca, N.Y., voted to electrify and decarbonize the entire city. Ithaca has about 30,000 residents who live and work in some 6,000 homes and buildings.

There are a number of ways that we can reduce the carbon footprints of our homes and reduce energy demand, while saving on our energy bills and improving the air we breathe, indoors and outdoors. But it's not just up to individuals. In November 2021, Congress passed an infrastructure bill that included \$3.5 billion in new funds for weatherizing homes of low-income households. The bill also included more than \$1 billion for building energy codes, new revolving loan funds aimed at residential, commercial, public school, and federal building upgrades and worker training. public school and federal building upgrades, and worker training. Government incentives, programs, and energy efficiency standards at all levels will ultimately help lower the barriers to entry for households to invest in efficiency upgrades and climate friendly appliances.

MAKING MULTIFAMILY HOUSING CLIMATE FRIENDLY

More than a third of all U.S. households are <u>renters</u>, with some 30 million households living in multifamily housing, such as apartments or condominiums. And while those living in apartment buildings generally use <u>less energy</u> than other households, energy efficiency measures are far <u>less likely</u> to be installed in multifamily rentals than in any other type of housing, according to the U.S. DOE.

Older apartment buildings tend to be less efficient than newer ones. Many steam-heated multifamily buildings <u>overheat in</u> <u>winter</u> due to poor boiler system controls and uneven heat distribution, leading to wasted energy and uncomfortable living conditions. A <u>study</u> of more than 900 multifamily dwellings and townhouses found that only 1% had right-sized heating equipment and 6% had right-sized cooling equipment.

Lack of efficient heating and cooling systems is often the case for multifamily properties that are home to low-income households. Under-resourced renters and Black, Indigenous, and people of color spend <u>disproportionately more</u> of their income on home energy costs. With a shortage of affordable housing in many parts of the country, energy efficiency upgrades can provide relief to low-income families and help keep rental units more affordable.

According to <u>research</u> from ACEEE, apartment buildings and condos present a considerable opportunity for reducing energy consumption that would result in reduced carbon emissions and lower utility bills. Energy efficiency measures could cut at least 15% of electricity use and provide up to \$8 billion in savings. But renters can't necessarily do the retrofits on their own, as it can take several years to make back the investment through lower electric bills, and landlords need an incentive.

There are a number of programs and examples of efforts to decarbonize multifamily housing.

ACEEE's review of state and local programs for <u>affordable</u> <u>multifamily energy efficiency</u> highlights the need for financing and incentives, technical assistance, collaboration among partners and stakeholders, and effective outreach.

Energy Efficiency for All (EEFA) is a collaboration that works at state and local levels to make multifamily homes more affordable and healthier places to live through energy and water efficiency measures.

<u>BlocPower</u>, a Brooklyn-based technology company, works on renewable energy and efficiency projects in urban areas, often retrofitting <u>multifamily buildings</u>.

Zero energy multifamily projects are being developed around the country, including in <u>Philadelphia</u>, <u>Salt Lake City</u>, and even a senior living community in <u>Rancho Cucamonga</u>, California.