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Transforming our buildings for a low-carbon era: Five key strategies

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ABSTRACT

Significantly reducing building sector greenhouse gas emissions is necessary to meet state and local climate stabilization goals. Initiatives to decarbonize home and building energy use are enabled by a new generation of advanced air source heat pumps (ASHPs) that provide efficient, comfortable heat even at low outdoor temperatures as well as highly efficient air conditioning in the summer. Coupled with thermal improvements to building envelopes and smart controls responsive to grid reliability needs, ASHPs are displacing the use of fossil fuels for comfort heating while providing a range of economic benefits. Investments to decarbonize buildings are most economical in natural market cycles of building construction, renovation and equipment replacement, and as part of community development initiatives to improve and preserve affordable housing. A growing number of state and local policies and programs are accelerating the rate of efficient electrification of home and building heating to replace fossil fuel heat with increasingly carbon-free renewable electricity.

1. Introduction: reducing building greenhouse gas emissions: an urgent challenge for the next decade

Recognizing the urgent need for climate stabilization action, many U.S. states, communities and businesses have adopted the Intergovernmental Panel on Climate Change's (IPCC) recommendation to reduce greenhouse gas (GHG) emissions 45% below 2010 levels by 2030 and reach net zero by 2050 (Myles et al., 2018 p14). For example, over 3000 states, cities and business have joined America's Pledge to aggressively reduce GHG (America's Pledge Initiative on Climate, 2018), and are implementing plans and initiatives to achieve these goals (Philander and Nursey-Bray, 2012). Recently, more than 100 U.S. cities adopted 100% renewable energy goals for their jurisdictions (Club, 2019).

This swelling of support builds on the success of federal, state and local policies to green the electric grid by reducing power plant GHG emissions and increasing the role of affordable renewable energy to meet electricity needs. For example, Northeast U.S. power plant GHG emissions fell more than 40% since the Regional Greenhouse Gas Initiative (RGGI) began a power plant GHG emissions cap-and-trade program in 2009 (Acadia Center, 2017). Since 2008, renewable electricity output grew by 100 percent in the U.S., while the cost of solar and wind energy declined 88 percent and 69 percent, respectively (Mahajan, 2018; Marcy, 2019). Buoyed by these policy-driven successes, concerned states and communities are turning their attention to reducing GHG emissions associated with fossil fuel use in transportation and buildings (Philander and Nursey-Bray, 2012). GHG emissions from buildings are a major challenge – constituting 15% to 40% of local GHG emissions (BEICITIES, 2019).

Reducing building GHG emissions (a.k.a. "building decarbonization") displaces the direct use of fossil fuels (e.g., heating oil, propane and natural gas) with efficient electrification of space and water heating using electricity from an increasingly renewable energy-powered grid (IPCC, 2018). A new generation of advanced air source heat pumps (ASHPs) makes it possible to efficiently displace the use of fossil fuel-fired boilers, furnaces and water heaters for space and water heating, even in cold climates. Coupled with building shell energy efficiency upgrades and smart controls responsive to peak grid use signals, advanced heat pumps make building decarbonization through efficient electrification the next major step to a low-carbon economy.

Considerable economic value can be achieved in reducing the GHG footprint of buildings with electrification, thermal efficiency and smart controls. In addition to reduced GHG emissions, benefits can include lower energy bills, local job creation, improved occupant health, safety, comfort, increased productivity and increased resilience in the face of extreme weather (Cowell, 2016; NEEP, 2017a). These multiple benefits are a critical part of the building decarbonization value proposition. When viewed together, they can make building decarbonization investments cost-effective, particularly when done at the time of natural market cycles of building construction, renovation, equipment replacement or community development (Cleveland et al., 2019).

Efficient building electrification as a key pathway to economy-wide

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decarbonization is largely a new effort in the U.S. with significant barriers to overcome (NEEP, 2017b). Currently, efforts to drive building decarbonization technology and market development are at an early stage, but significant progress is being made. This paper discusses the most important near-term opportunities to advance building decarbonization and strategies to begin the transition to a low-carbon built environment.

2. Strategy one – buildings as batteries: a flexible load for a modernized grid

How building electrification is implemented can make all the difference in electric grid usage and customer rate impacts. Adding advanced heat pumps to electric grid loads offers an opportunity as well as challenge. The opportunity is to improve the economics of our electricity system and reduce GHG emissions by using underutilized off-peak grid capacity to deliver renewable electricity for space and water heating, displacing the direct use of fossil fuels. The challenge is that, at the same time, building electrification can add to peak period demand, drive the need for costly new grid capacity, and increase the need for peak period fossil-based generation.

For example, in examining the potential impact of increased heat pump use in the Northeast U.S., a Northeast Energy Efficiency Partnerships (NEEP) study found the potential for heat pumps to shift the seasonal peak from summer peaking to winter peaking as shown in Fig. 1, including potentially increasing the current winter peak spike that occurs during prolonged periods of severe cold (NEEP, 2017b).

Efficient buildings with smart controls can minimize increases in electricity demand and shift demand to off-peak periods (DOE, 2019). For example, low-load homes and buildings using passive house design minimize grid requirements in all periods. Thermally efficient, air-sealed buildings with low emissivity windows can respond via smart thermostats to grid signals to reduce the demand for heating (or cooling) during peak periods while maintaining comfortable indoor temperatures. Similarly, water heaters and electric vehicle (EV) charging can further defer the call for electricity to meet grid reliability needs. Currently, 80% of EV charging is done at home and most of the remaining charging is completed at work, which makes EV charging effectively a "buildings" load.

Adding thermal storage within buildings (e.g., ice storage, hot water tanks) can be part of electrification strategies. Additional electric storage within buildings has been piloted and may have value for resiliency and reliability as well as load shifting. EV battery systems can also become part of a building's resiliency with modifications to controls. While most building-sited renewable systems to date do not include electricity storage, grid scale and community scale systems sometimes do include storage. As building-integrated batteries become more common (Jin et al., 2017), adding storage either to a building directly or within a community of buildings may become more common to smooth distribution loads.

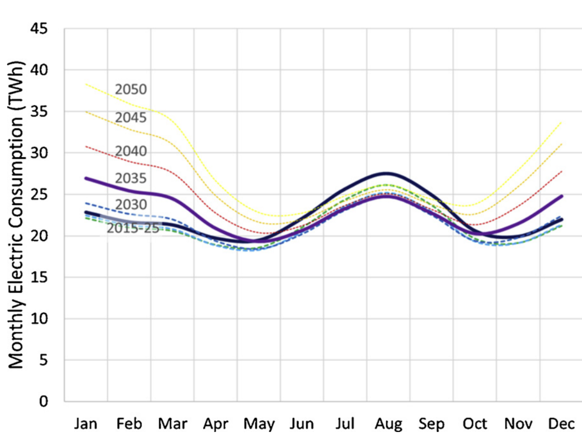

Fig. 1. Approximate monthly electricity consumption, 2015–2050 as modeled under the Plausibly Optimistic scenario, showing the shift to winter peaks.

In commercial buildings, building management systems use digital platforms to manage multiple building loads to optimize energy performance as well as respond to grid signals. Such systems are changing the way that buildings are managed to meet both occupant as well as energy system needs. While major manufacturers and service providers today offer a range of building energy management controls, research by the U.S. Department of Energy's Building Technologies Office is helping to provide greater insight into how such systems can enable a two-way interaction between buildings and the electric system to provide a range of grid services (e.g., demand response, virtual storage, reactive power) (Nemtzow, 2017).

3. Strategy two: accelerate adoption of advanced heat pump products and services

Almost all houses in the U.S. have a heat pump, if not three or four. We know them primarily by other names: refrigerator, freezer and air conditioner. Using a heat exchanger, compressor and pump, heat pumps transfer thermal energy (heat) from one location to another.

ASHPs use electricity to provide a combination of space heating and cooling to homes. They have been around for decades. In warmer parts of the country, ASHPs are commonly used for home heating as well as air conditioning. In San Diego, about half of all newly-constructed houses use heat pumps (Hopkins et al., 2018). Older heat pumps, however, do not perform well when outdoor temperatures approach or drop below freezing, at which point the heat pump reverts to inefficient, costly electric resistance heating. This feature has made ASHPs unattractive as a primary heating system in cooler climates.

Fortunately, ASHP product innovation is changing that. Using inverter-driven, variable-speed compressors, advanced cold climate ASHPs (ccASHPs) have radically improved heating performance while maintaining a high level of efficiency at even very low outdoor temperatures (at or below 5 °F). These same innovations also make advanced ASHPs among the most efficient space cooling systems available today. Cold climate air source heat pumps have opened vast new markets for efficient electric heating in cool climate regions including the Northeast, Mid-Atlantic and Upper Midwest in the U.S. Advanced heat pump technology also provides highly efficient water heating and can reduce water heating energy consumption by up to 63% (NEEA, 2016). In humid climates, heat pump water heaters (HPWH) can also assist space dehumidification. Other types of heat pumps (e.g., ground source and water source) further extend the climate range and types of buildings where heat pumps can meet space and water heating loads (NEEA, 2016).

Another important innovation is the use of natural refrigerants (e.g., carbon dioxide, water, air, ammonia) that eliminate the use of CFC-based refrigerants to further reduce the GHG impact of heating, ventilation and cooling (HVAC) product use. Currently, very few natural refrigerant-based ASHPs or HVAC products are commercially available. Further work is needed to accelerate their development and deployment (Green-Cooling-Initiative, 2019).

The GHG emissions offset of ASHPs depends in part on the carbon intensity of the electricity used to power the heat pump. However, in most cases, as shown in Fig. 2, the superior efficiency of advanced heat pumps – with co-efficients of performance between 1.5 and 4.0 – results in lower GHG emissions compared to conventional systems for space and water heating. The more thermally efficient the building shell, the smaller the ASHP system size and the lower the GHG emissions.

A key challenge is that ASHPs are a relatively new product and are unfamiliar to many HVAC installers and consumers. In addition, optimizing the size of an ASHP system for an older building often calls for thermal efficiency improvements to the building shell. Policies and programs can increase market attention and inform consumer choices

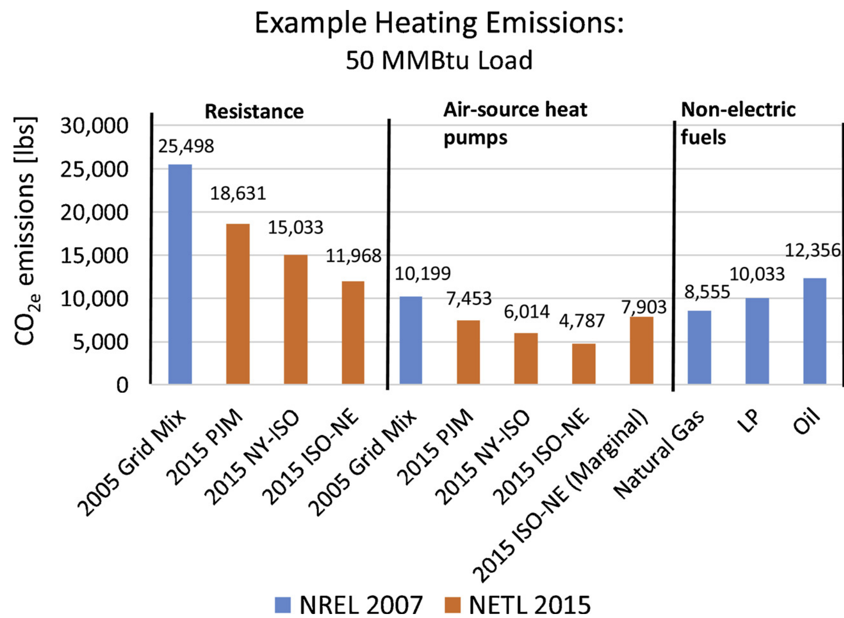

Fig. 2. Space heating-related emissions across heating technologies (Lis, 2017).

by referencing high performance ASHP product specifications; (NEEP, 2019a; NEEA, 2019) setting standards for and supporting training and certification of heat pump installers (NEEP, 2019b) and building envelope contractors; (Building Performance Institute, Inc, 2019) providing educational materials to help customers make informed product choices; (NEEP, 2019b; Green Energy Consumers, 2019) and supporting the use of building and home energy ratings and labels that distinguish energy efficient structures (NEEP, 2019c).

Consistency in heat pump performance specifications across programs helps ASHP manufacturers and installers scale up their products and services in a manner that reduces costs, increases product availability, expands options and improves customer satisfaction. For example, NEEP's ASHP market transformation initiative provides a ccASHP performance specification with a list of products that meet that specification, along with best practice guidance for consumers and installers developed collaboratively with industry, government, utilities and advocates. These are used by efficiency and electrification programs in seven states. Similarly, the Northwest Energy Efficiency Alliance (NEEA) is helping to overcome market barriers through a high performance HPWH program with equipment specifications referenced by efficiency programs across the Pacific Northwest. The California-based Building Decarbonization Coalition is leading an effort to reduce installation costs with cost competitive "retrofit ready" heat pump water heaters.

4. Strategy three: focus on natural market cycles for building decarbonization investments

Building electrification and decarbonization can require significant investments, particularly for existing buildings that need thermal shell improvements. In that context, natural market cycles of building construction, renovation and equipment replacement (e.g., replacing aging or malfunctioning water heaters, central air conditioners, furnaces or boilers) are the best and most economic opportunities to invest in home and building electrification to minimize GHG gas emissions. Leading programs and policies offer incentives and technical assistance to accelerate market adoption and build market capacities, as well as accelerate the timing of investments through building energy performance standards.

4.1. New construction

Fundamental building efficiency features (e.g., architectural massing, solar orientation, natural ventilation, insulation level) can last the lifetime of the building. Similarly, building equipment or building shell elements (HVAC system type and windows, for example) can easily last 20 years or more (Brand, 1995). As a result, it is most economical, and sometimes only possible, to get the deep efficiency elements of a building right the first time, in the initial design and construction of homes and buildings.

The pathway to deep efficiency has been developed and demonstrated through Zero Energy Buildings, Zero Energy Ready Homes, and Passive House. The market progresses as these leading building concepts are included in design guidance; supported by training, technical assistance and incentives; and then incorporated into building energy codes. This has already happened in a few leading states and cities (New Buildings Institute, 2018).

Zero Energy (commercial) Buildings (ZEBs) use 60–80% less energy than buildings built to typical construction standards and draw the remaining energy from onsite renewable power. Over 500 commercial buildings have been documented to achieve zero energy performance across the U.S. and Canada (New Buildings Institute, 2018). Over 8000 zero energy residential buildings have been documented in North America, comprising about 13,000 housing units (Net-Zero Energy Coalition, 2019). A Zero Energy Ready Home (ZERH) that meets the U.S. DOE's criteria is at least 40–50% more energy efficient than a typical new home and has the structure and electrical connections ready to add solar panels to supply the remaining energy needs. Over 5000 ZERHs have been built as of 2017 (Hewitt, 2017). ZEBs and ZERHs may seem extreme to some, but the North American market for ZEBs is projected to grow at an annual rate of 38%, increasing in size to $127 billion by 2035. NEEP's building energy code program has set a goal of zero energy codes in all Northeast states by 2035. Most of these buildings can readily use some form of electric heat pump, and many already do. The pathway is developed, but moving to mainstream market adoption will require years of program support to fully build market capacities.

4.2. Existing homes with central air conditioning

Homes with central air conditioning (CAC) and fossil heating can be

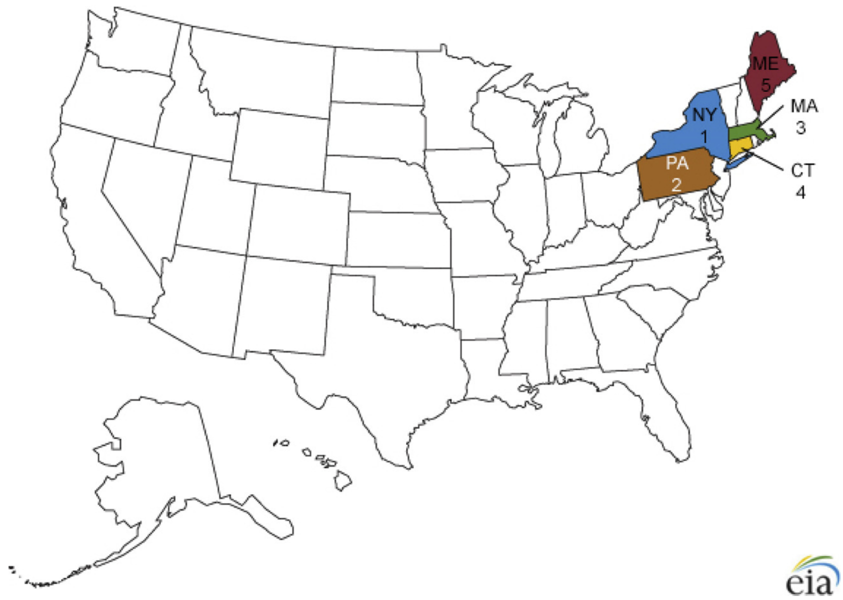

Fig. 3. Top five residential heating oil consuming states, 2017. Source: U.S. Energy Information Administration.

great candidates for advanced ASHPs when either of the incumbent systems requires replacement. Expanding a CAC system to a heat pump can be a relatively inexpensive switch in existing homes, and has even lower initial costs and greater efficiency in new construction (Hopkins et al., 2018). With the advent of ccASHP, the heat pump option that is already strong in many southern markets for new construction can be expanded into cooler climates where central air conditioning is becoming more common (Lis, 2017).

In existing homes and buildings, some building energy design features have already been established and can be difficult to alter (e.g., wall cavity size and thermal gaps), but opportunities exist to change HVAC and water heating equipment along with some building envelope measures. Making building envelope efficiency investments at the same time as ASHP sizing and installation can reduce heating system size and cost, reduce grid impacts, and sometimes enable more system choices (e.g., a single ductless system vs. a multi-head system). Coupling a heat pump retrofit with building shell efficiency upgrades in a single project can reduce transaction costs and improve the overall economics. Choices in system efficiency and building efficiency will impact long-term energy performance and should be comprehensively considered as part of electrification efforts.

Controls are the third part of the equation for existing homes. In a developing low-GHG economy, both heat pump water heaters and electric vehicle charging will become more common. While controlling HVAC loads may have limited electric system benefits, better control of water heating and EV charging has proven, major system benefits. Controls (or home energy management systems) that can support future electrification should be part of any building electrification retrofit.

4.3. Water heater replacements

The consumer economics of electrifying water heating vary significantly based on climate, fuel type, electric rates and housing type; but in many situations, consumer economics support changing to HPWHs when incumbent equipment fails. In addition to reduced energy consumption, high efficiency HPWH's also provide flexible, controllable loads needed to match the timing of energy use with variable renewables or to shift demand to lower cost time periods (Farnsworth et al., 2019). While many consumers may wonder what a HPWH is, in Oregon and Washington HPWHs make up 10 percent of the market share of electric water heaters — still early in the technology adoption, but increasingly familiar (Cadeo Group, 2018).

4.4. Consumer-driven air conditioning retrofits

Across the country, as climate change-driven summer heat waves increase, residential consumers without CAC are deciding to upgrade their air conditioning strategy from a couple of aging window units to a system that offers more comfort. Ductless heat pumps are the most frequent choice and are certainly much more efficient, but some consumers also move to CAC. Ductless heat pumps, of course, include heating, which comes as a surprise to some consumers who care more about cooling. Similarly, moving to a CAC could simply be extended to moving to a central ASHP, displacing the existing fossil system. ASHP incentive programs in several Northeast states (e.g., Massachusetts, Rhode Island, and Connecticut) began with a focus on advanced ASHP for air conditioning before incentives for efficient fuel switching were approved (Vermont Energy Investment Corporation, 2018).

When ductless systems are chosen for retrofit, optimizing the system to provide heat in conjunction with an incumbent fossil system requires dual system controls (Vermont Energy Investment Corporation, 2018). Currently only a limited number of such controls are commercially available – another issue for market transformation programs to address.

5. Strategy four: begin the difficult work within high value opportunities — some important targets

5.1. Northeast homes & buildings: cold, old and oily

When considering GHG reductions in individual buildings using ccASHPs, the Northeast U.S. offers great potential. The region has some of the coldest weather, the oldest housing stock, and the highest use of carbon-intensive heating oil in the country. The U.S. Energy Information Administration (EIA) recently reported that the 20% of households in the Northeast Census region that use heating oil as their main space heating fuel account for about 80% of the U.S. households that use heating oil for space heating (Energy Information Administration, 2018) (Fig. 3)."

The complete fix to replace heating oil (and propane) in existing buildings, especially when used in boiler systems, can be complicated and expensive, but the GHG savings are large, as are the health, safety and comfort benefits (Cowell, 2016). Heating oil and propane are expensive per unit of heat delivered, which improves the long-term cost effectiveness of ASHP conversions (Billimoria et al., 2018). But the first cost of the replacement system can be expensive, and only some ccASHPs offer high efficiency below 0 °F.

For many households, the near-term fix is a ductless heat pump, a partial solution that consumers and some states and utilities are adopting (Lis, 2017). More complete solution sets for these building types need to be optimized, and will likely include deeper efficiency to minimize heat pump system size and load, along with the possibility of other technologies (such as energy storage, local renewables, or other heat pump types) necessary to reduce the grid impacts of such fuel switching at scale. Because of the potential GHG savings and building complexities, this cold, old and oily market needs more technical analysis and continued product development to have complete solution sets for the full range of housing types (Cleveland et al., 2019).

5.2. Warmer climates: one system in place of two

In hot/humid and other warmer climates, HVAC retrofits using advanced ASHP can displace both older CAC and electric resistance heating systems, providing overall increased energy efficiency and lower energy bills. Likewise, installing a HPWH to replace inefficient electric resistance water heating can provide needed dehumidification. Programs and policies that build scale for HPWH and advanced ASHP installation in hot/humid and warmer climates can help increase competitiveness and reduce product costs, leading to improved costs effectiveness in additional climate zones.

5.3. Affordable housing and community development initiatives

Efficient electrification of affordable housing offers important value for economically disadvantaged households by providing improved occupant health, safety and comfort in addition to lower, more affordable energy bills. It is a key sector to address as states and cities move forward with building decarbonization initiatives to meet GHG emission reduction goals.

In new construction, the Pennsylvania Housing and Finance Authority offers an excellent example. By making passive house design a winning competitive option in its annual new affordable housing solicitation that awards federal low-income housing tax credits, it has inspired 14 other states to, likewise, include points for passive house design in their affordable housing procurements (Legere, 2018).

For many low- and medium-income households, many of whom live in housing needing repair as well as energy retrofits, building electrification and decarbonization retrofits offer the potential to improve the health, comfort, safety and affordability of their homes. But low- and medium-income households are hard-pressed to afford such improvements. Worse yet, energy retrofits in rental properties can expose tenants to increased rents they can ill-afford even if the improvements lower energy bills. Nonetheless, both new and retrofitted housing that serves economically disadvantaged communities offers a very high value opportunity to reduce building GHG emissions. It's a question of how this is done.

Critical to such initiatives is community involvement that integrates electrification of heating and energy efficiency retrofits with community development initiatives that address multiple goals (e.g., housing affordability; economic development; improved education, health and quality of life). Technical retrofit solutions for 3–4 unit low-rise multifamily buildings readily exist, but solutions for larger multifamily and mixed-use properties are still evolving. Done thoughtfully, such strategies can make social equity and energy justice a successful focus of low- and medium-income building decarbonization initiatives.

5.4. Areas with fuel availability issues

In areas of new development and redevelopment, or in areas where gas lines require expansion (ICF, 2019), repair to reduce leaks or other major upgrades, electrification in combination with renewable power generation can be an economic option. It is more cost-effective to develop one infrastructure (a smart electric grid) rather than two (smart electric grid and expanded or upgraded gas infrastructure). When dealing with a broader geographic area, moving to community-scale projects rather than individual buildings can reduce costs of renewables and create alternative mechanisms for financing, maintenance and grid integration of heating and cooling resources (Gerdes, 2018). Other technologies can also come into play for building electrification, such as a larger scale ground field for ground source heat pumps or use of a community low temperature heat resource, such as sewer waste, to drive a water source heat pump.

6. Strategy five: local government leadership for building electrification

Some of the most aggressive strategies in GHG reduction are being developed and implemented at the city level. The international Carbon Neutral Cities Alliance and the Sierra Club's growing network of over 100 U.S. cities pledging to use 100% renewable energy are two examples of pioneering city efforts. Cities have begun to tackle the issue of building electrification more directly. Eight U.S. cities across the country are participating in the Building Electrification Initiative, a project that emerged from city-led efforts within the GHG Neutral Cities Alliance (BEICITIES, 2019). These cities are pursuing a range of actions to accelerate equitable building electrification strategies, including voluntary outreach and assistance programs, utility partnerships, and new codes that will eventually help achieve a widespread transition away from fossil fuel-based building systems in their communities.

When it comes to building decarbonization, cities have the ability to innovate in program design to accelerate voluntary local and regional action. New York City, for example, partnered with the state and its utilities to create innovative programs such as the NYC Retrofit Accelerator and the NYC GHG Challenge (NYC Mayor's Office of Sustainability, 2019; NYC Retrofit Accelerator, 2019) to build the market for energy efficiency upgrades. Many cities also have the ability to regulate building energy performance through their local building and energy codes by adopting advanced "stretch" codes, building energy rating and disclosure ordinances and, very recently, minimum energy performance standards for existing buildings. More than 20 cities have enacted building performance ordinances that include energy benchmarking (City Energy Project, 2015), with several leading cities including New York City and Washington, D.C. requiring aggressive levels of energy or GHG emission reductions from their larger buildings (Progressive Caucus of the New York City Council, 2019); (Hill, 2018). In California, more than 30 cities are pursuing "reach codes" that will go beyond the already-stringent statewide energy code to encourage or require all-electric new construction, ensuring that the buildings of the future are being constructed today. The City of Vancouver, Canada is implementing a detailed and comprehensive Zero Emissions Buildings Plan that employs "catalyst tools" such as density bonuses, guidance, technical support and, ultimately, building code requirements to transition its building stock to a zero GHG future.

Cities pursuing GHG neutrality, 100% renewable energy, or other aggressive GHG reduction targets can increase their economy-wide impacts by pursuing similar building energy strategies with similar requirements to achieve their goals. They also benefit from partnerships with industry, state programs/policies, electric utility programs and regional market transformation initiatives to build consumer interest and market capacities to reduce product costs and increase consumer options. Such market development can also make new regulations and requirements more viable options. As such, coordinating with leading cities can be a powerful opportunity to build early scale for electrification and lay the foundation for future efforts that will be needed to reach scale.

7. Summary

Building decarbonization is a key GHG emissions reduction strategy to achieve international, state and local climate stabilization goals. We cannot get to 80% GHG emissions reduction by 2050 unless we decarbonize the majority of U.S. homes and buildings. While it is important to make all new construction GHG-free as soon as possible, the most urgent challenge is to decarbonize existing homes and buildings as they represent the bulk of the building GHG emissions.

Building decarbonization uses current and evolving technologies to replace the combustion of fuels in homes and buildings with efficient electrification, energy efficiency, and smart controls responsive to customer needs as well as grid reliability. The critical target is the efficient electrification of space and water heating in buildings which account for more than 80% of building fossil fuel use. Technology innovation has yielded a new generation of advanced high efficiency heat pump products that displace the need for fossil fuels for space and water heating, including ccASHPs that extend the climate range for high efficiency heat pump use.

Building decarbonization requires public policies and private investments to replace the use of fossil fuels for space and water heating, and in many cases, to improve building energy efficiency to reduce thermal losses. Doing so offers considerable value to the public, consumers, utilities and grid operators well beyond GHG emission reductions. These multiple values are key to leverage the resources needed for meaningful building decarbonization investments.

Investments to decarbonize buildings are most economical in natural market cycles of building construction, renovation and equipment replacement, and as part of community development initiatives to improve and preserve affordable housing.

The most important and cost-effective opportunities for decarbonization are when buildings or homes are built or renovated, or when existing heating and cooling equipment is replaced (e.g., retired due to age or malfunction, or as part of other planned building or home improvements). Working within these natural construction and appliance replacement market cycles uses existing market capacities to provide products and services, and requires only the incremental cost of increased efficiency (e.g., the cost of an advanced heat pump to replace a central air conditioner, or to replace an aging, less efficient furnace or boiler). Community economic development initiatives to reduce the energy burden and improve the quality of life for economically disadvantaged households and communities offer another practical and economic opportunity to decarbonize buildings. Building energy standards for existing buildings such as those recently adopted by the District of Columbia and New York City accelerate these natural market cycles, an initiative many cities find necessary to achieve climate stabilization goals such as reducing GHG gas emissions 45% below 2010 levels by 2030 or to reach net zero by 2050.

Building decarbonization efforts are beginning in the U.S., but government, utility and industry leadership is needed to accelerate policies and programs to overcome market barriers and unlock the economic, environmental and health benefits of replacing fossil fuel heating. Doing so offers many social and economic benefits today, while making a livable climate possible for future generations.

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