

# America's **ZERO CARBON ACTION PLAN**

## 5.4 Accelerating Deep Decarbonization in the U.S. Buildings Sector

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### 5.4.1 Introduction, Context, and Goals

To advance the building sector's deep carbon reductions, we propose policies to create—in a job-intensive fashion—a new generation of greener and healthier low-carbon buildings and communities. Today, the U.S. residential buildings sector by itself has a larger footprint than the entire greenhouse gas (GHG) output of Germany or Brazil. In bringing those and associated carbon emissions to zero, the U.S. can lead in the development of cutting edge technology, restore its productive capacities and global competitiveness, create millions of well-paid construction related jobs, and cut the energy bills for those Americans who can least afford them.

The policy plan put forward in this chapter would ensure that by 2050, GHG emissions from onsite fossil fuel consumption in buildings have been reduced by at least 90 percent. Instead, buildings would be powered by clean electricity (including from on-site renewables where it is reliable and cost-effective), or in limited circumstances from low-to-no-carbon gas, pending the development of more affordable technologies. Electrification supported by renewables, energy efficiency, and grid-wide demand-response strategies will ensure the 2050 goals of this overall report are achieved at the lowest incremental cost to society improving the health, security, and livelihoods of Americans across the country.

Prominent and highly progressive policy proposals have set forth ambitious goals for the building sector – either directly, such as “reducing the carbon footprint of the U.S. building stock 50 percent by 2035,” or by implicitly assuming those types of savings by requiring the entire U.S. economy to reduce greenhouse gas emissions by 37 percent below 2010 levels by 2030.<sup>1</sup> They also include detailed lists of possible legislation including potential revisions to existing financial incentives (tax or financing) or capacity-building programs that impact the U.S. building stock. The proposals in this chapter present a holistic, data-supported action plan for assessing and prioritizing these more granular ideas. This chapter also details how the building sector is currently using and wasting energy resources, the strategies that are necessary to decarbonize the sector, and, where appropriate, how these proposals advance beyond the status quo trends in policymaking at the federal and sub-national levels.

Finally, this chapter provides a distillation of the roadmap to those policies and practices most critical to meeting the ambitious 2050 target date for a carbon-free U.S. economy.

## Building Sector Decarbonization for Job Creation, Cost Minimization, and Poverty Reduction

### Efficiency Gains Ensure Lowest Cost Pathway & Energy Poverty Reduction

The deep decarbonization pathway to net-zero by 2050 laid forth in this plan is built on the firm assumption that across all sectors we can achieve a 40 percent per capita reduction in energy demand (energy efficiency) by 2050 and a 300 percent increase in the share of energy from electricity (see Figure 5.4.2). Failure to accomplish this level of efficiency (principally from the transportation and building sectors) could increase the total costs of building out and managing the new and expanded clean energy grids by as much as 300 percent in major metropolitan population centers (See e.g., Figure 5.4.1).<sup>2</sup> In short, efficient buildings fueled by clean energy are the lowest cost pathway to accomplishing the broader policy action plan set forth in this document.

The value of energy efficiency will not be limited to reducing the overall costs to our society of decarbonization. Individual Americans, especially those in low income housing, will also be beneficiaries, through reduced energy costs. Energy poverty reduction was a large part of the Obama administration's clean energy stimulus initiatives included in the American Recovery and Reinvestment Act (ARRA) passed in the Winter of 2009. For example, through ARRA's Energy Efficiency and Conservation Block Grant (EECBG), for every federal \$1 spent, the beneficiaries received \$1.76 in annual bill savings over the lifetime of the measures installed with total cumulative savings on energy bills assessed to be \$5.2B.<sup>3</sup> This chapter builds on and surpasses these types of outcomes.

## Four Pillars of a Net-Zero or Net-Negative Energy System

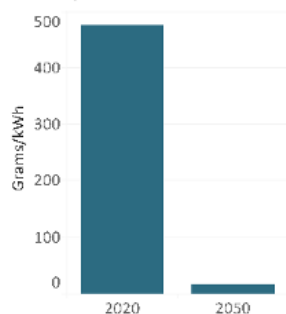
### U.S. Benchmarks

#### Electricity Decarbonization



95% reduction in emissions intensity

#### Electricity Decarbonization

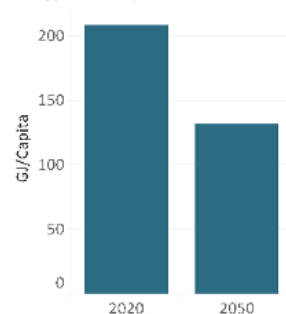


#### Energy Efficiency



40% reduction in per-capita final energy demand

#### Energy Efficiency

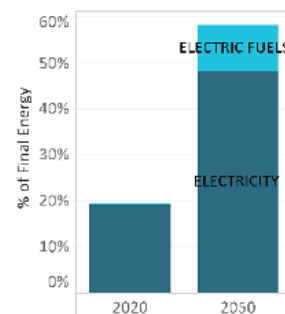


#### Electrification



300% increase in share of energy from electricity

#### Electrification

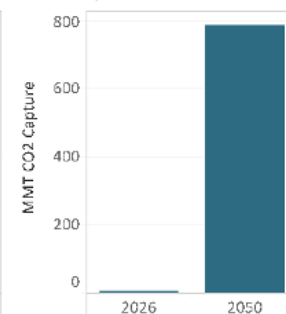


#### Carbon Capture



800 MMT+ carbon capture and use/storage

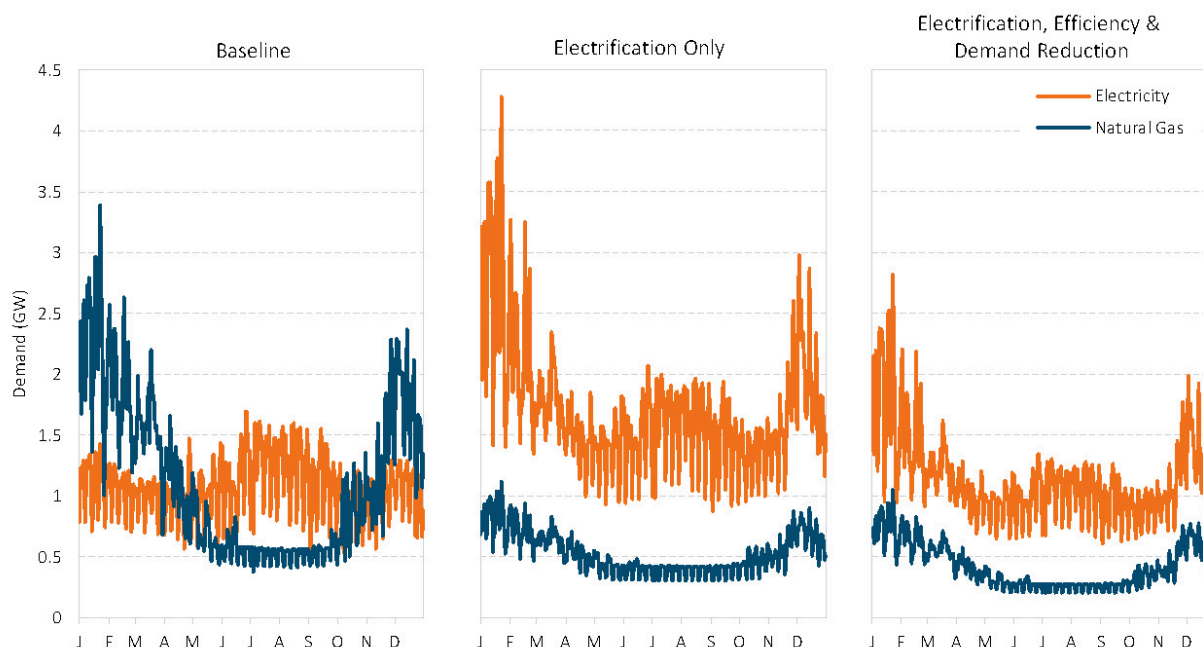
#### Carbon Capture



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**Figure 5.4.1.** Four main strategies to achieve deep decarbonization, 2020 vs. 2050 (Williams, Jones and Farbes, Chapter 2).

Daily city-wide energy demand for natural gas and electricity in 2015 (left) and 2050 (middle and right). The values represent the maximum hourly quantity of electricity or gas consumed in a given day. The Electrification Only scenario reflects deep electrification of the buildings and transportation sectors, with no additional action by the City to improve energy efficiency in buildings, or to dampen the demand for travel in personal EVs. In the third scenario (far right), deep electrification is coupled with deep efficiency gains and demand reduction in the buildings and transportation sectors. Source: model calculations



**Figure 5.4.2.** The impacts of energy efficiency and electrification (Hatchadorian et al., 2019).

### Stimulus & Job Creation

In the short term, the policy roadmap proposed here would create millions of high-paying jobs particularly suited for those most adversely impacted by the COVID-19 era recession. Construction and property management jobs are uniquely incapable of being outsourced as they require the physical presence of workers at sites and are distributed across all regions of the U.S. During the first four years of implementation, the U.S. should budget two to three hundred billion in seed capital to catalyze the rapid, large scale decarbonization of public housing, low income housing, and public buildings (national, state, and local)—a portfolio that includes everything from military bases, embassies, public hospitals, universities, fire stations, and post offices. The building decarbonization programs should be designed to leverage private and public investments at the state and local level to create an overall investment of \$1 trillion over 4 years.

The immediate impact to gross domestic product (GDP) will be prodigious. In 2019, construction contributed \$1.46 trillion dollars to the GDP and every million in construction jobs will generate an additional 2.26 million jobs (indirect, and induced jobs).<sup>4</sup> Prior to the COVID-19 recession, energy efficiency jobs<sup>i</sup> were held by 2.3 million Americans.<sup>5</sup> That represents twice the number of jobs in the entire fossil fuels industry and jobs that were (until the first quarter of 2020) growing at twice the rate of the overall job market. Indeed, there have been huge energy efficiency job losses in 2020 - 18 percent of the entire sector and almost double the number of such jobs created since 2017.<sup>6</sup>

<sup>i</sup> Energy efficiency jobs include performing architectural and engineering work such as energy audits, retro-commissioning or designing new systems, and construction work such as installing new electrical, lighting or HVAC systems, replacing windows, or installing insulation.

As a result, there are a huge number of Americans with either the proven experience or capacity to take on new energy efficiency jobs right now. Decarbonization of the building sector thus has the potential to promote much-needed opportunities for economic revitalization.

## Goal Setting and Multi-Jurisdictional Coordination

As set forth in Chapter 1, achieving economy wide carbon neutrality will require codification in federal law (as opposed to executive orders), the creation of a White House Office of Climate Change, and the creation of clear goals and plans. Likewise, success in decarbonizing the building sector will require an organizational structure that can coordinate the powerful but sprawling parts of the federal bureaucracy that impact buildings. To that end, the Federal Government should establish an Office of Buildings, led by an undersecretary or high level official that reports directly to the head of the department or White House Office of Climate Change. The Office of Buildings will be responsible for setting sector goals at regular intervals (such as 2030, 2040, and 2050), regularly updating plans, tracking progress, and coordinating the activities of the multiple federal agencies, the states, the territories, and the localities that impact the building sector.

The need for a clear organizational structure with sufficient clout and resources becomes apparent when considering that today, building sector related policies are advanced by a jumble of national and local programs with little coordination or sector-wide goal setting. Also, state and local governments have primary jurisdiction over building construction codes through a myriad of health and safety codes and programs that vary vastly across states, cities, territories, and tribal governments.

At the federal level, multiple departments are involved in the building portfolio. Most buildings owned or operated by the Federal Government (including offices, ports of entry, courthouses, laboratories, post offices, and data processing centers) are administered by the U.S. General Services Administration (GSA) while the individual services of the Department of Defense (DOD), the Department of State, the Department of Veterans Affairs, and a number of other agencies construct and or manage their own buildings.<sup>7</sup> Meanwhile, federal agencies and programs like the Federal Energy Management Program (FEMP) at the Department of Energy (DOE) advance higher performance of buildings across agencies.

The agencies that impact the private sector are even more complex. DOE has a myriad of programs to advance energy efficiency for public and private buildings of all kinds (e.g., a program for new single-family residences, programs for existing buildings, weatherization programs, and programs to support strategies and building codes at the state level). The Environmental Protection Agency (EPA) also has a fairly high-visibility efficiency program for existing commercial and multi-family buildings (ENERGY STAR for Buildings) and ENERGY STAR for appliances. The Department of Housing and Urban Development (HUD) has programs for low-income housing efficiency upgrades. Additionally, via various programs that “backup” residential mortgages (single family and multi-family), the Federal Government has a large impact on the shape of residential stock throughout the country including “green” or “energy efficient” mortgage programs.

Building related Research, Development, Demonstration and Deployment (RDD&D), education, and manufacturing also lacks a unified vision and leadership. RDD&D is advanced principally by DOE and the national labs, but there are other programs at Commerce (e.g., via the National Institute of Standards and Technology (NIST), the National Institute of Building Sciences (NIBS), and the National Science Foundation). Even the White House can play a role on RDD&D matters via the National Science and Technology Council's Buildings' Technology Research and Development Subcommittee. When it comes to education, deployment, and manufacturing, the Departments of Education, Labor, and Commerce all have roles to play. The approach laid out in this chapter recognizes that such a mosaic of governmental programs needs to be coordinated by a single entity in order to execute the national decarbonization goals. Such coordination will be essential for effective building sector policy and successful decarbonization of both new and old building stock.

## 5.4.2 Decarbonization of Buildings

### Building Sector Emissions

The operation and construction of buildings are responsible for almost half of America's greenhouse gas (GHG) emissions.

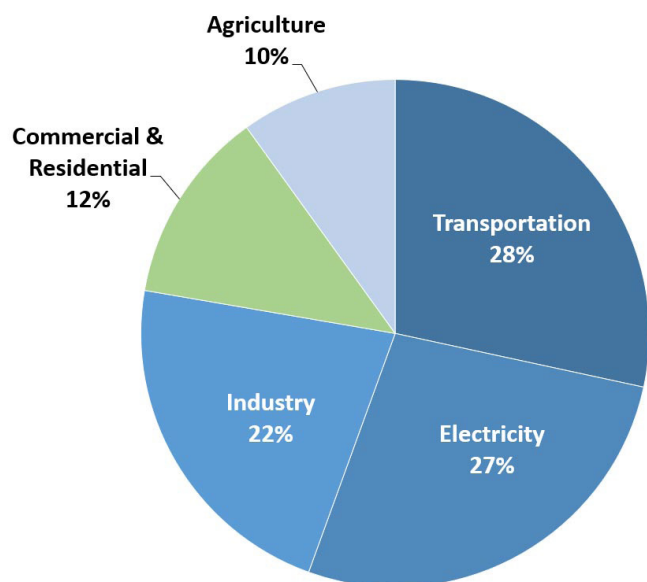
The biggest chunk of the building sector's emissions come from building operations, which produce two streams of GHG emissions. The first is the fossil fuel combustion, typically natural gas or oil, that is burned onsite for space heating, domestic hot water<sup>ii</sup>, cooking, and a variety of smaller end uses, such as clothes dryers, absorption chillers, and emergency power. This burning of fossil fuel accounts for 12 percent of national GHG emissions.<sup>8</sup> The second is electricity, which is typically produced at power plants, many of which are currently burning fossil fuel and thereby creating GHG emissions. This electricity is used for lighting, cooling, ventilation, fans and pumps, elevators, appliances, and to cover the "plug loads" of many small pieces of equipment, from computers to music systems. The electricity used in buildings contributes another 20 percent of national GHG emissions, for a total of 32 percent from building operations.

The second largest chunk is building construction, which is estimated to be responsible for 11 percent of global GHG emissions.<sup>9</sup> Known as "embodied carbon," these emissions result from the extraction, refinement, fabrication and transportation of building products and the energy used onsite by construction equipment such as backhoes, cranes, and a multitude of smaller electric tools. The steel and concrete used in buildings are especially carbon intensive. These construction related emissions are typically attributed to the industrial and transportation sectors rather than the building sector, but they bear mention here because they are so considerable and because building policies will be an important strategy in reining them in. A national carbon and energy code should be established, which in addition to driving efficiency and electrification, can also drive down emissions from construction. RDD&D to develop low-carbon materials, products, and construction methods will also be necessary.

An additional 1 to 2 percent of national GHG emissions is due to leaked refrigerants, fire suppression gases, and foam insulation used in buildings; these, too, can be addressed through building codes and appliance standards. Finally, the siting and design of buildings impact transportation emissions; where building policies can reduce such emissions, they are included.<sup>10</sup>

ii "Domestic hot water" is hot water that comes out of the tap as opposed to hot water that is used to heat spaces.

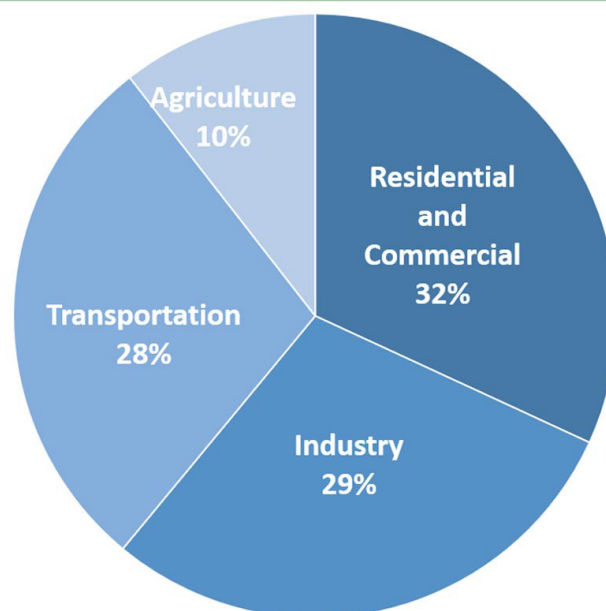
### Total U.S. Greenhouse Gas Emissions by Economic Sector in 2018



U.S. Environmental Protection Agency (2020). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018

**Figure 5.4.3.** Total U.S. Greenhouse Gas Emissions by Economic Sector in 2018 (“Commercial and Residential Sector Emissions”, 2020)

### Total U.S. Greenhouse Gas Emissions by Sector with Electricity Distributed



U.S. Environmental Protection Agency (2020). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018

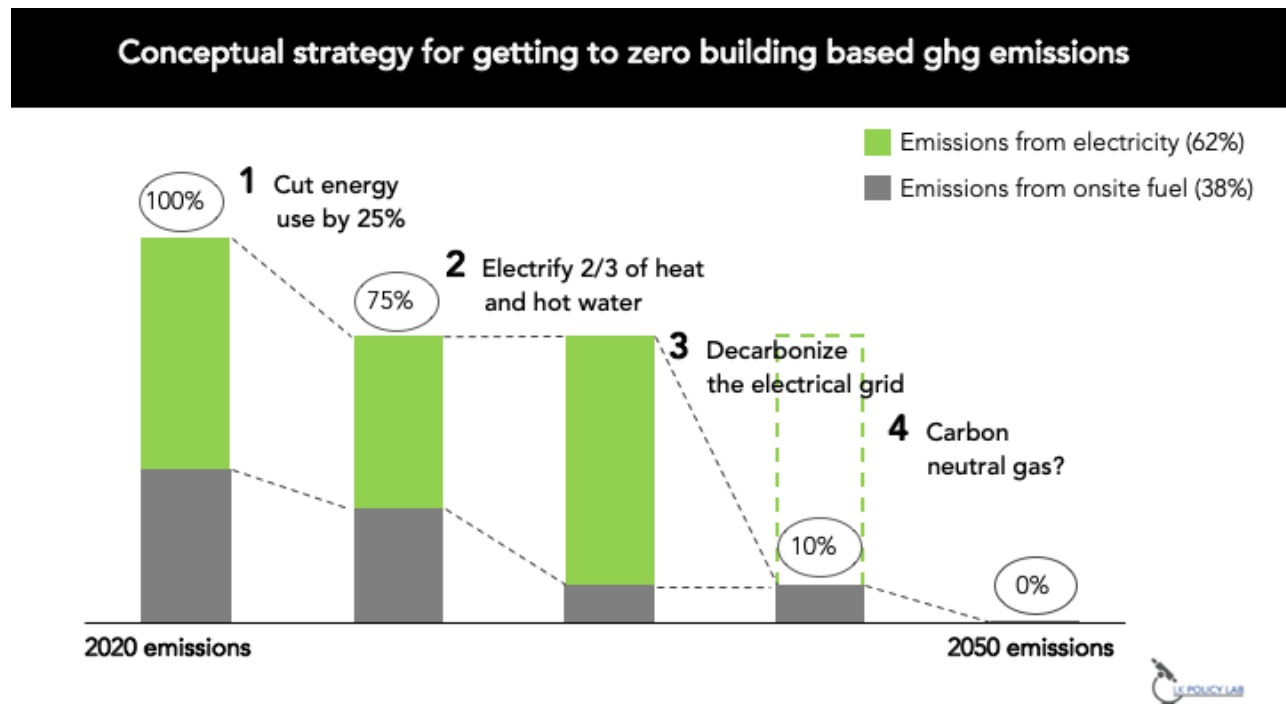
**Figure 5.4.4.** Total U.S. Greenhouse Gas Emissions by Sector with Electricity Distributed (“Electricity”, 2020)

## Reducing Building Sector Emissions

Reducing building sector emissions from energy use can be explained in a four-step process, although these steps will not happen sequentially.

- The first step is energy efficiency. Efficiency directly reduces the greenhouse gases emitted from fossil fuels burned onsite and in power plants, and reduces the amount of clean electricity that needs to be generated, transmitted, stored, and distributed as we transition to electric buildings and vehicles. To ensure reduced loads are aligned with periods of peak demand, demand response management will be key.
- The second step is transitioning from onsite fossil fuel burning equipment such as boilers and water heaters to efficient electrical equipment. The all-electric building is the stationary counterpart to the electric car. All-electric buildings have become feasible in most situations, except for certain older buildings in cold climates, because of new heat pump technologies, which supply heat much more efficiently than the inefficient electric resistive heaters of the 1970's and 1980's. Heat pumps are now so efficient that in many cases they cost less to run than gas-fired heaters. In addition, new technologies, such as induction stovetops and heat pump clothes dryers, make it feasible to phase out fossil fuel use for many secondary heating uses.

- To achieve the high levels of electrification that will be required, we propose phasing out fossil fuel for heating and domestic hot water in new buildings, limiting hot water heater replacements in existing buildings to electric units everywhere, and limiting space heating replacements to electric units in the warmer regions of the country. These strategies are discussed more fully in the next section.
- The third step is decarbonizing the electric grid, i.e., replacing fossil fuel power plants with carbon-neutral ones, such as solar or wind and supplementing these with on-site renewable electricity generation where appropriate. This will radically reduce the emissions from electricity used in buildings – both from traditionally electrified uses, such as lighting, and newly electrified uses, such as domestic hot water. The greening of the grid is addressed in Chapter 5.1 of this plan.
- The fourth step is to invest in RDD&D for the development of affordable carbon-neutral gas, such as synthetic hydrogen or methane, and for improved technologies for the electrification of the older national building stock. There are some buildings, especially older steam-heated buildings in the colder parts of the country, where it may be prohibitively expensive to replace the existing steam heating systems and to create an electrical grid that can support a massive winter peak due to heating loads. National resources should be allocated to developing the solutions that can enable these regions to decarbonize affordably.



**Figure 5.4.5.** Conceptual strategy for getting to zero building based GHG emissions (LK Policy Lab, 2020).

## The Strategy for New vs. Existing Buildings

Reducing GHG emissions from buildings requires a new building strategy and an existing building strategy. GHG emissions from new buildings represent a net increase in total emissions because the building stock is growing, with a relatively small amount being retired. Therefore, that increase must be kept as small as possible in order to reach zero carbon emissions. That will entail reducing GHG emissions from energy use, construction, and refrigerants.<sup>iii</sup>

Buildings that already exist today are the bigger piece of the puzzle—assuming a 1 percent annual growth rate in built area and a 0.2 percent demolition rate, by 2050 America's square footage will have increased by 35 percent, and roughly 70 percent of the built area will be in buildings that already exist today. Existing buildings present a more complex problem than new buildings because there are so many of them—over 150 million, of which roughly 95 million are single-family homes whose owners are unlikely to accept intrusive and/or expensive requirements. Effective building policy responds to the unique characteristics of new and existing buildings in order to efficiently target and reduce carbon emissions.

### New Building Strategy

#### Energy use

Currently available technologies, such as heat pumps, and design strategies, such as the super-insulated, super-tight “Passive House” model, can enable new buildings to be built free of fossil fuels and highly efficient at a reasonable cost. Buildings that do not burn fossil fuel onsite will become carbon neutral as the grid is cleaned and as clean electricity via onsite or district-wide renewables becomes more available.

In many parts of the country, high electricity rates mean that all-electric buildings could pay more for heating if they are not efficient. Therefore, new buildings should be built to use minimal energy for heating and cooling—something that can be achieved reliably by building tight, well-insulated and well-ventilated buildings. This strategy will also diminish the peak summer and winter loads that would otherwise necessitate large and expensive expansions of the electrical grid. Therefore, as soon as possible, all new buildings will need to be fossil fuel free and hyper-efficient for heating and cooling, particularly as buildings built over the next 30 years cannot be expected to replace major equipment before 2050.

The phase out of natural gas for cooking could lag behind the phase out of fossil fuels for heating and hot water without incurring much of a penalty because cooking accounts for about 2 percent of fossil fuel use in buildings. Such a lag would enable the public to experience the benefits of electric induction cooking, which is cleaner, safer, and cooler than gas, and which is recommended by chefs because of its responsiveness.

#### Construction

Reducing the carbon emissions from construction is an emerging discipline, but there are already some very effective techniques, such as low-carbon concrete. Federal investments need to be made into RDD&D for low-carbon construction to help create carbon accounting tools and metrics for the industry and to develop increasingly low-carbon materials, equipment, and engineering strategies that builders can use. Requirements to reduce construction-related carbon emissions will need to be introduced into the carbon and energy code and made increasingly stringent as new strategies become viable.

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<sup>iii</sup> Emissions from construction are also addressed in the industrial and materials sections.

Chapter 5.3 also addresses the reduction of emissions from concrete.

### **Refrigerants and Fire Suppression Gases**

As refrigerants with increasingly low greenhouse gas potential are developed, EPA regulations and codes will need to ensure that new buildings use them. As long as refrigerants with relatively high global warming potential are still being used, leak detection should be required.

## **Existing Building Strategy**

The most cost-effective time to improve efficiency or electrify existing buildings is at the time of renovation and/or equipment replacements/upgrades, when work is already being done. If a perfectly operating gas hot water heater is replaced with a new heat pump, the full cost of the job would be roughly \$2300 (\$1500 for the heater and \$800 for the installation). If the heater already needed to be replaced, a new gas one would cost \$1600 (\$1000 for the new gas heater and \$600 for the installation).<sup>iv</sup> A new heat pump unit only costs \$700 more than a gas one – which would be an incremental cost increase at the time of equipment replacement, and much less than the full \$2,300.

The regulatory tools as applied to existing buildings (i.e., through energy codes and equipment standards) are well positioned to take advantage of equipment replacement cycles. They don't require that owners replace any equipment; rather they require that if a piece of equipment does need to be replaced, it must be replaced with one that meets certain standards. For this reason, carefully crafted codes and standards can garner widespread and fairly cost-effective efficiency improvements and electrification across the entire population of buildings over the decades. Since water heaters are replaced every 10 to 15 years and hydronic boilers and furnaces every 15 to 20 years, codes and standards could result in the vast majority of targeted equipment in pre-2020 buildings being replaced with more efficient, electric units between 2020 and 2050.

## **Determining Targets of Equipment Electrification and Decarbonization**

In considering which types of equipment the codes should target to be electric or fossil free there are two issues: the impact on the grid and the cost of upgrading building systems.

### **The Grid**

As buildings electrify, they will add load to the electric grid, as will electrifying vehicles. The cost of increasing the size of the grid to accommodate higher peak loads, including generation, transmission, and distribution within localities and within buildings, could be considerable – even astronomical in some regions if not enough efficiency is achieved and/or if too much heating is electrified.

Electrifying domestic hot water should not increase peak load significantly because the load is relatively small, evenly distributed throughout the year, and easy to move to times of day when loads are smaller. Thus, codes and standards should move aggressively to require new or replacement water heaters to be fossil fuel free.

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<sup>iv</sup> Costs for equipment and installation are hypothetical. In some cases, in fact, a new electric unit might cost less than a gas unit.

The same is not true for space heating. In the colder parts of the country, heating loads are very high, concentrated in the few colder months of the year, and they cannot be moved – you need heating when it’s cold outside. Additionally, air source heat pumps, which are likely to be the type most commonly used, become less efficient and their heating capacity drops the colder it gets. The result could be a new winter peak load that is two to three times the current one in the colder parts of the country if too much heating is electrified and if too little efficiency is achieved. The more grid friendly solution in such areas would be to relieve the electric grid by using the current gas distribution system to distribute carbon neutral gas for heating, supposing such gas can become affordable.

### **Building Systems**

Domestic hot water is typically generated by a central heater, stored in a tank, and distributed around the building through pipes.<sup>v</sup> That makes it fairly simple to electrify hot water in most situations: all that needs to be done is to replace the heating unit/tank combo, but the distribution pipes are unchanged.

The same is not true for some space heating systems. For most buildings that distribute space heat through hot air or hot water systems, an electrified source could be installed that could utilize the existing distribution system. But for most buildings that distribute heat via steam pipes and radiators, the distribution system would need to be replaced since heat pumps cannot deliver hot enough heat to create steam. (This is especially true for large urban buildings that cannot install multiple mini split condensing units on their facades.) This would be an extremely expensive and invasive proposition in most buildings, since it would entail work in every room, apartment, or office.

Steam heat was a widely used, extremely durable technology from the time James Watt invented it at the dawn of the Industrial Age through at least World War II. It remains common in the colder, older areas of the country—the mega-region of the Northeast and northern Midwest – areas of the country that use the most heat. Unfortunately, because this is a regional issue, there is little data on the prevalence of steam heating systems, with the exception of New York City. Here the city’s audit data documents that roughly 75 percent of the square footage in buildings larger than 50k square feet (half the city’s square footage) is heated with steam heat, and another analysis found that 86 percent of the multifamily buildings between 5k and 50k square feet (another 15 percent of the city’s square footage) are heated with steam.<sup>11</sup> Steam heat is also quite prevalent in other large cities of the mega-region, such as Boston, Chicago, and Philadelphia.

## **5.4.3 Conclusions and Policy Recommendations**

### **Policy Recommendations**

Outlined below are specific policy recommendations for the decarbonization of the building sector. These federal policies would help to mobilize building decarbonization at city, state, and national levels while keeping costs as low as possible and capturing the associated benefits of the journey to zero carbon emissions. These recommendations include a national carbon and energy code for new and existing buildings, aggressive appliance standards, a federally funded stimulus program, leadership by example, and fiscal and tax incentives.

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<sup>v</sup> There are point of use hot water systems, wherein the hot water is locally generated for local use, say, within a bathroom or a kitchen. But those are fairly rare in the United States.

## National Carbon and Energy Code

### New Buildings

**Status Quo:** Today, local and state governments have exclusive jurisdiction over new building construction standards including energy performance and efficiency set out in local building codes. Lobbyists (including those representing construction companies and real estate developers) have resisted climate change mitigation precautions on the grounds that stricter codes would increase the price of housing. Consequently, many states and localities have energy efficiency standards well below those of other states and similar jurisdictions in other countries. As with (similarly criticized) requirements that cars be more efficient, in reality these codes have lowered fuel costs and any minimal upfront costs have quickly been recouped by the resulting cost savings.

**Policy Recommendations:** Develop a model National Energy Code for Buildings (NECB) that is updated triennially as per the current energy codes and that regulates carbon as well as energy. Require all states to adopt and enforce energy codes that are consistent with the national carbon goals or adopt the NECB. This departs from the current situation in three essential ways.

- First, to motivate the electrification necessary to achieve our goals, we need to transition from a building energy code to a carbon and energy code that, for example, would preclude the installation of new fossil fuel burning equipment under many conditions.
- Second, the current energy code structure does not allow for the regulation of carbon from construction or refrigerants, as will be necessary to reduce the non-energy related carbon from buildings.
- Third, there will be teeth in the requirement for states to adopt energy/carbon codes consistent with the national carbon goals.

A NECB is necessary because about half of the states lag in code adoption<sup>vi</sup> by at least a decade.<sup>12</sup> The current regulatory structure requires that DOE certify new energy codes for commercial and residential codes every three years, requiring the states to adopt the commercial code and to state whether they can adopt the residential codes within a few years of the promulgation of the new codes. Because DOE has no enforcement powers over the states and because of the loose language regarding residential buildings, state codes are often severely lagging, resulting in generation after generation of relatively inefficient new buildings that lock in high emissions for five decades or more.

The NECB should:

- Require that, no later than 2025, all new buildings be fossil fuel free and hyper-efficient, particularly with respect to heating and cooling, to avoid significant increases in winter peak and summer peak electrical use. The code for new and existing buildings should reduce heat loss through new or replacement windows by approximately 40 percent from current requirements for thermal resistance and air leakage by 2025.
- Include requirements for on-site or district generation, grid harmonization and peak load reduction capacity, and minimum levels of passive survivability and resilience.
- Include requirements that reduce the embodied carbon of new buildings, including requirements for low-carbon concrete, that become increasingly stringent as low-carbon building strategies emerge in this rapidly developing new expertise.

<sup>vi</sup> In Nov. 2018, 19 states referenced a commercial code that was at least 11 years old and 27 states referenced a residential code that was at least 9 years old.

- Ban the use of refrigerants with high global warming potential and require that refrigerant leaks be monitored.
- Require a minimum percent of parking spaces to have Level 2 charging stations for electric vehicles.

### Existing Buildings

**Status Quo:** Existing building energy performance issues are currently addressed as an afterthought in the energy codes. Otherwise, they are addressed principally through public and private sector investments, utility-funded programs, and increasingly by state or local mandatory energy performance standards (MEPS). These MEPS typically ratchet up stringent mandatory targets over time to achieve reductions in energy use and/or carbon intensity of energy use over the next thirty years.<sup>13</sup>

Federal programs – principally at DOE - support state, local, and private sector efforts via targeted programs that reach no more than 1 percent of existing buildings annually. Here the federal tools include carbon and energy codes, appliance standards, tax credits, recognition programs, and weatherization support programs. The weatherization program at DOE and some programs at HUD focus particular attention on low-income housing. If the Federal Government limits itself to moderate actions of the type we have seen in the past, even if combined with those undertaken in a few states with ambitious energy codes (e.g., California) or existing building programs (e.g., New York City, Washington, DC), carbon reductions in the building sector will likely be stuck in the 65 to 75 percent range by 2050.<sup>14</sup> That prediction assumes that the nation's grid achieves 90 percent decarbonization.

At the current rate of investments in home energy efficiency at the federal level – even when combined with the often more substantial investments at the state and local level – we are only creeping slowly toward a lower carbon economy. Per a recent study by the American Council for an Energy Efficient Economy (ACEEE), 2018 funding levels for the two main federal programs for whole home retrofits (DOE's Home Performance with Energy Star and the Weatherization Assistance Program) served just .09 percent of the 138.5M housing units in the U.S.<sup>15</sup>

Assuming that level of service comprises half of today's annual home retrofits in the U.S., it would take 500 years to retrofit the current stock of U.S. homes. Improvements to the commercial sector are somewhat less glacial but still inadequate. Commercial Buildings Energy Consumption Survey (CBECS) data shows 14 - 39 percent of commercial buildings have had an energy efficiency retrofit over the past 18 years, with those retrofits ranging from modest to deep.<sup>16</sup> At this same rate, it would take 67 years to retrofit the current commercial stock with even modest upgrades. In sum, according to the ACEEE analysis, to significantly retrofit 80 percent of current buildings by 2050, the current retrofit rate would need to increase for residential by 13X and the rate for commercial buildings by 2X, while also increasing the depth of the commercial retrofits.

**Policy Recommendations:** Ensure that the NECB is designed to accrue significant energy and GHG emissions reductions when existing buildings are renovated and/or equipment is replaced. The code should:

- Require that, no later than 2025, domestic water heaters cannot be replaced with heaters that use fossil fuel. Since domestic water heaters are replaced roughly every 15 years, this should ensure the electrification of hot water nationally by 2040 or 2050.

- Require that, no later than 2025, in climate Zones 1, 2, 3 and 4, boilers and furnaces cannot be replaced with fossil fuel burning units.
- By 2025, require 40 percent better performance for replacement windows above current standards.
- Complement the above requirements with federally funded rebates or tax cuts to reduce the economic burden, especially for low income households (see financial/tax section below).
- Begin to phase in low embodied carbon requirements for renovations and retrofits.
- For larger existing buildings, motivate the largest existing buildings to reduce their energy use and carbon emissions measurement and disclosure policies. Of the nation's 150 million buildings, 7 million, or less than 5 percent of them – the ones > 25k sq. ft. in size – account for roughly 1/3 of America's built square footage. Require that all properties > 25k sq. ft. be benchmarked annually, that their energy use and carbon emissions be publicly disclosed, and that by 2025 efficiency grades be posted in a highly visible place in the buildings. Create and maintain a national database of these large properties, including their energy use, carbon emissions, and available information about their energy systems.

## Aggressive Appliance Standards

**Status Quo:** Prior to the 2016 Administration, the federal appliance standards promulgated by DOE have been very successful at delivering a more efficient economy and in decreasing the energy used by appliances, lighting, electronics, and other technologies used in buildings. However, more could be done. Striking gaps in the federal standards remain, such as computers and monitors. There are no overall goals, nor is there any regulatory authority over carbon. Finally, the upgrades for existing standards, which are required by the existing statute to be developed every six years, have fallen way behind schedule, and there is no consequence if DOE misses its deadlines.

If DOE adopted strong upgrades to the existing standards expeditiously, the cumulative impacts by 2050 would be enormous. Based on preliminary estimates by the Appliance Standards Assistance Project, even assuming a grid that is approaching carbon neutrality over the next 30 years, 1.5 billion tons of carbon would be avoided cumulatively—an amount equal to almost ¼ of America's current annual emissions. The impact on summer peak cooling loads by 2050 would be huge: a reduction of 93 Gigawatts or roughly the average available capacity of 120,000 windmills.<sup>vii</sup> These impacts would be even greater if the first round of upgrades were stronger, and of course the cumulative impact of more than one round of upgrades would be still larger. (There will be 5 six-year upgrade cycles between 2020 and 2050.)

Finally, there is another multiplying effect: as America upgrades its standards on many products, it drags the rest of the world along, as purchasers in other countries buy brands developed to meet American requirements and other economies adopt and upgrade standards. As the world's middle class grows and as global temperatures rise, the amount of installed air conditioning is predicted to quadruple by 2050.<sup>17</sup> The global impact of improved standards for air conditioners will therefore be quite significant.

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vii Predicted impacts are from a soon to be published report by the Appliance Standards Assistance Project (ASAP), and provided on a Zoom call August 28, 2020.

**Policy Recommendations:** Congress should amend the Energy Policy and Conservation Act (EPCA) to:

- Ensure that product standards are upgraded according to the mandated six-year schedule by removing the federal preemption of state standards when DOE misses its deadline, thereby allowing states to set requirements that are stronger than the federal ones.<sup>viii</sup>
- Enable DOE to address carbon impacts in addition to energy efficiency by allowing the standards to be fuel neutral and/or by allowing the standards to address carbon.
- Require DOE to establish an overall reduction goal across each six-year cycle that is in line with the country's overall carbon reduction plan.

In addition, Congress should impose taxes on gas fired appliances and further incentivize the purchase of electric options through tax policies or other incentive programs.

Making up for lost time:

- DOE should be directed to catch up on overdue upgrades on all existing appliance standards as expeditiously as possible, but no later than the end of 2022, including requirements for grid-flexibility functionality for key products, such as water heaters.
- By the end of 2021, DOE should create a goal that is at least 25 percent more stringent in aggregate than this first set of upgrades.
- By the end of 2021, DOE should implement the 45 lumen-per-Watt light bulb standards as required by the Energy Independence and Security Act of 2007.
- By the end of 2024, DOE should have set in motion a second set of upgrades, to be fully adopted by the end of 2028 and that meet the 25 percent reduction goal.

Including new products and addressing carbon emissions:

- By the end of 2023, DOE should set national standards for all appliances that had been regulated by California by 2020, such as computers and monitors, with such standards being at least as efficient at California's.
- As part of the second set of upgrades to be fully adopted by the end of 2028, phase out gas-fired appliances.

International:

- DOE, in partnership with the Department of State, should create an Office dedicated to working with other countries on appliance standards and providing assistance.

## Federally Funded Stimulus Package

**Status Quo:** The 2008-2009 ARRA stimulus funding, created in response to the Great Recession, provides a model and lessons for the stimulus funding that will be required to recover from the Covid-19 Recession. The ARRA funding produced rapid economic benefits (often with full expenditures made within 2-3 years) and leveraged state and local spending by as much as 10X.

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<sup>viii</sup> As proposed by the Appliance Standard Assistance Project.

For example, of the \$3.1B in funds that went to the state energy program (SEP), each \$1 leveraged \$10.70 worth of local and state funds<sup>ix</sup> and resulted in measurable progress in states and localities developing building codes and standards, building retrofits, loans, grants, and incentives programs.<sup>18</sup> More than 62,900 direct, indirect, and induced jobs were created or retained as a result of this investment.<sup>19</sup>

The ARRA increase in low-income housing weatherization (via the Weatherization Assistance Program) to \$5 billion (from prior year authorizations of \$230 million per program year) ended up supporting the weatherization of over 800,000 sites over the 2009 to 2013 period with weatherization costs covered per site increasing from \$2,500 to \$6,500. The dollars were spent very quickly – \$4.9B by May 2013 with the largest annual expenditures by 2010. Hundreds of thousands of units were weatherized when stimulus was most needed and with savings at an average of \$444 per year for each weatherized site.

**Policy Recommendations:** Congress should provide sufficient funding, such that when it is leveraged with state and local funding and private funding, will provide \$1 trillion for efficiency and electrification in buildings over the next 4 years. Improving existing buildings is guaranteed to provide a large number of well-paying construction-related jobs. Indeed, prior to the COVID-19 recession, 2 million out of the 3 million green economy jobs were building-related because building efficiency and electrification is labor intensive. Moreover, most of the work must be done onsite and therefore can't be outsourced. Additionally, because all areas of the country have existing buildings, this stimulus funding can be apportioned to all parts of the country – north and south, rural and urban.

In addition to the jobs benefits, the program should ensure that the American public and low income households benefit from this huge investment of public funds. Therefore the stimulus package should prioritize public buildings which serve everyone and on public housing and low income housing which serve the most vulnerable. Rules should ensure that jobs are equitably distributed among different demographic groups, in proportion to their regional numbers.

Buildings to receive such funding should include:

- Public buildings, federal, state and local (see Leading by Example below).
- Public housing and low-income housing, both urban and rural.
- Buildings that will reduce heating costs with electrification due to their high costs of fuel, notably buildings that use propane, oil or electric resistance heating.

The stimulus program as a whole will provide benefits that go well beyond its direct carbon reductions. Such a program stimulates demand for trained professionals and high performance products and helps advance the state of knowledge in the industry by providing experience to the design and construction communities and creating examples and data.

The stimulus program should also provide funding to train the supply chain on the use of new technologies and to financially incentivize suppliers, installers, contractors, and/or building owners to electrify heat and hot water and to upgrade buildings with better technologies, such as LED lights and high-performance windows. Local suppliers and installers are trusted sources who could be instrumental in promoting the clean energy transition in existing buildings.

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ix By contrast, for the Program Year 2008 prior to ARRA, State Energy Program funding was \$33 million.

As to funding levels, significant increases should be made in the ARRA levels of funding for the SEP, Weatherization, and EECBG programs—increases at an order of magnitude of 3X to 10X depending on the cost-effectiveness of the programs. Unlike the ARRA approach, expansion of potential recipients should include weatherization subsidies from federal housing authorities and via block grants to low-income housing and state and local governments to all federal buildings (including military buildings), and all federally supported hospitals and medical facilities. In addition, the amount of the state and local government block grants should also be expanded to 10X the ARRA amounts (or \$32B up from the \$3.2B authorized in 2008 and spent over the next 7 years).

## Leadership by Example

**Status Quo:** In the past, some Administrations and/or some individual departments (GSA and the DOD) have demonstrated real leadership in improving the standard for building performance. Existing law – including the Energy Independence and Security Act (EISA) of 2007, established additional environmental management goals. EISA requires new GSA buildings and major renovations to reduce fossil-fuel-generated energy consumption by 100 percent by 2030.<sup>20</sup>

**Policy Recommendations:** The Federal government should create a fully funded program to retrofit and substantially electrify the federal building portfolio on an accelerated schedule, achieving 90 percent decarbonization by 2035 or 2040.<sup>x</sup> The federal portion of the 4-year stimulus funding would provide the first installment toward achieving this deep decarbonization, with continued funding required over the next 10 to 15 years. Interim requirements should be set for the end of the 4-year stimulus funding, such as a minimum 25 percent carbon reduction per square foot when all the stimulus projects have been fully implemented. The federal portfolio includes military bases, court houses, federal office buildings, courthouses, post offices, embassies, public housing, museums, etc.

Local leadership by example programs should be funded, by federal block grants or the like, to retrofit and substantially electrify state and local government public portfolios. These portfolios include public universities, hospitals, and schools, office buildings, libraries, court houses, etc. Funds should be provided to state and local governments for staffing, knowledge sharing, and technical assistance for such programs along with funding for the retrofits themselves. As with the stimulus program, leadership by example programs have additional benefits beyond the direct carbon reduction benefits.

## Fiscal and taxation policies, including those impacting residential mortgages

**Status Quo:** Fiscal and taxation policies at the federal level have, to date, had only a modest impact, on improving the energy performance of buildings. There are two areas that show some promise. The first are green banks, financial institutions that have begun to proliferate and to develop a proven track record of incentivizing and otherwise motivating energy efficiency and electrification projects. In recent years, green banks have led to \$3,670,000,000 of investment in cost-effective clean energy projects across the United States, lowering energy costs for end-users, with the investment total composed of \$1,079,000,000 in public funds and \$2,591,000,000 in private and philanthropic capital.<sup>21</sup>

x The 90 percent decarbonization would be based on the anticipated 2050 grids.

The second relates to federal financial institutions, including federally chartered organizations such as Fannie Mae and Freddie Mac that are in a position to advance, at a greater scale than they are today, the decarbonization of single family and multi-family buildings.

Once the mandatory new and existing decarbonization requirements set out in this chapter gain momentum, banks will increasingly see real risk in real estate collateral that is not meeting (or not on its way to meeting) the technology and performance standards set out in our policy plan. They will begin to request (as part of their due diligence) documentation from borrowers regarding how they will meet these requirements. Once banks and other lenders take even minor steps toward including energy performance in their underwriting criteria, private sector investment toward our 2050 goals will accelerate rapidly. In England and the Netherlands, where existing buildings must meet certain energy performance goals or face grades (on a scale of D to A), banks are already beginning to veer away from lending on projects with grades below a certain level.<sup>22</sup>

**Policy Recommendation:** Legislation containing the key components of HR 5416 for a National Climate Bank (with a maximum liability of \$70,000,000,000) should be adopted.

Federal programs that allow Americans unique levels of financing for new home acquisitions (such as those referred to above) should take steps to begin to align their underwriting policies so they are not exposed to the risk of “brown” collateral that is out of compliance now – or in the foreseeable future – with potential future local or national carbon or energy performance standards. Such institutions should begin to require disclosures or affirmative covenants on the part of prospective buyers that they are meeting certain minimum energy performance standards. Such policies will quickly be echoed by private sector banks.

Federal tax policies that encourage – and functionally subsidize – the financing of homes should also be refined as necessary to advance national climate goals. For example, homes with energy infrastructure that are becoming obsolete because they are clearly not on the path to electrification should not enjoy the full benefits of the residential mortgage tax deduction. Those that are making exemplary progress should be offered a superior deduction.

## **Federal Support for State and Local Programs and Policies to Advance Decarbonization of their Respective Building Sectors**

**Status Quo:** The DOE’s State Energy Program (SEP) should be expanded to assist states in meeting the new national building targets. As part of the Obama stimulus package, the SEP also provided training to those developing and implementing progressive code enforcement. Resources were also usefully invested in helping states on the cutting edge of code development. An area requiring greater attention is alignment of these local government programs with carbon emissions reductions. In addition, regulation of the siting of buildings and allowable uses key is entirely within the jurisdiction of local governments via their zoning and other land use authorities. Some have used these powers to create increasingly low-carbon communities while others have made little to no effort to advance that goal. Specifically, land-use policies that support compact and (mass) transit-oriented development patterns don’t separate land uses in the way that “sprawling” zoning patterns do. Members of communities that are composed of more proximate mixes of (zoning code approved) uses including affordable housing at high densities do not need to make long and/or frequent trips between, for example, residential, retail, and commercial districts. As a result, their carbon footprints are measurably lower.

**Policy Recommendations:** Code adoption enforcement and training: Congress should provide significant funding over the long haul to states and localities for energy/carbon code adoption, enforcement, and training. Funding enforcement is one of the most cost-effective ways to achieve energy and carbon reductions dollar for dollar.

**Leading edge policies:** Provide funding to states and localities that seek to adopt decarbonization policies that go beyond the federal minimums, including funding for policy development, analytics, and staff and funding for knowledge transfer between localities. Advanced policies can include advanced energy codes, energy and or carbon reduction requirements for existing buildings, like those recently adopted by Washington, DC and New York City, or updated fire codes, building codes, or other policies that would reduce GHG emissions or increase resilience. Finally, state and local governments should be encouraged to adopt zoning and land use plans that produce more compact, and transit-friendly land use patterns as well as more affordable housing at higher densities.

**Assistance for State and PUC Decarbonization Initiatives:** Technical assistance, convening of key players for knowledge transfer, and targeted funding. States should be encouraged to explore proven or promising ideas including (i) renewable portfolio standards for natural gas serving the building sector, (ii) smart grids, and (iii) IOT management solutions.

## RDD&D, Education, and American Manufacturing

**Status Quo:** In the U.S. and around the world, the construction industry typically invests less than 1 percent of net sales into RDD&D (3.5 to 4.5 percent for the auto and aerospace sectors.).<sup>23</sup> In the U.S., programs at the DOE and those undertaken by the national labs system have de-facto become the industry's RDD&D. However as a percentage of overall federal RDD&D, buildings-related programs are less than 1 percent. When the Federal Government has promoted technological improvement to meet major goals, such as space travel, the Internet, or the Human Genome Project, America has led the world. The U.S. has the opportunity to utilize the same approach for green building construction.

**Policy Recommendations:** Develop and fund a broad, unified strategy to support smarter, more effective strategies to decarbonize buildings. The strategy should include funding for RDD&D, incubators, and manufacturing, along with funding for vocational schools and college and university departments to develop programs that focus on research and training across the spectrum of energy professionals.

Commit 5 percent of the national RDD&D budget to the development of technologies and techniques that will help lower the cost of decarbonizing the building stock and create future jobs in the manufacturing sector by supporting:

- The development of new and/or improved low-carbon technology for building operations, such as batteries, heat pumps, including high temperature heat pumps that can create steam, high performance windows, advanced control systems, etc.
- The development of carbon-neutral fuels appropriate to buildings that can be used in existing gas lines; assist states in piloting renewable portfolio standards for gas.
- The development of low-carbon building products and construction techniques, accounting tools for embodied carbon, and data on embodied carbon in the national building stock.

- An integrated data system for the nation's 150 million buildings, including information at the building level on energy use and carbon emissions, energy systems, embodied carbon, refrigeration gases, etc. To include data from the annual benchmarking of existing buildings, as per the proposal in the Existing Building section.
- On-site and district microgrid solutions serving all building sectors.
- Smarter building design, and building siting and land use decisions that encourage more compact, low-carbon communities.
- Education must be enhanced for building and infrastructure architects and designers, civil engineers, trades people, building code regulators and everyone else involved with the building and infrastructure supply chain.

Decarbonizing America's building stock will not be just a matter of installing better widgets; it will require a much larger, more knowledgeable, and better trained building efficiency workforce. The Federal Government should invest in the creation of a network of departments, generally located within existing schools, that can train the next generation of energy efficiency professionals. The network should include everything from vocational schools and community colleges that can train installers, contractors, and auditors, to research institutions that will educate the PhDs who will develop the next cutting edge strategies. The national laboratories should partner with the research institutions and play an active role in this network.

Finally, the Federal Government should ensure that the benefits of nationally funded RDD&D benefit American workers and companies. The Federal Government should help support nascent technologies with incubators and pilot programs. And the Federal Government should provide seed funding and launch policies to support the development and long-term success of American manufacturing of clean technology (batteries, heat pumps, high-performance windows, components of products, low-carbon materials, low-to-no carbon gas, etc.). Planned deployments should be in the Rust Belt, in areas with abandoned factories such as the old mill towns of the Northeast, and in areas that would otherwise lose jobs in the clean energy transition.

## Conclusions

Several of these proposed policies are likely to be controversial and resisted by affected industries, lobbies, and political interests—namely the creation of a NEBC, the adoption of aggressive appliance standards, and working to develop affordable low-carbon fuels for buildings. Since these may not be easy solutions to push forward, it is important to assess which policies will be necessary to achieving carbon neutrality by 2050.

For this plan we considered two scenarios - both with the same assumptions for the decarbonization of the electric grid and gas network (95 percent decarbonization for electric and 80 percent for gas); a massive stimulus efficiency program and the ramping up of federal incentives and assistance; but one including aggressive policies outlined above, while the other assumes the status quo for gradual progress on appliance standards and uneven state level action on efficiency and electrification - yield the following results.

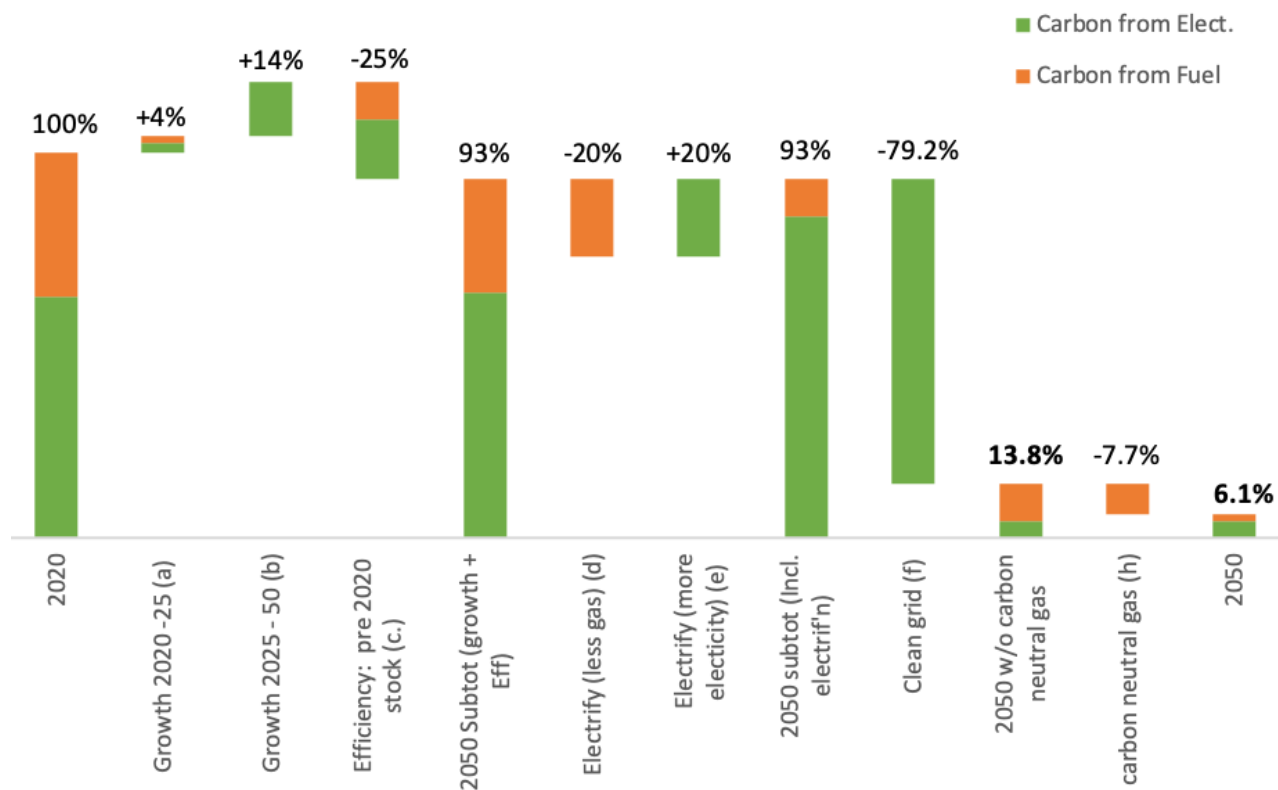
- Aggressive scenario (see Figure 5.4.6): Without carbon neutral gas, the sector achieves an 86 percent reduction; with carbon neutral gas it achieves 94 percent reduction.
- Less aggressive scenario (see Figure 5.4.7): Without carbon neutral gas, the sector achieves slightly less than 70 percent reduction; with carbon neutral gas it achieves 90 percent reduction.

The less aggressive scenario gets a lot of mileage from the decarbonized grid, but it is not a robust solution; it sets things up poorly for the last mile of expensive reductions and it will necessitate building a larger and more expensive renewable network.

- Without the widespread deployment of affordable carbon neutral gas – as of yet, an unproven technology – the less aggressive scenario falls far short of carbon neutrality for the sector. Without such gas, it achieves slightly less than 70 percent carbon reductions in contrast to the 86 percent achieved in the aggressive scenario.
- Even with carbon neutral gas, the less aggressive scenario will need 60 percent more carbon capture and sequestration to achieve neutrality than the aggressive scenario.
- The amount of decarbonized electricity plus decarbonized gas in the less aggressive scenario is 22 percent more than the aggressive scenario. Since most carbon neutral gas will be created by renewable power generation, the less aggressive scenario will need 22 percent more renewable power than the aggressive scenario.

In conclusion, the aggressive approach is worth the potential political challenge. The less aggressive scenario misses the mark significantly, setting America up for potentially huge expenses and an unwise level of dependence on uncertain markets like carbon neutral fuels and carbon sequestration and capture. In contrast, the aggressive scenario gradually accrues decarbonization when it is least expensive: when new buildings are being built and when renovations are occurring. While it might seem at first like burdensome regulations, this path will be far less costly for most Americans, since it will gradually and inexorably deliver a low-carbon building sector at a fairly low increased incremental cost. This path will also bring sector emissions close enough to zero that emerging technologies could be expected to take us across the finish line.

## Proposed policies: Impact of growth and aggressive policies

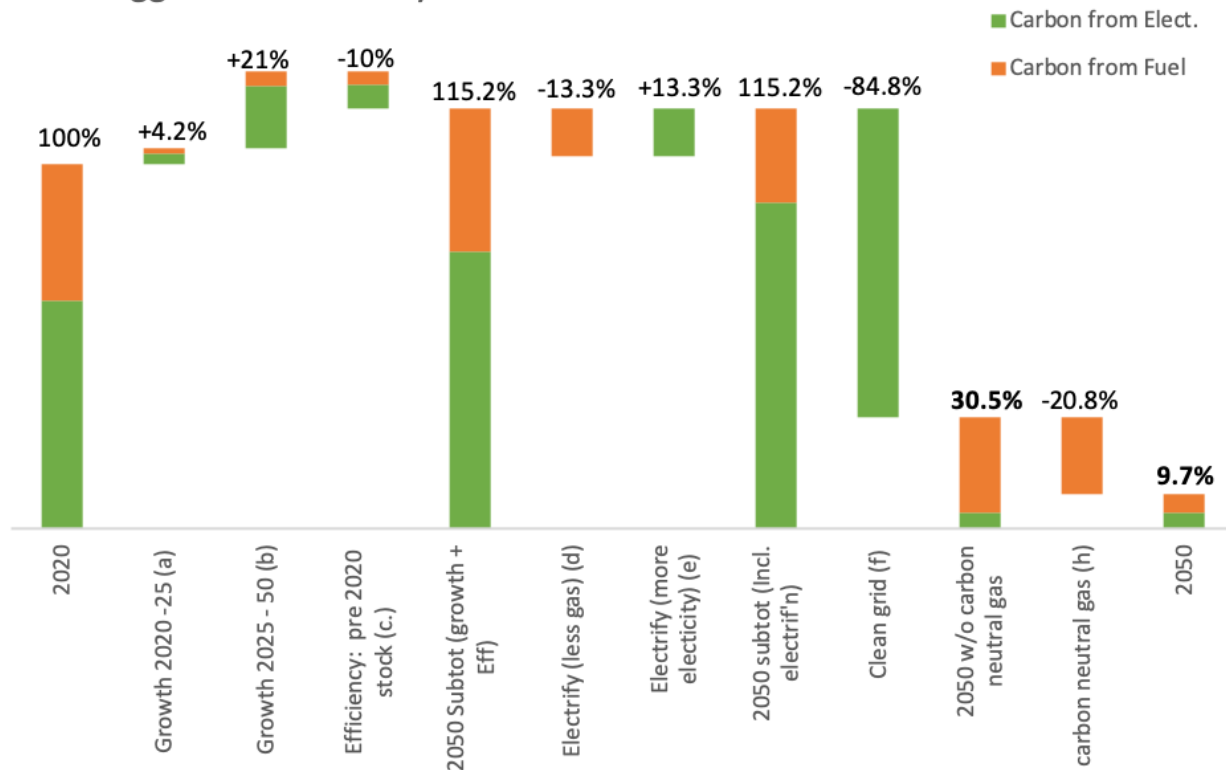


**Figure 5.4.6.** Aggressive scenario (LK Policy Lab, 2020).<sup>xi</sup>

<sup>xi</sup> Aggressive Scenario Assumptions:

- (a) 2020 – 2025: 1% increase per year = 5%; Effic: 80% avg use compared to current stock; same percent elect vs fuel
- (b) 2025 – 2050: 1% increase per year = 28%; Effic: 50% avg use compared to current stock; all electric
- (c) Efficiency for pre-2020 stock: all electric and all gas reduced by 25%
- (d) DHW electrified at 90% because of code; heat, cooking, dryers electrified at 60% because of code, tax, and appliance standards
- (e) Assume transition before cleaning of the grid is 1:1 carbon from electricity: carbon from gas
- (f) Decarbonize electric grid by 95%
- (g) Decarbonize gas by 80%

## Less Aggressive Efficiency and Electrification Policies



**Figure 5.4.7.** Less aggressive scenario (LK Policy Lab, 2020).<sup>xii</sup>

<sup>xii</sup> Less Aggressive Scenario Assumptions:

- (a) 2020 – 2025: 1% increase per year = 5%; Effic: 85% avg use compared to current stock; same percent elect vs fuel
- (b) 2025 – 2050: 1% increase per year = 28%; Effic: 75% avg use compared to current stock; 50% heat & hot water electrified.
- (c) Efficiency for pre-2020 stock: all electric and all gas reduced by 10%
- (d) DHW electrified at 45% because of code; heat, cooking, dryers electrified at 30% because of code, tax, and appliance standards
- (e) Assume transition before cleaning of the grid is 1:1 carbon from electricity: carbon from gas
- (f) Decarbonize electric grid by 95%
- (g) Decarbonize gas by 80%

## 5.4.4 Costs and Jobs

What will be the impact of decarbonizing the building sector on economic activity, the federal budget and job growth? Below is a summary of impacts, as extracted from the chapter 2 “central case” scenario and the chapter 3 jobs analysis.

The average net increase in annual economic activity above the DOE BAU “reference case” scenario can be determined by aggregating the increases in construction, HVAC, appliances, refrigeration, and other commercial/ residential as per the chapter 2 analysis. The result comes to \$64 billion per year, or \$1.98 Trillion over the full 31-year period 2020 -2050. On average, this amounts to a modest 0.3 percent increase in GDP. But more to the point for our present discussion, it amounts to a 4.5 percent increase in annual spending on construction, which has important implications for blue-collar jobs, as discussed below. It will also represent a significant infrastructure investment in updating the nation’s aging building stock.

Assuming that the federal government will cover 25 percent of the overall costs, with the remainder being covered by state and local governments and the private sector, decarbonizing the building sector will add approximately \$16 B to the Federal budget above the amount it currently spends on energy efficiency and R&D for the building sector. This would amount to an increase of approximately 0.4 percent to the federal budget. Taxes on the \$64 billion in increased economic activity would likely cover most, if not all, of this budgetary increase. These federal funds would pay for the decarbonization of the federal portfolio, financial incentives for private buildings, development and enforcement of codes and standards, assistance to states and local governments, including block grants, subsidies to American manufacturing, research and development, education and training, and the overhead of developing and managing this vast program.

In estimating the number of direct and indirect jobs produced, we averaged over the different trades, and took a median between current manufacturing levels and full American manufacturing of equipment used in upgrades, to arrive at roughly 7.5 direct and indirect jobs per \$1 million spent nationally. Consequently, the increased annual spending of \$64 billion results in roughly 480,000 additional well-paid, construction-related jobs each year. The majority of the jobs would be in the construction trades, but others would be in architecture, engineering, manufacturing, retail, research, education, government, etc. These jobs would be spread across the country because buildings are everywhere, and most retrofit work must happen onsite. And because most of the jobs would be in the construction trades and the demand for work will be durable over 30 years, this job growth will be a boon to many blue-collar workers who have seen their opportunities and paychecks shrink over the past decades. Finally, if a chunk of the expenditure is front-loaded over the next four years, as this plan has proposed, the first steps toward decarbonizing the building sector will also help the nation recover from the Covid-19 recession.

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