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ELECTRIFICATION IN COMMERCIAL BUILDINGS

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1. PURPOSE

The concept of electrification has evolved from a regional to national concept. BOMA's goal of this effort is to help inform their members about electrification, including offering an overview of the benefits and challenges of electrification, available technologies, current and future conditions of the electric grid, public policy, available programs, and other relevant issues and items.

To aid in this effort, BOMA engaged Steven Winter Associates (the "study team") to write this report to help inform these items.

2. KEY TAKEAWAYS

The study team identified the following key findings and potential next steps based on the work performed in this report.

- Building stakeholders should plan for electrification given market drivers and the policy landscape. This entails understanding a building's physical characteristics for the most appropriate retrofit, the costs of electrification, and operational requirements based on changing policy.
- Even with current grid makeup in most regions, smart electrification results in overall emissions reductions. This can be paired with other strategic electrification measures such as installation of solar PV to further enhance emissions reductions.
- Governments and utilities must plan for a future grid that emphasizes clean energy sources and efficient delivery.
- Some regional jurisdictions (cities, counties, and states) either have or are considering laws and regulations that either directly impact onsite energy use or emissions in general or gas use specifically. These laws and regulations vary by region, but in general onsite energy use and emissions reductions, if determined to be significant enough, may also functionally require most buildings to engage in smart electrification.
- Most regions can handle electrification projects happening in the near term (with the exception of Texas). Longer-term, most utility regions will need to plan for adjustments in grid peaks and potential expansion of capacity.
- Lease structures can present obstacles for building owners to realize the financial impacts of electrification: some leases pass through all costs (and in turn, all savings). Green leases help address this shortfall, but by and large are not heavily utilized by the market today.
- Multiple and disparate incentive programs are both available today and coming online in the near term to further help defray costs of strategic electrification work. These take different forms ranging from direct equipment rebates to tax credits.
- Smart electrification options and approaches vary by region and by building type; building owners will need to evaluate what works best for their specific buildings. Similar technologies and approaches can apply at portfolio levels, but each building will need its own specific solution.
- Workforce development remains a key question. Building owners will need to evaluate if the workforce in their region is capable of performing strategic electrification work or maintaining new systems. If building owners are unsure, this represents an opportunity to advocate for and utilize workforce training programs in their region.

3. INTRODUCTION

As jurisdictions strategize ways to decarbonize at scale, policymakers are turning towards electrification, transitioning away from on-site fossil fuel combustion and towards electrically powered alternatives. These growing requirements take multiple forms, depending on location, whether through performance-based targets, or regulations on the use of natural gas. Commercial buildings are included in this transition because of their substantial impact on local greenhouse gas emissions. In the U.S., commercial buildings alone contribute to 16% of greenhouse gas emissions (GHGs).[1] The accounting often doubles when looking at local emissions in dense, urban areas, as buildings play a more significant role in energy use. This study is designed to help illuminate the current national landscape around electrification. It examines the benefits and challenges of commercial building electrification, the state of the electric grid both today and in the future, technologies to achieve electrification, and the policy landscape.

Building electrification is the act of replacing fossil fuel powered boilers, domestic hot water heaters, and commercial grade ovens with all electric appliances such as heat pumps, ground-source heat pumps, and induction stoves. The adjectives “beneficial” or “strategic” may be used to further define that replacements only take place when they benefit the end-user and reduce overall emissions. Strategic electrification means considering a holistic approach to building retrofits, including energy efficiency measures, demand response programs, solar PV, and other interventions that reduce energy demand. While the requirements to strategically electrify appear daunting, there are programs, resources, and funding mechanisms coming online to assist building owners with capital planning.

Simultaneously, the market is moving towards electrification. Tenant demand for low-carbon spaces has created a market for commercial real estate. The use of electric heating in the U.S. has been steadily increasing, primarily driven by costs and affordability. While only 1% of buildings were electrically heated in the 1950s, this increased to 40% by 2020, including homes. Electricity is the main form of heating in the South and is also prevalent in the West[2,3]. Advancements in research and technologies, such as cold climate heat pumps, have allowed electric heating to be an option in the northern parts of the country as well.

Ultimately, building electrification will require long term planning and financial commitment for building owners. It also requires investment from all levels of government to support the building industry to achieve these goals as well as substantial investment from utilities to provide clean energy to achieve emission free electricity generation.

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[1] https://www.nrel.gov/news/program/2021/path-to-net-zero-emissions-runs-through-us-buildings.html
[2] The Economics of Building Electrification (upenn.edu)
[3] How Americans heat their homes, from electric heat pump to natural gas - Washington Post

4. BENEFITS AND CHALLENGES

There are significant benefits to building electrification that are not reflected when only considering costs. Additionally, there are both perceived and definite challenges to commercial building electrification that must be addressed. The table below identifies the relevance of issue areas to identified stakeholders: tenants, building owners and managers, and governments and utilities. While many of these issues are relevant to all three stakeholder groups, this table seeks to identify who is most impacted and/or will have the most influence to address outcomes.

Table 1 Benefits and Challenges by Stakeholder

	Building Owners & Staff	Tenants	Governments & Utilities
CRE Market Drivers	✓	✓	
Capital Planning	✓		
Costs	✓		
Operations & Maintenance	✓	✓	
Workforce Development	✓		✓
Health & Safety	✓	✓	✓
Emissions Reductions	✓		✓
Equity		✓	✓
Grid Capacity			✓

Benefits	Challenges
Commercial Real Estate Market Drivers	
Despite challenging markets, national asking rents continue to grow. Supply and demand dynamics within high-quality, sustainability focused commercial buildings are unique. Higher demand exists for newer, Class A offices than older stock because a significant share of tenants chose to expand or relocate since the beginning of 2020. Studies have shown that companies, and their workers, want higher quality offices with newer amenities and buildings that are low to zero carbon emitting to meet their company sustainability goals.[4] Building owners report a 9% increase in value when 'greening' their assets, including both new construction and renovation/retrofit projects[5]. Properties that undergo electrification in the near term have opportunities for collaborative marketing with local governments and industries. This creates positive publicity for building owners and positions them as industry leaders in this effort.	The office real estate market has not bounced back from the pandemic like it has after other fiscal crises. Office construction has come to a near halt despite the desire for newly built stock. JLL reported that although "8.9 million sf. of new space was delivered in Q1 2023, just over 2 million sf. broke ground, mostly consisting of smaller-scale infill developments in stronger markets or build-to-suit product for corporate occupiers with a more mission-critical nature"[6]. This creates a financial obstacle around electrification: how is electrification work paid for by building owners? This is especially relevant for Class B or C office building stock. Properties undertaking an electrification effort in occupied buildings will need to navigate tenants working in occupied spaces. For some tenants, this may be impossible; for other tenants, this may require work to be done outside of typical business hours.

[4] https://www.us.jll.com/content/dam/jll-com/documents/pdf/research/americas/us/jll-us-office-outlook-q1-2023.pdf

[5] World Green Building Trends 2021, Nov. 8, 2021. Dodge Construction (https://www.construction.com/resource/world-green-building-trends-2021/)

[6] https://www.us.jll.com/content/dam/jll-com/documents/pdf/research/americas/us/jll-us-office-outlook-q1-2023.pdf

Benefits	Challenges

Costs and Planning

Electrification is typically accomplished via the installation of heat pump technology (see Section 5 for details). Electrification can produce savings in construction costs for new buildings and can drive lower energy costs in existing buildings if retrofits are timed and planned well. Studies show that packaging efficiency, electrification, demand response, and solar results in a positive or neutral Net Present Value over a 20-year time period in some markets.[7]

Electrification brings some predictability to long-term capital planning. Since the work is typically more intensive than a standard like-for-like gas-fired equipment replacement, electrification requires planning over the course of years. This creates a more defined capital planning schedule for building stakeholders.

Additionally, opportunities to defray the costs of electrification projects partially or fully are increasing with new financial mechanisms like C-PACE and incentives through the Inflation Reduction Act (See Section 8 for more information on Incentives).

Operating costs can also decrease when replacing older systems with highly efficient heat pump technology and packaging energy savings projects. The average reduction in operating costs for packaged renovations and retrofits have shown to be 11.5% and 17% respectively[8]. The reduction in demand also reduces risks associated with accelerating utility costs or spikes.

In some locations, policies attach financial penalties to poorly performing buildings. Electrification helps to reduce exposure to these penalties. Owners could use avoided financial penalties as a potential cost savings.

Electrification retrofits can be more challenging than incorporating low carbon strategies in new construction. Buildings may need to upgrade their electrical service capacity prior to the purchase and operation of new equipment to accommodate major new electric HVAC systems. This may be an expensive or difficult proposition.

Increased capacity in the heat pump industry is needed for equipment availability and installation capacity. This impacts equipment delivery schedules and could impact timing of electrification retrofits.

Costs are dependent on a complex set of variables such as the type of building, replacement technology, utility rates, cost of capital, available incentives, where the building is located, and if deferred maintenance dollars can be put towards upgrades. Buildings must identify space for the physical components of electrification including additional switchgears, electric feeders, panels, and the HVAC equipment itself which can entail condenser units (which requires venting or exterior placement) and hot water storage. Mechanical room space or exterior space may be a constraint for older buildings. This creates unique financial considerations around electrification that need to be evaluated on a building-by-building basis.

Depending on lease terms and system architecture, the owner may incur capital expenses for an energy retrofit while the tenant receives the benefit of lower energy bills. Green leases are contractual solutions to address this issue but are currently underutilized. The U.S. market could reap $3.3 billion in annual cost savings if every leased office building implemented green leases, as estimated by the Institute for Market Transformation (IMT).[9]

[7] https://rmi.org/insight/economics-of-electrifying-buildings-medium-size-commercial-retrofits/
[8] World Green Building Trends 2021, Nov. 8, 2021. Dodge Construction (https://www.construction.com/resource/world-green-building-trends-2021/)
[9] Revamping green leases is critical to driving decarbonization (jll.com)

Benefits	Challenges
Operations & Maintenance	
Most electrified mechanical systems are designed to be operated or maintained by occupants, residents, or lightly trained staff, which necessitates simpler and easier operations and maintenance requirements. To maintain a heat pump, the main considerations are keeping coils clean, changing air filters, and checking condensate drains. In simple designs, the operations and maintenance of heat pumps can be minimal and cost effective. When installed properly, heat pumps can save on operating and maintenance costs when compared to fossil fuel systems – in some cases cutting costs by half.	If new heat pump systems are not installed and commissioned properly, these new systems may experience persistent maintenance issues such as leaks and electrical issues. This would raise O&M costs until addressed systematically. While some heat pump systems are simple, other heat pump systems can be rather complex in design and operation. This presents a potential difficulty: the more complex the design, the more room for error in operations. Centralized heat pumps require more maintenance than unitized heat pumps, but tend to have simpler requirements (e.g., chilled water systems require eddy current testing on a regular basis while heat pumps do not).
Workforce Development	
Large-scale electrification efforts entail the need for people to supply and install heat pumps. Global employment in heat pump supply is rapidly growing. Installation is the most labor-intensive part of the heat pumps value chain, with an estimated 210,000 workers employed globally. Manufacturers have recognized the need for additional training; these trainings are generally accessible to building staff and cover new equipment in detail. This helps bridge gaps from building operators being unsure about equipment. The projected growth of the heat pump workforce worldwide is accompanied by around 700,000 additional workers building more energy-efficient buildings and carrying out retrofits improving the insulation of building envelopes. This creates a need for jurisdictions to help develop and maintain additional training resources for designers, installers, and operators, which building owners can take advantage of for their own staff.	To meet the growing need for electrified systems, the number of heat pump installers will need to quadruple globally. Air-to-water and ground-source heat pumps typically require more worker-hours per installation than conventional fuel-fired systems, boosting the numbers employed in the sector and the need to recruit new workers as the market expands.[10] As the maintenance workforce ages, the need for building staff who can properly maintain and operate new systems becomes more critical. This includes both training existing staff on newer systems they may not be familiar with as well as recruiting new building maintenance workers and properly training them on these newer systems. Many installers still have misperceptions about heat pump performance and may discourage consumers from using heat pump technologies. Section 5 describes current technologies present in the market, many of which are mature and applicable in most installations.

[10] https://iea.blob.core.windows.net/assets/4713780d-c0ae-4686-8c9b-29e782452695/TheFutureofHeatPumps.pdf

Benefits	Challenges
Health & Safety	
Electrification replaces on-site combustion equipment with new electrically-driven equipment. On-site combustion creates air pollution at varying levels depending on the type of fuel. Natural gas combustion emits methane, nitrogen oxides, carbon monoxide, particulate matter, and other compounds which can be damaging to human health.[11] Studies have linked respiratory illness cases to gas cooking.[12] Heat pumps and induction stoves are a safer option compared to gas or liquid fuels. There is no chimney, gas line, oil tank, or burning of fuels and no risk of generating carbon monoxide. This creates a safer environment for building occupants.	If the electricity used to power new heat pumps comes from fossil fuel power plants, there are still health hazards caused by air pollutants at power plant sites, such as SO_2, NOx, and PM2.5. This issue primarily exists at the utility level and is addressed by renewable portfolio standards (discussed in more detail in Section 6). While not within the scope of this report, onsite renewable energy generation such as onsite solar can help somewhat with this challenge.
Emissions Reductions	
Commercial building electrification offers the potential to reduce GHG emissions by 44%.[13] While total emission reductions will vary by building type and equipment type, these savings will align building owners with current and future energy performance and carbon regulations. Even with today's technology, is it less efficient to burn gas onsite than it is to burn gas at a power plant and run it to a building.[14]	The GHG emissions savings at the building level will require the electric grid to keep pace with the demand for clean energy. Site GHG emissions reductions are immediate when combustion fuel equipment is replaced with electric counterparts as they generate no emissions on site. Electricity generation itself, however, can generate emissions. The electric grid will ultimately need to switch to renewable energy sources, away from coal and fossil fuels, for building electrification to achieve the economy-wide targets being set. The elimination of fossil fuel usage at the building level and utility level are complimentary efforts working toward the same goal. Projections from the IEA place renewables as the leading source of worldwide electricity generation by 2025.[15] The U.S. will need to remain competitive with the global renewables market to ensure emissions reductions locally; Section 6B discusses the current US market and its growth in this area.

[11] Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes | Environmental Science & Technology (acs.org)
[12] https://heetma.org/wp-content/uploads/2019/04/Gas-cooking-can-harm-children-4-15-19-clean-1-1.pdf
[13] Cutting Carbon Emissions Through Electrification - Commercial Property Executive (commercialsearch.com)
[14] https://rmi.org/insight/the-economics-of-electrifying-buildings/, pages 38-39
[15] Executive summary – Renewables 2022 – Analysis - IEA

Benefits	Challenges
Equity	
Historically, gas prices are less stable than electric prices over time[16], so buildings that transition today will achieve more stable utility costs in the long term. Getting ahead of forthcoming electrification requirements ensures that those with fewer resources are not left paying more in gas costs to support stranded assets. Additionally, the growing demand for employment creates an opportunity to address demographic and salary gaps in commercial real estate.[17] Many property managers and building operators are nearing retirement age, leaving an opening to fill with diverse hires, along with innovative and new ways of problem solving.	Policies without alternative compliance pathways or funding mechanisms for disadvantaged stakeholders may lead to significant financial strain. Small business owners and tenants should be kept in mind when designing electrification policies and programs. Access to funding can also be challenging. While financial incentives may be available, they should be adequately marketed and assistance should be provided to prioritized stakeholders such as small business owners and tenants located in disadvantaged areas. Short-sighted decisions on who bears the costs and the risks can lead to unanticipated consequences and inequitable outcomes.
Grid Capacity	
All-electric equipment has the potential to better utilize the electric grid and inspire new utility incentive mechanisms. For example, heat pump water heating already stores heat energy and can be used as a flexible grid asset if coupled with appropriate controls. Using peak demand controls during rare extreme weather events will minimize strain on the grid, providing value to the electric utility**.** This creates a financial incentive in favor of electrification. These are discussed in more detail in Section 6B.	If the rate of electrification outpaces grid resiliency improvements, the capacity of our future grid may not be able to keep up with added electrical demand. Some research highlights the potential of some regional grids switching from summer peaking to winter peaking, which could lead to issues if capacity is not added. Grid capacity is highly variable by region, which the study team will explore in Sections 6A and 6C.

[16] https://www.eia.gov/outlooks/steo/special/winter/2021_Winter_Fuels.pdf
[17] https://crewnetwork.org/about/resources/industry-research/gender-and-diversity-in-commercial-real-estate-202

5. BUILDING LEVEL CONSIDERATIONS

While a given building considering electrification will have their own specialized needs, many approaches apply across most building types. This section describes technologies and potential applications that building owners can explore in their building using smart electrification. Smart Electrification refers to choosing intelligent, highly efficient electric options that best satisfy the needs of the building, primarily heat pump technology with regard to heating and DHW purposes.

Most buildings' mechanical equipment efficiency can be measured with Coefficient of Performance (COP). COP is a measure of useful output (such as heating or cooling) to input power. In most cases, heat pumps are highly efficient, with COP measurements of 2 and above. This is twice as efficient or more as electric resistance heat.

Simple electric resistance technology is not uncommon in the United States. For heating and DHW this means an element is heated with electricity and releases energy directly into the air or water. This technology is 100% efficient as one unit of energy is released for every unit of energy input. For comparison, fossil-fuel fired equipment efficiency is lower, ranging from 60-85% efficiency in most cases, for a COP between 0.6 and 0.85. Electric resistance technology is not a recommended strategy to reduce GHG emissions because electric heat pumps have COP much better than 1.

Heat pumps can use different mediums to extract and reject heat:

- Outdoor air: Air-source heat pumps use outdoor air, directly pulling it from and exhausting it to the exterior of a building. Individual air source heat pump units can service dedicated spaces directly connected to the outdoors in a through-wall penetration, via refrigerant piping, or a larger central unit can be tied to a water loop to serve the building.
- Water: Water-source heat pumps extract and release heat through a water loop which circulates throughout a building. The water loop can be heated or cooled with a variety of different technologies.
- Ground: ground-source systems typically couple a water-source heat pump with a water loop that gets heated and cooled passively by the ground, which results in a very high total system efficiency.

Heat pumps can operate across temperature ranges seen within the United States. The efficiency and capacity of air-source heat pumps decreases as it gets colder. When it gets cold enough, some models of air-source heat pumps may revert to supplemental or backup heat[18], while cold climate models do not.

In order to understand the magnitude of space heating's impact on smart electrification strategies and in turn the potential impacts of heat pumps to meet electrification needs, it's worth understanding how space heating is fueled today. Commercial building electric heating prevalence varies by region and climate zone within the US. Nationwide, natural gas is used slightly more often than electricity (44% to 43% of buildings, respectively, with the remainder being fuel oil, district heating, or propane). To understand regional differences, the U.S. Energy Information Administration organizes the country into four areas. Electricity usage ranges from roughly 30% to 55% by region, while natural gas ranges 35% to 55%.[19] Electricity usage for heating is highest in the South, whereas the Northeast has the largest percentage of fuel oil usage for space heating.

[18] https://www.osti.gov/biblio/1876177
[19] https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS_2018_Building_Characteristics_Flipbook.pdf

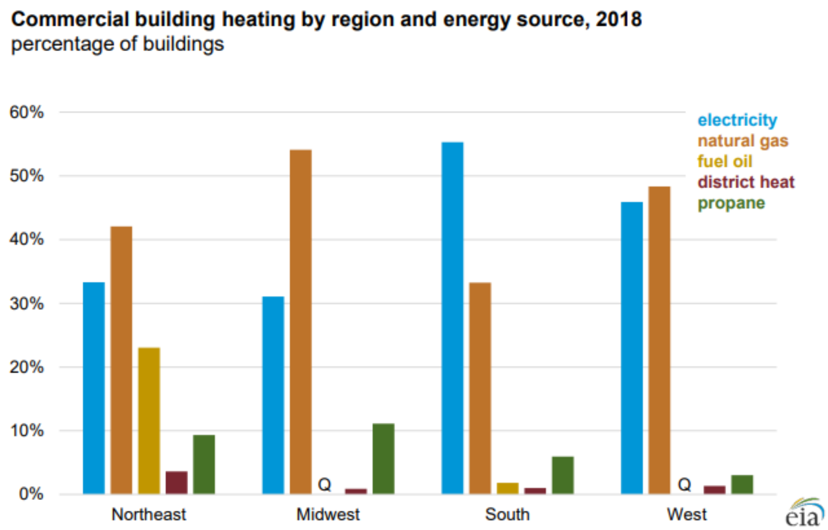

Figure 1: Commercial Building Heating by Region and Energy Source[20]

5A. End Use Equipment

Heating and Cooling

Cold Climate Air Source Heat Pumps

Cold climate air source heat pumps (ccASHPs) are designed for heating in cold weather. These operate as heat pumps in temperatures below 40°F and can often work in weather below 5°F. ccASHPs can be used in heat pump mode in cold climates where ordinary heat pumps need to revert to backup heat; this brings an energy benefit for ccASHPs. According to Northeast Energy Efficiency Partnership (NEEP), ccASHPs can be used in regions similar to and north of the Mid-Atlantic.

This is a mature technology.

Mini-Split or Multi- split Heat Pumps

In this configuration, one outdoor heat pump unit is placed outside, either mounted on an exterior wall or on a roof and is connected to indoor units (generally one to five indoor units per outdoor unit) to provide heating and cooling. Mini-splits refer to a 1:1 outdoor unit to indoor unit configuration, while multi-splits can be anywhere from 1:1 to 1:5 outdoor to indoor. Mini-split heat pump refrigerant piping length maximum is about 160 feet. Outdoor units are often affixed to exterior walls to minimize refrigerant piping runs. Heat pump system performance is increased with shorter line lengths.

The outdoor unit can either be on the individual or the central common meter; indoor units are typically powered from the outdoor unit serving the space.

This is a mature technology.

Electric Packaged Terminal Heat Pumps

Packaged Terminal Heat Pumps (PTHP) are self-contained, individual pieces of equipment that provide heating and cooling and are installed in a wall penetration in each room. PTHPs use the same refrigerant circuit and hardware to control and manage room conditioning. The air directly outside the room is the heat source when in heating mode, and heat is rejected into the outside air in cooling mode.

[20] https://www.eia.gov/consumption/commercial/data/2018/pdf/CBECS_2018_Building_Characteristics_Flipbook.pdf

Package Terminal Air Conditioners (PTACs) are a common existing heating and cooling option in buildings. PTHPs are similar in size and operation and can often be used as replacements for PTACs. The improved efficiency of PTHPs compared to PTACs comes in heating mode; while PTACs use either electric resistance or some form of central heat (e.g., hot water from a central gas-fired boiler), PTHPs use efficient heat pump technology.

This is a mature technology.

<u>VRF Systems/ Central Heat Pumps with Refrigerant Distribution</u>

Variable Refrigerant Flow (VRF) systems consist of a central heat pump with refrigerant distribution to individual units. A central heat pump plant (or plants) is connected to individual fan coil heating and cooling in each apartment or room. Variable speed compressors adjust refrigerant flow to satisfy part-load conditions for increased efficiency. There are two main types of VRF systems:

- Heat pump VRF systems: Heat pump VRF systems require all indoor units to be in either heating or cooling mode. These systems carry lower costs but cannot utilize heat transfer between served spaces as a result of this decreased flexibility. Heat pump VRF systems should only be used where zones are expected to have heating and cooling loads at the same time as this configuration cannot serve opposite loads simultaneously.
- Heat recovery VRF systems: Heat recovery VRF systems are more comfortable and more energy efficient than heat pump VRF systems. Heat recovery VRF systems allow different indoor units to be in heating or cooling mode. Refrigerant is routed between indoor units which allows for heat transfer from units in cooling mode to those in heating mode. This configuration is generally recommended for spaces that may require different conditioning needs simultaneously. Heat recovery VRF systems are more expensive than heat pump VRF systems as they require additional refrigerant piping and equipment.

This is a mature technology.

<u>Central Air to Water Heat Pump with Hydronic Distribution</u>

A central air to water heat pump (AWHP) can generate hot water for heating; some models can also produce chilled water for cooling. This conditioned water can be pumped to hydronic terminal units within served spaces in the same way as a conventional central gas-fired boiler system serving a water loop, but without the fossil fuel plant.

The AWHP plant must be designed to supply lower temperature heated water than is generated in standard hot water heating systems today. Some plants are able to generate chilled water for cooling. Alternatively, a cooling tower can be installed in the building to reject heat for air conditioning in water source heat pump (WSHP) systems.

The terminal units must be fan coil units, WSHPs, or a low-temperature variation with hybrid water-cooled air conditioners to work best with the characteristics of a central AWHP plant.

This is a mature technology.

<u>Ground Source Loop with Hydronic Distribution</u>

This configuration is similar to the Central Air to Water Heat Pump with Hydronic Distribution above, but instead of a central heat pump conditioning the building water loop, the water loop circulates underground to reject or inject heat to the building loop and feeds the hydronic distribution to terminal WSHPs via a heat exchanger or central water-to-water heat pump (WWHP). This means there is no central plant in some cases.

Ground temperature varies much less than air temperature, so ground-source methods remain efficient even on the coldest days of the year and result in a more stable, predictable load. Pumps circulate water between the ground or body of water and building.

Apartments or spaces will contain WSHPs which inject or remove heat to the central loop. Temperatures are controlled by occupants, and heating and cooling can be provided simultaneously since the central loop uses heat recovery. DHW can also be generated with this system with the addition of a central WWHP. This approach can also improve cooling efficiency in the summer as it cools the loop water.

This is a mature technology.

Domestic Hot Water

Domestic hot water (DHW) loads are not a major concern for most commercial office buildings but comprise a significant load for other space types such as multifamily buildings.

Electric Point-of-Use (POU) DHW Systems
In most commercial applications, recirculation losses are a significant driver in overall DHW energy use. This can be mitigated by installing POU heaters in places like bathrooms and shower areas.

This is a mature technology.

Central Air to Water Heat Pump (AWHP) Plant
These plants are of more use in applications with significant DHW load. A heat pump DHW central plant uses the same distribution as a standard central DHW system. An AWHP plant is coupled with adequate thermal storage to generate DHW. The AWHPs cool air to heat water. Depending on the AWHP plant design, a WWHP may also be needed to further boost the loop temperature of the water to get it hot enough to kill bacteria such as Legionella. Thermal storage is necessary as these plants operate most efficiently with long runtimes with minimal compressor cycling. Storage also allows for a reduction in plant capacity as the tanks can act as a buffer during demand spikes. Appropriate sizing of a plant and storage is crucial for this reason.

The AWHPs typically are located outdoors and only indoors if there is a unique condition leading to a high and continuous need for substantial amounts of cooling. This is a stand-alone equipment option that solely generates DHW and can be paired with other heating and cooling systems.

This is a developing technology.

DHW - Decentralized Heat Pump Water Heaters
These plants are of more use in applications with significant DHW load. Decentralized heat pump water heaters operate in the same manner as the AWHP system described above. The benefits of this system include distributed metering, less noise from models that use CO_2 as a refrigerant medium, and no building size constraints. However, these units will require space in residences with additional electrical service.

This is a mature technology.

Commercial Cooking

Many developments contain retail and commercial spaces on the ground floor. Commercial cooking equipment, which includes stove top cooking as well as griddles, fryers, ovens, etc. can be electrified. Commercial grade electric induction equipment can reduce emissions resulting from natural gas-fired equipment.

This provides the benefits of improved performance, better indoor air quality and reduced gas piping. Sometimes, the business owners may prefer natural gas equipment over electric equipment for cooking and some types of cooking are more amenable to electrification than others, depending on need.

Residential induction cooking technology (applicable in multifamily applications) is a mature technology. Commercial induction cooking technology is a developing technology.

Backup Generation

An electrified approach to backup generation is both expensive and complicated. The use of diesel fuel is likely the most appropriate as of the publication of this report. Diesel fuel combustion emits more GHG emissions than natural gas but its use in this context is not necessarily in conflict with a low carbon strategy because the generators run so infrequently.

<u>Traditional Generator</u>
Traditional generators can be gas or oil-fired. They are typically tested once per month at most for a period of a couple of hours, so the climate impact is small. Using an oil-fired generator for an all-electric building may be reasonable since the generator runs infrequently and the owner avoids adding or maintaining gas infrastructure.

<u>Combined Heat and Power (CHP)</u>
In most applications, CHP provides convenience power. CHP is not well-suited for emergency backup power and might not satisfy the code requirements for emergency power sources in some jurisdictions. In order to be used for power during an outage, a transfer switch must be installed; the transfer switch switches the building's power source from the grid to the CHP during an outage. Many buildings with CHP for backup power have a manual transfer switch, so a staff person must make their way to the switch in the dark and turn it before the backup power can engage.

CHP costs much more than a traditional generator, so it does not make sense to put in excess CHP capacity for rare grid outages only.

<u>Solar PV With Batteries</u>
This configuration requires a battery to be used for emergency power, and even that is somewhat misleading. The battery can be used for load shaping during normal conditions but cannot be deeply discharged. The remaining untouched discharge depth must be sized for the emergency loads for a given duration to ensure the building always has emergency capacity available for unplanned outages. During an outage the battery can be deeply discharged, which is not great for its durability long term. The solar may be able to recharge the battery sometime during the outage, but design for an emergency scenario has to be under the assumption that it is cloudy, at night, etc. and the solar is not a contributor. This solution is often not cost-effective as the portion of the battery that is sized for emergency use is not usable during day-to-day operations, so it is a sunk cost in commercial applications.

5B: Other Building Technologies and Considerations

Design considerations to prepare for electrification should be implemented where possible to reduce load requirements, first costs, and better system performance.

Envelope

The building envelope helps control the transmission of heat, air, and moisture. A robust and airtight envelope can save energy and minimize operating costs based on reduced demand for heating/cooling. Reducing uncontrolled air movement through air sealing or even improving the building's envelope for better insulative properties can lead to reduced HVAC equipment sizing and better system performance.

Ventilation

Ventilation supplies fresh outdoor air to buildings, while exhaust is used to remove contaminants from buildings. Ventilation is extremely important in buildings with tight envelopes. Current building codes prescribe ventilation rates based on occupancy, space type, and space square footage.

A central ventilation supply system can utilize heat pump technology when needed rather than electric resistance or natural gas. Some manufacturers partner with VRF manufacturers to create heating and cooling sections that integrate with a space conditioning system and or control system.

The most efficient approach is a Dedicated Outdoor Air Supply (DOAS) system, a unit that supplies fresh outdoor air to the building in a controlled manner to meet ventilation needs. It is capable of cooling and dehumidifying the air in the summer and heating it in the winter if needed, but the air flow rate is not sized to provide conditioning to the space above base ventilation needs.

The addition of an Energy Recovery Ventilator (ERV) can create major efficiencies and cost savings. An ERV transfers heat from one air stream to another; in winter it transfers heat from exhaust air to warm the fresh supply air, in the summer the supply air is cooled. This technology can reduce the fresh air heating and cooling load by up to 75%. This means up to 75% of the load is met passively, and when designed properly, no additional heating or cooling element may be needed if the use case can support some additional load in the spaces served. For example, interior heat gains and the existing heating systems may keep temperatures comfortable on their own. This reduces equipment cost significantly up front, as well as reducing energy usage and associated piping and other components needed for conditioning.

Electric Service Upgrades

Electrification of systems entails replacing gas-fired equipment with electrically-driven equipment; since this adds electric loads to a building, it may require an increase in electrical capacity. This may entail upgrading existing switchgear, electric panels, feeders, and wiring capacities. A building's existing infrastructure, especially if electric chillers are already in place, may be adequate and obviate the need for a major upgrade.

These costs tend to be highly site-specific.

Future-Proofing

Electrification measures may fit in a later stage of a building's long term capital plan. In these cases, future-proofing for electric-readiness should be included in any near-term projects. The specific methods of future-proofing will vary by building, but includes items such as leaving access in mechanical spaces and roofs for additional equipment, planning roof layouts and ensuring structural capacity exists for potential equipment placement, and leaving additional electrical capacity if other electric upgrade work is occurring.

Demand Response

Demand response programs are designed to motivate building owners to reduce or shift their peak loads to off-peak hours. Demand response programs are normally triggered by a local utility if the electricity demand is likely to exceed the available supply. Shifting demand peaks can significantly improve grid operation in reducing stress and line losses associated with the system; with enough demand response, this can delay the need for major upgrades resulting in lower reliability risks in the grid system[21].

[21] https://www.4cleanair.org/wp-content/uploads/Documents/Chapter_5.pdf

Demand response programs include a mix of approaches such as rate designs, price signals and rebates for building owners. The specific approach for a building will depend upon the local utility and technology available at a given site.

Electrical and Thermal Storage

Both electrical and thermal storage technologies help smooth out power concerns at an electric grid level. These technologies are normally installed at a single building or a campus of buildings and used for either demand response programs or resiliency needs.

Different technologies are available for electrical energy storage including batteries, ice storage, compressed air energy storage, flywheels, and other similar systems. Electrical energy storage systems have inefficiencies associated with the conversion and storage of power.

Thermal storage uses a medium such as water or ice to store thermal energy for use during certain conditions such as demand response. Thermal storage does not have the conversion losses associated with electrical storage but does tend to require extra equipment energy. Some energy storage can be remotely located requiring additional transmission infrastructure to bring the capacity to load centers. Storage can increase system reliability by providing fast responses to load ramping and additional flexibility.

Power Factor Management

Power factor management maintains voltage levels at all points of the distribution systems. Power factors can be corrected using technologies like capacitors to cancel the capacitive effects of the loads. Automatic power factor correction monitors can switch blocks of capacitors in and out of service as required and this enables lower losses, voltage regulation and additional available system capacity.

6. ELECTRICITY SOURCES AND GRID CAPACITY

The study team reviewed existing electricity generation sources and the electric grid across the nation. In most regions studied, today's grid capacity can support heat pump replacements for heating. Additional capacity will be needed in the future to accommodate full electrification.

The electric grid is a complex regulatory structure where electricity is generated through power plants and transported to an end user.[22] The electric grid differs largely by region and as such, regional grid power supply and transmission differences play a role in understanding the environment around electrification. To better understand these impacts to building electrification, the study team explored 10 regions across the US. These regions were selected based on a combination of factors:

- Do jurisdictions in these regions have policies that either directly or indirectly encourage electrification?
- Do certain areas of the US have short-term grid needs?
- Are these regions a reasonable encapsulation of the different grids in the US?

Based on the answers to these questions, the study team arrived at the following regions: New York, New England, Mid-Atlantic, Great Lakes, West Coast, Pacific Northwest, Rocky Mountains, Texas, Southeast, and Mid-West. Each region has a sample city used as an example.

Specific building-level and local challenges may still exist even if grid-level improvements occur. Most utilities require building owners to submit some form of documentation[23] specifying increased electric loads from electrification projects; the utility then evaluates service to the building and would indicate what, if anything, would be needed at the utility level to handle an increase in load. This process naturally lends itself to utilities not overextending the capacity of the existing grid.

6A. Electric Generation

There are three primary types of energy sources used for generating electricity: fossil fuels (including coal, natural gas, and petroleum), nuclear energy, and renewable energy sources (including hydropower, solar, wind, biomass, and other related sources)[24]. Natural gas is the largest energy source, accounting for roughly 38% of electricity generated. Coal is the second-largest energy source, accounting for approximately 22% of electricity generated. Almost all coal-fired power plants utilize steam turbines, while a small number convert coal to gas for use in a gas turbine to produce electricity. Nuclear energy is responsible for roughly 20% of electricity generated. It uses nuclear fission to power steam turbines. Lastly, renewable energy sources account for around 20% of total US electricity generation, as seen in Figure 2.

[22] https://www.epa.gov/green-power-markets/us-electricity-grid-markets
[23] e.g., https://www.coned.com/-/media/files/coned/documents/small-medium-large-businesses/electricbluebook.pdf
[24] https://www.eia.gov/energyexplained/electricity/electricity-in-the-us.php#:~:text=The%20three%20major%20categories%20of,geothermal%2C%20and%20solar%20thermal%20energy.

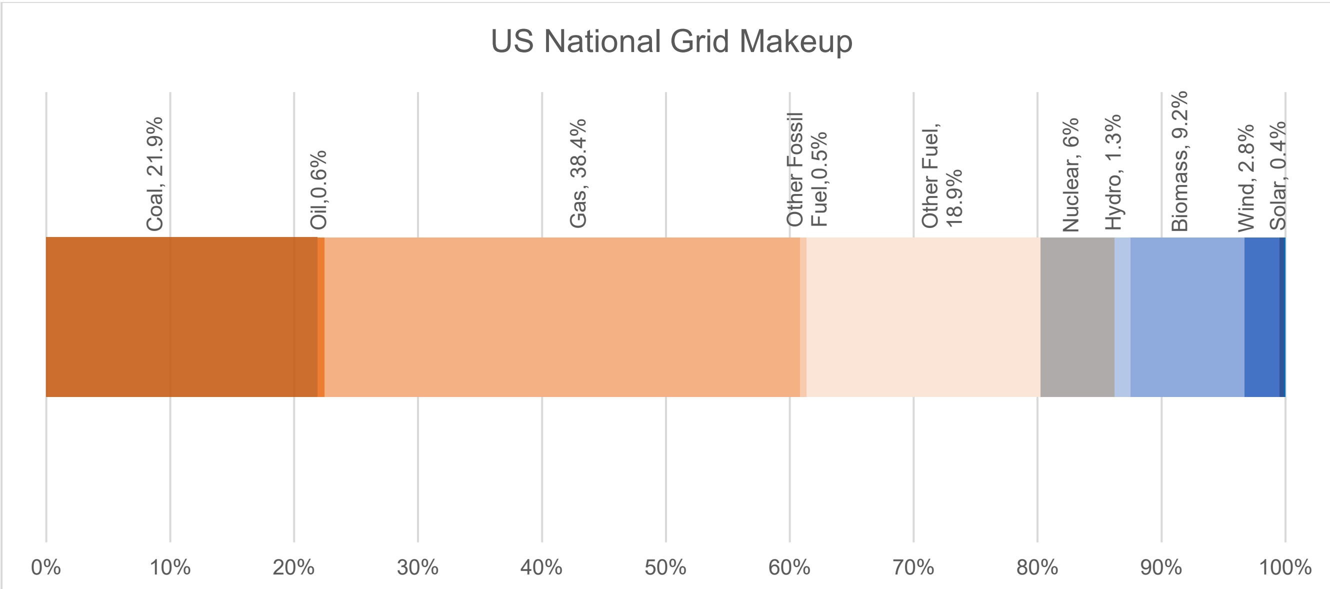

Figure 2: National Grid Makeup of Electric Generation based on 2021 data[25].

Electrification of buildings substitutes combustion-fueled technologies with electric technologies. Electric demand will increase, and the electric grid will need to generate and transmit more low-carbon electricity. Below is the regional grid generation makeup for the identified regions, using a sample of Emissions & Generation Resource Integrated Database (eGRID) subregions as a framework to discuss current energy sources, building electrification projections, and overview of the electric grid. As the emission rates imply, decarbonization of the grid may require different approaches depending on regions.

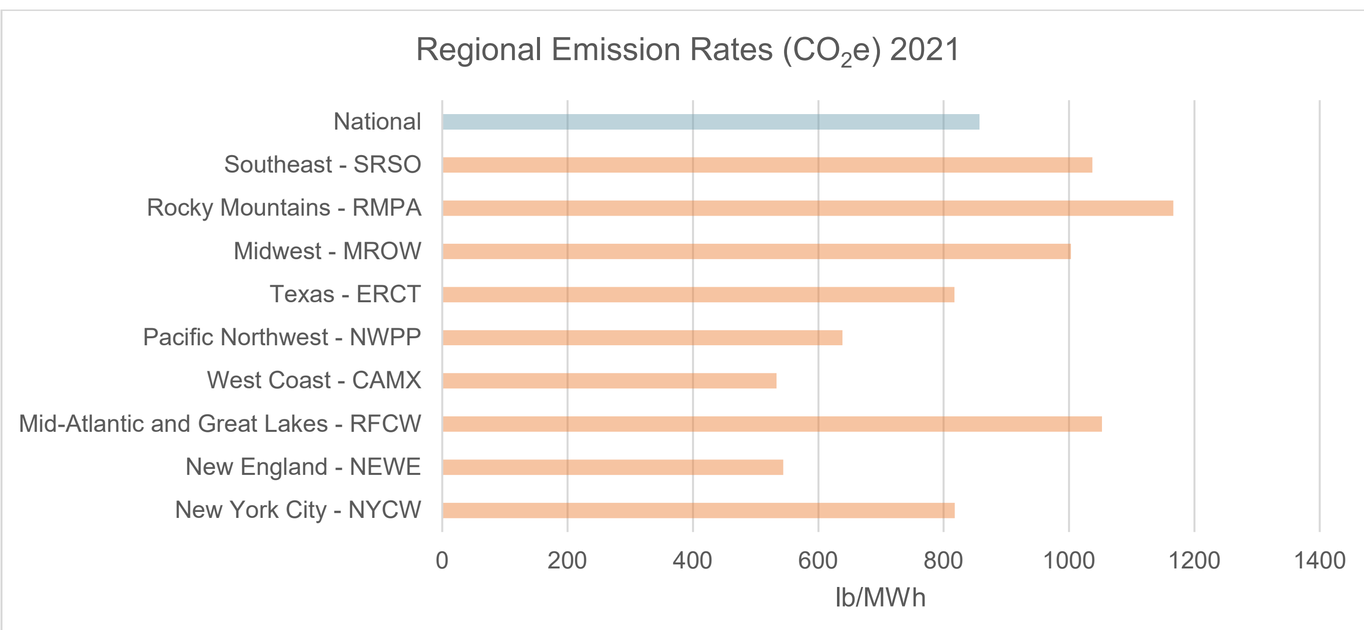

Figure 3: Average Emission Rates (CO2e) for eGrid Subregions[25]

The Inflation Reduction Act (IRA) includes several research opportunities, funding mechanisms, and tax credits to expand renewable energy production. Provisions such as the Energy Infrastructure Reinvestment Financing

[25] https://www.epa.gov/egrid/power-profiler#/

allows Department of Energy (DOE) to make loan guarantees to repurpose energy infrastructure. The Clean Electricity Projection Tax Credit subsidizes the cost of renewable energy systems.

Given the regulatory structure of power generation, many states have little influence on power plant investment. States' only means to regulate power production is through plant siting and utility portfolio requirements. But 26 states have implemented Renewable Portfolio Standards (RPS) or Clean Energy Standards (CES) to encourage or even mandate grid decarbonization, the diversification of domestic energy resources, and emissions reduction. An RPS/CES specifies a percentage of electric generation that must come from renewable or zero-carbon resources. About half of the growth in U.S. renewable energy generation since the beginning of the 2000s can be attributed to state renewable energy requirements[26].

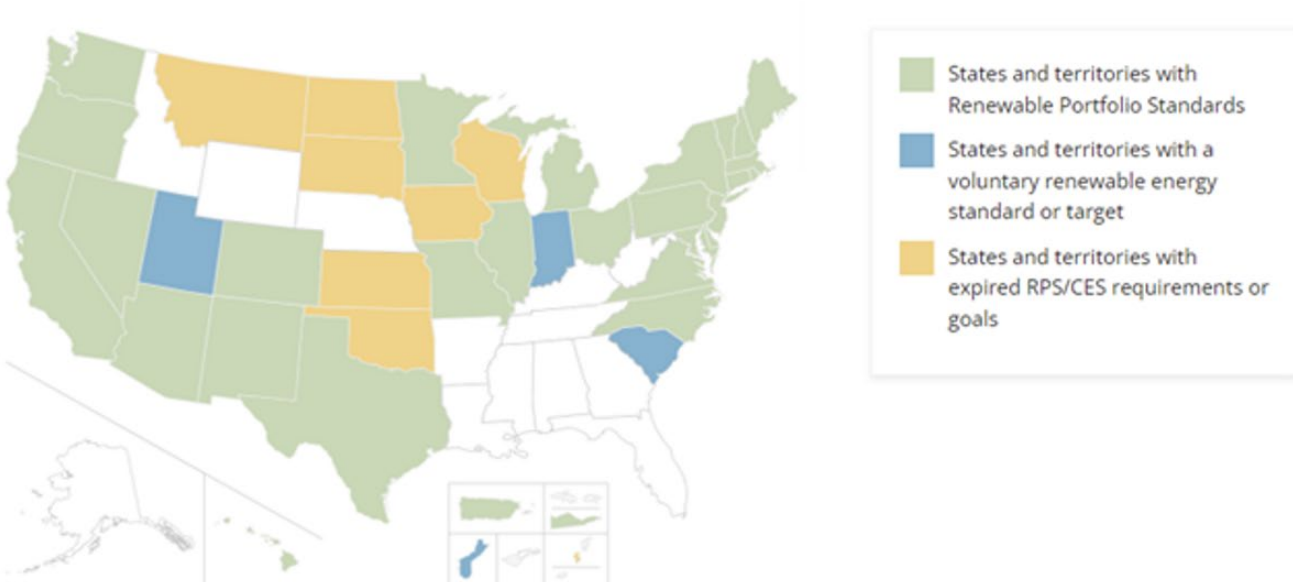

Figure 4: Renewable Portfolio Standards or Voluntary Targets by State[27]

State RPS/CES targets by 2030 and 2050 are shown in the two figures below. Currently, 10 states have set 100% RPS/CES requirements by 2050, while others have requirements of 40% or more with similar deadlines[28]. These states are generally located in the West and Northeast regions. States labelled as having a "0%" RPS target are those that require specific amounts of renewable energy capacity rather than percentages, such as Texas which requires 10,000 MW by 2025.

[26] https://www.ncsl.org/energy/state-renewable-portfolio-standards-and-goals#undefined
[27] https://www.ncsl.org/energy/state-renewable-portfolio-standards-and-goals#undefined
[28] https://www.ncsl.org/energy/state-renewable-portfolio-standards-and-goals#undefined

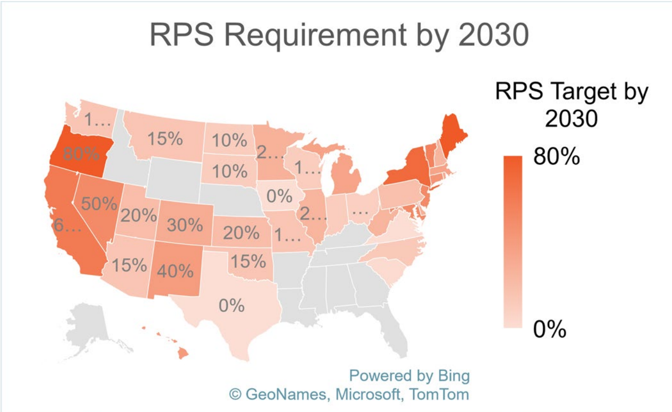

Figure 5: State RPS Requirements by 2030

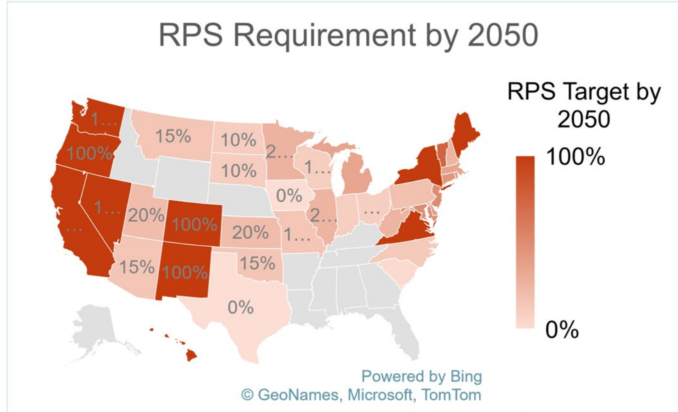

Figure 6: State RPS Requirements by 2050

6B. Grid and Transmission Capacity

Grid Capacity

Grid generation capacity is partially a function of when buildings electrify; as noted in Section 6C, most regions have grid capacity today to handle electrification of heating loads. Regions that have peak demand in summer (which is the case in most of the US) have capacity in spring, fall, and winter to handle additional electric load.

At present in most regions, the electricity load peaks in summer as space heating is primarily served by natural gas and other fossil fuel technologies. Only a few regions, like the Pacific Northwest, have winter peak loads with electric heating and historically modest summer cooling loads. The Southeast has a high prevalence of electric heat, and peak load can occur in either summer or winter based on the weather[29]. However, with the predicted growth of electric heat pumps, the peak loads will occur in winter in most regions. Although not an immediate shift, the winter peak could occur by the 2040s, with some exceptions like Arizona and California which are expected to continue to be summer peaking.

[29] https://www.aceee.org/blog-post/2023/02/coming-electrification-will-require-grid-evolve.

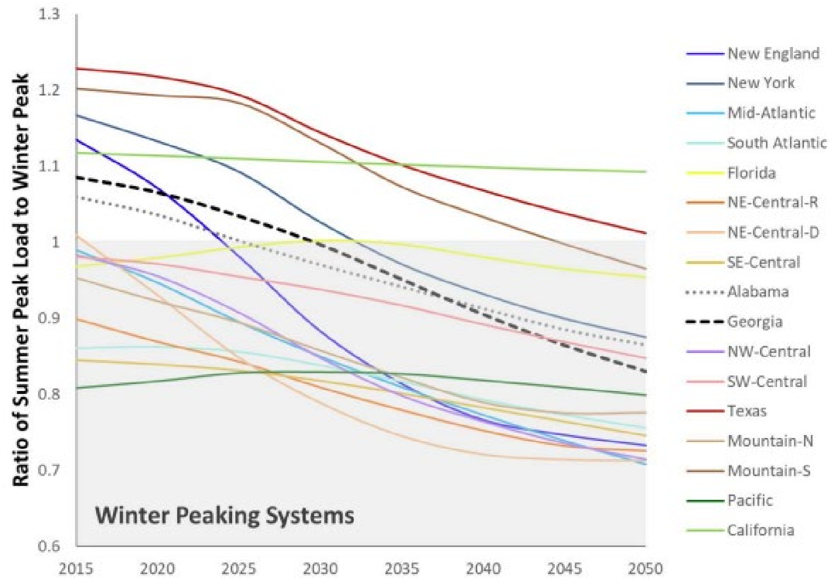

Figure 7: Ratio of summer peak load to winter peak load by region[30]

The ultimate question is, if in the medium- and long-term, can a given grid increase capacity at pace with increased electrification. The answer is region-specific, based on their given capacities and plans for growth.

Transmission Capacity

Transmission capacity is also relevant. The grid is a combination of differing operators across the country, but the long-distance transmission lines that connect electricity to end users are also regulated by various regional authorities. The decentralized nature of the electricity grid, as compared to other large-scale infrastructure, makes planning difficult.[31] Nationwide, improved transmission capabilities are needed to keep up with the demands of the 21st century resulting from increased renewable sources of energy, and increased demand from electrified buildings and transportation.

A draft report from the Department of Energy indicates that most regions in the US will need to expand transmission capabilities by 2030 even without electrification and all regions will need to expand transmission capabilities by 2040. The magnitude of the expansion required will depend on two components: the rate of deployment of clean energy in the region, and the rate of load growth in the region, including load growth due to electrification.[32]

The specific transmission increase required by region depends on the amount of electrification undertaken. Required increases generally fall into one of four major categories:

1. No significant impact in required transmission capacity even with an increase in high clean-energy penetration and/or electrification
2. Minimal additional transmission capacity needs for electrification of building stock assuming a high clean energy penetration environment
3. A marked increase in required transmission capacity for high-clean energy penetration compared to a more business-as-usual case for electric generation

[30] https://www.epri.com/research/products/3002019860
[31] https://www.nytimes.com/interactive/2023/06/12/climate/us-electric-grid-energy-transition.html
[32] National Transmission Needs Study - Draft for Public Comment (February 2023) (energy.gov),, pgs. 84-90

4. A marked additional increase in required transmission capacity for electrification compared to the required transmission capacity required for high clean-energy penetration *in addition* to the electric demand

The IRA also includes funding to improve and expand the electric grid. The Department of Energy has $3 billion earmarked for grants and loan financing toward the planning, siting, construction, and/or modification of electric transmission facilities. An additional $2 billion is set aside for electric distribution, transmission, and generation in rural areas. These are just two programs that expand upon the Building a Better Grid Initiative, a $20 billion investment enabled by the Bipartisan Infrastructure Law.[33]

6C. Regional Outlooks

A sample of locations below have investigated grid capacity following electrification of major sectors. The research focuses on current grid capacity and includes information on current grid peaking behaviors. In general, electrification of other sectors like transportation and industry were not discussed.

The generation from clean sources is included in policies in some regions but not others. This widely varies in different regions according to the climate plans and policies.

New York: New York City, NY

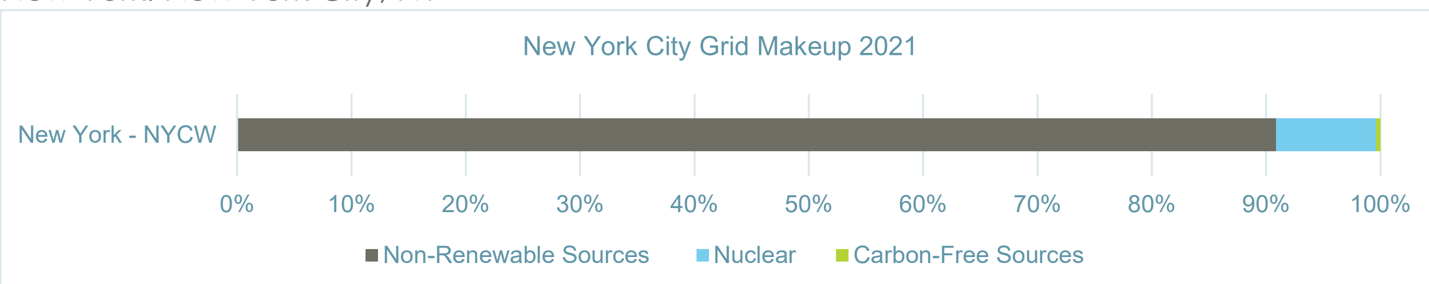

Figure 8: 2021 Grid Makeup in New York City and Westchester

NYC's peak electric power demand is 42% higher in summer than in winter in an average year[34]. Hence, the city's local grid is currently equipped to handle building electrification and has no immediate risk. This leaves a substantial amount of current spare capacity for electrification projects. NY's winter peak is projected to occur between 2035 and 2040. So far, the pace of electrification has been gradual, and the peak will shift once 40 to 50% of the building area is electrified[35].

Although New York City's grid has the capacity for gradual building electrification, it relies exclusively on fossil fuels. Local Law 97 places strict emissions caps on large buildings, which necessitates a lower-carbon grid in NYC[36]. Based on the current energy performance, about 76% of the properties would need to take action to meet the caps by 2030 which means significant changes in building energy use and electrification[37].

[33] https://www.energy.gov/gdo/building-better-grid-initiative
[34] https://www.urbangreencouncil.org/grid-ready-powering-nycs-all-electric-buildings/
[35] https://www.urbangreencouncil.org/how-doable-are-renewables-in-nyc/
[36] https://www.urbangreencouncil.org/greening-the-grid-bringing-canadian-renewables-to-nyc-recap/.
[37] https://www.urbangreencouncil.org/what-we-do/driving-innovative-policy/ll97/#updates

The upstate grid is mostly carbon-free[38]. The Climate Leadership & Community Protection Act (CLCPA) sets a statewide goal of 70 percent renewable generation by 2030.

New England: Boston, MA

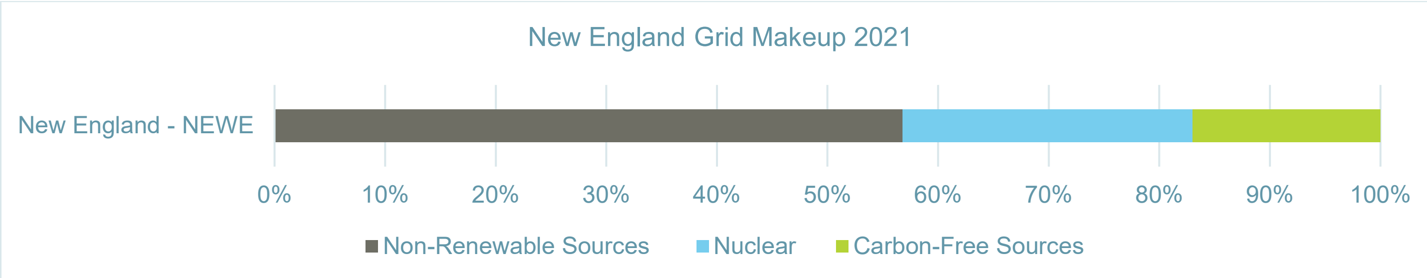

Figure 9: 2021 Grid Makeup in New England

Peak grid electric demand currently occurs in summer afternoons and early evenings on very hot days. The equivalent natural gas heating demand is higher than the electric cooling demand in Boston. Electrification of heating will shift peak electric grid demand from summer to winter[39]. As a state, Massachusetts will need to expand the clean electricity supply to meet the net zero emissions goal by 2050. The demand for clean electricity is projected to be nearly double by 2050 as the end – uses shift to electricity[40].

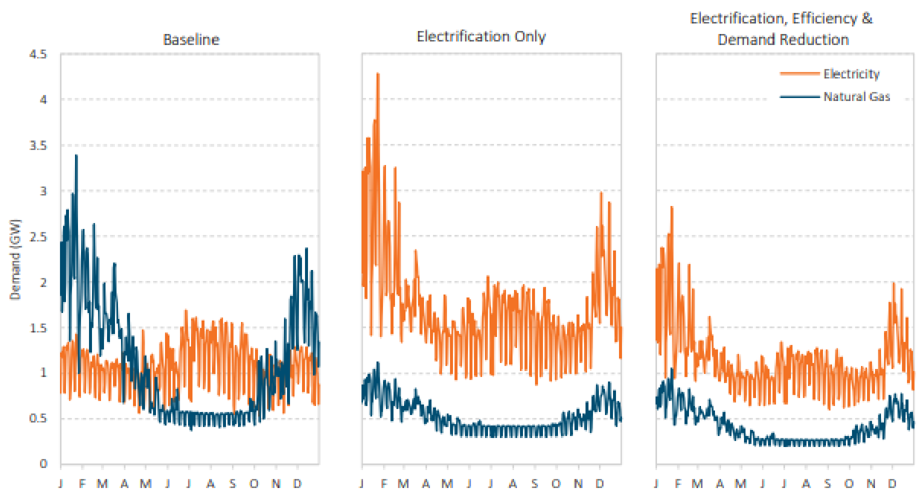

Figure 10: City wide energy demand for natural gas and electricity in Boston for 2015 (baseline) and 2050[39]

Mid-Atlantic: Washington, DC

With the Clean Energy DC Plan, the District of Columbia plans to reduce the GHG emissions of the city by 50% by 2032 using building energy reduction strategies in conjunction with adding renewable energy sources. DC will have peak heating instead of cooling with building heating electrification. In case of accelerated electrification scenario where new buildings would be all-electric and approximately 32% existing buildings would incorporate electric systems in DC by 2032, the wintertime peak electricity demand does not surpass the current summertime peak demand, posing no immediate threats to the grid[41]. However, once the electrification

[38] https://www.urbangreencouncil.org/how-doable-are-renewables-in-nyc/
[39] https://www.boston.gov/sites/default/files/file/2020/08/CFB_Energy_Technical_Report_190514_0.pdf
[40] https://www.mass.gov/doc/ma-2050-decarbonization-roadmap/download
[41] https://doee.dc.gov/sites/default/files/dc/sites/ddoe/page_content/attachments/Strategic%20Electrification%20Roadmap-reducedsize.pdf

rate passes roughly 36% beyond 2032, the wintertime electric loads will be higher than the current summertime peaks.

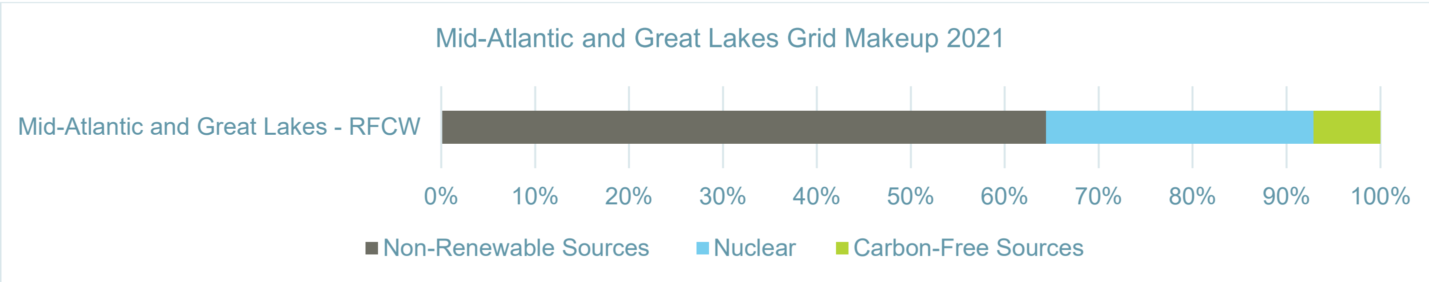

Figure 11: 2021 Grid Makeup in the Mid-Atlantic and Great Lakes

Great Lakes: Chicago, IL

Chicago has a Climate Action Plan to reduce GHG emissions by a of minimum 62% by 2040[42]. Chicago is aiming to electrify 30% of existing privately held buildings and 90% of the city owned buildings by 2035. The climate plan also includes installation of community solar and renewable projects. In addition to several renewable energy project installations, the city plans to decommission fossil power and develop a transition strategy for the removal of fossil fuels by 2024.

West Coast: San Francisco, CA

California is expected to continue to have summer peaks with heating electrification scenario. Research by several consulting firms indicate that California's grid is equipped to handle the increase in electricity demand with efficient building electrification. In a scenario where 50% of buildings are completely electric, the new winter peak demand would still remain below summer peak.[43] If the space heating and water heating electrification surpasses 90% statewide, winter peak may occur instead of summer.

Figure 12 shows the projected electricity demand under a 50% electrification scenario from California Independent System Operator (CAISO) on peak summer and winter days. In the long term when electrification becomes more widespread, the California grid may require additional generation, transmission and distribution infrastructure.

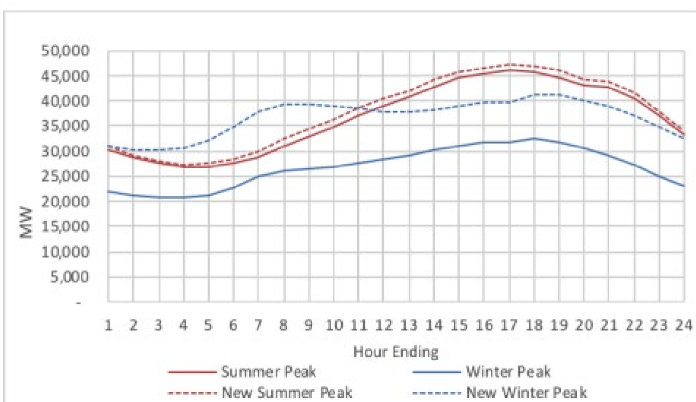

Figure 12: Projected electricity demand in a 50 percent electrification scenario[44]

[42] https://www.chicago.gov/content/dam/city/sites/climate-action-plan/documents/CHICAGO_CAP_20220429.pdf
[43] https://www.nrdc.org/bio/merrian-borgeson/californias-grid-ready-all-electric-buildings
[44] https://www.synapse-energy.com/sites/default/files/Decarbonization-Heating-CA-Buildings-17-092-1.pdf

However, there may be areas like San Francisco with low cooling loads that may be impacted from increasing winter demand. San Francisco has required new buildings to be all-electric since 2021[45] and has set a goal to decarbonize all new and existing buildings by 2040[46] which includes electric space heating, water heating, stoves, and appliances. In some cases, this would require the expansion of local power grid capacity in upcoming years for San Francisco[47].

Pacific Northwest: Seattle, WA

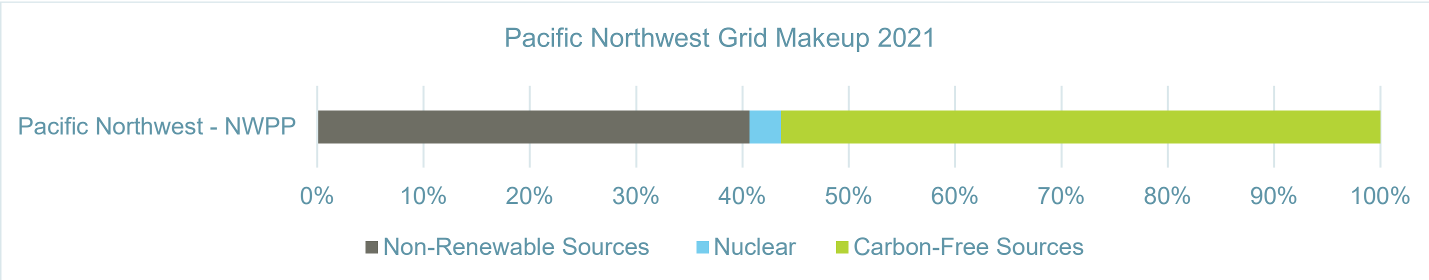

Figure 13: 2021 Grid Makeup in the Pacific Northwest

Seattle's Green New Deal focuses on electrifying buildings and transportation by 2030. If Seattle completely adopts electrification technologies by 2030, winter peak is projected at 4,605 MW load compared to a 2020 winter demand peak of 1,739 MW[48]. When full electrification of buildings and transportation by 2030 is considered, the winter peak exceeds the current capacity of the grid. However, if Seattle remains in a scenario where there is gradual electrification consistent with the goals and policies of Seattle Climate Action Plan[49], the grid would be able to handle the additional electrification load without any major upgrades.

Rocky Mountains: Denver, CO

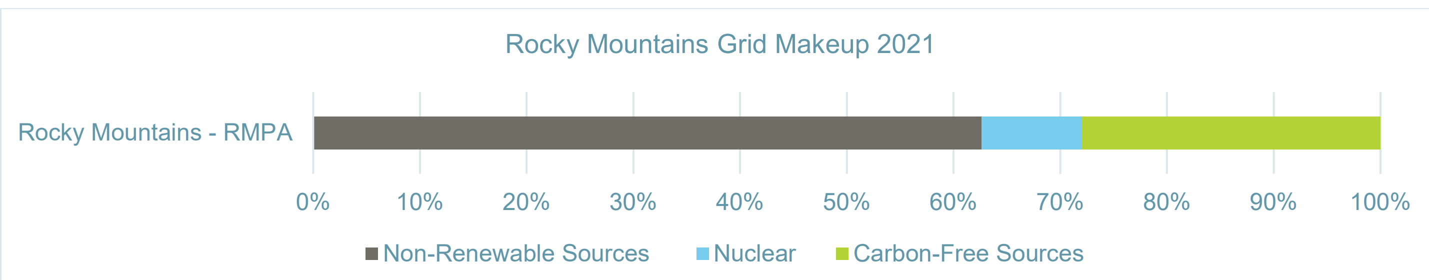

Figure 14: 2021 Grid Makeup in the Rocky Mountain Region

Denver's electric grid experiences the highest hours of electricity demand during the summer, when air conditioning demands are greatest. New building electrification loads may place additional strain on the electric grid, potentially requiring investment in grid upgrades. According to a study, in near term, Denver is forecasted

[45] https://sfenvironment.org/electrify#:~:text=Since%202021%2C%20the%20city%20has,be%20part%20of%20the%20solution!
[46] https://www.sfexaminer.com/news/in-san-francisco-s-push-to-electrify-buildings-hurdles-remain/article_556c066e-288a-11ed-b8f5-439d249ecf4a.html
[47] https://www.sciencedirect.com/science/article/pii/S2210670723002196
[48] https://powerlines.seattle.gov/wp-content/uploads/sites/17/2022/01/Seattle-City-Light-Electrification-Assessment.pdf
[49] https://www.seattle.gov/Documents/Departments/Environment/ClimateChange/2013_CAP_20130612.pdf

to be able to electrify at least 50% of buildings without requiring additional system-level generation and transmission capacity[50].

With Denver's 80x50 goal of Climate Plan (80% carbon emission reduction by 2050), one of the main sectors for emission reduction is buildings. However, achieving Denver's long-term climate goals and 100% electrification may require incremental generation capacity. Both building and vehicle electrification will increase total electricity demand over time.

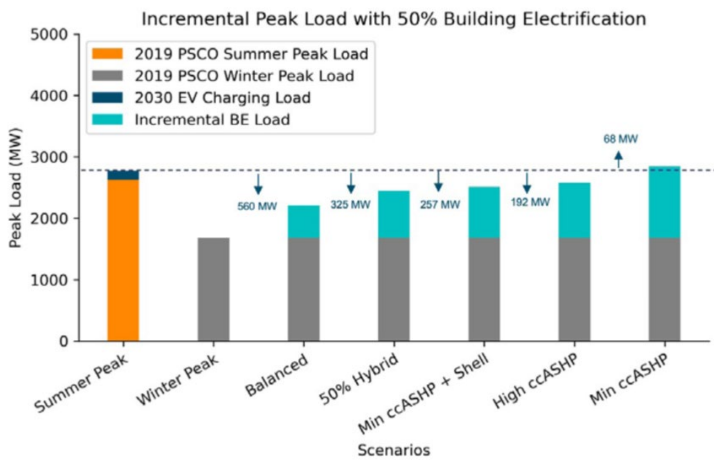

Figure 15: Estimated winter peak demand in Denver due to electrification of 50% existing building stock[50]

Texas: Dallas, TX

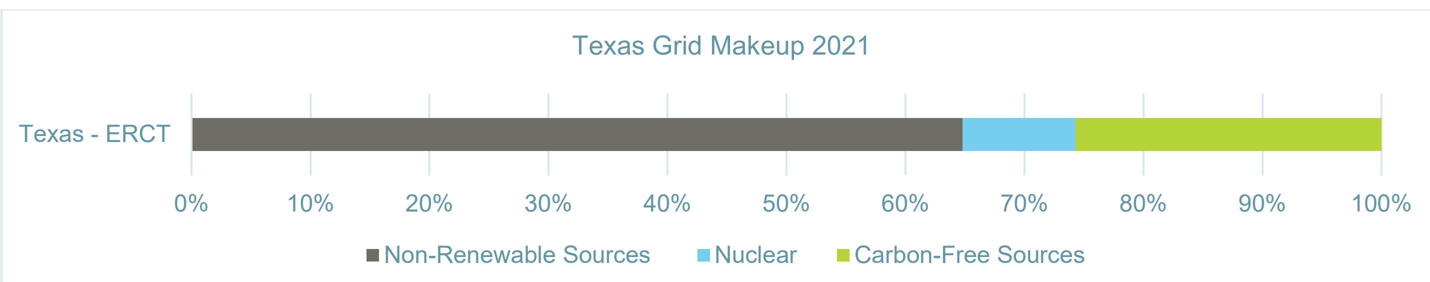

Figure 16: 2021 Grid Makeup in Texas

Texas has its own power grid which allows the state to distribute power without exporting any over the state lines. This was viable for Texas mainly because of its size, covering two time zones which results in two different peak hours in the same state. This permits Texas's power authority, the Electric Reliability Council of Texas (ERCOT), to produce sufficient energy for its customers[51]. The Texas grid is uniquely vulnerable to cold weather, and it is not equipped to handle high heating loads, even at present. A major winter storm in February 2021 caused massive blackouts with the overwhelming use of electric heaters. The emergency electricity reserves were depleted, and power plants shut down from frozen equipment and scarcity of natural gas[52].

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[50] https://www.denvergov.org/files/assets/public/climate-action/documents/hpbh/renewable-hampc/denver-renewable-heating-and-cooling-plan_june-2021.pdf
[51] https://www.investopedia.com/texas-power-grid-5207850
[52] https://www.texasmonthly.com/news-politics/texas-electric-grid-failure-warm-up/

Following this, different initiatives like implementing weatherization plans, legislative changes, incentives etc. were undertaken to better prepare the power grid[53].

Southeast: Atlanta, GA

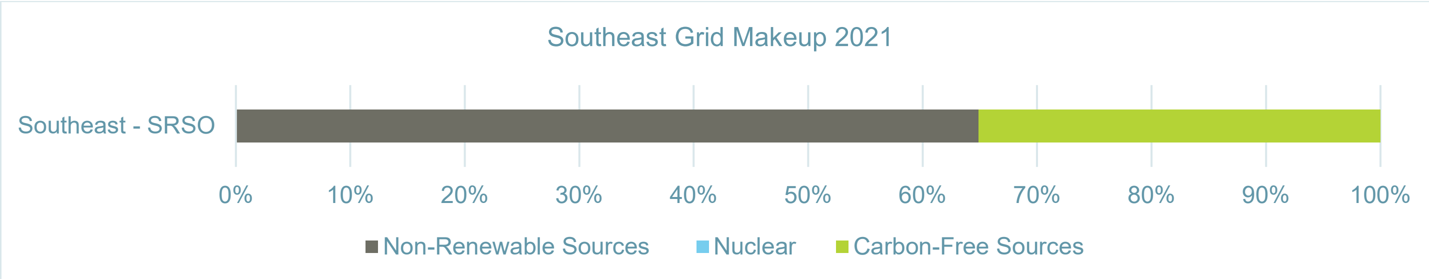

Figure 17: 2021 Grid Makeup in the Southeast

Georgia's grid is mainly powered by coal and plans to be 40% nuclear in a couple of years[54]. Georgia already shares energy with other states from East Coast and the middle of the US and is not likely to face a sudden blackout in events like winter storm. That also allows the Georgia grid limited capacity to serve additional building electrification loads from space heating and this will lead Georgia to have a winter peak of electricity demand instead of current summer peaks[30].

Midwest: Minneapolis, MN

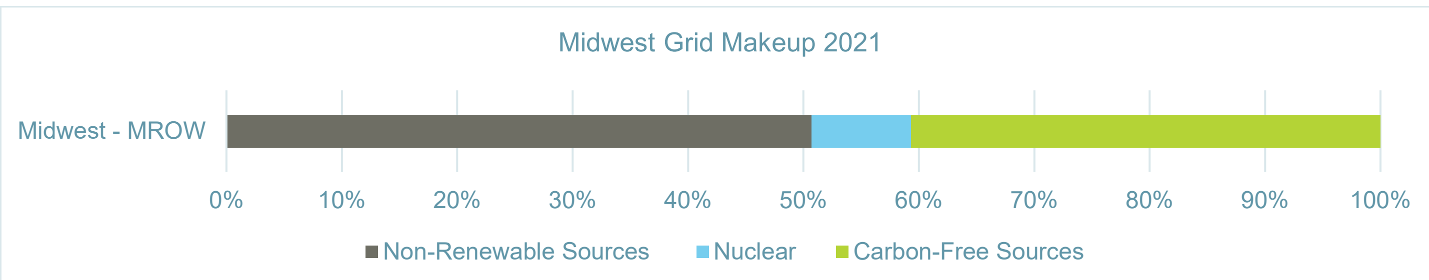

Figure 18: 2021 Grid Makeup in the Midwest

Minnesota currently faces the risk of blackouts in summer as the Midcontinent Independent System Operator (MISO) power grid transitions away from coal generators. However, the coal generators slated to close between 2023 and 2030 would be made up with renewable sources by 2041. In addition to the changes in generation mixes, severe weather is also causing a natural gas shortage in Minnesota. As MISO projects a higher summer peak demand than before, Minnesota is at an increased risk of temporary, controlled power outages[55].

[53] https://www.kvue.com/article/news/investigations/defenders/kvue-defenders-texas-power-grid-past-present-future/269-a4f073aa-43bc-46f4-b588-b0e601f3fa77
[54] https://www.wtoc.com/2021/02/20/how-resilient-is-gas-power-grid/
[55] https://www.startribune.com/midwest-including-minnesota-at-greater-risk-for-rolling-blackouts-this-summer/600173261/

7. BUILDING POLICY LANDSCAPE

The number and scale of building electrification and decarbonization policies have only grown in the past 5-10 years. There is every indication more localities are preparing to implement their own policies, coupled with direct federal government support and national coordination among like-minded legislatures.

In January 2020, the City of Berkely became the first jurisdiction to ban the use of natural gas in residential new construction. This was a turning point for the electrification movement and since, many jurisdictions have followed suit. A recent federal court ruling has challenged the Berkely ordinance, but other jurisdictions are approaching the topic in different technical and legal manners and moving forward with implementation.

Many requirements take the form of mandating carbon reductions from building operations. Fossil fuels by definition release carbon directly when combusted on site whereas electricity does not. Carbon limits may eventually necessitate the removal of fossil fuel combusting equipment by virtue of standards which are impossible to meet without electrifying systems.

Other requirements take the form of energy intensity limits. While not explicitly tied to carbon, the limits require efficiency gains that may only be possible through some forms of electrification.

In some cases building code strengthening or outright requirements for certain types of equipment require use of electric equipment.

7A. Building Codes & Natural Gas Prohibitions

Separate from jurisdictional policies, building energy codes are trending towards decarbonization and electrification. As it can be seen from Figure 19, codes have been established around energy consumption and improved efficiency since 1975. Several regions have even more stringent code requirements than the national building code. There has also been a push towards either adopting the International Energy Conservation Code (IECC) for new construction or setting more aggressive goals for decarbonization and energy efficiency in states like New York and Massachusetts.[56]

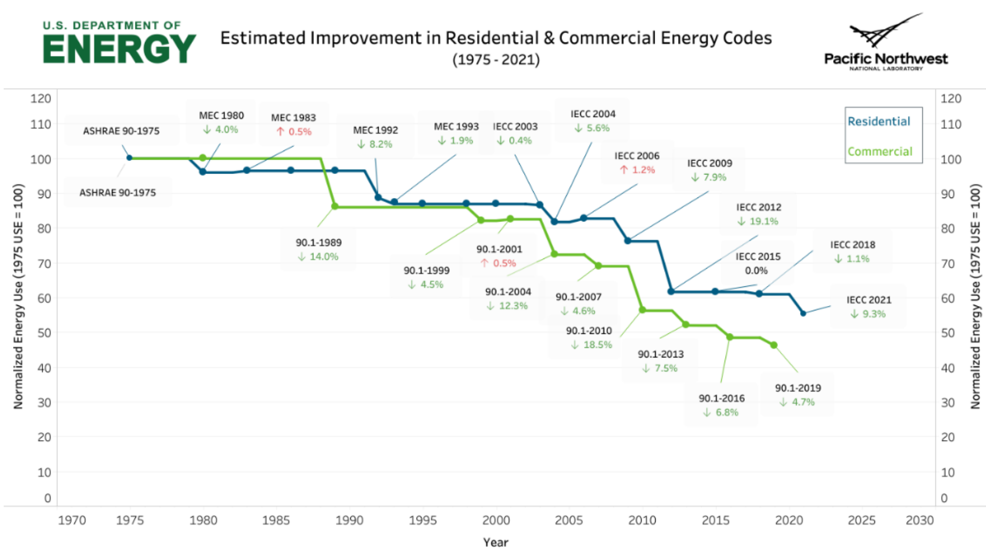

Figure 19: Improvements in Residential & Commercial Energy Codes building stock[57]

[56] https://neep.org/sites/default/files/media-files/building_codes_and_electrification_brief.pdf
[57] https://www.energycodes.gov/infographics

California

The California Energy Commission has passed the 2022 Energy Code that goes into effect January 1, 2023, where most new construction for residences and commercial buildings will need to have heat pumps for heating and electric appliances instead of natural gas equipment. This code also requires new constructions to be electric-ready and have stronger ventilation standards.[58]

New York, NY

New York City's Local Law 154 (LL154) begins the phase out of fossil fuel use in new construction beginning in 2024. LL154 sets restrictions on fossil fuel usage in newly constructed residential and commercial buildings by phasing in strict emissions limits. Buildings of all sizes must be constructed fully electric by 2027. The new law provides limited exemptions for certain uses, such as commercial kitchens and emergency or standby power.[59]

Washington

Washington state has mandated all electric space heating and hot water systems for new commercial and large multifamily buildings with four or more floors that goes into effect July 2023[60].

Colorado

Senate Bill 21-264 in Colorado has a Clean Heat Standard that establishes GHG reduction targets for gas distribution facilities. The required reduction is set at 4% by 2025 and 22% by 2030, with more rigorous goals in upcoming years.[61]

Massachusetts

Although not mandatory, Massachusetts developed a voluntary energy code that provides substantial advantages for an all-electric new construction over buildings with natural gas connections. From July 2024, the residential and commercial buildings with gas connections will have to achieve a lower minimum Home Energy Rating Score (HERS) of 42 while the score for electric buildings is 45.[62]

7B. Performance Mandates

Building Performance Standards (BPS) are performance-based policies that require existing buildings to meet energy and/ or greenhouse gas emissions-based performance targets.[63]

Dozens of cities, counties, and states are considering or have passed BPS. The inherent tightening of standards within a BPS ultimately leads toward electrification – most far-reaching standards, particularly zero GHG emissions targets, cannot be reached without buildings shifting to more efficient electric systems.

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[58] https://www.reroyalties.com/post/california-energy-code-what-does-this-mean-for-energy-storage
[59] https://climate.cityofnewyork.us/subtopics/buildings/
[60] https://www.cleanenergytransition.org/post/washington-passes-nation-leading-residential-energy-codes
[61] https://www.canarymedia.com/articles/policy-regulation/policy-win-colorados-innovative-clean-heat-standard
[62] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/massachusetts-favors-building-electrification-in-final-energy-code-update-72296997
[63] https://www.energycodes.gov/BPS

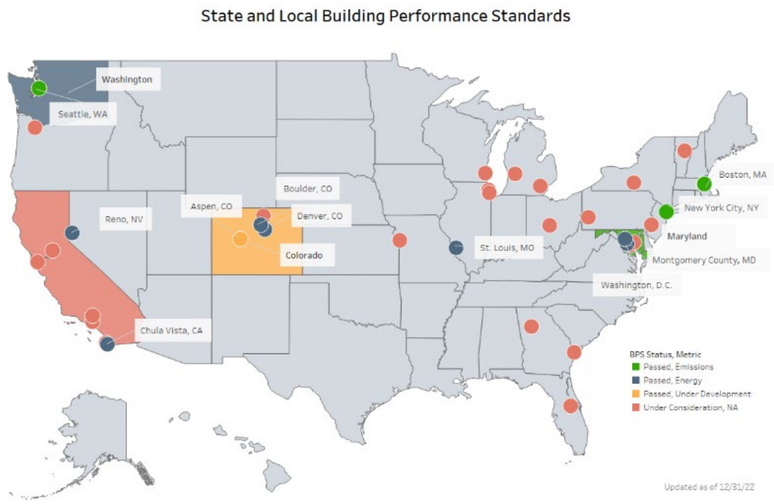

Figure 20: Current BPS Adoption Status[64]

With federal government support, a National BPS Coalition consisting of over 40 state and local governments has committed to design and implement policies within their boundaries. This coalition will aid increased adoption and standardization of BPS, with a goal of incorporating workforce engagement, technical analysis, equity strategies, and overall stakeholder engagement.[65]

New York, NY

New York City's Local Law 97 (LL97) requires most buildings over 25,000 square feet meet GHG limits by 2024, with stricter limits coming into effect in 2030 and beyond, or face financial penalties, scaled to the amount of emissions a building exceeds its target. Alternate compliance paths and extensions are in place for certain types of affordable housing. The goal is to reduce the emissions produced by the city's largest buildings 40% by 2030 and 80% by 2050.[66]

Washington, DC

The Washington, DC BEPS policy establishes energy use standards for buildings to meet based on property type. Buildings not meeting their respective property type will be required to improve their performance over the course of a compliance cycle by 2026 and demonstrate improved performance.[67]

Montgomery County, MD

The Montgomery County BEPS covers buildings 25,000 SF and above. Within this standard, buildings are grouped by property type and size, and each group is assigned a long-term site energy use intensity (EUI) performance standard. This BEPS starts based on group between 2023 and 2026; all buildings within a property type must meet the same final performance standard by the designated compliance deadline of 2033 to 2036 depending on the group. Buildings will be required to meet an interim standard after 5 years to ensure progress toward the final standard. The intent is for better-performing buildings to improve more gradually than poorer-performing buildings.[68]

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64 https://www.energycodes.gov/BPS
65 https://nationalbpscoalition.org/
66 https://www.nyc.gov/site/sustainablebuildings/ll97/local-law-97.page
67 https://buildinginnovationhub.org/resource/regulation-basics/dc-building-energy-performance-standards/
68 https://www.montgomerycountymd.gov/green/energy/beps.html

Maryland

The Maryland Climate Solutions Now Act of 2022 requires Maryland to develop a BPS policy that achieves a 20% reduction in net direct GHG emissions by January 1, 2030, and net-zero direct GHG emissions by January 1, 2040. The policy applies to buildings 35,000 SF and above, Historic properties, public and nonpublic elementary and secondary schools, manufacturing buildings, and agricultural buildings are exempt. Owners of covered buildings will need to report data each year beginning in 2025. The draft BEPS regulations with proposed energy and GHG targets by building type were released in May 2023.[69]

St. Louis, MO

The St. Louis BEPS ordinance covers municipal, commercial, institutional, and residential buildings 50,000 SF and above. Standards are set for each building type and will impact the highest energy users. Building owners have the option of selecting physical or operational improvements to meet the standard and have until May 2025 to reduce their energy use to comply. The standards set strengthen each four-year compliance cycle.[70]

7C. Permitting & Equipment Replacement

Another approach to encourage electrification is triggered during the permitting process for replacing major HVAC equipment. In this situation, buildings must consider replacing their equipment with high performance, electric-power alternatives as opposed to replacing existing gas-fired equipment in kind at the end of useful life.

Burlington, VT

Starting in 2024, existing commercial buildings over 50,000 SF and municipal buildings must install 100% renewable technology or fuels for replacement heating or water heating systems at the time of permit. Buildings that continue to use a fossil fuel system will pay a carbon pollution impact fee.[71]

7D. Gas Moratoria

A natural gas moratorium has occurred in at least two instances in New York State, where natural gas availability was exceeded by demand. As a result, the utility ceased allowing connections in new construction. Con Edison stopped accepting natural gas applications in its Westchester County service area in 2019. Connections may potentially be resumed in late 2023.[72] Also, in 2019 National Grid temporarily halted new gas connections in Brooklyn, Queens, and Long Island.[73]

7E. Preemption Laws

Multiple states have introduced or passed “preemption laws” in response to localities’ efforts to limit or prohibit the use of natural gas in buildings. These laws restrict the ability of municipalities or other jurisdictions to restrict the use of natural gas. As of Spring 2022, 19 states have enacted legislation that preempts local regulations banning natural gas use in new construction.[74]

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69 https://mde.maryland.gov/programs/air/ClimateChange/Pages/BEPS.aspx
70 https://www.stlouis-mo.gov/government/departments/public-safety/building/building-energy-improvement-board/documents/beps-ordinance.cfm
71 https://www.burlingtonvt.gov/Press/mayor-weinberger-burlington-electric-department-and-partners-celebrate-passage-of-carbon
72 https://www.coned.com/en/our-energy-future/electric-heating-and-cooling-equipment/about-the-westchester-natural-gas-moratorium
73 https://www.nationalgridus.com/News/2019/11/-National-Grid-to-Lift-Natural-Gas-Moratorium-Immediately-for-Customers-in-Brooklyn,-Queens-and-Long-Island/
74 https://www.forbes.com/sites/patrickgleason/2022/04/19/why-states-continue-to-overrule-local-regulation-of-fossil-fuels/?sh=3d099a33769e

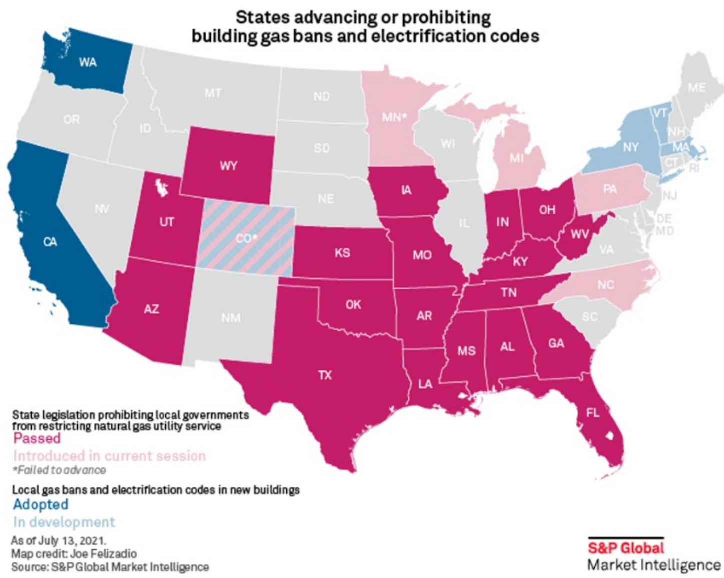

Figure 21: Preemption Laws and Electrification Code[75]

These state's preemption laws in some cases overlap with jurisdictions which have already passed or are considering GHG emissions reduction targets, highlighting that there are ultimately many paths to electrification within buildings.

7F. Legal Challenges

A recent court challenge has overturned the country's first natural gas prohibition in new construction.

In 2019 Berkely, CA approved an ordinance to prohibit natural gas connections in multifamily construction with some allowances for ground floor retail and other large buildings. A federal appeals court in 2023 overturned the ordinance based on a lawsuit filed by the California Restaurant Association. The suit was based on the grounds that the ordinance violated federal law, as the US government has the authority to set energy-efficiency standards for appliances.[76] The city may challenge the ruling. Each jurisdiction's approach to the use of natural gas in construction differs; a ruling in one location does not necessarily equate to comparable responses in other locations.

[75] https://www.energycodes.gov/BPS
[76] https://apnews.com/article/berkeley-california-natural-gas-ban-overturned-appeals-court-7dafca58d19963f322100d73caf9c31a

8. INCENTIVES

Incentives encouraging building electrification often make upgrades more financially viable and take many forms. Each offering has its own criteria and not all buildings necessarily qualify. Differing types of incentives may go toward building owners, installers/contractors, or local governments, and can take the form of direct payments or tax burden reductions. Each state contains differing types and from differing providers.

8A. Types of Incentives

Incentives are generally delivered in the following forms:

Table 2 Incentive and Financing Summary

Approach	Description
Tax Deduction	This approach reduces the amount of income subject to taxes. In this situation, a tax rate is applied to a lower figure, resulting in a lower tax.
Tax Credit	Credits reduce the actual amount of tax due. The entity in question must have tax liability.
Rebate	Occurs at the point of sale and reduces the price of the purchased equipment. Rebates can include the cost of labor and supplemental equipment such as panel upgrades.
Grants	Incentive providers may choose to provide direct funding for upgrades, depending on the incentive structure.
Financing	Specialized loan products are available for energy efficiency upgrades. Additional financing or preferential interest rates may be available in exchange for a commitment to energy efficiency or carbon reductions in order to fund these improvements.[77] Commercial Property-Assessed Clean Energy (CPACE), when enabled in a given state, allows borrowers to pay back the cost of upgrades through an authorized assessment on a property tax bill. This arrangement can benefit from beneficial interest rates and longer repayment terms.[78]

8B. Inflation Reduction Act

The 2022 Inflation Reduction Act (IRA) is $370 billion investment in clean energy solutions across the economy[79] and represents the most significant federal action on the topic. The funding in this package will flow to local jurisdictions through grants, loans, rebates, incentives, and other investments to local governments and utilities. The funding from this program is designed to alter the market and encourage electrification on multiple fronts. The IRA contains funding for many elements, electric grid modernization, electric vehicle charging infrastructure, battery supply chain support, public transportation, and clean energy generation.

A suite of programs within the IRA address building electrification in particular:

179D – Energy Efficient Commercial Building Deduction

179D is a $0.50-$1.00 tax deduction per square foot for buildings achieving a 25-50% reduction in energy use from a qualified retrofit baseline or ASHRAE 90.1 guidelines. A larger bonus up to $5.00 per square foot is available if certain labor requirements are met. The ASHRAE pathway must use Internal Revenue Service (IRS) approved modeling software and for both pathways, a qualified person must certify savings. Lighting,

[77] https://www.usgbc.org/articles/major-companies-use-green-financing-build-their-leed-portfolios
[78] https://www.energystar.gov/buildings/save_energy_commercial_buildings/finance_projects
[79] https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/

HVAC, and envelope improvements are covered, and the deduction applies to existing buildings and new construction.

Clean Electricity Investment Tax Credit (ITC)

The ITC provides deep reductions for clean energy system costs (including solar, wind, geothermal, energy storage, microgrid controllers and dynamic glass) via a credit of up to 30% of cost. Up to an additional 20% credit is available depending on the location of the project within a designated “energy community”.

Multifamily Components

Specific sections apply to multifamily properties. These are described here to highlight the breadth of the incentives:

- 45L Tax Credit - Energy Efficient Home Credit: For buildings meeting energy efficiency targets
- High Efficiency Electric Home Rebates (HEEHRA): Rebates for electric HVAC equipment upgrades
- Home Energy Performance-Based Whole-House Rebates (HOMES): Rebates for energy-saving retrofits, include heat pump installation

Funding for Local Government, Utilities, and Non-Profits

- Technical assistance for building energy code adoption: $1B grants to help local governments adopt and implement new energy codes
- Greenhouse Gas Reduction Fund: $27B to be distributed to Green Banks or similar
- Environmental and Climate Justice Block Grants: $3B for local governments and nonprofits for disadvantaged communities
- GHG Planning and Implementation Grants: Support for municipalities to develop and implement plans for reducing GHG emissions
    - Includes support for development of BPS
- Advanced Industrial facilities deployment program
- State Home Efficiency Contractor Training Grants

8C. Other Notable Programs/ Grants

Local governments and programs are being incentivized to encourage energy efficiency and electrification. This means that beyond individual building support, jurisdictions will be encouraged to develop programs of their own, including strengthening codes and potential BPS development.

Infrastructure Investment and Jobs Act

The Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Plan, is the largest reinvestment in our country’s infrastructure in generations. Similar to IRA funding, far reaching incentives are being provided to local jurisdictions.

- Grants for Energy Efficiency Improvements and Renewable Energy Improvements at Public School Facilities ($500M through 2026)
- Energy Efficiency and Conservation Block Grant Program ($550M until spent)
- Energy Efficiency Revolving Loan Fund Capitalization Grant Program ($250M until spent)

Investing in America & Defense Production Act

The federal government is engaging directly with the market to encourage growth in specific industries. The Investing in America program provides direct funding to select industries to strengthen supply chains and invest in clean energy technologies. The current Administration recently released $250 million to accelerate electric heat pump manufacturing.[80] This funding stems from authorization through the Defense Production Act to accelerate domestic production of solar technology, transformers and electric grid components, heat pumps, insulation, and electrolyzers.[81]

Potential Federal Legislation

The current Congress introduced H.R. 1491, the Small Business Energy Loan Enhancement Act[82], which would double the size of SBA loans available for energy efficiency upgrades to $10 million. Although it has not passed as of this time, this represents an important potential source of assistance.

8D. Incentive Resources

Incentives vary across jurisdictions and are available from multiple sources. Beyond federal incentives, local utilities, city, county, and state governments, and various authorities provide resources with their own application criteria.

An initial starting point for building owners and managers is The Database of State Incentives for Renewables & Efficiency (DSIRE) site is a non-profit resource to identify incentives by state and building type.

DSIRE Website: https://www.dsireusa.org/

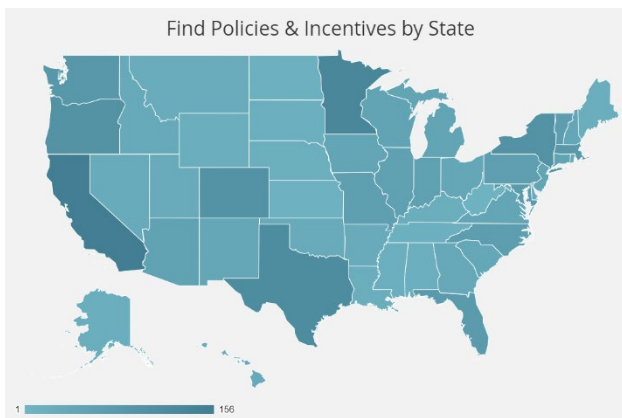

Figure 22: Preemption Laws and Electrification Code

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[80] https://www.energy.gov/articles/biden-harris-administration-announces-250-million-accelerate-electric-heat-pump
[81] https://www.energy.gov/articles/president-biden-invokes-defense-production-act-accelerate-domestic-manufacturing-clean
[82] H.R.1491 - 118th Congress (2023-2024): Small Business Energy Loan Enhancement Act | Congress.gov | Library of Congress