THE FUTURE OF BUILDINGS

New York's Carbon Neutral Buildings Roadmap

DECEMBER 2022

NEW YORK STATE

Notice

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Acknowledgements

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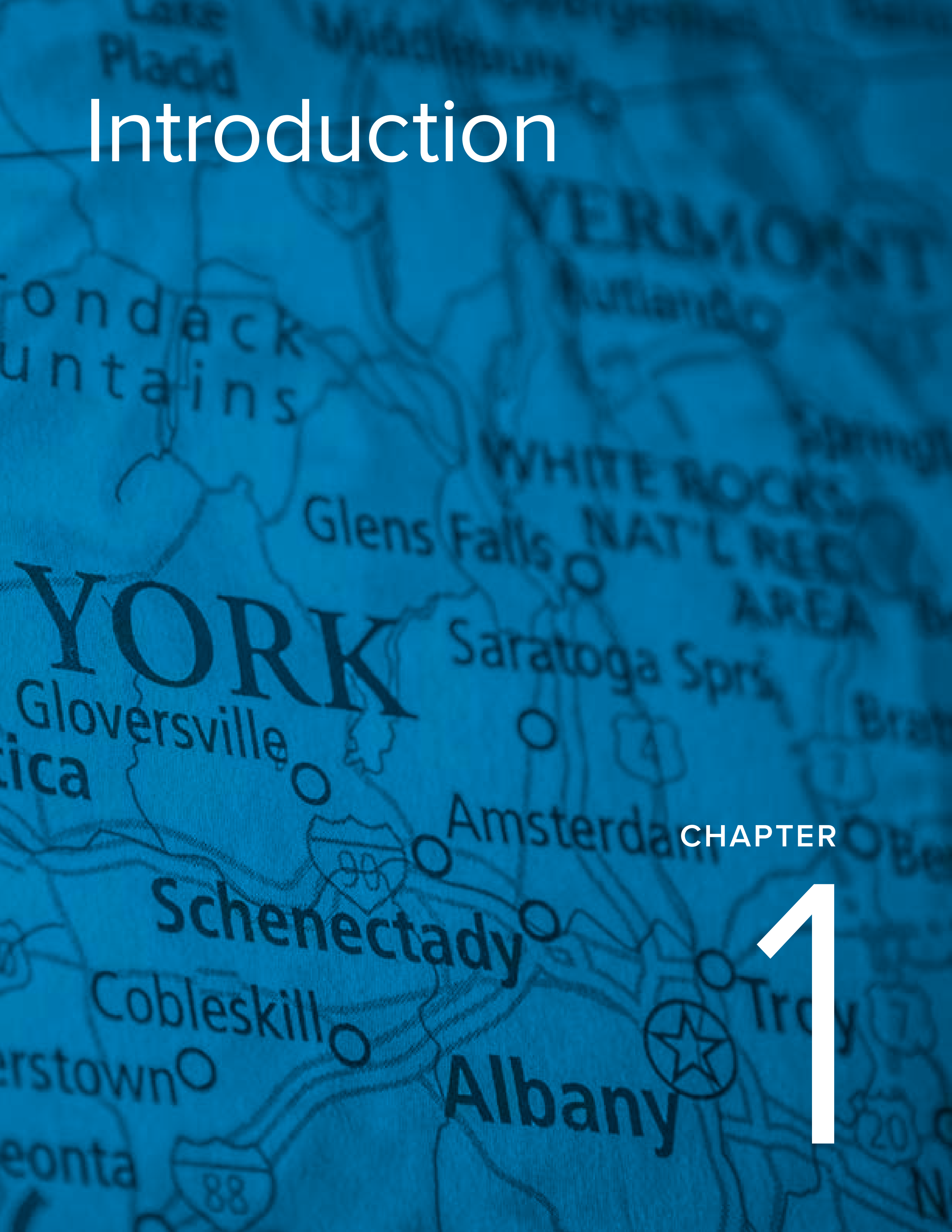
Introduction



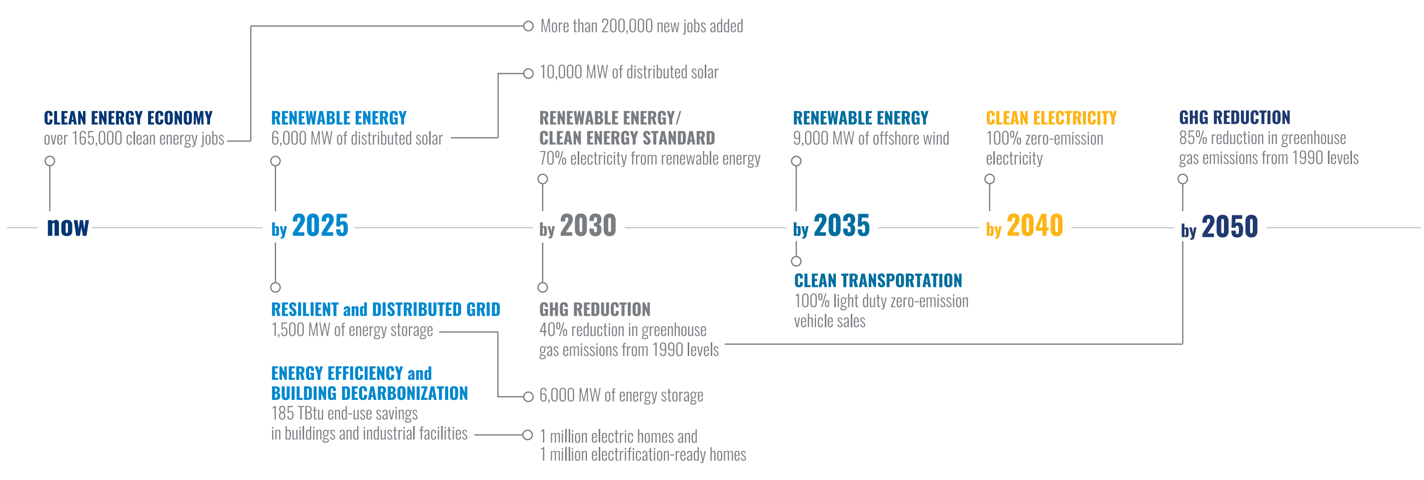
CHAPTER 1

New York State's current nation-leading climate action builds on decades of data and science-based work in climate, architecture, engineering, and economics. As a result, the State's climate targets are among the most rigorous of any economy in the world. Equitable access to high-quality, clean, and resilient spaces where we live, work, and play is fundamental to a healthy and sustainable society, and represents the Future of Buildings in New York State.

Built upon years of rigorous analysis, programmatic development, and stakeholder outreach and feedback, the first report in a new series, NYSERDA's **Future of Buildings,** is the *Carbon Neutral Buildings Roadmap* (the "Roadmap"), which lays out a guiding framework and general solution set for the critical work that must be undertaken to modernize New York State buildings while reducing, and in most cases eliminating, their use of fossil fuels. The *Roadmap* provides a long-term vision of the built environment in 2050, including recommendations on key policies, potential focus areas for technology advancement and programmatic needs, while also highlighting the near-term actions that are technologically ready, economically viable, and are being adopted in the market today.

The impetus for these efforts is the need to avoid the worst effects of catastrophic climate change. With each passing year it becomes increasingly clear that New York State is vulnerable to the many impacts of a warming planet. And it's also clear that the cost of inaction is enormous—flooding, heat waves, other extreme weather events, disruptions to ecosystems, food chains, forced migrations, and the list goes on.

FIGURE 1.1: CLIMATE ACT TARGETS AND TIMING



Source: Climate Leadership and Community Protection Act

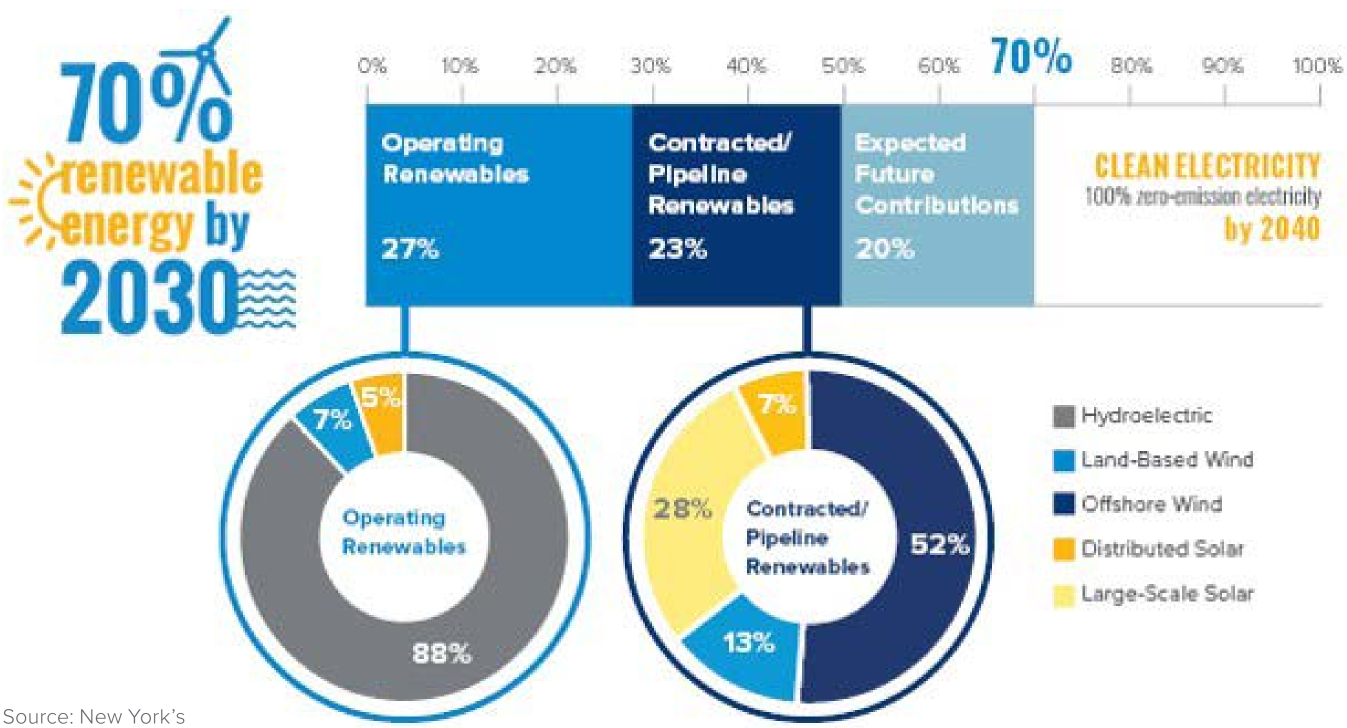
To boldly address this challenge, the Climate Leadership and Community Protection Act (the Climate Act), passed in 2019, commits the State of New York to an 85% reduction in greenhouse gas (GHG) emissions by 2050, and a 40% reduction in GHG emissions by 2030. In addition to emission reductions targets, the Climate Act includes targets for clean electricity, renewable energy, energy efficiency, and grid resilience as summarized in Figure 1.1.

To develop a plan for reaching these goals, the Climate Act established a Climate Action Council (CAC), which was charged with finalizing a [Scoping Plan](#) to delineate the actions that New York State will need to undertake to achieve the required GHG limits. The CAC works across all industries and has been advised by a number of industry-specific advisory panels, including the Energy Efficiency & Housing panel, which is focused on the building sector. The CAC is also advised by a Just Transition Working Group and the Environmental Justice Advisory Group. The CAC issued the Scoping Plan in December of 2022. In addition, the Clean Energy Standard (CES) works to ensure that 70% of New York's electricity comes from renewable energy sources such as solar and wind by 2030 and requires 100% clean electricity by 2040, which makes building electrification a powerful tool in decarbonizing the built environment. Currently, New York State has secured 27% of its renewable energy goal with another 23% coming online or contracted, and 20% targeted for acquisition by 2030 (see Figure 1.2).

In January 2022, Governor Hochul launched an unprecedented commitment to achieve a 100% carbon neutral building stock by 2050. This is the most ambitious clean energy and climate agenda in the nation's history—underscoring the State's role as a leader in these solutions. Recommendations set a course for all new construction to be zero emissions no later than 2028, for transitioning the existing building stock to be highly efficient and all-electric by mid-century, and for a 100% emissions-free energy grid by 2040. Additional discussion and detail around the legislative and policy path and how this will shape and drive the carbon neutral trajectory is discussed in Chapter 9: Policy Solutions.

To enable decarbonization of the built environment, NYSERDA in 2019 was directed to prepare a roadmap leading to a carbon neutral building stock across the entire State of New York. This *Carbon Neutral Buildings Roadmap* (Roadmap) builds on over two years of collaboration between NYSERDA, consultants from across the country, and input from over 1,000 stakeholders in the community to provide decarbonization solutions and policy recommendations that best fit the circumstances of the State.

FIGURE 1.2 NEW YORK CLEAN ENERGY STANDARD



Source: New York's
Clean Energy Standard

A Roadmap to 2050

Achieving the goals of the Climate Act requires significant changes and investments into all aspects of the economy. The current emissions trajectory would result in New York's building sector emitting 69 MMT CO_2e in 2050—more than double the economywide emissions allowable under the Climate Act requirements.

Direct emissions from onsite fossil fuel combustion and the release of hydrofluorocarbons (HFCs) used in building equipment and products comprise about one-third of the State's total current carbon emissions. That percentage increases to roughly 43% when including the indirect emissions associated with the generation of electricity used in buildings today.

As such, building decarbonization represents a significant part of achieving statewide carbon neutrality by 2050. While there is a constantly growing list of carbon neutral buildings locally, nationally, and globally that demonstrate what is achievable and at what costs, these represent a tiny fraction of the State's current overall building stock. Additional policies, programs, and initiatives will need to be implemented for the building sector to realize New York's 2050 goals.

This *Roadmap* provides a vision of how a carbon neutral building stock could be achieved in New York, and how clean and resilient buildings will be an essential element of a statewide decarbonized economic system by mid-century. It identifies ways to promote and accelerate current solutions, achieve cost reductions to implement these existing solutions, while also building a foundation to make investments that develop better and more cost-effective future solutions. The *Roadmap* also ensures a focus on Disadvantaged Communities so that they are able to equitably participate in and enjoy the benefits of this transition, while also addressing the historical injustices imposed on communities of color.

More than two-thirds of the buildings projected to be in use in New York State in 2050 are already built today. As a result, the *Roadmap* emphasizes the retrofit of existing buildings, as well as new construction. It targets four key sectors, which collectively represent over 50% of building energy use in New York State: 1) single-family residential, 2) low-and mid-rise (up to 20 stories) multifamily residential, 3) low-and mid-rise (up to 20 stories) office buildings, and 4) higher education (focusing on dorms and classrooms). Across these typologies, the *Roadmap* highlights common decarbonization solutions and barriers, top policies with the most potential to effectively achieve carbon reductions, market-based strategies to build demand and reduce the cost of implementation, gaps in technologies and construction/renovation solutions, and goals for current and future research and analysis.

Key outcomes for the *Roadmap* include:

- Establish a common definition and understanding of carbon neutral buildings. (Chapter 2: Defining and Measuring Carbon Neutrality)
- Showcase carbon neutral and low carbon construction practices and technologies that are useable today, the potential for technology cost reductions, and high-priority focus areas for investment in technology research, development, and demonstration. (Chapter 4: Construction Technologies and Building Methodology)
- Defining the challenges of electrification and hard-to-electrify buildings and opportunities for increased demand flexibility to improve grid health. (Chapters 5: Building Electrification and the Grid and 6: Limits to Electrification)
- Discuss the value proposition and business case for carbon neutrality. (Chapter 8: The Economics, Benefits, and Challenges for Carbon Neutral Buildings)
- Recommend policy solutions to achieve the State's emissions reduction goals and reduce costs. (Chapter 9: Policy Solutions)

Policy solutions are especially important to drive New York State's long-term climate goals and are essential to making progress over the next 10 years, a period when these policies must overcome a deeply entrenched status quo that exhibits a preference for continue business as usual in the design, construction, renovation, and operations of buildings and homes.

Roadmap Process and Key Areas of Focus

Development of the *Roadmap* was built on extensive outreach to audiences across New York State, and included local and national experts. In all, 15 formal small group engagements were held with outreach to nearly 1,000 stakeholders. An additional uncounted number of one-on-one and other informal meetings were held to gather information and feedback on solutions and policies. NYSERDA also gave a formal public presentation of the draft findings of the *Roadmap* in June of 2021 and has considered and addressed a number of comments from that presentation in this final version. This *Roadmap* truly belongs to the people of New York. It is both a planning document for the buildings sector to reach the long-term vision of carbon neutrality and an action plan for what is needed over the next several years.

Kathleen Grimm School for Leadership and Sustainability at Sandy Ground. New York, NY. *Photo Courtesy of SOM*

The *Roadmap* development process has elevated some key priorities that will be critical in the coming years for the State in achieving its carbon reduction goals, as summarized further in the subsequent chapters. These include:

- Significantly **improving building envelope** (thermal performance and reducing air infiltration) to reduce heating and cooling loads, as well as **reducing water consumption** to reduce domestic hot water heating need;
- Rapidly **electrifying** thermal loads;
- Equipping buildings with **energy storage and/or the ability to shift energy use** and to interact in real time with the electric grid;
- Satisfying building energy loads with distributed **renewable energy resources** or other emissions-free energy sources from the community or the grid;
- Focusing interventions on **reducing costs** of measures and construction and renovation techniques; and
- **Educating** building owners, occupants, and operators on behaviors that enable carbon neutrality and minimize costs, and providing them with the tools (e.g. advanced metering) to do so.

NYSERDA intends to continue to publish information regarding additional building types, new technical solutions, updated research and up-to-date building and market performance information. With electrification being such an important tactic of the building decarbonization strategy, a companion document that is part of **The Future of Buildings,** the **Building Electrification Roadmap,** is being developed to plan over a 2030-time horizon with near-term actions needed to electrify the State's residential and commercial buildings.

Solutions-Focused for Impact

Establishing a carbon neutral building sector and economy will indeed require a very significant investment by New York State. But it is important to recognize that these investments will support some of the State's most important long-term assets—the electricity grid and our residential and commercial buildings.

Substantial investments will be needed in any circumstance to maintain and modernize these assets over the next three decades. These investments will also create additional societal benefits as part of the clean energy transition, including good paying jobs, increased economic activity, and improved health, comfort, resiliency, productivity, and safety outcomes. The solutions that deliver carbon neutral buildings can also improve economic efficiency and reduce waste in the building construction and operation industries.

Efficient building envelopes and reduced water consumption reduce energy loads, allowing installation of smaller (and less expensive) equipment. Expanded onsite solar and other distributed energy resources will reduce demand on central grid generation. The ability to shift loads, and to facilitate better interactions between the building and the grid, will have a major impact on peak demand, thereby avoiding the cost of—and potential emissions from—substantial infrastructure investments.

The *Roadmap* includes several key principles to bear in mind throughout the State's clean energy transition:

Managing the Cost: There are commercially available solutions in the market today that are expected to have significant cost reduction in the future. The *Roadmap* identifies strategies to reduce these costs through driving economies of scale; focusing on targeted research, development, and demonstration (RD&D); raising awareness (i.e., driving consumer demand); developing the workforce; lowering the cost of financing; and various other tactics. In order to minimize the cost of the transition, State policy and program offerings will need to take advantage of natural events in the lifecycle of buildings, including building sales, renovations, repositioning, refinancing, resident/commercial tenant turnover, tenant fit out, and end-of-life equipment replacement.

Technology Ready and Viable RD&D: The solutions

included in the *Roadmap* rely predominantly on off-the-shelf technology and those with a demonstrable RD&D path. Technologies are prioritized based on market readiness, and potential cost reduction and impact. The *Roadmap* also highlights technology gaps that could be bridged with focused investment.

Policies Drive Scale and Benefits: Decarbonization policies can accelerate adoption as well as catalyze workforce development programs and create new jobs for New Yorkers. The *Roadmap* includes policy recommendations based on analysis that will support speed and scale, and will lead to equitable job creation, resiliency, and greater societal benefits. Expanding existing policies is essential to enable cost reduction and economies of scale for several technologies, especially in existing buildings.

Prioritizing Disadvantaged Communities: The Climate Act requires 35%, and targets 40%, of the benefits from clean energy investment to flow to Disadvantaged Communities. Decarbonization solutions must directly benefit Disadvantaged Communities with investment and better access to jobs in the clean energy workforce. Equity and environmental justice are foundational principles in this *Roadmap,* striving to include frontline communities and advocates in decision-making so that resulting solutions will work to solve those communities' respective needs, relieve economic and racial inequities, and improve health and resilience outcomes while creating jobs.

Focus on Load Flexibility: Grid interactive building solutions will provide cost and carbon mitigation benefits to both owners and grid operations, and are an essential, emerging decarbonization solution. Demand flexibility reduces building peak loads, supports grid decarbonization by reducing the grid impacts of electrification, and can provide cost-effective alternatives to help building owners meet legislative mandates.

Stakeholder Engagement and Feedback: Stakeholder engagement is critical to drive robust and equitable solutions in the varied communities across the State. As noted previously, the *Roadmap* development included a broad-ranging stakeholder engagement process. But the lion's share of outreach is yet to come, as NYSERDA and carbon neutral advocates must undertake a far-reaching consumer awareness campaign across the entire State of New York.

Roadmap Structure

Each of the *Roadmap's* chapters provides key information to support high priority near-term actions that the State and the ecosystem of stakeholders can take to get on the path toward achieving the Climate Act's 2050 goals. In pursuing these actions, the following strategies will be important in achieving success:

- Advancing the development and increasing the utilization of decarbonization technologies for the built environment, with a focus on cost reduction as a major demand driver.

- Enacting programs and policies that analysis shows will encourage and/or require high levels of efficiency, energy recovery, and thermal performance to enable electrification as a primary strategy of reducing emissions.
- Continuing to support market-based financing and insurance mechanisms and products that leverage private sector capital sources eager for clean energy investment opportunities.
- Working closely with utilities and aligning the work of all relevant New York State agencies to support the State's transition to a carbon neutral building stock and economy.
- Incorporating the full cost of GHG emissions into all fuels.
- Identifying non-energy benefits (e.g. health, comfort, resiliency, productivity, safety, etc) and better quantifying their value in the building owner decision-making process.
- Investing in the education and training of the clean energy workforce, building owners, operators, end users, other real estate actors and the general public.

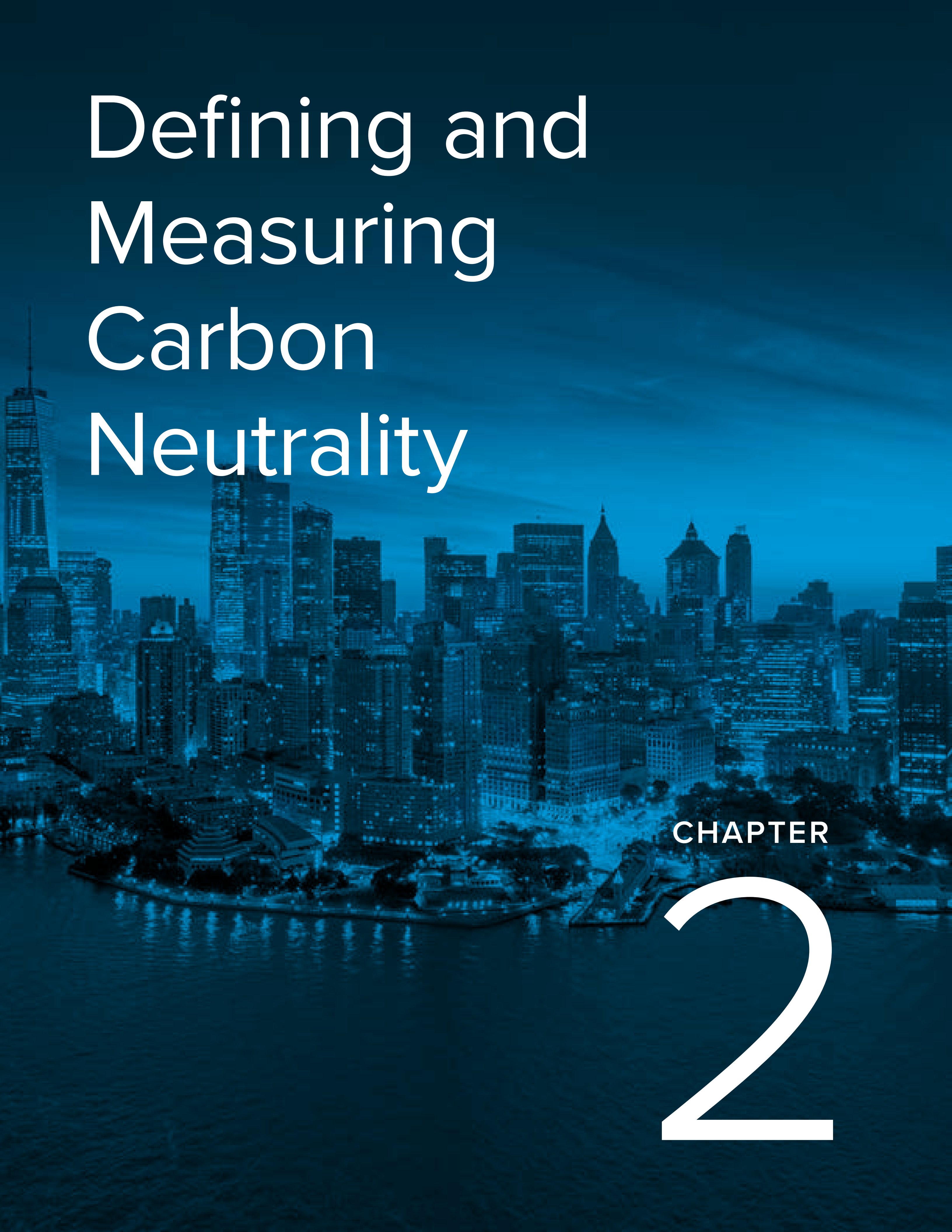
Last Words

Addressing climate change will require an analysis based, no regrets approach and full engagement from all sectors of the economy.

It is a complex undertaking but offers a massive economic and innovation opportunity. The end goal is to achieve very efficient buildings that do not use fossil fuel appliances and equipment, have flexible and grid-responsive capabilities and are supplied by renewable electricity. These actions will impact various market actors across the State, including the people living and working in New York's buildings—those who pay the bills—and the various professionals who design, build, manage, and supply homes and businesses.

We are calling on all of these New Yorkers to join in realizing the goals of the Roadmap and keeping New York on the forefront of the climate fight.

Defining and Measuring Carbon Neutrality



CHAPTER 2

Introduction

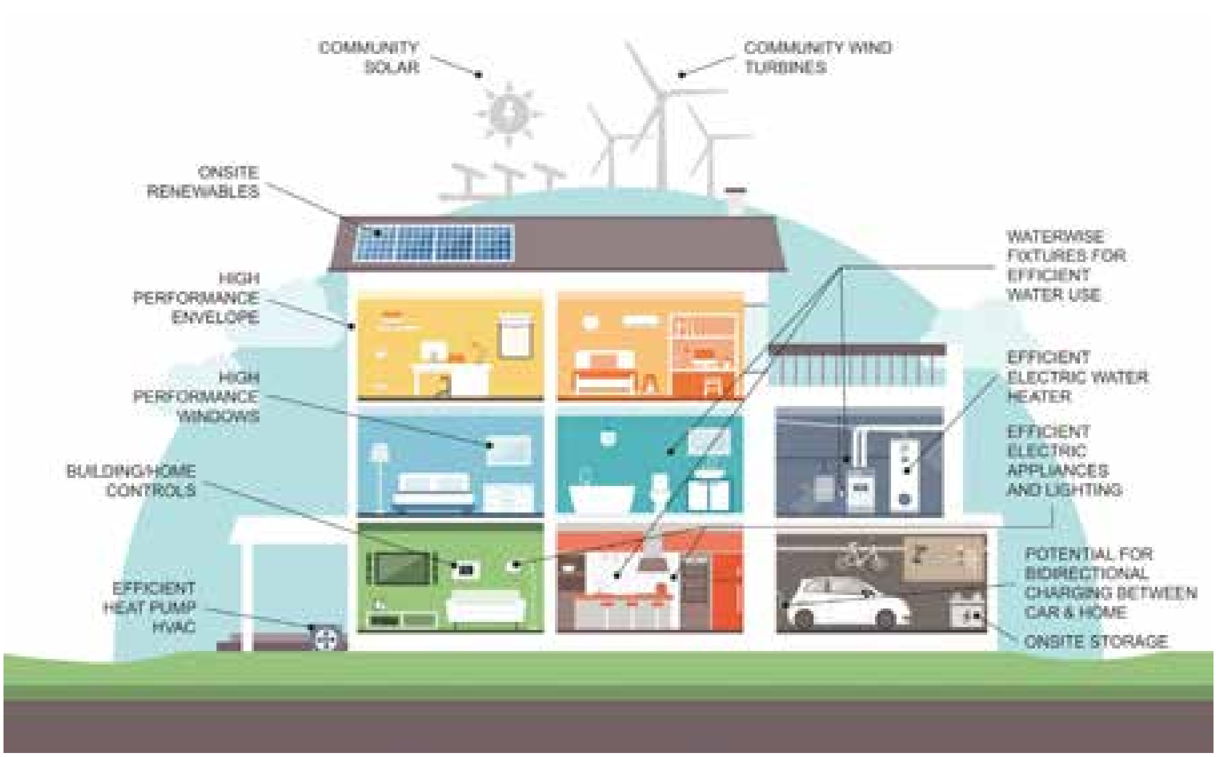
To achieve carbon neutrality in buildings, the attributes of these buildings must first be understood. This chapter provides a definition and discussing metrics for carbon neutral buildings.

In New York State, a carbon neutral building is a **highly energy efficient building whose design, construction, and operations do not contribute to emissions of carbon and other greenhouse gases (GHG)** that cause climate change.

A carbon neutral building has no onsite combustion of fossil fuels for space heating, hot water, cooking, or other appliances. The State will have a decarbonized electrical grid by 2040 so all building use of electricity will be supplied by renewable or other zero emission sources. Most of the lifetime energy needs of buildings designed today will be served 100% by electricity.

Fossil fuel-based onsite emergency electricity generation, and many process and industrial energy uses, are expected to be exempted from the carbon neutral building policy requirements in the short term. Over time, since nearly all carbon neutral buildings will be grid connected, it is expected that they will incorporate load flexibility into their design and operation.

FIGURE 2.1 A CARBON NEUTRAL SINGLE-FAMILY HOME



This carbon neutral home is highly energy efficient (with particular focus on building envelope efficiency and water efficiency to reduce thermal loads) has all-electric appliances and equipment, a high performance envelope, onsite renewable energy generation and battery storage, and is grid integrated.

A carbon neutral building is different and distinct from a (net) zero energy building. According to the U.S. Department of Energy, a Zero Energy Building is an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the onsite renewable exported energy.

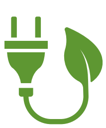
There are two key differences between net zero energy buildings and carbon neutral buildings. First, net zero energy definitions generally allow onsite fossil fuel combustion to be offset by exported renewable energy, but a carbon neutral definition generally excludes buildings with onsite fossil fuel combustion. Second, net zero energy definitions track the energy balance of a building measured in energy or cost units, but the carbon neutral definition establishes that a building's operations do not contribute to additional carbon emissions, and hence is usually measured in units of carbon equivalent.

Unless noted otherwise, this *Roadmap* uses the term carbon neutral building to apply only during the operational or use stages of a building's lifecycle. Other stages of the lifecycle, such as embodied carbon of components and materials or FF&E (furniture, fixtures and equipment), are described in this section but not yet incorporated into the *Roadmap's* carbon neutral definition. To reach true economy-wide carbon neutrality for the building sector, New York will need to address the GHG emissions coming from the building materials supply chain and from the actions taken at a building's end-of-life, and upon equipment replacement and other mid-cycle renovations.

Carbon neutral performance can be considered at the scale of an individual building, or at a campus, community, or portfolio level. The definition of carbon neutrality allows for buildings to achieve such performance in isolation from other buildings, or to do so as part of a larger carbon neutral campus, community, district, or portfolio. Sometimes, multiple buildings share energy assets, such as Con Edison's district steam system in New York City or the district energy systems found at many college campuses. In other situations, the same owner has control over multiple buildings and may face constraints in one building that could be offset by achievements in a different building.

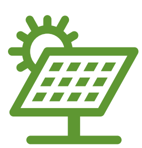
Attributes of a Carbon Neutral Building

These attributes focus upon the building, the impact of that building on the electric grid, and the value of infrastructure as an investment. A carbon neutral building in New York should focus on the following attributes:



Maximizes **energy efficiency,** especially to reduce thermal needs.

No fossil fuel combustion for building services or other appliances onsite.*



Produces or procures **zero-emission electricity** consistent with the Climate Act.

Designed with flexible loads and real-time control strategies and/or storage that can respond to grid conditions.

Features **resiliency measures** that protect buildings and occupants.

Designed and operated with the **health, wellness, comfort and productivity** of occupants as a priority.

* A building may also be able to achieve carbon neutrality using low carbon fuels like renewable natural gas or hydrogen, but those fuels are projected to be in very limited supply and utilized primarily for harder sectors of the economy to electrify. See **Chapter 6: Limits to Electrification** for discussion of the approaches to hard-to-electrify building types and sectors.

Units of Measurement for Carbon Neutrality in Buildings

To translate and measure the foregoing definition of carbon neutral buildings into quantitative carbon neutral goals and targets, the units of measurement or metrics must be considered.

With New York State's growing legislative and administrative designations of carbon neutrality, determining a metric, or suite of metrics, is becoming clearer. Metrics allow different buildings to be compared directly to each other, and to objective thresholds set by the government or by third-party building standards in the market. The choice of metrics for carbon measurement can have a significant impact on how buildings are designed—especially when specific metrics may be required, such as the carbon basis for New York City's Local Law (LL) 97. Based on current legislation and regulatory, policy, and program activities, the *Roadmap* outlines three primary objectives for the metrics to meet:

1. Minimize energy consumption and peak loads.
2. Decarbonize all possible end uses with 100% zero emissions energy supply.
3. Facilitate the real-time ability for a building to shift or offset energy loads to be responsive to grid needs and electricity rate structures, and to utilize the cleanest mix of energy resources.

New York regulatory actions recommend a suite of metrics rather than a standalone GHG metric to provide the accuracy and flexibility needed in the State's shift toward carbon neutral buildings and to send clear market signals, including the following:

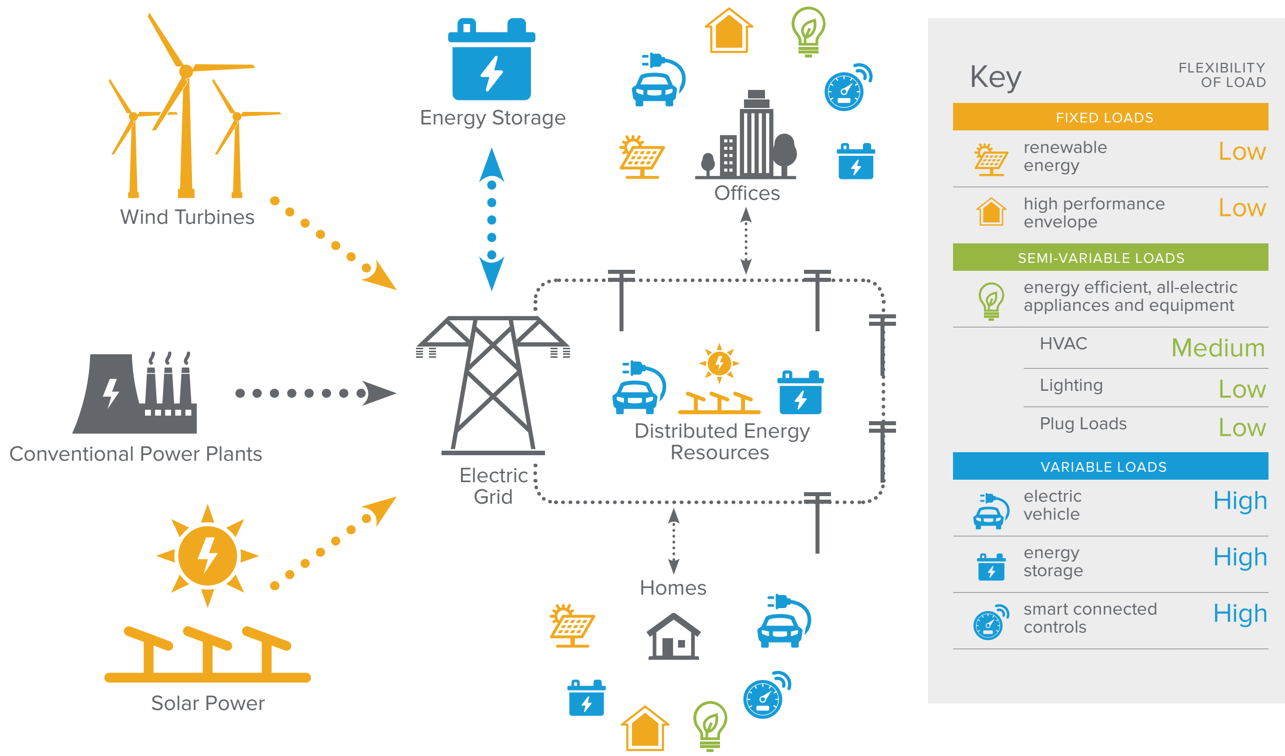
- Site Energy Use Intensity (EUI), expressed as the amount of energy use per area of floor space per year. Site EUI should be adjusted (normalized) for inherently high energy use occupancy types (like data centers or 24/7 operations), as an indicator of efficient use of energy. In combination with a GHG metric for onsite combustion, an EUI metric could focus exclusively on electricity.
- GHG emissions from onsite combustion to indicate direct contributions to climate change.
- The State's progress towards a decarbonized grid by 2040, and towards providing clean hydrogen or other renewable gases for difficult-to-electrify end uses.

Units of Measurement Under Development—Grid Flexibility

A key component of a carbon neutral building is its connection to the grid allowing it to be utilized as a clean and flexible energy resource. The U.S. Department of Energy (DOE) denotes these buildings as Grid-Interactive Efficient Buildings (GEBs), as shown in Figure 2.2 and further described by DOE as: "Grid-Interactive Efficient Buildings have an optimized blend of energy efficiency, energy storage, renewable energy, and load flexibility technologies." GEBs can deliver both time-oriented energy efficiency through passive strategies and load flexibility through active strategies.

The Climate Action Council in consultation with NYSERDA and New York State Department of Environmental Conservation (DEC), New York State Department of State, local municipalities, and international model code organizations will work to formalize these metrics for market adoption.

FIGURE 2.2 A GRID-INTERACTIVE EFFICIENT BUILDING (U.S. DOE)



The Next Steps in Carbon Neutrality: Embodied Carbon and Refrigerant Global Warming Potential (GWP)

As New York makes progress on decarbonizing building operations, it is also working to incorporate a broader range of emission types that occur throughout the lifecycle of a building into the ultimate definition of a carbon neutral building.

Future decarbonization work will include a focus on embodied carbon in building materials, as well as the Global Warming Potential (GWP) of refrigerants, used in heat pumps and other equipment, that may leak and be released. Metrics for these two additional elements will be added to the carbon neutral definition in the next iteration of the *Roadmap*.

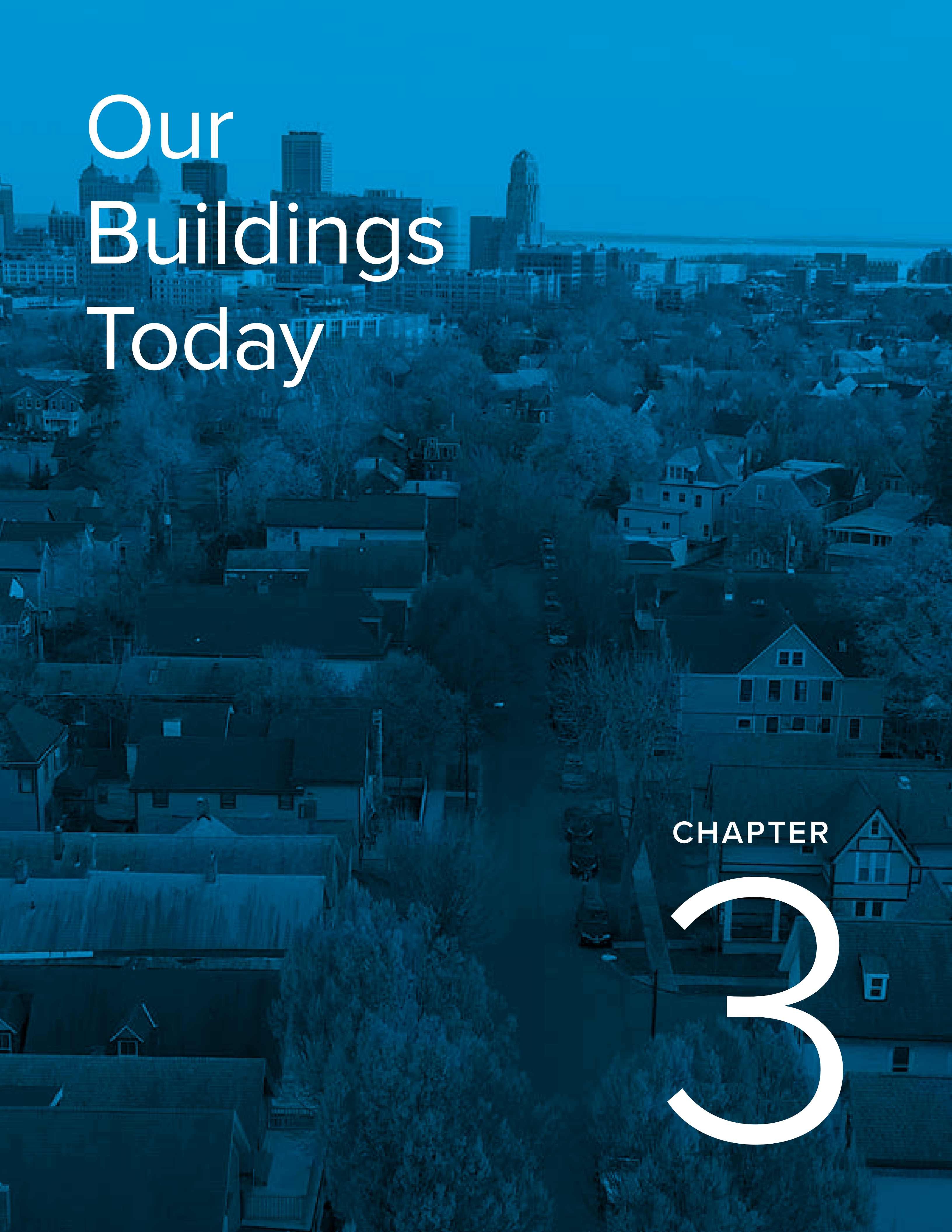
In fact, New York has begun incorporating these aspects of building decarbonization into its clean energy programs offered through NYSERDA and other agencies. The State will pursue additional research and stakeholder outreach to inform how the climate impacts of embodied carbon and refrigerants can be directly compared with operational GHG emissions. The Climate Act mandates that this *Roadmap* and New York policies employ a metric with a 20-year GWP time horizon, which results in greater emphasis on GHGs like methane and refrigerants, relative to reducing emissions of CO_2.

Last Words

New York's policy focus on carbon neutral buildings has become better defined with the passage of the Climate Act, decisions by the Climate Action Council, and administrative directions from Governor Hochul.

The *Roadmap* helps define what carbon neutrality is and provides guidance on details such as units of measurement and metrics to express those. The carbon neutral building definition included in the *Roadmap* is essential to measuring carbon reduction progress at the project level and for policymaking to achieve a carbon neutral building stock by 2050.

Night aerial skyline of Buffalo, New York.



Our Buildings Today

CHAPTER 3

Introduction

Achieving a carbon neutral building stock will require transitioning both new and existing buildings in New York State to emission-free electricity and away from onsite fossil fuel use.

Understanding the current building stock, the systems they use, and the fuel mixes serving them is critical to creating a plan that effectively achieves carbon neutrality, protects the health and well-being of—and disruptions to—occupants, minimizes costs, and ensures equitable access to benefits.

This chapter provides a high-level summary of the building stock in New York State. It outlines variations across the State based on location, construction types and fuel types, and it explains why these have important implications for building decarbonization.

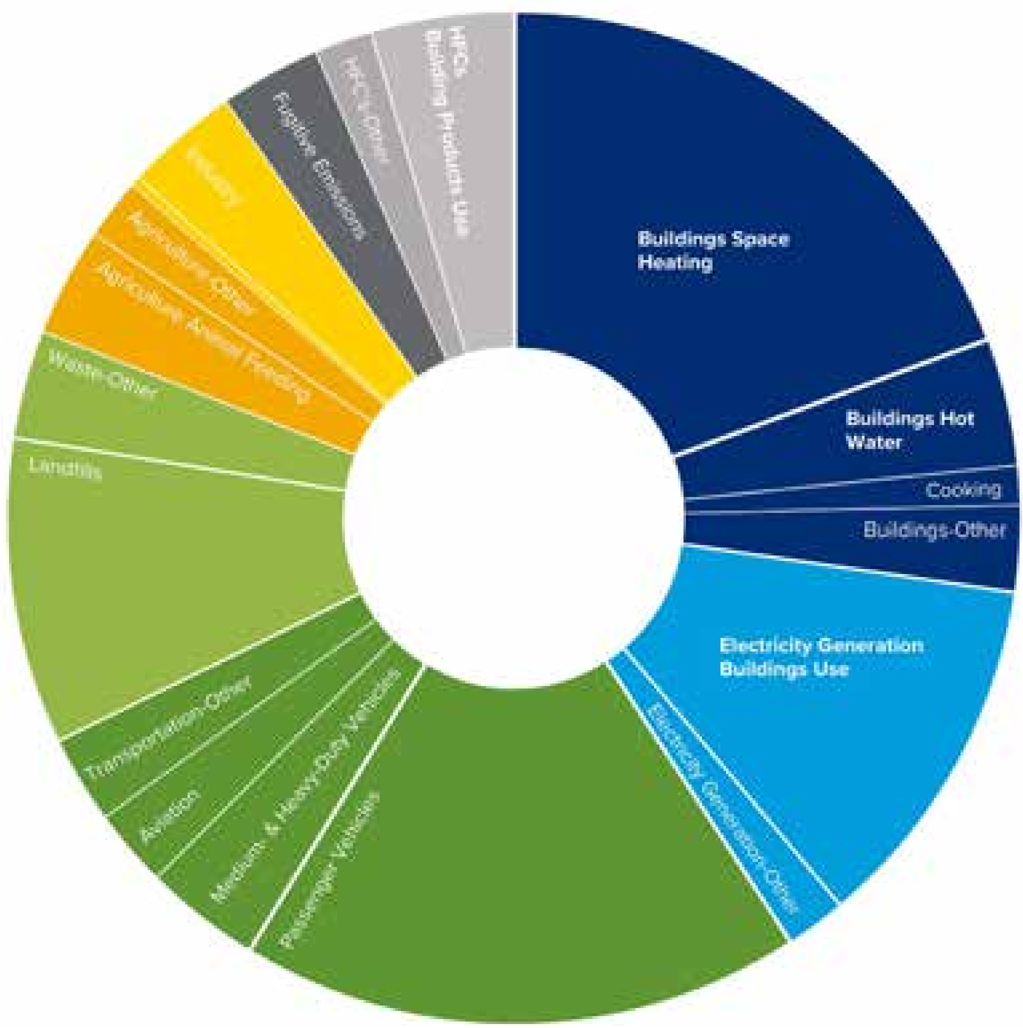
Key characteristics of four priority building types for New York State are summarized including: single-family residential, multifamily residential, office, and higher education buildings.

Framing

With over 20 million residents, New York State is the fourth most populous in the United States.[1] The State covers 54,455 square miles and boasts the third largest economy in the nation. Estimated at

FIGURE 3.1: SOURCES OF GHG EMISSIONS IN NEW YORK STATE

Source: New York Pathways model (Oct. 2021), Reference scenario in 2020 as developed for the New York State Climate Action Council



$1.5 trillion annually,[2] the New York economy ranges from heavy industry to tourism, agriculture to advanced chip manufacturing, and Wall Street to main street business interests.

The buildings sector was the largest source of New York State greenhouse gas emissions in 2019, responsible for 32% of emissions statewide from the combustion of fossil fuels in residential and commercial buildings, emissions from imported fuels, and hydrofluorocarbons (HFCs) released from building equipment and foam insulation. When further accounting for 'indirect' emissions from buildings' use of fossil-generated electricity, building operations are responsible for 43% of annual emissions statewide.[3]

The large scope of New York's economy and the diversity that gives New York great strength, also present challenges to building decarbonization, including:

- The older and taller building stock in New York make it more difficult to scale building retrofits and to transition from gas to renewable electricity as the primary fuel for heating buildings and hot water.
- The large proportion of leased space in New York makes for a more complicated value proposition for owners and tenants when investing in decarbonization.
- New York has a diverse geography spanning multiple climate zones and regional fuel mixes. Significant variations exist among building types and their respective mechanical systems.

Times Square, New York City, New York.

Taking Stock of New York's Buildings

New York State has approximately 6.2 million buildings, and the average age of buildings in New York State is much older than most other states in the nation.

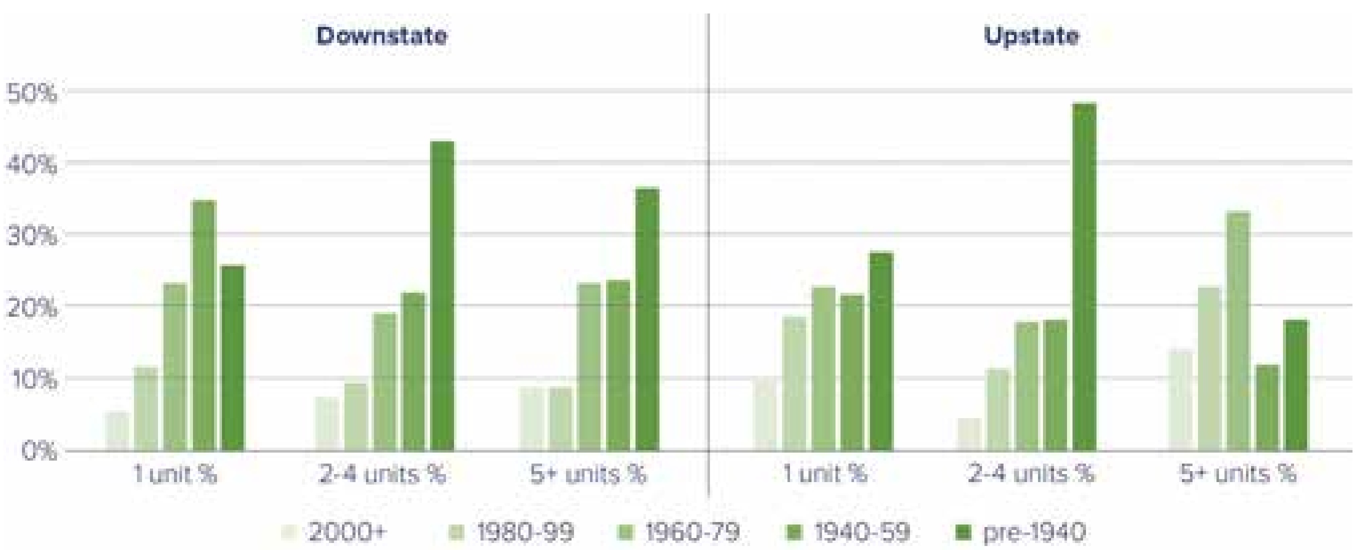
For example, more than 55% of New York City's multifamily building stock was built before 1940, and across the State, more than three quarters of all multifamily buildings were built before 1978, when energy codes were first enacted by Congress.[4]

Nearly half of homes (1-4 units) were built pre-1940, with the majority of all homes and multifamily buildings being built before 1960. In addition, the downstate housing stock tends to be older than upstate. The age of these buildings is important because at least two-thirds of the existing building area that exists today in the United States, will still be in operation in 2040.[5] That percentage is likely understated for New York, where there is expected to be less new construction over the coming decades than in other places in the country.

Decarbonizing an existing building is more challenging and more expensive than achieving carbon neutral performance in new construction. This is because retrofits must consider impacts and disruptions on current occupants, often require costly upgrades to be modernized, such as environmental remediation or electrical system upgrades, and are generally constrained by the building's existing systems configurations. As such, this *Roadmap* emphasizes the need for accelerating the adoption of carbon neutral new construction and adaptive reuse projects to future-proof and prevent the need for more costly upgrades in coming years.

Major events in a building's lifecycle are opportunities to reduce carbon emissions and manage costs. Although major building retrofits generally happen only every 20-30+ years, they are seen as a primary opportunity for improvements, as are scheduled renovations and system replacements. In addition, upgrades scheduled at point-of-sale and tenant turnover are common intervention points that can be

FIGURE 3.2: NEW YORK'S HOUSING STOCK BY REGION, UNIT TYPE, AND AGE



Source: NYSERDA Housing Stock Characterization 2022 leveraged to minimize occupant disruption for building upgrades. However, this will require a widespread understanding among critical market actors of the value proposition and the technical approach for carbon neutral retrofits.

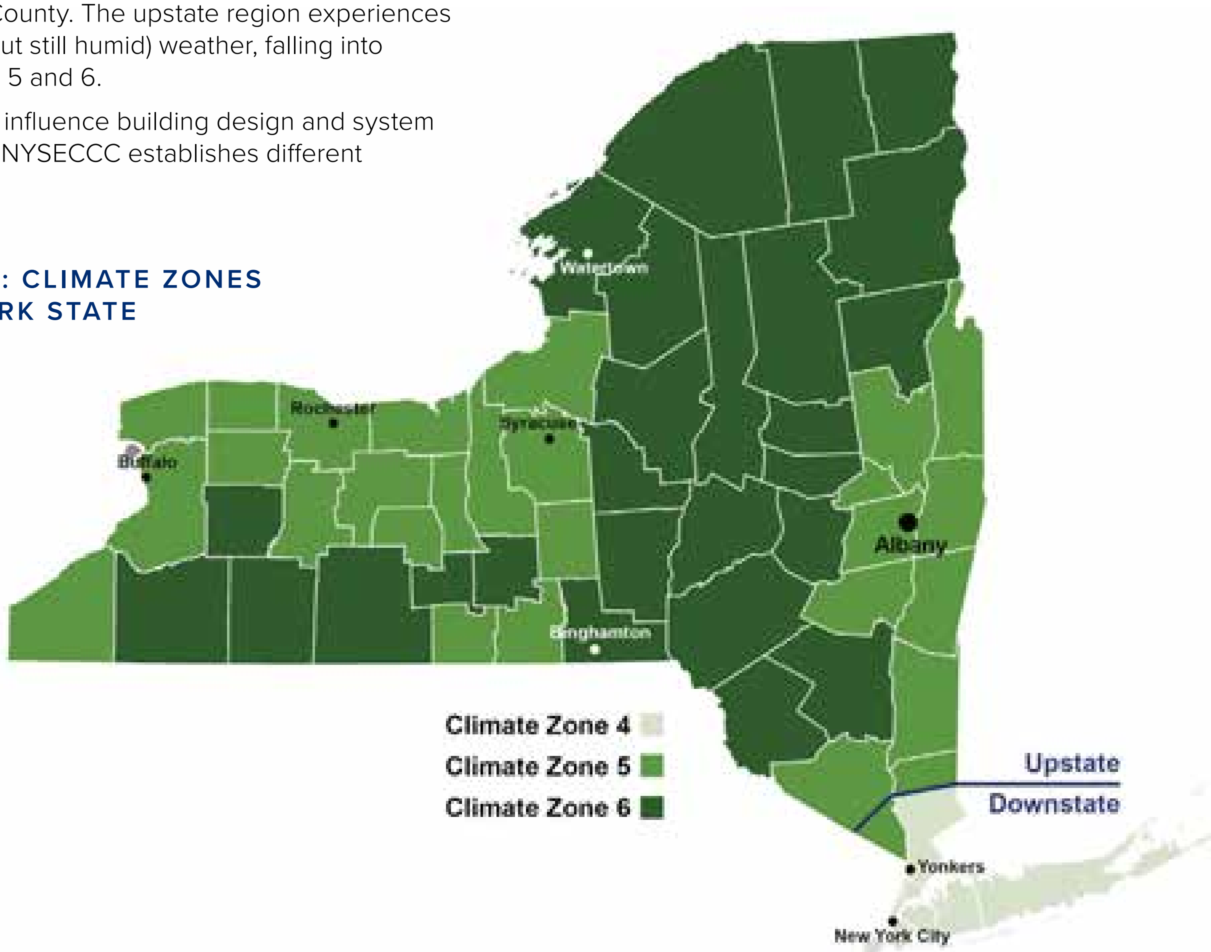
Retrofits of tall buildings, especially in New York City, face their own unique obstacles. These can have greater technical challenges, and owners are unlikely to vacate their buildings for gut-rehabilitation projects. Many leased buildings have an additional barrier that must be overcome including the "split incentive," which relates to the disconnect between landlords and tenants as to who pays for and who benefits from energy and carbon-saving retrofits.

Climate region, geography, and land value variations across the State present additional challenges to decarbonizing buildings. For example, New York experiences cold/humid and mixed/humid climate conditions that warrant different technical solutions. According to the New York State Energy Conservation Construction Code (NYSECCC), New York has three climate zones, shown in Figure 3.3. Climate Zone 4 represents the mixed humid zone and includes downstate regions of New York City, Long Island, and Westchester County. The upstate region experiences even colder (but still humid) weather, falling into Climate Zones 5 and 6.

Climate zones influence building design and system requirements. NYSECCC establishes different requirements based on climate zones and occupancy types. Building retrofits will need to strike a balance between investments in space conditioning and building envelope upgrades, and approaches will be different across the State. More specific discussions of technology applications can be found in Chapter 4: Construction Technologies & Building Methods.

Building and land value across the State also has implications for approaches to building decarbonization. Where property values are lower, ancillary costs of efficiency and electrification, such as building envelope and electrical upgrades as well as environmental remediation costs, present a challenge. For example, an $85,000 home in Syracuse will have a harder time justifying retrofit costs than a $675,000 home in Yonkers. Approaches to cost reduction and measure packages to achieve carbon neutral performance are discussed in Chapter 8: The Economics, Benefits, and Challenges for Carbon Neutral Buildings.

FIGURE 3.3: CLIMATE ZONES IN NEW YORK STATE



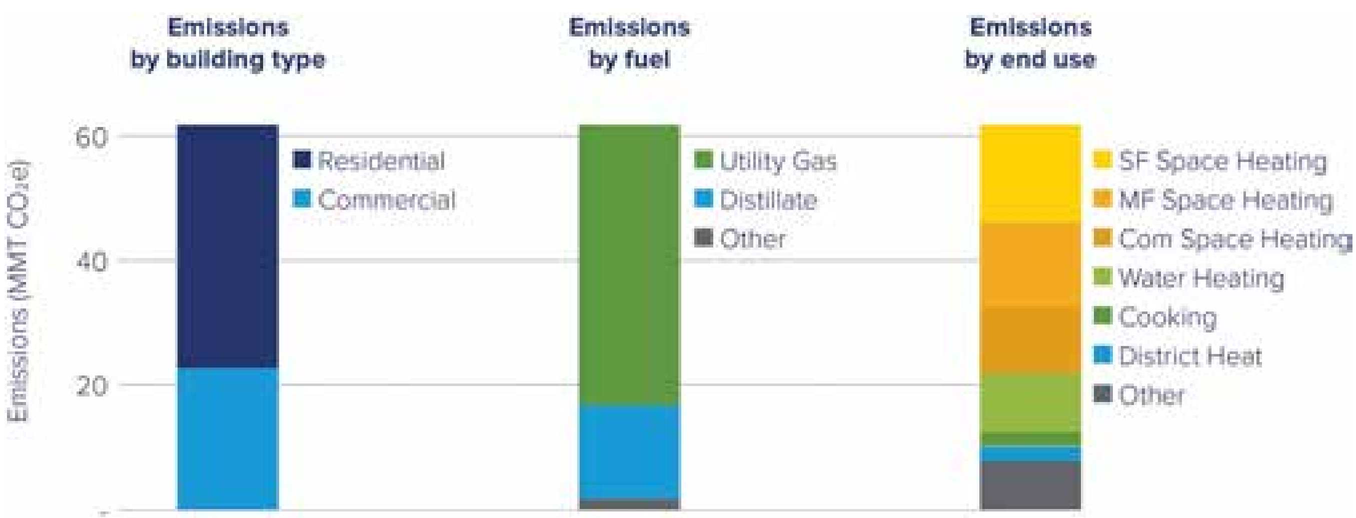
Emissions by Primary Sector and Energy Use in Priority Building Types

Emissions from onsite combustion of fossil fuels in residential and commercial buildings can be further characterized to support approaches outlined in the *Roadmap* as seen in Figure 3.4.

For example, residential buildings contribute more emissions from onsite fuel combustion than commercial, and gas combustion is more prevalent (and impactful) than other fuel sources. When looking at end uses, space heating in single-family, multifamily, and commercial buildings comprise more than two-thirds of emissions from onsite combustion, with the remainder from water heating, cooking, district heating, and other sources.

Over the next two decades, carbon emissions from electricity generation in New York will be reduced due in large part to the State's Clean Energy Standard, which requires utilities to deliver 70% of energy generation from renewable sources by 2030. The Climate Act requires all central generation to be emission free by 2040. At the same time, the push to electrify buildings, along with significant decreases in the cost of lithium-ion batteries and State policies encouraging electric vehicle adoption will substantially increase electricity consumption from transportation and the built environment over this time period. The addition of these new loads on the electrical grid requires a continued emphasis on building energy efficiency and peak demand management to reduce overall load growth and societal costs in the transition away from fossil fuels.

FIGURE 3.4: RESIDENTIAL AND COMMERCIAL BUILDING EMISSIONS FROM ONSITE COMBUSTION



Characteristics of Priority Building Types

New York State has more than six million buildings. This Roadmap focuses on four priority building types:

1. **Single-family residential**
2. **Multifamily residential**
3. **Office**
4. **Higher education**

Engine 16 Redevelopment, New York City
Credit: Baxt Ingui Architects

These four typologies represent the large majority of New York's building stock (by number of buildings) and collectively account for more than 50% of the State's building sector energy use. There is a high level of diversity across buildings, even within the same building typology, which will require different solution packages. Approaches will vary further given diversity in climate, local installation costs, tenant split incentives, and other factors.

Residential: Single and Multifamily

New York State has more than 7.8 million residential units comprised of 4.3 million households occupying 4.1 million single-family (1-4 unit) buildings,[6] nearly 3 million residential units occupying 1.6 million multifamily (5+ unit) buildings, and approximately 560,000 residential units in other condo or co-op multifamily configurations.[7] Most households in New York use more than one fuel, such as electricity, natural gas, and propane to meet their home energy needs. Space heating and cooling, hot water heating, cooking, and electric vehicle integration are of special concern to decarbonization in residential buildings.

Residential buildings in New York State have a wide variety of building typologies and ownership structures. Buildings range from single-story to high-rise. Rental housing suffers from a split incentive barrier, and co-op and condominium ownership and decision-making structures also present challenges for efficiency and decarbonization.

The single-family sector has regular rehabilitation schedules that typically revolve around home sales and equipment replacement. The average homeowner stays in their home 10 years, and typical heating equipment life is approximately 15-25 years. These events in the building's lifecycle identify clear decarbonization opportunities in the single-family residential market.

While homes may have a technically and economically viable path to achieve carbon neutral performance for new construction and gut rehabs, the majority of retrofit projects occur for a single system at a time and generally at the end of the equipment's useful life, often as an emergency replacement at point of failure. Homeowners may not value energy and carbon reduction as much as other priorities, especially when quick decisions need to be made. Moreover, the single-family home sector is very fragmented, creating further challenges for this market. A bright spot for the carbon neutral home market however is that many families, particularly those whose family members have allergies or asthma, place a high value on improved indoor environmental quality which is a co-benefit of carbon neutral performance.

Fossil Fuel Use in the Residential Market

Two of the largest sources of direct emissions from all buildings statewide are space heating and domestic hot water heating in single-family and multi-family buildings.[8]

Millions of single-family and multifamily homes in New York rely on gas for space heating, hot water heating, and cooking. In single-family homes, gas furnaces and boilers dominate the market, but in many parts of the State, delivered fuels are dominant due to a lack of gas infrastructure. Delivered fuels present a unique challenge such as fuel oil systems that are typically not ducted, making upgrades more costly. A study published in 2019[9] suggests that just under half of the residential heating systems sold between 2013-2017 were gas furnaces and about one-third were gas boilers. In new residential construction, central forced-air furnaces comprise the bulk of the new construction market.

Hot water heating in residential buildings is also dominated by gas and fuel oil, although it varies by location, as shown in Figure 3.5.[10] In the downstate single-family market of Climate Zone 4, water is heated overwhelmingly by gas and fuel oil. Upstate in Climate Zone 5, the majority of water heating is powered by gas and fuel oil, with some electric water heating in single-family homes. Climate Zone 6 already has broader adoption of electric water heaters, although most are less efficient electric-resistance models.

Multifamily buildings tend to have more centralized heating systems that use gas or fuel oil. A recent report from Urban Green Council[11] estimated that a majority of residential buildings in New York City are heated by fossil fuels, often with a steam distribution system. The research highlighted the opportunities associated with retrofitting steam distribution systems to hydronic systems in New York City, especially buildings larger than 5,000 square feet. This migration of buildings from steam to hydronic can increase occupant comfort and reduce carbon emissions today, even though full decarbonization of the building will happen in the next retrofit cycle.

Governor Hochul Announces Plan to Achieve 2 Million Climate-Friendly Homes by 2030

Governor Hochul's plan to achieve a minimum of 1 million electrified homes and up to 1 million electrification-ready homes (with at least 800,000 of those being located in Disadvantaged Communities) is anchored by a series of legislative and policy actions. These include:

- Requiring zero onsite greenhouse gas emissions for new construction no later than 2027,
- Providing the training programs necessary to ensure that the State has a skilled workforce to deliver these services,
- Establishing a dedicated green electrification fund, and
- Electrifying low-income homes through the housing capital plan, among others.

Electrification of space and hot water heating loads in residential buildings will have a major impact on the electric grid. This will be compounded by the need for electric vehicle charging in residential buildings. These potential grid impacts mean that residential buildings will continue to be ideal candidates for maximizing efficiency and implementing load management strategies, like onsite battery storage capability and heat pump water heaters with thermal storage to help manage peak demand times on the grid. With these strategies in place, the residential sector will play an important role in transitioning away from gas to reduce statewide carbon emissions. Another key place that natural gas is burned in the home is for kitchen use. This is critical because indoor air pollution from fossil fuel combustion is a threat to human health, especially when not properly ventilated. This can exacerbate respiratory conditions like asthma, which affects at least 1.4 million people in New York.[12]

Most homes in the Northeast census region (including New York) have gas cooking appliances.[13] The transition away from gas cooking will require broad market acceptance, which will face its own barriers. Transitioning to new technologies like induction cooktops goes against current consumer preferences.

Commercial Offices

Offices make up a large share of commercial space in New York.[14] The commercial office sector has a regular cycle of retrofits and tenant improvements, which are likely to happen at the time of sale, lease, or refinance. The decarbonization challenges in office spaces are different than residential buildings, in that there is a significantly reduced amount of fossil fuel consumption in most offices. Domestic hot water usage is minimal in most cases, and offices often require cooling through most of the year due to the heat generated by people, computers, and indoor lighting.

There are other important distinctions in the office building type. One is ownership structure. Owners have little control over tenant energy use, which typically represents 40-60% of total office building energy use. The office market in New York State also varies by region. The downstate area of New York City and Westchester County have few owner-occupied buildings, but this is reversed in the upstate region, where more businesses often operate in their owned buildings.[15]

The energy-use profile for office buildings is very different from residential buildings. Typically, about half of the energy use in office buildings located in the Northeast is for space heating, ventilation, and air conditioning.[16] Gas furnaces and boilers are prevalent for heating in New York's commercial buildings.[17] Chapter 6: Limits to Electrification outlines certain buildings that will be difficult to decarbonize, including retrofits of very tall buildings and laboratories. These span both residential and commercial building typologies.

Higher Education

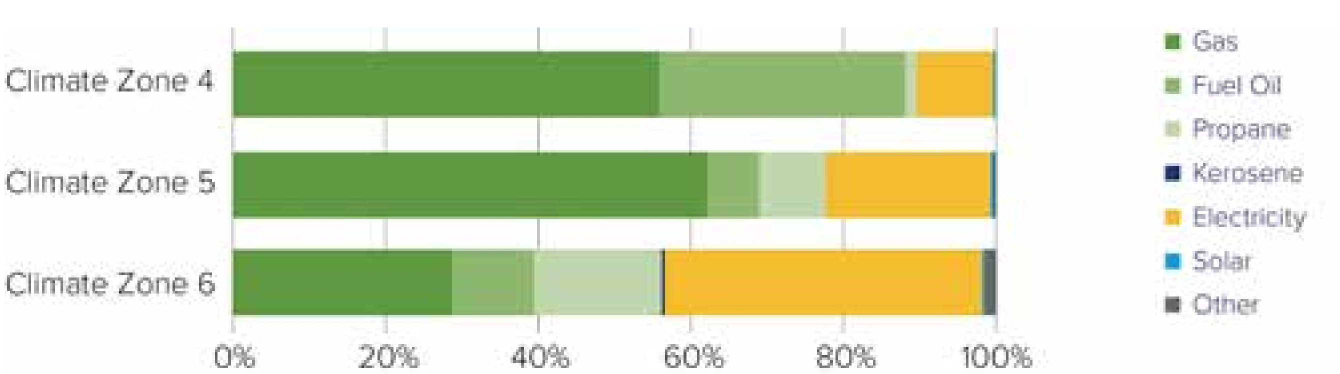
New York State is known for exemplary leadership in high quality, postsecondary education. In the 2020-2021 academic year,[18] New York State public and private higher education institutions had almost 794,701 full time and 340,884 part time students in degree-credit enrollments.

The State has a higher proportion of private college attendance than most states, with 195 independent and proprietary college campuses accounting for 44.5% of statewide full-time equivalent (FTE) enrollment. Buildings owned by colleges and universities also tend to be older than many other buildings in the State.[19]

New York has two major public educational institutions, the State University of New York (SUNY)[20] and the City University of New York (CUNY).[21] In 2022, SUNY operated or leased more than 2,827 educational buildings, hospitals, residence halls, and community colleges, representing over 110 million square feet of space. CUNY has 29 million square feet in 300 buildings across 25 campuses.

Many of these public buildings are old and in need of updates. Primary objectives in capital infrastructure planning at universities include extending the life of educational facilities, providing life and safety enhancements to meet code, and improving operational efficiency, including energy conservation. SUNY's buildings have an average age of 48 years, while CUNY's average building age is more than 50 years old. Importantly for decarbonization efforts, 30% of the immediate asset repair needs in the SUNY system are HVAC upgrades, estimated to cost over $1.3 billion. HVAC needs represent 26% of CUNY's lifecycle infrastructure renewal need, estimated at a cost of over $1.5 billion.

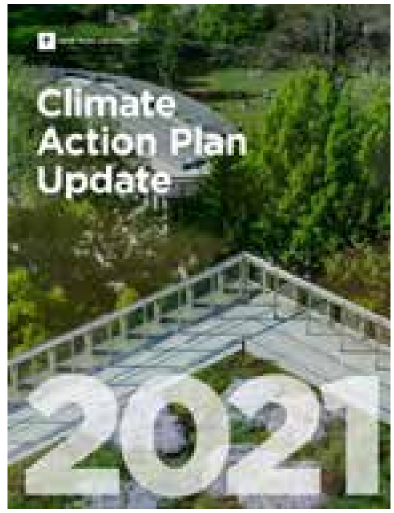
FIGURE 3.5: WATER HEATING FUEL SOURCES IN SINGLE-FAMILY HOMES IN NEW YORK STATE



University campuses face a large challenge of addressing the central plants that run on fossil fuels and are so prevalent in these institutions. Central energy plants produce heating, cooling, and/or electrical power for multiple buildings. They achieve efficiencies that cannot be obtained in localized systems because of the energy sources used, the types of equipment utilized, and the savings in operation and maintenance through centralization and scale of equipment.

Many central energy plants achieve savings by using energy, which would ordinarily be wasted in the generation of electric power, to heat and cool buildings (also known as cogeneration). Some central plants also incorporate concepts such as thermal energy storage (TES) to store heating and/or cooling from lower-cost energy sources or time periods. However, many college central heating plants use gas or other fossil fuels to create and distribute steam to the buildings on the system. This is one of the most challenging system types to decarbonize.

Figure 3.6 shows a schematic of a centralized energy system at a college or university. In the case of campuses, the centralized system allows for trading efficiency targets among buildings. In contrast to central steam systems, the geothermal district loop system depicted is a very promising community-scale decarbonization solution.

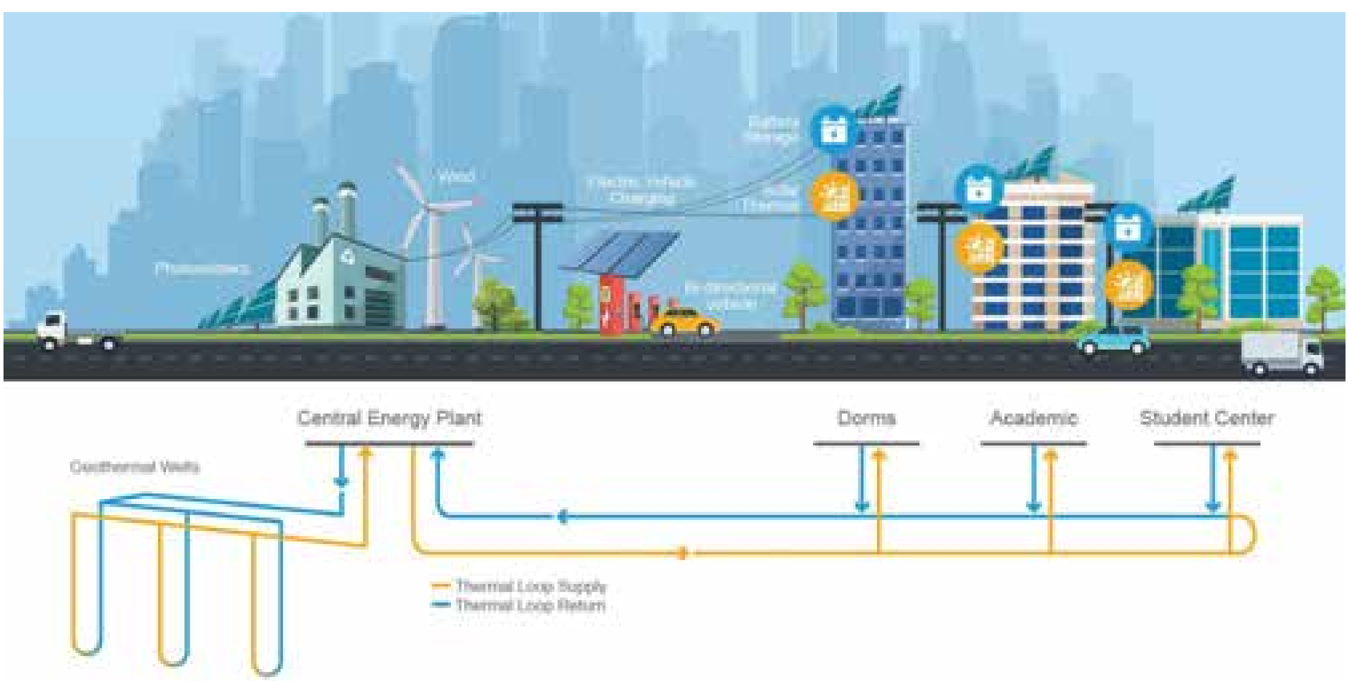


Carbon Neutral Community for Economic Development: NYU Campus

New York University will perform a study of contiguous university-owned properties to determine a Roadmap to Carbon Neutral Performance for the campus. The study will evaluate strategies to reduce energy loads, leverage heat recovery, identify sticking points for high-intensity process loads and limited roof areas, transform existing high temperature hot water loop infrastructure, reimagine the central water heating plant, and layer in renewables.

NYU Climate Action Plan Update 2021

FIGURE 3.6: SCHEMATIC OF A CENTRALIZED ENERGY SYSTEM



Today's Carbon Neutral, Zero Net Energy & All-Electric Buildings

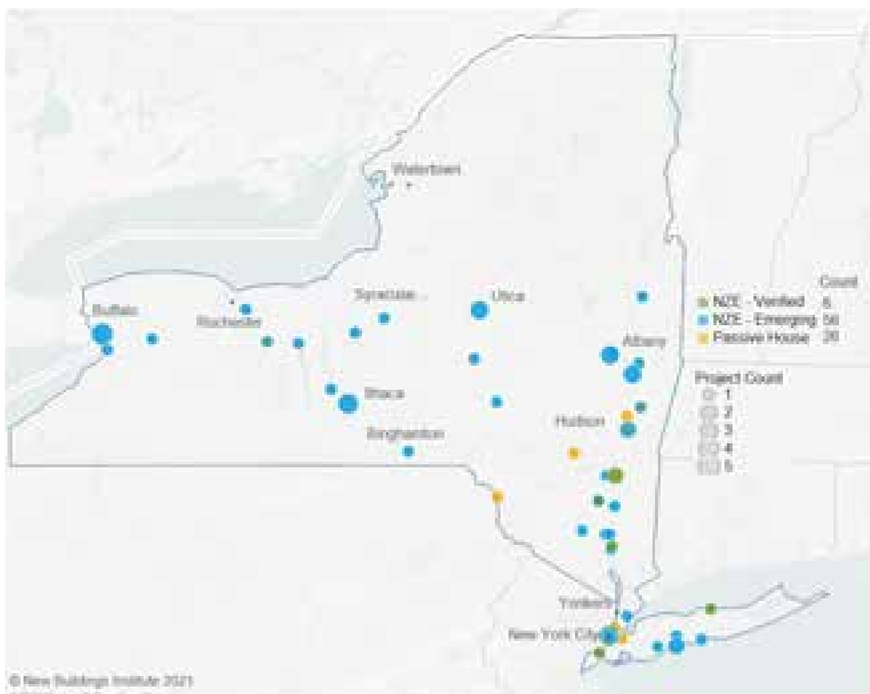
New York is leading the Northeast in high performance, net zero energy, and Passive House buildings. Projects are found across the State, from Buffalo to the Adirondacks, through the Hudson Valley into New York City and Long Island.

As part of the State's effort to achieve a carbon-neutral economy, NYSERDA initiated the Buildings of Excellence (BOE) Competition in early 2019 to recognize and reward the design, construction, and operation of very low or zero-carbon emitting multifamily buildings. The Buildings of Excellence competition has played an important role in catalyzing the growth of high performance buildings within the multifamily sector.

NYSERDA has served 238 single-family homes and over 8,600 multifamily households that have either demonstrated net zero energy performance, are certified Passive House, or are capable of net zero energy performance with sufficient renewables.

The great majority of net zero energy buildings are all-electric, with no onsite gas combustion. Most net zero energy buildings produce their own renewable energy through onsite distributed energy resources such as solar photovoltaics. But certain typologies like tall and high-intensity buildings—hospitals or those in dense urban areas, or where site conditions limit solar access—may also leverage offsite clean generation resources to achieve net zero performance.

FIGURE 3.7: LOCATION OF COMMERCIAL AND MULTIFAMILY NET ZERO ENERGY AND PASSIVE HOUSE BUILDINGS



Buildings of Excellence Round Three Competition

NYSERDA's Buildings of Excellence (BOE) Competition aims to accelerate the design, development, construction, and operation of carbon neutral multifamily buildings. It does so by recognizing new construction and adaptive reuse projects that will achieve carbon neutral performance while being beautiful and functional, providing healthy, safe, comfortable, and resilient living spaces for their occupants, and that will be profitable for the project's developers and owners.

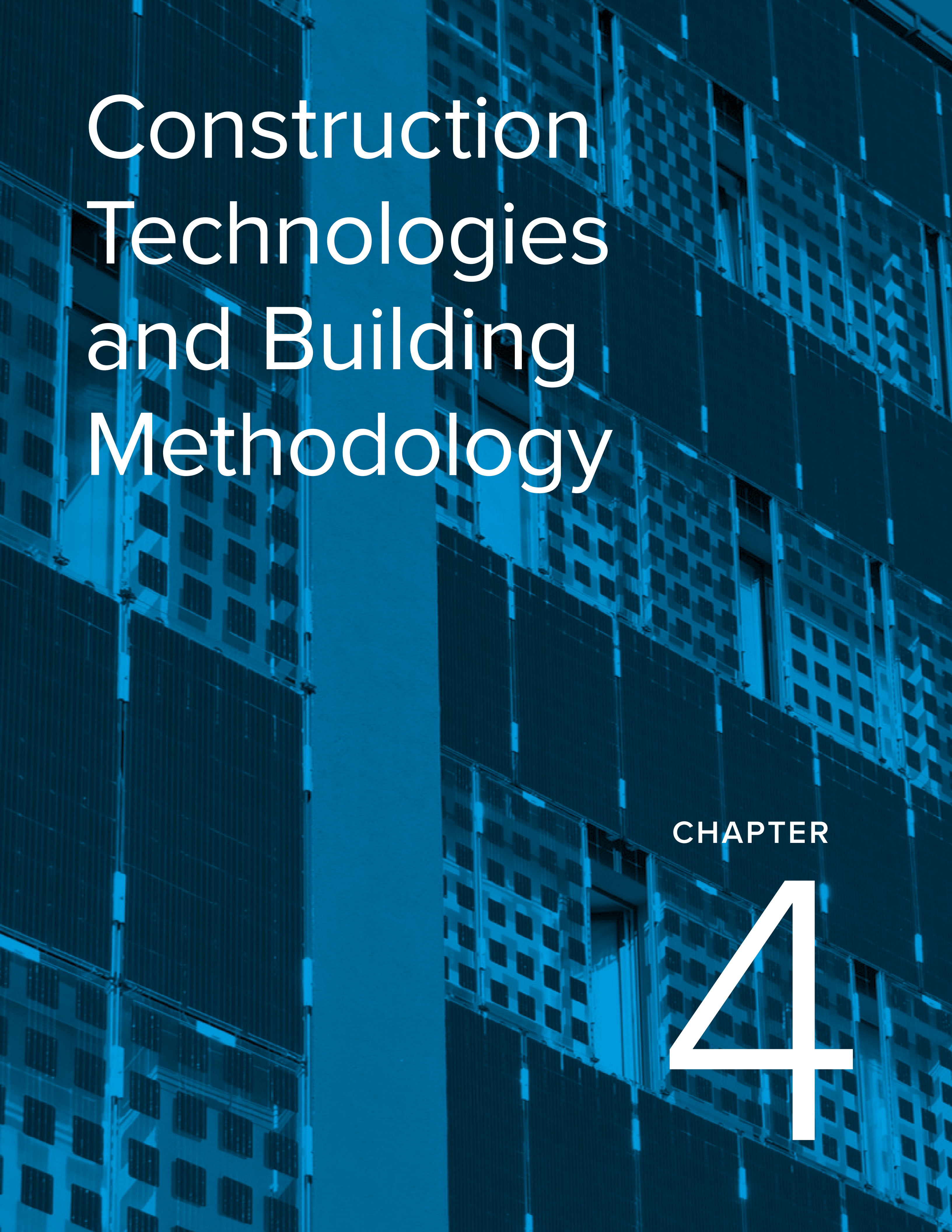
Since the program began in 2019, NYSERDA has selected 42 awardees in the first two rounds of the program, representing a diversity of building typologies and locations throughout the State. All of the BOE awarded projects will have all-electric HVAC, and the 14 Round-2 projects will also provide all-electric domestic hot water. Seventy-nine percent of projects from Round 1 and Round 2 represented low- and moderate-income units, demonstrating that the industry can deliver carbon neutral buildings to Disadvantaged Communities across the State. Governor Hochul announced Round 3 in April of 2022.

St Marks Passive House. *Photo Credit: Cycle Architecture LLC and BQE*

Last Words

New York is the fourth most populous state in the United States and represents a large and diverse building stock.

The *Roadmap* prioritized the four building types: single-family residential, multifamily residential, offices, and higher education buildings for analysis as they have the potential for the greatest emissions reductions. Buildings are the largest contributors of greenhouse gas emissions in New York (32%) so it will take a concerted effort to address the emissions in New York State's building stock but addressing these four building types first has the potential to reduce energy use in the State by half. New York has already begun this transition and proved feasibility with the large number of net zero, passive house, and carbon neutral homes and commercial buildings already in existence across the diverse state climates, densities, and regions.



Construction Technologies and Building Methodology

CHAPTER

4

Introduction

Based on studies and analysis, this Roadmap is recommending advancing a number of priority technologies and approaches to building efficiency and decarbonization.

The market-readiness and opportunity for these products and methods are described in this chapter as well as activities that will be needed in the next decade for continued progress. These technologies, as summarized in Figure 4.1, were selected for their high potential energy savings, cost effectiveness, and future cost reduction potential. There are several decarbonization technologies recommended but not discussed here since they have already achieved significant market penetration, such as LED lighting, high-efficiency heating, ventilation and air conditioning equipment, low-flow water fixtures, and ENERGY STAR appliances.

FIGURE 4.1: SUMMARY OF PRIORITIZED TECHNOLOGIES TO ACHIEVE CARBON NEUTRAL BUILDINGS

Load Reduction Strategies

- Air Sealing
- High Performance Insulation
- High Performance Fenestration
- Prefabricated Panelized Solutions
- Ventilation and Air-Side Solutions

Electrification

- Heat Pumps
- Variable Refrigerant Flow Systems
- Heat Pump Water Heaters
- Integrated Mechanical Systems
- Efficient Electric Cooking

Advanced Controls and Grid Interactivity

- Software: Smart Controls
- Hardware: Smart Devices and Sensors
- Grid Signals and Interoperability

Distributed Energy Resources

- Battery Energy Storage Systems
- Photovoltaic Systems
- Thermal Energy Storage

District and Community Scale Solutions

- Hydronic Thermal Networks
- District Heat Pump Plants
- Decarbonization of Remaining Steam

Does not include technologies that have already gained market penetration (e.g. LED lighting, ENERGY STAR appliances)

Envelope & Ventilation

“Build tight and ventilate right” is a core principle of high performance buildings and critical to achieving carbon neutral buildings of all types.

The building envelope (roof, walls, windows, doors, and floor) controls the transfer of air, heat, water, vapor, fire, smoke, dust, sound, and light between the inside and outside of the building. Typically, a residential building’s envelope has roughly a 30-40% impact on the building’s space conditioning energy consumption (heating & cooling).[22] Key building envelope decarbonization technologies include air sealing, high performance insulation, high performance fenestration, energy recovery and leveraging prefabricated panelized solutions, as detailed along with other priority technologies in the following Table 4.1.

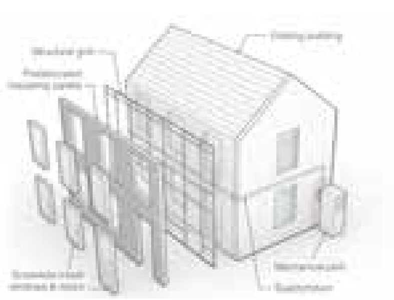
TABLE 4.1: SUMMARY OF KEY BUILDING ENVELOPE AND VENTILATION TECHNOLOGIES

Technology	Priority	Maturity
AIR SEALING Air sealing is a low-cost, high-value strategy for all building types. It reduces unintended air leakage in and out of a building, improving comfort and reducing energy use. Air leakage typically drives about 20% of commercial building heating and cooling and 25-40% of home heating and cooling energy use.[23] Regardless of the insulation type or system being used, designers and building owners should never rely entirely on insulation alone to do the job of air sealing. Air sealing should be coupled with proper ventilation strategies to ensure good indoor air quality. Blower door testing should be done on new and existing single-family homes and low-rise buildings to help target leakage areas. Smoke testing can help identify the source of air leakage. A 2005 LBNL review cites studies showing an energy loss of 30-40% when ductwork is installed in unconditioned spaces. Other modeling and field testing have demonstrated that leakage through the average duct system was 37% greater than infiltration through the building envelope.[24] Buildings with leaky ductwork and air handlers located in unconditioned spaces are vulnerable to increased infiltration rates. Duct leakage can also prevent effective distribution of the supply air, substantially impacting the actual ventilation rate found in the average building.	**High**	**Mature**
HIGH PERFORMANCE INSULATION The best practice for high performance insulation is a continuous insulation layer to avoid thermal bridging. For retrofits, exterior insulation and finish systems are often used. Materials such as exterior rigid insulation, insulated sheathing, Structurally Insulated Panels (SIPs) and Insulated Concrete Forms (ICFs) are especially beneficial in new construction applications. Different forms of insulation can be used alone or in combination on walls, roofs and slabs to significantly reduce energy. Thermal bridging, where construction materials transfer heat between the conditioned interior space and exterior should be avoided. Where possible, spray foams using high global warming potential agents should also be avoided. Phase change materials (see more in Table 4.4) can be used to improve the thermal performance of building envelopes. Target insulation levels at or above code and Passive House levels wherever possible.	**High** single-family residential **Medium/ high** multifamily, commercial	**Mature** Market adoption highly influenced by codes, standards

Continued >

TABLE 4.1: SUMMARY OF KEY BUILDING ENVELOPE AND VENTILATION TECHNOLOGIES

Technology	Priority	Maturity
HIGH PERFORMANCE FENESTRATIONS (WINDOWS AND DOORS) Windows and doors are significantly less efficient in managing the thermal gradient between interior and exterior spaces than walls and are a significant source of air infiltration, even when closed. Windows transmit solar radiation, adding welcome heat in the winter and, unless appropriately shaded, increasing cooling load in the summer. Wood, fiberglass, composite, and other non-metal frame materials will help to decrease the overall conductivity. Strategies include double pane windows with layers of film, triple-pane windows, and dynamic windows that can modify thermal and visible light transmission. Thin triple-pane windows (which fit into a double-pane form factor) are commercially available for both new construction and retrofit applications. There have been advancements in dynamic glazing and a variety of coatings including low-e coatings and wavelength-selective coatings. Other innovations include vacuum-insulated windows and super insulating "aerogel" cores.	**High** single-family residential **Medium/ high** multifamily, commercial	**Mature**
PREFABRICATED PANELIZED RETROFIT SOLUTIONS Prefabricated panelized solutions are integrated wall and roof assemblies, often with pre-installed windows/doors, manufactured offsite in controlled environments that provide improved and consistent insulation, air sealing and window/door performance (e.g. RetrofitNY and EnergieSprong). There are several manufacturers that create prefabricated assemblies that are primarily for new construction today. However, there are a few—and more coming—solutions targeted at existing, low-rise buildings in New York.	**High**	**Early** quickly growing for new construction, emerging solutions for existing buildings
VENTILATION AND AIR-SIDE SOLUTIONS Reduce energy for heating, cooling, and dehumidification of ventilation by exchanging heat from exhaust air to (or from) incoming air using: Heat/Energy Recovery Ventilators (HRV/ERV), heat/enthalpy wheels and other air handler heat exchangers, or even compressor-driven cooling/heating of exhaust air. As building codes require higher levels of airtightness, increased focus on balanced ventilation will be essential for maintaining high indoor air quality. Other solutions which optimize air-side system operations: converting to dedicated outdoor air systems (DOAS), decoupling heating/cooling from fresh air; performance-based ventilation design; sorbent air cleaning technology; and general optimization of air-based systems using occupancy-based controls and scheduling, pressure and temperature resets, optimized warm-ups, etc. Additional solutions beyond ventilation heat recovery are also needed in the future, where heat is recovered from one use (e.g. ventilation) and reused for another (e.g. water heating).	**Medium**	**Mature** some solutions are underutilized



Whole-Building Retrofit Solutions

With support from the U.S. Department of Energy and NYSERDA, Syracuse University, TKfabricate, and Cocoon Construct are developing a transformational whole-building retrofit solution for residences in cold/very cold climates that achieves 75% savings in energy used for thermal loads (HVAC and DHW). The approach addresses the need for innovation in integrated design, fabrication, and installation. The solution comprises a prefabricated modular exterior envelope and attachment system that is compatible with a high-efficiency mechanical "pod" for HVAC and DHW.[25]

Key Innovations:

- **Prefabricated Façade Panels:** Unitized, prefabricated wall and roof panels are attached directly onto the existing facade to improve the thermal performance and airtightness of the envelope, with minimal disruption to the building occupants.
- **Integrated Mechanical System:** A prefabricated mechanical system is installed, which includes an air-to-water heat pump for domestic hot water (DHW) and space conditioning, a heat recovery ventilator (HRV) or energy recovery ventilator (ERV), a hot water tank, photovoltaic (PV) inverters, and controls in one "pod."
- **High-Precision Fabrication Methods:** Energiesprong uses drones or lidar technology to scan the building and develop a precise digital model of existing conditions. Manufacturers with a high level of automation can produce panels for 500-600 buildings a year.[26]
- **Economics:** Retrofits are sometimes financed through energy savings. Instead of paying the utility companies, tenants pay an energy service plan to the housing association. The energy plan guarantees an energy budget to achieve net zero energy, and the energy cost savings are used to finance the retrofit (financing model required policy changes in the Netherlands).

Technology Development Needs

Below is a summary of activities needed in the next decade for continued development.

Insulation and other envelope-based load reduction strategies

- Focus research and development efforts on advancement of insulation types with low embodied carbon, improved R-value per inch performance, and less costly and disruptive installation techniques for existing buildings.
- Improve the commercial viability, installation, and adoption of high performance building fenestration solutions by enabling automated production and lowering installation costs.
- Further research fenestrations for curtain wall systems.

Air sealing and thermal bridging

- Scale up the market presence of liquid, aerosol, and integrated air barrier air sealing systems in new construction and retrofits. In addition, facilitate development and adoption of other technologies such as expanding foam tapes around windows and flexible tapes that can improve air sealing.
- Improved duct air sealing techniques with an emphasis on existing ductwork solutions.
- Integrate thermal break requirements into procurement specifications and building codes and standards.

Off-site manufacturing utilizing advanced manufacturing techniques

- Continue research and pilots and develop new construction programs focused on advanced construction techniques, including digital fabrication of customized off-site construction, and cross laminated timber panels.
- Support the industrialization of construction with modular building support.
- Leverage advanced manufacturing techniques, robotics, innovative business models and scale to compress installed cost.

CASE STUDY

Energiesprong: A Model for Industrialized Net Zero Energy Retrofits

Energiesprong is an innovative industrialized zero energy retrofit approach developed in the Netherlands. As public-private partnership, Energiesprong has implemented thousands of zero energy retrofits over the past five years using prefabricated façade panels and all-electric mechanical systems, with another 100,000 planned across Europe, including UK, Germany, and France.

Lessons Learned from Energiesprong

- Prefabricated retrofits and innovative financing model create a cost-effective retrofit solution.
- Aggregated demand drives down the cost of the panels and mechanical pods, in less than 10 years.
- Energiesprong was able to achieve 40% cost reduction for the panels, 55% for the mechanical pod, and 60% for the total retrofit cost.

A multifamily building in the Netherlands before (left) and after (right) an Energiesprong retrofit.

Project Type: National energy efficiency program design; Public-Private Partnership

Location: Netherlands

Building Type: Multifamily Residential

Learn More

Building Electrification

As with solutions that improve building efficiency, technologies that will enable rapid electrification of the built environment are readily available or emerging in the marketplace. This section addresses priority products and equipment to electrify space and water heating as well as kitchen ranges. These include heat pumps, domestic hot water heaters, ventilation, integrated mechanical systems, and induction cooktops.

TABLE 4.2: SUMMARY OF KEY ELECTRIFICATION TECHNOLOGIES

Technology	Priority	Maturity
HEAT PUMPS		
Heat pumps are seeing increased adoption and are a critical part of the decarbonization solution. Heat pumps absorb heat and efficiently transfer that heat either into occupied spaces (in the winter) or from occupied spaces to the outdoors (in the summer). A major benefit is that both heating and cooling can be provided with the same equipment. There are three main types of heat pump systems: 1. **Central Air Source Heat Pump (ASHP)** systems circulate hot and cold refrigerant, or water to hydronic systems, to distribution system components like terminal fan coil units. This includes ducted mini-split systems which are often found in residential applications. Emerging cold climate heat pumps provide increased functionality for colder climates, at a slightly higher cost premium. 2. **Packaged Air Source Heat Pumps** including window- or wall-installed terminal packaged units, ductless mini-splits and packaged rooftop systems often found in small- to medium-sized buildings. 3. **Water-Source Heat Pumps (WSHP)** extract heat from water loops. Within this category, **Ground Source Heat Pump (GSHP)** systems have deep underground wells or ground loops that use a heat pump to transfer heat between the ground and the indoor space for both heating and cooling. GSHPs significantly reduce operating costs, but upfront costs are higher than ASHPs. In developed areas, the biggest challenge is to find nearby open space for the in-ground wells. The infrastructure can be expensive for single-family homes, though new financing solutions are emerging as well as district offerings enabling infrastructure costs to be shared across multiple customers. District hydronic loops, wastewater heat recovery, and thermal storage are other examples of potential heat sources/sinks for WSHPs. Smaller distributed WSHPs are used within buildings to extract heat from hydronic distribution loops and heat individual spaces or floors.	**Very High**	**Mature** ASHP technology is mature for single-family residential buildings and emerging for large commercial applications, although innovation is needed on performance efficiency (COP) of cold climate ASHPs in the coldest outdoor conditions **Mature** GSHP technology, though innovations in drilling are needed to achieve cost competitiveness
VARIABLE REFRIGERANT FLOW (VRF)		
VRF systems use piped refrigerants to heat and cool indoor spaces and are most commonly found in medium- to large-buildings. For all heat pumps (and especially for VRF, where there is a higher volume of refrigerant), innovation in low global warming potential (GWP) refrigerants is critical. In new construction applications, manufacturers cited VRF installations as having a lower ducting and piping cost than comparable ASHP or GSHP systems. Retrofitting a VRF system may be more difficult if there is already a ducted system in place. For recommended VRF system efficiencies, please refer to the most recent version of ASHRAE 90.1.	**Medium**	**Mature** VRFs widely available however low GWP refrigerants are still emerging

Continued >

TABLE 4.2: SUMMARY OF KEY ELECTRIFICATION TECHNOLOGIES (CONTINUED)

Technology	Priority	Maturity
HEAT PUMP WATER HEATERS (HPWH) In-unit HPWHs are used for smaller buildings and centralized HPWHs can be used for larger building types. Centralized systems include large hot water storage tanks with several heat pumps in series. There are existing low Global Warming Potential refrigerant options for domestic water heating, but the predominant technologies on the market today use more standard refrigerants. Water heaters should have smart controls to enable grid interactivity.	**High**	**Mature** HPWHs available however low GWP refrigerants are still emerging
INTEGRATED MECHANICAL SYSTEMS Integrated mechanical systems are pre-manufactured, bundled, all-electric packages capable of delivering heating, cooling, ventilation, dehumidification, and domestic hot water to individual spaces. They are commonly used in up to seven-story buildings. This product is not yet commercially available in the United States but shows significant carbon and cost reduction potential and is under research and development by several manufacturers serving the U.S. market. These systems have been used in Europe, and early solutions are focused on multifamily and single-family applications. This technology is intended to be part of a net zero retrofit package to overcome difficult-to-retrofit legacy HVAC systems. It can also be used in new construction.	**Medium**	**Early** Currently not available in the U.S. beyond pilots

Continued >

Lower Cost Ground Source Heat Pump Installations

With support from NYSERDA, Dandelion Energy is demonstrating a more efficient process to drill ground source loops for geothermal heat pump systems. Drilling and installing the loop is the largest cost component of ground source heat pump system (GSHP). The new drilling technology is expected to reduce the time and cost to install GSHPs. The compact drilling equipment will also offer opportunities for installations not serviceable by the typical larger drilling equipment used today.[28]

TABLE 4.2: SUMMARY OF KEY ELECTRIFICATION TECHNOLOGIES (CONTINUED)

Technology	Priority	Maturity
EFFICIENT ELECTRIC COOKING Induction cooking heats by transferring currents directly to the magnetic induction cookware. Lab testing shows induction cooking efficiency of around 90% compared to 32% for gas and 75-80% for traditional electric systems.[27] Induction stove prices are coming down, close to parity with gas stoves, and they offer comparable levels of cooking performance. In some cases where electric capacity is very constrained, an electric panel upgrade and wiring may be necessary, which could impact cost effectiveness and increase technical complexity. Retrofits from gas-to-electric stoves can help improve indoor air quality and safety.	High	Mature widely available

Induction Cooktops and Health

Indoor air pollution from natural gas ranges can reach levels that exceed even outdoor air quality standards, creating unsafe levels, especially for children and those with asthma.[29, 30] Lower-income households and communities of color are more likely to experience exposure to air pollution and higher rates of asthma.[31] Creating programs that allow communities to affordably switch to safer cooking systems can help improve public health as well as advance New York's climate goals.

Packaged Terminal Heat Pumps

There are hundreds of thousands of packaged terminal air conditioners (PTACs) in multifamily buildings in New York State. These systems are inexpensive and notoriously inefficient. Heating often relies on electric resistance or fossil fuel plants and distribution. Ice Air from Mt Vernon, NY, with assistance from Steven Winters Associates and NYSERDA is demonstrating a new cold-climate Package Terminal Heat Pump (PTHP). The design offers an affordable PTHP by carefully optimizing controls and components for PTHP packages addressing defrost, ice melt removal, proper sizing, and controls to provide better comfort and efficiency.[32]

Technology Development Needs

Below is a summary of activities needed in the next decade for continued development.

Support cold-climate heat pumps

- Support innovation in heat pump RD&D, especially for: improving performance at even colder temperatures; and applications for large buildings and district systems.
- Further develop control solutions that enable integration with existing HVAC systems, to potentially serve as backup heating sources for resiliency.
- Design codes and standards that incentivize and/or mandate high performance cold-climate air source (and/or ground source) heat pumps.

Advance ground source heat pumps

- Conduct research, pilots and support emerging business models, with a particular focus on further reducing the cost of drilling.
- Incentivize lower cost strategies for single-family or small multifamily such as minimally disruptive horizontal piping or district aggregation.

Advance thermal networking and district thermal solutions

- Educate industry practitioners of the techno-economic opportunities
- Build programs to accelerate the integrative solution provider marketplace and address any regulatory or administrative barriers.

Grid Interactivity

This section addresses technologies that support interactivity between buildings and the grid, including software solutions, hardware solutions and grid interoperability.

Grid interactivity leverages demand flexibility to reduce or shift building loads to reduce peak demand while also balancing high levels of variable renewable generation on the grid. Buildings with smart controls that enable demand flexibility have been demonstrated to reduce energy cost by approximately 29%[33] and have the potential to reduce daily peak demand by 30-50%.[34] Table 4.3 highlights the major building-grid interactivity technologies.

TABLE 4.3: SUMMARY OF KEY BUILDING-GRID INTERACTIVITY TECHNOLOGIES

Technology	Priority	Maturity
SOFTWARE SOLUTIONS: SMART CONTROLS		
Smart controls provided through an Energy Management Information System (EMIS) or Building Management System (BMS) allow building owners and operators to control their buildings. Advanced EMIS supports the integration across end uses (e.g. the ability to stage distributed energy resources, plug loads, HVAC, and EV charging) in a central control system to manage peak demand, cost and emissions, ideally in response to a signal from the utility or Independent System Operator. EMIS/BMS are most commonly found in larger multifamily and commercial buildings.	**High**	**Mature** BMS Systems **Emerging** Multiple system integration and interoperabilty with external signals
HARDWARE SOLUTIONS: SMART DEVICES AND SENSORS		
All major plug loads and appliances should either have the intelligence to self-regulate or the ability to integrate with a master BMS or EMIS. Smart devices can optimize to a variety of signals, including cost and carbon. For residential buildings, key smart devices include thermostats, water heaters, EV chargers, and pool heaters. For commercial and educational buildings, this technology should include the ability to track and stage plug-and-process loads including laptops, monitors, printers and multifunction devices, appliances, IT hardware, etc.	**High**	**Emerging**
GRID SIGNALS AND INTEROPERABILITY		
A master BMS or EMIS can respond to building-level information from internal sensors or from external grid-level information like real-time carbon emissions or electricity prices. Availability of granular real-time marginal carbon emissions or time-variant electricity prices would allow building operators to optimize performance to avoid emissions or high prices. Time-of-use pricing is often aligned with the price of the generation source rather than associated emissions (although with many peaker plants, these two signals are often aligned). Emissions avoidance could be prioritized in rate-design or provided by system operators and/or utilities via Application Programming Interfaces (API's) in the future. Until emissions avoidance is incentivized by pricing, buildings can reduce their operational emissions using signals available from third party services.	**Medium**	**Emerging**

Technology Development Needs

Below is a summary of activities needed in the next decade for continued development (per A National Roadmap for Grid-Interactive Efficient Buildings).

Research, Development, and Data

- Develop load curve benchmarks for major building typologies to better understand the needs of customers and the grid throughout the day
- Confirm the efficacy of various grid carbon intensity signal characteristics (e.g. type, timestep, level of advanced notice) to determine which yield the maximum carbon reduction potential and
- Pilot price signaling to verify buildings can respond efficiently and owners are properly incentivized to consume power during low-carbon times of the day
- Standardize grid-to-building and building-to-grid communication protocols

Enhance the Value to Consumers and Utilities

- Introduce incentives for utilities to deploy demand-side resources and develop new, innovative incentive-based programs
- Expand price-based program adoption
- Incorporate demand flexibility into resource planning

Empower Users, Installers and Operators

- Develop GEB design and operation decision-making tools
- Integrate smart technology training into existing training programs

Support GEB Deployment Through Federal, State and Local Enabling Programs and Policies

- Issue lead by example goals for government buildings
- Expand funding and financing options
- Consider use of codes & standards, including standardizing communications protocols
- Consider implementing State targets or mandates

Distributed Energy Resources

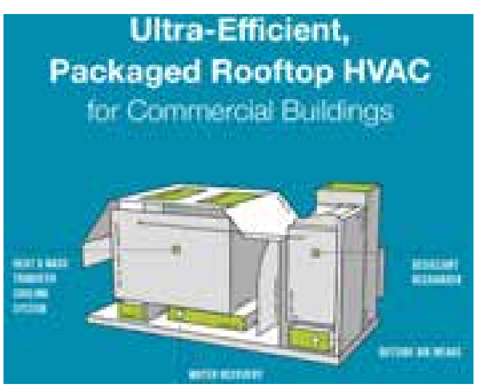
The electricity grid, designed originally with power flowing from centralized power plants to downstream consumers, has become more distributed.

As new energy generation sources and battery storage systems are distributed throughout New York's towns and neighborhoods, the grid will become increasingly resilient. Table 4.4 highlights the major components of storage and onsite generation technologies and their potential.

TABLE 4.4: SUMMARY OF KEY DISTRIBUTED ENERGY RESOURCES

Technology	Priority	Maturity
BATTERY ENERGY STORAGE SYSTEMS (BESS)		
Lithium-ion batteries are seen as the most widely adoptable BESS technology today. There are other emerging technologies including zinc-air batteries and solid-state technology that may eventually compete with lithium-ion batteries[35] with less environmentally harmful and less expensive chemistries, but they have not yet reached a high level of adoption in the U.S. When charging and discharging is optimized against utility rate structures or to avoid carbon intensive times, batteries can provide enormous operational cost and carbon savings potential. Due to high costs, fire code restrictions, and size constraints batteries remain difficult and expensive to install in buildings in New York. However, the average cost of installation fell 72% between 2015 and 2019 in the U.S. and is expected to continue to drop.[36]	**High**	**Emerging**
PHOTOVOLTAIC (PV) SYSTEMS		
Most PV systems are rooftop- or ground-mounted systems. Sizing is determined by building size, site, and typology. There is a growing focus on Building Integrated Photovoltaic Systems (BIPV) that are part of the building facade (windows, walls and roofs). BIPV often has lower efficacy than panel-based systems.	**High**	**Mature** BIPV is emerging

Continued >



Climate-Friendly Energy Storage AC

Decarbonization of commercial and multifamily buildings supports a large potential market for load flexible, high efficiency, and environmentally friendly solutions for air conditioning. NYSERDA is working with Blue Frontier to commercialize its core air conditioning/energy storage technology that integrates desiccant-enhanced indirect evaporative cooling, thermochemical energy storage and an efficient converter for transforming renewable electricity into heat. Technology benefits include a reduction in energy use and peak electrical demand, thermal storage for cooling, and reduction in GWP of refrigerants.[37]

TABLE 4.4: SUMMARY OF KEY DISTRIBUTED ENERGY RESOURCES

Technology	Priority	Maturity
THERMAL ENERGY STORAGE (TES) Thermal Energy Storage technologies store energy for cooling and heating to reduce or shift peak demand. Chilled water and ice storage systems are commonly used and commercially available. Key considerations include the capacity, power, efficiency, storage period, charge and discharge time, and cost. Phase-change materials (PCMs) can be installed on the interior of buildings to reduce daily thermal swings and reduce peak heating or cooling loads. PCMs can also include other advanced absorption or desiccant materials. While new unitized solutions for residential application are being explored, most research and deployment of TES is limited to commercial buildings due to space constraints. Advances in control algorithms and optimization with time-of-use rate structures can shorten payback periods.	**Medium**	**Mature** but under deployed

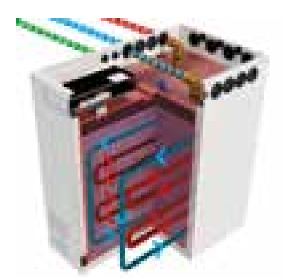
Technology Development Needs

Below is a summary of activities needed in the next decade for continued development.

- Demonstrate safety of onsite battery storage through a UL listing standard, incorporate into codes and standards.
- Continue research and demonstrations for less environmentally harmful and less costly battery chemistries / technologies.
- Facilitate distributed renewable energy siting through improved permitting rules.
- Create market development and economic signals to further accelerate adoption of solar and BESS, especially for Disadvantaged Communities.
- Install distributed energy resources with the ability to be grid-interactive, allowing building operators to manipulate charging and discharging to the benefit of occupants, emissions reductions and the grid.

Thermal Energy Storage Technology

Thermal energy storage uses sensible heat, latent heat, or thermochemical methods in order to store energy for later consumption in order to shift all or a portion of a building's thermal needs to off-peak times. Sunamp (based in the UK), with support from NYSERDA, will adapt and install its innovative thermal batteries in up to eight archetype buildings and heating systems commonly found across the State to evaluate how Sunamp's technology can be transferred to New York to help meet its carbon reduction targets, improve grid resilience, and lower fuel bills for customers.[38]



District & Community Scale Solutions

Electrification of Steam Loads

One of the biggest challenges in New York's built environment will be the decarbonization of today's district steam loads. The primary uses for steam in non-industrial buildings include space heating, water heating, process loads, and absorption chillers. Steam is predominately generated with gas today. To decarbonize, either the steam generation infrastructure needs other fuel sources, or buildings will need to convert to hydronic systems fueled from new hot water sources or to other distributed heat pump solutions within buildings. Transitions from steam to hot water are particularly challenging for many institutions given existing steam equipment and high capital cost for hot water conversion. As a result, these solutions have not yet scaled.

Limited options may also be available for all-electric steam generation where specifically required, but commonly available electric boilers are costly to operate. That said, electrification of steam process loads could be cost effective when considering reduced operations and maintenance, and all-electric steam generators might be viable for some heating retrofit projects where full-system conversion is cost prohibitive or where steam-to-hot water conversion is not an option, for example in industrial processes.

Decarbonizing steam loads is especially important because a large percentage of New York City buildings use some form of steam for space heating. In New York, there have been several case studies of retrofitting two-pipe steam to hydronic distribution systems.[39] Repairing and upgrading systems are projected to result in average annual cost savings of $41 million and $75 million (or $147 million including steam trap offset costs) across one- and two-pipe multifamily buildings respectively.[40]

Technology Development Needs

Below is a summary of activities needed in the next decade for continued development.

- Develop technologies that can facilitate the electrification of boiler systems.
- Create technical solutions and business models for steam-to-hot water conversions.

Thermal Energy Networks

A heat pump system is frequently installed to serve the needs of a single building. However, to leverage economies-of-scale and to expand clean energy options for buildings with space constraints, a heat pump system can be integrated with a network of distribution pipes to serve multiple buildings in a configuration referred to as a Thermal Energy Network, Community Thermal or District Thermal System. A Thermal Energy Network enables a cluster of buildings to share heating water to provide space heating of occupied spaces, as well as the production of domestic hot water.

A chilled water piping network could also be included to serve the space cooling needs of the building cluster. The heating water could be centrally produced as hot water via electric-driven heat pumps and used in the buildings via radiators for hydronic heating, (or via fan coils) or the system could utilize ambient-temperature water serving as a thermal source feeding electric-driven heat pumps located in each building. Either configuration could take heat input from ASHPs, GSHPs or other WSHPs tapping into thermal storage or opportunistic heat recovery sources like wastewater.

Thermal Energy Networks within and between buildings have an important opportunity to recover and move heat from where and when it's not needed to where and when it is. Even during colder months, commercial buildings have significant cooling loads, and today those are typically satisfied with economizer cycles, so-called "free cooling" that releases unwanted heat to the outdoors via exhaust air or cooling towers. Instead, this wasted heat can be recovered in hydronic systems either intrinsically (e.g. in ambient or condenser water loops) or actively (e.g. heat recovery chillers or even compressor-driven cooling of exhaust air). It can then be moved to other parts of the building or district network that need the heating in real-time. It also can be injected into thermal storage such as water, ice, other phase-change materials, the ground or the building structure itself. In both commercial and multi-family applications, the more loads are connected in thermal networks within buildings or districts, the more opportunity for time-of-use thermal profile diversity and/or thermal storage that can level peak loads, reduce needed heat pump sizes, and attain better capacity factors for installed equipment. Hydronic networks also have the benefit of optionality and future-readiness at both the end-use by allowing plug-and-play for a range of different tenant fit-out options and at the heat source by allowing easy integration of new heat generation and storage technologies in coming decades.

Thermal Energy Network systems can address the needs of new construction projects as well as retrofits of existing buildings and can be applicable to single-owner campuses such as colleges/universities, medical campuses, or residential complexes, as well as multi-owner nodes such as downtown corridors.

NYSERDA issued a competitive solicitation to support development and demonstration of low-carbon Thermal Energy Network system installations in 2020. The Community Heat Pumps Pilot program is supporting 30 projects across the State to explore business models that can cost-effectively grow this market to scale through support for scoping, design, and construction.

Technology Development Needs

Below is a summary of activities needed in the next decade for continued development.

- Research, development and innovation focused on use of various available thermal energy resources (air, ground, water [loop field, waste or river], solar thermal), as well as systems that combine onsite renewable energy systems with battery and/or thermal storage to achieve improved resiliency and improved building – grid interaction.
- Research into various elements of thermal energy transfer between buildings and Community Thermal Systems, to expand the base of buildings that could participate. Research needs include digitization, metering, prefabrication, low temperature distribution, and applications for machine learning/artificial intelligence.
- Explore Multi-Source heat pumps that can operate as an air or ground/water source heat pump simultaneously.
- Identify and explore the potential vulnerabilities/benefits of Community Thermal Systems with respect to building resiliency in the event of electrical grid outages.

Renewable Hydrogen Conversions

An alternate approach under consideration is the renewable production of hydrogen and reuse of existing natural gas pipelines to convey hydrogen for combustion, potentially in central locations to replace natural gas as the fuel for a district steam system. This requires significant additional research and development to overcome concerns such as pipeline brittleness when subjected to hydrogen, leakage, development of safe hydrogen substitutes for equipment, and the elimination of co-pollutants from the hydrogen combustion. More information about clean hydrogen can be found in **Chapter 6: Limits to Electrification.**

Technology Development Needs

To further develop use of hydrogen, the state should consider expanded planning for continued market development and use of clean hydrogen, including technical feasibility, safety, market sizing and priority applications.

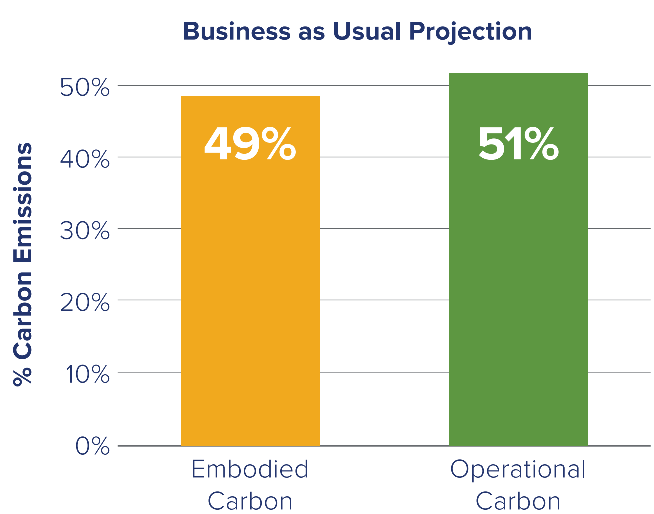
Embodied Carbon & Refrigerants

Embodied Carbon

Materials matter: a comprehensive approach to carbon neutrality must account for ***embodied*** carbon, or the GHG emissions associated with the extraction, manufacturing, transportation, installation, maintenance, and end-of-life handling of building materials and equipment. This is particularly relevant in new buildings. According to Architecture 2030, nearly half of emissions from new buildings between 2020 and 2050 will come from embodied carbon under a business-as-usual scenario as shown in Figure 4.2.

The most impactful approach to reducing embodied carbon in buildings is to re-use or retrofit existing structures rather than build new. A building's structure and substructure can make up as much as 80% of a building's up-front embodied carbon, due to the high levels of carbon embedded in structural steel, concrete, and other materials that make up those building components.[41]

FIGURE 4.2: TOTAL CARBON EMISSION OF GLOBAL NEW CONSTRUCTION FROM 2020-2050



Source: 2018 2030, Inc. / Architecture 2030. All Rights Reserved. Data Sources: UN Environment Global Status Report 2017: EIA International Energy Outlook 2017

The concrete and steel industries account for 11% and 10% of total global emissions respectively and thus provide the biggest opportunity for embodied carbon reductions.[42] A 2021 case study by RMI shows that by simply specifying concrete products with lower CO_2e content, the embodied carbon of a commercial building construction project can be reduced up to 33%.[43]

Some of the most promising material innovations to date are carbon-storing materials that remove and store carbon from the atmosphere through natural processes or by using carbon capture and storage technology. These materials can be bio-based (wood, hemp, or cellulose) or mineral-based (concrete utilizing carbon capture and storage technology). In general, carbon-storing materials offer comparable levels of performance relative to their higher embodied carbon counterparts. Table 4.5 provides examples of high and low embodied carbon insulation materials and their corresponding performance values.

Building practitioners can select low- or negative-carbon materials by using environmental product declarations (EPDs) to compare between two functionally equivalent products such as different types of insulation, or concrete mixes in a particular strength category. An EPD discloses the environmental impacts per unit of material including the embodied carbon content, expressed as Global Warming Potential (GWP).

Conducting whole building lifecycle assessments (WBLCA) allow design teams to measure embodied carbon at the building scale. WBLCAs are useful tools for assessing design strategies that reduce overall embodied carbon, such as efficient structural design or replacing concrete and steel with mass timber.

Technology Development Needs

Below is a summary of activities needed in the next decade for continued development.

Market and regulatory shifts

- Expand support of adaptive reuse of existing, particularly currently vacant, buildings.
- Evaluate and publish the market availability and costs of existing and emerging low-embodied carbon materials.

TABLE 4.5: WALL COMPOSITION R VALUES FOR HIGH EMBODIED CARBON INSULATION PRODUCTS AND LOW EMBODIED CARBON OR CARBON STORING INSULATION PRODUCTS BASED ON FRAMING TYPE

Higher R Values indicate greater thermal performance.

High embodied carbon ← → Low embodied carbon/ Carbon storing

INSULATION TYPE

FRAMING TYPE	XPS	Fiberglass Batt	Spray Foam	Mineral Wool/ Rockwool	Dense Cellulose	Cork/Wood Fiber	Hempcrete
2x4	N/A	12.5 (3.5″ Fiberglass Batt (R-15))	10.7 (3.5″ Spray Foam (R- 3.5/ in.))	9.8 (3.5″ Rockwool (R-3.15/in.))	11.9 (3.5″ Dense Cellulose (R-4/in.))	11.2 (3.5″ Gutex Wood Fiber (R-3.7/in.))	N/A
2x6	N/A	17.8 (5.25″ Fiberglass Batt (R-21))	16.1 (5.25″ Spray Foam (R-3.5/ in.))	14.8 (5.25″ Rockwool (R-3.15/in.))	17.8 (5.25″ Dense Cellulose (R-4/in.))	16.8 (5.25″ Gutex Wood Fiber (R-3.7/in.))	N/A
2x8	N/A	21.7 (8.25″ Fiberglass Batt (R-25))	24.3 (8.25″ Spray Foam (R-3.5/ in.))	22.4 (8.25″ Rockwool (R-3.5/in.))	26.8 (8.25″ Dense Cellulose (R-4/in.))	25.3 (8.25″ Gutex Wood Fiber (R-3.7/in.))	N/A
Block/ Brick	15.8 (3″ R-5/in XPS board with sheathing on top)	N/A	N/A	N/A	N/A	11.6 (90mm Gutex (R-10.8) with sheathing on top)	11.1 (4″ Hempcrete Exterior Wall Addition (R-10.3))

- Conduct market education and outreach to major designers and builders to drive specification and acceptance of low-embodied carbon materials.
- Enact carbon pricing (or similar) to create a larger market for carbon-sequestering materials like hempcrete and other biomaterials.
- Expand product selection and update code restrictions to better address the potential of engineered wood.
- Implement codes and policies that require EPD disclosure and set GWP limits for materials.
- Lead by example with State and municipal procurement processes to require EPD disclosure and favor or require lower embodied carbon content in state or municipal construction projects.

Research and Development

- Conduct assessments of embodied carbon to develop regionally specific baselines for whole-building life cycle analysis.
- Develop guidelines for accounting for systems boundaries in Life Cycle Analyses for materials, equipment, and construction activities including accounting for building material waste and disposal.

Carbon Challenge: Holcim (La Farge Selkirk)

Holcim US will retrofit their Ravena, New York, plant—currently the largest industrial GHG emitter in the State—to produce cement with lower embodied carbon. The retrofit will allow Holcim to manufacture a cement product with an increased percentage of limestone and a decreased percentage of clinker. This results in a significant reduction in GHG emissions and, crucially, a reduction in some of the hardest to abate chemical process emissions.[47]

Refrigerants

Heat pumps rely on refrigerants to move heat from outdoors to indoors, and vice-versa. The primary refrigerant used in modern heat pumps is R410a, which is a very potent greenhouse gas that can be released to the atmosphere via multiple mechanisms, including refrigerant leaks and improper disposal. Other refrigerants have different GWP levels, and alternative refrigerants with low GWP are starting to appear on the market.

The amount of refrigerant per unit of capacity in heat pump systems varies by technology, with VRF systems using a comparatively large volume of refrigerant. Furthermore, heat pump configuration and typology affect the risk and rate of refrigerant leaks. Systems with more field-connected refrigerant distribution piping and longer refrigerant runs, such as VRF systems, have a higher risk of leakage than systems using air or water for distribution. The refrigerant lines within the packaged heat pump equipment are factory assembled and leak-tested, making them less susceptible to failure.[44] Due to these differences, two systems with comparable energy performance may have very different emissions impacts. Designers should consider these differences when specifying mechanical systems. Installers must also exercise extreme caution to avoid refrigerant losses during installation and ensure field-assembled piping is properly installed to minimize leaks. Excessive refrigerant leaks can effectively negate the carbon benefits of more efficient heat pump systems. Wherever possible, VRF systems should be futureproofed for compatibility with future low GWP refrigerants to avoid additional costs associated with replacing refrigerant lines.

Emerging Refrigerants

In recent years, major manufacturers of HVAC equipment have been working to develop lower-GWP refrigerants. These refrigerants include hydrocarbons, carbon dioxide, ammonia, and water, as well as HFC and hydrofluoro-olefins (HFO) blends.

Table 4.6 describes lower-GWP alternatives for different HVAC applications that are in development or available today.[45] In addition to low GWP, selection of a refrigerant should also consider aspects such as refrigerant efficiency under varying ambient conditions, which depends on refrigerant's thermodynamic and physical properties, flammability, and toxicity. For instance, R-290 and R-441A are common throughout Europe and Asia and are listed acceptable substitutes in small AC units by the U.S. EPA, however their flammability requires technical training and can increases installation costs.[46]

Technology Development Needs

Below is a summary of activities needed in the next decade for continued development.

- Support the development and adoption of low global warming potential refrigerants for heat pumps.
- Develop real-time leak detection of refrigerants.
- Develop workforce training for better installation practices for field installed refrigeration piping.
- Support research and development into the safety and efficiency tradeoffs of low GWP refrigerants through field testing and modeling and adopt standards that can guide performance and market adoption.

TABLE 4.6: R-410A AND LOWER-GWP REFRIGERANT ALTERNATIVES FOR HVAC APPLICATIONS

Refrigerant	GWP	Small Self-Contained AC	Small Split AC	Single and Multi-Split AC (Large)	VRF (Large)	Ducted Systems (Large)	Chillers
R410a	2088	Current refrigerant	Current refrigerant	Current refrigerant	Current refrigerant	Current refrigerant	Current refrigerant
HFC-32	675	Available now	Available now	Available now	Available now	Available now	Under development
R-513A	630						Available now
R-450A	601						Available now
HFO-1336mzz[Z]	9						Under development
HFO-1234ze[E]	6					Under Development	Available now
R-441A	<5	Available now					
Solstice 1233zd[E]	4.7-7						Available now
HFO-1234yf	4					Under Development	
R-290	3	Available now	Available now				Available now
R-744 (CO_2)	1					Available now	Available now
R-717 (ammonia)	0						Available now

- Ensure there is a plan for end-of-life disposal for heat pumps and refrigerant collection programs.
- Standardize the use of low GWP refrigerants in codes and performance standards; work with building code and fire code regulators to reach consensus on risks associated with flammable natural refrigerants as well as CO_2 systems.
- Investigate incentives that can offset first costs of low GWP equipment, especially in key typologies such as supermarkets.
- Increase the adoption of available alternatives like R-290 in the marketplace.

Environmentally Friendly Refrigerants without HFCs

Under NYSERDA's **NextGen HVAC Innovation Challenge**, NYSERDA is supporting the development of advanced refrigerant monitoring and leak detection solutions, new compressor technologies, in-field leak repair solutions, demonstration and evaluation of emerging technologies, refrigerant capture and recycling, industry collaboration on training, market awareness and product requirements and overall development of low GWP refrigerants.[48]

Hydronic System Integration

Improving hydronic heating systems and integrating them with other building systems such as storage and thermal mass can improve the efficiency of the building. This solution has the added advantage of circulating water rather than high global warming potential refrigerants throughout the building's distribution system.

The Nordic radiant hydronic approach uses continuously circulating water and the mass of the building to moderate the temperature of the conditioned space. It both heats and cools the indoor air through the circulation of water that moves excess heat from one portion of the space to the other. The water can circulate through a matrix of tubing in a concrete slab in the floor via tubing in exposed beams in the ceiling, or in wall and ceiling panels containing circulating water.

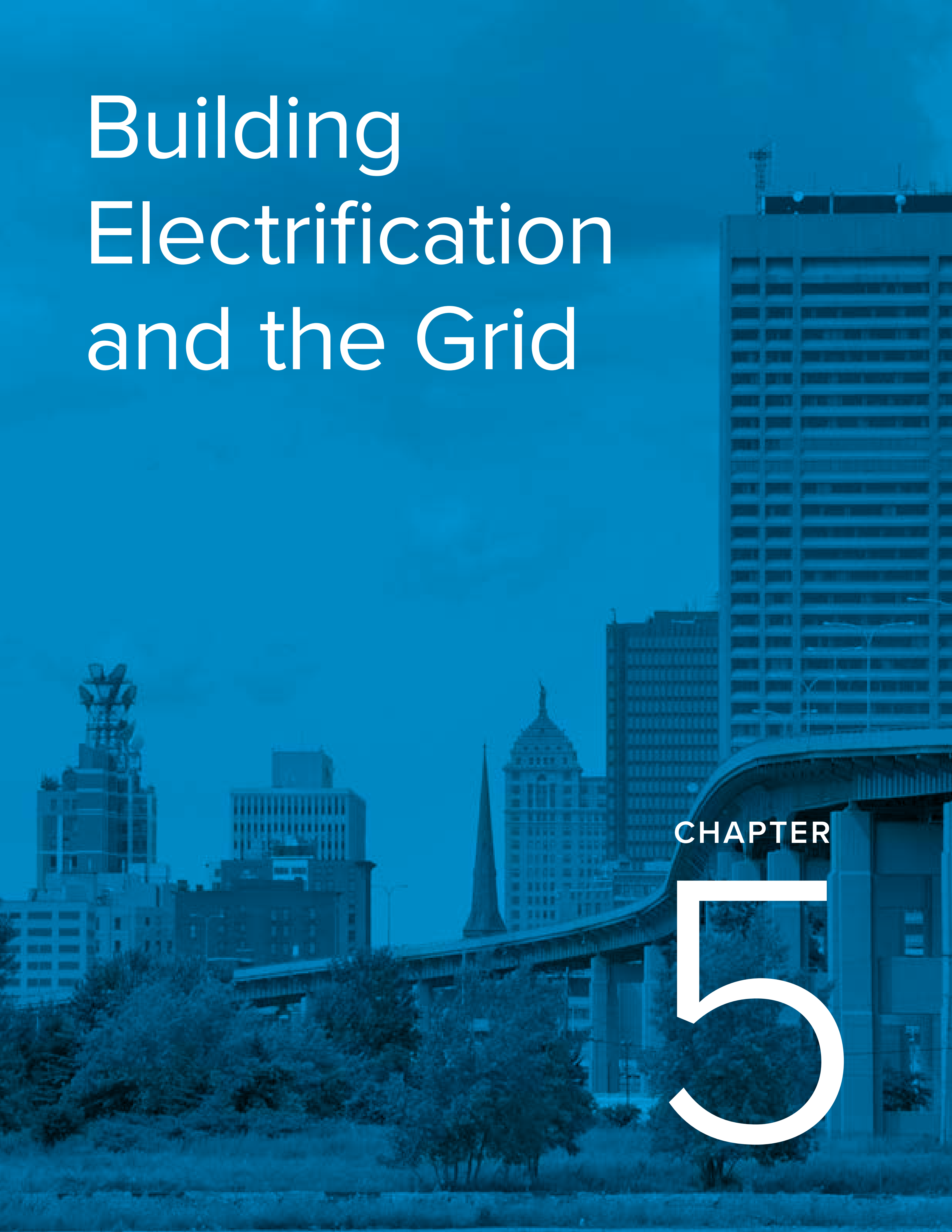
The efficiency gains result from recirculating the Btus in a single zone, avoiding the need for simultaneous heating and cooling. The system is all-electric, using heat pumps to treat the water to the desired temperature and small electric pumps to circulate the water.

Last Words

The challenges and solutions to improve performance and reduce costs of building materials, equipment, technology and construction processes will continue to evolve to meet the State's carbon neutrality goals.

As climate impacts become more severe and common, the usage patterns of buildings may change. Creating dynamic, flexible buildings with efficient envelopes, mechanical systems and appliances is the best way to ensure that a building continues to be usable and beneficial to occupants. Over the coming decades, improvements in traditional building load reduction technologies (e.g. building shell, ventilation, heating and cooling, appliances, etc.) must be met by advancements in building and community level adaptability and flexibility (GEBs, DERs, load management, and BMS/EMIS). Achieving advancements in efficiency, reliability, and adaptability will require targeted RD&D efforts, stakeholder education, private sector investment, and policy pushes at the state and municipal level.

Building Electrification and the Grid



CHAPTER 5

Introduction

Building space and water heating demands are the second largest source of energy consumption in New York State, second only to the transportation sector (Figure 5.1). Electrification of heating, paired with energy efficiency and demand flexibility, is a key strategy to achieve carbon neutral buildings in New York.

Building electrification displaces combustion of GHG emitting natural gas, fuel oil, and other fossil fuels used in buildings.[a] As a result, combined with the State's rapidly decarbonizing electric grid, electrification of space-heating, domestic hot water, cooking, drying and other building energy end uses offers a clear pathway for the State to achieve a carbon neutral building stock.

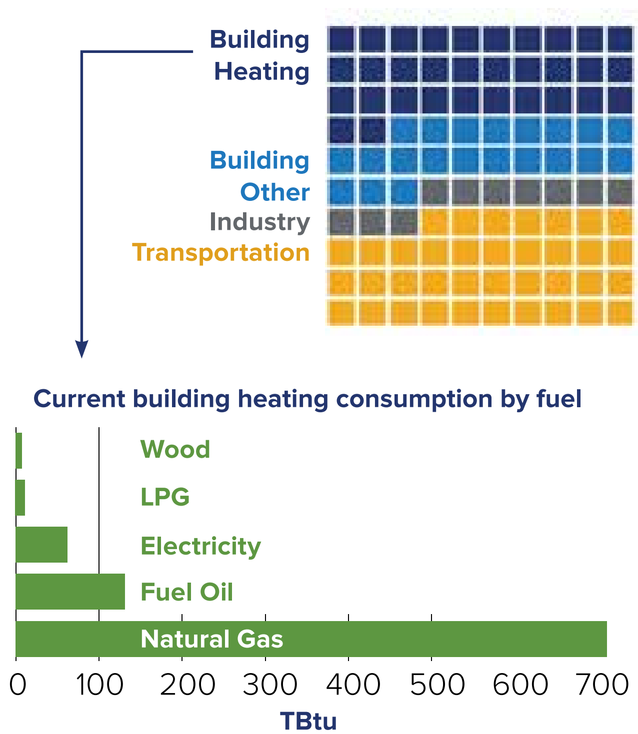
Many of New York's buildings, particularly residential buildings, operate with a space heating-dominated load pattern. Today, the heating loads of buildings in New York are largely served by fossil fuels. At their peak, New York's buildings demand sensible heating energy that is equivalent to more than triple the current air conditioning-driven summer peak demand of the State's electricity system. Electrifying heating will therefore add substantial new loads to New York's grid,[49] though several factors mitigate the scale of those impacts.

First, electric heat pump technologies serve heating loads far more efficiently than conventional systems. This is true on both an annual basis and, given rapid improvement in the cold-weather performance of air source heat pumps, on a peak basis as well. Second, improvements in building envelopes can decrease building heating demands and reduce the impact of building electrification on the State's electricity system. Third, building heat demands can become more flexible and grid interactive through measures like smart controls, battery storage, thermal storage or in certain cases the utilization of a back-up non-electric heating system.

Finally, this chapter reemphasizes the role of refrigerants in an electrified building stock. Most heat pumps available today use high global warming potential HFCs like R410A. Identifying lower GHG refrigerants and reducing refrigerant leakage will therefore be important considerations in achieving carbon neutral buildings in New York.

a The Climate Leadership and Community Protection Act (Climate Act) requires that New York's electricity system deliver 100% carbon free electricity by 2040.

FIGURE 5.1: NEW YORK FINAL (SITE) ENERGY DEMANDS BY SECTOR AND FUEL, TOTAL EQUALS 2.7 QUADRILLION BTU



There are several additional issues related to building electrification that are considered elsewhere in this *Roadmap,* as well as in the forthcoming NYSERDA **The Future of Buildings: Building Electrification Roadmap** which will contain guidance for near-term electrification solutions to 2030 in more detail. The technical suitability of electrification technologies is discussed in Chapter 4: Construction Technologies and Building Methodology, while the adoption trajectories, cost reductions, and the customer value proposition can be found in the **Building Electrification Roadmap.**

Grid Carbon Content & Electrification Adoption

Today, New York's electricity system is largely powered by a mixture of natural gas, oil, nuclear and hydropower. In 2019, 58% of generation in the New York Control Area was zero-emissions, resulting in an average system GHG emissions intensity of 0.17 tons CO_2/MWh, or less than half the national average.[50]

The Climate Act targets an 85% reduction in economy-wide direct emissions from a 1990 baseline by 2050 and 100% decarbonized electricity by 2040. New York is already on its way to achieving those goals, with 9,000 MW of off-shore wind slated for construction by 2035 and additional renewable procurements and transmission investments keeping the State on track to meet its 70% by 2030 renewable energy goal.

The State's economy-wide and electric sector goals are tightly linked. Electrification of building and transportation energy demands will put upward pressure on electric loads, and the electricity supplying those loads is required by the Climate Act to rapidly decarbonize over time. This linkage provides surety on the emissions benefits of electrification, but also raises important questions on the amount and pace of electric infrastructure additions that electrification will spur.

NYSERDA has begun to study scenarios to identify the scale of consumer and grid-scale infrastructure transitions that are consistent with the State's climate policy commitments. All scenarios considered by NYSERDA include large scale transformations of New York's building sector, including high levels of electrification. For example, Figure 5.3 shows two scenarios for residential space heating transformation in scenarios presented to the Climate Action Council in June 2020. In both cases, most homes in New York shift from natural gas and fuel oil heating systems to heat pumps, but with different adoption trajectories. Similar transitions occur for other key residential and commercial heating equipment, including domestic hot water, cooking, and clothes drying.

Electric System Impacts and Costs

Building electrification in New York will add large new loads to the State's electricity system. However, the magnitude of those impacts depends on what electric technologies are installed, how those technologies'

FIGURE 5.2: PROGRESS TO DATE TOWARDS MEETING THE 70% BY 2030 RENEWABLE ENERGY GOAL

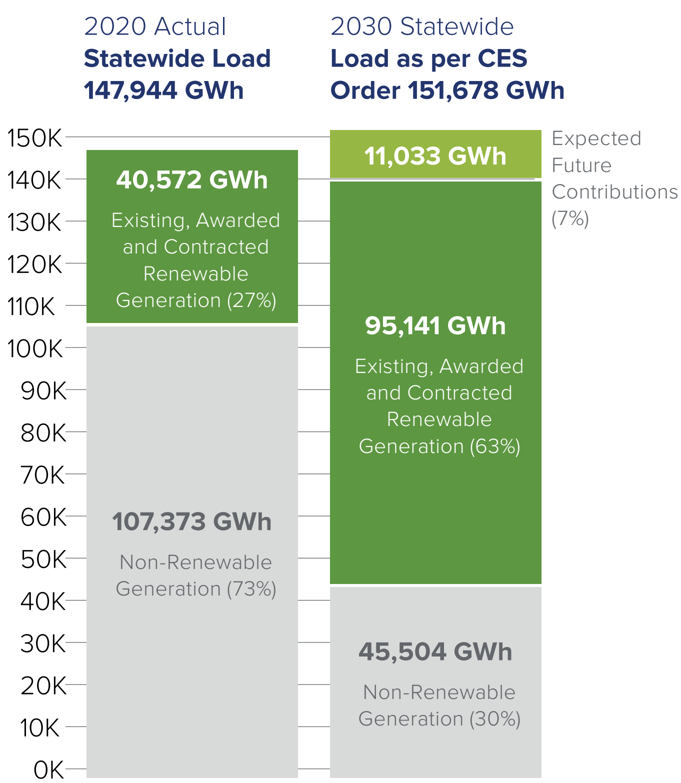
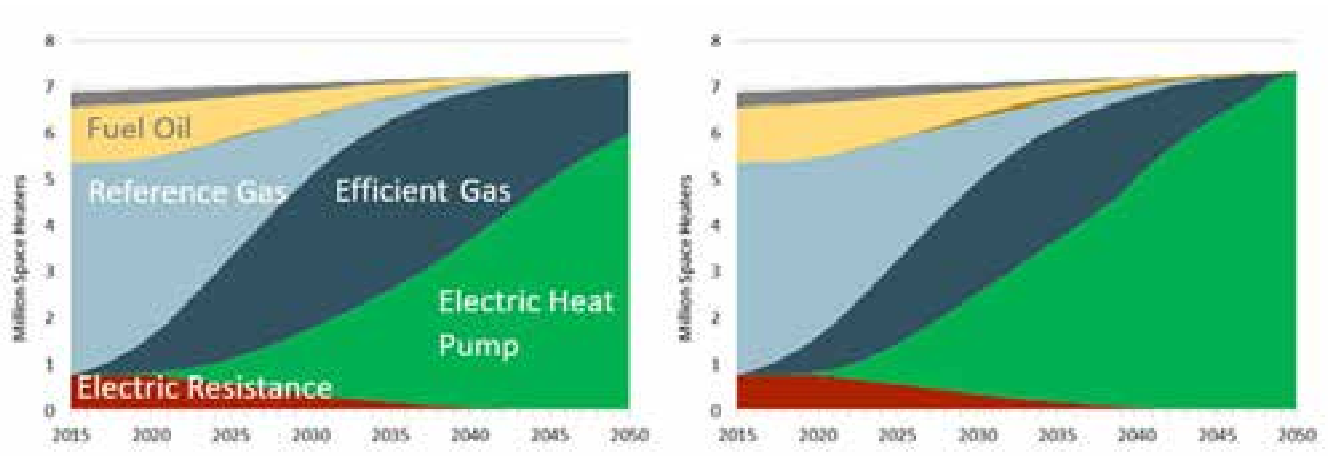


FIGURE 5.3: SINGLE-FAMILY SPACE-HEATING TRANSFORMATION IN TWO SCENARIOS



Scenarios include a "Core" case (left) and an "Accelerated Transition and No Biofuels" case.

performance improves over time and what other demand-side interventions are adopted alongside electrification. For instance, high reliance on air source heat pumps, which have declining efficiency during very cold weather, could result in large new winter peak loads. An alternative approach could be to rely more on ground source heat pumps or heat pumps installed with a boiler or furnace for back-up. Those systems' performance will be less sensitive to outdoor temperature leading to lower grid impacts. However, leaving legacy fossil heating appliances in place could also lead to increased emissions, assuming New York achieves its grid decarbonization goals and decarbonized fuels are not available at scale. Building shell and other energy efficiency improvements, electric and thermal storage, energy recovery and redistribution, and grid-interactive buildings could also have important roles in reducing the magnitude of building peak heating loads and in shifting some heating energy away from peak hours. Finally, technology improvements—more efficient cold-climate air source heat pumps, for instance—will also play an important role in the State's heating transition.

Load Scenarios

Over the course of developing the *Roadmap,* NYSERDA commissioned E3 to identify the grid impacts of alternative building electrification strategies. E3 implemented several scenarios that examine different types, and mixes, of building electrification measures to compare their impacts on New York's electricity system. E3's work extends the building energy modeling conducted by ARUP (Chapter 8: The Economics, Benefits, and Challenges for Carbon Neutral Buildings) to electric system impacts, accounting for the diversity of loads across the State's entire building stock. The modeled scenarios include a variety of different measures including:

- **ASHP + No Shell:** In this scenario, all buildings that electrify in New York are served by heat pumps that meet the minimum requirements to be listed on the Northeast Energy Efficiency Partnership's Cold Climate Air Source Heat Pump (ccASHP) Specification. Inclusion on that list requires that systems achieve a COP of 1.75 or higher at 5F. This scenario assumes improvements in the efficiency of new buildings but does not assume widespread shell retrofits in existing buildings.

- **ASHP + Shell:** This scenario is similar to the ASHP Scenario, but with large scale retrofits of existing building envelopes in New York. As a result of those retrofits, peak demands are 30% lower than in the previous scenario.

- **Managed + Shell:** In this scenario, a portfolio of different heat pump systems is used, including more efficient air source heat pumps (consistent with the highest performing systems on the NEEP ccASHP Specification), ground source heat pumps and two system installations that use a furnace or boiler as a back-up to an air source heat pump. The scenario also assumes shell improvements in existing buildings and some flexible building heating demands, and results in a 45% reduction in peak demand from the ASHP + No Shell scenario.

The peak demand impacts of each scenario in 2050 are shown relative to 2018 in Figure 5.4. New York's electricity system is currently summer peaking, creating headroom for building electrification loads. However, given the scale of New York's heating demands, all scenarios become winter peaking between 2030 and 2040. The magnitude of those winter peaks depends on what types of heat pump technologies and other peak mitigation solutions are deployed in buildings. Peaks could double relative to today if electrification occurs primarily using cold-climate air source heat pumps without significant envelope measures as in the "ASHP + No Shell" scenario. In contrast, peak impacts are much lower in the "Managed + Shell" scenario where a portfolio of solutions is used.

Electric Infrastructure Impacts

The large variations in annual loads and peak demands described above lead to equally large variations in the electric system infrastructure required to achieve a reliable and clean electricity system. Figure 5.5 shows the change in electric generation infrastructure by scenario as modeled by E3. E3 used the RESOLVE model, a capacity expansion and operations optimization model, to identify the least-cost portfolio of electric generation resources. To assess the cumulative impact of each scenario, E3 assessed the impacts of different carbon neutral buildings scenarios alongside load impacts from transportation electrification and other decarbonization measures.

Both scenarios add a substantial amount of zero-emissions

FIGURE 5.4: SCENARIO 2050 PEAK DEMANDS COMPARED TO 2018 WINTER AND SUMMER VALUES

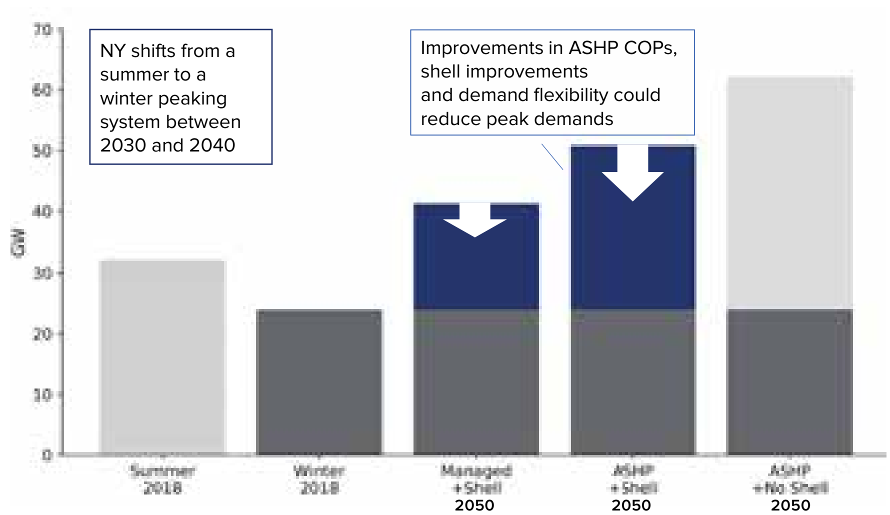
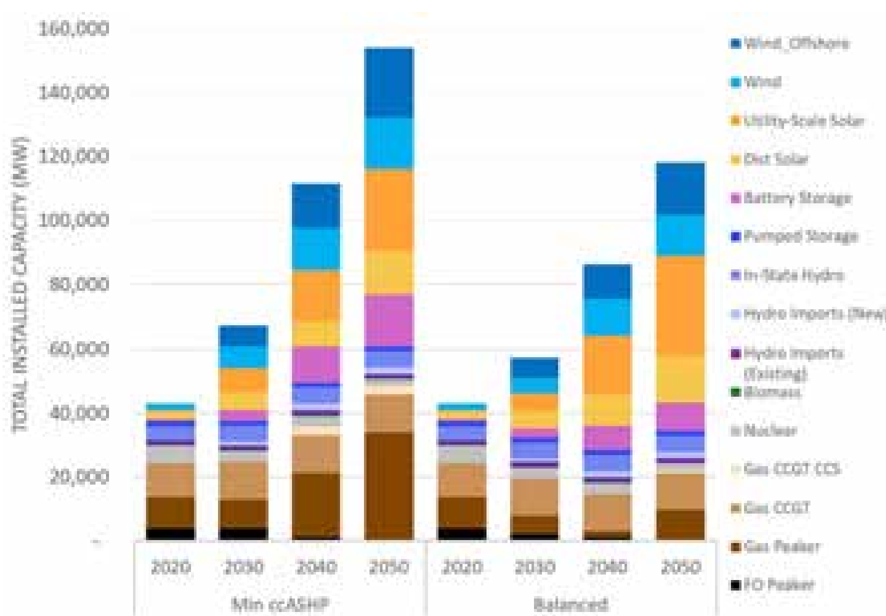


FIGURE 5.5: INSTALLED ELECTRIC GENERATION CAPACITY IN NEW YORK FOR TWO BOOKEND SCENARIOS



generation, primarily renewables firmed by grid-scale battery storage. The primary difference between the scenarios is the infrastructure added to serve the peak loads associated with large-scale building electrification.

The All ASHP scenario sees much higher peaks and a markedly different portfolio of firm and renewable resources compared to the Managed Portfolio scenario. By 2050, the All ASHP scenario requires the addition of 15 GW of battery storage, 22 GW of offshore wind, and 25 GW of new gas generation.[b] In contrast, the Managed Portfolio scenario sees a modest decline in installed gas capacity, 5 GW more utility scale solar than All ASHP, 5 GW less offshore wind, and 7 GW less battery storage.

Differences in both gas capacity and renewable build-outs between the two scenarios are driven by winter peaks. To illustrate, more offshore wind resources are selected in the All ASHP scenario despite them being more costly than utility scale solar on a $/MWh basis. In that case, however, the system value of off-shore wind resources is higher because that resource category's generation profile aligns well with the load shape of winter space heating demands.

The substantial additional infrastructure additions in the All ASHP scenario make it $90 billion more costly in net-present value terms than the Managed + Shell case. That cost increment includes both the incremental cost of generation and a first order estimate of incremental delivery infrastructure costs. On a household level, this is equivalent to $15,000 in avoided electric infrastructure costs[c] per-single-family home. This finding shows that substantial electric system value can be delivered from demand-side interventions like load flexibility, thermal storage, and grid interactivity.

There are also customer-side electric upgrade costs that are additional to the grid impacts discussed above. For example, some older buildings will need increased amperage at their service panel to accommodate higher electric loads. Required upgrades go beyond panel upgrades, as technologies like induction stoves and some heat pump water heaters will require 240V branch circuits. However, many of these upgrade costs will be required regardless of building electrification[d] and certain costs would be reduced via new technologies.

Carbon challenge: Columbia, St. Johns

St. John's University will implement several projects over the next three years to reduce energy and carbon emissions at their Queens, New York campus, and will specifically focus on electrifying natural gas loads. Columbia University Irving Medical Center will undertake a number of energy efficiency measures, including steam-to-hot water conversion in two buildings and installation of a heat recovery heat pump that will be leveraged to balance heating and cooling loads in the impacted building.

St. Johns University, Queens, New York.

The substantial additional infrastructure additions in the All ASHP scenario make it $90 billion more costly in net-present value terms than the Managed + Shell case. That cost increment includes both the incremental cost of generation and a first order estimate of incremental delivery infrastructure costs.

b By 2050, gas generation in the RESOLVE model is powered in part by climate neutral fuels, like clean hydrogen.

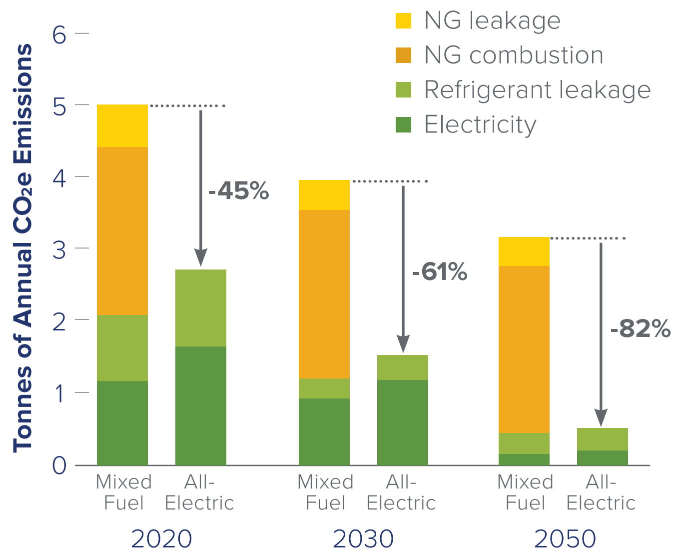
c On a net present value basis.

d A service panel upgrade is typically needed to accommodate an electric vehicle or to install rooftop solar.

Impacts of Increased Use of Refrigerants

Heat pumps and AC units rely on refrigerants to efficiently move heat from outdoor to indoors, and vice versa. The refrigerant used in most heat pumps today is R410A, a very potent greenhouse gas that can be released to the atmosphere via multiple mechanisms, including both leaks as shown in Figure 5.6 and improper disposal. As a result, GHG emissions associated with refrigerant usage in heat pumps will need to be addressed if buildings are to achieve carbon neutrality. In recent years, major manufacturers of HVAC equipment have been working to develop lower-GWP refrigerants. More discussion of low-GWP refrigerants and embodied carbon can be found in [Chapter 4: Construction Technologies and Building Methodology](#).

FIGURE 5.6: EMISSIONS FROM A SINGLE-FAMILY HOME IN CALIFORNIA BY SOURCE



From Mahone et al 2019. "Mixed fuel" customers are heated with natural gas and have an air conditioner. "All-electric" customers replace those appliances with heat pumps.

Future Research Needs

Research undertaken over the course of the *Roadmap* has characterized the electric system impacts of achieving carbon neutral buildings. Key recommended research next steps include:

- A distribution system analysis that considers impacts at a finer geographic resolution.
- Characterization of the expected supply and cost of decarbonized fuels that would be required to make buildings with two heating systems carbon neutral. This topic is also covered in Chapters **6: Limits to Electrification** and **8: The Economics, Benefits, and Challenges for Carbon Neutral Buildings**.
- Identifying the operating characteristics and business models required for the benefits of grid-interactive building loads to be incorporated into electric system planning in NY.
- Research into and piloting of potential regulatory structures that focus incentives for expanded energy efficiency, load flexibility (including thermal storage), and grid interactivity where they provide the highest temporal and locational value to the grid.
- Pilots and documentation of performance and economics of non-HFC refrigerants.

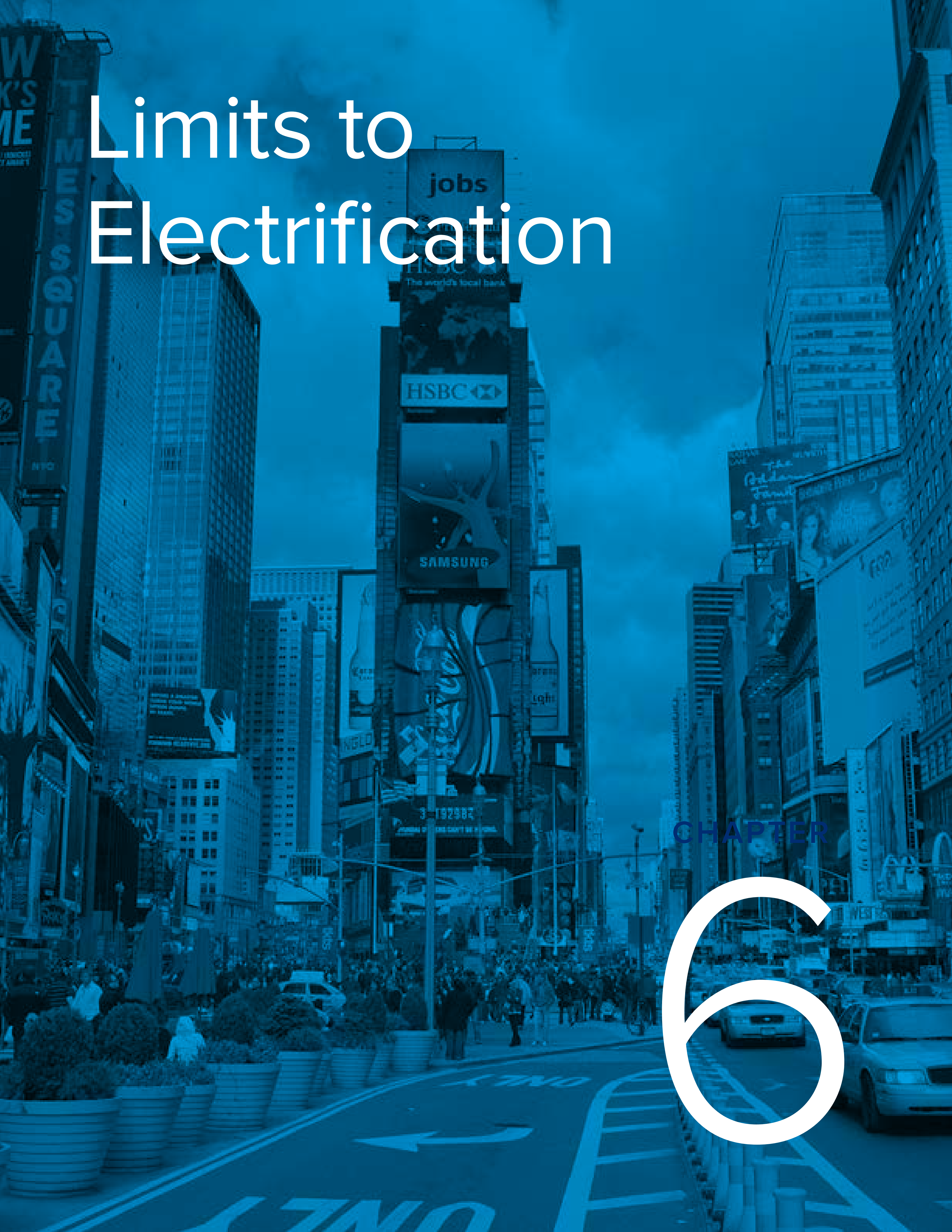
Last Words

Extensive research aligns on what's needed for building decarbonization including high levels of efficiency, electrification, and grid interactivity. Building electrification displaces combustion of GHG emitting natural gas, fuel oil, and other fossil fuels used in buildings, which is necessary in fighting climate change, but along with a decarbonized grid, also provides better indoor and outdoor air quality.

The path to electrification is complex due to the diverse nature of New York State's building stock, the large number of existing buildings, and high percentage of homes and commercial spaces that are currently supplied with fossil fuels. At their peak, heating energy used in New York buildings is equivalent to more than triple the current air conditioning-driven summer peak demand of the State's electricity system. Electrifying heating will therefore add substantial new loads to New York's grid. However, there are several factors that can mitigate the scale of those impacts. These include proliferation of electric heat pump technologies, improvements in building envelopes that can decrease building heating demands, and installation of flexible and grid interactive. More research is needed to fully anticipate the impacts of electrification including in the area of low GWP and non-HFC refrigerants.

Limits to Electrification

CHAPTER 6



Introduction

While energy efficiency and electrification currently represent two of the primary pathways to decarbonize New York's building stock, not all building types and energy demands can be readily or cost-effectively electrified with today's technical solutions.

The limitations to electrification include both technical and economic barriers. In some cases, there may be a role for low or zero-emissions fuels to reduce or eliminate GHG emissions from hard-to-electrify building energy demands, but those fuels are projected to be limited in quantity and in high demand from other sectors of the economy.

Today, a substantial share of New York's energy demand is met by fossil fuels.

This is especially true of building heating demand, which constitutes over 30% of final energy demand in the State.[51] The largest source of thermal energy in New York is natural gas, transported over an extensive regional pipeline system and delivered to buildings via gas distribution, transmission, and storage assets that are worth approximately $9 billion.[52]

Given the magnitude of the energy demand transformation required, electrifying the State's building stock represents one of the greatest challenges facing Climate Act implementation. If electrification is to achieve scale, there will be a substantial shift of energy demand from the State's natural gas and fuel oil delivery systems to its electric grid.

Empire State Building, New York City, New York.

Empire Buildings Challenge Awards

NYSERDA recently announced its first four awards in the Empire Buildings Challenge recognizing best-in-class solutions for decarbonizing existing high-rise buildings, achieving aggressive energy performance and GHG emissions targets through public private partnerships with leading commercial and multifamily real estate owners. Awardees Include the Empire State Building, a phased retrofit of a historic icon; a Hudson Square Portfolio building, a comprehensive retrofit demonstrating a novel technology package from northern Europe for radiant heating and cooling; Omni New York, retrofit of two affordable housing buildings in Yonkers showcasing how to leverage a recapitalization opportunity to comprehensively retrofit energy systems and modernize affordable housing; and L+M Fund Management's retrofit of three buildings in Harlem to dramatically cut heating and cooling through building envelope improvements, packaged terminal heat pumps, state of the art heat pump water heaters, and electric laundry dryers.

Difficult-to-Electrify Buildings & Loads

Most buildings in New York can achieve carbon neutrality through the primary path of electrification and energy efficiency.

However, a subset of the State's building stock will be more challenging to electrify. These building types include:

- **Some very tall buildings** that are primarily located in dense urban settings such as New York City.
- **Energy uses that require very high temperatures,** especially industrial and laboratory buildings with energy intensive processes.
- **Multi-building central steam plants and district energy systems** where investments are both large and long-lived, making electrification of existing steam systems challenging.
- **Thermally inefficient buildings** where electrification of space heating will contribute to increased peak space heating loads.

Very Tall Buildings

The *Roadmap* refers to very tall buildings as those that are 40 stories or taller. Within the State, these buildings are primarily located in New York City. There are several features of these buildings that make them potentially difficult to electrify including curtain wall envelopes, large base energy loads, exposure to high winds, heat stack effects that increase heating demands on lower floors, and the need to both heat and cool simultaneously during many hours of the year. They also have small roof space in relation to building energy load which limits equipment options.

Due to these features, there are less highly efficient technical solutions—such as hydronic solutions which are expensive to apply in a retrofit—and the cost of improving envelopes of existing buildings to high performance levels can be prohibitively expensive, particularly for buildings with predominantly glass curtain walls. This sector is an important area for RD&D on potential decarbonization solutions, some

Court Square

As proposed, Court Square will be a 'super-tall' mixed use building containing thirty-eight floors of luxury condominium dwelling units, nine floors of office space, a future city library and future retail space. The project embodies sustainable luxury re-imagined to meet today's energy and climate based challenges and serves as a leading example of how all of the above can be realized seamlessly together. The project will fully electrify its HVAC and hot water systems with water-source heat pumps and heat pump boilers for the residential space, and heat-recovery VRF units for the offices. A combination of both may be used in the retail and library spaces. The project will certify as LEED Gold under MFMR protocol and will incorporate induction cooktops, heat pump dryers and smart learning thermostats in all residential units. Set to be completed in 2025, it may also include additional daylighting and energy management measures. More information on this project can be found on the Buildings of Excellence website.

of which are expected to be demonstrated in the near term through NYSERDA's **Empire Building Challenge initiative**. Tall buildings will be studied in depth in a subsequent iteration of this *Roadmap*.

Buildings with High Temperature Process Loads

Industrial customers used 11% of natural gas consumed in New York in 2020.[53] Industrial sector gas demand includes both product creation (e.g. reformation of methane to produce hydrogen) and combustion to provide process and space heating. According to Lawrence Berkeley National Laboratory, a large share of industrial end uses can be electrified from a technical perspective but face significant economic barriers due to the fuel cost differential between natural gas and electricity.[54] In 2020, the average delivered cost of natural gas to industrial customers in NY was $7/MMBtu while the average cost of electricity delivered to the State's industrial sector was over $16/MMBtu.[55] Electrified systems offer efficiency advantages over thermal systems, but not enough to offset the incremental cost of electricity for large process heat sources such as boilers. A potential exception is industrial HVAC and lower-temperature hot water demands where heat pumps offer operating cost advantages. These applications constitute a small proportion of industrial energy demand, estimated at about 5% of total U.S. industrial energy demand.[56]

Barriers to electrification in the industrial sector extend beyond differentials in input energy costs. Some industrial loads will require reengineering of certain processes in order to be electrified. For instance, industrial processes that use combined heat and power (CHP) would need to be reconfigured to be powered by electro-technologies.[57] The cost of those retrofits is difficult to generalize and will require detailed analysis at the sector or facility level to characterize with accuracy. However, the economics of industry electrification are unlikely to remain fixed over the course of the next 30 years. If fossil fuels become more expensive, or low-carbon fuels are required to reduce the GHG intensity of fuels, then the economics of industrial electrification may improve.

Multi-Building Central Plants and District Energy Systems

District energy and central plant systems are an important form of heat delivery in New York. These systems deliver heat to urban cores and to buildings on institutional campuses throughout the State. District heating and central plant systems in New York typically use natural gas as a fuel source and often power a CHP process that delivers high temperature hot water or steam to buildings. District energy systems sometimes deliver lower temperature hot water and chilled water to buildings, for example the district thermal networks described in **Chapter 4 Construction Technologies and Building Methodology**. In both cases, district heating systems represent an energy efficient method to deliver heat but cannot be considered carbon neutral when powered by natural gas or other fossil fuels.

425 Grand Concourse. *Rendering Credit: Dattner Architects Synoesis, LLC*

The largest district energy system in the State is the Con Edison steam system in New York City which provides heat to over 1,600 buildings. The Con Edison steam system is primarily powered by five central plants that use natural gas for energy. A recent study developed in partnership by Con Edison and the City of New York found an ongoing, though reduced, role for a decarbonized Con Edison steam system in the future. That role includes continuing to serve very large commercial, institutional, and industrial facilities where full electrification upgrades are costly or otherwise infeasible.[58]

District energy and central plant systems are large, centralized, and capital intensive. Replacing or substantially retrofitting these systems will require significant investments that will increase the total system costs for all building users. A further challenge is that district and central plant systems are long-lived infrastructure assets, creating fewer opportunities to replace them at end-of-life within the Climate Act timeframe. Barring end of life replacement, it may be possible to electrify certain buildings or loads within a district energy system with technologies such as mini-split or package terminal heat pump installations.[59] However, electrification of a subset of a district energy system's customer base would increase the average cost for remaining customers, potentially spurring additional customer defection and making district systems less economically viable.

Alternatives to natural gas-fueled district energy and central plant systems include geothermal, water-source heat pumps, combustion of woody biomass, and advanced zero carbon fuels like zero emission hydrogen or renewable natural gas.[60] The suitability of these solutions will depend on both technical and economic factors specific to each district energy system. A key technical consideration is whether a system currently delivers heat via steam or hot water. This informs the temperatures required from the energy source powering the district system. In general, heat pumps have lower heat capacities than boilers and so may be ill-suited to steam-based systems. It may be possible to convert certain steam systems to hot water by retrofitting distribution piping and radiators, though such conversions may double the cost of replacing a failing central plant relative to the conventional approach.[61]

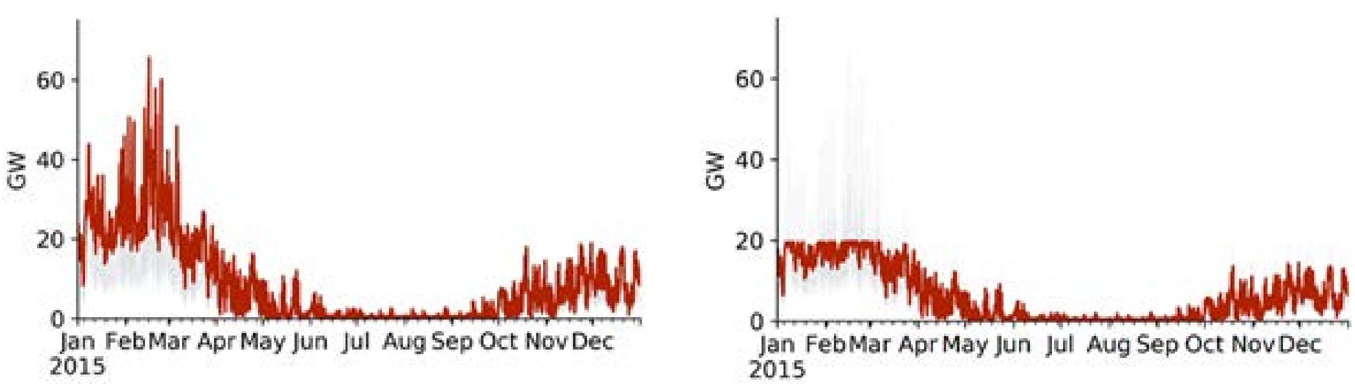
Peak Space Heating Loads

During very cold weather, less thermally efficient buildings using air source heat pumps as their primary heating system may require a source of supplemental heat to maintain occupant comfort. Electric resistance strips could provide supplemental heat, but this could lead to adverse electric system impacts, which were discussed in Chapter 5: Building Electrification and the Grid. These loads can be markedly reduced via investments to improve the efficiency of building envelopes, though the energy system and comfort benefits of such investments will need to be weighed against their costs. An alternative approach would be to partially electrify buildings by installing electric heating systems with combustion backup using low or zero carbon fuels. Figure 6.1 compares two different hourly load outcomes across New York's building stock. One outcome shows loads consistent with adoption of minimum cold-climate air source heat pumps per the NEEP Cold Climate Heat Pump Specification,[62] compared to a second outcome showing widespread deployment of heat pumps with combustion backup.

Systems with combustion heat backup have the potential to substantially reduce grid impacts and may also offer reliability and resilience benefits. These systems have emerged as a promising technology strategy across a range of European heat decarbonization studies[63, 64, 65, 66] and pilot projects there have begun to explore the operations and business models of partial electrification.[67]

The energy system value of systems with low or zero carbon combustion backup is predicated on the availability of lower-GHG fuels and maintenance of liquid or gaseous fuel delivery systems in order to reduce costs in the State's electric system. Regulatory and business model innovation would be needed to ensure that the combined costs of these energy systems are considered in the State's planning and rate-making processes. Absent cost-reflective rates, the electric system cost savings that would be enabled by scenarios with combustion backup will not be incorporated into consumer decision-making, reducing the chance that those benefits are captured. Finally, high reliance on lower GHG fuels carries cost and availability challenges, which are discussed in the next section.

FIGURE 6.1: NEW YORK SPACE-HEATING PEAK LOADS IN 2050



NEEP minimum ASHP (left) vs heat pumps with combustion backup (right) as modeled by E3

Low-Carbon & Renewable Fuels

Low-carbon and renewable fuels refer to several different liquid and gaseous energy carriers. In many cases, low-carbon fuels could be delivered by existing energy infrastructure and utilized in existing appliances.

The 'drop-in' nature of these fuels means that they could be well-suited to applications where electrification is either not technically feasible or where retrofit costs are prohibitive. For example, low-carbon and renewable fuels might be used to decarbonize district heating and central plant systems without the challenges associated with substantial retrofits or to allow the use of combustion back-up without the associated greenhouse gas emissions. However, supply and cost constraints will very likely limit the use of these fuels to a small number of priority applications within the buildings sector.

Sources of Low-Carbon and Renewable Fuels

Low-carbon and renewable fuels can be produced from a variety of sources:

Waste biomass resources can be converted via thermo-chemical processes into renewable fuels like biomethane, renewable diesel, renewable gasoline and renewable jet fuel. These resources are typically less expensive than most other forms of low-carbon fuels, but are limited in quantity.[68, 69] Waste biomass can also be gasified to produce hydrogen in a process that, if paired with carbon capture and sequestration, could potentially produce a carbon negative fuel.[70]

Electricity can also be used to produce hydrogen via electrolysis of water. Hydrogen produced via electrolysis needs to take into account the fuel source that generated the electricity to fully understand its emissions and environmental impact.[71] These fuels are in effect an indirect form of electrification and are most useful when their relative inefficiencies compared to direct electrification are offset by their ability to store energy for long-periods of time. Small shares of hydrogen, up to 15% by energy content, can be blended into gas pipelines to reduce the GHG intensity of delivered gas.[72] Higher blends of hydrogen can plausibly be delivered to end-users, though doing so will require upgrades to both natural gas delivery infrastructure and end-user equipment.[73] A potential alternative use of hydrogen is as an intermediate input to create synthesized forms of methane, diesel or jet kerosene. Synthetic fuels are produced by combining hydrogen and a climate neutral source of CO_2 using Fischer Tropsch or Sabatier processes.[74, 75]

Fossil fuels, especially natural gas, can also be used to produce hydrogen. Hydrogen produced with fossil fuels is considered by some to be a lower emission fuel.[76] However, other research has found hydrogen produced from fossil fuels may carry incremental emissions relative to the direct use of natural gas in buildings.[77] As a result, it would not be accurate to describe a building heated by hydrogen produced from fossil fuels as carbon neutral.

Low-carbon and renewable fuels carry substantial cost and scalability challenges. Fuels produced from waste biomass are, in most cases, the lowest cost, low-carbon fuels available, but carried incremental costs of $10 per MMBtu or more compared to the price

Albany, New York.

TABLE 6.1: LOW-CARBON AND RENEWABLE FUEL PRODUCTION APPROACHES

Each column represents low-carbon fuels that can be produced using waste biomass, electricity and fossil fuels respectively.

Waste Biomass (manure, wood, cellulose, etc)	**Electricity** (solar, wind, hydro, geothermal, nuclear)	**Fossil Fuels** (natural gas, coal)
Biogas	Hydrogen via electrolysis	Hydrogen via steam methane reformation of natural gas with carbon capture
Biomethane	Synthetic natural gas	Hydrogen via coal gasification with carbon capture
Renewable diesel	Synthetic diesel	
Renewable gasoline		
Hydrogen via gasification		

of natural gas in 2019.[78] Furthermore, fuels produced from waste biomass are limited in quantity and will be demanded by other energy intensive sectors of the economy where large-scale electrification may not be possible, such as aviation. After the potential of waste-biomass based resources is exhausted additional demands for low-carbon and renewable fuels will need to be met via hydrogen and synthetic fuels. These fuels are advantageous in that they do not face the same fundamental resource limits of biofuels, but they do come at present with substantial incremental costs over both fossil fuels and biofuels.

The costs of producing low-carbon fuels are high due to their substantial required infrastructure investments. Production of renewable natural gas (RNG) requires either anaerobic digestors or gasifiers, as well as infrastructure to upgrade the resulting gases to pipeline quality. Clean hydrogen production requires investments in both electrolyzer and zero-GHG electricity generation. Hydrogen production carries roundtrip efficiencies of between 60% and 70% today, or approximately one-quarter the efficiency of a heat pump.[79, a, b] Synthetic fuel production requires additional infrastructure in the form of Sabatier or Fischer Tropsch reactors and capital associated with capturing climate neutral CO_2 to ensure the system's carbon neutrality. As a result the forecasted commodity costs for renewable natural gas, hydrogen and synthetic natural gas range from $10 to $20 per MMBtu for biomethane and hydrogen, and approach or exceed $30 per MMBtu for synthetic natural gas The GHG intensities of low carbon fuels can vary substantially based on feedstock and production processes. Certain biofuels, for instance, corn ethanol, may carry lifecycle GHG emissions that approach or exceed the emissions of the fuels they displace.[80] Production of certain other fuels, such as hydrogen produced through gasification of biomass, can be paired with carbon capture to produce negative emissions opportunities.[81] Finally, the production of some biofuels and hydrogen using carbon capture may result in incremental methane leakage, which could erode or eliminate the climate benefits of those fuels.[82, 83] A complete accounting of the GHG intensities of low-carbon fuels is beyond the scope of this *Roadmap,* but developing such an accounting framework will be important as the State continues to study pathways to achieve both carbon neutral buildings and its economy-wide GHG reduction ambitions.

Finally, lower carbon fuels result in non-CO_2 combustion emissions that are similar to natural gas for biomethane or synthetic natural gas, and NO_x emissions from combustion of hydrogen. Those emissions result in air pollution that causes negative health outcomes in New York, particularly in Disadvantaged Communities. Indeed, the Climate Action Council Draft Scoping Plan identified health benefits of up to $170 billion from today through 2050 from decarbonizing New York's economy, with most of those benefits following from improved air quality as a result of reduced combustion.

a Note that electrolyzer efficiencies are expected to improve over time, with efficiencies of 80% possible by mid-century.

b Heat pumps in New York can deliver over three times their input energy as useful heating energy.

Low-Carbon Fuel Suitability

Low-Carbon and Renewable Fuels as a Source of Back-Up Power

Back-up power is one potential use of low-carbon fuels. Electrification will shift heating energy demands from multiple energy systems to the State's electricity system and raises concerns about reliability. A typical customer will experience approximately one outage per year, while 1 in 100 natural gas customers experience a planned outage per year and 1 in 800 experience an unplanned outage.[84] The risk of increased frequency and intensity of severe weather makes the reliability and resilience of building energy supply a critical consideration.

Solutions like distributed solar, batteries, and microgrids could both increase the reliability of electric power system as well as provide resiliency for building owners in the event of a grid outage. Substantial improvements to the duration of battery storage technologies are necessary for battery storage systems to address lengthy outage events. Alternative technologies like stationary fuel cells or generators have nearly unlimited duration so long as liquid and gaseous fuel supplies are physically and economically available during an outage. Reliance on these technologies could be consistent with carbon neutral buildings, provided they use low-carbon or renewable fuels. A detailed examination of resilience considerations is reserved for **Chapter 7: Carbon Neutral Buildings and Resiliency**.

Considerations for the Delivery of Low-Carbon and Renewable Fuels

An important consideration for the role of low-carbon fuels in carbon neutral buildings is the cost of their respective delivery infrastructures. New York's natural gas system accrued $2.2 billion in operating revenues in 2016.[85] Of that total, $1.9 billion in revenues were collected from residential and commercial customers and this *Roadmap* envisions a future where large numbers of those customers choose to electrify their buildings. Absent substantial reductions in system investments and maintenance costs, large-scale building electrification will lead to gas system costs being spread over a smaller customer base. As a result, it may be challenging to maintain the financial and operational viability of the State's gas system for those end uses that do need renewable fuels. Depending on how system costs are managed, this dynamic could mean that the cost of fuels like hydrogen and renewable natural gas will incur substantial incremental commodity and delivery costs compared to natural gas today. As a result, the economics of electrification versus reliance on low-carbon fuels is likely to be contingent on a variety of production and delivery cost factors that are currently uncertain.

Manhattan skyline.

Rural Heating Load with Modern Wood Heat

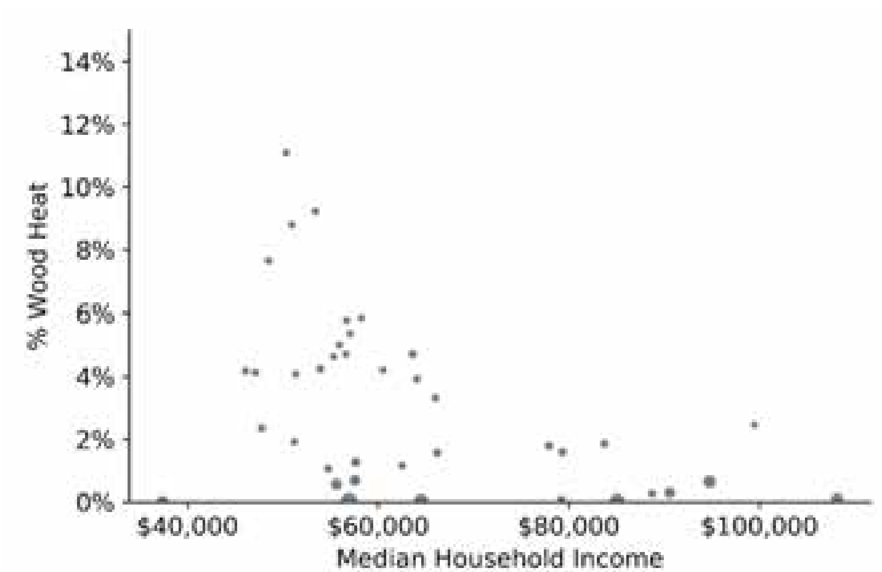
New York's rural regions are often colder, have lower per-capita levels of income and wealth, and are less likely to have access to natural gas. In many of these regions, woody biomass in the form of cord wood or pellets is an important source of heat for many residents. While only 2% of statewide residential heating energy is provided by wood, in some rural counties, up to nearly 12% of homes rely on wood as their primary source of heating.[86] However, actual reliance on wood heat may be higher than is identified via surveys because wood is often sold as a cash product or directly gathered by its users. Counties with higher levels of wood heat tend to have lower per capita incomes than counties that do not rely on wood heat (Figure 6.2). In those counties, wood heat may provide a more cost-stable alternative for low-income customers to fuels with relatively volatile costs like propane, fuel oil, or kerosene.

There is a debate among experts about under what, if any, conditions serving an energy load with wood can be considered renewable.[87] In addition to technical arguments, there are unresolved questions of whether wood fuel, and biomass generally, counts as GHG-neutral under the Climate Act. In addition to GHG accounting considerations, it is also important to acknowledge that wood heating produces air pollution in the form of fine particulate matter with its well-established negative health consequences. In fact, wood combustion is the primary source of particulate matter emissions in several rural New York counties.[88]

An emerging set of technologies, including biomass boilers and wood pellet stoves, categorized under the term Modern Wood Heat (MWH), hold the potential to improve the efficiency of wood heating and markedly reduce particulate emissions from these systems. MWH also incorporates sustainable forestry practices increasing the likelihood that wood heat can be a lifecycle carbon neutral resource.

However, residents who currently rely on wood heat may be unwilling or unable to electrify their homes. Conversions to heat pump systems may require substantial incremental costs that low- and medium-income households cannot afford. Furthermore, the operating cost savings associated with a heat pump may not be realized in cases where occupants gather some or all of their own wood, thereby negating the direct investment required to heat their home with that fuel. As a result of those economic considerations, wood is likely to continue to be a source of heat for some homes in New York over the timespan of the *Roadmap,* and it is important to convert these homes to MWH and improve the energy efficiency of the homes, particularly with regarding to the building envelope.

FIGURE 6.2: MEDIAN HOUSEHOLD INCOME AND SHARE OF RESIDENTIAL HOMES WITH WOOD AS THE PRIMARY SOURCE OF HEAT BY NY COUNTY

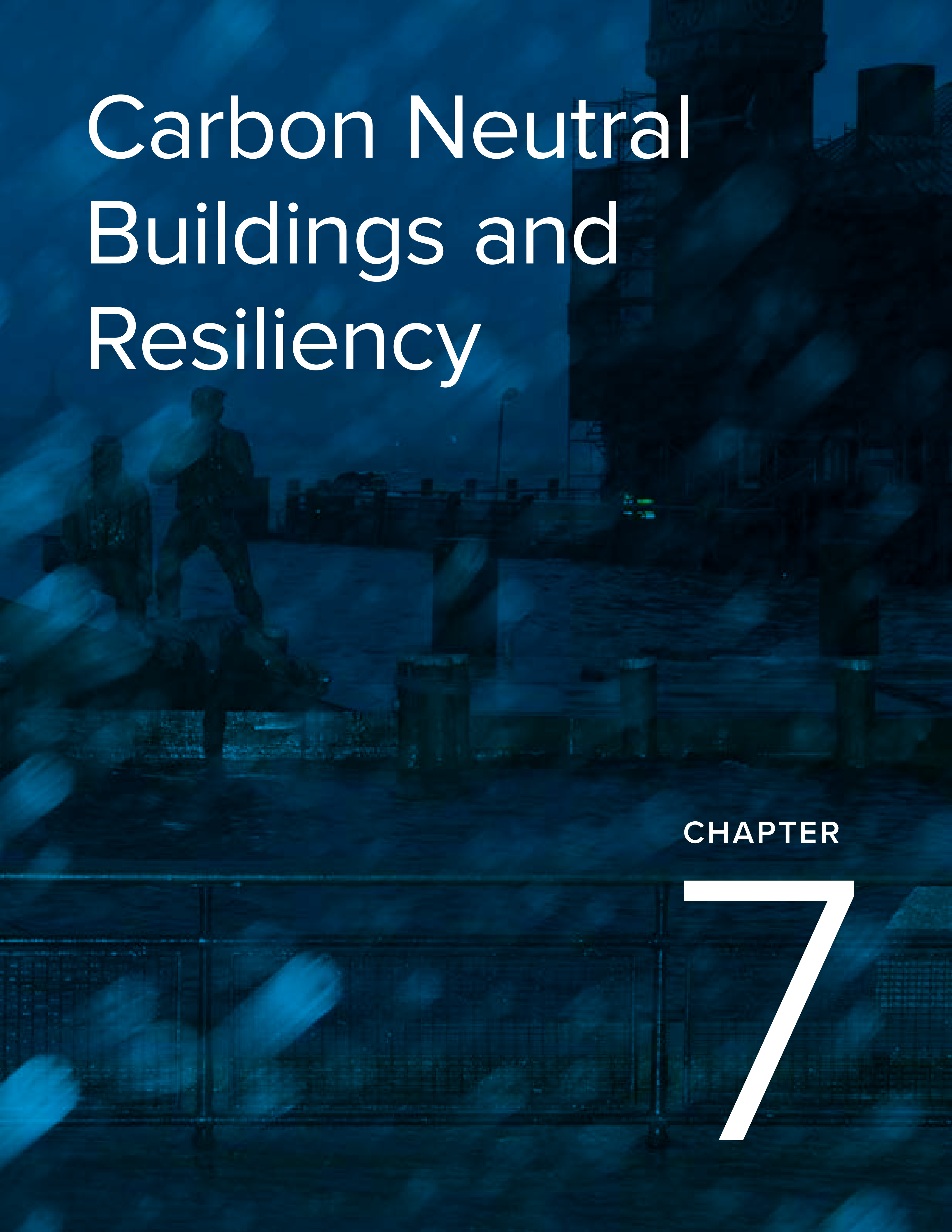


Source: Data are from the American Community Survey. The size of dots indicate the relative number of households in each county.

Last Words

There will be some building types and loads that cannot be easily electrified for both technical and economic reasons.

For these end uses capital planning, cost compression, technological improvement, and innovation will make electrification easier or more cost-effective over the medium- and long-term. Even so, a proportion of buildings may remain extremely difficult to electrify in the timeframe considered by the *Roadmap*. For these cases, a limited quantity of low-carbon and renewable fuels may be the best option to cost effectively satisfy these buildings' heating and process energy demands. However, these fuels face substantial uncertainties in terms of their commercialization, cost, and environmental attributes.



Carbon Neutral Buildings and Resiliency

CHAPTER 7

Introduction

Buildings across New York State will continue to be exposed to more extreme flooding, precipitation, and heat events due to a changing climate. These challenges not only highlight the imperative of reducing carbon and other GHG emissions to help slow the pace of climate change, but also the need to embed resiliency measures in the State's residential and commercial buildings. These measures will help protect lives and infrastructure from impacts of future climate hazards.

Research by the Federal Emergency Management Agency (FEMA) suggests that proactive resiliency investments are highly cost effective, yielding $6 in avoided post-disaster recovery costs for every $1 invested in pre-disaster resilience upgrades.[89]

Resiliency and decarbonization strategies are mutually supportive, making carbon neutral buildings inherently more resilient than their code compliant counterparts. Decarbonization strategies such as electrification, efficiency, (emphasizing high performance envelopes), demand flexibility, and onsite energy generation and storage support both active resiliency and passive survivability.

This chapter provides an overview of key climate hazards, discusses their impacts on buildings, and explores how technologies can deliver carbon neutral buildings and improve resiliency at the same time. Resilient buildings are those built to withstand, or recover quickly from, natural hazards, as well as to perform to its intended design standard throughout its useful life in a changing climate.[90] The resilient design strategies and technologies discussed in this chapter are relevant to both new construction and existing building stock in New York State.

Buildings are typically designed for long lifespans and will experience increased intensity and more frequent threats as the climate changes over the coming decades. This will amplify pressures to improve building performance, and reduce casualty risk. Incorporating these considerations in building design and construction will maintain the long-term viability of the built environment's ability to respond to a warming climate while supporting the health, safety, and comfort of occupants.

Moreover, resilient design enables buildings to last longer, extending the period before a building needs to be replaced or substantially renovated. Because construction is carbon intensive, reducing the frequency needed for upgrades can significantly decrease embodied carbon impacts. Several New York State policies, initiatives and resources currently address resiliency. The Community Risk and Resiliency Act (CRRA) mainstreams the consideration of climate change through five major provisions:

- Adoption of official sea-level rise projections;
- Consideration of sea-level rise, storm surge, and flooding in certain State policies and programs;
- Addition of Smart Growth Public Infrastructure Policy Act resiliency criteria;
- Development of guidance on natural resiliency measures; and
- Development of model laws concerning climate risk.

Through the Resilient NY Initiative, the State is advancing recommendations for climate resiliency in the building code, developing and implementing agency adaptation plans, and supporting local resiliency plans. While the recently enacted Climate Act mainly focuses on emissions reduction, it also includes provisions for increasing the State's climate resiliency, particularly in Disadvantaged Communities. A shift to a resilient, carbon neutral building stock presents an immense opportunity for the State to not only mitigate climate change but also ensure that the low- and zero-carbon buildings of the future are functional, safe, and sustainable spaces for decades to come.

Climate Hazards

New York State faces a wide range of climate hazards due to its size, geography, and socioeconomic diversity. These hazards are expected to increase in frequency, intensity, and duration due to climate change.

Buildings must be resiliently designed to perform across a widening range of conditions such as extreme heat, extreme cold, and storm events that increase in frequency and severity.

Hurricanes and Tropical Storms

Hurricanes and tropical storms develop over tropical and sub-tropical waters before moving inland. Severe winds, intense precipitation, and both inland and coastal flooding.

Storms likely to increase in strength due to rising oceanic and atmospheric temperatures.

Flooding

Floods result from an increase in small-scale thunderstorms, coastal storms, storm surge, higher tides from sea-level rise, seasonal Nor'easters, and rapidly melting snowpack.

Extreme precipitation projected to increase, with the greatest increases expected to occur in the northern parts of New York State.

Severe Storms

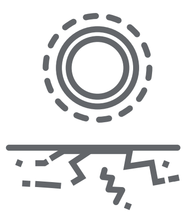
Severe storms bring lightning, high winds, intense rainfall, hail, tornadoes, and flooding.

With projected rising temperatures, frequency, intensity, and duration of severe storms is expected to increase.

Winter Storms and Cold Snaps

Winter storms, including cold temperatures, snow, ice, high winds, blizzard conditions, and lake effect snowstorms.

Strong potential for increased lake effect snow in the near term resulting from a decrease in ice cover over the Great Lakes.



Heat Waves

Extreme temperatures can have direct health impacts and can also impact infrastructure and equipment performance.

Summers are expected to become hotter. Frequency and duration of heat waves (3+ consecutive days with maximum temperatures ≥90°F) expected to increase.

Sea-Level Rise

Warming ocean waters expand and glaciers and ice sheets melt. Coastal erosion, permanent flooding, and coastal displacement will occur.

Sea levels along the State's ocean coast and Hudson River are projected to increase 5–8″ by the 2020s, 18–28″ by the 2050s, 44–52″ by the 2080s.

Impacts of Climate Change on Buildings

Climate hazards pose unique challenges to the more than six million buildings in New York State today. Historical flood maps show that approximately 700,000 New Yorkers live in "flood-prone" zones, with many more working, traveling, or recreating in these areas.

As the floodplain expands, and the number at risk rises, buildings must be adapted to prevent damage to health and home.[91] Some hazards, such as increasing average temperatures and sea-level rise, will occur gradually while others, including heat waves and severe storms, will cause emergency scenarios. The impacts of these events will be regionally distributed and will also vary depending on building type, making certain areas and occupants more vulnerable than others.[92]

Building Envelope

Roofs have the greatest exposure to precipitation with low-slope or geometrically complex designs being most prone to water penetration. Windows and doors are vulnerable to water intrusion and breaches to the building envelope may result in internal damage as well. The possibility of winter storms with increased precipitation may cause increased snow and ice roof loading that leads to structural damage or collapse. Ice dam formation may damage eaves and allow water to penetrate roofing. Heat waves can also damage building envelopes, reducing the service life of building cladding material, while higher humidity levels may increase corrosion or rotting of structural elements. Building envelopes also create the most significant passive survivability benefit by helping to keep internal temperatures in buildings comfortable and survivable for much longer periods of time.

Critical Systems and Facilities

Within buildings, critical systems include heating, ventilation, air conditioning, security, life safety, lighting, telecom, and energy management. These systems are rarely independent—often, they rely on each other to operate effectively. For example, most building systems require base electrical service for power, and computer systems often need supplemental cooling to operate properly. These systems can be especially vulnerable to flooding if they are located below the base flood elevation.

Hurricane Sandy aftermath.

Critical community facilities, including hospitals, nursing homes, prisons, water treatment facilities, and emergency operations centers, must be functional both during and after an extreme weather event. Other buildings such as schools, airports, and community centers can provide essential services, shelter, and a safe refuge. These facilities must have sustained operation for their critical systems in order to act as cooling or heating centers.

Cross-dependencies in building systems and community facilities create a potential for cascading effects, which occur when failure in one part of a system causes failure in another. Following Superstorm Sandy, power outages led to cascading disruptions to cell towers and prevented individuals from charging their mobile devices, leaving people unable to communicate with emergency services. During COVID, heat waves combined with the need for isolation left many inside buildings in dense urban areas without ventilation or cooling.

Occupant Health and Safety

Occupant health and safety must be the primary consideration. Some of the key climate risks to occupant health include thermal stress from heat waves or cold snaps and unsafe levels of indoor air quality as a result of mold growth and material breakdown due to the presence of floodwater. The mold and bacteria growth can lead to disease or exacerbate conditions such as asthma.[93]

Heat waves stress the energy systems that buildings rely on and put occupants at risk for heat-related illnesses and death—especially, and disproportionately, heat-vulnerable individuals—due to lack of air conditioning or other cooling strategies. Seniors living alone and without access to air conditioning are particularly high risk. For example, the average age of the 79 individuals who died just in Oregon during the June 2021 heatwave that swept the Pacific Northwest was 67 years old.[94] The first communities to lose power during the 2021 Texas winter storm were predominantly Black and Latino.[95] Children are also vulnerable due to the amount of time they spend in school buildings that may have inadequate cooling infrastructure or a lack of protocols in place to respond to heat waves.

Resiliency: Strategies & Benefits

Resilient design strategies are well documented today and becoming better understood and emphasized by the design and construction community. Many carbon neutral design features contribute to passive survivability, allowing building occupants to remain safe and comfortable for longer during an outage.

Higher insulation, better air sealing, proper building orientation, high performance windows, and other passive heating and cooling measures, reduce thermal exchange between the outdoor and indoor environment. These measures enable buildings to maintain safe indoor temperatures longer during a loss of power or extreme heat wave or cold event. Thermal mass improvements help moderate temperature swings and reduce the need for additional heating or cooling. Examples of these measures to follow and resources on best practices are available. Further, design strategies that improve both energy efficiency and resiliency are often very cost-effective over the lifecycle of a building.

Overarching Concepts and Benefits

Resilient design touches many different physical and economic considerations of buildings. The following include some of the most notable benefits of resiliency.

Resiliency Provides the Biggest Benefits to the Most Vulnerable

Due to historical injustices, New York's underserved communities are the most vulnerable to climate risks. Poorly constructed and maintained buildings, a lack of green-space, and limited financial resources have left swaths of environmental justice communities with building stock that is disproportionately exposed to the risks of climate change. As a result, these communities will see the most benefits from fortifying their buildings with resiliency measures.

Significantly hotter temperatures in the future will increase the urgency of bringing cooling technology to residential buildings, especially affordable multi-family buildings in urban locations that are susceptible to heat island effects. Disadvantaged Communities and communities of color are at a greater risk of heat-related deaths, as they are frequently situated in areas with higher Heat Vulnerability Index (HVI) ratings from the Health Department. More about how the Roadmap addresses work necessary to support Disadvantaged Communities can be found in **Chapter 10: Equity and Decarbonizing Disadvantaged Communities.**

Passive survivability is the ability of buildings to maintain safe conditions and a reasonable level of functionality in the event of a power outage.[96] Passive survivability can be achieved by incorporating resilient design principals such as load-reducing strategies, natural ventilation for cooling, passive solar for heating, high efficiency building envelopes, and daylighting.

Passive measures like tighter envelopes improve the efficacy of cooling equipment and offer energy savings, but should be implemented in conjunction with ventilation systems to improve indoor air quality and avoid moisture build-up in wetter weather and extreme temperatures. Natural ventilation and operable windows provide a way to exhaust hot and stale air without the use of fans and allow for free passive cooling via natural cross ventilation.

Passive survivability helps ensure all homes are safe and comfortable. In exceptional times, such as during public health emergencies when families are sheltering in place for extended periods, a climate controlled and adequately ventilated indoor environment is essential to enable families to work from home, attend online school, and care for and communicate with loved ones. This is especially important for vulnerable groups who may be less likely to have alternate locations to shelter during heat waves, extreme cold spells, or power outages.

As weather events become more severe there will be limitations to how much passive survivability can satisfy occupant needs in emergency conditions. And while new construction can be designed explicitly for passive survivability, it may be challenging or impossible to retrofit intrinsic strategies like natural ventilation into existing buildings. One of the major benefits of electrification is that heat pumps provide cooling as well as heating. Heating electrification can thus provide life-saving cooling in buildings previously lacking mechanical cooling, and emergency considerations will be especially important in challenging existing buildings.

Resiliency Improves Lifecycle Economics

When it comes to resiliency the cost of action is far lower than the cost of inaction. For both new and existing buildings, adaptation efforts can help owners avoid high costs from damage during extreme weather events. For example, a building constructed to meet current code was found to produce a benefit-cost ratio of $11 of avoided extreme weather damage for every $1 invested when compared to design standards from the 1990s. Since New York State has many buildings built before 1990, the benefit-cost ratios may be even higher for a significant portion of the building stock.[97]

EcoVillage. *Photo Source:* **GO Logic**

Passive Survivability in Practice

Belfast, ME

The EcoVillage in Belfast, ME, is a passive house community that boasts R-45 wall insulation and R-80 ceiling insulation, heat-recovery ventilation, is PV ready, and faces south. When an ice storm led to a power outage that lasted five days, only 8 to 10 degrees of internal temperature were lost. Residents pay $300 in annual heating costs, and the homes' design results in a 90% reduction in energy use for space heating compared to the average house.[102]

> Studies have shown that adding one to three feet of freeboard above the base flood elevation can pay for itself within a few years through a 25-60% annual reduction in flood insurance premiums.[103]

Resiliency Reduces Insurance Costs

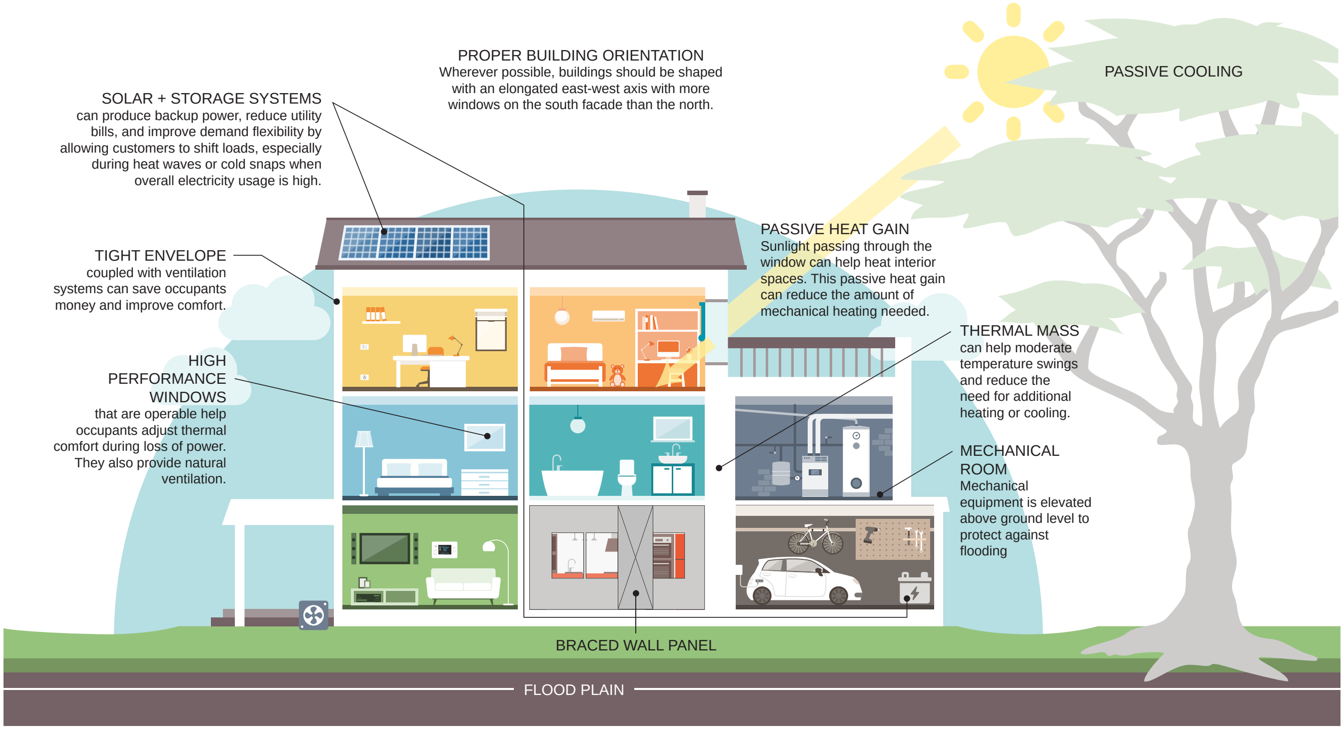
Inclusion of resiliency and efficiency measures can reduce insurance costs for building owners. For example, mitigating risks associated with flooding or other natural disasters is financially prudent today in many regions. Studies have shown that adding 1 to 3 feet of freeboard above the base flood elevation can pay for itself within a few years through a 25–60% annual reduction in flood insurance premiums.[98]

Verifying the installation of natural disaster mitigation techniques with insurance companies could result in a reduction of insurance premiums. There are several accepted third-party certifications and programs that standardize this process, mostly for residential buildings. According to the U.S. Green Building Council, LEED-certified homes can qualify for discounted homeowner's insurance, tax breaks, and other incentives.[99]

Homes with the Insurance Institute for Business and Home Safety (IBHS) FORTIFIED certification could also qualify, though the number of certification evaluators is currently limited. Additional research and collaboration are needed to aggregate information on existing resiliency measures that could qualify for insurance reductions in New York State.

For potential reductions to flood insurance for buildings owners, officials can look to enroll qualifying communities located in floodplains with the National Flood Insurance Program **Community Rating System** (CRS) to reward the use of enhanced floodplain management activities that encourage risk-reduction measures for buildings and with lower premiums.[100] Currently, 53 communities in New York take part in the CRS, along with over 1,500 communities nationwide.[101]

FIGURE 7.1: PASSIVE BUILDING FEATURES THAT SUPPORT RESILIENCY AND CARBON NEUTRAL BUILDINGS, ENABLING A HOME TO RUN LONGER ON LESS ENERGY



Resiliency is Supported in Codes, Standards, and Zoning

As updates to codes and standards catch up to changing conditions and best practices, local governments can choose to enact additional new code provisions. Over 50 municipalities in New York State have already adopted local standards that are more stringent than state codes to address the unique needs of their jurisdictions. Building standards which focus on resiliency have proven effective in minimizing climate disaster fallout while increasing insurability. The National Institute of Building Sciences suggests that the IBHS FORTIFIED Hurricane standards have a high Benefit-Cost Ratio for wind protection.

Additionally, third-party building certifications provide alternative mechanisms for preparing buildings for resiliency beyond code-minimum requirements. Certifications such as the Institute for Market Transformation to Sustainability's RELi 2.0 provides a holistic, resilience-based rating system that combines design criteria with integrative design processes for next-generation buildings, neighborhoods, and infrastructure.

Building-Level Resiliency Strategies

Resilient and carbon neutral building strategies are reflected at two different scales, at the building level and community level. The fundamental principles behind carbon-free, resilient design are efficiency, flexibility, and durability, which work together to increase a building's or a community's ability to maintain comfort and functionality with fewer external inputs such as power from the grid.

There are many inherent resiliency benefits to decarbonization strategies. Electric heat pump conversions in existing residential buildings, for instance, can increase resilience against heat waves by providing cooling for occupants that did not previously have air conditioning.

Building-level resilient and carbon neutral solutions can be applied to all types of both new construction and existing buildings while lowering energy costs. Integrative design can reduce the scope and cost of resiliency measures, particularly in new construction (e.g. additional insulation may reduce the size of the required HVAC and backup power systems, saving cost and space). Features of a typical passive building design with resiliency and efficiency measures are illustrated in Figure 7.1.

Consider Long-Life Components and Systems

Climate resiliency enables buildings to last longer, which saves money, materials, and embodied carbon. When designing for climate resiliency, it is important to account for the lifespan of the component or system and its suitability for future climate conditions. Systems with long lifespans (25-year+ lifecycle), such as major HVAC equipment, exterior cladding, and insulation, should be designed for mid-century climate projections. Since major equipment upgrades are often large expenditures, it is important to consider the lifecycle operational costs of any major equipment, and the payback on incremental capital costs is usually justified. The siting, orientation and building of new structures should consider climate projections through their reasonable lifespan or 2100. Some design standards may need to be updated to accurately reflect operating requirements in future climate conditions.

Consider Partial Electrification

Building electrification should be implemented in such a way that it does not reduce resiliency. Even if a building is heated with a gas furnace or boiler, in most instances the systems still require electricity to function (e.g. for ignition and to operate fans to circulate the heated air). If the electric grid goes down in an extreme weather event, all-electric and partially electric buildings will both face challenges, and emergency systems should be tailored to an individual building's fuels, systems, occupancy and passive survivability. Residential fireplaces can provide resiliency safely in some applications, preferably with a small amount of low-carbon fuel or wood that is used primarily for supplemental heat or emergency backup.

Partial electrification is when a new all-electric system or systems are added to address most heating loads in an existing building, and existing fossil fuel-fired equipment is left in place to be used when temperatures drop to extreme lows. These backup systems would need to run on low or no carbon fuels for such a building to be considered carbon neutral. This strategy allows for smaller, cheaper electric heat pumps yet achieves significant emissions reduction, as discussed further in **Chapter 6: Limits to Electrification**.

In particular, refuge spaces, such as designated rooms or sections of buildings could be supplemented with a wood or pellet stove or fossil-fuel heating backups to extend the hours of safety for the occupants. It should be noted that gas infrastructure, like electrical grids,

High Performance Resilient Design in Practice

Brooklyn, NY

The solar-powered R-951 Residence in Brooklyn is the first Passive House-certified and net-zero-capable building in New York City. The three apartments have 4 kW of grid-tied generation from rooftop solar, an energy recovery ventilation system, triple-glazed tilt-and-turn windows and doors, a high performing building envelope, and a 1,200-gallon rainwater harvesting system. There is an outlet for daytime backup power during a utility outage. The high performance envelope improves passive survivability, and the rainwater harvesting can be used as a non-potable water source.[104]

Photo Source: ***GO Media Studios***

Home destroyed in Belle Harbor. Photo Source: New York State Division of Homeland Security and Emergency Services

Mayor's Office of Climate Resiliency

New York City Climate Resiliency Design Guideline

New York City, NY

To ensure that the New York State building stock can withstand and recover from natural hazards, resiliency strategies must be implemented rapidly. To support this aim, the New York City Mayor's Office of Climate Resiliency developed the New York City Climate Resiliency Design Guideline to provide advice on the construction of resilient buildings using forward-looking climate data in the design. **Click to find out more**

are also prone to failures, although with less frequency. Gas line failure also presents significant safety risks from potential explosions, which could be mitigated in an all-electric future.

Maintain Optionality

Resilient building technologies are constantly evolving, so whenever possible, buildings should electrify with integrated, modular systems to allow for greater flexibility in the future as technologies advance and building needs change. Building clusters should consider thermal energy networks to share heat, recover waste heat, and connect a range of heat sources and sinks in an urban setting. Back-up power sources and the ability to redistribute thermal energy or decouple from the electrical or thermal grid during times of emergency or stress will build resiliency.

Greater dependency on electricity calls for utility-level grid hardening and accountability. Laws such as the Soil Health and Climate Resilience Act of 2022 now requires climate assessments and resiliency plans to be submitted to the New York State Public Service Commission. Building level resiliency issues will be addressed further in the **Building Electrification Roadmap.**

Community-Level Resiliency Strategies

In addition to building-level resiliency upgrades, there are focal points that should be targeted to ensure the protection of the community at the neighborhood and city level. The following include some of the most notable community-level methods of ensuring both resiliency and carbon-neutrality.

Properly Site and Manage New Construction

In growing urban areas and population centers, land-use planning is important—new construction projects should avoid locating buildings in current or future flood-prone areas or locations where critical transportation routes face flood exposure. This is especially true for buildings that will serve as critical facilities during an emergency. Roadways should be oriented to optimize buildings' passive heating and cooling on cardinal north-south-east-west grids and to optimize daylighting.

Community-scale planning and infrastructure choices can help complement the building-level strategies discussed above. Through onsite stormwater management, erosion control, mechanical flood recovery, and water accommodation, communities can minimize risk of sewer overflow and reduce the risk of flooding. In addition to water management, tree-trimming and the burying of electrical distribution lines can reduce the likelihood of power outages caused by wind and ice damaged electrical lines.

Resilient Carbon Neutral Buildings and Affordable Housing

Queens, NY

Beach Green Dunes provides 101 affordable housing units and small commercial space in Far Rockaway, Queens. As the single largest Passive House multifamily building in the country certified by the Passive House Institute of America (PHIUS), Beach Green sets an important precedent of resilient and sustainable affordable housing.

The resilient design features include raised habitable space and utilities above the flood plain, flood relief elements like flood vents and flood barriers, daylight corridors and stairwells to provide light in case of power outage, and controllable elevators to prevent the cab from descending into flood waters. The project showcases a super-insulated building envelope, high performance windows, all-LED lighting, cogeneration for power and hot water, a mini-split heat pump system with air-to-air energy recovery, and solar for onsite generation.

*Photo Source: **The Bluestone Organization***

Hardening the Grid—Microgrids and Distributed Energy Resources

A resilient building stock requires a stable electricity system with a variety of sources and the flexibility to swap between them in times of crisis. The carbon neutral building stock of the future will be heavily reliant on flexible low-carbon technologies and microgrids with battery storage, smart controls, and solar. Solar-plus-storage systems can enable buildings to run during grid outages caused by climate events. This type of arrangement is essential for mission-critical facilities such as hospitals as well as many other building types (e.g. homes, schools, community centers). Smart controls enable staging of loads, so buildings can sustain critical systems in grid constrained conditions as well as contribute to the restart of grid operations after an outage through soft-start capabilities. Using smart controls in conjunction with solar and storage can allow buildings to supply their own energy needs, islanding from the grid when need be.

Climate Refuge Spaces

During long-duration power outages and natural disasters, communities need spaces of refuge to safely gather to wait out extreme weather and blackout conditions. Refuge spaces are intended to provide indoor, livable space to enable occupants to survive climate emergency events, such as extreme heat or cold, storms, or floods that could result in loss of power for up to a week or longer. These spaces can be individual rooms within a residence, common spaces within multifamily buildings, or public buildings such as community centers, libraries, and schools that are available to accommodate local residents for extended periods.

While the primary purpose of refuge spaces is for survival during emergencies, refuge spaces can also provide sufficient power for refrigeration of medications, power for in-home medical processes/equipment, air filters for critical conditions, basic lighting, cooking, and water heating.

Last Words

As natural disasters become more frequent, the development and proliferation of resiliency focused building strategies will protect New Yorkers and prevent costly damage.

The building stock must be adapted to provide safe shelter to its occupants while improving building performance to minimize the emissions which are causing the escalating climate crisis, and to minimize the impact of large-scale building electrification on the grid. Resilient design can maintain the longevity of the building stock while ensuring improved health, safety, and comfort of its occupants for generations to come.

Additional research is needed to help understand how current passive design strategies and standards will perform in the State's future climate, the impacts of electrification on building resiliency and the need for back-up energy systems, and passive survivability thresholds and measures during winter and summer conditions. Additional analysis must also be conducted to evaluate the resulting economic implications of resiliency at scale and where further RD&D funding should be focused.

The Economics, Benefits, and Challenges for Carbon Neutral Buildings

CHAPTER

8

Business Case by Typology

The respective business cases for carbon neutral buildings vary significantly across different building typologies, new construction versus renovation, and from the perspective of a building owner versus occupant.

This chapter provides modeled analysis about the capital and operational costs, savings, benefits, and challenges of decarbonizing buildings. Tax credits and incentives were not modeled, but a list of available programs can be found at the end of the chapter. This chapter also includes real world case studies for decarbonization and aggregated project data for the most common building types including single-family residential, multifamily residential, commercial office, and higher education.

This iteration of the *Roadmap* does not directly address other use types (such as P-12 schools or hospitals), but the key recommendations found in this edition can be extrapolated to other sectors. Further information on decarbonization of high-rise buildings is being made available to the market through NYSERDA's **Empire Building Challenge** efforts.

Some general trends that were found through this analysis include:

- Improving cost effectiveness of building decarbonization upgrades for the customer involves being able to access designers and trades people who have prior experience designing and installing decarbonized solutions and addressing both technology first-cost and energy/operational lifecycle cost.
- Many home and building owner decisions to advance a carbon neutral building are driven in part or in whole by benefits that result from building modernization, improved health, comfort, safety, productivity, reliability, and resiliency.
- There is no silver bullet. It will likely require multiple cost reduction strategies working in parallel to reduce current cost premiums, including: training and general awareness, technology cost reduction, integrated design, innovative business models, low-cost financing, incentives, and rebates, etc.
- Today's low relative cost of gas compared to electricity is a major challenge. Under current commodity pricing structures, some building decarbonization measures can result in higher annual energy costs than the natural gas baseline cases.
- The modeled 20-year cost premiums are higher for upgrades in Climate Zone 4 (New York City) compared to Climate Zones 5 (Buffalo) and 6 (Massena), due to higher electricity, labor, and material costs downstate.
- In general, residential buildings have a larger cost premium than commercial buildings.
- Cost of new home gas connections are avoided with all-electric new construction, providing an economic benefit to the gas system as a whole over conventional construction.
- Pre-end-of-life replacement planning prior to actual failure of equipment is important to break the cycle of like-for-like replacement: it can reduce the cost of emergency replacement and avoid spending on infrastructure assets that will be required to be replaced midcycle. More education is needed to better inform the building industry, and homeowners in particular.
- Weatherization efforts/programs, effective water/damp proofing and management, ventilation system maintenance, recommissioning, and general maintenance (including refrigeration system maintenance and leak detection) are not discussed here in further detail, but their importance cannot be understated. These lighter touch practices are critical to reducing energy consumption and maintaining healthy and comfortable indoor environments in buildings.

Single-Family Residential

Key Characteristics

- There are 4.3 million households, residing in 4.1 million buildings in New York State.[105] To meet climate targets, from 2030 through mid-century, over 200,000 homes per year must be upgraded to be all-electric and energy efficient.
- Space heating for single-family residences is the single largest contributor of direct carbon and other GHG emissions by end use from the entire building sector.[106]
- Over two-thirds of energy in single-family homes is used for space and water heating.
- Changes in natural gas and electricity prices will have a high impact on economics, particularly as gas prices increase.

Recommended Decarbonization Measures

TABLE 8.1: DECARBONIZATION STRATEGIES FOR TWO ‘RECOMMENDED SCENARIOS’ (REPRESENTING THE MODELED RESULTS IN FIGURES 8.1 AND 8.2) AND A ‘BEST-IN-CLASS SCENARIO’

Scenarios	**Modeled Comfort Shell** (Applies only to retrofits)	**Modeled Code Compliant Shell** (Applies to both new construction and retrofits)	**Best in Class Strategies** (Applies to both new construction and retrofits)
Load Reduction	• Air sealing • Attic insulation	Modeled Scenario—Comfort Shell + • Double-pane windows • Code-compliant wall and roof insulation • LED lighting	Modeled Scenario—Code Compliant Shell + • Passive-house level wall and roof insulation • Best-in-class air sealing • Thermal breaks • Triple-pane windows • Energy recovery ventilators • Smart, electric appliances
Building Electrification	• Cold climate air sourced heat pump • Heat pump water heaters	• Cold climate air sourced heat pump • Heat pump water heaters • Efficient electric appliances, such as induction cooktops	Modeled Scenario—Code Compliant Shell + • Ground sourced heat pumps in lieu of cold climate air sourced heat pump
Advanced Controls	*Not modeled*	*Not modeled*	• Automated load shifting of thermostats and hot water • Delayed start capability for clothes washer and dishwasher • Managed EV charging
Distributed Energy Resources	*Not modeled*	*Not modeled*	• Battery energy storage system • Thermal storage • Photovoltaic systems • Solar thermal

Building envelope measures labeled ‘comfort shell’ include air sealing and attic insulation only. ‘Code-compliant shell’ measures includes air sealing, code-compliant wall and roof insulation, and double-pane windows. The ‘Best-in-Class’ scenario will provide the greatest operational cost savings, enhance resiliency, support electricity system decarbonization, and provide other co-benefits but will have higher capital costs except with the use of modular design and under other limited circumstances.

Capital Expenditures and Operating Expenses Costs Compared to Savings

Use cases and results below are a mix of modeled scenarios and actual real world case studies. Decarbonization retrofits of single-family homes currently heated with oil are often cost effective today using traditional energy efficiency calculations, even before incentives. The resulting homes also then provide significant additional health, comfort, safety, and resiliency benefits beyond the energy savings calculated and presented below. The typical homeowner spends 10 years in their home, and the simple payback for the modeled package of measures shown in Figure 8.1 falls under that timeframe. When incentives and tax credits available today are included, it would bring the simple payback down to approximately five years. Comfort shell upgrades consisting of air sealing and attic insulation reduce energy use and enable smaller capacity heat pumps to be installed. This reduces the required capital costs for electrification equipment and reduces annual utility bills, while providing improved indoor air quality and comfort, resulting in a better living space.

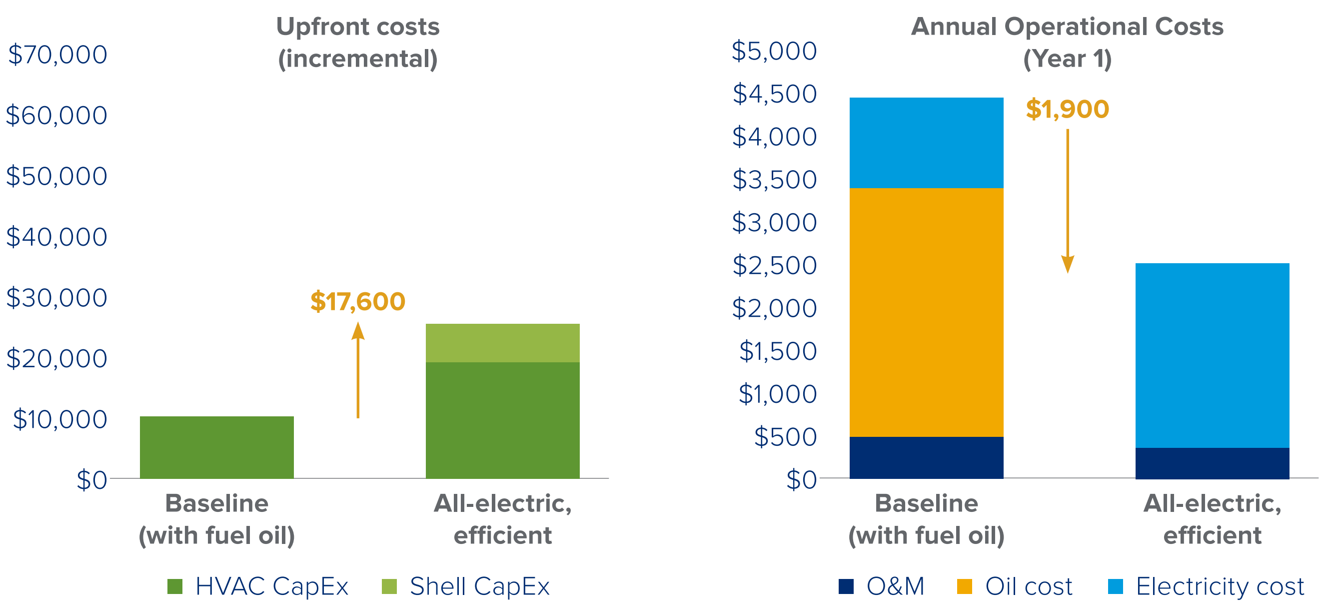
Single-family homes in New York today are predominately heated with gas, which changes the economics (not shown). The capital costs will be slightly higher (+$18,500) due to more efficient, all electric equipment and improved shell. The operational costs will also likely increase (+$400) since electricity is more expensive than gas today. However, there are four moving pieces that aren't included in these calculations that will bring the cost down in the near-term to help make this scenario financially attractive:

- Incentives and tax credits, which would cut capital costs in half.
- Technology cost reductions which are expected to be 15-30% by 2030.
- The increasing cost of energy, both gas and electricity in the future, which will make reduced energy consumption more valuable.
- Accounting for the co-benefits of decarbonized buildings.

The analysis also compared costs of a ground source heat pump system (not shown) and found that after applying tax credits and incentives, a ground source heat pump-based package of measures can have a comparable payback to air source heat pump systems, with a simple payback of about 10 years.

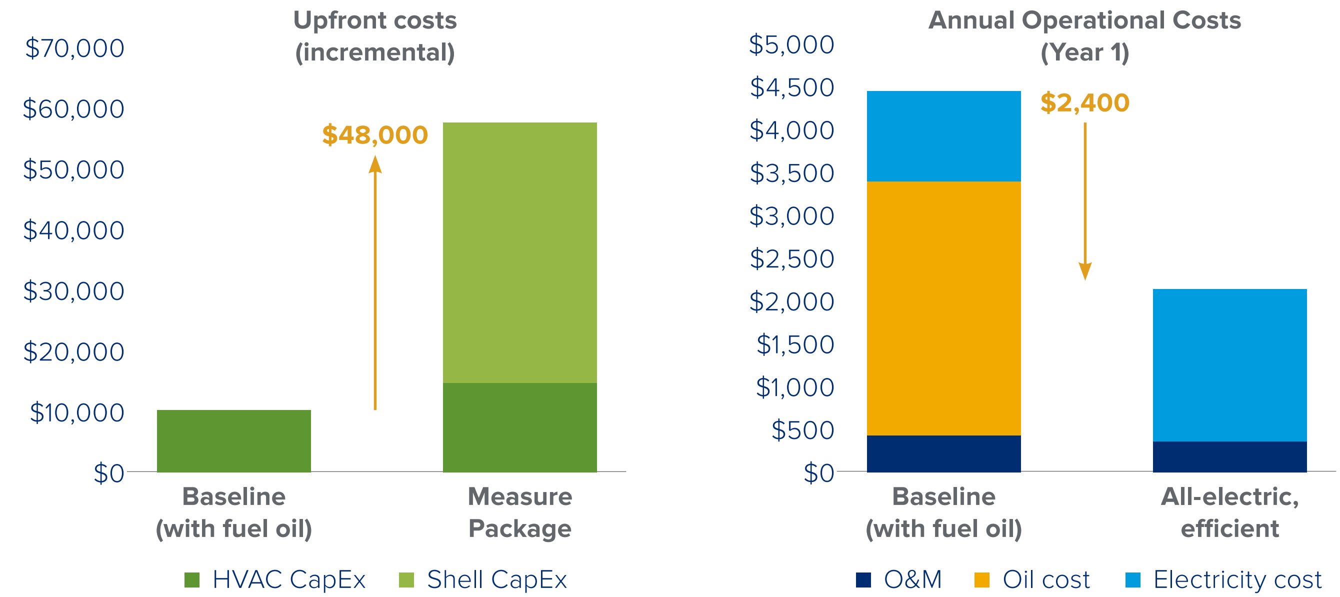
When considering an upgraded shell package, such as retrofitting an older home to meet current energy code

FIGURE 8.1: RETROFIT OF AN OIL HEATED, PRE-1980 HOME IN UPSTATE NY (CLIMATE ZONE 6A) WITH A COMFORT SHELL UPGRADE



Retrofit includes a ducted cold climate air source heat pump, heat pump water heater, and a comfort shell upgrade (air sealing and attic insulation only).

FIGURE 8.2: RETROFIT OF AN OIL HEATED, PRE-1980 HOME IN UPSTATE NY (CLIMATE ZONE 6A) WITH A CODE COMPLIANT SHELL UPGRADE



Retrofit includes a ducted cold climate air source heat pump, heat pump water heater and a code compliant shell upgrade.

levels of performance, the payback will be longer than a simple comfort shell upgrade, but it will also bring significant additional comfort and resiliency. Coupled with electrification, a code compliant shell upgrade will save about $500 per year more in operating expenses than a comfort shell upgrade. Another important dimension of code compliant shell upgrades is that they reduce peak load on the grid, thus reducing the necessity for a clean grid buildout over the coming years. As noted in Chapter 5: Building Electrification and the Grid, shell upgrades could translate into a 50% reduction in incremental grid expansion if rolled out across all homes, compared to electrifying homes without shell upgrades.

The reduced capacity requirements on the grid will also lower grid systems costs that are borne by all ratepayers. As a result, efficiency and shell measures are of vital importance in electrification, not just at the building level but at the energy system level. These measures also inherently improve community resiliency.

Benefits to Occupants and Owners

- **Increased Resilience:** Building envelope improvements such as air sealing and insulation paired with electric solar systems and battery storage enable the home to retain comfortable temperatures in the event of a power outage.
- **Health, Comfort, and Safety Benefits:** Building envelope air sealing and weatherization improve comfort (see below) and reduce risk of pests and mold, but need to be coupled with appropriate ventilation strategies. Electric appliances, especially electric stoves and cooktops, reduce harmful indoor air pollutants and eliminate risks of burns and house fires from gas stoves.
- **Increased Comfort:** Improving building envelope through air sealing and adding insulation reduces drafts, cold surfaces, and noise pollution. Replacing an existing heating system with electric heat pumps that also provide cooling can meet formerly unaddressed or inadequate cooling needs.
- **Potential Utility Cost Savings:** Building envelope air sealing and insulation reduce heating and cooling demand, which can reduce energy bills. Depending on system capacity, solar PV systems and solar thermal hot water systems can lead to significant utility savings. Some building decarbonization measures result in higher annual energy costs (despite reduced energy demand) due to the current low relative cost of gas compared to electricity.

CASE STUDY

Coons Residence Renovation, 2010

Clifton Park, NY

The owners of an 1840s farmhouse in the Capital Region invested in a fossil-fuel free, deep energy retrofit that resulted in a comfortable home that produces more electricity than it uses.

Retrofit measures included: Ground source heat pump for heating and cooling, energy recovery ventilator, all-electric ENERGY STAR appliances, solar hot water system, solar panels, electric vehicle hook-up powered by solar, and insulation. Post-retrofit, the monthly utility bills averaged $18,[110] roughly the cost of connection to the grid. The homeowners participated in NYSERDA's Green Home Program, which provided financial rebates for the solar and solar hot water systems. The owners also leveraged tax credits to offset the capital installation costs. The owner's return on investment for the solar electric panels and solar hot water system was 16%,[111] and the geothermal system achieved a return on investment of 11%.[112]

Photo Source: ***Paul & Joanne Coons***

- **Maximize Usable Square Footage:** Electric heat pump units can be installed high up on interior walls and out of the way, freeing up floor and window space compared to radiators, electric baseboard heaters, and window-mounted air conditioners.

Challenges

- **Scale:** The huge volume of homes that need to be retrofitted (>200,000 per year starting in 2030).
- **Fragmentation:** Different home styles, age, condition, legacy heating fuel, and current level of efficiency requires customized solutions.
- **Cost/Payback:** Traditional energy efficiency cost effectiveness calculations do not include what is in many cases driving homeowner decisions to move forward with a project. Improved inclusion of those benefits is needed to better understand the values and benefits that customers make decisions on.
- **Contractor Experience:** Contractors lack familiarity and experience with all-electric products (heat pumps) and may increase price to account for perceived technology performance risks during extreme cold. Vendors have perpetuated preferences for gas stoves, water heaters, fireplaces, and pool heaters. Additionally, most vendors provide single solutions, thus multiple vendors are often required to install a package of measures, making implementation complex and cumbersome.
- **Additional Issues:** Remediation of pre-existing conditions such as mold, lead, asbestos, structural, or indoor environmental quality issues, and the potential need for electrical system upgrades to panel and circuits may add costs.

Multifamily Residential

Key Characteristics

- Nearly 50% of existing multifamily buildings in New York State were built before 1940.[107]
- There are approximately 3.5 million multifamily residential units in apartment buildings and condos/co-ops in New York State.[108]
- 80% of multifamily buildings in New York City use steam for space heating and decentralized window or through-the-wall air conditioning.
- This is a heating dominated building type, although heating loads are typically smaller per dwelling unit than in single-family homes.
- Approximately 1,000 new multifamily buildings/developments are constructed annually, with about 35,000 new units.[109]

Solara Homes. Rotterdam, NY. *Photo Credit: Peter Barber*

Recommended Decarbonization Measures

TABLE 8.2: DECARBONIZATION STRATEGIES FOR A 'RECOMMENDED SCENARIO' (REPRESENTING THE MODELED RESULTS IN FIGURES 8.3 AND 8.4) AND A 'BEST-IN-CLASS SCENARIO'

	Modeled Scenarios— Retrofit of Gas or Oil Heated Building (Applies to both new construction and retrofits)	**Best in Class Strategies** (Applies to both new construction and retrofit)
Load Reduction Strategies	Code compliant walls, roof Double-pane windows Air sealing LED lighting Low-flow water fixtures	Modeled + High performance insulation Thermal breaks Energy recovery ventilators Prefabricated panelized solutions* Smart, electric appliances
Building Electrification Technology	Distributed cold climate air sourced heat pumps Heat pump water heaters Efficient electric appliances, such as induction cooktops	Modeled + Ground sourced heat pumps in lieu of air sourced heat pumps Integrated mechanical systems**
Advanced Controls	*Not modeled*	Load flexibility and advanced controls of hot water, space conditioning systems, equipment, and appliances
Distributed Energy Resources	*Not modeled*	Battery energy storage system Thermal storage Photovoltaic systems Solar thermal

* Prefabricated Panelized Solutions are an integrated wall and roof assembly, manufactured off-site in a controlled environment, which provides improved insulation, improved window performance and air sealing (e.g. RetrofitNY and EnergieSprong)

** Integrated mechanical systems are all electric integrated systems capable of delivering heating, cooling, ventilation, dehumidification, and domestic hot water to individual apartments and installed on 1- to 7-story buildings (source: NYSERDA manufacturer specifications for scalable Net Zero Energy retrofit solutions)

Capital Expenditures and Operating Expenses Costs Compared to Savings

In existing multifamily buildings that heat with gas, analysis has shown decarbonization retrofits can have long paybacks if just looking at energy savings (up to 40 years) due to high capital costs and low operational cost savings. However, these payback periods do not account for future technology cost reduction, integrated design, tax credits, incentives, or co-benefits. When those factors are included, especially with the newly extended and expanded federal tax credits, the capital cost can be cut by half or more. As shown in Figure 8.3, the capital cost premium to electrify HVAC mechanical systems was found to be around $5,000 per unit and to upgrade shell to current code performance is around $16,000 per unit, which includes adding wall and roof insulation, double pane windows and air sealing. Note that the baseline models a much more limited set of shell measures, incorporating only interior finish replacement and double-pane windows.

There is some good news. From an operating standpoint, even though electricity is more expensive than gas on a per unit of energy basis today, the annual operating costs do go down because the heat pump equipment is more efficient and shell improvements significantly reduce heating/cooling needs. Furthermore, higher levels of efficiency, particularly in the shell, drive greater benefits to the grid.

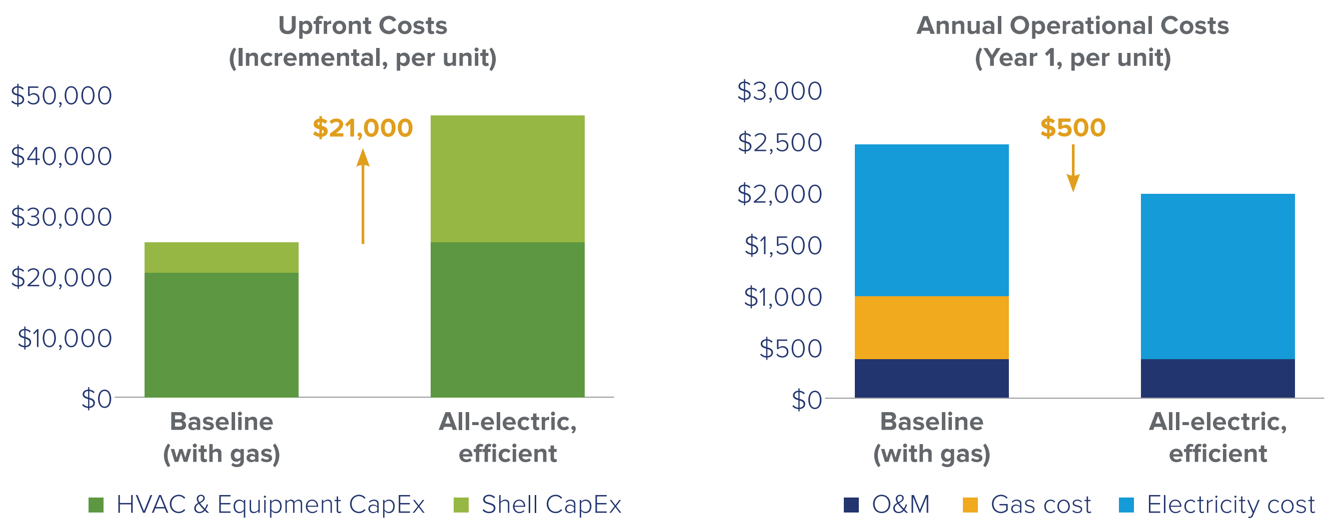
Our analysis found that decarbonizing existing multifamily buildings that currently use oil for heat (Figure 8.4 on page 99) resulted in better paybacks than those heated with gas, cutting the simple payback in half, equating to a period of about 20 years before additional cost reduction factors.

Prioritizing oil-based buildings in the short term provides an economically viable path forward based on capital costs and energy savings. These upgrades will also improve comfort, health, and resiliency, which are not quantified in these calculations.

Capital cost reduction opportunities, including contractor efficiency improvements and increased learning, lower perceived risk as adoption increases, manufacturing improvements, availability of labor, and technology development, are expected to reduce capital costs by roughly 35% by 2030. Integrated design helps as well, but to a lesser extent in retrofits.

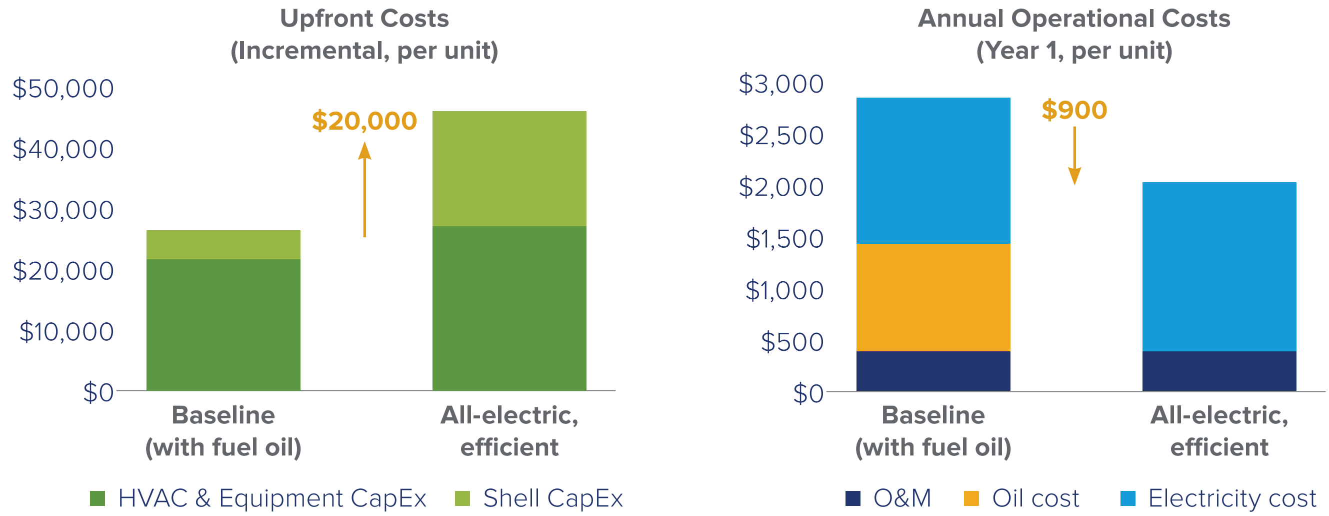
The business case improves when considering new construction, and our analysis found that building a new all-electric, efficient multifamily building is nearing cost parity with conventional gas construction, with a small capital cost premium of $2,000 per unit. This upgrade does modestly increase operating costs versus a natural gas baseline, but our analysis does not reflect any health or comfort co-benefits or prospective compliance costs for the baseline scenario.

FIGURE 8.3: RETROFIT OF A 7-STORY, GAS HEATED, PRE-1980 MULTIFAMILY BUILDING IN DOWNSTATE NY



Retrofit includes a distributed cold climate air source heat pump system, heat pump water heating, code compliant shell, LED lighting, and smart, electric appliances.

FIGURE 8.4: RETROFIT OF A 7-STORY, OIL HEATED, PRE-1980 MULTIFAMILY BUILDING IN DOWNSTATE NY



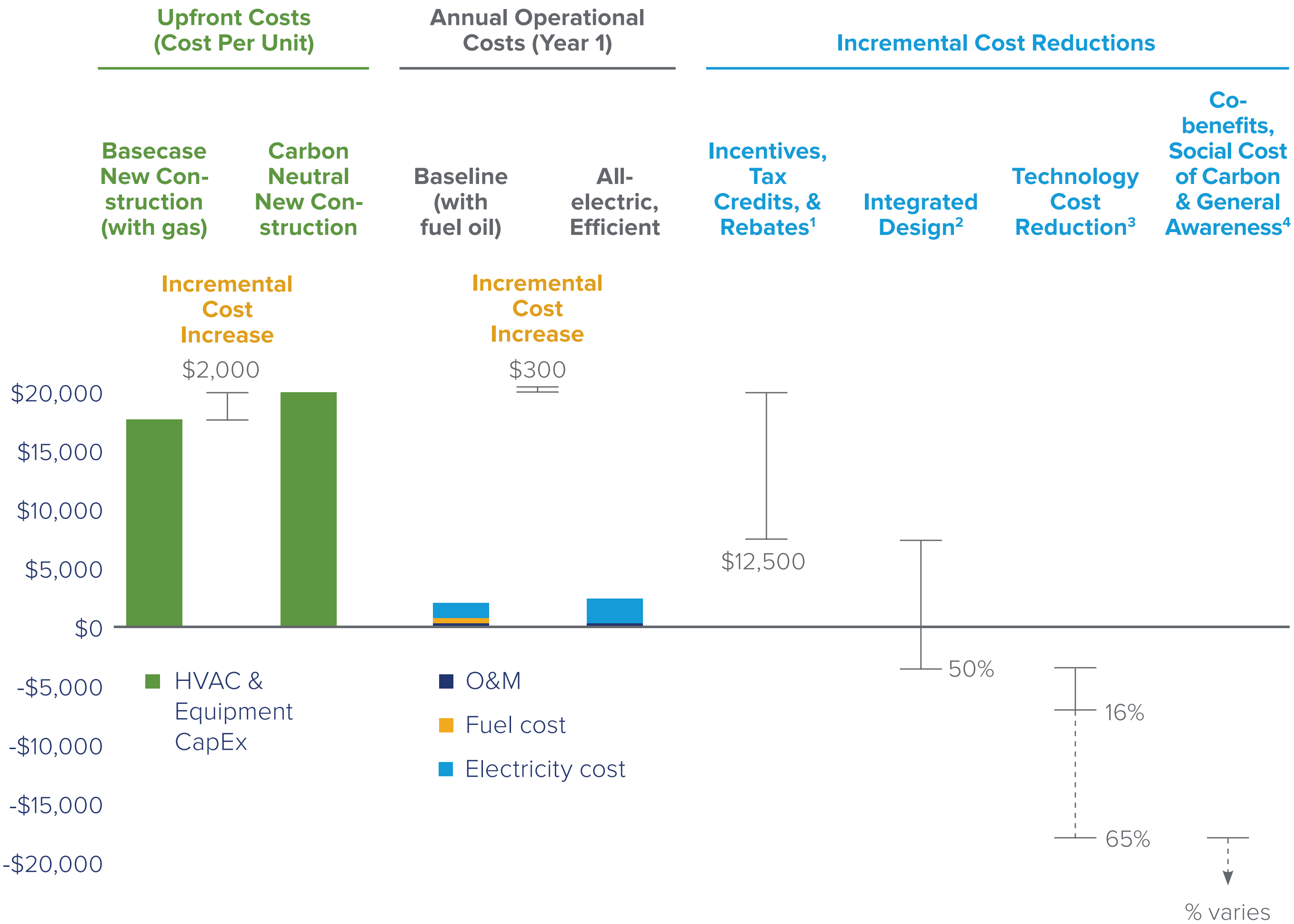
Retrofit includes a distributed cold climate air source heat pump system, heat pump water heating, code compliant shell, LED lighting, and smart, electric appliances.

Actual costs from the first two rounds of NYSERDA's Buildings of Excellence Design Competition shown in Figure 8.6 demonstrate that new buildings that are highly efficient and all electric, are averaging an incremental cost of less than 7% for projects that prioritize efficiency and integrated design practices. This incremental cost decreases to below 2% after building owner identified federal and state tax credits, and NYSERDA and utility incentives. Several projects from some of the most advanced and experienced developer and design teams reported costs that are less than what a code compliant gas building would cost to build. The biggest driver of savings in these projects was successful teamwork and project experience, including collaboration, repeatable and adaptive design, technical solution development, and schedule and risk management.

Benefits to Occupants and Owners

- **Health and Safety:** Improved health for occupants due to better indoor air quality, elimination of gas leaks, and reduced fire and/or burn risk with induction stove tops.
- **Comfort:** Improved comfort and acoustics due to better building envelope.
- **Improved Passive Survivability:** Efficient buildings will maintain internal temperature conditions in a power outage longer than uninsulated, leaky buildings, and reduce or minimize damage that may occur to buildings due to freezing pipes, etc.
- **Increase Asset Value and Revenue Potential:** Owner can sell or rent units at a higher price due to the demand for carbon neutral buildings expressed by prospective tenants and buyers. In rent stabilized multi-family units, there may be an opportunity to balance adjustments between rent and operating expenses, which would allow owners to increase rents modestly to help repay the cost of capital improvements, without increasing residents' cost of living (rent + utilities).
- **Minimize Liability and Future Proof:** Carbon neutral buildings safeguard against changing energy prices where natural gas and other fossil fuels are likely to become less accessible and more expensive due to the transition away from fossil fuels. In New York City, carbon neutral buildings reduce risk of incurring fees or other penalties associated with Local Law 97 (only applies to buildings 25,000 square feet or greater and includes exceptions for low-income housing) or other forthcoming carbon laws.
- **Maximize Usable Square Footage:** Electric heat pump units can be mounted high on interior walls, freeing up extra floor and window-space compared to radiators, electric baseboard heaters, and window air conditioners.
- **Reduce Operating Costs:** Building envelope air sealing and insulation reduce heating and cooling energy demand.

FIGURE 8.5: NEW CONSTRUCTION OF A 7-STORY MULTIFAMILY BUILDING IN DOWNSTATE NEW YORK



Measure Package includes a distributed cold climate air source heat pump system, heat pump water heating, code compliant shell, LED lighting, and smart, electric appliances.

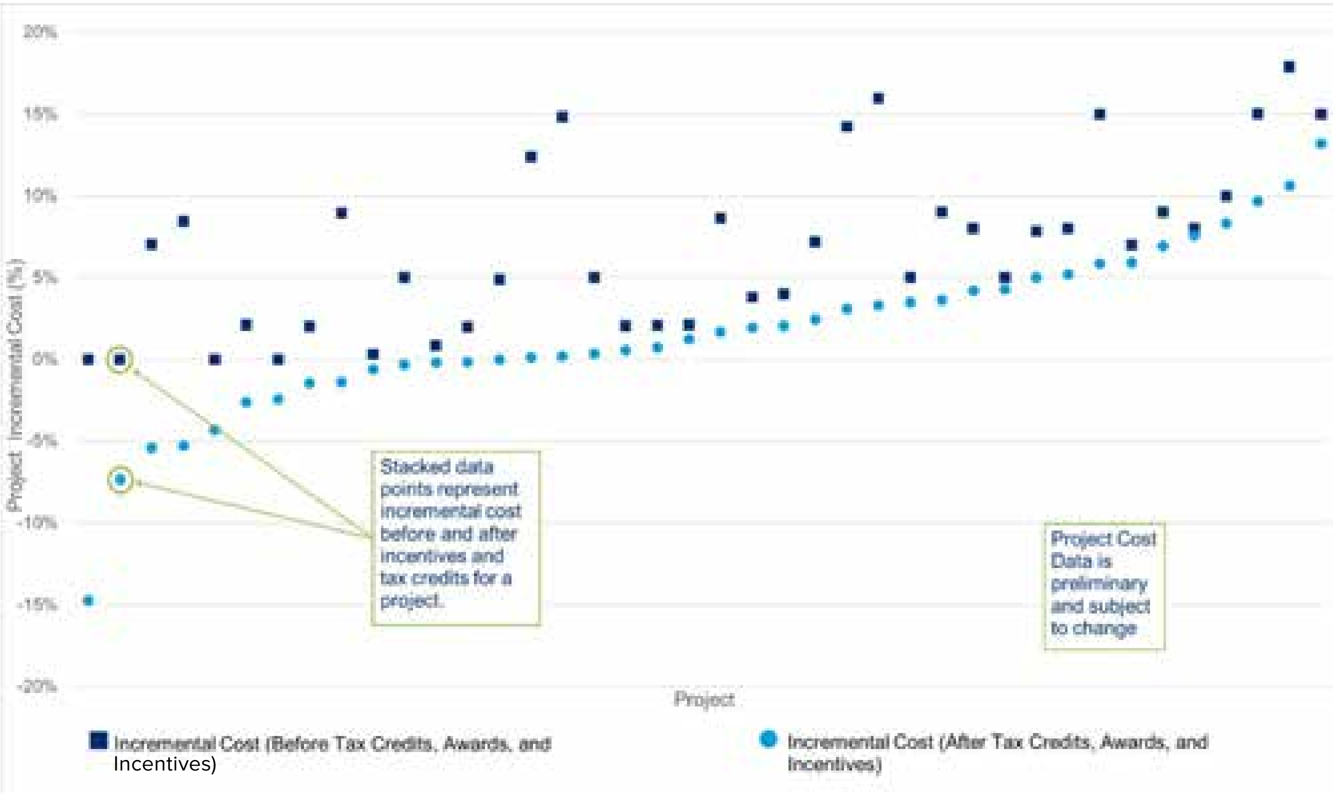
1 One example currently available is the HCR Clean Energy Initiative which provides $12,500 per unit for all electric and highly efficient affordable housing units.

2 According to a NYSERDA internal analysis, integrated design has shown a 50% reduction in capital costs due to design optimization and team alignment.

3 Between 5-10% reduction in capital costs for ASHP is anticipated by 2030 and 9-18% cost reduction for HPWH by 2030.

4 Monetizing the co-benefits of avoided carbon emissions ($125 per ton as stipulated by the DEC) and increased awareness will bring down the real cost.

FIGURE 8.6: PERCENT INCREMENTAL COST BEFORE AND AFTER INCENTIVES AND TAX CREDITS FOR ROUND 1 AND ROUND 2 BUILDINGS OF EXCELLENCE PROJECTS



The average incremental cost goes from 7% down to 2% when accounting for incentives and tax credits.

Challenges

- Some prevalent HVAC configurations are more challenging to electrify, including steam and district heating, cooling, and energy systems.
- Electrification should be coupled with efficiency first to minimize cost impacts for tenants, and to reduce required equipment sizing (and consequently first capital costs to owners).
- Current low relative cost of gas compared to electricity.
- Split incentive (especially for electrification scenarios which could shift rent dynamics), potential tenant disruption and the need to ensure housing affordability. Even in multifamily buildings with owned units (not rented), the unit owners may not have control over energy systems.

Casa Pasiva. *Photo Credit: RiseBoro Community Partnership*

RetrofitNY

RetrofitNY, a NYSERDA initiative, is working to make cost-effective, carbon neutral retrofits a reality by revolutionizing the way multifamily buildings are renovated through five key actions:

1. Leveraging the collective market power of building owners to create demand; stimulating cost compression on new technologies; and reducing project costs for carbon neutral solutions
2. Mobilizing the building industry to develop innovative technical solutions to substantially improve affordable housing buildings while residents continue to live in their apartments
3. Engaging with manufacturers to help drive innovation, availability, and cost compression of relevant technologies
4. Working with financial organizations to fund projects by capturing energy savings
5. Engaging regulatory agencies to help facilitate widespread adoption

RetrofitNY is working aggressively to retrofit a large number of affordable housing units in New York State by 2025, so that more New Yorkers have access to the benefits of carbon neutral performance.

CASE STUDY

Zero Place, 2022

New Paltz, NY

This all-electric, carbon neutral, 63,320-square-foot mixed-use building offers 46 residential units. Using passive survivability strategies, Zero Place can maintain safe temperatures inside during extreme climate events or grid outages despite being located in a cold climate. The building utilizes ground source heat pumps for space conditioning and hot water heating, energy recovery ventilation, photovoltaics, triple-pane windows, all-electric, ENERGY STAR appliances, and a backup generator. The building's three solar arrays generate a net surplus of electricity back to the grid in a typical year. The building's annual net site energy use intensity (EUI) is 0.1 kBtu/sf/yr. Total project cost was $10,547,313—about $166 per square foot. An integrated design team that collectively understood high performance was a critical aspect of the project's success.

Photo Credit: BOLDER Architecture, PLLC

Brooklyn multifamily building with rooftop solar. *Photo Credit: Joshua Armstrong*

Commercial Office

Key Characteristics

- Offices make up the largest share (27%) of commercial space in New York.[113]
- Office buildings are generally cooling dominated.
- Gas furnaces and boilers are prevalent for heating in New York State's commercial buildings, except in New York City where many commercial buildings rely on Con Edison's steam system.
- Tenant energy use represents 40-60% of total office building energy use. The downstate region of New York City and Westchester County have few owner-occupied buildings, whereas more businesses are in owner-occupied buildings in upstate New York.[114]

New York City skyline.

Recommended Decarbonization Measures

TABLE 8.3: DECARBONIZATION STRATEGIES FOR A 'RECOMMENDED SCENARIO' (REPRESENTING THE MODELED RESULTS IN FIGURE 8.7) AND A 'BEST-IN-CLASS SCENARIO'

The 'Best in Class' scenario will provide the greatest operational cost savings, enhance resiliency, support electricity system decarbonization, and provide other co-benefits but will have higher capital costs.

	Modeled Scenario (Applies to both new construction and retrofits)	**Best in Class Strategies** (Applies to both new construction and retrofit)
Load Reduction Strategies	- Code compliant walls, roof - Double-pane windows - Air sealing - LED lighting - Low-flow water fixtures - Smart appliances	Modeled + - High performance insulation - Thermal breaks - Heat recovery
Building Electrification Technology	- Cold-climate air sourced heat pumps - Heat pump water heaters with storage tanks	Modeled + - Ground sourced heat pumps in lieu of air sourced heat pumps
Advanced Controls	*Not modeled*	- Load flexibility and advanced controls of hot water, space conditioning systems, and plug and process loads
Distributed Energy Resources	*Not modeled*	- Battery energy storage system - Thermal storage - Photovoltaic systems

Capital Expenditures and Operating Expenses Costs Compared to Savings

In office buildings, the capital retrofit costs for decarbonization are driven by shell measures. The scenario in Figure 8.7 assumes bringing a pre-1980 building up to current code levels of efficiency, which requires the significant expenses of additional insulation and window replacement. The improved shell and equipment efficiency provides improved comfort and productivity for end users and are responsible for almost all of the operational cost savings. **Without shell upgrades, post retrofit utility operating costs would likely increase since electricity is more expensive than gas on a relative basis.**

Along with cost reduction factors such as technology cost reduction, integrated design, tax credits, incentives, or co-benefits, capital costs could be improved through an incremental retrofit strategy where decarbonization upgrades occur over time during equipment replacement, tenant turnover, or pre-scheduled building maintenance. Operational costs could be improved through tenant energy use improvements and green leasing strategies, as well as installing point-of-use, instant hot water systems rather than centralized heat pump water heaters. Participating in demand response programs that shift energy use away from peak electricity hours can help avoid high electricity bills.

Our analysis found that a passive house-inspired shell scenario (not shown) is not yet financially attractive in an office retrofit scenario but will support other co-benefits. The costs for the passive house inspired shell include taking the wall R value from R-20 (code) to R-30; improving roof R values from R-30 (code) to R-45; and incorporating triple pane (vs double pane) windows, which is a substantial upgrade. Office buildings often have a higher cost to retrofit to passive house levels (approximately $13.70 per sq ft per the analysis) compared to other typologies because they have more glazing area (windows).

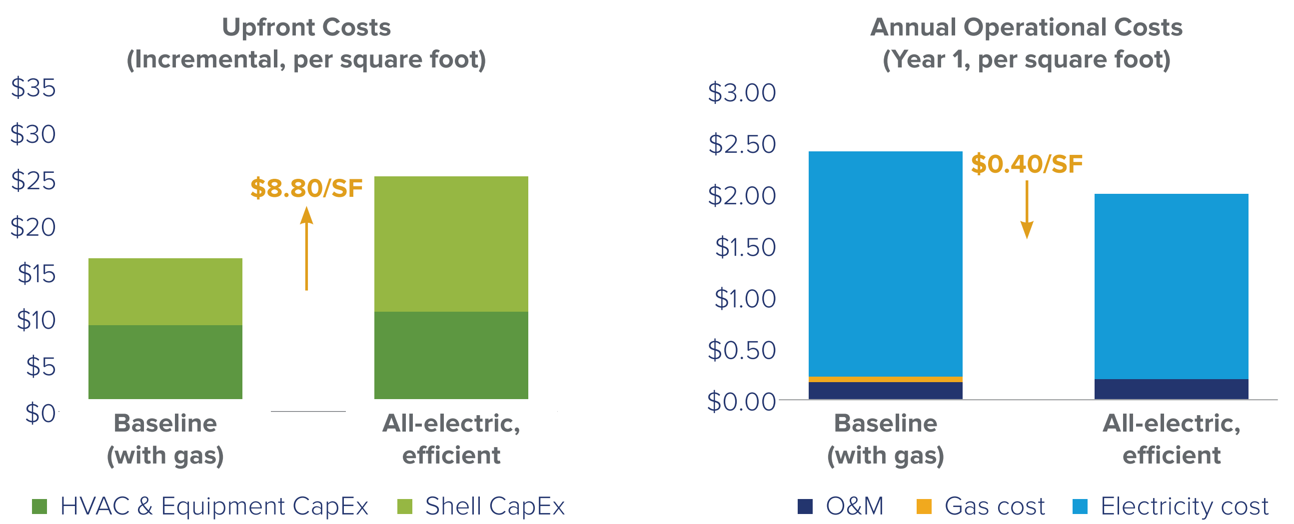
Also, office buildings are internally load driven, and so are less influenced by a high performance envelope and more influenced by the density of occupants, equipment, and appliances. Without incentives, cost reduction or targeted market demand, it may not make financial sense to retrofit an office building's shell up to the passive house-inspired level. As with multifamily buildings, high performance shells have a much better financial return for commercial office new construction projects.

Benefits to Occupants and Owners

- **Improved comfort, health, and productivity for occupants:** Demand controlled ventilation and envelope air sealing improves indoor air quality, which increases occupant health and productivity.

FIGURE 8.7: RETROFIT OF A PRE-1980 500,000 SQUARE FOOT, 12 STORY OFFICE BUILDING IN DOWNSTATE NEW YORK

Retrofit includes a distributed cold climate air source heat pump system, heat pump water heating, code compliant shell, LED lighting, and smart, electric appliances.



Dynamic and controllable lighting paired with daylighting can reduce migraines and also boosts productivity. These health benefits can lead to fewer sick days and absenteeism, making carbon neutral buildings attractive to employers.

- **Improved net operating income and asset value for owners:** Owners of market rate buildings may be able to rent units at a higher price due to demand for carbon neutral buildings expressed by prospective tenants, increasing net operating income. Additionally, carbon neutral buildings can increase tenant satisfaction and retention leading to lower vacancy rates. Upon sale of the asset, owners often realize lower cap rates because carbon reducing retrofit work has already been completed, but even at a consistent cap rate, increased NOI will boost sale value.

- **Improved passive survivability:** Envelope improvements such as air sealing and insulation paired with solar and battery storage help sustain equipment and temperatures consistent in the event of a power outage or extreme weather event.

- **Annual utility bill savings:** Building envelope air sealing and insulation reduce heating and cooling energy demand, offsetting the more expensive fuel cost of electricity relative to gas. Participating in demand response programs or shifting loads to off-peak hours can reduce utility costs, depending on the local utility pricing structure.

Challenges

- Project complexity and lack of streamlined long term capital improvement planning.

- Split incentive, tenant disruption, and intervention points that are dependent on tenant turnover and/or lease structures (although tenant turnover may provide floor by floor improvement opportunities).

- Remediation of existing conditions may add additional costs.

- Current low relative cost of gas compared to electricity (the economics for oil-to-heat pump conversion are better than for a gas baseline).

Commercial Playbooks Launch

NYSERDA launched the **Empire Building Playbook**, an online commercial office decarbonization guide developed in partnership with four leading real estate owners. The Playbook articulates the respective processes utilized by each of the four partners to develop a long term decarbonization strategy and demonstrates a range of four possible solution sets for retrofitting commercial buildings to dramatically decrease GHG emissions and energy use.

Photo Credit: ***Maxime Levrel***

CASE STUDY

Net Zero Energy Office Building, 2015

New Paltz, NY

This 5400 square foot office building nicknamed the "Green Building," was constructed in New Paltz, NY, in 2015, has received LEED Zero Energy and LEED Zero Water certifications, while meeting Passive House standards. The building's envelope is airtight, using insulated concrete down to the foundation without any thermal bridging. The envelope's efficiency is maximized using high performance structural insulated panels on the roof and triple pane windows. The building achieves an air tightness rating of 0.6 air changes per hour which is five times better than current energy code requirements.[115] Through its recapture of AHU condensate, stormwater management, gray and blackwater recycling, and subsurface infiltration, the building reclaims 65% of all water used—using municipal water only as a backup source.

Photo Source: ***Alfandre Architects***

Higher Education

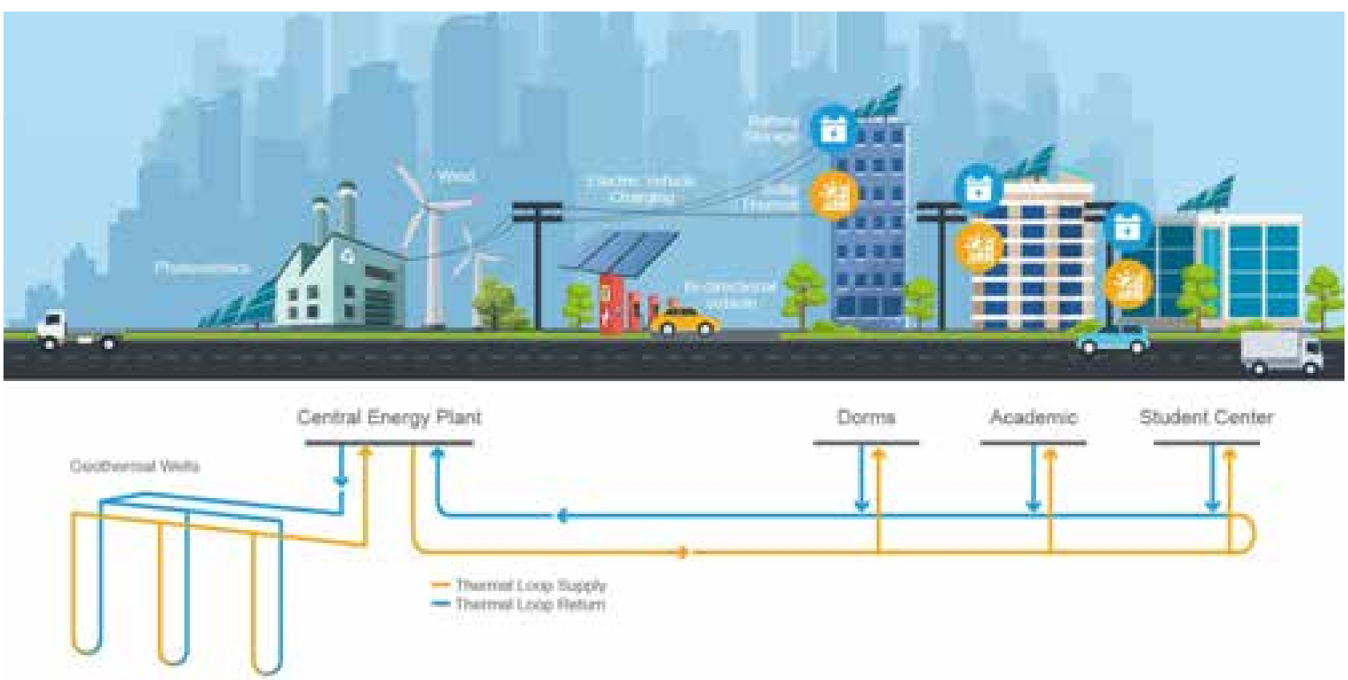
Key Characteristics

- There are over 300 institutions of higher learning in the State.[116]
- While the number of customers is low, the square footage, resources available, and complexity of most colleges and universities are significant.
- Many college and university campuses in New York State use central plants for steam, chilled water, and electricity.
- There is an opportunity to maximize investment impacts by making coordinated upgrades to campus portfolios and leverage shared thermal resources.
- Because colleges and universities typically hold long-term ownership or leases of buildings, and funding streams and decision-making processes tend to have a long-term outlook compared to private development, administrators are therefore generally more accepting of longer pay back times.
- Due to classroom loads, energy demand from education buildings is more occupancy-driven.
- A critical feature to consider is the campus-wide ability to manage loads and mitigate peaks.

Decarbonizing Central Energy Plants

Campus central plant systems present unique challenges and opportunities for decarbonization. Hydronic-based systems—whether ambient loops, 2-pipe or 4-pipe systems—have benefits of load diversity and heat recovery within thermal networks. This both improves the overall system efficiency and allows for more optimal plant sizing than individual building systems. Hydronic systems can also be designed for optionality in fuels and heat generating

FIGURE 8.8: SCHEMATIC OF A CENTRALIZED ENERGY SYSTEM



equipment that can evolve over time toward high efficiency air- or ground source heat pumps, potentially including central thermal or battery storage to further reduce carbon emissions and support resilience. Large-scale central plants are generally managed and optimized by sophisticated operators, oftentimes third-party service providers with service and finance models tailored to institutional clients. However, many legacy systems operate with steam distribution that is not readily served by heat pumps. Plant decarbonization conversions that do not include distribution system conversions to lower temperature hot water are limited to relatively inefficient electric resistance boilers, preheating of feedwater with heat pumps, or the prospect of renewable combustion fuels. Given the long life of both the central plant and distribution system, detailed campus decarbonization planning should occur as soon as possible in order to hit state-aligned decarbonization timelines, identifying pathways to convert the campus over time based on the nuances of the campus distribution network, deferred maintenance, and capital improvement plans. SUNY Albany and Binghamton, Bard College, and Skidmore College are leading the way in decarbonizing central energy plants.

Recommended Decarbonization Measures

TABLE 8.4: DECARBONIZATION STRATEGIES FOR TWO 'RECOMMENDED SCENARIOS' (REPRESENTING THE MODELED RESULTS IN FIGURE 8.9 AND 8.10) AND A 'BEST-IN-CLASS SCENARIO'

The 'Best in Class' scenario will provide the greatest operational cost savings, enhance resiliency, support electricity system decarbonization, and provide other co-benefits but is more expensive up front.

Scenarios	**Modeled Code Compliant Shell** (Applies to both new construction and retrofits)	**Modeled Passive House Inspired Shell** (Applies to both new construction and retrofits)	**Best in Class Strategies** (Applies to both new construction and retrofits)
Load Reduction	Code compliant walls, roof Double-pane windows Air sealing Smart appliances LED lighting Low-flow water fixtures Heat recovery	Modeled + Passive House levels of wall and roof insulation Triple pane windows Thermal breaks Improved heat recovery	Modeled + Passive House levels of wall and roof insulation Triple pane windows Thermal breaks Improved heat recovery
Building Electrification	Cold climate air sourced heat pumps Heat pump water heaters with storage tanks	Cold climate air sourced heat pumps Heat pump water heaters with storage tanks	Modeled + Ground sourced heat pumps in lieu of air sourced heat pumps
Advanced Controls	*Not modeled*	Programmable thermostat	Load flexibility and advanced controls of hot water, space conditioning systems, and plug and process loads
Distributed Energy Resources	*Not modeled*	*Not modeled*	Battery energy storage system Thermal storage Photovoltaic systems Solar thermal

Capital Expenditures and Operating Costs Compared to Savings

All-electric, efficient new construction for higher education facilities has a minimal incremental capital cost and less than a seven-year simple payback. This payback threshold is well within the typical holding period for higher education buildings. Further, spanning out to the total project costs, the premium for an all-electric, efficient new building is less than 1% of the total construction cost of a project.

For Passive House-inspired new construction, the capital premium is less than 2% of total construction costs for the project, before accounting for available incentives and tax credits. This measure package, before incentives, would result in a less than 20-year payback. Compared to offices, energy demand in classroom buildings is driven less by internal loads, so higher levels of shell efficiency are more beneficial compared to offices.

FIGURE 8.9: NEW CONSTRUCTION OF A 12-STORY, 500,000 SQUARE FOOT CLASSROOM BUILDING IN UPSTATE NEW YORK WITH A CODE COMPLIANT SHELL

Measure Package includes a central cold climate air source heat pump system, heat pump water heating, heat recovery, code compliant shell, LED lighting, and smart, electric appliances.

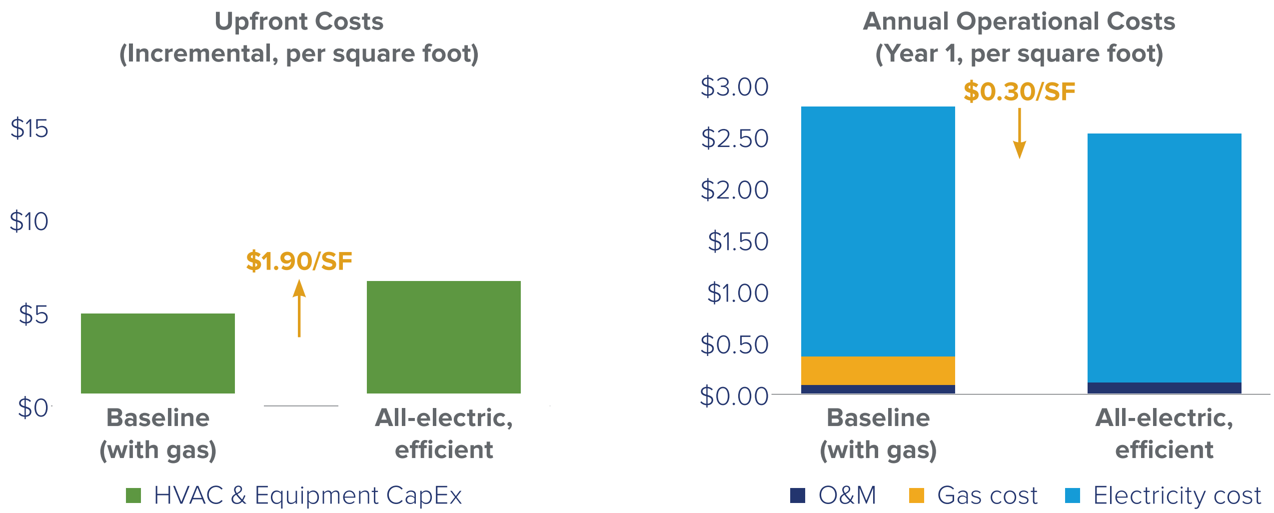
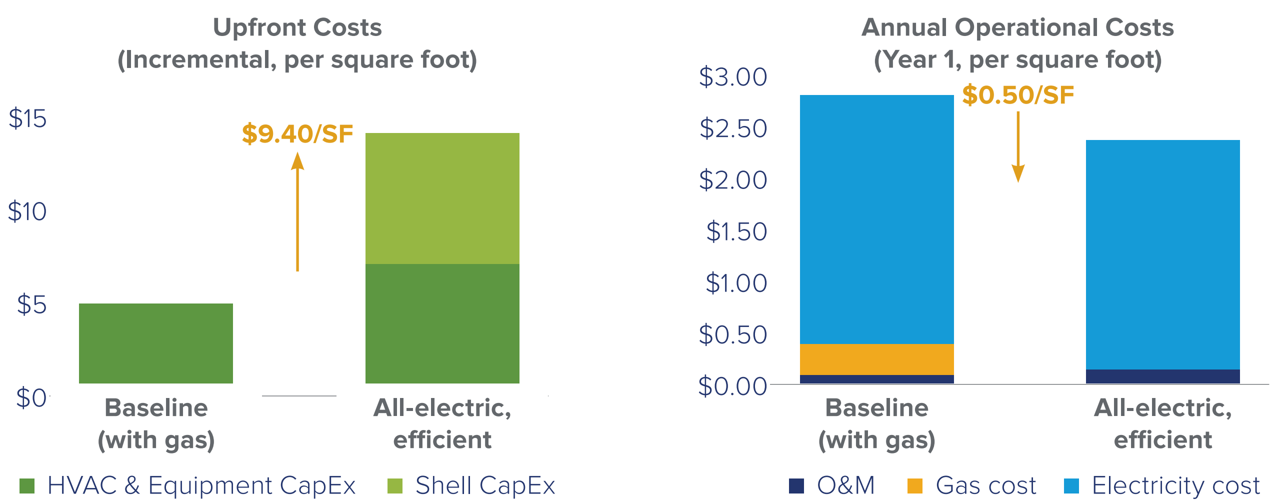


FIGURE 8.10: NEW CONSTRUCTION OF A 12-STORY, 500,000 SQUARE FOOT CLASSROOM BUILDING IN UPSTATE NEW YORK WITH A PASSIVE HOUSE-INSPIRED SHELL

Measure Package includes a central cold climate air source heat pump system, heat pump water heating, heat recovery, Passive House-inspired shell, LED lighting, and smart, electric appliances.



Benefits to Academic Institutions and Building Occupants

- **Improved health and productivity for students and occupants due to better indoor air quality:** Demand controlled ventilation and building envelope air sealing improves indoor air quality, which increases occupant health and test scores. Dynamic and controllable lighting paired with daylighting can reduce migraines and also boost productivity. These health benefits can lead to fewer sick days and higher test scores.

- **Educational value to students:** Carbon neutral buildings enhance the reputation of academic institutions as leaders in sustainability, increasing grant funding, donation prospects, and attracting top tier students and faculty. Colleges and universities can integrate sustainable living/learning experiences for students, faculty, staff, and donors.

- **Reduce Operating Costs:** Building envelope air sealing and insulation reduce heating and cooling energy demand, offsetting today's more expensive fuel cost of electricity relative to gas. Depending on system capacity, solar PV systems and solar hot water systems can lead to significant utility savings. Participating in demand response programs or shifting loads to off-peak hours can reduce utility costs, depending on the local utility pricing structure, and reduce impact on the electric grid.

- **Increased Resilience:** Building envelope improvements such as air sealing and insulation paired with electric solar systems and battery storage help keep power running and temperatures consistent in the event of a power outage or extreme weather event.

Challenges

- Project complexity and lack of streamlined capital improvement planning.

- Retrofitting campus central energy plants is costly and creates technical challenges to reuse distribution systems.

- The need to avoid occupant disruption during the school year leads to limited intervention points that are dependent on academic calendars (construction periods often limited to summer months).

- Remediation of pre-existing conditions may add additional costs.

- Current low relative cost of gas compared to electricity (the economics for oil to heat pump conversion are better than for a gas baseline).

Photo Credit: ***EYP Inc.***

CASE STUDY

ZEN (Zero Energy Nanotechnology) Building, 2016

Albany, NY

At 363,000 GSF, SUNY Polytechnic University's flagship building is the largest zero-energy capable, mixed-use facility in the United States. In collaboration with NYSERDA and Japan's New Energy and Industrial Development Organization (NEDO), the doughnut-shaped building was modeled and executed using integrated design, a sophisticated building management system, and the latest efficient technology. The building's 10,000 square foot atrium allows for natural light to cut traditional lighting needs by 70%. Reclaimed heat from adjacent data centers offsets winter heating loads, and the use of a 2.4MW offsite PV farm and pilot-scale fuel cells reduce the building's energy costs by ~60%.[117]

Opportunities to Enhance the Value Proposition

As shown in the use cases above, there is usually a capital cost premium to achieve carbon neutral buildings, particularly for retrofits of existing buildings.

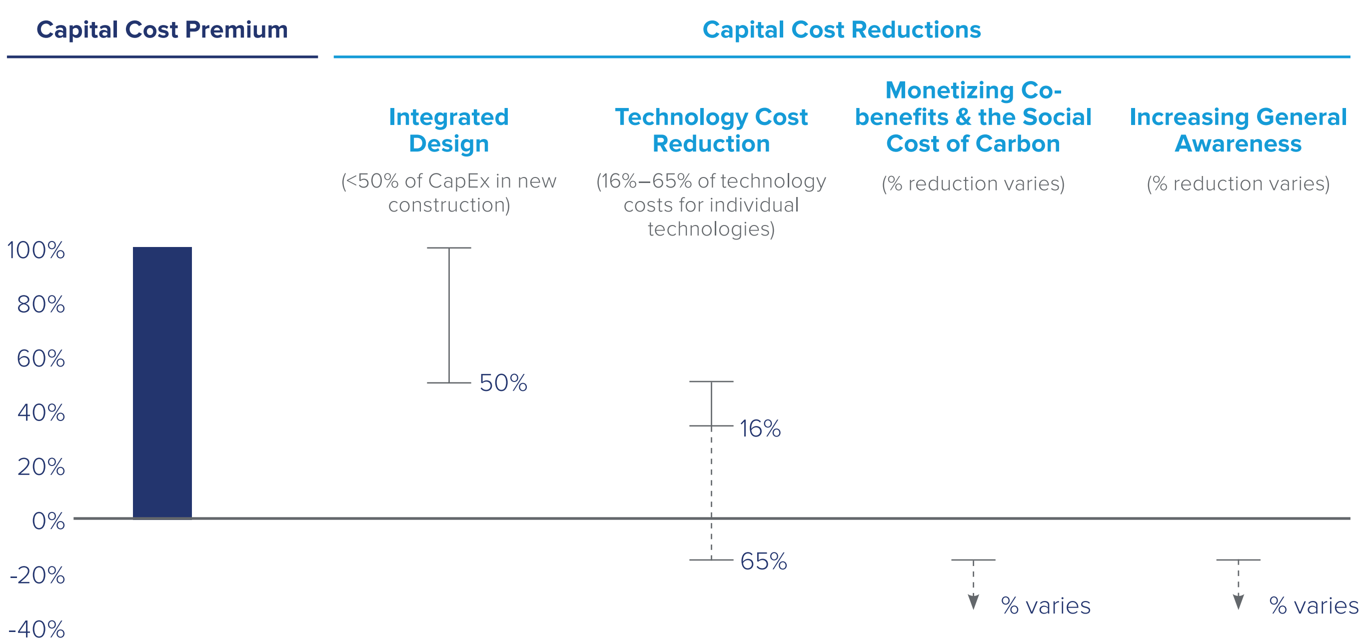
Fortunately, there are several promising influencing factors that will improve the value proposition over the next decade including technology cost reduction, integrated design, increasing general awareness, and monetizing co-benefits. There is no silver bullet—none of the individual factors alone can sufficiently reduce the current cost premium for decarbonized buildings. Emerging financing models will provide access to capital and as-a-service offerings. Improving the cost effectiveness involves addressing both technology first cost and operational lifecycle cost, however first cost reduction is the most important priority today.

Reducing Capital Costs Through Integrated Design

The American Institute of Architects defines Integrated Design as an "approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction."[118] Based on an internal NYSERDA analysis, integrated design

FIGURE 8.11: KEY INFLUENCING FACTORS CAN BRING CAPITAL COST PREMIUM TO PARITY WITH NATURAL GAS HEATING AND CONVENTIONAL BUILDING SYSTEMS

Monetizing co-benefits and increasing general awareness will continue to enhance returns.



CASE STUDY

Empire State Building Retrofit (v1.0)

By leveraging an integrated design approach to upgrading one of the nation's most iconic buildings, the project team developed a retrofit strategy that led to a 38% reduction of the building's energy use and $4.4 million in annual operational savings with an overall simple payback of three years.[121] The retrofit emphasized a "right-steps in the right-order" strategy that piggybacked energy upgrades on planned improvements, used life cycle cost analysis, and incorporated energy modeling into the design process. Retrofit measures included envelope and HVAC improvements which enabled smaller HVAC system installations.

- Considerable operational expense savings delivered a three-year payback
- Part of comprehensive asset repositioning resulting in significantly improved tenant profile
- Increased asset value

As part of NYSERDA's **Empire Building Playbook** initiative, Empire State Realty Trust recently undertook an extensive analysis to develop a new long-term capital planning strategy (ESB v2.0) which, together with the measures from the building's completed v1.0 retrofit, is projected to achieve a total reduction of the Empire State Building's carbon emissions by almost 90% over the next 12 years from a 2007 baseline, with an average simple payback period of under seven years.

Photo Credit: Charles Parker

in new construction can reduce costs by up to 50% compared to conventional processes, and in some cases bring carbon neutral building measures to lifetime cost parity with gas building baselines. Integrated design has the most reduction potential for new construction since there are design, engineering and construction teams working together to holistically optimize across multiple systems, particularly envelope and mechanical systems.

Reducing Technology Premiums Through Technology Cost Reduction

Technology cost reduction is one of the most significant factors influencing the business case for carbon neutral buildings—it could provide 16–65% reduction in the capital cost of various equipment. Technology cost reduction includes the reduction in material costs, labor and upscaling labor costs, commissioning and startup costs, indirect costs, and overhead costs.

There are 4 key drivers of technology cost reduction:

1. **Scale and Supply Chain Innovation:** As demand increases, production scales and more products become available, economies of scale will be realized. Also, the increase in demand will drive additional investment in automation and innovation in manufacturing and the supply chain, especially for prefabricated panels and high performance glazing. There will also be increased competition as more manufacturers produce compliant products. Increases in demand will be driven by positive market signals including mandates, performance targets, HVAC and other appliance standards, and low interest finance, which reduces risk.
2. **Designer and Contractor Education:** Educating the design and construction industry will help increase familiarity with electrification, efficiency and high performance measures which will both increase implementation capacity and reduce cost inflation. Contractor education on right-sizing

designs, integrating controls, efficiency measures, and installation best practices reduces costs for heat pumps for both space and water heating, especially for single-family homes. Vermont, Maine, and Boulder, Colorado, have all had success through government partnered educational programs that drove reductions in design and installation costs.

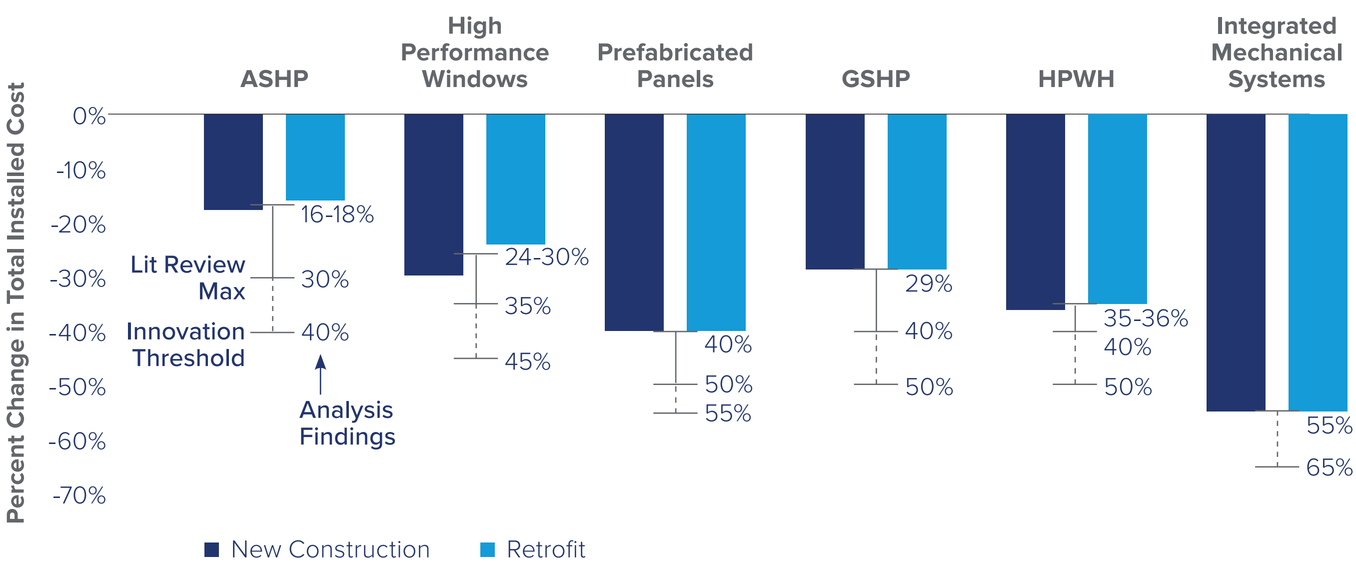
3. **Removing Regulatory Roadblocks and Perceived Technology Risks:** Streamlined permitting can support greater contractor adoption of technologies that are perceived as higher risk, such as prefabricated panels, ground source heat pumps, and integrated mechanical systems. Standardized approval processes, appropriate regulation for new and innovative use cases, adoption "playbooks," and sponsoring data collection to reduce the contractor burden of proof will further encourage the adoption of technologies currently perceived as high risk.

4. **Technology Innovation:** Technology innovation such as improved efficiencies, larger unit sizes for non-residential heat pumps, and real-world testing and refinement of integrated mechanical systems, can reduce costs per ton of heating capacity. Competitions or challenges (e.g. SunShot or Global Cooling Prize) and creating performance thresholds for incentives will help drive manufacturers to innovate and reduce costs while improving efficiencies.

FIGURE 8.12: COST REDUCTION POTENTIAL BY 2040 FOR KEY DECARBONIZATION TECHNOLOGIES

Based on analysis findings, capital costs for nearly all technologies are anticipated to drop by at least 30% by 2040 as the market scales. Innovation could further decrease costs for a total capital cost reduction between 40-65%, depending on the technology.

The most significant drop is likely in Integrated Mechanical Systems (unitized, combined HVAC and water heating systems)—these are only applicable to residential typologies and are not yet commercially available in the U.S. Maximum found in literature is based on highest values cited from both academic/industry review and interviews with manufacturers. Not all literature or interviews were New York specific. Innovation threshold is based either on identified threshold for widespread adoption in literature or discussion with NYSERDA stakeholders on "moonshot" goals.



Quantifying and Monetizing the Co-Benefits and Social Cost of Carbon

Decarbonizing the building stock brings many additional benefits beyond direct energy and carbon savings. These co-benefits are not uniformly monetized today, but there is a growing dataset backing their economic value which provides the opportunity to fundamentally transform the value proposition. For example, pilot efforts are underway to bring healthcare funding into the mix of resources for comprehensive building improvement projects that have been demonstrated to reduce respiratory illnesses through improving indoor air quality.

TABLE 8.5: RECENT STUDIES ON THE CO-BENEFITS OF DECARBONIZATION DEMONSTRATE SIGNIFICANT VALUE

Reduced Healthcare Costs	Benefits to Disadvantaged Communities	Resilience	Job Creation	Productivity and Performance
Avoided healthcare costs for **reducing energy usage by 15%** for New York City would be the highest in any city across the US, per ACEEE and NRDC. Decreases in pollution in NY will reduce hospital visits from respiratory related illnesses, according to an New York City Health report. UCLA projects **$3.5 billion in annual health benefits** from outdoor air quality improvements due to residential electrification in CA.	**At least 35% of benefits from New York State's clean energy transition** will be invested directly into Disadvantaged Communities; this translates to **$4 billion annual benefits** for Disadvantaged Communities, RMI suggests. The median energy burden for low-income housing in New York City is **3.3 times** higher than non-low-income households. Energy efficiency targeted at these households will help alleviate that burden.	Investment in upgrading the building stock can improve resiliency. For example, according to the National Institute of Building Sciences, **every $1** invested in mitigation through federal grants **results in an average of $6 saved** during disaster recovery.	Employment in the buildings sector will more than double the 2019 workforce by adding over 200,000 new jobs and continue to increase through 2050.	According to RMI, net zero energy commercial buildings can lead to increases in productivity of 6-16%.

Social Cost of Carbon:

The social cost of carbon (SCC) is a metric that estimates the net damages from global climate change resulting from greenhouse gas emissions. The New York State Department of Environmental Conservation (DEC) determined the monetary value for the avoided emissions of greenhouse gases as part of implementation of the Climate Act, **arriving at a value of $125 for avoiding one ton of CO_2 in 2020.**[119] When factored into a cost-benefit analysis, the social cost of carbon helps Federal and State agencies as well as all building decision makers make informed decisions on carbon neutral investments. Private entities may also find value in incorporating the social cost of carbon as part of environmental, social, and corporate governance (ESG) reporting. In the event that the federal or New York State government places an actual cost on carbon through a carbon tax or other mechanism, the value proposition for building decarbonization will improve dramatically.

Cost Savings by Increasing General Awareness

General awareness, consumer education, and performance validation are generally viewed as low cost, high impact opportunities to influence consumer behavior, stimulate market development, and enhance community engagement, leading to increased end user demand for decarbonization solutions. Some examples of general awareness and consumer education activities include:

- Create easy to use 'Toolkits.'
- Lead voluntary community competitions such as Carbon Challenges or sustainability initiatives in office spaces.
- Conduct statewide Marketing Campaign: digital and static—website, media, social media, out of home (OOH), influencers, demonstrations, virtual tours, press releases, events, blogs, mailers, public service announcements, QR codes, and augmented reality experience, mobile platforms, etc.
- Expand community/municipal engagement programs (not incentive programs) with empowered change agents and collaboration with grassroots organizations and retailers.
- Leverage New York's new Clean Energy Hubs.
- Develop an education database with case studies, analysis, research, and reports.
- Create a contractor database offering sell sheets and talking points for builders/contractors, positive sales, installation, and operation resources.
- Utilize training workshops, job fairs, resource access, outreach to high schools.
- Enact building performance disclosures such as energy and carbon benchmarking, energy efficiency rating labels, and environmental product disclosures.
- Publish playbooks for residential projects with standardized measure packages and process playbooks for larger, more complex buildings that won't have technology standardization, but where the process itself is the key.

Tax Credits, Incentives, Financing, and Emerging Business Models

To reach the level of investment necessary to decarbonize its entire building stock, New York needs to facilitate and accelerate access to all existing funding and financing options. The use case modeling presented above indicates that carbon neutral buildings typically have up-front cost premiums compared to conventional building construction and renovation. Many tax credits, incentives and low-cost financing options are available to help project owners cover the extra cost. Clear and easily accessible incentives are important signals to the market to maintain affordability and speed scaling, particularly in use types such as schools, affordable housing, and community spaces.

Below is a list of various financing opportunities available today:

1. **Tax Credits:**
    - The recently enacted Inflation Reduction Act of 2022 extended and expanded a number of tax provisions across the full spectrum of technologies and market sectors.
    - The 179D commercial building energy efficiency federal tax deduction enables building owners to claim a tax deduction for installing qualifying systems and technologies.
    - Federal Solar Investment Tax Credit (ITC) provides a 26% tax credit for solar systems installed on residential and commercial properties and can be applied to both customer-sited systems and large-scale solar farms.
    - The NY State Solar Energy System Equipment Tax Credit offers 25% (max. $5000) state tax reduction for purchased home solar systems.

- New York Real Property Tax Law, Section 487 and 487-a provide exemptions from taxation for certain solar, wind energy systems, and other energy conservation improvements to residential properties and protects against increased assessed property values from these improvements.
- New York State Geothermal Tax Credit offers 25% (max. $5000) state tax reduction for homeowners who install geothermal heat pump systems.
- The City of New York Solar Electric Generating System (SEGS) Tax Abatement program provides a property tax abatement to properties that use onsite solar power, which is applicable to most building types in New York City.

2. **Green Lending Programs:** Green lending programs such as property assessed clean energy (PACE) financing, power purchasing agreements (PPA), energy service agreements (ESA), green construction loans, and energy efficient equipment loans. Loan providers and programs include:
    - NYSERDA residential financing options
    - NYSERDA small business financing
    - New York Green Bank building decarbonization financing
    - Energy Improvement Corporation (EIC) PACE program
    - New York Power Authority Financing (NYPA)
    - Dormitory Authority of the State of New York Financing (DASNY)
    - New York City Energy Efficiency Corporation (NYCEEC)
    - New York City Commercial PACE program, administered by NYCEEC
    - Green Housing Preservation Program (GHPP)
3. **Loan-Loss Reserve Funding (LLRs):** Credit enhancement strategy used by local/state government to improve the chances that financing will be repaid. Used to encourage private lenders/ investors to put money into the unfamiliar elements of the decarbonization market and offer lower interest rates. NYSERDA's Loan Loss Reserve Program provides a no-cost credit enhancement to support clean energy projects, covering up to 90% of Qualifying Eligible Losses on the remaining loan balance in the event of a default.
4. **Energy Savings Performance Contracting (ESPC):** Financial approach to make building energy and water efficiency improvements with no upfront capital cost to the building owner, predominately applied to public sector and institutional buildings. The building owner partners with an energy service company (ESCO) which installs and commissions the efficiency improvements and uses the cost savings from the improvements to repay the project costs.
5. **Community Shared Solar:** An alternative to onsite or roof-top solar. Most Community Shared Solar programs offer a subscription service to local off-site solar farms to help reduce a customer's monthly electricity bill. Some community solar projects offer purchase plans that enable ownership of a portion of a community solar project which can yield greater savings over time.
    - NYSERDA's guide to Community Solar
6. **ESG Investment Options and "Green" Securities:** Single-family green mortgages could meet a significant portion of the needs for low-cost financing solutions.[120]
7. **Utility Loaned & Controlled Equipment:** Low-cost loans of high-efficiency equipment in return for grid-balancing control (e.g. Green Mountain Power's battery program and New Brunswick Hydro's domestic hot water programs).
8. **Electricity Market Participation:** Facilitate better resource utilization and distributed energy resource procurement for grid balancing purposes. Augment existing demand response and demand flexibility programs while opening greater access to participation in the wholesale electricity markets for individual buildings and through 3rd party-aggregated portfolios (i.e., virtual power plants).
9. **Affordable Housing Finance Assistance:** NY State Homes and Community Renewal's (HCR) Clean Energy Initiative provides access to up to $12,500 per dwelling unit (funded by NYSERDA through HCR's financing processes) for projects committed to meeting HCR's Stretch Sustainability Standards, including electrification and shell improvements.
10. **Heat Pump Rebates:** Rebates available for Air sourced and Ground sourced Heat Pumps for both space and water heating through the NY State Clean Heat Program.

11. **Other Financing Opportunities through NYSERDA Programs:** An array of NYSERDA programs offer funding opportunities through awards and competitions (Buildings of Excellence, Commercial & Industrial Carbon Challenge), funding to test innovative approaches to decarbonizing tall buildings (Empire Building Challenge), funding for single-family, carbon neutral homes (Building Better Homes) and community-scale projects (Carbon Neutral Community Economic Development Program), and incentives for home "seal and insulate" packages (Comfort Home Program).

    - Buildings of Excellence
    - Building Better Homes
    - Empire Building Challenge
    - Commercial and Industrial Carbon Challenge
    - Comfort Home Program

Last Words

The primary business case for decarbonizing buildings is based on reducing building capital and operating costs while increasing asset value.

Multiple solutions to achieve building decarbonization exist for each building typology, and the business case varies significantly across these solutions. In all instances, the business case is challenged by today's low cost of fossil fuels, high cost of electricity and decarbonization technologies, and lack of long-term market signals regarding future energy costs. Despite these challenges, experienced design and developer teams can decarbonize new construction projects at or near cost parity with conventional construction through integrated design and utilizing federal and State tax credits and incentives. Cost reduction strategies such as technology cost reduction, integrated design, innovative business models, low-cost financing, incentives, and rebates, and quantifying the co-benefits of building decarbonization, must all work in parallel to reduce current cost premiums and make building decarbonization available to all New Yorkers.

Policy Solutions

CHAPTER 9

Introduction

Achieving a Statewide carbon neutral building stock by mid-century will require a suite of policy actions, encompassing a coordinated combination of incentives, mandates, and other regulatory actions focused on developing and leveraging market opportunities.

The scopes of work and technologies needed to decarbonize buildings have been mostly identified, and the private sector will need to build zero onsite emissions new construction and retrofit all existing buildings to eliminate emissions from the built environment at an unprecedented pace in fewer than 30 years. Leadership from government needs to prioritize decarbonizing buildings, and all public agencies will need to incorporate decarbonization into their policies and standards in support of their core missions. Contractors and suppliers need to be induced to quickly start new sales and services, incentives will continue to be needed to motivate early adopters and provide a bridge until costs are compressed, and regulations must send clear signals to the market that decarbonization and the end of fossil fuel combustion in buildings will be required by dates certain.

One of the primary goals of the *Roadmap* was to conduct analysis to develop a suite of policy action recommendations that will enable the State to decarbonize its building stock by mid-century in the most cost-effective manner while prioritizing equity and environmental justice. The decarbonization of new and existing buildings must be considered in the context of decarbonizing the entire economy, even beyond the borders of New York State. These considerations are situated within the framework of the entire economic system, including an energy sector driven by utility-provided energy and delivered fuels, as well as the transportation, industry, agriculture, and waste management sectors. Equity and Disadvantaged Communities must also be prioritized in the consideration of the State's broader set of building energy policies (see **Chapter 10: Equity and Decarbonizing Disadvantaged Communities**). These interdependencies are complex and further complicated by the short term impacts of building operations changes in the wake of the COVID-19 pandemic.

> A large scale of investments to achieve decarbonization will be necessary both at the individual asset and societal levels, and these investments will need to be motivated by regulations, subsidies, and co-benefits beyond simple energy-related financial returns.

A large scale of investments to achieve decarbonization will be necessary both at the individual asset and societal levels, and these investments will need to be motivated by regulations, subsidies, and co-benefits beyond simple energy-related financial returns. Across New York State, regional differences warrant specific actions based on rural or urban densities, prevalent building typologies, climate zones, congestion on the electric grid and gas distribution system, and the industries that drive local economies. A leading tactic identified by analysis in this *Roadmap* focuses on eliminating emissions from the onsite combustion of fossil fuels primarily through the electrification of space heating and hot water production, while limiting the impact on the electric grid through cost-effective investments in building envelopes and water efficiency measures, other energy efficiency measures and load flexibility, and focusing on lowering the global warming potential of refrigerants. The *Roadmap* does not address energy intensive operations related to critical care or industrial production.

Legacy of Policies

The Roadmap builds upon New York's legacy of foundational laws, policies, and technical requirements that are facilitating building decarbonization across New York State.

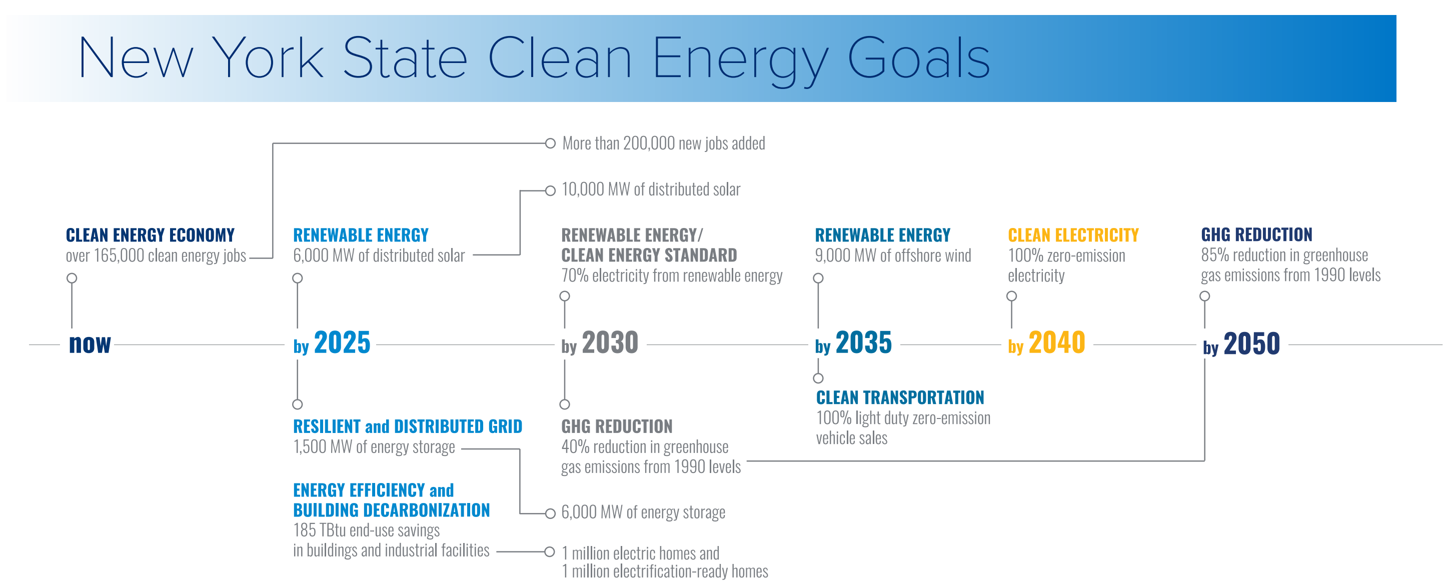
Key policies include:

Climate Leadership and Community Protection Act (Climate Act) legislates an 85% reduction in GHG emissions from 1990 levels. A Climate Action Council has been convened to deliver policy recommendations to reach this goal. Figure 9.1 includes a timeline of the targets in the Climate Act.

Analysis from the ***Carbon Neutral Buildings Roadmap*** contributed to the Climate Action Council's policy recommendations for the buildings sector. Analysis conducted for the Roadmap informed an advisory panel tasked with developing and presenting to the Climate Action Council recommendations for policy actions necessary to reach the Climate Act goals. Those recommendations were largely adopted in the Climate Action Council's draft Scoping Plan and are very closely aligned with the *Roadmap*.

New Efficiency: New York set an ambitious 2025 statewide efficiency target of 185 trillion British thermal units (TBtu) of end-use energy savings below that year's energy-use forecast, a target subsequently codified in the Climate Act. This target is equivalent to saving the energy consumed by 1.8 million New York homes. As part of this initiative, New York's utilities have been called upon to do more, in both scale and innovation, to achieve aggressive energy efficiency and energy-efficient heat pump targets; their authorized targets and budgets for 2021-2025 roughly double the utilities' energy efficiency commitments over historic levels. Other key components of New Efficiency: New York include prioritizing solutions for low- and moderate-income households, strengthening State energy codes and appliance standards, leading by example in New York's own facilities and construction activities, and scaling-up New York's investments in training and

FIGURE 9.1: TIMELINE OF CLIMATE ACT TARGETS



workforce development to support high-quality energy efficiency jobs across the State. New Efficiency: New York is a great foundation, but not nearly enough for the buildings sector to help meet New York's economy-wide 2030 GHG emissions limits, as is evident in the integration analysis conducted to inform the Climate Action Council.

Accelerated Renewable Energy Growth and Community Benefit Act launched a Power Grid study and program to ensure that clean power can be delivered to where it is needed most, with a plan for investments in the grid infrastructure necessary to maximize the benefits of renewable energy and achieve the mandates of the Climate Act.

Climate Mobilization Act of New York City requires GHG emissions from large buildings to achieve 40% reductions by 2030 and 80% reduction by 2050. The Act also legislates an Energy Code requiring the highest standards for energy efficiency in new construction.

New York City Local Law 154 of 2021 sets CO_2 limits that effectively prohibit fossil fuel systems in new buildings and gut renovations through the Building Code. The law phases in the requirements starting with low-rise buildings in 2024 and then becoming applicable to taller buildings in 2027.

Buffalo, New York.

Potential GHG Impacts of Policies

As of 2018, the New York buildings sector accounted for 115 million metric tons of CO_2 equivalent.

Fuel combustion in residential and commercial buildings represents the majority of emissions, which includes “imported fossil fuels”—meaning emissions associated with extracting, processing, and transporting fossil fuels. Hydrofluorocarbons, or HFCs—used mainly for refrigerants—accounted for almost all of the increase in emissions since 1990, when they were not in use. HFCs are much more potent GHGs over the short term than CO_2, so these emissions will need to be reduced dramatically, even as the use of air conditioning and heat pumps expands.

The policy suite of the *Roadmap* has been modeled to achieve a 30% reduction in New York’s building sector emissions from the 1990 baseline by 2030 and put the State on track to reduce emissions from its buildings by 85% by 2050. For updated information about New York’s emissions profile, please visit the Climate Act website at: **https://climate.ny.gov/**

New York, New York.

Policy Solutions

Eliminating GHG emissions from buildings in New York will require broad systemic changes and new resources to help pay for those changes.

Ambitious policies, in the form of regulations and codes to phase out fossil fuel use in buildings, enabled by incentives, financing, workforce development, research and development to spur innovation, and public outreach, can induce these broad systemic changes.

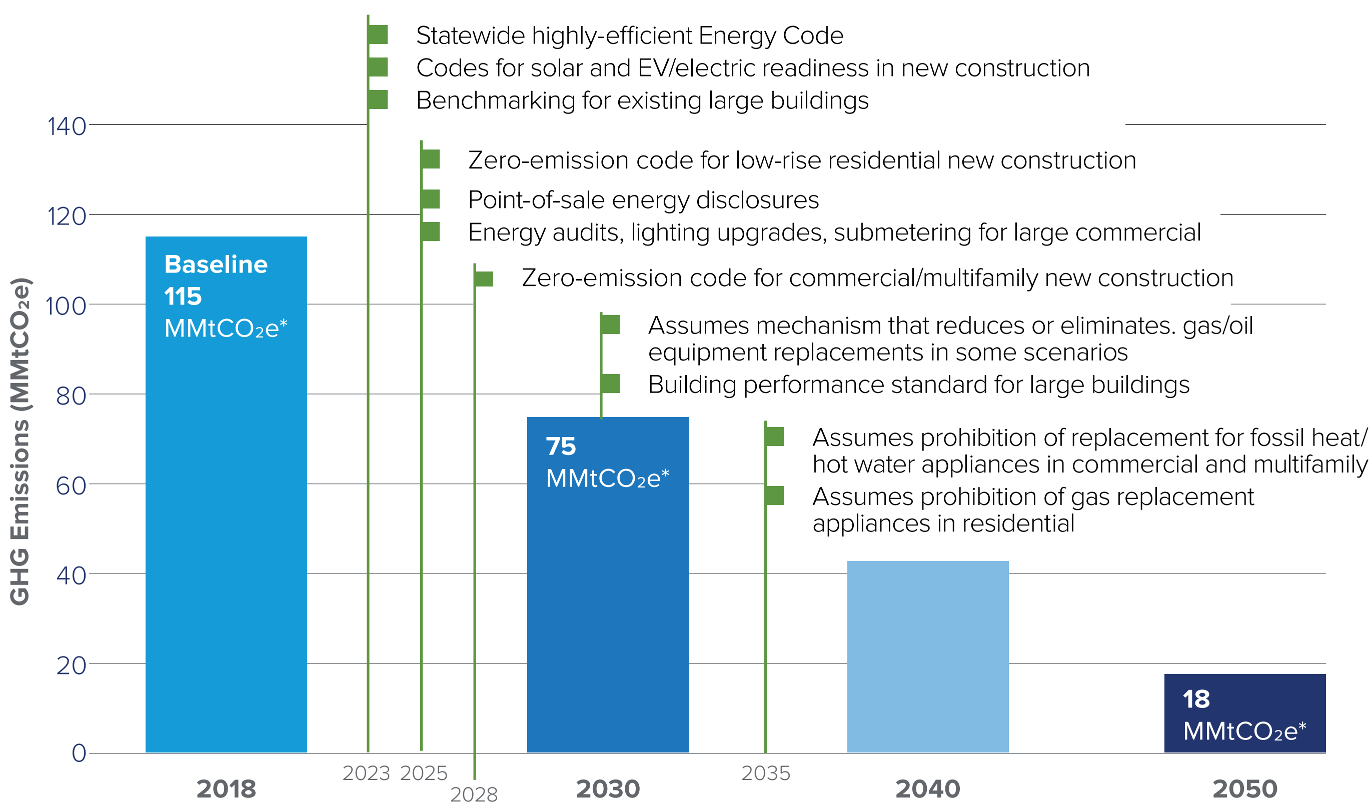
Regulations send clear market signals, and given enough time for technology development, job training, professional development, and supply chain growth, the industry and service providers can respond to these market signals to meet educated consumer demand.

In the quantitative analysis detailed in the Scoping Plan that demonstrates the feasibility of nearly 85% emissions reduction in the buildings sector by 2050, the lion's share of the projected emissions reductions is attributable to the electrification of heating and hot water systems as a modeled market response to regulatory prohibitions on installing or replacing fossil fuel equipment.

Advanced Building Codes and Code Compliance

The most transformative strategy identified in the analysis uses Codes and Regulatory Standards to send clear market signals ending reliance on fossil fuels in buildings—phasing in over time. New York's Advanced Building Codes, Appliance and Equipment Efficiency Standards Act of 2022 enables the State to adopt this level of building codes, equipment standards,

FIGURE 9.2: TIMELINE FOR BUILDING POLICY PHASE IN AS MODELED FOR THE ROADMAP



New York City Council Law, Instituting an All-Electric New Construction Code

New York City Local Law 154, adopted Dec 22, 2021, bans gas connections in new buildings and gut retrofits, for heating and cooking. It goes into effect in December 2023 for buildings less than seven stories, and 2027 for those seven stories and above.

The New York City Council—File #: Int 2317-2021

and regulations to promote energy reduction, water conservation, GHG reduction, and/or increased demand flexibility. New York will need a committed public to support these legislative, regulatory, and programmatic changes.

To manage dependencies on energy and to bring costs down for operators, the analysis demonstrates that the State should adopt and adequately enforce an advanced Energy Code for new construction (and additions and alterations as applicable) that requires highly efficient buildings and takes effect as soon as practicable. The advanced codes should consider emphasizing performance and outcomes that encourage electrification and decarbonization during the interim period before those outcomes are required. The State should continue developing and implementing NYStretch codes for adoption by progressive municipalities to allow them to decarbonize faster and participate in the clean energy economy sooner, until the zero onsite emissions, highly efficient code is adopted statewide.

The Uniform Building Code, and related construction codes including Plumbing, Mechanical, and Electrical, should also be considered to be amended to require solar photovoltaics on rooftops (where suitable); grid-interactive capabilities for electrical devices and equipment (e.g. batteries, hot water heaters); energy storage readiness; electric readiness for space conditioning, hot water, cooking, and dryers; and EV readiness where parking is already provided. The codes could be further amended to account for the embodied carbon of building materials and the GWP of refrigerants used in HVAC and other applications.

As the markets quickly mature for non-fossil-fuel technologies in HVAC and hot water, the State should enact construction codes that prohibit gas and oil equipment for heating and hot water in new construction and gut renovations, and instead enable highly efficient electric equipment to dominate industry practices. The enforcement needs are continually expanding as requirements become more stringent and expansive in scopes. The State should explore ways to expand support to municipal building departments' respective capabilities to enforce the codes and ensure the highly efficient, low-emissions outcomes mandated by the codes.

Replacement of Fossil-Fuel Heating and Hot Water Equipment

The State can continue to demand the best of new construction, but the majority of emissions are attributable to the buildings standing in New York today, most of which are likely to still be operating in 30 years. This policy addresses the sale and installation of efficient and zero emission equipment, when replacing fossil burning heating, cooking, and drying equipment at the end of that equipment's useful life. By targeting

TABLE 9.1: THE ANALYSIS DEMONSTRATES THE NEED FOR PHASED ACTIONS FOR ADVANCING BUILDING CODES

ASAP	2023	2025	2028
Adopt highly efficient State Energy Code for all new construction in next code cycle. Scale up building decarbonization requirements in affordable housing and State supported economic development projects.	State building code council considers solar, electrification-readiness, grid-interactive capability, battery readiness, and electric vehicle readiness.	State building code council consider adoption of zero onsite emissions (all-electric and highly efficient) State code for new construction or gut renovation of homes and low-rise residential.	State building code council consider adoption of zero onsite emissions (all-electric and highly efficient) State code for new construction or gut renovation of multifamily and commercial.

replacements at end of life, costs are contained by leveraging the natural investment points in the lifecycle of a building or piece of equipment. The analysis conducted to date suggests that emissions based standards that prohibit replacing space conditioning and water heating equipment with fossil fuel new equipment.

The full decarbonization of the buildings sector would require an end to the use of fossil-fuel in HVAC and hot water equipment. While use of fossil-fuel combustion continues through the useful life of the equipment, new energy performance requirements should be considered for existing buildings. Lighting upgrades to standards in current code already make economic sense and could be required for large commercial properties, alongside required periodic energy/emissions audits that will afford building operators the planning opportunity to transition from fossil-fuel systems. Sub-metering of tenants provides building energy and water use transparency to building owners and end-users. In the immediate period, more stringent efficiency standards on appliances that are not federally preempted could be applied to further reduce building energy consumption and reduce the growth of demand on the electric grid, while providing savings to consumers.

Benchmarking and Disclosure of Energy and Carbon Performance

For building owners today, better information in the market drives better decisions. The merits of requiring the measurement of building energy use and making that information available via disclosures have already been proven in major real estate markets, including New York City.

Building Energy Benchmarking is a process of measuring a building's energy, GHG emissions and water use, tracking that use over time, and comparing performance to similar buildings. Actionable information on building energy use and GHG emissions helps identify opportunities to cut costs and reduce waste.

A Statewide energy and water benchmarking requirement would expand upon existing localized benchmarking programs and could be uniformly applied to all properties larger than 25,000 square feet in size. Following an introductory period of benchmarking and understanding of the incoming data, a building "Energy Grade" labeling or rating system, including energy use and carbon, could be deployed to create public awareness and increase demand for higher-performance buildings by prospective tenants and purchasers. Buildings of all sizes can be evaluated, including single-family homes. Whereas larger buildings could be benchmarked annually with public disclosures, homes and smaller buildings could disclose an energy performance metric or historic

TABLE 9.2: THE ANALYSIS DEMONSTRATES THE NEED FOR PHASED ACTIONS FOR FOSSIL-FUEL HEATING AND HOT WATER EQUIPMENT

2030	2035
Zero emission standards prohibiting fossil fuel replacements of heating, cooling and domestic hot water equipment in homes.	Zero emission standards limiting fossil fuel replacements of heating, cooling and domestic hot water equipment in multifamily and commercial buildings. Zero emission standards limiting replacement of fossil fuel cooking and dryers in residential buildings.

TABLE 9.3: THE ANALYSIS DEMONSTRATES THE NEED FOR PHASED ACTIONS FOR BENCHMARKING AND DISCLOSURE OF ENERGY AND CARBON PERFORMANCE

2023	2025	2027
Statewide benchmarking and disclosure of energy use, emissions, and water use for buildings larger than 25,000 square feet.	Public disclosure, as part of sale or lease listing, of the energy consumption or energy rating for large buildings. Energy/emissions audits for buildings larger than 25,000 square feet.	Energy/emissions performance grades for homes at point-of-sale.

energy consumption data only upon listing a property for sale to prospective buyers, thereby informing purchases and encouraging homeowners to improve the energy and carbon performance of the property. Healthy building-oriented certification systems, like WELL or Fitwell, increase visibility into indoor air quality and other wellness attributes of a building or tenant space. Proliferation of this information will increase tenant demand for healthy spaces in energy efficient buildings.

Building Performance Requirements for Existing Buildings

Planning for efficiency improvements, energy conservation, and emissions reductions in large buildings with complex systems requires operational targets and benchmarks indicative of high performance. A statewide energy efficiency performance metric applicable to buildings larger than 25,000 square feet could set visible markers to individual property owners and managers regarding a building's energy consumption required to manage the decarbonization transition. The initial period of benchmarking data would inform the compliance standards for a performance metric, and the compliance mechanisms can range from prescriptive building upgrades to limits on energy use intensity (adjusted for various use and occupancy characteristics) to minimum "energy grade" requirements as seen in the UK and Washington, D.C. Commercial property owners pursuing business interests will respond and conform to performance metrics, while multifamily property owners, particularly in affordable housing, will face implementation hurdles and costs that makes the legislation of a performance requirement on multifamily housing challenging. However, given the sheer number of residential properties and their outsized proportion relative to all buildings, the full efficacy of an energy efficiency performance metric would only be achieved by applying the standard to buildings of all typologies, including multifamily housing. Any approach would need to include safeguards to the continued affordability of multifamily properties in Disadvantaged Communities.

Existing buildings must be significantly modernized and upgraded to reduce energy consumption and may need to transition to electric systems for heating and hot water. A requirement to meet standards for energy performance could be triggered by a property sale or major tenant turnover would ensure buildings are retrofitted to decarbonize at the transactional event when capital improvements are most likely to be incurred. The costs must be carefully considered in the context of underlying property values, especially among smaller buildings and single-family homes. The application to commercial properties would yield immediate performance improvements and efficiency gains that result in lower operating costs to the property purchaser.

Highly-efficient buildings demand less heating and cooling energy, while participating in demand response programs or shifting loads to off-peak hours can reduce utility costs and preserve grid reliability. Energy conservation measures, both in capital improvements and operational patterns, as well as expansion of solar and other distributed energy resources, will be necessary to manage a future where buildings are heated and cooled by clean energy provided by the utilities in order to minimize the societal cost of expanding the electric grid with emission-free generation assets.

TABLE 9.4: THE ANALYSIS DEMONSTRATES THE NEED FOR PHASED ACTIONS FOR BUILDING PERFORMANCE REQUIREMENTS FOR EXISTING BUILDINGS

ASAP	2025	2030
Energy efficiency standard for appliances outside Federal preemption.	Lighting upgrades to current Energy Code standards and submetering of tenants in large commercial buildings.	Building performance standards for existing large buildings regulating energy efficiency.

Managed, Phased, and Just Transition to a Clean Energy System

To decarbonize its economy, New York will need to dramatically reduce the use of fossil fuel use, in its buildings, for power generation, and in industry. Policymakers and regulators need to advance a managed, phased, and just transition from reliance on fossil fuel gas and the gas distribution system to a clean energy system, including elimination of embedded subsidies for fossil fuel gas.

The State should consider a long-term planning strategy to manage the State's transition away from fossil gas-fueled technologies. A comprehensive long-range plan is important to facilitate equitable and strategic decommissioning or repurposing of the State's gas infrastructure and afford pathways for incumbent workers in the clean energy economy. The plan would likely need to examine regulatory and legislative changes, with attention to safety, equity, reliability and affordability of service; assessment of existing gas infrastructure and options for contraction; identification of end-users highly reliant on gas, technically feasible alternatives, and economic impacts; and alternative models for the gas utility's long-term role, business model, ownership structure, and regulatory compact, as part of a managed transition.

The plan should also consider including a comprehensive equity strategy to incorporate the needs of low- to moderate-income (LMI) households and Disadvantaged Communities (DACs) in the transition, ensuring they are not left behind. This requires meaningful LMI/DAC engagement in the transition process and prioritizing technical and financial assistance to enable LMI/DAC households to make energy efficiency upgrades and electrify affordably. There must also be an equitable transition plan for the gas industry workforce, including protections, retraining that leverages transferable skills, and job transition opportunities with attention to

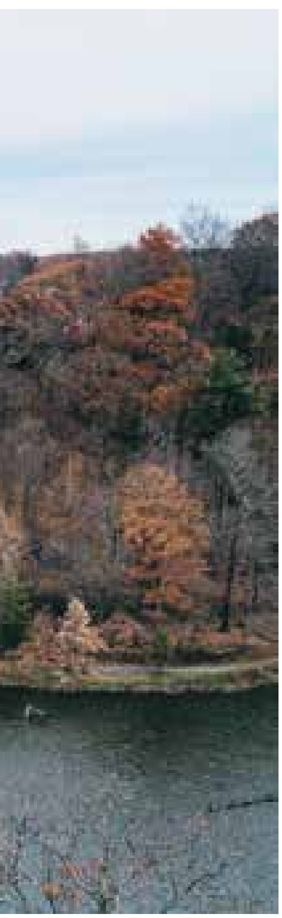
opportunities at dual commodity utilities. This would require both a comprehensive system-wide equity strategy and utility-level equity strategies that include adequate accountability and oversight.

A primary objective of the plan could include how to minimize new investments in gas delivery infrastructure, not otherwise needed for safety/reliability. This will include changes to utility incentives and planning to promote alternatives to conventional gas infrastructure investment and align long-term utility planning with the adoption cycle for updated building codes and standards that end fossil fuel use.

Managed Transition from Hydrofluorocarbons (HFCs) Used as Refrigerants

HFCs are potent greenhouse gases, which are used in refrigeration, air conditioning and heat pumps, and spray foam insulation. HFCs currently account for approximately 14% of the direct GHG emissions from buildings. of the total GHG emissions from buildings. Fortunately, the federal government, other states, and the industry are working to drive toward technologies that use alternative refrigerants that have much lower climate impact.

The *Roadmap* forecasts widescale adoption of refrigerant-cycle HVAC systems, and the fluids currently used in those systems have an extremely high global warming potential and are prone to leaking from installed equipment. While the federal government has recently put forth new phase-out requirements for the production of new equipment, the refrigerants used in current systems must be systematically captured and disposed. Requirements for leakage detection and management, plus for the proper disposal of refrigerants, will reduce the emissions impact from existing equipment. New equipment should be limited to low-GWP refrigerants by regulation on a faster timetable than the federal government would implement. Similarly, the propellants used in foam construction materials should be limited to low-GWP fluids by regulation.



City of Ithaca—Goal to Decarbonize 100% of Building Stock By 2030

In 2021, the City of Ithaca voted to decarbonize all buildings in the city by 2030. To do so, it has created the Efficiency Retrofitting and Thermal Load Electrification Program, which starts with the electrification of buildings. The plan will retrofit 6,000 residential and commercial buildings, replacing fossil fuel appliances with electric. This is in addition to the Ithaca Green New Deal plan, adopted in 2019, to transition to a carbon neutral economy by 2030.

Photo Credit: ***Li Guan on Unsplash***

Community-Scale Decarbonization

The full decarbonization goal demands new systems thinking that considers how buildings, distributed energy resources, transportation, and the grid interact within a community system, and begin to foster actions at the community scale. The regulatory agencies need to develop pathways for district energy systems and facilities that deliver fossil fuel free solutions. Regulatory frameworks for utilities that intersect with the development of shared thermal loops must be reconciled at the levels of the legislature and the New York Public Service Commission, with the State's emissions reduction objectives given the highest priority, while minimizing regulatory burdens on the Department of Public Service (DPS) and on the projects.

Thermal Network Energy systems are only one element of community scale action. The State should support community and municipal engagement programs so the public and business understand and advance building decarbonization and increase clean energy awareness. New York State should also provide incentives, guidance (e.g. model local ordinances) and technical assistance to support local jurisdictions intent on decarbonizing their own communities, with a focus on serving Disadvantaged Communities.

Market Building & Support

Direct Incentives

Through collective efforts to decarbonize buildings, housing quality can be improved, and economic opportunities can be expanded for low-income households and Disadvantaged Communities. Public funding should be invested to support building upgrades, and training and job placement for priority populations should be a key focus.

Public incentives enable market development of electrification and other clean and resilient building, efficient building solutions, with an emphasis on Disadvantaged Communities and affordable housing. Expansion of financial incentive programs to motivate early adoption in market-rate housing and commercial buildings will also be needed for at least the coming decade. This support should target existing buildings more so than new construction and eventually phase out (once efficient, zero emission codes and standards go into effect), with a longer timeframe for support for low-income households and, as appropriate, for next-generation technologies as they emerge. Public dollars must be targeted to seed markets by incentivizing early adopters to build market demand and afford low-income residents and Disadvantaged Communities an equitable participation in the clean energy economy. Transparency into the planned incentive reduction over time enables market adoption and ensures milestones are achieved and market solutions and cost compression fill the void as incentives shrink.

> In addition to public incentives, the sheer scale of transformation will also require unlocking private capital to provide low-cost financing to homeowners and building owners to pay for the necessary building upgrades for decarbonization.

Additional funding is likely needed for incentive programs supporting building upgrades that serve LMI households, affordable and public housing, and DACs on an ongoing basis, to avoid the risk of disinvestment. The emphasis on incentives for Disadvantaged Communities starts with ensuring the existing housing regulations align with the State's objectives. Utility incentives should consider providing direct resources for electrical service upgrades and in-building wiring and equipment. Additional incentives could be directed in the form of a "Retrofit and Electrification Readiness Fund" that covers the costs of non-energy building improvements, including for health and safety, that are necessary to install energy measures and broadband installation costs when funding energy projects.

Funding sources will need to be identified more broadly, including accessing additional program resources through Federal budgeting. Creative applications and synergies with health outcomes can also be leveraged through existing programs and partnering with community-based organizations for healthy housing services and homes.

Low-Cost Financing

In addition to public incentives, the sheer scale of transformation will also require unlocking private capital to provide low-cost financing to homeowners and building owners to pay for the necessary building upgrades for decarbonization.

Private sector capital must be mobilized to enable whole market transformation. Low-cost financing for energy efficiency, electrification, electrification readiness, solar, and related improvements in buildings will give all building owners access to low-cost capital at the scale needed to pay for the building upgrades necessary for decarbonization. The public sector can provide support for lenders to shift from concern over their return on investment in the decarbonization space and instead underwrite to energy performance standards and applicable regulatory requirements.

In addition to public incentives, the sheer scale of transformation will also require unlocking private capital to provide low-cost financing to homeowners and building owners to pay for the necessary building upgrades for decarbonization.

New York State will continue to scale up green requirements in affordable housing financing transactions while ensuring that sufficient resources are available to maintain, preserve and produce clean, safe and affordable housing. Streamlined access to incentives and resources for regulated affordable housing building decarbonization should run through housing agencies, making those resources more easily accessible while delivering projects that are affordable, energy efficient, all-electric or electric-ready, and resilient. The State should offer greater access to low-cost financing products for electrification and efficiency upgrades to LMI homeowners by providing credit enhancement to lenders.

The State can further work with lenders to develop products that offer more attractive financing rates and terms for deep decarbonization projects through a concerted stakeholder engagement with private capital. Green Banks, like the New York Green Bank (NYGB) and New York City Energy Efficiency Corporation (NYCEEC) will play a role in expanding the clean energy financing market. The full scope could entail Fannie Mae and Freddie Mac green discounts for Passive House or net zero certified projects. New York could also look to replicate municipal-based financing options that have been deployed at scale in clean drinking water projects by coupling low-cost financing with public mandates.

Expanded eligibility for financing through New York's commercial Property Assessed Clean Energy (PACE) financing programs could encompass energy efficiency, renewable energy, and electrification measures in new construction and retrofit projects. The State could also consider expanding PACE eligibility to building resiliency measures, including advanced ventilation and filtration systems. Authorization for a statewide Residential PACE program, while ripe with potential, must carefully address consumer protection issues and the interests of the mortgage industry.

Expanded on-bill recovery enabled by the Green Jobs—Green New York (GJGNY) on-bill program could attract third-party capital, but specific issues need to be addressed regarding the priority of partial utility payments, utility fees for providing billing and collection services, transferability of loans, and bill neutrality requirements.

New York could also continue to explore the viability of Inclusive Financing Mechanisms such as tariff-based financing models, which are location-based and tied to a meter, and thus available to renters and consumers with poor credit. This financing model is set up to be cash flow positive to consumers.; If the utility rate-base can backstop defaults, the utilities' low cost of capital should lead to lower interest rates.

Third-Party Support & Advancing Code Compliance for Local Municipalities

Recognizing the importance of local communities in achieving carbon neutral buildings, New York State is providing direct support to expand code compliance capacities statewide. PON 4600 helps communities adopt new third-party code compliance practices and supports critical upgrades to permitting and compliance technology systems that will make it easier for local officials to manage, and builders and owners to comply with, code requirements.

Third-Party Support and Advancing Code Compliance Technology Pilot Program (PON 4600)

Electrification Readiness Fund

To support electrification for low-income customers, the Governor's 2022 budget includes $250 million to the NYS Homes and Community Renewal for a nation-leading electrification fund to decarbonize and improve energy efficiency in low-income housing units.

State-Owned Buildings Lead the Way

Expanded State capabilities to utilize energy performance contracting will enable government facilities to lead by example. New York must first update existing statutes and authorizing language to enable State agencies and authorities—as well as local governments, K-12 schools, and other public entities—to include a broader package of energy upgrades, water savings upgrades, and deep decarbonization projects in performance contracts, thereby enabling public entities to self-fund and implement a greater volume of efficiency upgrades and deeper efficiency projects. Early decarbonization projects in State and municipal buildings will help expedite the development of industry capacity to meet the burgeoning demand for these projects that will result from the implementation of New York's carbon neutral policy framework.

Workforce Development

Support from the public sector will be necessary to invest in workforce education, training, job placement, and development that will equip the State's current and future workforce to design, install, inspect, maintain and operate healthy, comfortable, low-carbon buildings while increasing clean energy job placement for DACs and advancing industry diversity (see Chapter 11: A Just Transition to a Green Workforce). This means scaling up training for incumbent and new clean energy workers and adjacent industries, through investments in training delivery, career pathways, on-the-job-training, and industry partnerships. The approach prioritizes Disadvantaged Communities and low-income residents for training and job placement by creating community-to-employment pipelines and career pathways. The State must first analyze current on-the-job training investments for their effectiveness as an employment pathway and refine as appropriate. These efforts should promote good wages and benefits and increase the ranks of Minority and Women-owned Business Enterprises (MWBE) and Service-Disabled Veteran Owned Business Enterprises (SDVOB) and cooperatives through increased access to workforce training and business development support leading to broader participation in State-funded investments and projects.

Targeted training and hiring through Community Benefits/Workforce Agreements and On the Job Training Funding should be deployed where appropriate, feasible, and permitted by law. Building decarbonization on a broader basis will need to be incorporated into the curricula and career services in State-funded education (K-12, technical schools, apprenticeships, and engineering and architecture programs at public universities) and encouraged at private universities.

Among professionals, the State can require continuing education on building decarbonization (e.g. energy efficiency, electrification, embodied carbon) as part of licensing for architects, engineers, trades, contractors, building operations and maintenance personnel, and real estate professionals (inspectors, brokers, etc.).

Partner with Trusted Community Leaders for Public Awareness and Consumer Education

Widespread public awareness and educated consumers will be necessary to increase demand for building decarbonization at the scale necessary to meet the State's 2030 GHG reduction goals. New York should create strategic partnerships with various stakeholders, including trusted community leaders, and provide targeted outreach and decision-making support to increase market demand and accelerate the transition to low-carbon, energy-efficient, all-electric buildings. Strategic partnerships with utilities can have broad impact promoting decarbonization and ending messages of "clean gas." The impacts will be further enhanced through partnerships with trusted community leaders and religious organizations, and with cooperative extensions, business councils, industry organizations, corporations, unions, teachers, media, public venues, and elected officials. At the building level, challenges and commitment campaigns build awareness and leverage the competitive spirit of companies, municipalities, and individuals.

The public awareness campaign replaces messaging and media must reflect DACs in marketing efforts and

Virtual Power Plants

A virtual power plant (VPP) is a cloud-based system that aggregates various distributed energy generation resources (such as wind, solar PV, and CHP), controllable/flexible loads, and energy storage resources (such as batteries). VPPs rely on software and grid connected resources to provide reliable, balanced power for both supply- and demand-side management regardless of the time of day or year. VPP software companies operating in New York include OhmConnect and Swell Energy.

prioritize education and technical assistance. New York State should maintain a "one-stop shop" website for clean energy, electrification, and energy-efficiency programs, and partner with community clean energy hubs to offer education, resources, local contractors, technical assistance, and program navigator support. This builds on the commitment of NYSERDA and New York State utilities to maintain the NY Energy Advisor website and coordinated marketing for a statewide portfolio of programs, and on NYSERDA's development of regional Clean Energy Hubs. These commitments include publicizing best practices for efficient building operations and recognizing leaders in efficient operations and early adoption. New incentive programs can attract others and further expand pledges of carbon neutrality.

Research, Development, and Demonstration (RD&D)

The State will continue supporting RD&D projects, aimed at enticing more companies and manufacturers operating in the State to bring innovative solutions to the marketplace for highly efficient, all-electric, and resilient buildings; grid-interactive buildings, with revenue opportunities; and the reduction of embodied carbon in buildings. Innovations are not local to the State and are influenced by global and national efforts. The federal government can be a powerful partner with increased funding and coordination with aligned neighboring states. New York's robust innovation ecosystem can be leveraged to drive market adoption and bring production costs down.

Further State resources can be deployed to identify and expedite the deployment of technologies ready for the New York market and to enable MWBEs, cooperatives, and B Corporations opportunities for

Corning, New York.

leadership in emerging market sectors. Direct support will need to be accelerated for HVAC technologies, building envelopes for high performance, and the more difficult solutions sought in community thermal loops, advanced heat recovery and ventilation, thermal storage, and innovations in systems, materials, and production.

As the electrification of buildings takes a greater share of overall energy demands, grid-interactive efficient buildings will play a more significant role, and today's investments in developing advanced energy management systems will result in more resilient systems through improved energy efficiency, load flexibility, and modulation capability. Additional assessments of the resilience risks and needs of grid-dependent buildings are urgently needed due to the increasing frequency of extreme weather events and probability of network outages. "Demand Response" programs (for example, Special Case Resources or Emergency Demand Response Programs) can be updated to create a pathway to grid-interactive efficient buildings through cost effective load management. The implementation of each investor-owned utility's Distribution System Platform will provide market intelligence and data upon which private companies can build better products and service businesses to serve energy consumers.

Lead by Example with Materials Specifications That Account for Embodied Carbon

Support for building reuse, along with education, research, and development of in-state manufacturing of alternative products with lower embodied carbon will lead to broader carbon literacy and adoption of carbon-sequestering products. The State can further provide business development assistance to expand in-state manufacturing of building products (for example, concrete and insulation) that minimize embodied carbon or sequester GHGs and can be made of biogenic or agriculture-based materials.

Procurement requirements and design specifications for State-funded projects will prime the market for lower embodied carbon products, initially by requiring Environmental Product Declarations (EPDs) for various building materials and the use of modeling software for embodied carbon calculations. Similar to operational carbon emissions, embodied carbon reductions can be achieved through goals specified by numerical GWP targets and verified by standardized accounting systems. The accounting can be used to incentivize building owners, developers, and utilities to specify lower embodied carbon materials in projects. These actions can lead the way to codes and standards further ensuring low-carbon outcomes over the entire life cycle of buildings.

Last Words

Equitable change at this scale in the building sector in New York will require significant new technical and financial resources.

This is an economy-wide undertaking that requires coordination of private capital and public investments. Achieving carbon neutral buildings statewide requires New York State policy interventions to send clear market signals, public subsidies to prime the market and support low-income households and Disadvantaged Communities, and business development assistance to reduce costs and advance technologies.

Equity and Decarbonizing Disadvantaged Communities

CHAPTER

10

Introduction

New York has a three-part vision to ensure equity in building decarbonization for low- and moderate-income (LMI) housing and Disadvantaged Communities (DACs) that will be implemented over the next five years.

This chapter discusses this approach including electrification while preserving affordability and how efforts to decarbonize buildings in LMI and Disadvantaged Communities will be carefully designed to reduce economic burdens and increase opportunities for LMI households to save on utility expenses. Disadvantaged Communities (DACs) are communities that bear burdens of negative public-health effects, environmental pollution, impacts of climate change, and possess certain socioeconomic criteria, or comprise high concentrations of low- and moderate-income households. Environmental burdens in the U.S. have historically fallen on communities whose residents are disproportionately African American, Indigenous, or other people of color. Climate change heightens the vulnerability of these communities which have dealt with higher levels of pollution in their lives, as well as socioeconomic burdens, and legacies of racial and ethnic discrimination.

Prioritizing LMI and DAC decarbonization investments first in the statewide drive to zero emissions buildings is both the right thing to do and will ultimately benefit all New Yorkers by developing markets and supply chains that will bring down costs and increase economic efficiency in the entire buildings sector. This chapter also covers efforts underway to improve engagement with LMI and DAC communities to enable long-term benefits for historically underserved communities from the State's clean energy investments, and an increasing emphasis on place-based and community-led strategies and initiatives.

> Environmental burdens have historically fallen on communities whose residents are disproportionately people of color. Climate change heightens the vulnerability of these communities, which have dealt with higher levels of pollution in their lives, as well as socioeconomic burdens, and legacies of racial and ethnic discrimination.

Disadvantaged Communities, and particularly Environmental Justice and frontline communities, face multiple intersecting environmental hazards. These communities, which include but do not directly overlap with LMI communities, have demonstrated sustained climate and decarbonization leadership. They have also expressed their need for State initiatives that align climate and decarbonization investments with solutions to longstanding environmental injustices and vulnerabilities such as extreme heat, hazardous living conditions, and barriers to safely navigating emergency situations.

Under the Climate Act, the **Climate Justice Working Group** (CJWG) established criteria for identifying DACs across the State. Once identified, agencies are required to ensure that these communities receive no less than 35% of the overall benefits from decarbonization investments. As of this writing, the Department of Environmental Conservation (DEC) and CJWG have released *New York's Disadvantaged Communities Barriers and Opportunities Report* and released for public comment **draft criteria for identifying DACs** in New York State, and a draft list of DACs statewide.[122]

The finalization of these criteria will clear the way for State agencies to target programs and investments into DACs. In the meantime, agencies like NYSERDA will use interim criteria in order to track and account for investments that might count toward the Climate Act's 40% target.

Key Principles, Market Context, & Early Highlights

New York's vision for building decarbonization in LMI housing and DACs follows these four key guiding principles:

1. **Do No Harm:** Decarbonization should not increase a low-income household's energy burden or otherwise put them at risk. Housing decarbonization policy and programs must safeguard the stock of affordable housing.

2. **Accessibility:** The Climate Act requires that the State pro-actively seek input from and collaboration with DACs in developing decarbonization programs and policy. New York must also address barriers preventing equitable participation in the clean energy transition, including the complexity and quantity of state programs serving LMI households, which can require multiple time-consuming applications that discourage under-resourced households from participation; and market barriers that might result in LMI households and DACs being left behind and disproportionately reliant on legacy fossil fuel-based energy systems with rising user fees.

3. **Transparency:** Targeted efforts, including sensitivity to language and educational barriers, will be needed to meaningfully include DAC residents in decarbonization awareness campaigns and to give these communities confidence in current and future decarbonization policies, programs, technologies, and financing products.

4. **Accountability:** State-supported decarbonization efforts should be subject to feedback and oversight from representatives of DACs, with acknowledgement and assumption of responsibility by applicable State agencies for current and past performance of those efforts and the obligation to report, explain, and be answerable for resulting consequences.

New York's early efforts supporting decarbonization retrofits in LMI housing must navigate often challenging market conditions. Both upfront costs and post-retrofit utility bill impacts are part of the challenge. One or more of the following features typically create significant energy cost barriers to decarbonization:

Current price mismatch between gas and electricity—Under today's market conditions, gas-to-heat pump conversions, absent other energy cost saving measures, will usually result in net energy cost increases to the building.

Potential for energy cost shifting between tenants and landlords—Existing buildings that convert to heat pumps will confront changed configurations for energy metering and, in the case of some rental housing, the party responsible for heating bill payment. Buildings in which the landlord pays for heating fuel while tenants pay for electricity face the difficult prospect of shifting heating costs from the building (fuel) meter onto the tenant (electric) meters. Avoiding these cost shifts may require a landlord to re-negotiate rental agreements, or to change metering configurations, potentially leaving owners with added costs or new administrative burden to collect utility payments from tenants.

Outdated provisions for subsidizing low-income energy costs—Most subsidized housing agreements, utility-administered bill assistance programs, and other household benefits programs have not yet incorporated heat pump energy costs into their program frameworks. Furthermore, the addition of cooling services (through heat pump installation), while important in protecting residents against health-threatening heat waves, may also lead to added energy costs in housing that previously lacked cooling systems. The cooling challenge also extends to benefit programs that have outdated methodologies for assigning cooling costs between landlords and tenants.

Photo Credit: Corporal John A. Seravalli Nelson Ndongala

Ground source heat pumps low operating costs vs. high upfront costs—Ground source heat pumps are the most cost-friendly heating and cooling systems to operate in today's market. However, these systems have the highest upfront costs to install, especially for existing buildings.

Regulations governing solar energy discounts in multifamily housing—In regulated housing, residents can face barriers to receiving solar generation credits on their utility bills. To allow individual resident participation in all cases, utility policy may need to allow for the allocation of solar generation to each meter in onsite multifamily solar projects, like virtual net metering or similar policies. Methodologies for calculating tenant utility allowances may also need to change to enable these solar discounts.

Additional economic barriers exist related to the upfront costs for decarbonization retrofits of LMI housing:

Older, poorly maintained LMI housing stock—Failing roofs, structural deficiencies, and substandard wiring and plumbing are common conditions found in both regulated and unregulated affordable housing. Additional capital must be found to address non-energy conditions prior to decarbonization retrofits.

Homes that are valued too low to justify major investment—Homes with maintenance deficiencies as described above, or that are located in depressed real estate markets, may be worth only $100,000 or less. Decarbonization investments that can cost $25,000 or more may be hard to justify in such cases, both for homeowners and for State subsidy programs.

Disincentives for multifamily building owners—In many multifamily buildings, landlords lack incentive to pursue energy upgrades where the cost savings accrue to tenants.

Potential pressure to raise rents and/or exit affordability programs—Decarbonization projects in multifamily rental buildings may trigger capital improvement thresholds, resulting in possible rent increases beyond affordable levels. On the other hand, if building owners are made to bear the costs of these projects with no means to recoup their investment, it may create pressure to exit affordability programs or result in unworkable business models.

The path to LMI housing decarbonization must ultimately resolve all of these challenges.

NYSERDA defines low-income households as those that are income-eligible for New York State HEAP ([Heating Energy Assistance Program]) benefits—households with incomes at or below 60% of state median income (SMI). Similarly, moderate-income households are defined as those with incomes above the HEAP threshold, but less than 80% of the greater of state median income and area median income for the household's geographic area. Moderate-income households are not eligible for HEAP, but are often income-eligible for housing programs. Household size and annually updated SMI guidelines are taken into consideration for LMI status classification; for a one-person household, the 2021 low-income classification guideline is $32,752, and for a four-person household, the 2021 guideline is $62,984.[123] NYSERDA's most recent **LMI Market Characterization Study from 2017** finds that approximately 48% of New York households are low-to-moderate-income according to these definitions.[124] Energy bills have a disproportionate impact on these New Yorkers—on average, non-LMI **households face a 2.4% energy cost burden while very low-income households can face up to a 20% energy cost burden**.[125]

The draft criteria put forward by the CJWG under the Climate Action Council proposes a definition of DACs that includes places with a high concentration of low-income residents and individual criteria that include all low-income people in the State, regardless of whether they live in a community designated as a DAC. A map of communities that meet the criteria identified for a disadvantaged community as defined by New York State can be accessed **here**.

Early Highlights

The Climate Act requires a target of 40% of all clean energy investments, and a minimum of 35% of investments, go to Disadvantaged Communities. The 2022 Governor's State of the State address set a target of achieving 800,000 Climate Friendly Homes for LMI households by 2030—requiring a roughly tenfold increase in the current annual pace of electrification and electrification readiness projects.

Current State programs are testing high potential strategies for accelerating LMI electrification. These include:

- Injecting **public clean energy funding to cover incremental capital costs directly into HCR and HPD financing deals**, plus providing the agencies with clean energy technical support, and helping them revise their building standards and specifications toward requiring all electric, high performance projects through low income housing tax credit (LIHTC) eligibility criteria.
- NYSERDA, NYCHA, and NYPA have partnered to launch a **technology challenge RFP seeking a new window mounted air source heat pump product** to help NYCHA electrify thousands of its units, which will also be fit for similar affordable housing building typologies throughout the Northeast.
- Supporting the multi-year **New York State Healthy Homes Value-Based Payment Pilot**.
- Working with the state's private electric utility companies to develop and implement the **NY Clean Heat program** and the new statewide **Affordable Multifamily Energy Efficiency Program (AMEEP)**, with affordability protections.
- Continuing the **RetrofitNY program** in developing an approach to decarbonization retrofits in LMI housing using pre-fabricated components manufactured offsite which are more simply and quickly assembled onsite; and
- Administering a **$31 million LMI electrification budget** supporting research, household education about heat pumps, and the evaluation of projects performed under a recent incentive pilot for LMI heat pump installations.
- Updating NYSERDA's longstanding **FlexTech program** to support **Affordable Multifamily Energy Efficiency Program** (AMEEP) and LMI electrification projects more broadly.

In 2022, NYSERDA expects to award and support the formation of Regional Clean Energy Hubs (Hubs) in each of the State's 10 economic development regions. Over $50 million in funding will be awarded to the Hubs to ensure that all New Yorkers have equal access to the benefits of the State's clean energy transition. The Regional Clean Energy Hubs will:

- Act as a trusted local resource for community members to learn more about the energy-related programs and services available to them.
- Increase awareness of these programs and services by leveraging the expertise and trust of local community organizations—particularly those with a proven track record of engaging Disadvantaged Communities.
- Develop outreach and engagement strategies to elevate the needs of communities and residents into program and policy development.
- Advance diversity of the clean energy workforce by connecting residents with educational, training, and job opportunities, and small businesses with resources to support economic development.

Electrification While Preserving Affordability: Charting the Path

The complexity of New York's LMI housing stock requires a nuanced approach to decarbonization. Because low-income households are much more sensitive to changes in monthly expenses compared other households, the operating costs (utility bills) resulting from a decarbonization retrofit must be carefully considered prior to pursuing the project.

In charting a path to LMI housing decarbonization, New York is giving careful consideration to the following factors, among others:

- What is the building's current heating fuel, and what is the cost of this fuel relative to electricity?
- How well is the building insulated?
- In rental buildings with more than one unit, what metering configurations and billing structures exist for existing heating fuel versus electricity use?
- Is the housing unit covered by a regulatory agreement that provides legal and economic protections for low-income residents?

New York is committed to an approach to decarbonization of LMI housing and DAC buildings that ensures neutral or positive impacts on residents' total housing expense (rent plus energy cost) and energy burdens. Actions undertaken by New York State to mitigate GHG emissions from buildings must control potentially regressive impacts of decarbonization policies on these communities, particularly regarding the State's transition from gas utility infrastructure. Careful design and implementation of programs is needed to ensure protections to these customers, and to holistically assess energy costs alongside other monthly housing costs and the impacts that clean energy retrofits might have on existing benefits that residents receive.

It should be noted that energy affordability risks are more acute in the non-regulated or naturally occurring LMI housing stock, which is not subject to safeguards against rent increases or utility cost shifting from building owners to tenants. The State's regulated affordable housing stock, on the other hand, has protections in place that limit the costs that can be added to a household's monthly housing expenditures. However, the risk of increased costs that would reduce subsidized building owner cash flow may dissuade voluntary participation in decarbonization programs, result in post-retrofit pressures to exit affordability programs, and/or strain housing agencies' budgets and consequently their ability to meet housing production and preservation targets.

Selective Electrification to Control for Utility Bill Impacts on Residents

In today's market, some electrification scenarios are not cost effective and may result in utility bill increases for residents. See Chapter 8: The Economics, Benefits, & Challenges for Carbon Neutral Buildings for more information about cost effective use cases. These affordability concerns mean that New York needs to control for utility bill impacts as it supports LMI electrification.

Clean energy programs supporting heat pump conversions will be targeted initially to capture cost-effective opportunities, while discouraging those that are projected to result in utility bill increases. In the short term, this means a focus on buildings heating with oil, propane, or electric resistance because of the more favorable economics of these conversions. In addition, programs will pair electrification with measures that are known to provide energy cost savings, such as comprehensive efficiency measures, weatherization measures, and auto-enrollment in subscriptions to lower-cost community solar installations. These efficiency and weatherization measures will also improve occupant comfort and benefit the electric grid.

To lay the groundwork for future scaling of LMI electrification, pilot initiatives will explore solutions and test strategies for tackling LMI use cases with more extensive affordability barriers, especially gas-to-heat pump conversions. Even today, not all of these conversions result in utility bill increases. Work is underway to compare the costs of running heat pumps versus the costs of running older, less efficient gas systems. This information will enable an expansion of electrification use cases that are known to have favorable utility bill impacts.

In the long term, new utility bill risks will emerge. As consumers move away from gas, the costs of the existing gas distribution network will be shared amongst a shrinking pool of users, likely resulting in higher user fees. The risk is that low-income households, for whom gas historically has been a low-cost heating fuel, and who may not be able to pay for project costs to move off gas, will be left with higher and higher gas bills. New York's decarbonization approach must be conscious of these risks of leaving communities with an even heavier burden than they have already been carrying. Balancing a cautious approach to electrification in the short term, against the long-term costs of inaction, will be an integral part of New York's path to equitable decarbonization.

Policy and Regulatory Solutions Supporting Bill Affordability

Other affordability solutions are being explored on a regulatory and policy level, where the State seeks to align longstanding household and individual benefits programs with electrification measures. This means exploring changes to programs such as **Weatherization Assistance Program** (WAP) and LIHEAP to ensure that every household being served by these programs is also being assessed for, or where feasible provided, electrification measures.

It also means streamlining application processes and braiding program support for low-income households to maximize the impact of State and ratepayer dollars. NYSERDA is undertaking a comprehensive assessment of the current rules and regulations governing subsidized affordable housing as well as other State-administered energy affordability programs. In collaboration with sister agencies, NYSERDA's LMI electrification efforts seek to align approaches across programs, integrate support for heat pumps and electrification make-ready work, and ensure that energy assistance programs and LMI housing programs are fully utilizing their budgets and regulatory options to support decarbonization. Again, auto-enrolling benefit program participants in community solar subscriptions will help reduce energy burden for LMI households.

The Public Service Commission (PSC) Energy Affordability Policy is currently under review. This policy sets a target that customer energy burden should not exceed 6% of income on average and directs New York's utilities to offer bill assistance programs for low-income customers. The utilities structure these programs based on a methodology developed under the Public Service Commission's umbrella **Energy Affordability Program**. This methodology requires re-assessment due to the State's newly adopted decarbonization targets. Additionally, the Program is not well understood by many actors within New York's clean energy ecosystem, hampering efforts to leverage it as the State's building stock is decarbonized.

In early 2022, NYSERDA launched a "Low-Income Bill Analysis Study" to provide more insight into the nature of energy consumption and associated costs for low-income customers. The study's scope includes analyzing the bill impacts of various interventions, including cash assistance (LIHEAP), energy efficiency and weatherization (WAP), electrification of heating and cooling, and access to solar (rooftop or community solar). Outcomes of the study are expected to inform the evolution of the Energy Affordability Program to better meet its objectives. Anticipated updates will factor in the financial impact of decarbonization work and are expected to result in more impactful subsidies to preserve and protect affordability for vulnerable households, with suggested modifications to maximize the impact of the utility-run, ratepayer-funded bill assistance programs.

On the federal level, New York will engage HUD and USDA on streamlining and improving utility allowance calculations for subsidized housing to appropriately reflect the typical costs of operating heat pumps. Locally, NYSERDA has collaborated with New York City's Department of Housing Preservation and Development (HPD) to develop a new utility allowance schedule for buildings using heat pumps. This utility allowance will be piloted in a select number of HPD buildings receiving financing in 2022. Results from this pilot will further inform the State's approach to affordability protections for residents in subsidized multifamily LMI housing.

Analyzing LMI Building Stock and Targeting Opportune Segments

Though today's electrification retrofits in LMI housing in general are unlikely to be driven by energy cost savings, there are some segments with favorable project economics. The affordability challenges identified above underline the need for a variety of strategies targeted to distinct segments of the LMI housing stock. To this end, NYSERDA recently sponsored an "LMI Electrification Study" to perform market characterization and analysis.[126] Key insights from this study include:

1. Roughly 3.3 million housing units statewide are characterized as low- or moderate-income (LMI).
2. Approximately 46% of all LMI housing units are subsidized affordable or public housing, while the remainder are naturally occurring affordable housing.
3. The majority of LMI housing units statewide heat with natural gas, with a higher gas proportion in 1-4 family homes compared to multifamily buildings of 5+ units.
4. The vast majority of LMI 1-4 family homes require some sort of make-ready work prior to installing heat pumps, such as insulation and shell improvements, panel box upgrades, or internal wiring upgrades.
5. The vast majority of LMI units statewide (over 80%) have some level of air conditioning installed.
6. LMI residents (particularly low-income) will have trouble paying for up front project costs especially those that include make-ready work, and project paybacks are long or non-existent. Thus, program planning should assume significant subsidy.
7. The use cases with best project economics and fewest affordability concerns from electrification are housing units currently heating with fuel oil, propane, or electric resistance, or those using older, inefficient steam heating regardless of fuel type.
8. One-third of all LMI households heat with oil, electric resistance, or propane. Only 11% of these are subsidized affordable/public housing.
    - At least 200,000 small homes outside of New York City are using these fuels currently and could be electrified in the near-term with fewer affordability risks.
    - Similarly, 125,000 multifamily units outside of New York City use these fuels and present near term electrification opportunities.
    - In New York City, there may be as many as 300,000 LMI units across roughly 14,000 multifamily buildings that heat with these more costly fuels. In low- or mid-rise multifamily buildings alone, over 600,000 LMI units rely on steam heat.

    Deeper analysis of the height, size, age, and heating distribution type of these buildings can help target segments with optimal characteristics for successful electrification under current market conditions.
9. Preferential electricity rates for heat pump customers are often cited as a key solution to overcome project economic and affordability challenges of electrification.

In 2022-2023, NYSERDA expects to release evaluation and market analysis results from projects completed through its LMI Heat Pump Demonstration program, which is converting over 400 1-4 family homes and over 1,000 multifamily units to heat pumps. One early insight from this program's limited sample is that the average single-family home has sufficient electrical service to handle adding a cold climate air source heat pump. However, adding other electrified loads such as cookstoves, hot water, or laundry, may necessitate electric service upgrades in a higher proportion of homes. As additional findings come in, market and State actors can use them to further refine strategies and target opportune project types for near term LMI decarbonization.

In subsidized housing, Homes and Community Renewal (HCR) and NYSERDA are working to adopt Integrated Physical Needs Assessments (IPNAs) as a standard practice for subsidized housing developments. IPNA is a property evaluation tool that identifies opportunities for capital projects in buildings by assessing current energy, water, and health needs of a property. In parallel, NYSERDA is expanding the scope of IPNAs to cover electrification and/or decarbonization opportunities, in addition to typical energy efficiency measures. Once broadly adopted, expanded IPNAs will provide a detailed picture of decarbonization needs across the State's subsidized housing stock, with anticipated project costs and savings. This information is expected to be a valuable resource enabling the targeting of and planning for cost-effective decarbonization opportunities in subsidized housing. This tool is also highly applicable to market-rate properties and the industry in general.

LMI & DAC Decarbonization Investments First

The work to improve affordability outcomes of and to lower barriers to electrification in LMI housing will support the next two major elements of New York's Equity and Disadvantaged Communities decarbonization approach. These are: Prioritizing LMI and DAC Investments First; and Improving Engagement Toward Place-Based and Community-Led Strategies and Initiatives.

Under the Climate Act, New York's approach to building decarbonization prioritizes investment in LMI residents and DACs. In addition to the Climate Act's explicit equity mandates, the unprecedented emissions reduction targets require a rapid acceleration in the current pace of decarbonization retrofits. While the State's market-rate housing will likely respond quickly to changing market conditions that make decarbonization a good investment decision, the LMI housing stock faces long-term challenges in securing and deploying capital for improvements to their buildings.

This situation calls for early and deep support for this sector of the housing stock. Under currently existing programs, the State will invest approximately $250 million per year in decarbonization programs and initiatives for LMI customers from 2020-2025. These investments aim to create sustained economic opportunities, long-term wealth building, and homes whose health and energy performance does not degrade substantially over time.[127] The Climate Action Council's **Scoping Plan** recommends a four-fold increase in the current annual investment level—to a minimum of $1 billion per year for efficiency and electrification programs that serve LMI households, affordable housing and public housing, and DACs.

Along with more funding, new strategies and delivery models are needed for deploying heat pumps and other decarbonization technologies into the market. The mid-2020s will be years of pilots and experimentation with promising approaches that may help reach scale and accelerate progress toward 2030 and beyond. As the State moves toward finalizing

Photo Credit: Spectrum News NY1

NYCHA/ NYPA/ NYSERDA-Packaged Window-Mounted Cold-Climate Heat Pump Pilot

New York City Housing Authority (NYCHA), New York Power Authority, and NYSERDA are partnering in issuing a solicitation for manufacturers to deliver a unitary, standalone Packaged Window Heat Pump (PWHP) product with cold-climate performance to install in NYCHA properties. Such a product would deliver efficient space heating and cooling and could be easily installed in existing buildings with minimum resident disruption. The product would reduce costs of electrification in multifamily buildings by enabling room by room electrification at boiler end of life and eliminating the electrical service and distribution upgrades associated with current heat pump products. The winning manufacturer(s) will be awarded with a purchase order of up to 20,000-24,000 PWHP in NYCHA properties.

its definition of DACs and providing the public maps of where these communities are located, new paths will be opened for investment in such communities.

Some businesses are already focusing efforts on DACs, while working to reduce capital cost premiums with innovative business models. One example is BlocPower, an energy technology startup that uses proprietary software for analysis, leasing, project management, and monitoring of electric heating, cooling, and hot water systems for buildings in DACs. BlocPower then offers no-money-down electrification solutions, where feasible, via a leasing model with repayment of project costs via energy cost savings. Results from these investments will become apparent over the next several years.

The intersection of novel approaches with deep financial support for LMI and DAC decarbonization investments is driving NYSERDA to launch initiatives aimed at electrification in low-income housing and in DACs. Additionally, NYSERDA has launched unprecedented collaborations with the largest affordable and public housing agencies in the State: New York State HCR, New York City HPD, and NYCHA. These efforts. These efforts illustrate how New York is pursuing LMI Decarbonization First.

Decarbonizing Regulated LMI Housing

Regulated affordable housing owners tend to have more existing touchpoints with state agencies compared to market rate or naturally occurring affordable housing. Streamlining access to all incentives and resources through housing agencies and utilizing financing, refinancing, and other touchpoints to drive decarbonization are key to early-stage market development. This is a major goal of NYSERDA's collaborations with New York State HCR, New York City HPD, and NYCHA. The near-term objectives of these Affordable Housing partnerships are: to "inject" clean energy funding directly into HCR and HPD's refinancing process; to support housing agencies in making highly

HCR/NYSERDA Partnership

NYSERDA is partnering with HCR to directly include NYSERDA-funded solar, efficiency, and/or electrification grants and supplemental capital within HCR's financing processes, creating a single process for affordable housing owners/developers to access financing and clean energy support.

NYSERDA Will Make a Total $100 Million Investment with about $20 Million Expected Annually Through 2025. Expected Outcomes Include:

- Finance solar, efficiency, and/or electrification in 10,000-15,000 units, with potential to expand as costs decline.
- Updated building performance standards and Green Design Guidelines.
- Larger pool of owners and developers experienced with Passive House-style new construction and deep energy retrofits.

Achievements to Date

- Established a new carbon neutral performance standard and selection criterion for new construction projects that was used in 2021 4% and 9% Low Income Housing Tax Credit (LIHTC) Pilot Clean Energy Initiative awards.
- $7.5M awarded to HCR projects for all electric high performance new construction projects through HCR's 2021 4% and 9% LIHTC RFPs.
    - $12,500 incentive/dwelling unit (DU) included $2,500 funding for integrated design to reduce project costs, improve quality of construction, and enable scaling.
- Expanded the pilot by issuing revised 4% and 9% LIHTC RFPs with ~$25 million per year supporting new construction and retrofit projects.
- Issued a Clean Energy Initiative offering in the 4% and 9% LIHTC RFPs supporting new construction and retro-fit decarbonization.
- Supported HCR with development of updated building performance standards and design guidelines.

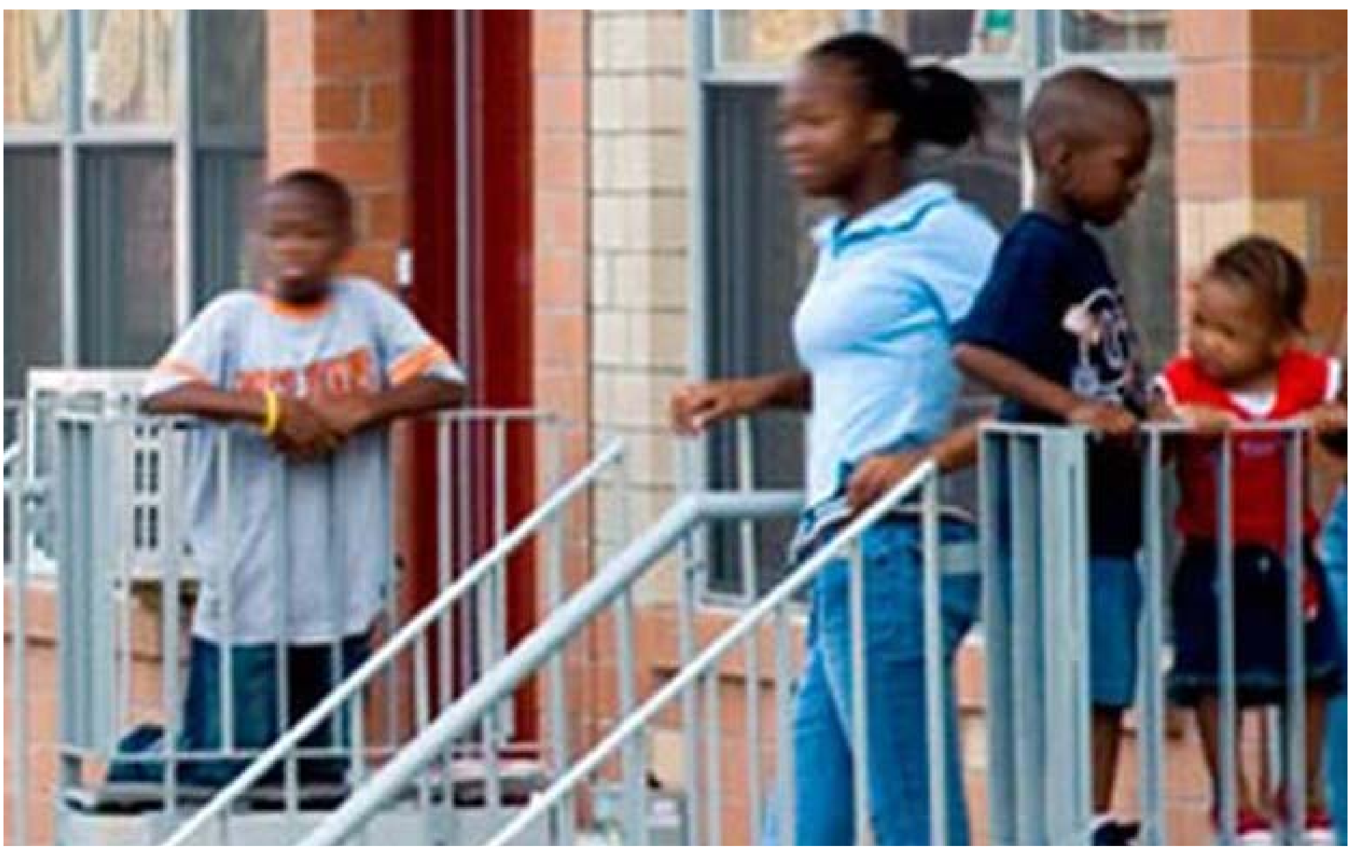
efficient, all-electric buildings their business-as-usual, via updates to building performance standards; building internal capacity through technical assistance for building owners, developers and agency staff; and to create models for decarbonizing and electrifying existing affordable housing buildings that can scale as more funding becomes available.

Putting DACs and LMI Housing First to Benefit All New Yorkers

There is significant opportunity embedded within New York's drive to carbon neutral buildings in LMI housing and Disadvantaged Communities. For low-income New Yorkers and those living in DACs, the potential benefits range from improved housing conditions to better health outcomes, to employment opportunities, to increased access to long-term wealth building.

The current prominence of LMI housing decarbonization goals is creating unprecedented collaboration across State agencies that administer low-income energy programs, including NYSERDA, Office of Temporary and Disability Assistance (OTDA), HCR, and Department of Public Service (DPS). If successful, these collaborations will lead to more efficient and effective use of State and ratepayer funding. These collaborations, currently housed in the State's Low Income Energy Task Force (LIETF), are aimed at simplifying and streamlining application and administrative processes, aligning scopes of work to support electrification and electrification-readiness, better calibrating benefit levels to match the needs of different households, and expanding participation among income-qualified residents.

Many benefits from early State investments in LMI and DAC decarbonization will flow to those communities specifically—but not all. Early targeted State investments weighted toward LMI housing are kickstarting market activity, illuminating pathways to building decarbonization to the broader real estate industry, and incentivizing contractors from HVAC to weatherization to electricians to modify their business models to incorporate holistic decarbonization solutions. By creating success stories and building confidence in decarbonization approaches in LMI housing and DACs, New York will drive market



development and cost compression in decarbonization products and services statewide, ultimately benefiting all New Yorkers.

State-led decarbonization efforts focused on LMI housing and DACs remain incomplete without engagement of the residents and communities themselves. Decades of institutional racism, redlining, and exclusion have eroded trust among community members, local leaders, and institutions, as they relate to State-led agencies and initiatives. The success of New York's LMI and DAC building decarbonization efforts rests on patiently building trust via sustained engagement. From this engagement will flow actions that acknowledge the leadership and expertise of these communities to determine their own path to a clean energy transition.

New York City HPD/ NYSERDA Electrification Pilot

NYSERA Investment Including $24 Million over Three Years. Expected Outcomes Are:

- Serve roughly 1,100 units (~40 buildings)
- Expand as costs decline
- Technical assistance for affordable housing developers and housing agency staff
- Pilot a new Heat Pump Utility Allowance

New York City HPD Preservation Pipeline

- Typical property: 10–50 dwelling units, pre-war building; central fossil-fuel hot water and heating with steam distribution
- 7–15 projects of this type out of 20–25 projects in annual HPD pipeline

Achievements to Date

- Pilot launched in December 2021 with pre-defined scopes and funding for partial and full electrification in common multifamily building types
- Technical assistance provider onboarded (Taitem + SWA)
- Direct outreach to projects in HPD pipeline

In Progress/Next Steps

- Eight projects comprising 556 dwelling units expressed interest
- Project administrators confirming projects are good fit and conducting scoping call
- First projects expected to close financing and start construction in 2022

Place-Based & Community-Led Strategies for Long Term Benefits

The activities and strategies to invest in DACs are supported and led from the highest levels of New York's public policy leaders and decision makers, with unprecedented collaboration across State agencies.

They are also increasingly led from the bottom up, with communities themselves supported by a robust ecosystem of Community Based Organizations (CBOs), nonprofits, and mission-driven clean energy businesses designing, advocating for, and seeking State funding and technical assistance for on-the-ground implementation, including community outreach and engagement.

Pilot efforts are underway to support creative and innovative proposals for deploying clean energy and building decarbonization solutions in Disadvantaged Communities. The solutions include energy efficiency, grid responsiveness or load flexibility, and solar and storage capabilities. Some organizations based in Disadvantaged Communities are advancing these diverse, locally sited clean energy solutions with the goal of reducing loads currently served by nearby polluting peaker plants. These efforts may help to develop models for effectively combining building decarbonization with local pollution reduction and public health improvement efforts.

New York is aware that environmental justice does not only mean achieving targets and outcomes for clean energy deployment. It also means shifting away from exclusive decision-making processes and expanding the range of knowledge and voices that shape the clean energy transition. The path to equitable building decarbonization leads to a place where historically underserved stakeholders determine how the State supports decarbonization efforts in their communities. It also leads to a place where such communities have the opportunity for a literal equity stake in clean energy assets and businesses as a pathway to long term energy affordability and wealth building. As New York accelerates toward its 2030 goals for building electrification and decarbonization, it will look to increase its support for place-based and frontline community-led strategies and initiatives.

Recognizing Concerns of Environmental Justice and DAC Stakeholders

The CAC's work to date, especially that of the CJWG, has brought to prominence several concerns from frontline communities about how clean energy policy decisions and program investments have been carried out in the past. These concerns led to the creation of NYSERDA's Energy and Climate Equity team, which has been working to build internal expertise within State government on issues of Environmental and Climate Justice, collect insights from and improve stakeholder engagement mechanisms with frontline communities, and design pilot programs that are responsive to and shaped by local organizations representing these communities. Stakeholder concerns voiced via these forums are highlighted below:

- There are often more urgent community priorities in the built environment than building decarbonization.
- There is a history of extractive/exploitative relationships with businesses based outside these communities.
- There is a history of exclusion and tokenization in decision-making processes.

- The engagement process itself can be taxing on local organizations with limited resources and capacity, especially when engagement activities are uncompensated.
- There is a need for translation into multiple languages and use of salient framing on energy efficiency, bill savings, electrification, and decarbonization.

Evolving Mechanisms for Stakeholder Engagement and Community Capacity Building

The State continues to work to increase community capacity to engage and control investments and decision making by improving existing stakeholder engagement processes. NYSERDA is currently working to increase CBO and DAC capacity through initiatives including the Regional Clean Energy Hubs (Hubs) and the Energy Equity Collaborative.

The Regional Clean Energy Hubs initiative is a $53 million program that will establish **Clean Energy Hubs** in each of the State's ten economic development regions. The Hubs will provide community education and work to promote public awareness about building decarbonization, as well as providing the public equal access to benefits from clean energy investment including energy savings programs, building electrification incentives, renewable energy options, and job opportunities.

The Energy Equity Collaborative will be a consultative and planning body that centers environmental and climate justice issues, promotes greater transparency, and identifies collaboration opportunities early in the program design process. The Collaborative is expected to include several Working Groups, including one organized around equitable housing electrification stakeholders. The Collaborative and its working groups will host public meetings, lead sector-specific stakeholder engagement, and facilitate dialogue between NYSERDA and its interagency task force peers, with historically marginalized community stakeholders.

Enabling Long-Term Benefits

The vision for equitable building decarbonization is still in early stages of development, but its outlines are becoming clear: decarbonization investments will strengthen community and local business engagement and improve the quality of housing and other buildings in DACs. These investments will create clean energy jobs and entrepreneurial opportunities, and early adoption of new technology and demonstration projects will help build knowledge and expertise in the community. They will deploy assets in the community that generate revenues that remain in the community. They will enable more robust generational wealth transfer by improving the value and durability of residents' homes.

Aside from these economic benefits, there are a host of non-energy benefits that decarbonization of

Corning, NY.

the built environment will bring to the State's most vulnerable and historically underserved residents. Building decarbonization, by virtue of the replacement and removal of fossil-fuel burning equipment and infrastructure, improves indoor and outdoor air quality which results in better health outcomes for residents. There is evidence that reducing onsite fossil fuel combustion in buildings results in the mitigation of asthma and other illness.[128, 129, 130] As the State broadens the scope of supported electrification technologies beyond space and water heating, electrification of cookstoves in particular will offer significant health and non-energy benefits for communities suffering from high rates of respiratory disease.

As the climate warms, heat waves are happening more frequently and lasting longer. A sizable percentage of New Yorkers lack entirely or have limited access to cooling in their homes. The benefits of added cooling services that are provided by efficient electrification with heat pumps are twofold: occupant comfort and protection from extreme heat conditions, which have proven particularly deadly in the United States in recent years. Building decarbonization, particularly in Disadvantaged Communities, supports better resilience of vulnerable, heat-sensitive populations, particularly seniors and the disabled, in the face of climate, environmental and socioeconomic stressors.

Enabling these long-term benefits will require significant amounts of capital. Currently, there is a funding gap to meet both the State's climate and housing goals. The State must also continue to identify existing and future funding that can be deployed to meet the specific needs and desires of low income and Disadvantaged Communities. New York is taking a proactive approach to address both funding gaps. Policy proposals based on real world data are being leveraged to justify increased budgets for affordable housing and LMI decarbonization. Part of this work is improving regulatory requirements, programs, and policies to maximize the impact of public funds, as described above. NYSERDA's *Building Electrification Roadmap* will outline these improvements in detail.

Another part is creative data collection, research, and pilots that can pave the way for additional funding to be braided into the public investments in clean energy, such as Medicaid funding. Currently, NYSERDA is exploring ways to bring additional funding to support decarbonization and environmental health outcomes in DACs. Adoption of mandatory rental housing efficiency as well as health and safety standards can yield significant environmental, economic and health benefits—particularly in hard to reach naturally occurring affordable housing.

Weaving together resources from both the health and energy sectors can increase funding opportunities, expand services, and reach more households in vulnerable communities. The New York State Healthy Homes Value-Based Payment Pilot demonstrates a framework that allows New York's managed care organizations to fund residential healthy home interventions as part of

Photo Credit: Cycle Architecture LLC and BQE

SOTS Initiative: Clean Green Schools

The Clean Green Schools Initiative will benefit more than 1000 public schools in Disadvantaged Communities, with clean energy and energy efficiency solutions, creating a healthier learning environment in schools across New York State. The initiative will offer funding for services that will help schools evaluate, plan for, and facilitate energy reduction projects, clean energy projects, and indoor air quality projects as well as funding to implement decarbonization projects. Additional funding will be provided for students, faculty, and staff to engage in clean energy educational opportunities, such as integrating clean energy concepts into the classroom or supporting students to explore clean energy careers.

their value-based payment arrangements with healthcare providers within the Medicaid healthcare delivery system.[131] The Pilot's residential healthy home intervention combines energy efficiency/weatherization measures with in-unit environmental trigger reduction measures aimed at addressing respiratory conditions such as asthma and includes additional measures aimed at addressing home injury. The intervention includes home skilled nurse visits and community health worker support. Nascent efforts around cooling equity are another potential avenue for leveraging funds at the intersection of clean energy, public health, and resiliency.

Private investment will continue to have a significant impact on the funding landscape and the State will look to de-risk and leverage such private investment. Expanding affordable housing financing mechanisms to include decarbonization capital improvements, implementing credit enhancement and third-party aggregation, and ensuring that initiatives are "shovel-ready" can also maximize the opportunities where federal funding can contribute (e.g. future climate bills, expanded weatherization, and public housing capital budgets).

The CJWG will send clear signals for the State's direction by explicitly calling for the resources and commitments needed to center Disadvantaged Communities on the pathway to decarbonization. As the State increases community engagement as well as racial and environmental justice activities, DAC stakeholders will have a stronger voice in the clean energy decisions that affect them. As outlined in this chapter, the equity commitments in the Climate Act are leading to new approaches and investments that will bring the benefits of building decarbonization to those who need it most and ensure that nobody is left behind.

Last Words

The Climate Leadership and Community Protection Act requires a target of 40% of all clean energy investments, and a minimum of 35% of investments, go to Disadvantaged Communities that bear burdens of negative public-health effects, legacies of racial and ethnic discrimination, environmental pollution, and impacts of climate change.

Unique challenges and opportunities exist in decarbonizing buildings in Disadvantaged Communities, requiring solutions driven by community stakeholders that provide them with control of clean energy assets. Under current market conditions, some decarbonization efforts run the risk of increasing economic burdens on low- to moderate-income stakeholders. Current programs led by NYSERDA, utilities, and State housing agencies are testing strategies that mitigate this risk by creating sustained economic opportunities, increased energy affordability, and long-term wealth building. Over the next five years, successful pilots and investment will need to scale up to meet the urgent need to rapidly decarbonize the State's low- to-moderate income housing stock while ensuring the well-being of families and communities.

A Just Transition to a Green Workforce

CHAPTER 11

Introduction

For New York State to achieve its goal of a fully decarbonized built environment by 2050, it must prioritize strengthening, scaling, and transitioning the current workforce to be able to deliver low-carbon buildings at scale.

The energy efficiency industry already employs over three quarters of the clean energy workers in New York State, and demand for skilled workers will only increase as New York State's building stock decarbonizes, resulting in significant job growth and economic opportunity in every region of New York State.

The workforce needs to broaden their understanding of buildings: from brick-and-mortar shelters to machines that interact with vehicles and the energy grid. With that in mind, expanding education and skills-training in energy efficiency, electrification, and construction of low-carbon buildings needs to be a core focus of time and monetary investments. Direct investments for new business development and for retraining existing workers in fossil-fuel related industries are necessary, and the most vulnerable communities must also be prioritized and protected to ensure they are not left behind.

New York State needs to continue scaling current training programs for incumbent and new clean energy workers, grow and develop new training programs, and provide resources for retaining and recruiting talent that also focus on diversity, equity, and inclusion to increase clean energy job placement in Disadvantaged Communities.

Current Workforce Barriers to Building Electrification

Many industries will be impacted by decarbonization. These impacts are not always positive. For example, sometimes the cost pressure of making building upgrades results in wage depression for certain segments, such as building service workers.

However, there will be opportunities for new and incumbent workers to receive further training and upskilling in order to meet the growing demand for skilled labor in the fields of energy conservation (e.g. building envelope weatherization work), electrification, low-carbon fuels, building/grid-integration, and other decarbonization activities. Certain workforce gaps limit industry capacity (e.g. trained heat pump installers; drilling is a pinch point in geothermal industry capacity) and make it more difficult for clean energy initiatives to advance. There is already a lack of skilled labor, and a large percentage of the existing workforce is preparing to retire in the next five to 10 years, which will slow the advancement of the clean economy if these positions are not refilled quickly. As these skilled workers begin to depart the workforce, their knowledge base needs to be captured and retained for the next generation of skilled workers.

Contractors need to adapt and grow their workforce in order to be able to meet the growing demands of the clean energy economy. Most contractor businesses, for instance, are not structured to offer whole home electrification (mechanical, electric, and plumbing [MEP] skillsets), to say nothing about efficiency and weatherization services as well. While contractors can provide all three MEP services, very few contractors currently have all three capabilities on staff. And contractors that can perform an entire electrification and weatherization job are very rare. Partnerships between contractors with complimentary skillsets would help solve this problem. Another problem that contractors face is the lack of available equipment to suit their customer needs without oversizing or increasing their energy burden.

TABLE 11.1: REASONS FOR HIRING DIFFICULTY AMONG HEAT PUMP EMPLOYERS (FOR KEY OCCUPATIONS)

Heat Pump Employers Top Reason for Hiring Difficulty: **Lack of Relevant Work Experience**

	Technical Skills	Relevant Work Experience
Licensed HVAC Installer	76%	70%
HVAC Supervisor	67%	77%
Plumber	88%	88%
Plumbing Supervisor	83%	92%
Electrician	88%	100%
Owner/Senior Management	76%	76%
Construction/Installation Helper or Apprentice	76%	85%

Source: New York Clean Energy Industry Report, 2020

Local Capacity Building

In order to attract, develop, and maintain the necessary workforce needed to decarbonize the built environment, job opportunities need to offer family-sustaining wages, benefits, job security, and accessible, in-person, hands-on technical skills training.

A new generation of workers, innovators, and entrepreneurs need to be educated and brought into the clean energy industry to keep it moving forward and growing. This will be made possible in part with training programs designed to accommodate different skillsets and education levels and comprehensive career path programming.

Projects that meet certain workforce criteria, such as projects with trained heat pump installers, should be incentivized, potentially with accelerated permitting or financial renumeration. Incentive programs and funding will help contractors overcome the perceived risk associated with modifying their existing successful business practices to develop their workforce, with the goal of having contractors realize the risk of not converting their business-as-usual practices. Likewise, manufacturers and distributors are more likely to increase their investment in trainings when there is a high dollar incentive with simple program requirements, as well as clear regulatory policy signals. It is also necessary to encourage manufacturers to extend their warranty to cover services, distributors to supply multiple end uses, and contractors to obtain new licenses to make investments that ultimately reduce market fragmentation, consolidate risk, and improve the customer experience.

Organizations that are well-positioned and willing to invest in training and evolve their business to support building decarbonization and electrification should be identified and rewarded for skills building, business model evolution, risk consolidation, and outreach that encourages others in the supply chain to participate and evolve. When all participants in the supply chain work together to provide value with their processes, it can increase a company's profitability while reducing waste in the supply chain, a strong motivator for all participants. Coordination and collaboration between utilities and the supply chain should be strengthened to provide incentives and offer general trainings.

Addressing Transitional Industries

All workers need to have the opportunity for training and employment in the clean energy economy.

That being said, those who are currently working in the fossil fuel industry will have their jobs impacted directly by the transition to clean energy and may need additional service to support their path to alternate employment, including new career training and familial support. Strategically retraining the impacted workforce needs to be a consideration in long-term planning for a natural gas transition, alongside prioritizing geographic considerations to stabilize the industry and protect low-income and gas-dependent consumers. The oil and gas industry workforce needs an equitable transition plan that includes protections and retraining that leverages transferable skills and job transition opportunities (e.g. in dual-commodity utilities). Workers transitioning away from the oil and gas industry need new jobs that are high-road, good quality jobs, with benefits earned during tenure and protected resources for retirement. In addition to higher median wages, the New York State Just Transition Working Group 2021 Jobs Study found that 80% of those workers in the clean energy sector received some level of health insurance, as compared to 73% in the general workforce.[132] Skilled workers can be retrained or retained to focus on smaller gas systems or other jobs within the utility.[133] Two examples have taken place on the West Coast: utilities coupled the rollout of smart meters with job retraining for meter readers to fill other positions as part of agreements negotiated in the planned closure of the Diablo Canyon nuclear plant and the TransAlta coal plant in California and Washington, respectively.

Scaling Workforce Development Efforts

Targeted workforce training programs should be designed by a diverse group of stakeholders, including local clean energy businesses, community and environmental justice groups, and residents, in order to produce the necessary talent pool to fill good paying jobs that support employer demands.

Training programs develop the workforce more effectively when they utilize partnerships that engage educators, industry associations, contractors, labor and labor organizations, utilities, and government agencies to share their concerns and insights. These partnerships will better leverage resources for trainings, enhance and encourage best practices, and provide diverse and informative perspectives that help the workforce develop further. Opportunities also exist for training providers to partner on actual local clean energy projects to provide the clearest avenues for industry exposure.

Education and Training

Education is a crucial cornerstone for building the workforce. Affordable education costs, scholarships, or other incentives for continuing education would create more opportunities for interested parties to pursue higher levels of knowledge and training. To this end, NYSERDA is coordinating closely with the SUNY and CUNY state systems to support scholarships, recruitment in public schools with an emphasis on those located in DACs, and training and certification programs with connections to union apprenticeship initiatives. State-funded education institutions (e.g. K-12, technical schools, apprenticeships, engineering and architecture programs at public universities) should raise awareness of building decarbonization (including health benefits), provide information on clean energy jobs, integrate market and industry needs into the curricula, and provide career services to help students transition to the workforce. Private education institutions should be encouraged to provide the same opportunities and standards as their public counterparts. Certifications and degrees for vocational skills training in variable refrigerant flow (VRF) systems, ground source and air source heat pumps, controls, facilities, management, green building technologies, and other technical aspects, as well as partnerships between junior colleges and the New York State Education Department would also help produce graduates that are more "work ready." Requiring continuing education on building decarbonization (e.g. energy efficiency, electrification, embodied carbon, health benefits) as part of licensing for architects, engineers, trades, contractors, building operations and maintenance, and real estate professionals will also help motivate the workforce to gain further knowledge in the area. Labor unions, trade associations, and accreditation bodies need to be engaged to incorporate renewable energy, decarbonization, and electrification training into apprenticeships and other programs to increase diversity in the trades. There is already an ecosystem centered around labor-management sponsored training programs (e.g. Pre-Apprenticeships and Apprenticeship Readiness Collective), which could be utilized and invested in to help grow good, family-sustaining jobs and minimize job loss.

NYSERDA's expansion of workforce development programs and initiatives has set NYSERDA up as a leader in workforce development, providing opportunities for training and education to New York State's workforce. Building on the State's $175 million Workforce Development Initiative, NYSERDA is working to change the landscape of New York State's workforce through clean energy workforce development and training and programmatic changes across the authority. This includes a $108 million investment into training programs that will benefit more than 40,000 New Yorkers over the next five years. These programs will prepare new entrants to enter the clean energy economy and upskill existing workers across sectors and through the supply chain. Assistance will also be provided for on-the-job training for priority populations and community-based workforce development. The emphasis on these aspects of workforce development will further support clean energy businesses to hire from priority populations and advance training partnerships between clean energy businesses, training organizations, industry associations, and un/under-employed residents in historically Disadvantaged Communities. Within this larger investment, $25 million will be utilized to create a Climate Justice Jobs Training Initiative to prepare historically disadvantaged individuals for clean energy jobs; $14 million is to support clean energy businesses hiring new workers with wage subsidies for on-the-job training; $9 million is to support intern wages (up to 90%) paid by businesses and organizations for clean energy related internships; $8.5 million is for Career Pathway Training Partnerships for high-efficiency HVAC and heat pumps; $8 million is to support building owners and property managers for training building operations and management staff across building portfolios; and $4 million is for training organizations to develop clean energy training capacity. New York State has also committed hundreds of millions of dollars to expand Low-Moderate-Income Consumer programs and enhanced community engagement initiatives, in addition to hundreds of millions of dollars for building electrification solutions for approximately 130,000 buildings in New York State, including a variety of heat pump technologies. Approximately 25% of the workers trained from these programs will be from Disadvantaged Communities or priority populations.

The existing network of manufacturers, distributors, and contractors in the supply chain can be leveraged to share information and develop the workforce further, as well as engage customers to drive demand. Manufacturers and distributors have a unique ability to identify contractors and already have dedicated resources to train contractors on technical subjects and business considerations. Further clarification of the business opportunity that decarbonizing presents and its implications for contractor business models will help encourage interest in new education and supporting resources, such as equipment sizing tools, energy bill impact calculators, and marketing materials. Growing the Advanced Trade Outreach Program to support larger HVAC companies and distributors and creating a taskforce of former HVAC personnel who are familiar with the industry and network would help communicate to contractors why now is the time to decarbonize buildings and why they should support their workforce in pursuit of greater knowledge and training. Contractors and technicians can communicate with customers to drive demand for decarbonization technology adoption. In particular, service technicians can serve as ambassadors for customers: their opinion is the most trusted source of information and is essential in preparing customers for choosing new all-electric HVAC systems.

Collaboration

It is important to collaborate with local governments and other State agencies, including those focused on affordable housing, in order to clarify licensing requirements for electrification activities so that the workforce is aware of the necessary standards and can pursue the appropriate training as needed. The appropriate skill standards can be required by law or as a condition of qualifying for rebates, permits, or incentives. Upfront labor standards may be an added cost and effort for the State (e.g. licensing or training requirements, wage standards, responsible contractor criteria) but as centralized or aggregated smaller projects become widely implemented, economies of scale can be realized to adopt labor standards through a project labor agreement (PLA) or community workforce agreement (CWA), which would drive down per-unit costs without weakening labor standards. Other key groups to collaborate with include New York State Department of Homes and Community Renewal (HCR), New York City Housing Preservation and

Development (HPD), New York City Housing Authority, New York State Public Housing Authority Directors Association (NYSPHADA), New York State Association of Counties, New York State Association of Towns and Villages, and New York State Department of Labor.

Utilities already offer training based on program requirements to ensure that contractors have the necessary technical skills and understanding of available programs. As a result, they should be a major driver behind executing new training skills and will need assistance from their community-based partnerships in order to make their customers aware of the new programs and ensure participation where it's needed most. In addition, collaborating with the New York Independent System Operator (NYISO) will enable utilities across New York State to work together and find mutually beneficial ways to sync up program management.

As part of their mandate, the new NYSERDA Clean Energy Hubs will provide community-based outreach and engagement to residents, small businesses, nonprofits, and multifamily building owners to increase access to clean energy programs and resources, improve energy literacy, and build capacity in Disadvantaged Communities to participate in and benefit from the clean energy economy. Thus, they will be well positioned to embrace and leverage that community-based engagement to expand outreach, promote education, build interest in decarbonization and electrification, recruit new workers, and advance diversity in the workforce by connecting residents and small businesses with resources and training opportunities that can lead to jobs. They can also work with regional economic development councils to develop and implement a New York State strategy on regional workforce development for decarbonizing buildings and address energy code enforcement at the community level.

Efforts from the Climate Action Council and NYSERDA's programs and initiatives demonstrate New York State's commitment to scaling and transitioning a talented workforce to equip them to be able to design, construct, install, inspect, retrofit, maintain, and operate healthy and comfortable low-carbon buildings. The CAC's Just Transition Working Group, led by the New York State Department of Labor and NYSERDA, is prioritizing workforce development. Their actions, including developing a forward-looking jobs report, identifying workforce training needs and hiring trends, and assessing opportunities to put former power plant sites to productive use, will inform the equitable transition of New York State's workforce to a clean energy economy. Similarly, the Energy Efficiency and Housing Advisory Panel, led by New York State Homes and Community Renewal and NYSERDA, recommended programmatic, regulatory, and financial changes to support workforce education, training, and development that will also advance industry diversity and increase clean energy job placement for Disadvantaged Communities.

TABLE 11.2: NYSERDA CLEAN ENERGY WORKFORCE DEVELOPMENT PROGRAMS

Program Name	Program Number
Building Operations and Maintenance	PON 3715
Career Pathway Training Partnerships	PON 4463
Energy Efficiency and Clean Technology Training	PON 3981
On-the-Job Training	PON 3982
Clean Energy Training Services	RFQL 4145
Internships	PON 4000

Diversifying the Workforce

Disadvantaged Communities face additional barriers and challenges to securing or retaining jobs and are at risk of being disproportionately left behind in the clean energy transition.

This is reflected in the fact that New York State's clean energy industry employs significantly fewer women and people of color than the broader labor force. Diversifying the workforce should include an equitable distribution of jobs to LMI communities, communities of color, and EJ communities, and include high paying, family-sustaining jobs with good benefits. Residents of Disadvantaged Communities and opportunity zones, Minority and Women Owned Business Enterprise (MWBE) contractors, and service-disabled veteran-owned businesses need to be prioritized and elevated in order to ensure effective diversity, equity, and inclusion for a just transition. Local hiring and appropriate training of workers from vulnerable communities, low-income communities, and communities of color needs to be incentivized, perhaps with community benefit agreements or community workforce agreements.

Providers have often cited a lack of industry exposure and social ties as a hindrance to attracting individuals from Disadvantaged Communities. According to interviews, targeted outreach that increases clean energy career exposure—particularly for elementary through high school students—has been found to be successful. Such outreach requires clear articulation of career pathways and opportunities for success, plus additional outreach and placement support. Other factors that would help diversify the clean energy workforce include wrap-around support (e.g. childcare subsidy, free MetroCard), community-to-employment pipelines, business development support, and requiring employers that take public subsidies to also conduct periodic racial bias training. Offering flexible scheduling for training/retraining and providing courses in different languages would also help transition a more diverse workforce. Any on-the-job training investment needs to be revisited and analyzed for its effectiveness as an employment pathway and refined based on the findings, as appropriate.

New York State has implemented workforce training initiatives that emphasize drawing priority populations into the clean energy workforce. Priority populations include minority workers, veterans, Native Americans, individuals facing substantial cultural barriers, low-income New Yorkers, homeless individuals, individuals with disabilities, previously incarcerated individuals, youth in work preparedness training programs, and single parents. In line with this work, the New York Power Authority (NYPA) has announced a ten-point action plan in partnership with the American Association of Blacks in Energy (AABE).[134] The plan includes a $10 million investment into internal and external initiatives to increase Black representation in the broader energy, renewable energy, and electrification fields in order to build a more diverse, equitable, and inclusive workforce and grow the pipeline of utility and clean energy workers (Jobs Report, 2020).

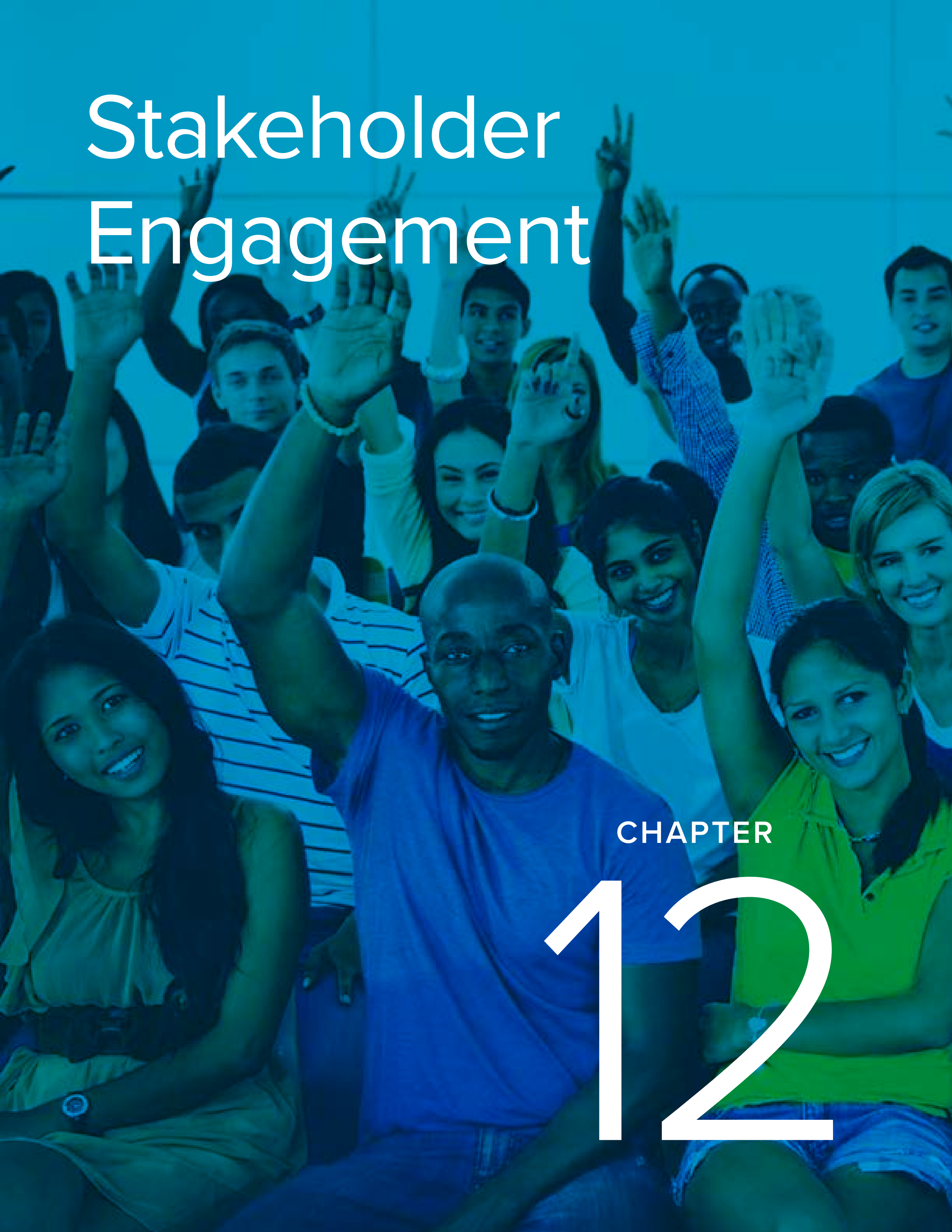
Last Words

Decarbonization is a shared responsibility among government, the private sector, labor unions, trade associations, and the general public to reduce GHG emissions to combat climate change in the most cost-effective manner possible.

We must strengthen partnerships among these groups to increase collaboration in recruiting, developing, and training the green collar workforce of the future. A well-trained and experienced workforce is essential to reducing the cost of decarbonization projects and investing in workforce development will create long-term jobs and economic growth that benefit local communities. To support any further analysis, the Just Transition Working Group of the Climate Action Council released the 2021 Jobs Study to provide measurements of the number of jobs in New York State that help counter climate change, to project the skills and size of workforce needed to meet the demand for climate change countering jobs, and to provide guidance on developing a workforce that includes those from Disadvantaged Communities and typically underrepresented populations in the clean energy sector.

Stakeholder Engagement

CHAPTER 12



Introduction

All New Yorkers will be impacted by, and many will be tasked with implementing, the *Roadmap's* tenets and recommended solution sets.

Public outreach and engagement in the *Roadmap* development has been a focus from the beginning and has facilitated a no regrets approach to building decarbonization. Ultimately, this participatory process works to bring greater capacity-building within communities and promote collective problem solving for these challenging issues.[135]

Market actors have been consulted at each phase of the process. From serving as technical advisory group (TAG) members to providing public comment, a diverse array of market actors has brought technical knowledge, community needs, and policy hurdles to the forefront of the discussion.

An important component of NYSERDA's agency-wide engagement strategy is partnership. To this end, the NYSERDA Team has collaborated with multiple public agencies, through stakeholder events and bilateral brainstorming sessions with the understanding that these collaborations must endure and strengthen to operationalize the *Roadmap*.

At the onset of *Roadmap* development, NYSERDA initiated a holistic and inclusive stakeholder engagement process by assembling a select group of subject matter experts to form a TAG. With the TAG's input NYSERDA planned for three phases of stakeholder participation: (i) targeted information gathering sessions by topic; (ii) a presentation of the preliminary findings of the *Roadmap* to build public awareness and solicit public input; and (iii) post-publication community-based outreach, awareness, and education.

The comprehensive stakeholder engagement process that NYSERDA deployed to inform the development of the *Roadmap* included nearly 1,000 participants in 15 in-person or virtual events held around the state, a lengthy public comment process that collected over 300 engagements, as well as targeted outreach and coalition building. Additionally, NYSERDA held several bilateral meetings and information sharing sessions with partners outside of New York State. This included collaborations with partners regionally, nationally, and internationally. Without this extensive stakeholder engagement, the *Roadmap* would not be the inclusive document that it is today. This chapter will provide an overview of research and information gathering, the phases of stakeholder engagement and the importance of community-based outreach necessary to scale adoption of carbon neutral buildings statewide.

FIGURE 12.1: GREG HALE, SENIOR ADVISOR FOR ENERGY EFFICIENCY MARKETS & FINANCE AT NYSERDA SPEAKING AT THE 2019 GETTING TO ZERO FORUM IN OAKLAND, CALIFORNIA

Technical Advisory Group

The engagement effort commenced with NYSERDA's convening of a strategic group of subject-matter experts known as the Technical Advisory Group, or TAG.

This body of advisors represented diverse technical and market perspectives and was instrumental in setting forth the framework for topics in need of further information gathering. Seven areas of technical and market sector expertise were identified as critical to the *Roadmap* and 18 experts were sourced from a wide range of public and private sector organizations to provide insight on both technical and policy issues. The 18 TAG advisors and the technical and market sectors that they represented are identified in Table 12.1.

The TAG met three times as a group and multiple times in smaller groups to review policy options. The subject matter experts were also consulted on an informal basis and, collectively, made extensive contributions to the *Roadmap*.

TABLE 12.1: TAG MEMBER ADVISORY GROUP

Technical and Market Sector	Advisor
Engineering, Design, and Innovation	**Pasquale Strocchia,** Building and Design, Inc. **Jeff Perlman,** Bright Power, Inc. **Scott Frank,** Jaros, Baum, & Bolles **Marc Zuluaga,** Steven Winter Associates, Inc.
Research & Federal Government	**Lieko Earle,** National Renewable Energy Labs (NREL)
Higher Education	**Nina Sharifi,** Syracuse University **Cecil Scheib, P.E.,** New York University (NYU) **Karren Bee-Donohoe,** SUNY System Administration
Local Government	**Ross MacWhinney / Lindsey Hirsch,** New York City Mayor's Office of Climate and Sustainability
Community, Financing & Affordability	**Sadie McKeown,** Community Preservation Corporation **Lauren Westmoreland,** Enterprise Community Partners, Inc.
Housing & Real Estate	**Zachary Steinberg,** Real Estate Board of New York **Linda Wigington,** Thousand Home Challenge **Christoph Stump,** Trinity Financial, Inc.
Energy & Carbon Advocacy	**Panama Bartholomy,** Building Decarbonization Coalition **Donna Decostanzo,** Natural Resources Defense Council **Adam Hinge,** Sustainable Energy Partnerships

Phases of Stakeholder Engagement

The public engagement process included three phases of input and outreach. Phase I was a Targeted Information Gathering process that sought to gather expert input on key topics.

Phase II, Public Input and Building Public Awareness engaged members of the general public in a two-way exchange of information. Phase III, Community-based Outreach, Awareness, and Education Campaign, is planned for post-publication of the *Roadmap,* and includes targeted community outreach and coalition building.

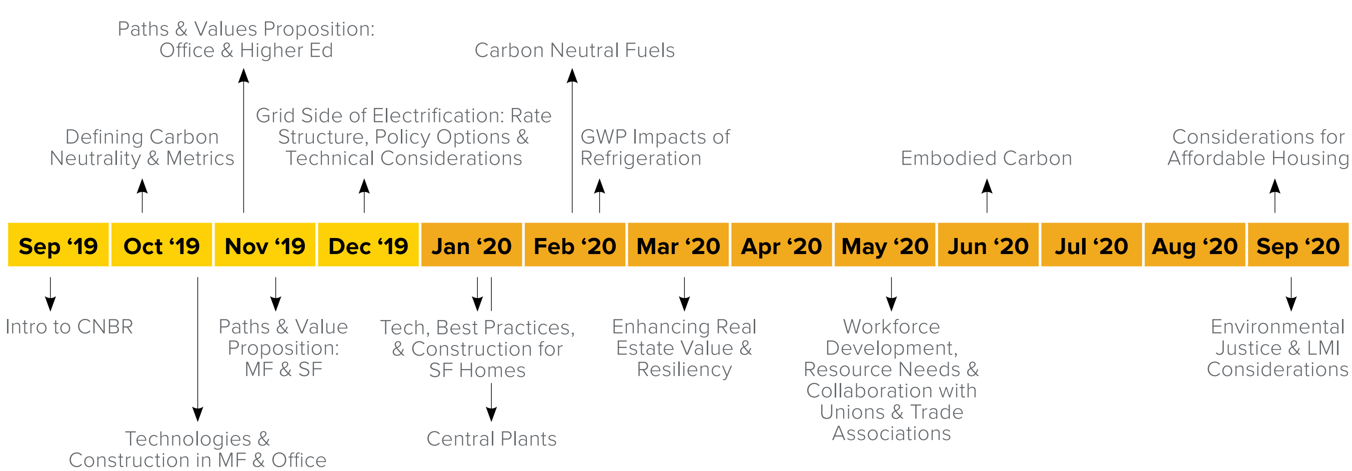
Phase I—Targeted Information Gathering Sessions by Topic

The Targeted Information Gathering phase began in September 2019 during the initial development of the draft *Roadmap.* This phase lasted a full year and included 15 small-group roundtables and participation from almost 1,000 local and national experts. In this early phase of engagement, the focus was on small-group information gathering sessions where experts provided input on key topics. Participants included market actors from government, business, finance, labor unions, trade associations, nonprofit entities, advocates for DACs and EJ, and national experts as well as interested individuals such as developers, builders, manufacturers, contractors, designers of single-family and multifamily housing, building owners, managers and operators, and real estate appraisers and brokers. The goal of Phase I was to provide NYSERDA with relevant feedback to guide the outline and foundational content of the *Roadmap.* The deep listening and idea exchange that occurred during this phase established mutual understanding of the issues being addressed and informed the subsequent policy and solution set recommendations included in the *Roadmap.*

Timeline and Topics

The information gathering sessions were designed to enable maximum access to interested parties across the State. In-person roundtable events, with online access for remote participants, were held in Albany,

FIGURE 12.2: ROADMAP STAKEHOLDER EVENT TIMELINE AND TOPICS



Buffalo, and New York City. Webinars were also held, as detailed in the list below. Topics included:

- Introductory Webinar—*Carbon Neutral Buildings Roadmap* (2 sessions)
- Roundtable on Defining Carbon Neutrality and Metrics
- Roundtable on Technologies and Construction Methods in Decarbonizing Buildings
- Roundtables on Paths and Values of Decarbonization in Single and Multifamily homes (2 sessions)
- Roundtables on Paths and Values of Decarbonization in Office and Higher Education (2 sessions)
- Roundtables on Grid and Grid Side of Electrification—Policy and Technical Feasibility (2 sessions)
- Decarbonizing Single-Family Homes
- Decarbonizing Central Plants
- Carbon Neutral Fuels to Decarbonize New York's Building Stock
- Addressing the GWP Impacts of Refrigerants
- Enhancing Real Estate Value through Investments and Resiliency
- Exploring Workforce Development Needs and Resources for a Decarbonized Built Environment
- Reducing Embodied Carbon in New York's Building Stock
- Disadvantaged Community Considerations: Affordable Housing
- Disadvantaged Community Considerations: Environmental Justice

In addition to the significant input received throughout this phase of the process, the *Roadmap* team also closely followed and supported the deliberations and recommendations of the Energy Efficiency and Housing (EE&H) Advisory Panel to the CAC. To support the framework established by the Climate Act, the CAC and NYSERDA initiated an Innovation Sprint, an accelerated analysis process to conduct statewide building sector policy assessment, and modeled building-level project energy savings and economics. This deep body of analytical knowledge simulated policy scenarios needed to meet the Climate Act emissions targets, while considering the added demands on electricity system capacity. The analysis of building-level cost impacts led cost mitigation strategy evaluation. The findings from the Sprint process and resulting recommendations were presented to the EE&H Advisory Panel and much of the analysis has been integrated into the *Roadmap.* This analysis helped shape the policy recommendations contained in the *Roadmap,* as well as the CAC's draft Scoping Plan.

Phase II—Public Input and Building Public Awareness

Once stakeholder input from Phase I was integrated into the draft *Roadmap,* NYSERDA moved to Phase II of its public participation strategy. Phase II was designed to obtain feedback from the public on the preliminary findings, as well as raise awareness and build momentum for building decarbonization amongst various stakeholders. NYSERDA reached out to over 15,000 stakeholders via direct email, web-forms, newsletters, and channel partners inviting them to attend the Phase II webinars. In June 2021, NYSERDA hosted two public webinars on the draft findings with a live question and answer session for public comment. The webinars were recorded and posted online, and public comment was accepted until August 6, 2021. NYSERDA's pioneering work to decarbonize New York State's building stock garnered over 300 comments and questions through the public comment period. The public comments were sorted into thematic groups and integrated, as appropriate, into the final *Roadmap* publication.

Photo Credit: Rodnae Productions

Phase III—Community-Based Outreach, Awareness and Education Campaign

For Phase III, a statewide community-based outreach campaign should be considered that builds awareness and provides education to prepare New Yorkers and generate support for the forthcoming building decarbonization policy and regulatory developments. Established partnerships with a variety of organizations will help to ensure that all households and businesses have the chance to understand the changes and opportunities offered in this clean energy transition. To help achieve the Climate Act goals, these efforts should include the initiation of a widespread education program and development of communications and marketing materials explaining the urgent need for building decarbonization, the actions called for in the *Roadmap,* and the existing technical and financial resources available through NYSERDA, utilities, and other State agencies to support those actions. These activities will also need to be closely coordinated with public outreach and consumer awareness efforts that will be undertaken by the CAC.

Mobilizing a strong network of community organizations will help create champions who can effectively and consistently address misinformation and communicate about decarbonization strategies and benefits from the perspective of community needs. Additionally, these community partnerships will provide repeat exposure to building decarbonization strategies that are needed to influence consumer behaviors and preferences, shape business practices, and help align the activities of other public agencies in support of a rapid decarbonization of New York's building stock.

The community-based outreach process should also target region-specific groups to advise the workforce of the shift to decarbonization, embed training opportunities and available resources, and provide additional information for displaced workers and Disadvantaged Communities (see **Chapter 11: Workforce Development and a Just Transition** for details). The information needs to be tailored for each audience to provide relevant material and guidance that is most applicable to the specific community. Through the process of communicating the motivations behind the decarbonization agenda, the benefits of investing in building decarbonization, and the steps necessary to decarbonize the built environment, community members will be empowered to serve as both advocates and participants.

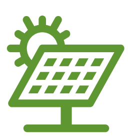
Coalition Building

Building decarbonization is a large and complex issue that transcends the purview of a single agency or organization, thus the need to convene an allied group of partners, organizations, and individuals in a coalition. The approach for coalescing such a group is to create a shared set of goals, target specific partners and allies, and create a network of Building Decarbonization Ambassadors and Champions. Building the cohort of informed community members that will scale the impact of the *Roadmap's* decarbonization aims will be a vital element of implementing the *Roadmap's* strategies.

The Coalition goals include:

Raise awareness and build support from trusted members of local communities

Address misinformation and strategies to increase implementation



Reduce GHG emissions

Save money and adopt cost-effective solutions

Make improvements to health, safety, comfort, and productivity

Stimulate community-scale decarbonization as an important step towards statewide decarbonization

The coalition partners and allies enlisted to spread building decarbonization messaging and assist with scaling decarbonization will represent multiple segments of the community, from state and local government to local environmental groups and environmental justice organizations, as well as building owners, contractors, installers, trade associations, and NYSERDA's Clean Energy Community Coordinators. Building Decarbonization Champions will serve as local advocates who promote electrification and decarbonization using techniques such as hosting community open-house events.

The Phase III outreach campaign could be integrated with the roll-out of NYSERDA's Regional Clean Energy Hubs which are being designed to:

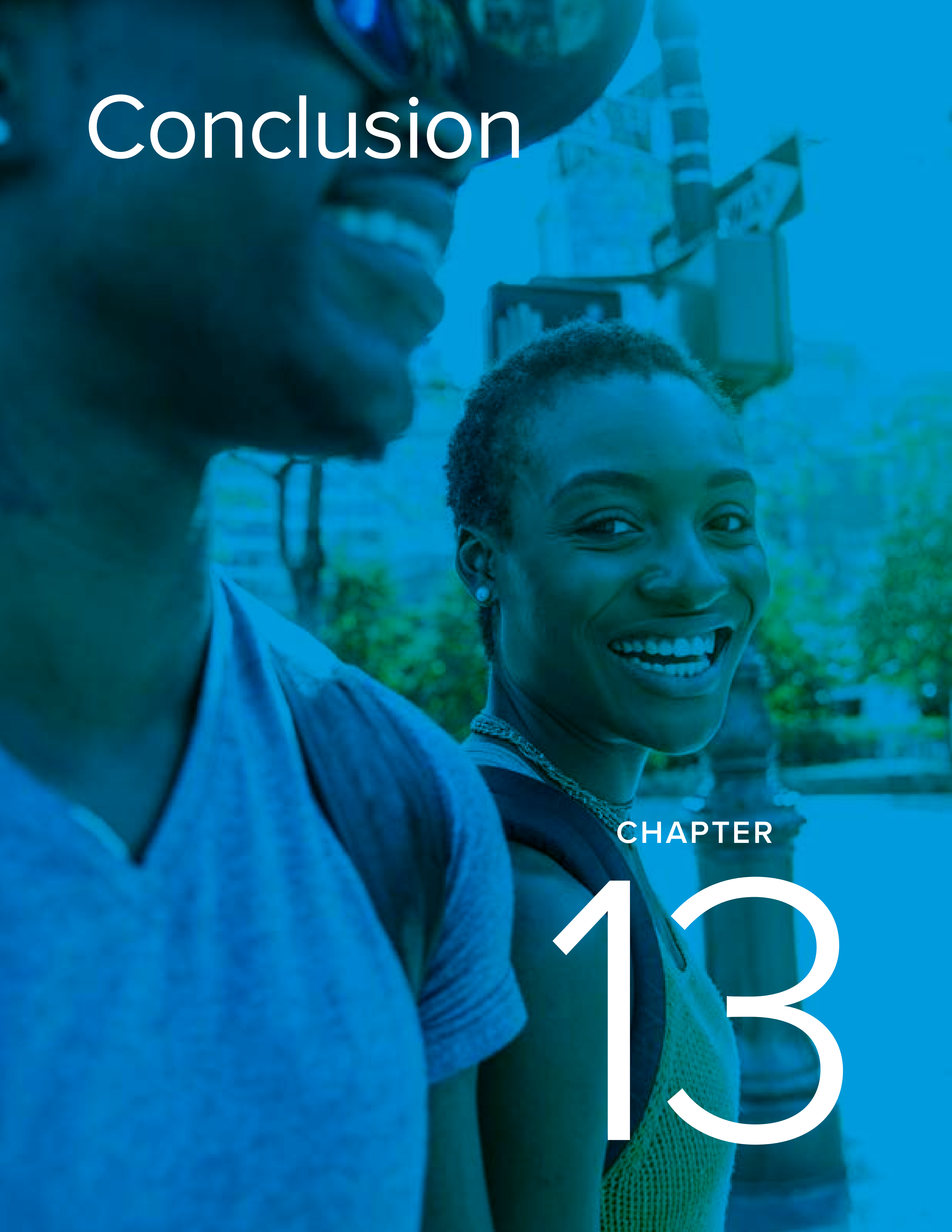
- Act as a trusted local resource for community members to learn more about the energy-related programs and services available to them;
- Increase awareness of these programs and services by leveraging the expertise and trust of local community organizations—particularly those with a proven track record of engaging Disadvantaged Communities;
- Develop outreach and engagement strategies to elevate the needs of communities and residents into program and policy development; and
- Address gaps in and advance diversity of the clean energy workforce by connecting residents with educational, training, and job opportunities and small businesses with resources to support economic development.

The Phase III outreach campaign should also include coordination with other New York State agencies and authorities, so that they integrate carbon reduction as a key element of their core missions.

Last Words

The Carbon Neutral Buildings Roadmap represents a deep commitment to the participation of a diverse array of market actors including governmental entities, for-profit and not-for profit organizations, community and industry groups, as well as individuals and subject matter experts.

The process of crafting the *Roadmap* resulted in local coalitions, public entity partnerships and associations that extend beyond the borders of New York State and will be critical to implementing the ambitious targets presented by the *Roadmap*. The process also helped raise awareness and provided high-level education on the key concepts of carbon neutral buildings, inspiring New Yorkers to adopt new technologies to make their homes and buildings healthier and more efficient and reduce GHG emissions. Continued advocacy and outreach for carbon neutral buildings is imperative for New Yorkers to plan for and then undertake the transition to a carbon neutral building stock. Together, New York can achieve this goal.



Conclusion

CHAPTER

13

The solutions outlined in this *Roadmap* are focused on effectively decarbonizing the built environment, both to achieve near-term emissions reductions, as well as to meet New York's long-term carbon reduction goals as outlined in the Climate Act.

These actions represent New York State's no-regrets approach to the climate fight and utilize a multi-pronged strategy to achieve the State's goals. While building decarbonization requires action prioritizing efficiency deployment, all-electric product installations, and decarbonization of the electric grid, there are several related considerations that are also critical in this transition to a carbon neutral economy. These considerations are largely about people rather than the buildings themselves. After all, buildings are built for the benefit of the people who occupy them, and this *Roadmap* aims to ensure that individuals, neighborhoods, and communities are bettered by the changes to come.

This *Roadmap* represents a new era for New York that brings together a number of positive outcomes from building decarbonization that will serve the current generation of residents, and their children and grandchildren as well. Eliminating the 32% of New York's total GHG emissions attributable to the direct onsite emissions from New York's building stock as well as decarbonizing the grid will tackle climate change head on, but also deliver healthier, more comfortable and productive places to live, work, and learn. The energy savings and load flexibility measures paired with electrification strategies will allow for a healthy, reliable grid as New York enters this new future. These upgraded buildings will also offer better resiliency while creating new jobs and economic opportunities.

New York State's clean energy transition is also an opportunity to make up for lost time by prioritizing Disadvantaged Communities. By including frontline neighborhoods and advocates in decision-making, decarbonization programs and policies can work to relieve past economic and racial inequities, improve health and resiliency, and create new and better paying jobs. The Climate Act requires that at least 35%, with a goal of 40%, of the benefits of clean energy investment go to historically Disadvantaged Communities.

Managing the Cost

Keeping the incremental cost of building decarbonization manageable is of utmost importance in reaching the State's climate objectives.

The *Roadmap* identifies strategies to reduce costs by driving scale, focusing technology RD&D to make products perform better or lower the cost of manufacturing, driving consumer awareness and demand, improving installations with workforce development, lowering the cost of financing, and other tactics. A number of approaches are already cost effective including the following:

- Installation of distributed energy resources and controls that enable flexibility and grid interactivity.
- Electrification in new construction projects. Electrification in existing buildings is on a trajectory to become cost effective with policy support that encourages installation of efficient, all-electric equipment at the time of replacement or during renovations.
- Envelope efficiency strategies in new construction. Insulation, window, and other envelope upgrades can become cost-effective for retrofits given proper codes and policy support.

The incremental costs of modernizing and decarbonizing the State's building stock also need to be understood within the context of the funds that would have been spent in any event in maintaining all of the New York's building assets for the next 30 years under a business-as-usual approach. This incremental cost can be minimized by careful long term capital planning that integrates decarbonization into a building's natural capital event, such as construction, sale, refinancing, planned renovations and upgrades, and tenant move-ins. And the cost needs to be weighed against the extreme costs of inaction.

Driving Scale Through Policy Adoption & Quantify Non-Energy Benefits

There are other cost savings achieved through avoided expenses that stem from the benefits of carbon neutral buildings.

In addition to energy savings, long-term and phased programs and policy drivers will provide carbon neutrality benefits at scale for New Yorkers by creating better building value, resiliency, health, safety, comfort, and productivity. In addition to the reduced energy expenses from efficiency measures, elimination of onsite fossil fuel combustion will bring New Yorkers better indoor (and outdoor) air quality that translates into healthier spaces in which to live and work.

The cost of treating the 1.4 million New York adults with asthma is estimated at $4.6 billion per year.[136] Cleaner indoor air will save on health care cost, improve quality of life, and raise productivity among students and workers. In addition, carbon neutral buildings' inherent resiliency means that indoor temperatures can be sustained longer, and onsite electricity generation and storage can provide places of refuge in the case of natural disaster and power outage. Finally, decarbonization policies will catalyze an economic engine that will put New York at the forefront of a new clean energy world. It will enable workforce development programs and create new jobs in the State, but also entrepreneurial opportunities and business growth.

Advance Technology Ready & Viable RD&D

Technologies are prioritized based on market readiness, and the potential for cost reduction and impact.

Building efficiency technologies are, for the most part, mature and can be rapidly deployed in most of the targeted building typologies. These include air sealing, high performance insulation and windows, heat recovery, solar photovoltaics, and induction cooking appliances.

New York State should focus its significant RD&D resources on high priority emerging technologies identified in the *Roadmap* that are essential to the proliferation of carbon neutral buildings, including expansion of heat pump form factors and efficiency, advanced controls enabling load management and grid interactivity, battery and thermal energy storage, electrification of steam loads, prefabricated panelized solutions, and integrated mechanical systems. The *Roadmap* also identified low-embodied carbon materials and low global warming potential (GWP) refrigerants as important areas needing innovation and expanded market share. In all cases, the *Roadmap* seeks to deploy innovation strategies that will reduce the cost of efficiency and carbon neutral building technologies either in product manufacturing, installation, or ongoing operation and management.

Prioritizing Disadvantaged Communities & Creating Jobs

At 77%, the energy efficiency industry already employs the largest share of clean energy workers in New York.

That number is poised to grow especially for LMI-wage earners. As noted earlier, the Climate Act targets 40% of the benefits of the State's clean energy investments to go to Disadvantaged Communities making equity, environmental justice, and just transition central concepts.

The State will invest nearly $1 billion in decarbonization programs and initiatives for LMI customers through 2025 with the aim of creating sustained economic opportunities including ensuring equitable access to workforce training. By partnering with frontline communities and advocates in decision-making, policymakers can increase the odds that the resulting solutions will work to solve those communities' respective needs, relieve economic and racial inequities, and improve health and resilience while creating better employment opportunities.

Making Demand Flexibility Inherent

Comprehensive electrification of end uses will add large, new loads to the State's electricity system.

To address this challenge, the *Roadmap* outlines an approach for enhancing demand flexibility to reduce grid impacts from electrification. Demand flexibility supports grid decarbonization by balancing the use of variable renewable generation sources. It can also provide cost effective alternatives to help building owners meet legislative mandates and can shift building energy loads to reduce peak demands on the State's electric grid, thereby reducing peaker plant operation, saving cost, and improving health.

Realistically though, there will be buildings that are difficult to electrify such as some very tall buildings in dense urban settings like New York City, some industrial facilities and labs with energy intensive processes, and multi-building central steam plants and district energy systems. To address this challenge, the *Roadmap* outlines low-carbon and renewable fuel options that could serve these properties while limiting the climate impacts.

The Work Ahead

In all, the Carbon Neutral Buildings Roadmap is designed to support both the long-term policy objectives of New York State and the requirements of the Climate Act.

It is a cornerstone piece of achieving a carbon neutral economy by 2050. Importantly, it is a plan for New Yorkers developed with New Yorkers. Over 1,000 individuals with ranging points of view gave input into the development of this *Roadmap,* with more stakeholder engagement planned in the future. Experts from around the world were also tapped for their insights. And the work continues.

This first component of the report series, The Future of Buildings, focuses on four building typologies: 1) single-family residential, 2) low- and mid-rise (up to 20 stories) multifamily, 3) low- and mid-rise (up to 20 stories) office buildings, and 4) higher education (focusing on dorms and classrooms). Future work will focus on the next set of priority building typologies, which may include:

- P-12 Schools
- Big box retail
- Warehouses
- Hotels
- Hospitals
- Central plants
- Skyscrapers (commercial and residential)
- Restaurants and commercial kitchens
- Grocery stores

Additional technologies and specific solutions will be highlighted for these building typologies, and future publications will also address new innovation and updated market conditions. Future publications will also take a closer look at lowering the embodied carbon of products and materials used in buildings. The best strategy to reduce embodied carbon is most often to encourage building reuse, beginning in urban centers. In addition, procurement requirements and design specifications for State-funded projects, support for education, RD&D, and business opportunities spawned by New York's clean energy transition will expand in-state manufacturing of alternative products that are lower in embodied carbon or made of carbon sequestering materials.

Along with the companion documents, Building Electrification Roadmap, and the Two Million Climate Friendly Homes Action Plan, this *Roadmap* outlines the current market gaps to developing carbon neutral buildings and best-in-class approaches that will be necessary to address those gaps between now and 2030. It also identifies the foundational work and investments that will be needed to trigger market forces over the next five-seven years that will accelerate progress in the period from 2030 to 2050. The *Roadmap* anticipates the development of a zero emission-renewable electric grid by 2040 and values a building stock whose aggregated attributes reduce the cost of building and operating the future grid while enhancing its reliability, value, and health. Today, the *Roadmap* calls on building owners, developers, architects, engineers, manufacturers, contractors, businesses, tenants, homeowners, lenders, and all other participants in New York's vibrant real estate market to become champions of carbon-neutral efficient buildings in order to realize the goals of the Climate Act.

As one of the most ambitious climate laws in the world, the Climate Act and its designated CAC were tasked with developing a Scoping Plan that will serve as a framework for how the State will reduce greenhouse gas emissions and achieve net-zero emissions, increase renewable energy usage, and ensure climate justice by mid-century. The development of the Scoping Plan builds upon decades of New York's climate leadership at all levels, including executive, regulatory, legislative, and programmatic. The implementation of strategies in the Scoping Plan will be guided by the State's past successes and informed by lessons learned here in New York and in other jurisdictions. This *Roadmap* served as part of the foundation to the buildings chapter of the Scoping Plan. Although much more work remains, the Scoping Plan represents a crucial step towards achieving New York's ambitious climate goals and provides a clear signal to the entire State community of what is to come.

Appendix

Glossary of Terms

Affordable: For the purposes of this report, “affordable” is defined as “where the homebuyer has a household income which does not exceed the income limits defined by the State of New York Mortgage Agency (SONYMA) low-interest rate mortgage program in the non-target, one- and two-person household category for the county where such property is located.”[1] This specification is equivalent to 100% of state median family income (SMI) or area median family income (AMI) whichever is greater.

All-electric building: No combustion equipment is used as part of the building heating, cooling, hot water, cooking, and laundry.

Baseline assessment: When appropriate, the baseline measurement to analyze the potential benefits of a home under an Affordable Green Building Program will be a home built in compliance with the current Energy Conservation Construction Code of New York State—2016 (ECCC-NY). This is based on the 2015 International Energy Conservation Code and ASHRAE 90.1-2013, as modified by the State of New York and, the 2017 Uniform Code Supplement for New York State based on the 2015 International Residential Code.

Best practice: In this report, best practice represents the most effective method acceptable for construction of any given measure or system. It includes construction industry standards that may go beyond code requirements. Best practice may also apply to program or administrative functions.

Building decarbonization: The reduction of carbon emissions (aka GHG emissions), through the conversion of existing equipment and systems powered by combustion processes, to highly efficient equipment and systems powered by emissions-free sources.

Building electrification: The conversion of an existing building’s heating, cooling, hot water, cooking, and laundry equipment and systems powered by combustion processes, to highly efficient equipment and systems powered by electricity.

Carbon coefficient: Carbon coefficient is defined as the quantity of CO_2e emissions attributable to a unit of energy consumed. New York City Local Law 97 sets near-term carbon coefficients by energy source (electricity, gas, steam, etc.) that are used to convert energy consumption to emissions impact.

Carbon emissions metric: Carbon emissions associated with the different energy sources consumed by the building on an annual basis ($lbCO_2e$/year).

Carbon footprint: Carbon footprint is defined as the totality of an organization’s energy consumption (or activities) and the resulting emissions from that consumption. Emissions are calculated by applying emissions factors to each activity. An emission factor is based on the Global Warming Potential (GWP) of each type of activity.

Carbon intensity: Please refer to the definition for emissions factor.

Carbon neutral building: A building that uses passive design strategies to minimize energy demand, whose systems are highly energy efficient, that meets its energy needs by producing onsite or procuring emissions-free energy, and that is responsive in real time to conditions facing the grid.

Carbon value: The value of carbon is a monetary estimate of the value associated with small changes in emissions of carbon.

Commercial building: All buildings or facilities that are not included in the definition for “Residential building.”

Direct emissions: Onsite fossil fuel combustion from the buildings sector. Direct emissions are dominated by fossil-fuel combustion for space heating and hot water. Electrification is the largest driver of direct emissions reductions.

Disadvantaged Communities (interim definition): Properties located in census block groups that are below the HUD 50% Area Median Income threshold and within DEC PEJAs (income + race/ethnicity) or New York State Opportunity Zones.

Electrification: Electrification refers to replacing direct fossil fuel use (e.g. propane, heating oil, gasoline) with electricity [use] in a way that reduces overall emissions and potentially energy costs while lowering other air pollutants. (Source: ***Environmental and Energy Study Institute***) In the context of buildings and homes, electrification commonly refers to the practice of replacing fossil fuel-powered measures, such as HVAC and domestic hot water equipment, with electric-powered equivalents.

Electric readiness: The installation of electrical service and panel capacity, conduit, fixtures, and outlets for a future installation of electric equipment for space heating and cooling, hot-water, cooking, and laundry.

Electric vehicle (EV) readiness: The installation of electrical service and panel capacity, conduit, fixtures, and outlets for a future installation of EV chargers.

Embodied carbon: The sum of all GHG emissions resulting from the mining, harvesting, processing, manufacturing, transportation and installation of materials and buildings.

Emissions factor: The emissions factor or carbon intensity of electricity indicates how much GHG emissions are created by all power plants operating at any given moment.

Emissions profile: An emissions profile indicates the amount of GHG emissions created by power plants during the course of an hour, day, month or year.

Energy affordability: A household's energy burden—the percentage of household income spent on energy bills—provides an indication of energy affordability.

Energy efficiency: Minimized consumption of energy required to perform useful work.

Energy storage readiness: The installation of electrical service and panel capacity, conduit, fixtures, and outlets for a future installation of electric batteries.

Environmental justice: Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. (EPA)

Equity: Equity means broadly that assets are distributed fairly and justly for the benefit of the public. (Office of Equity and Access)

Financing: The Public Authorities Law Section 1872-a states that financing can be from NYSERDA or other public or private sources and available to developers, builders, design professionals or potential owners for affordable units.

Future-proof: Many of the potential climate impacts to buildings and their occupants can be reduced through conscious efforts to incorporate resilient design measures—the idea of "future-proof" design that keeps flexibility and system/component service life in mind.

Green building measures: Green Building Measures refers to the green building practices or processes identified in The Public Authorities Law, Section 1872-a. Specifically included are energy cost and consumption savings, healthy indoor living environments, smart growth/smart planning, integrated design, environmentally responsible products, and waste reduction.

Green building standards: Standards that are used to incent green building. Green building can be defined as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building." (EPA)

Greenhouse gas intensity (GHGI): GHGI is a metric for commercial buildings. Considers the carbon emissions from the different energy sources consumed by the building on an annual basis in tons of CO_2 per square foot per year.

Grid integrated buildings: An energy-efficient building that uses smart technologies and onsite distributed energy resources (DERs) to provide demand flexibility while co-optimizing for energy cost, grid services, and occupant needs and preferences in a continuous and integrated way.

Hazards: Climate events that cause damage to buildings. For example: hurricanes, tropical storms, flooding, severe storms, winter storms, sea level rise, and heat waves.

HFCs or hydrofluorocarbons: HFC's are greenhouse gases, manufactured for use in refrigeration, air conditioning, foam blowing, aerosols, fire protection and solvents.

High performance: High performance projects received an incentive from NYSERDA because their predicted (modeled) energy consumption was at least 30% below the energy code in effect when the project began. These projects offer additional examples of buildings with low energy targets and outcomes.

Impacts: The potential effects climate change has or could have on buildings or occupants. For example, cladding damage, water damage to building contents, and increased occurrence of asthma are all potential impacts of climate changes on buildings.

Indirect benefits: Indirect benefits accrue from a green building measure or program, but are not immediately observable, secondary to the main focus of the program, and often difficult to calculate with any degree of confidence. For this report, potential indirect benefits are identified but not quantified.

Indirect emissions: Electricity usage accounted in the electricity generation sector.

Integrated design: Integrated design is a process to engage all project team members in the process of discovering synergies between systems, components, and co-creators (design and construction team) to produce much higher levels of building performance, human comfort, and environmental benefits, with less wasted time and resources.

Low-income and low- to moderate-income (LMI): Low- and Moderate-Income households in are categorized as the following, based on their annual income.

- **Very low income:** Income less than 130% HHSPG
- **Low income:** Income greater than 130% HHSPG but less than the greater of 150% HHSPG vs. 60% SMI for New York
- **Moderate income:** Income greater than the greater of 150% HHSPG vs. 60% SMI for New York but less than the greater of 80% SMI for New York vs. 80% PUMA AMI

Multifamily building: A residential building with five or more dwelling units.

Net Energy Use Intensity (Net EUI): Net EUI is annual energy use minus annual onsite renewable generation, divided by the building's floor area in SF. A building with a measured net EUI (site or source) less than zero has achieved ZE. Some buildings in the ZE Emerging category show a negative net EUI based on modeled or estimated data.

Net Zero Energy (NZE): NZE projects are buildings with significantly reduced energy loads, such that 100% or more of the energy use can be met with onsite renewable energy generation annually. In this list, projects are categorized as NZE Certified, NZE Verified, or NZE Emerging. For simplicity, projects that have set a net zero carbon goal are listed as net zero energy.

Net Zero Energy Certified: Net zero energy certified projects have been awarded Net Zero Energy (or equivalent) certification by a trusted third party such as the International Living Future Institute (ILFI). The certifier has thoroughly reviewed at least one continuous year of energy consumption and generation data to certify zero energy performance.

Net Zero Energy Emerging: Net zero energy emerging buildings have publicly stated goals of reaching NZE. These buildings may be in the planning or design phase, under construction, or have been in operation for fewer than 12 months. Others may have been operating for at least a year, but their measured energy use data either has yet to achieve NZE, or the data to document NZE performance was not available.

Net Zero Energy Verified: Net zero energy verified projects have achieved NZE for at least one full year and NBI has verified the performance data.

NYStretch Energy Code: A model code for voluntary adoption by local jurisdictions in New York State, to be enforced as the local Energy Conservation Construction Code, which sets energy conservation standards more stringent than the New York State Energy Conservation Construction Code.

Owner: For purposes of new construction, owner refers to a person who owns a residential building on the date that a certificate of occupancy. In the instances where the certificate is owned by the builder, it includes the potential owner.

Peak demand: Peak demand refers to times of the highest demand for electricity, which tend to happen during the hottest or the coldest hours of the year, as people turn on the heat or air conditioning in order to stay comfortable when outside temperatures are at their extreme.

Passive design strategies: Passive design strategies, such as reducing the volume of conditioned space, optimizing building orientation, minimizing thermal bridging, and using daylighting, thermal massing, and robust insulation, reduce the building's total energy consumption as well as the rate of energy use at any given time (energy demand).

Passive survivability: Passive survivability is the ability of buildings to maintain safe conditions and a reasonable level of functionality in the event of a power outage.

Residential building: A building where the main or dominant use is to provide complete independent facilities for living, sleeping, eating, cooking, and sanitation including single-family and multifamily but not to include transient uses classified as R-1 in the Building Code of New York State.

Resilience: The capacity to withstand and recover from events that incur stress and damage.

Risk: A product of the probability of a climate hazard occurring, the likelihood of impacts from that hazard, and the magnitude of consequences if that impact occurs. An example of a high-risk scenario is expensive electrical equipment located on the ground floor of a building in a flood plain.

Single-family building: A residential building with one to four dwelling units.

Site Energy Use Intensity (EUI): Site EUI is a metric for commercial buildings. This metric stands for the total gross site-level Energy Use Intensity (EUI), used to measure annual energy use per square foot (SF) of building floor area. Energy use includes consumption from all fuels (grid-delivered and onsite-generated electricity, natural gas, district energy, and delivered fuels) in thousands of British thermal Units (kBtu) per year (yr). That sum is divided by the building's gross size, thus the units are kBtu/sf/yr.

Source Energy Use Intensity (EUI): Source EUI is a metric for commercial buildings. Considers energy losses associated with generating a delivering fuel to the building by applying conversions factors to the fuel consumed onsite on an annual basis. Expressed in kBtu divided by square feet. The metric relies on site energy data and published conversion factors.

Source energy: Source Energy Use is the total amount of raw fuel that is required to operate a property. In addition to what the property consumes onsite, source energy includes losses that take place during generation, transmission, and distribution of the energy, thereby enabling a complete assessment of energy consumption resulting from building operations.

State Energy Code: The New York State Energy Conservation Construction Code promulgated pursuant Article 11 of the Energy Law.

Thermal Energy Demand Intensity (TEDI): TEDI Considers the amount of energy a building requires to maintain an indoor temperature that is comfortable for occupants per square foot of conditioned floor area per year. Expressed as a combination of annual heating and cooling demand.

Total System Performance Ratio (TSPR): TSPR is a relative whole system efficiency metric for HVAC systems based on the ratio of predicted heating, cooling and ventilation load to carbon emissions.

Vulnerability: The degree to which buildings, occupants, and related social systems are susceptible to and unable to cope with the adverse impacts of climate change. An example of increased vulnerability is elderly occupants' susceptibility to injury and death from heat waves relative to that of healthy younger occupants.

Zero Energy Performance Index (zEPI): zEPI is a metric for commercial buildings. The metric considers the energy performance of a building on a scale of 0 to 100 by comparing the modeled or actual performance of a building design against a fixed baseline. Additional terms related to LMI can be found in the LMI Market Characterization Glossary.

Acronyms

CO_2e: Carbon Dioxide equivalent

DAC(s): Disadvantaged Communities

EJ: Environmental Justice

EV: Electric Vehicle

GHG: Greenhouse gas

GWP: Global Warming Potential

HFCs: Hydrofluorocarbons

HVAC: Heating, ventilation, and air conditioning

LMI: Low- to moderate-income

MMt: Million Metric Tons

MWBE: Minority/Women-Owned Business Enterprise

PACE: Property Assessed Clean Energy

PV: Photovoltaic

R&D: Research and Development

SDVOB: Service-Disabled Veteran Owned Business

T&D: Transmission and Distribution

VRF: Variable Refrigerant Flow

WAP: Weatherization Assistance Program

Government Agencies and Authorities

DEC: Department of Environmental Conservation

DASNY: Dormitory Authority of the State of New York

DOH: Department of Health

DOS: Department of State

DOT: Department of Transportation

DOTF: Department of Taxation and Finance

DPS: Department of Public Service

HCR: New York State Homes and Community Renewal

HPD: New York City Dept. of Housing Preservation and Development

HUD: U.S. Department of Housing and Urban Development

NYCHA: New York City Housing Authority

NYPA: New York Power Authority

NYSERDA: New York State Energy Research and Development Authority

PHA: Public Housing Authority

PSC: Public Service Commission

SHPO: State Historic Preservation Office

Endnotes

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Clean energy can power New York while protecting the environment. The New York State Energy Research and Development Authority, known as NYSERDA, promotes energy efficiency and the use of renewable energy sources. These efforts are key to developing a less polluting and more reliable and affordable energy system for all New Yorkers. Collectively, NYSERDA's efforts aim to reduce greenhouse gas emissions, accelerate economic growth, and reduce customer energy bills.

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