urban green

December 2021

GRID READY

Powering NYC's All-Electric Buildings

Urban Green Council's mission is to transform buildings for a sustainable future in New York City and around the world. We develop cutting-edge policy, we educate a broad range of professionals, and we research solutions that drive policy and best practices nationally and globally. By working with both the public and private sectors, we leverage our effectiveness.

This report is possible through generous support from the **Energy Foundation** and the **New York State Energy Research and Development Authority**.

GRID READY

EXECUTIVE SUMMARY

IS NYC READY FOR ALL-ELECTRIC BUILDINGS?

Transitioning NYC's buildings off fossil fuels is critical to achieving our carbon reduction goals. We can start electrifying now and still avoid straining the grid.

July 2021 was officially the hottest month ever recorded on Earth.[1] Sweltering temperatures are becoming the norm in reliably mild places like the Pacific Northwest, and in New York City, heat is the leading weather-related cause of death. The latest Intergovernmental Panel on Climate Change report made it clear that humans are causing global warming, and it predicted dire consequences for our planet unless we implement drastic carbon cuts within the decade.

Burning fossil fuels is the predominant cause of this crisis, so it is imperative we make the switch to clean energy sources as quickly as possible.[2] This change will require a revolutionary shift, both in mindset and action: replacing combustion with renewable power in almost every circumstance.

New York City is no exception. Boilers, furnaces, and hot water heaters emit 40 percent of the city's carbon—more than the total emissions from electricity use citywide. To reach the city-mandated goal of reducing emissions 80 percent by 2050, we must electrify the majority of our energy. This conversion will require a new generation of technologies, from electric cars to heat pumps. Transitioning to these technologies will be challenging. And there is a critical underlying issue that must be addressed concurrently:

Is our grid ready to power this new way of life?

In short, yes: NYC's local electric grid is currently equipped to handle building electrification, and it has ample capacity to install cold-climate heat pumps before the city's peak power demand shifts away from summer (Figure 1). In addition, implementing flexibility and energy efficiency strategies at the same time as electrifying heat and hot water systems can keep building power demands manageable. Our analysis found that:

1. Building electrification poses no immediate risk to the grid.
2. Efficient electrification would level out demand, making power delivery simpler and more predictable while unlocking the potential for zero-carbon buildings through renewable power generation.
3. Affordable energy efficiency and demand flexibility measures, like roof insulation and smart thermostats, are highly effective at shaving peak demand; these upgrades should be used in tandem with heat pumps.
4. Heat pump installations should be tracked citywide, so planners can anticipate areas where infrastructure upgrades and governmental programs may be needed to ensure the proper resources are in place to keep pace with electrification, especially in low-income communities.

DID YOU KNOW?

Today, NYC's peak power demand is **42% higher** in the summer than in the winter.

5. Some buildings will need upgrades to electrical capacity, and that process should be improved and incentivized to facilitate electrification at scale. Building loads may be electrified incrementally, but incentives from the same programs assisting heat pump adoption could help ensure capacity upgrades are done strategically to anticipate future demand.

6. This study focuses on building electricity demand from conversion to heat pumps, but other important changes will affect how the grid must evolve. This work serves as a starting point and additional electrification research on NYC's local grid is needed to understand the impact of: future extreme weather patterns, increased demand from electric vehicle charging, new generation and transmission, and other factors that will inform infrastructure and capacity investment needs across the city.

What Is the Grid?

The electrical grid is the interconnected system of power plants, transmission lines, distribution networks and many other pieces of equipment that deliver electricity. New York State's grid is managed by the New York Independent System Operator (NYISO) and regulated by the Federal Energy Regulatory Commission (FERC). Privately owned power plants sell electricity to utilities that deliver it to customers—the people and businesses that pay for power. The rates, the amounts paid for electricity, are set by the New York State Public Service Commission (PSC), which regulates all state utilities—including Consolidated Edison Company of New York (Con Edison), the utility that delivers power to New York City and Westchester County.

The grid's reliability and upkeep costs vary significantly across the state. Increased demand due to more frequent extreme weather episodes as well as the inherently intermittent nature of renewable generation make it difficult to maintain the delicate balance between power production and consumption, also referred to as load. Power outages, which pose a serious threat to public health, are becoming more frequent. Across the U.S., major power outages from weather-related events increased by 67 percent since 2000. The Northeast suffered the most—its outages more than doubled over the last two decades.[3]

As we move toward the era of electrification, using electric heat pumps to efficiently heat and cool our homes could actually help stabilize the grid by enabling communication between power consumers and generators. Heat pumps can quickly ramp up and down in response to grid conditions to make it easier for utilities to match customer demand to power generation—especially wind power, which can be extremely variable.[4] This benefit, along with improvements in air quality and emission cuts, makes electrification even more compelling.

To explore the impact of building electrification on the grid, Urban Green modeled the conversion to heat pumps in NYC's over 1 million buildings, along with basic energy efficiency, storage and control upgrades. We also convened a panel of energy experts to review the models and weigh in on the findings. Based on the outcomes, this report describes the processes and technology that deliver power to New York City (page 13), examines how heat pumps will change power demand in buildings (page 19) and shows how electrification can be rolled out to carefully manage increasing demand (page 31).


WATERWORKS
A JOINT VENTURE

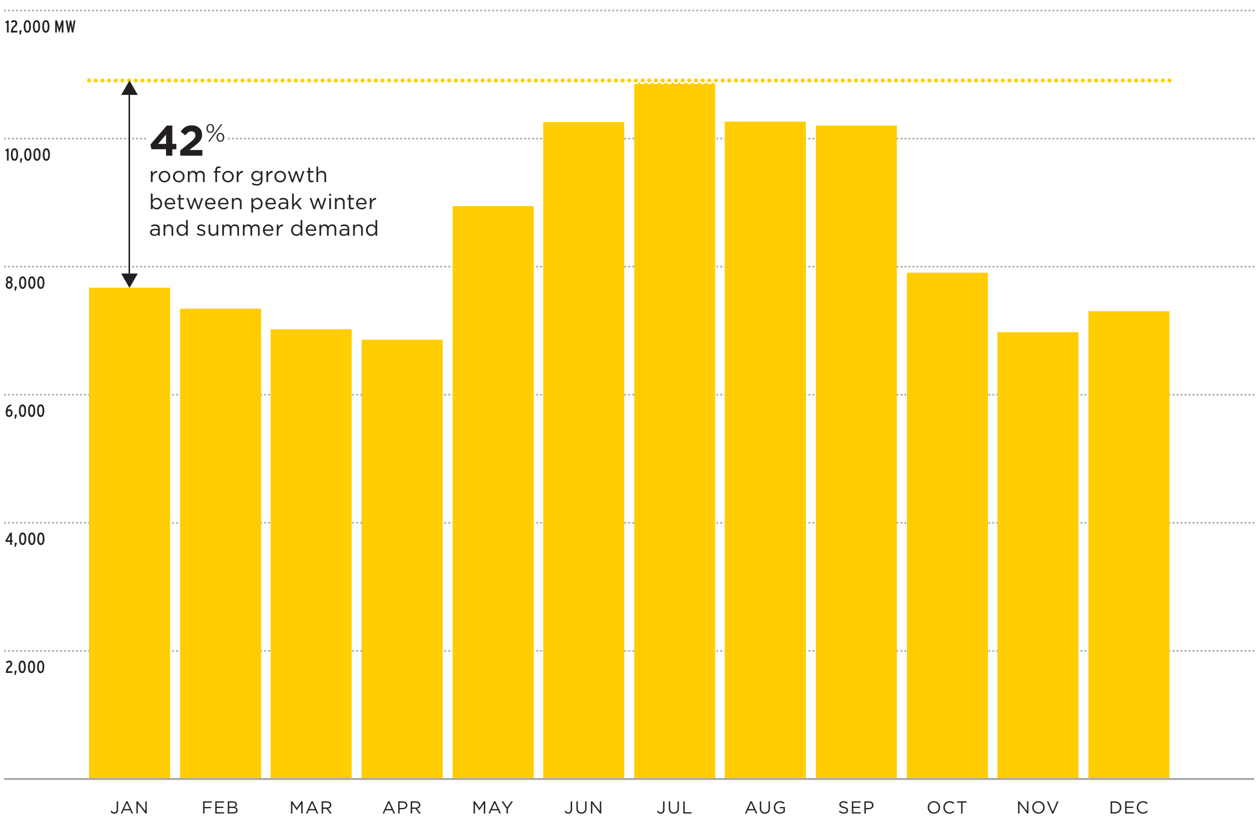
FIGURE 1

Room to Grow: Seasonal Patterns in Citywide Power Demand

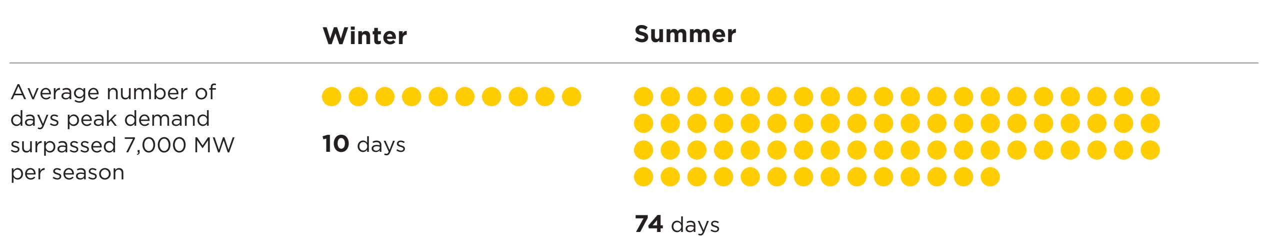
On average, NYC's peak power demand is over 40% higher in summer than winter. And colder temperatures allow the grid to carry more power, offering extra capacity to electrify heating in buildings.

Data: NYISO Actual Load 2010–2019

AVERAGE MONTHLY PEAK DEMAND OVER DECADE



HIGH-DEMAND DAYS BY SEASON OVER DECADE



The All-Electric City

Citywide building electrification will eventually shift NYC's peak power demand from summer to winter while significantly raising the peak (Figure 2). When that happens, on the coldest day of the year, building power demand could push that peak up by at least 4 gigawatts—the equivalent of 450 million LED bulbs being flipped on across the city. This massive increase will require improvements across the grid regardless of the actual peak, which will depend heavily on winter temperatures and how much energy efficiency, load flexibility and storage is installed in electrified buildings.

The good news is that utilities and their customers have plenty of time to adapt to these new peaks; the New York Independent System Operator (NYISO) does not predict this switch to a winter-peaking grid to happen statewide until 2040.[5] And so far, the pace of electrification has been glacial—efficient, all-electric buildings are limited to new construction and are still extremely rare. In order to prepare for this massive switch, Con Edison has identified nearly half of its ***network areas*** that may need to be improved to meet load and climate conditions in 2050.[6] While Con Edison could just upgrade power capacities across its network, other more cost-effective infrastructure solutions may be available: Networks can operate flexibly to preserve reliability; power can be shared between networks; and massive batteries can be installed throughout the city.

Electrified heat and hot water everywhere will mean the heaviest grid congestion is likely to occur in early January mornings rather than July afternoons. These loads will have to shift to other times to keep that peak manageable. Building owners and tenants can achieve this shift by heating spaces prior to temperatures dropping, adding insulation and thermal storage to retain heat, using smarter controls and installing on-site energy storage. However, they will need timely information and clear incentives to make those changes at the right moment.

Regulatory improvements will also be crucial to managing demand in the all-electric city. One important example is time-variant pricing for electricity. Millions of smart meters, which record the time of power use, have been installed in buildings across NYC and Westchester. But currently, even residential consumers who know their use pattern don't get the price signals to help them make beneficial changes. If consumers understand they can save money dependent upon when they consume power, they will have an incentive to act. This also will unlock the providers' ability to shift demand to match renewable generation, resulting in lower emissions.

Gradual Yet Consistent Improvement

Over the next few years, projected building electrification poses little to no threat to NYC's power grid. New York State hopes to save 4.6 TBtu through heat pump installations by 2025, but even if all those 130,000 installations were in NYC, that level of electrification would only necessitate routine upgrades to utility infrastructure, since heating is needed in winter, when power demand is lower.[7] Today, NYC's peak demand occurs in the summer, when cooling is needed most, and the grid's capacity has consistently grown to match that need.

NYC's summer peak demand is currently 42 percent higher than winter (Figure 1). On top of that, power equipment can handle more load at colder temperatures, leaving thousands of megawatts of spare capacity across the system. Buildings that electrify heating can fill in that gap without significant grid capacity upgrades—until peak power flips to winter.

Gradually, as more and more building area electrifies, parts of the city will need more power in winter than summer. This likely will occur first in areas of the outer boroughs, like Crown Heights in Brooklyn, that are comprised of mostly low-rise residential buildings. Not only do these structures have large heating demands but the lack of big commercial buildings in the area likely means the network system capacity has not required many upgrades. As low-rise residential neighborhoods install heat pumps, grid upgrades should be prioritized in communities where electrification could strain capacity sooner. Tracking building electrification will become increasingly important to identify these locations before they peak in winter.

Con Edison breaks most of its NYC network up into about 70 network areas. These "power neighborhoods" are linked by a common set

FIGURE 2

Modeling Tomorrow's Peaks: Impact of Electrification on Winter Demand

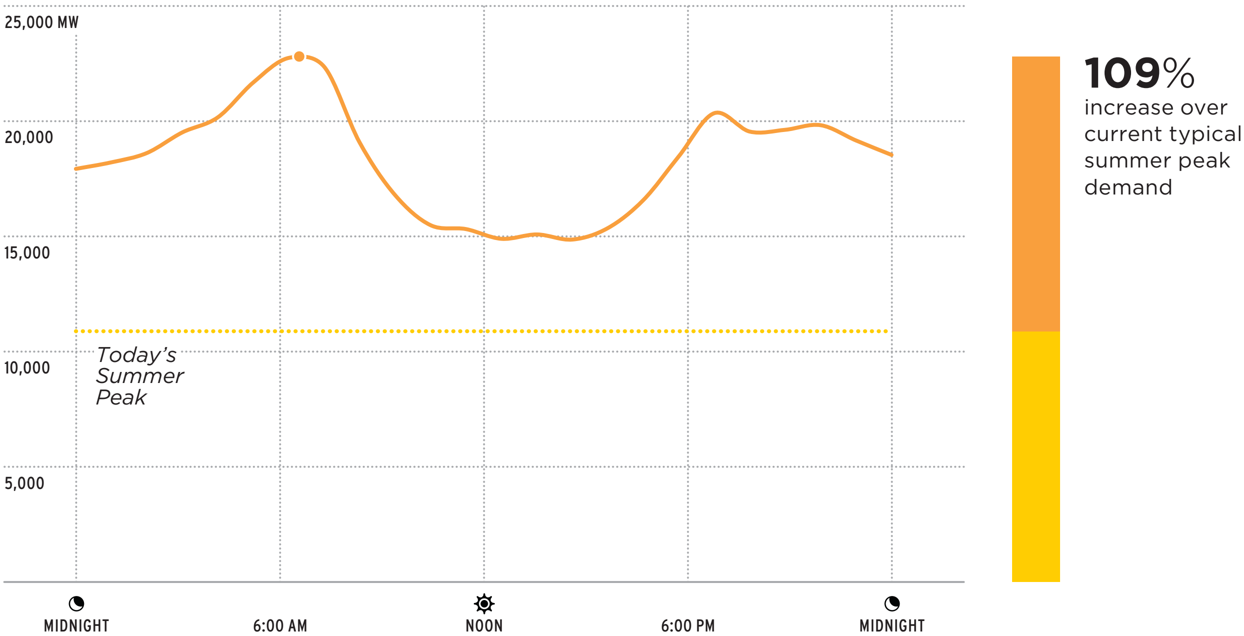
Installing heat pumps without upgrading other building systems could more than double NYC's peak power demand. Smart electrification—using efficiency and flexibility along with heat pumps—would shave roughly 7 GW off peak demand on the coldest winter day.

Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019

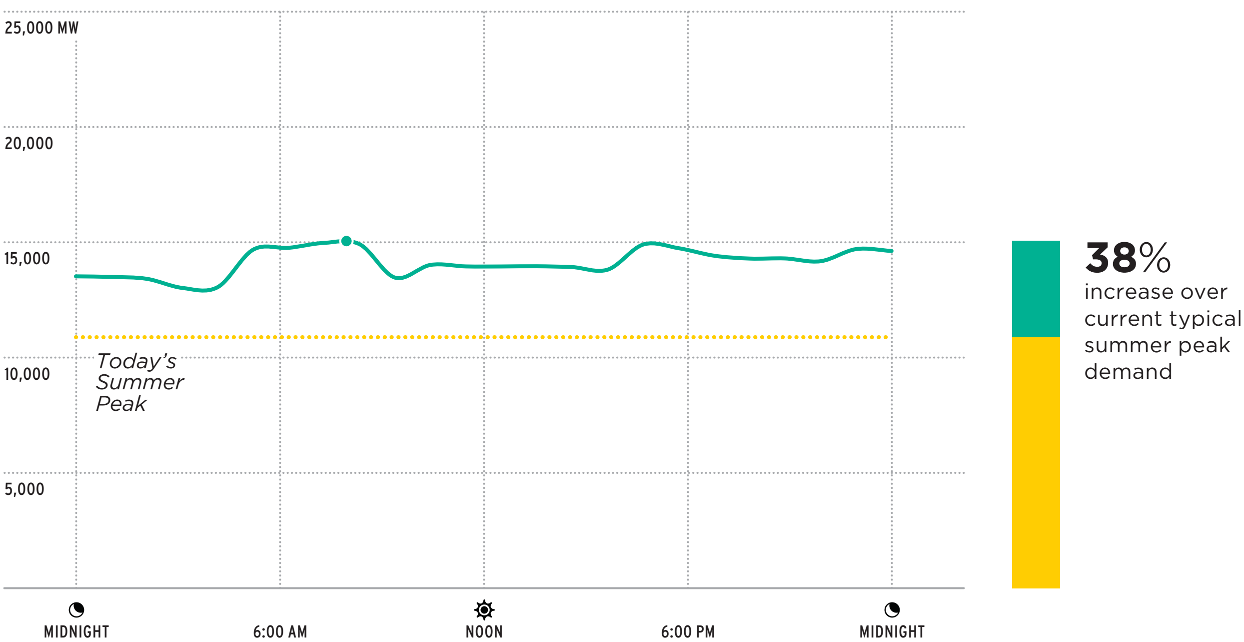
S1: ELECTRIFICATION ALONE (HEAT PUMPS ONLY)

S4: SMART ELECTRIFICATION (HEAT PUMPS WITH EFFICIENCY AND FLEXIBILITY MEASURES)

CITYWIDE WINTER POWER DEMAND
S1: ELECTRIFICATION ALONE, 100% OF FLOOR AREA



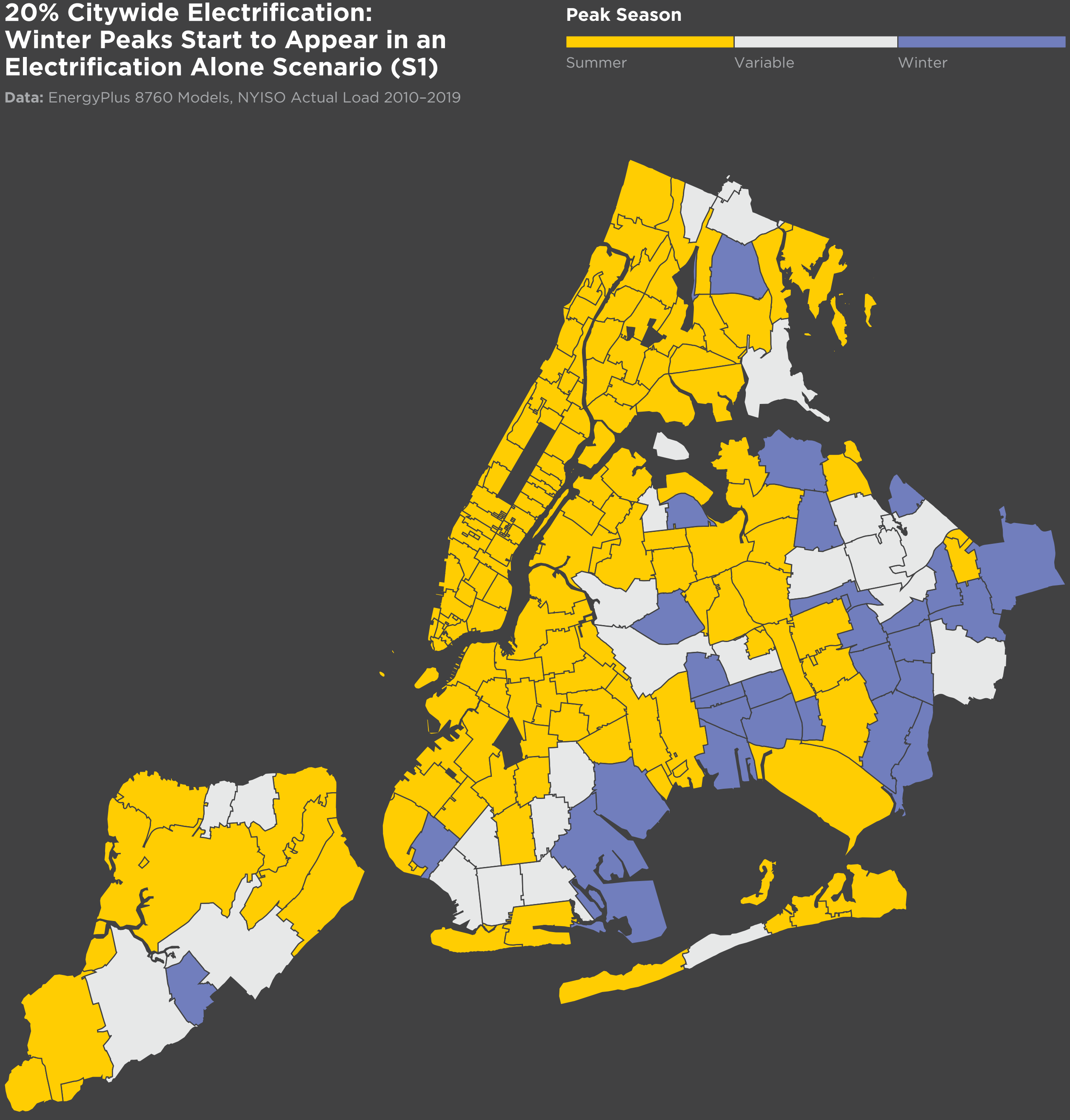
CITYWIDE WINTER POWER DEMAND
S4: SMART ELECTRIFICATION, 100% OF FLOOR AREA



MAP 1

20% Citywide Electrification: Winter Peaks Start to Appear in an Electrification Alone Scenario (S1)

Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019



The grid must be built out to meet peak power demand, so forecasting peak seasons can help plan infrastructure upgrades to support electrification. The timing of each zip code's flip to a winter peak depends on how its buildings electrify. Winter peaks signal that grid operations also need to change.

In our modeling, we found that power demand grew faster in outer boroughs than in Manhattan. If this trend plays out and heat pumps are installed without smart upgrades to manage demand (as described in Scenario 1 on page 21), then many Brooklyn and Bronx neighborhoods will soon see winter peaks.

DID YOU KNOW?

Most predictions expect a winter peak to occur in New York State **between 2035 and 2040**.

of underground wires that have varying power capacities. By the time 2.2 billion square feet, about 40 percent of NYC's building area, is electrified, almost 20 of these network areas will have winter peaks. Yet the distribution substations, the points where power enters the network, will be able to accommodate that level of electrification in almost every zone—so long as building upgrades include common sense energy efficiency and demand shifting measures alongside heat pumps. These measures cut peak power consumption by more than 30 percent (see *Building Electrification*).[8]

When Should We Electrify? Now.

After enduring deadly blackouts and flooding from Superstorm Sandy and now Hurricane Ida, New Yorkers recognize that climate change is the real threat to our grid. We need to start electrifying now.

Converting to heat pumps today will lower citywide emissions, even as NYC's power is still mostly generated by burning fossil fuels.[9] As New York State's grid evolves to become zero emissions by 2040, electrification will decarbonize buildings.

All-electric buildings that can change demand in response to grid conditions can improve the reliability of our power while lowering costs and dramatically reducing carbon emissions. Those emission cuts will help ameliorate the severity of future heat waves and storms.

The local grid already has the winter capacity to add megawatts of power in most network areas, and Con Edison routinely upgrades local network equipment. Heat pumps that efficiently heat and cool buildings level out demand, actually making it more predictable. Electrified buildings also could store excess energy as electricity (batteries) or, more affordably, as heat (thermal storage), to use when the wind slows or the sun sets. These upgrades would unleash renewable power while delivering a more consistent grid demand that is less costly to serve.

To keep building power demand manageable, customers need clear electricity pricing and feedback on their power consumption based on time of use. Additionally, simple energy-efficiency and demand flexibility upgrades must be installed in conjunction with heat pumps. A citywide strategy needs to be fleshed out for packaging simple, cost-effective measures—such as air-sealing, roof insulation and larger hot water tanks—along with electrification.

Local networks have varying degrees of reliability and will electrify at different rates. To avoid a network from shifting to a winter peak before the grid is ready, planners need a citywide method for tracking and reporting the size and location of heat pump installations, similar to today's maps of electric vehicle charging stations.[10] This information will help ensure reliability while making electrification equitable for all New Yorkers.

About the Scope of this Research

In 2013, Urban Green's groundbreaking report ***90 by 50*** *started the conversation on electrifying New York City. The idea of a future winter peak was introduced in* ***90 by 50****, and* ***Grid Ready*** *explores that issue in detail by looking at how building power demand will change as heating and hot water systems are converted to heat pumps. We focused only on buildings both for simplicity and because they use most of NYC's energy today. Their electrification is likely to have the biggest influence on future power demand.*

We compared current and future power demands to explore how many buildings could electrify before networks exceed today's peaks. This is the first step in understanding community infrastructure needs, but there will be upgrades needed block by block that we cannot yet predict. Future rate cases will address these upgrades and other major capital investments to advance beneficial electrification and continued reliability and resiliency needs due to the evolving dynamic electric grid.

This work serves as a starting point to understanding how electrification will affect NYC's grid. Other factors that will impact its reliability but are not part of this current research include:

- *Cooking: Gas stoves will be replaced by induction stoves that use electricity for cooking.*
- *Transportation: Electric vehicle charging, for cars, trucks and buses, will increase power demand.*
- *Expansion of cooling: It's unclear how summer demand will change as heat pumps bring cooling to buildings without it. That expansion, along with higher temperatures caused by climate change, may outweigh more efficient cooling from heat pumps.*

Electrifying NYC buildings is a multi-decade challenge. NYC's local distribution grid currently is reliable and has a process for gradual upgrades and long-term planning to meet evolving system needs. Our findings are not a substitute for a detailed distribution upgrade plan that considers the above factors and others to identify capacity investment needs in specific locations on Con Edison's network system.

This analysis was conducted in partnership with Elementa Engineering, who developed the citywide energy model to evaluate electricity demand scenarios in New York City.

HOW DOES NYC GET ITS POWER?

Electricity is critical to modern life. While it's easy to take for granted, delivering safe and reliable power is a complex process that involves many systems and entities.

The electrical grid is continuously in a delicate balance between generation and consumption. NYC's power is generated by power plants, many of which lie outside the city. Those power plants are owned and run by investor-owned firms, and so are most of the wires and equipment that move electricity. But the grid's supply and demand are regulated by the government, at the state and national level. Power is delivered to customers by utilities and other energy providers called ***load serving entities*** (LSEs). Electricity is sold to utilities on an open market, and nearly all of it—over 95 percent—gets purchased a day or more before it is generated.[11]

Major Grid Players

The **Federal Energy Regulatory Commission** (FERC) is an agency within the U.S. Department of Energy that regulates the transmission and sale of electricity between states. Within states or regions, Independent System Operators (ISOs) manage that transmission and sale of electricity, but they must comply with FERC orders where relevant to their operation.

The **New York State Energy Research and Development Authority** (NYSERDA) promotes energy efficiency and the use of renewable energy sources, which are essential to developing a cleaner, more reliable and affordable energy system for all New Yorkers. NYSERDA's goals are to reduce greenhouse gas emissions, accelerate economic growth and reduce customer energy bills. It is the driving force behind the Clean Energy Standard and has contracted thousands of megawatts of renewable power for New York State.

The **New York Independent System Operator** (NYISO) is responsible for operating New York State's electricity system and competitive electricity markets. NYISO also conducts long-term planning for the power generation and transmission needs across the state to ensure reliability and respond to policy objectives.[12]

The **New York State Public Service Commission** (PSC) oversees and regulates the electric industries active in New York. This includes reviewing and approving utility rate cases and directing entities—like NYSERDA and the utilities—to develop plans to meet state policy objectives.

The **New York Power Authority** (NYPA) is a public-benefit corporation that builds, owns and operates power generation and transmission facilities across New York. NYPA provides power for state entities like the Metropolitan Transportation Authority and SUNY campuses. The PSC can direct NYPA to pursue infrastructure projects to support state policy objectives.

To ensure reliability, New York's power system is overseen by multiple state, regional and international organizations including the New York State Reliability Council, the Northeast Power Coordinating Council and the North American Electric Reliability Corporation.

Consolidated Edison Company of New York (Con Edison) is the utility responsible for providing electricity to over 9.5 million people in New York City and Westchester County.[13] Its local distribution systems connect customers to power produced both in and outside of the city. Typically, power, whether coming into the city or generated here, is connected to Con Edison's ***local distribution network*** via high-voltage transmission infrastructure. These transmission lines energize more than 50 ***area substations***, which reduce the voltage of this power before supplying it to Con Edison's local network.

Almost 90 percent of NYC's power is delivered through Con Edison's network areas via underground wires—over 98,000 miles of them—that make up the network areas.[14] Each network area distributes power from the area substation via large cables called ***primary feeders***. These primary feeders then supply power to underground ***transformers*** that reduce voltages again before connecting to buildings.

Known as the ***network system***, this is the largest underground distribution system in the United States.[15] The areas of the city served by traditional overhead lines—known as the ***radial load areas*** and ***non-network systems***—are concentrated in Staten Island and the eastern edges of the Bronx, Brooklyn and Queens. Even overhead lines have ***redundancy*** built into their systems.

Con Edison's network system is designed to deliver uninterrupted power to customers even when one or two primary feeders—out of a dozen or so—go out of service for maintenance. An additional benefit of this underground system is that it is shielded from falling trees, snow and ice. The wires and transformers are still at risk of flooding, as experienced during hurricanes Sandy and Ida, but overhead wires usually take the brunt of storm damage.

Maintaining and Improving the Grid

Con Edison is continuously reviewing and upgrading its network to improve reliability, reduce costs and increase power capacities available to customers. The utility conducts an annual process that identifies areas of the network that need to be upgraded to improve overall resiliency and then creates a Network Reliability Index (NRI) for each network area. This process tests the grid against the conditions of ***peak power demand***, which typically occurs during one of the hottest days of summer, and allows Con Edison to prioritize what changes to make based on when and where failure is possible.

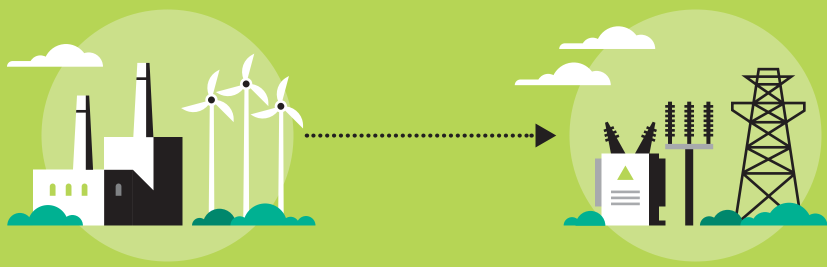
Common service upgrades to increase each network's overall capacity include installing higher-capacity equipment, splitting networks into smaller areas to reduce load, connecting networks with additional primary feeders and even building new distribution substations.

Utilities and regulators improve the reliability of NYC's power supply beyond just installing bigger wires and transformers. These ***non-wires solutions*** take the form of ***distributed generation***, ***energy storage***, ***energy efficiency*** and ***demand response programs***. These alternatives aim to lower the system-wide peak demand (***peak shaving***) and ensure reliability to network areas that are under stress.[16]

Distributed generation is small-scale electricity generation either within or nearby buildings. A variety of technologies could be used to achieve this, including solar photovoltaics, small wind turbines, and combined heat and power systems. Energy efficiency and storage are described in more detail in the next section.

Demand response programs ask customers to voluntarily reduce their electricity use for a short time. These programs typically are used only on the hottest summer days, when network-wide power demand is highest. Lowering demand avoids equipment overheating, which potentially could lead to blackouts. Depending on the program, customers are asked either a day or a few hours in advance to reduce their electricity use for several hours due to a ***demand response event***. For example, with the Brooklyn-Queens Demand Management (BQDM) program, high-power users like manufacturing plants volunteer to significantly reduce demand when notified, usually at least a day in advance; the program successfully cut over 30 MW of customer load in those boroughs in 2018. Typically, these programs are only active for a few days per year, but they can save billions of dollars in avoided capital costs.[17] Demand response is now poised to expand beyond big commercial users—paying residential customers for their flexibility too.

Powering New York City



1 GENERATION

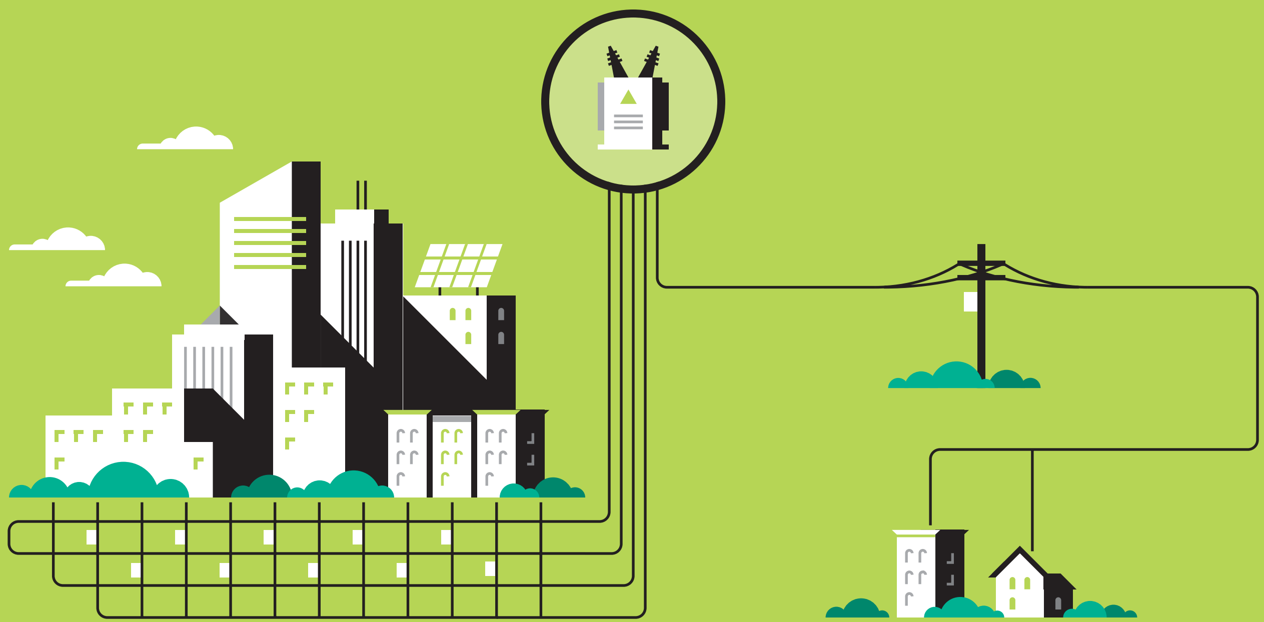
Many power plants generate electricity across New York State, and they use different energy sources and technologies to power the grid.

2 TRANSMISSION

High-voltage transmission lines and towers move electricity from power plants to transmission substations, which reduce voltages and connect to areas that need power.

3 DISTRIBUTION

Voltage is reduced at area substations. Lower-voltage power is delivered to properties to meet demand by feeders, transformers and other cables.



Network

Most of NYC's local distribution grid consists of underground network systems. These networks are shielded from wind and falling trees, and their redundant circuit configurations make them more resilient.

Non-network

Non-network systems make up 10 percent of NYC's local distribution grid. These systems are made up of poles and overhead wires that tend to be less resilient in storms and other emergencies.

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70 *network areas service NYC, along with 50 area substations.*

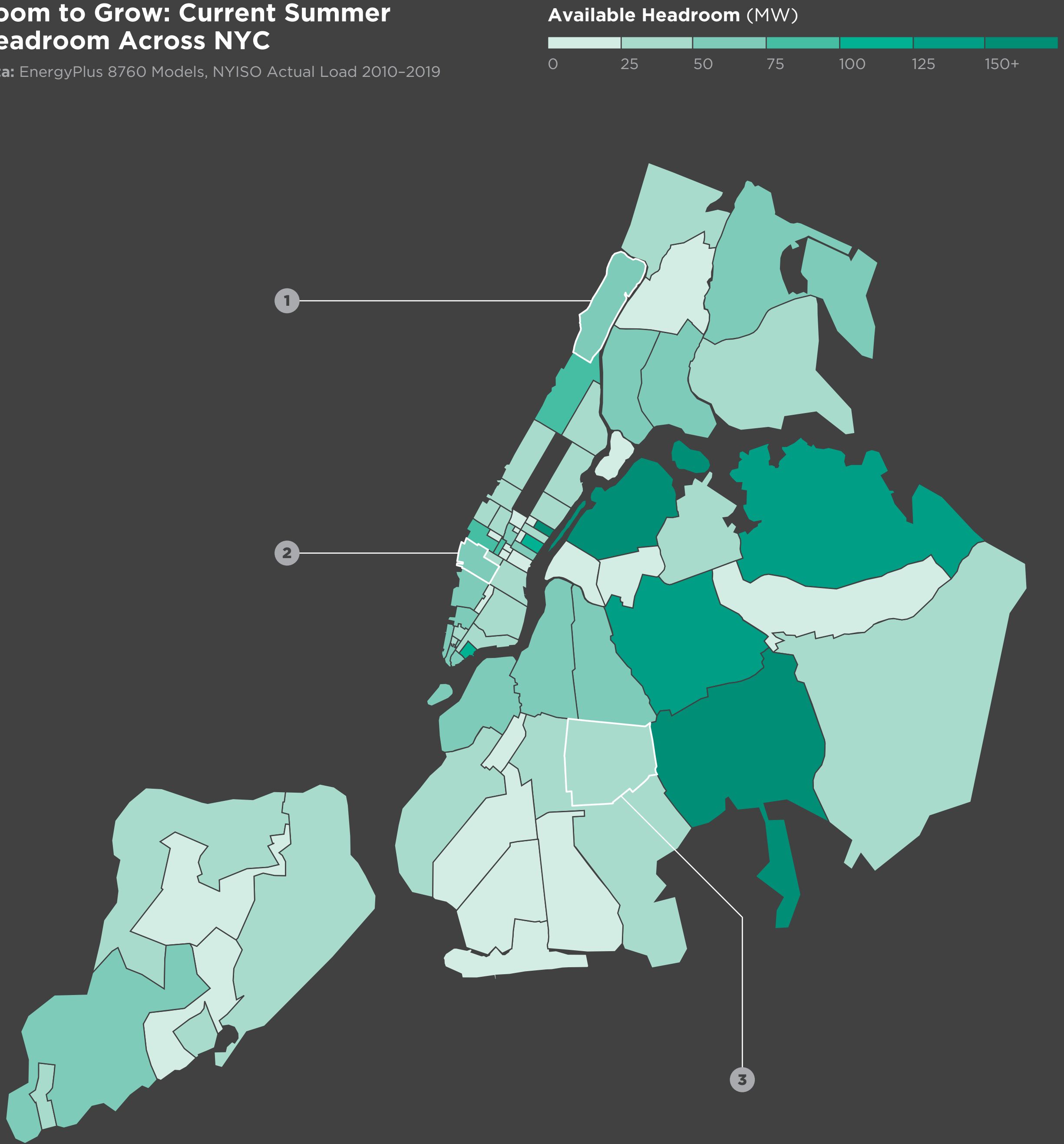
90% *of NYC's power flows through underground lines to network customers.*

70% *of the state's power will come from renewable sources by 2030.*

MAP 2

Room to Grow: Current Summer Headroom Across NYC

Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019



Even with today's summer peaking grid, all but seven networks have at least 10 MW of headroom—the difference between a network's capacity and peak demand.

1. **Washington Heights:** This network area covers the northern end of Manhattan. While it has around 70 MW of headroom, there are many low-rise multifamily buildings here and heat pump loads could shift this network to a winter peak soon.

2. **Chelsea:** The network area powering the blocks between 14th Street and 30th Street west of Fifth Avenue has around 30 MW of headroom, but it could take a while for this area's winter demand to exceed capacity because the network is already built to handle a much higher summer demand.

3. **Crown Heights:** The Crown Heights network area serves residential neighborhoods in Brooklyn and has less than 50 MW of headroom. Once electrification takes off, power demand could exceed capacity here.

DID YOU KNOW?

Most of NYC's power arrives via **95,000 miles** of buried wires—the largest underground distribution system in the U.S.

Total electrification will require implementing these new non-wires solutions along with the traditional grid upgrades—the necessary changes to keep pace with higher summer peaks—that have already occurred. Additionally, when a building owner wants to increase electrical service to a property, for example, in preparation for installing heat pumps, they must submit a ***load letter*** to Con Edison laying out the specifications for the work. Con Edison then conducts an analysis to see if any upgrades are needed to accommodate this service increase. These would typically be confined to upgrading transformers or cables near the building, but completing this work could take weeks or even months.

The overall capacity of the network area should not dictate if a building can increase service, since increasing the overall capacity of the network area—like adding new area substations or primary feeders—is a long-term planning consideration and can take years to complete.

The good news is that near-term building electrification can be accommodated through Con Edison's standard processes, while network-level capacity upgrades will start to become more prevalent as a high percentage of New York City buildings electrify in decades to come. Regardless, all of NYC's network areas currently have spare capacity, or ***headroom***, compared to actual load. Compared to summer peaks over the last decade, half the network areas have over 30 MW of headroom (Map 2).

Planning the Clean Energy Future

Over the last few years, New York State has made encouraging progress on meeting its clean energy goals, as set out in the Climate Leadership and Community Protection Act (CLCPA). The CLCPA requires that statewide electricity be 70 percent renewable by 2030 and 100 percent carbon-free by 2040. Now comes the hard work of coordinating all of New York's power producers, utilities and energy users to take action and ensure that the electricity we use is reliable, clean and affordable.

Essential work is now underway. New York has five offshore wind power projects sited and in active development that will bring 4,300 MW of power online for NYC. That's enough to power 2 to 3 million homes. Additionally, two renewable power transmission projects—Champlain Hudson Power Express and Clean Path NY—won the solicitation for Tier 4 REC status by NYSERDA.[18] Combined, these latest renewable sources will deliver over 2,500 MW into Queens, but the local distribution system must be upgraded to create ***off-ramps*** for this high-voltage power. Over the next few years, Con Edison will spend over $2 billion on local transmission and distribution projects directly tied to meeting the goals outlined in the CLCPA.[19]

This investment will prepare New York City's grid to support a clean energy future through increased interconnection and energy storage. These projects also will facilitate the planned closures of fossil fuel–burning ***peaker power plants*** in the city.[20] Phasing out these old dirty power plants is a key environmental justice objective connected to the CLCPA and will improve the health of many vulnerable New Yorkers.

HOW WILL HEAT PUMPS CHANGE ENERGY USE?

Electrifying heat and hot water systems will significantly alter seasonal power demand patterns. Our modeling allows us to predict these changes building by building.

All-electric buildings are nothing new. More than 50 of New York City's large postwar buildings were designed to get their heating from electric resistance, which uses the same technology as a toaster oven to convert energy directly to heat. While an inefficient system, it was suitable for the time, as the U.S. had a glut of electricity production, making electric resistance a welcome alternative to high-priced oil.[21]

Today's all-electric buildings use heat pumps, a system that triples the efficiency of electric resistance by harvesting heat from outside the building. This technology, already used widely in warmer climates and growing in popularity in the Northeast, will bring massive change to most of NYC's older building stock, which mainly relies on steam heat. Replacing oil and gas boilers with heat pumps will significantly reduce building emissions, provide occupants with more control over indoor temperatures (especially in colder months) and have the co-benefit of reducing air pollution throughout the city. Statewide, almost 100 new multifamily buildings have received New York State Energy Research and Development Authority (NYSERDA) funding to install heat pumps rather than fossil fuel heating.[22]

But switching to heat pumps also means increased electricity consumption and power demand. That's because in NYC, more energy is needed during the heating season. The difference between indoor and outdoor temperatures is typically around 35 F in winter, compared to less than 15 F in summer. We also know that some heat pump installations will require upgrades to the electrical circuits and equipment inside the building. To study the grid implications of heat pumps, we built two ***energy models***: One calibrated to current electricity demands for cooling, fans, ventilation, lighting and appliances, and another for transitioning building heating and hot water systems from fossil fuels to electricity.

Each newly electrified building will add a bit more demand to NYC's winter peak. But that amount will vary widely based on the type of building, how it electrifies and what other improvements owners make simultaneously.

Energy Use Today

New York City has over 1 million buildings, from assembly halls to zoo enclosures, each with different physical characteristics and energy-use profiles. These buildings account for approximately 95 percent of NYC's electricity consumption.[23] That encompasses many different applications, from operating factories and data centers to air-conditioning homes. It's important to capture this diversity with a range of building energy models while also being able to generalize enough to conduct a citywide analysis. Beyond use type, it is also important to consider the age and height of certain groups of buildings—like multifamily housing and

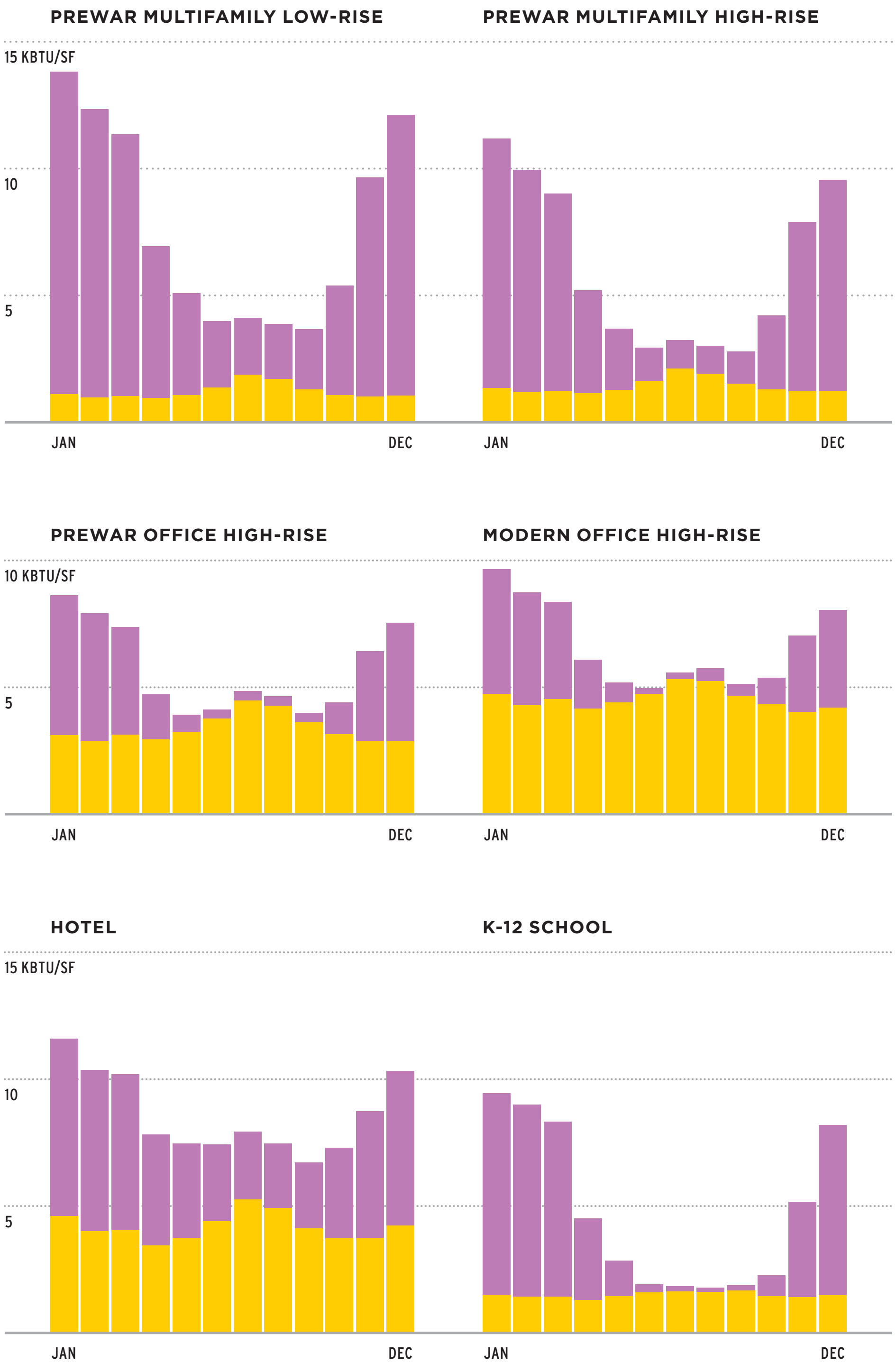
FIGURE 3

Monthly Site Energy Use in NYC Buildings, 2019

Month-to-month gas and electricity use varies by building type. Summer energy use data shows us how much gas is needed for providing hot water and how much electricity is used for cooling.

Data: LL84 Monthly Benchmarking Data

ELECTRICITY
NATURAL GAS



Building Size

Prewar multifamily low-rise buildings tend to use less electricity but more gas than their high-rise (more than 7 stories) counterparts.

Construction Date

Modern high-rise offices consistently use immense amounts of electricity throughout the year, but older prewar offices use less electricity, especially in winter.

Primary Function

K–12 schools use electricity consistently but use almost no gas in summer without hot water demand. Hotels use large amounts of electricity and gas throughout the year.

offices—that represent a large portion of the total citywide floor area.

We modeled 27 different building typologies based on the Department of City Planning's PLUTO dataset (the full list is shown in Table 3). Every NYC building was categorized as one of these typologies.[24] Modeling included six different size and age combinations for both multifamily buildings and offices.

To gain insight into seasonal energy use, typical energy use and power demand for each building typology was determined using monthly benchmarked data.[25] Monthly electricity and gas profiles were created for each typology (Figure 3). The energy models were calibrated to match these monthly profiles, so the output is based on both scientific modeling standards and measured data from NYC buildings to provide the most accurate results. More detail on this process is available in the Appendix.

We modeled each hour of the year for each building typology—first, with fossil fuel systems (Baseline); then, converting heat and hot water systems to heat pumps (Scenario 1); then, adding efficiency upgrades to Scenario 1 to lower energy use (Scenario 2: Efficient Electrification); next, adding measures to Scenario 1 to shift power demand without efficiency upgrades (Scenario 3: Flexible Electrification); and finally, combining all three previous scenarios into a combined smart electrification package (Scenario 4: Smart Electrification).

Initially, electrification will likely be simple heat pump installations paired with a couple of basic energy efficiency improvements, but ***behind-the-meter*** battery capacity is expected to double over the next 15 years and will eventually enable smart electrification.[26]

TABLE 1

Modeling Scenarios

We looked at four electrification scenarios that change baseline energy use. First, converting heating and hot water to air-source heat pumps; second, adding efficiency with envelope upgrades; third, instead adding flexibility with controls and energy storage. The fourth scenario includes all upgrades. Details on the measures included in each scenario can be found in Table 4 on page 44.

	Heat Pump Conversion	Efficiency Upgrades	Demand Flexibility
TODAY'S BASELINE No Electrification	—	—	—
SCENARIO 1 (S1) Electrification Alone	✔	—	—
SCENARIO 2 (S2) Efficient Electrification	✔	✔	—
SCENARIO 3 (S3) Flexible Electrification	✔	—	✔
SCENARIO 4 (S4) Smart Electrification	✔	✔	✔

DID YOU KNOW?

Buildings account for about **95%** of NYC's total electricity consumption.

How Will Electrification Change Power Demand?

As stated previously, each building has a different electricity use profile. However, most structures use more electricity in the summer—the cooling season. As outside temperatures increase, cooling gets more energy intensive, and almost all of it is driven by electricity. This power demand gets layered on top of everyday electricity needs, like lighting, leading to a stressed grid in July and August.

About two-thirds of NYC's big buildings have this high-demand summer pattern today.[27] On a hot day, each building's electricity demand builds hour by hour, peaking in the afternoon. The typical baseline demand curves for prewar low-rise multifamily buildings and prewar high-rise offices are shown in Figures 4 and 5. Benchmarked electricity use from 2019 revealed a wide range of power intensities: multifamily buildings typically peaked around 1 W/SF, while offices peaked closer to 3 W/SF and hotels peaked even higher, at 4 W/SF.

As these buildings install heat pumps, their power demands will not only increase but also will shift to different times of the day and year. Those changes are shown for two building typologies in Figures 4 and 5. The theoretical new demand curves for each building look slightly different based on their size and typology.

What Should Be Included With Every Heat Pump Conversion?

Heat pump upgrades need to be combined with other building improvements to lower electricity demand. We selected and modeled energy efficiency and demand flexibility measures to achieve this result in the most cost-effective manner. These upgrades to building envelopes and other systems are critical to ensuring that peak winter power demand grows slowly and stays manageable while keeping apartments comfortable (Figures 6 and 7).

Thermal storage that allows residential buildings to make enough hot water for the morning shower rush was most effective at lowering winter peaks. The full list of the measures modeled in this analysis is shown in Table 4. Solar panels were not included in any model due to high costs and limited rooftop space on NYC buildings, especially given that this area will eventually be needed for new heat pump units.

LOW-COST EFFICIENCY MEASURES

Energy efficiency lowers a building's power demand every day of the year, shifting the entire demand curve down. We modeled energy-efficiency measures that reduce peak power demand in residential buildings by 15 percent and commercial buildings by 10 percent. Typically, multifamily buildings should be able to complete these retrofits for $3 per square foot.[28]

We included measures that reduce the heat needed to keep each building warm in winter. Keeping indoor temperatures lower when people are not at home means heat pumps don't need to work as hard, so they use less energy. The same idea was applied to summer indoor temperatures: Unoccupied spaces had their cooling reduced.

Our models included cost-effective measures that lower heat load by upgrading the most important pieces of building envelopes to meet energy code minimums. These are things like sealing cracks and gaps around windows and doors to lower infiltration, adding insulation to the roofs (R-33) and upgrading to basic double-pane windows. While window replacements were the most expensive improvement, they would drastically improve occupant comfort.

Additionally, we included easy ways to reduce electricity used by other systems, like lighting and appliances. Lighting power was reduced by 30 percent through LED lighting upgrades to meet the energy code, which Local Law 88 mandates must be done in large buildings by 2025. We also lowered plug loads by swapping out old appliances for ENERGY STAR versions and shutting down idle computers late at night. Most commercial buildings were upgraded to energy-recovery ventilation, and offices varied ventilation rates based on occupancy.

BASIC DEMAND FLEXIBILITY MEASURES

We modeled demand flexibility in three ways: load shifting, thermal storage and electric battery storage. One drawback of using storage for flexibility is that some energy is lost as heat, since no battery is 100 percent efficient.

Load shifting involves moving power demand to times of day when the grid is not stressed. Doing so prevents the local distribution network from becoming overwhelmed and lessens the need for additional power plants. Buildings can shift their demand by carefully scheduling certain appliance runtimes and loads; for example, buildings could precool to reduce their cooling use in the afternoon.

Thermal storage for hot water will be essential for all-electric residential buildings. Thermal storage could be heat stored as hot water or future cooling capacity stored as ice. Hot water use spikes during morning shower and evening bath routines, which could drive steep peaks in power demand for those hours. This is especially important given the fact that residential housing makes up nearly 70 percent of NYC's total floor area and heavily influences citywide power demand.

Thermal storage allows the power demand associated with spikes in hot water use to be staggered over a longer period of time by filling tanks with hot water when there is low overall demand. In our models, these tanks were sized to store enough hot water to meet peak hourly demand from 6 a.m. to 10 a.m. and again from 6 p.m. to 10 p.m. The heat pumps would operate the other 16 hours of the day to fill the tank and keep it at a high temperature. This off-peak operation would reduce power demand in multifamily buildings by 27 percent in the mornings, the time of day when winter demand will likely be highest.

Electric battery storage is similar to thermal storage, but batteries are more flexible. They can serve any load without using electricity from the grid, and they could be tapped when a building's power demand is high. Batteries were modeled to charge when power demand fell below a building's daily average, then discharged when demand was above average. The batteries had capacity to store 3 hours of a building's peak electric demand, which also adds a layer of resilience to buildings during blackouts.

FIGURE 4

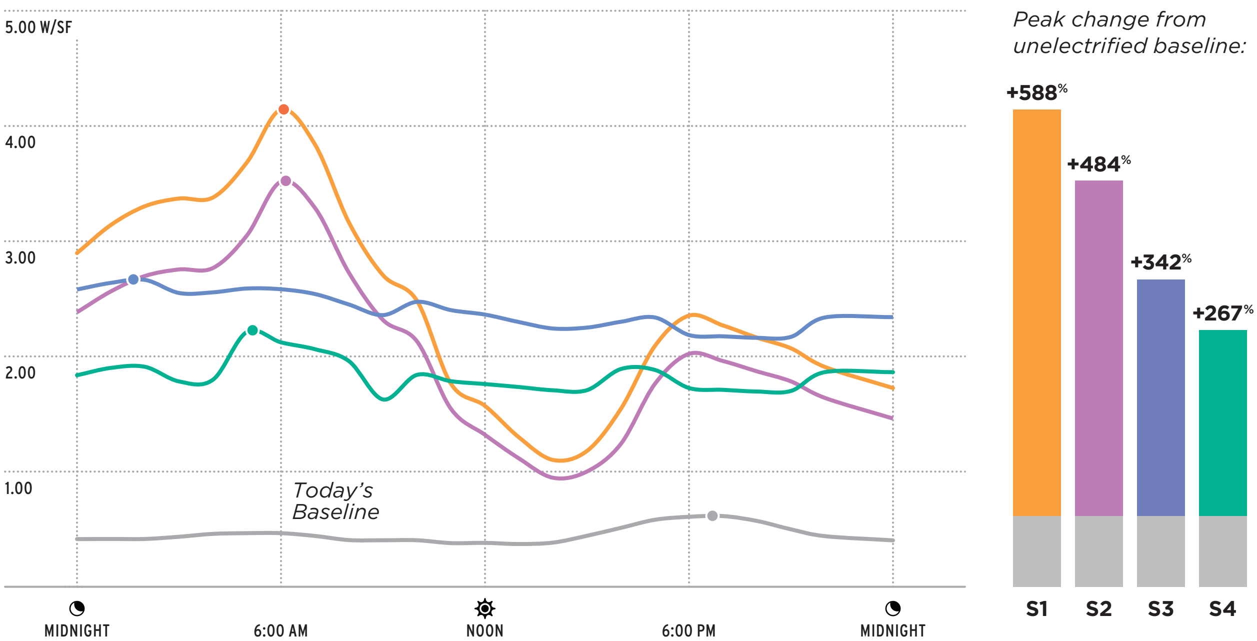
Projected Power Demand: Typical Prewar Low-rise Multifamily Building

Prewar multifamily low-rise buildings use very little electricity today, so their power demands will expand substantially. Efficiency and flexibility measures will be crucial for this type of building and would cut their electrified peak power demand in half.

Data: EnergyPlus 8760 Models: 90th percentile day

S1: ELECTRIFICATION ALONE
S2: EFFICIENT ELECTRIFICATION
S3: FLEXIBLE ELECTRIFICATION
S4: SMART ELECTRIFICATION
NO ELECTRIFICATION

WINTER DAY POWER INTENSITY



SUMMER DAY POWER INTENSITY

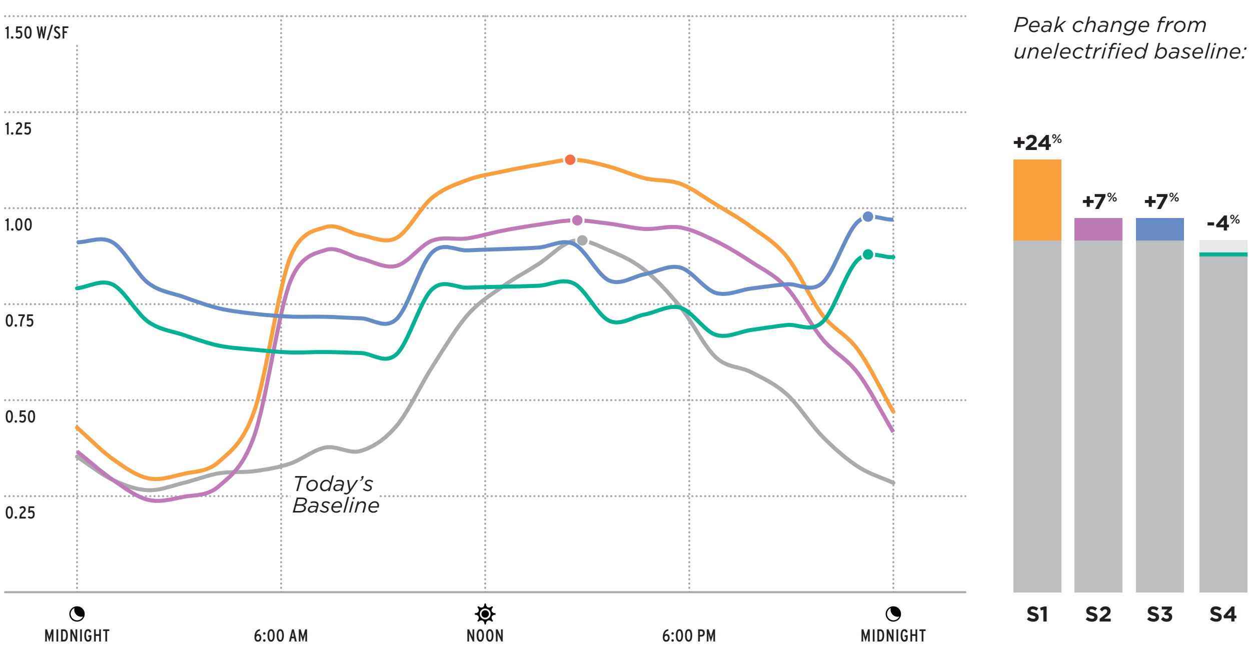
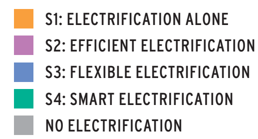


FIGURE 5

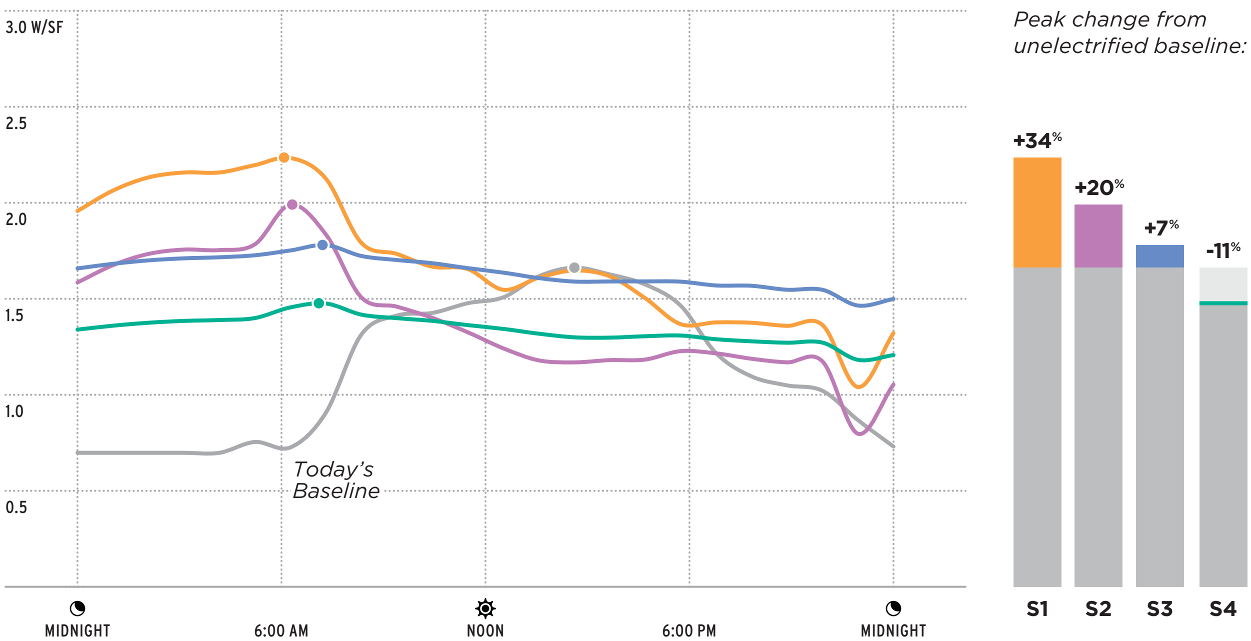
Projected Power Demand: Typical Prewar High-rise Office Building

Prewar office high-rises could nearly flatten their daily power demand curves with heat pumps, efficiency and storage. That leads to lower overall peak demand than today's baseline without electrification. Super-efficient centralized heat pump systems help make this possible.

Data: EnergyPlus 8760 Models: 90th percentile day



WINTER DAY POWER INTENSITY



SUMMER DAY POWER INTENSITY

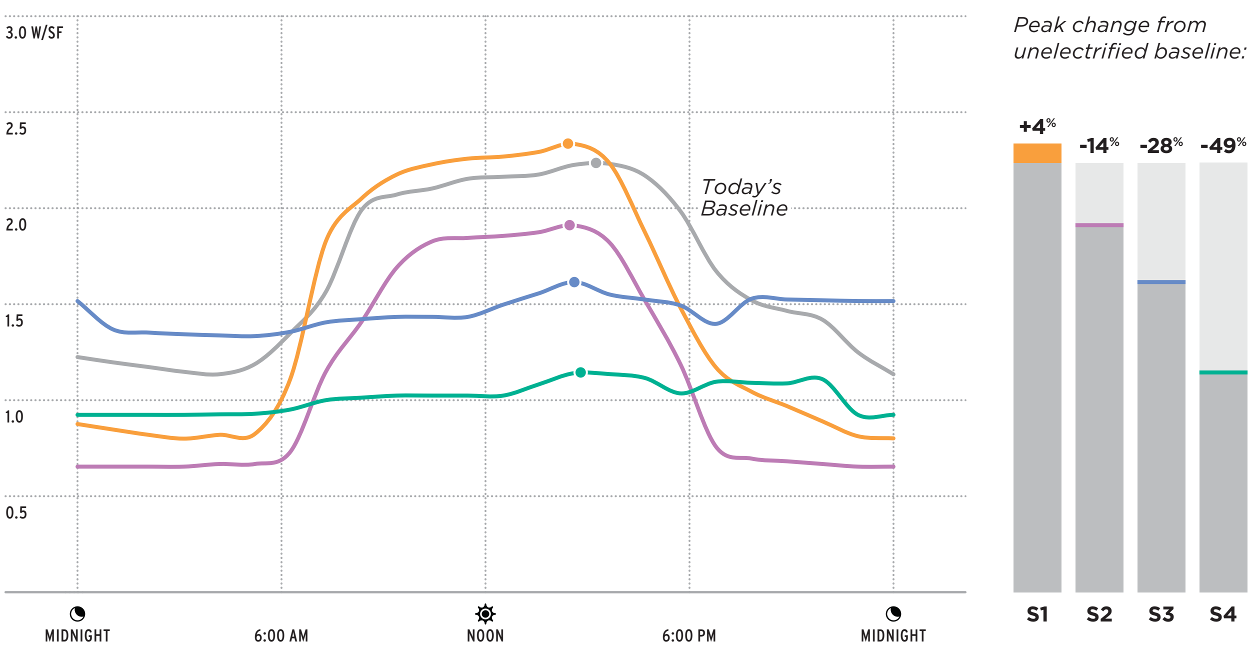


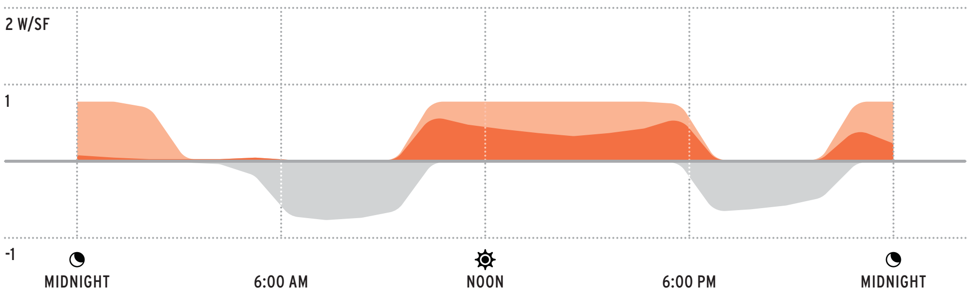
FIGURE 6

Projected Multifamily Building Power End Uses with Smart Electrification (S4)

Digging deeper into smart electrification, here's a look at how multifamily buildings will use electricity and the storage systems that will help lower power demands on winter and summer days.

Data: EnergyPlus 8760 Models: 90th percentile day

POWER INTENSITY: HOT WATER & STORAGE TANK

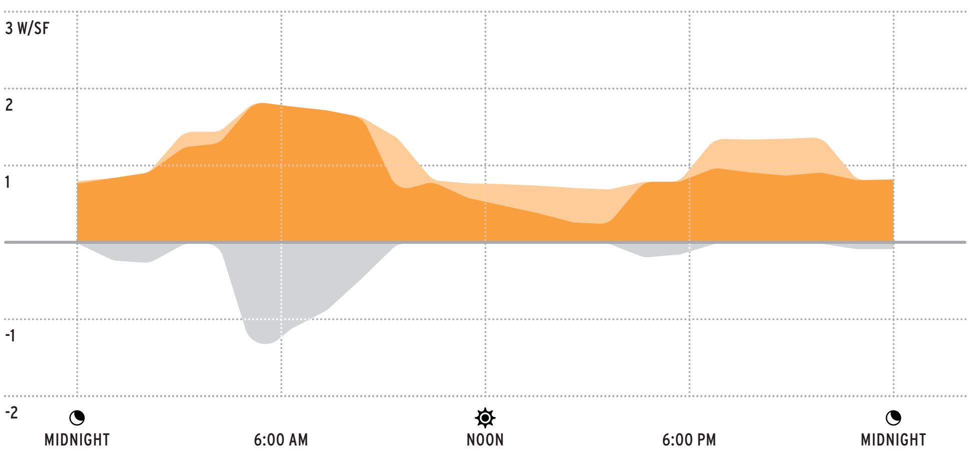


Thermal

Hot water tanks are charged at night and in the afternoon to offset morning and evening demand.

WATER TANK HEATING
HOT WATER DIRECT USE
TANK DISCHARGING

POWER INTENSITY: SPACE HEATING & BATTERY STORAGE

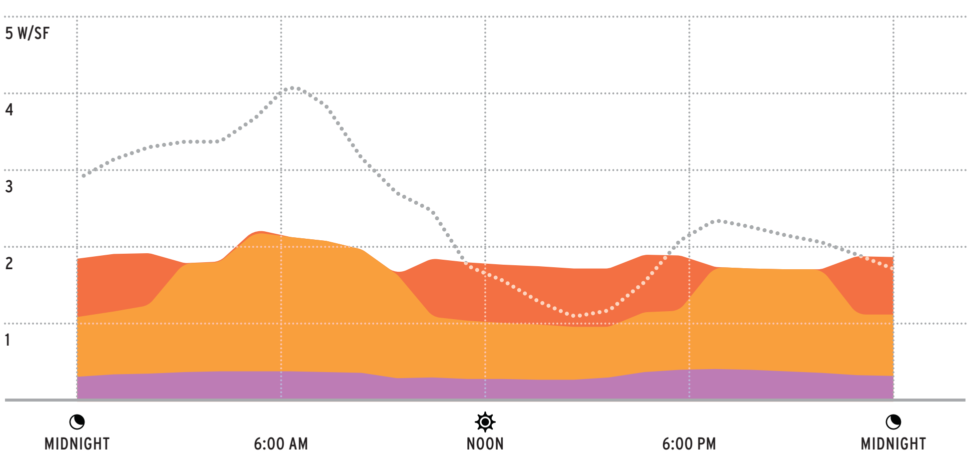


Battery

Batteries charge at opportune times throughout the day and discharge to serve various loads, especially heating on cold mornings.

BATTERY CHARGING
HEAT DIRECT USE
BATTERY DISCHARGING

POWER INTENSITY: TOTAL



Overall

Each use of electricity adds up to hourly power demand—adding efficiency and storage greatly reduces the maximum power that a building pulls from the grid.

NET HOT WATER DEMAND
NET HEAT DEMAND
APPLIANCES, LIGHTING & FANS
NO EFFICIENCY OR STORAGE

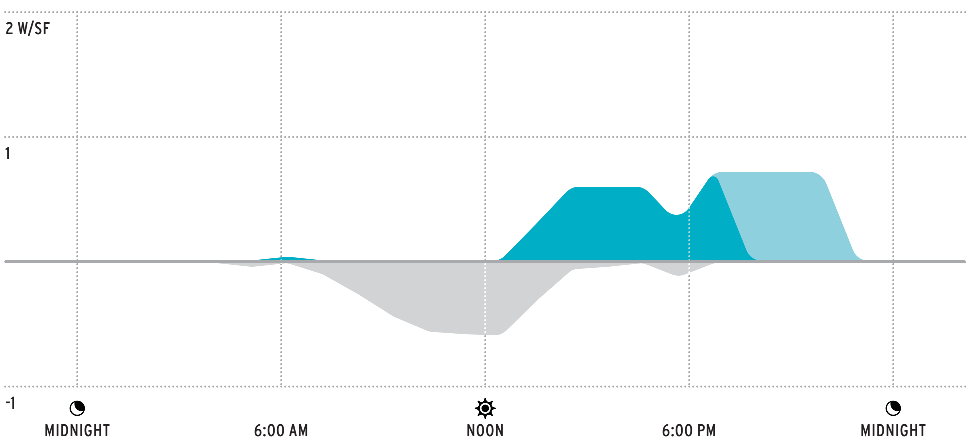
FIGURE 7

Projected Office Building Power End Uses with Smart Electrification (S4)

Demand flexibility has a dramatic effect on office power demand. Power needed for cooling on hot afternoons can be shifted and morning power demands kept in check as heating systems warm up before workers arrive.

Data: EnergyPlus 8760 Models: 90th percentile day

POWER INTENSITY: COOLING & ICE TANK

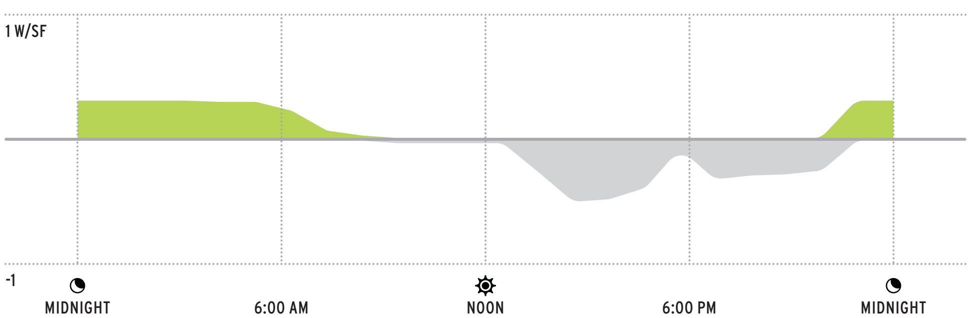


Thermal

These buildings can melt ice for morning cooling then recharge those tanks at night when outdoor temperatures are lower.

TANK MAKING ICE
COOLING DIRECT USE
ICE TANK DISCHARGING

POWER INTENSITY: BATTERY

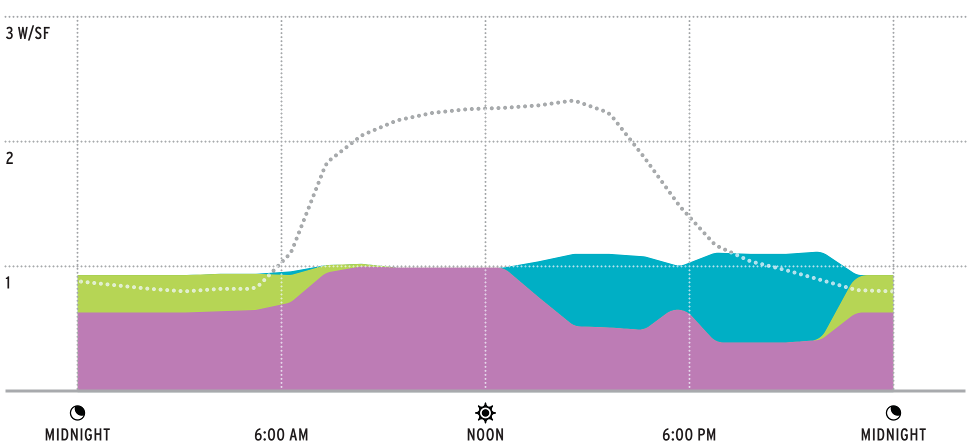


Battery

Batteries charge in the early morning to offset cooling loads in late afternoon, so it's important to shut down equipment when workers go home.

BATTERY CHARGING
BATTERY DISCHARGING

POWER INTENSITY: TOTAL



Overall

Large batteries, over 1 MWh in capacity, will be crucial in flattening out office electricity use.

NET COOLING DEMAND
NET BATTERY DEMAND
APPLIANCES, LIGHTING & FANS
NO EFFICIENCY OR STORAGE

When and Where Will Electrification Take Off?

While our energy models project the hourly demand increases from electrification in each of NYC's most common building typologies, they don't tell us anything about the path or pace electrification will take across the city. It is impossible to know exactly how or when building owners will choose to electrify, but in order to estimate the citywide impact of electrification, we predicted which types of buildings might convert sooner than later. Each of the 27 building typologies was assigned to one of four groups that will likely transition to heat pumps at different rates. There is tremendous uncertainty about how this process will evolve, and equipment replacement cycles will play a big role, but this sequence represents the latest expert opinions on electrification (the full list is shown in Table 3).

Group 1 typologies have the most realistic path to electrify soon, and there may even be economic reasons for them to convert now. Single-family homes and low-rise multifamily buildings are included here because they can install the simplest and least expensive heat pumps. Buildings that use fuel oil for heating, hotels and K–12 schools also are included because electrification offers significant financial, comfort and public health benefits. Group 1 covers 2.48 billion SF, or about 44 percent of the citywide area.

Group 2 typologies may wait to electrify until the cost gap between electricity and gas narrows and new technologies make electrification more attractive. This group includes low-rise offices, high-rise multifamily and mixed-use buildings that use gas-fired heating systems. Group 2 covers 1.55 billion SF, or about 27 percent of the citywide area.

Group 3 typologies will wait to electrify until new technologies and policies make electrification more attractive. Most high-rise offices are included here—many of them currently use district steam, and it will be hard to convince owners to switch. Hospitals and other large institutional buildings that need custom electrification solutions also are included. Group 3 covers 1.16 billion SF, or about 21 percent of the citywide area.

Group 4 typologies probably will be the last buildings to electrify. Modern offices, built after 1980, were included here because they likely have efficient centralized systems already. Other facilities, like manufacturing, may need more technology innovation before they can fully electrify or at least stop burning fossil fuels. Group 4 covers 460 million SF, or about 8 percent of the citywide area.

Per our modeling, Group 1 buildings would start upgrading first and would comprise the early majority of electrified buildings. Subsequent groups would gradually be added to the mix as more building area was transitioned. Once half of the city installed heat pumps, buildings from all four groups would have electrified buildings. Groups 3 and 4 would account for most of the late-stage electrification as the last one-third of NYC's building area upgraded.

So How Much Do Heat Pumps Increase Peak Power?

All this modeling resulted in a unique peak power increase for each typology. Most typologies increased their peak power demand between 1 and 2 W/SF.

Figure 4 shows these changes for prewar low-rise multifamily buildings, and most multi-family properties would have similar changes depending on their current power needs. Overall, multifamily buildings saw the largest proportional increase: Their peak power demand almost tripled. K–12 schools also had a big jump, as their peak demand doubled. Hotel peaks increased by about one-third. Offices, however, saw slightly lower peak power demand due to low heating loads, and efficiency and flexibility upgrades (Table 2).

In the next section, we'll look at how these new power demands impact different areas of the city.

TABLE 2

Peak Power Demand Changes by Building Type with Smart Electrification (S4)

Data: LL84 Benchmarking Data and EnergyPlus 8760 Models

	TYPICAL PEAK POWER IN 2019 (W/SF)	FORECASTED PEAK POWER (W/SF)	POWER INCREASE (W/SF)	PROPORTIONAL POWER INCREASE
Hotel	4.0	5.4	1.44	36%
K–12 School	2.2	4.5	2.32	105%
Multifamily Housing	1.0	2.9	1.91	191%
Office	3.0	2.7	-0.32	-11%

HOW WILL HEAT PUMPS CHANGE OUR CITY?

Electrification will have ripple effects across the boroughs, from reducing air pollution and slowing climate change to making buildings more comfortable.

Using heat pumps for heating, cooling and hot water will eliminate the need for building boilers, furnaces and other appliances that burn fuel, and will subsequently make NYC a more comfortable place to live. The air will be cleaner and healthier for all, and citywide emissions will plummet. On top of that, electrified buildings will transform NYC's grid, as local upgrades make it incrementally more robust and reliable.

Winter power demand has ample room to grow. With over 3,000 MW potentially available citywide, there is more than enough capacity to power heat pumps in all 865,000 one- to four-family homes and every public K–12 school in NYC. But demand will eventually surpass that amount, causing NYC's peak power demand to occur on its coldest day.

We don't know when that switch will actually happen, but heat pump uptake has been slow so far. **Most predictions expect a winter peak in New York State between 2035 and 2040**, so electrification may continue to be gradual, allowing building and infrastructure upgrades to keep pace.[29] Even without extensive modeling, we can determine that building electrification poses no immediate risk to the grid.

That is mainly because today's summer peak, driven by cooling loads, is 42 percent higher than the winter peak. But as discussed in the prior section, heat pumps need more power during winter than summer in New York City. As long as energy efficiency and demand flexibility upgrades keep up, between 40 and 50 percent of citywide building area could install heat pumps before peak power demand consistently occurs in winter (Figure 8). **Therefore, the winter peak shift will not occur until almost half of NYC's heat and hot water has been electrified.**

Our analysis predicts that once all buildings electrify, the NYC grid must be prepared to deliver at least 15 GW of electricity on the coldest day in winter. While that number is slightly more than double the current winter peak, it is just 40 percent higher than the current summer peak. Additionally, it will take years to electrify all of NYC's 1 million buildings. Thus, as a whole, even the grid upgrades needed for full electrification are achievable.[30] While this is certainly good news, these numbers also don't tell the whole story.

From the Outer Boroughs In

Some neighborhoods will electrify faster than others. As discussed in *The Grid*, Con Edison maintains 70 network areas with underground cables, as well as much smaller radial and non-network systems, throughout NYC. The network areas serve more than 80 percent of customers and account for almost 90 percent of electricity delivered, so they are the focus of our analysis. Each network area has overlapping feeders

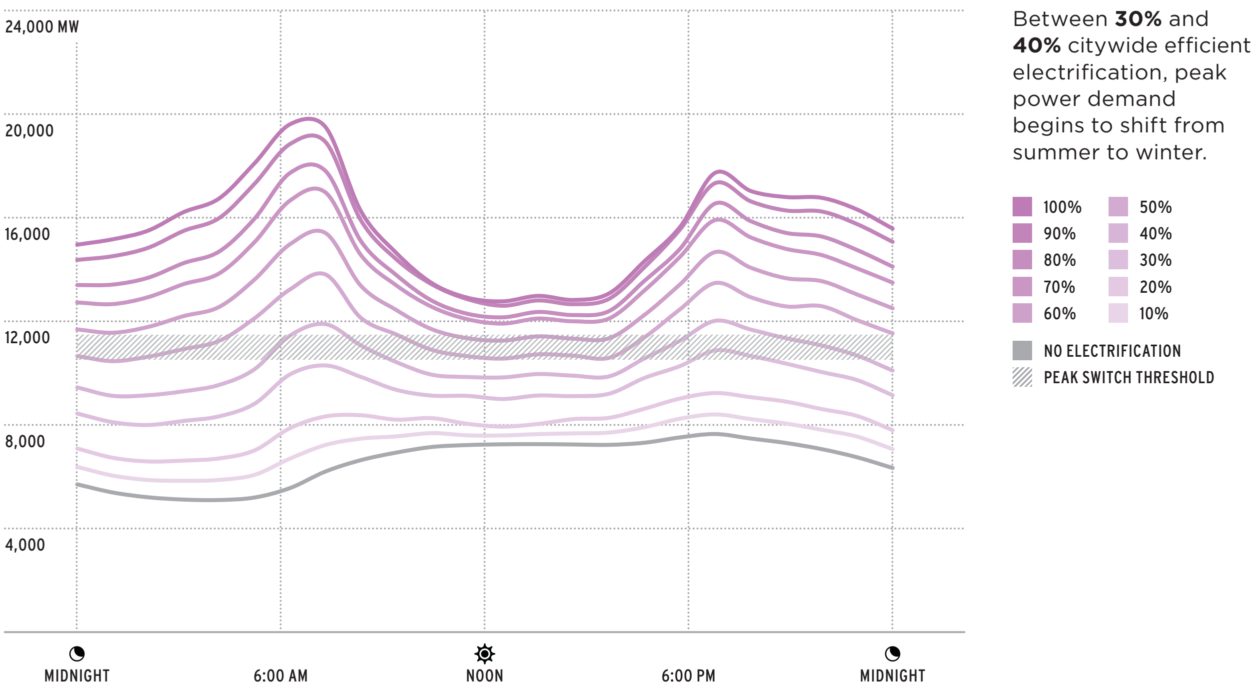
FIGURE 8

Projected Citywide Power Demand by Scenario and Percent Electrification

Winter peak demand rises incrementally as heat pumps are installed across NYC. Early electrification may only integrate energy efficiency upgrades (S2), but smart electrification that includes demand flexibility measures as well (S4) will be required to keep peaks below 16 GW.

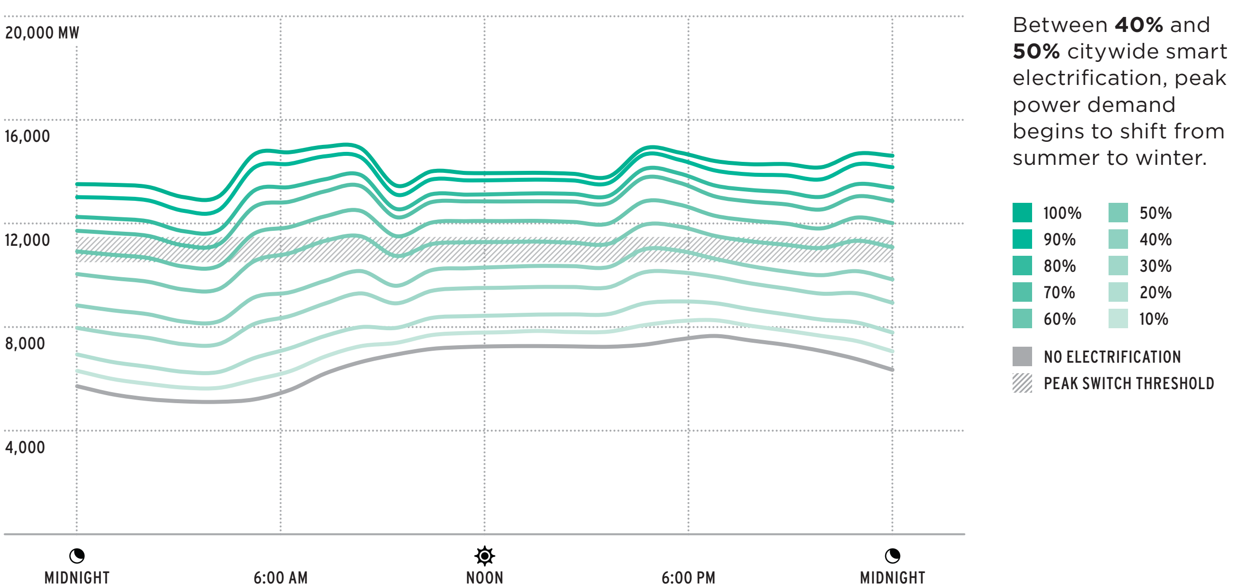
Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019

CITYWIDE WINTER POWER DEMAND
S2: EFFICIENT ELECTRIFICATION



Between **30%** and **40%** citywide efficient electrification, peak power demand begins to shift from summer to winter.

CITYWIDE WINTER POWER DEMAND
S4: SMART ELECTRIFICATION



Between **40%** and **50%** citywide smart electrification, peak power demand begins to shift from summer to winter.

DID YOU KNOW?

Based on national outage data, Con Edison consistently ranks as one of the most reliable utilities in the U.S.[3]

to improve redundancy, so any building that electrifies within the area should be able to tap into the network's full power capacity.[31]

Manhattan network areas have the highest power demands in the five boroughs; they also have high capacities and only cover small areas. Networks like Empire—which covers just 10 blocks around the Empire State Building—mainly serve commercial buildings, which have lower heating and hot water demands. As such, these networks won't flip their peaks from summer to winter until most of their buildings electrify.

In our modeling, we found that power demand grew faster in outer boroughs than in Manhattan. This was due to high heat loads in residential buildings, which can electrify by installing simple and widely available heat pumps. Those buildings also tend to be served by lower-capacity networks. If this trend plays out and heat pumps are installed without smart upgrades to manage demand (as described in Scenario 1), then many Brooklyn and Bronx neighborhoods will soon see winter peaks. In that case, electrifying just 20 percent of the city's building area, or just over 1 billion SF, would mean about 40 zip codes would have winter peaks higher than or equal to their summer peaks (Map 3).

But even as the outer boroughs begin electrifying, the citywide winter peak would still be much lower than today's typical summer peak. Standard upgrades to low-voltage equipment—on the local grid and inside buildings—would be sufficient to meet added demand except for two network areas: Jamaica and Northeast Bronx.[32] And those network upgrades could be delayed if buildings make simple energy efficiency upgrades when they electrify. Those changes would shave off 475 MW from citywide power demands for heating and hot water, and then almost all of the highlighted neighborhoods in Map 3 would remain summer-peaking.

This story played out in our modeling scenarios across all five boroughs. Residential neighborhoods flipped early, as electrification hit 1 billion SF. However, other building upgrades made that demand manageable and were, in fact, critical to keeping building electrification from exceeding capacities. Those measures are included in some of the following scenarios and maps.

It also is worth noting that most network areas have plenty of spare capacity to accommodate winter peaks—all but three could safely tolerate at least 100 MW of additional winter demand without exceeding capacity. **So even at the network level, there is no imminent risk of electrification overwhelming the local grid's capacity.**

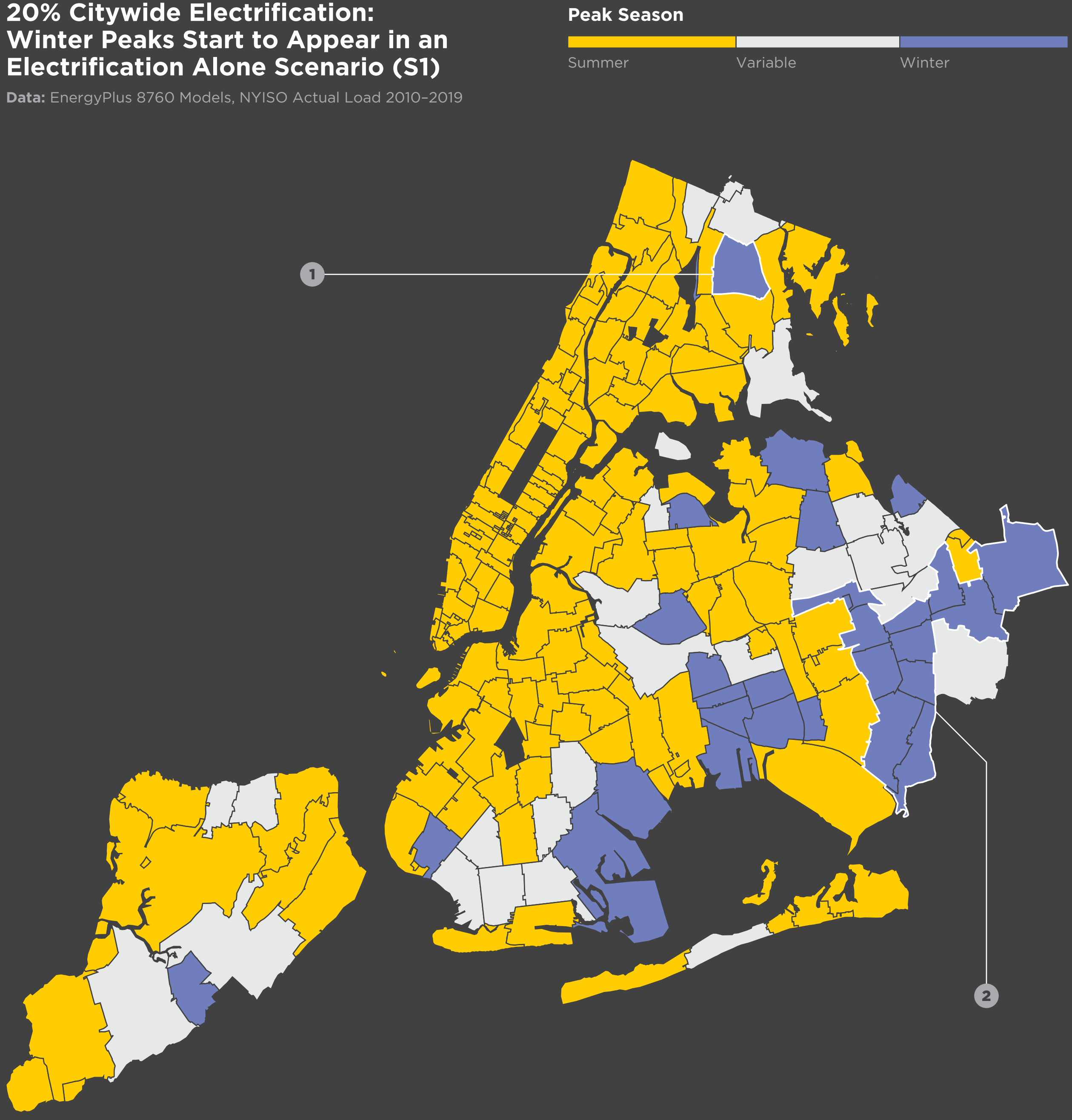
Assisting Low-income Neighborhoods

According to our modeling, power demand would start to exceed capacities once heat pumps cover 2 to 3 billion SF of building area, or over 40 percent of the city total. Network-level capacity constraints would start to affect every borough at this point, but not uniformly. Projected winter peaks would exceed network capacity in certain residential areas such as Jamaica in Queens, Flatbush in Brooklyn and Fordham in the Bronx.

MAP 3

20% Citywide Electrification: Winter Peaks Start to Appear in an Electrification Alone Scenario (S1)

Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019



The grid must be built out to meet peak power demand, so forecasting peak seasons can help plan infrastructure upgrades to support electrification. The timing of each zip code's flip to a winter peak depends on how its buildings electrify. Winter peaks signal that grid operations also need to change.

1. **Northeast Bronx:** About 70 percent of the building area in this large zip code (10469) are one- to four-family homes. Successful heat pump upgrades have been completed on these types of buildings in NYC and could help inform early adopters.

2. **Jamaica:** Zip codes around Jamaica, Queens, develop winter peaks early on in citywide electrification. Almost half of the building area in these zip codes are single-family homes or low-rise multifamily buildings.

MAP 4

40% Citywide Electrification: Even with Efficient Electrification (S2) Major Areas Will Experience a Winter Peak

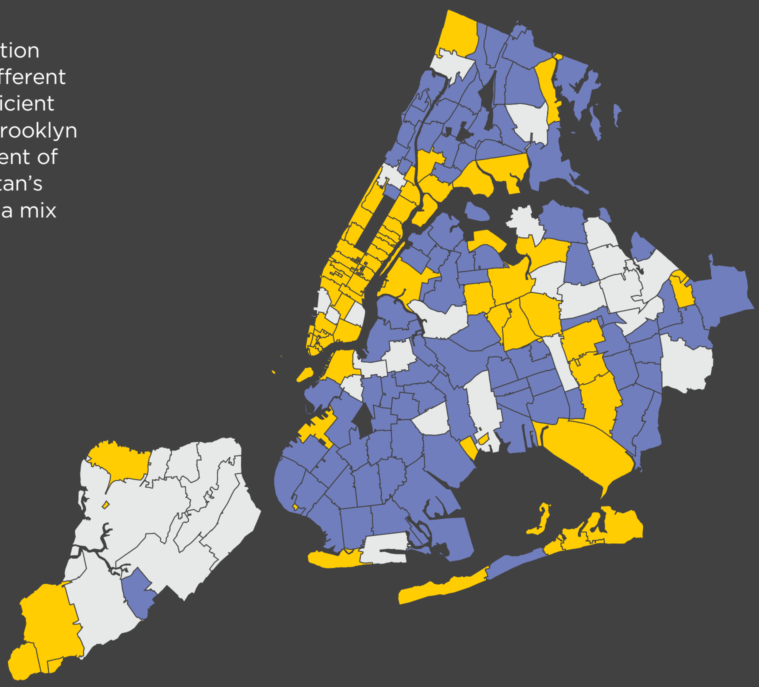
Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019

Peak Season

Summer | Variable | Winter

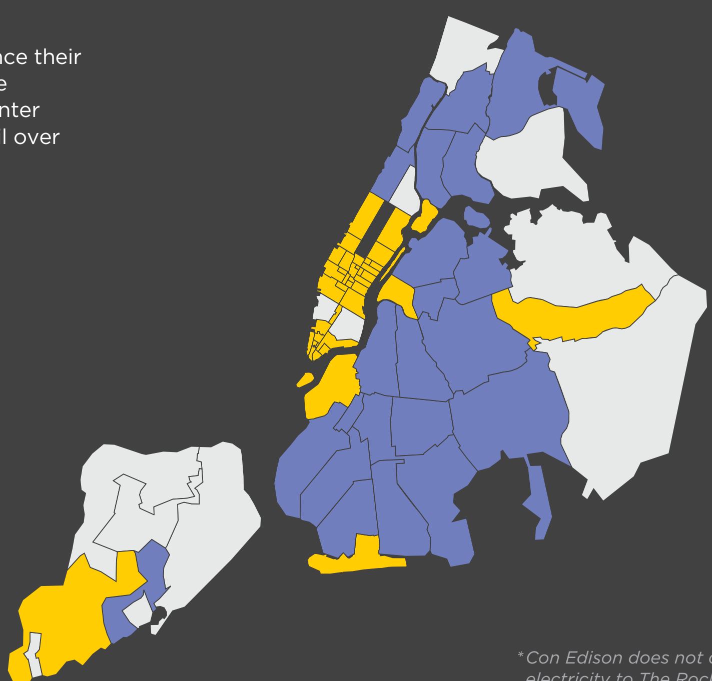
SEASONAL PEAK BY ZIP CODE

Both of these maps have the same electrification conditions, but the results are displayed in different geographies—zip code and network area. Efficient electrification creates winter peaks in most Brooklyn and Bronx zip codes once it reaches 40 percent of citywide building area. Yet areas like Manhattan's Upper West Side still peak in summer due to a mix of residential and commercial buildings.



SEASONAL PEAK BY NETWORK AREA*

Network areas tend to flip to winter peaks once their zip codes flip. But there are exceptions: In the Flushing network, multiple zip codes have winter peaks, but the network area doesn't shift until over half of its building area electrifies.



**Con Edison does not deliver electricity to The Rockaways.*

MAP 5

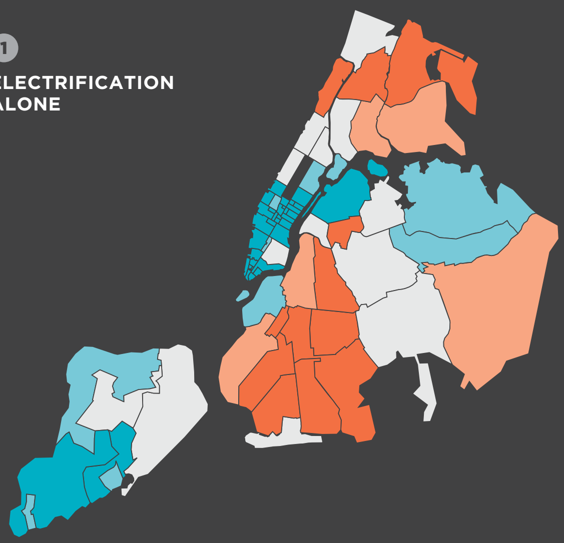
Comparing Scenarios at 40% Citywide Electrification: How We Electrify Matters

Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019

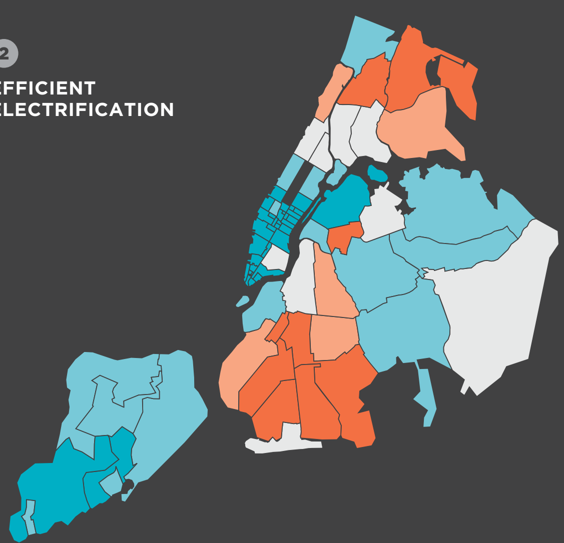
Capacity for Electrification

Room to Grow | At Limit | Constrained

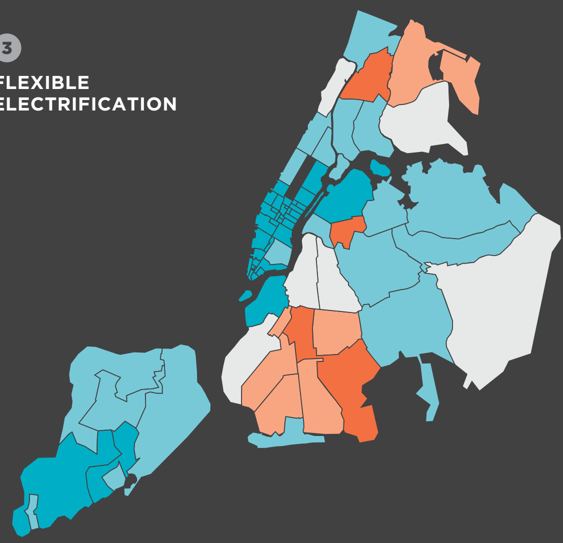
1 ELECTRIFICATION ALONE



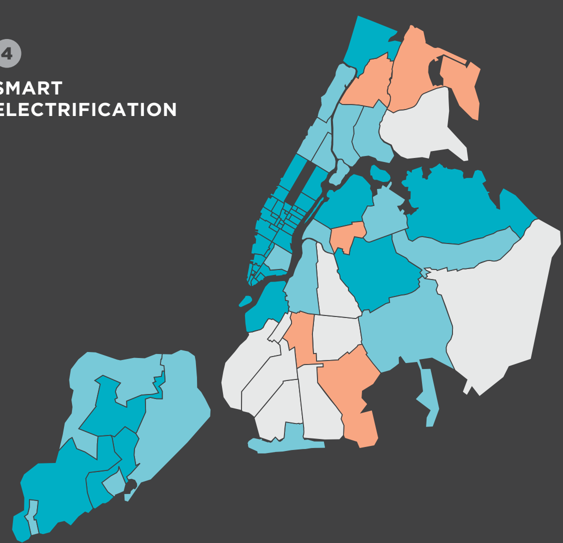
2 EFFICIENT ELECTRIFICATION



3 FLEXIBLE ELECTRIFICATION



4 SMART ELECTRIFICATION



1 **Electrification Alone:** Electrifying 40 percent of the city without any efficiency or flexibility upgrades leads to demand exceeding capacity throughout Brooklyn and the Bronx.

2 **Efficient Electrification:** Pairing affordable energy-efficiency upgrades with heat pumps reduces power demand in each network area. Capacity upgrades are probably still needed to meet peak demand in network areas of southern Brooklyn and the northern Bronx.

3 **Flexible Electrification:** Demand flexibility measures were more effective at reducing peak demand than energy efficiency measures. These measures could delay major capacity upgrades in the Central Bronx network area.

4 **Smart Electrification:** Smart Electrification that includes energy efficiency and demand flexibility measures allows for this level of electrification with potential upgrades needed in the Flatbush, Sunnyside, Fordham and Northeast Bronx networks.

MAP 6

90% Citywide Electrification: Almost Every Network Will Need to be Upgraded

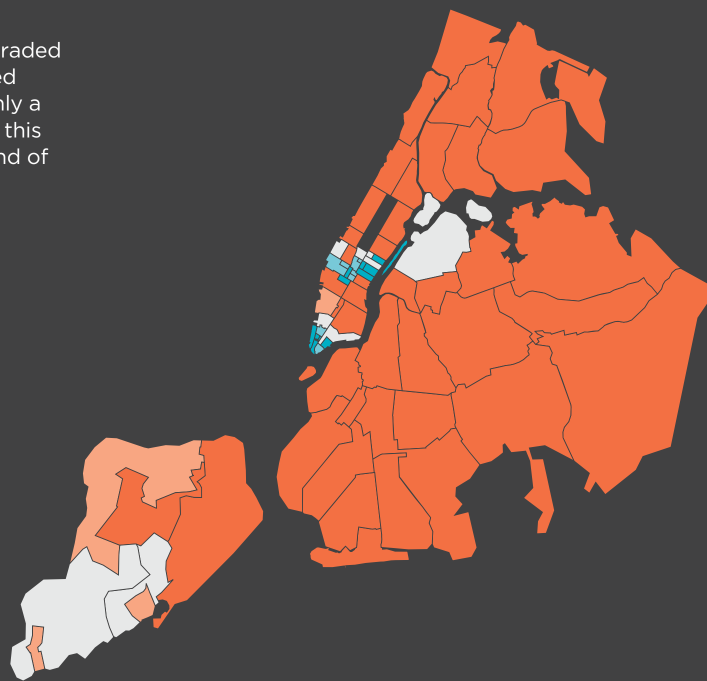
Data: EnergyPlus 8760 Models, NYISO Actual Load 2010–2019

Capacity for Electrification

Room to Grow — At Limit — Constrained

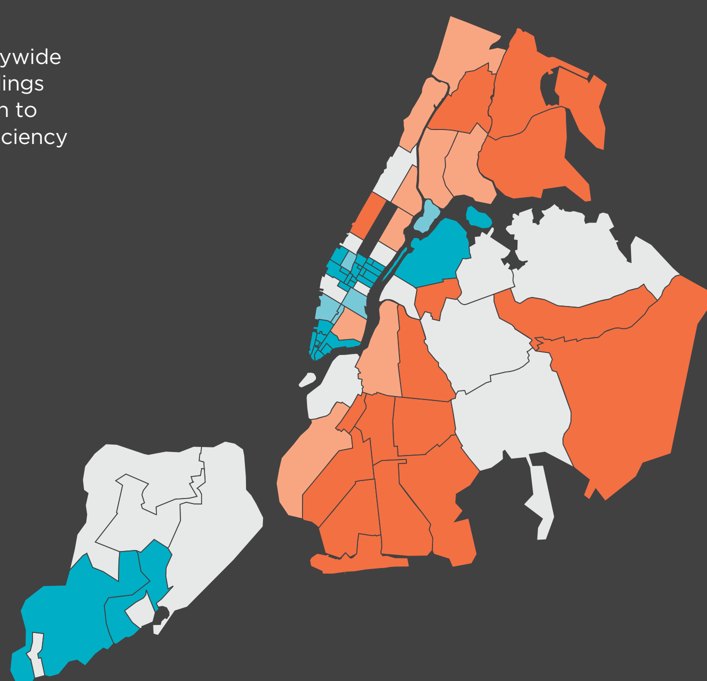
SCENARIO 1: ELECTRIFICATION ALONE

Almost every network would need to be upgraded if 90 percent of NYC's building area electrified without any demand-reduction measures. Only a handful of Manhattan networks could handle this scenario, which led to a citywide peak demand of more than 22 GW.



SCENARIO 4: SMART ELECTRIFICATION

Smart electrification leads to manageable citywide peak demand even when 90 percent of buildings electrify. This scenario also allows Con Edison to focus on upgrading network areas where efficiency and flexibility may have lagged.



Network areas in central Brooklyn and the Bronx would reach their current capacities first, mainly because they supply power to many low-rise residential buildings. More so than the rest of the city, many of these neighborhoods are home to low- and moderate-income New Yorkers. These residents already are cost-burdened, so it is fundamental that electrification not increase their utility costs.[33] But it is unclear how to pay for the upgrades and higher heating costs, especially when many rent-regulated building owners already struggle with thin margins and deferred maintenance.

Targeted support and regulatory improvements will be necessary to spur equitable heat pump retrofits in this large and important sector, and funding will be needed to offset installation costs for owners and energy costs for tenants. Low-income residents could benefit most from the expanded cooling and reliable heat that come with electrification, so gaining community support and tracking the progress and impact of these building upgrades is important. In addition, heat pump installations create job opportunities; residents should be made aware of these opportunities as well as the health benefits of cleaner air and quiet cooling and heating. Campaigns like Better Buildings NY will be crucial in this effort.

Once electrification becomes more prevalent, the city will need to track heat pump installations to predict and prepare for winter peaks. Con Edison may be able to help locate customers who use heat pumps based on their seasonal electricity use patterns. That information will help city planners and policymakers address the needs of winter peaking communities and ensure that network upgrades and other power-saving solutions keep pace with demand in low-income neighborhoods.

Tomorrow's Winter Peak

Per our analysis, once electrification reaches 40 to 50 percent of NYC's building area, citywide peak power will consistently occur in winter. The shift happened in that range for each of the scenarios—electrification alone, efficient electrification, flexible electrification and smart electrification. Once 90 percent electrification is reached, peak power demand could exceed 15 GW (Figure 8), depending on how much efficiency and flexibility gets implemented. The time of day when peaks occur also will shift from evening to morning.

At that point, about half of the city's network areas will have met or exceeded their capacity. However, some Manhattan network areas would still have spare capacity, especially the smaller networks with fewer multifamily buildings around Midtown and the Financial District. Again, it is unclear when NYC will reach this point, but it's likely decades away. The city's recent report, Pathways to Carbon-Neutral NYC, projected that about 60 percent of buildings will be electrified by 2050.[34] We hope building electrification can go farther and faster than that.

Ninety percent electrification means heat pumps would serve almost 5 billion SF. More populated areas would need changes and upgrades to their substations and networks to accommodate increased demand. These results are all highly dependent on the efficiency, flexibility and storage measures detailed in the last section, which cut about 30 percent, or over 7,000 MW, from the citywide peak power demand.

Without these efficiency and flexibility upgrades, winter peak demand could exceed 22 GW once all buildings are electrified. Energy efficiency alone could bring that down below 20 GW, but even that would be a much heavier lift for the local grid, stressing power generation and transmission flowing into New York City. Incentives and policies should be designed to ensure every heat pump installation comes with assistance for building electrical service upgrades, basic energy efficiency upgrades, like air-sealing and roof insulation, as well as smart controls and energy storage that allow buildings to shift their power use to hours with less demand.

An All-Electric Future

It is clear that heat pumps will benefit every NYC resident by increasing occupant comfort while reducing air pollution and greenhouse gas emissions. Together, these improvements have huge health and safety benefits—not the least of which are slowing climate change and making buildings more resilient in the face of extreme weather events.

Once they electrify heat and hot water, residential and commercial buildings would eventually cut over 21 million tonnes of carbon dioxide from citywide emissions, and smart electrification would add 14 billion kilowatt-hours of electricity use annually. New generation needs to be built to supply that power, but it will open the door to zero-carbon buildings—assuming a completely renewable grid by 2040.

It will take years to electrify the heat and hot water systems of every building in NYC. Despite this, we need to start planning today—not just for heat pumps but also for a future where almost everything runs on electricity. This fully electric future will require a major transformation of our grid infrastructure. Building efficiency and flexibility measures will help, but we will need utility-scale solutions to ensure reliable power for NYC. Expanding the capacity of major network areas in every borough to accommodate a fully electrified city will require significant investment and long-term planning by policymakers and utilities. The clock is ticking. It's time to act.

APPENDIX

ANALYSIS METHODOLOGY

This report's power demand predictions came from a multitiered analysis. Engineers created a series of energy models, calibrated them against measured data, then electrified heat and hot water loads and aggregated the results citywide. Citywide power demands were then compared against capacities from Con Edison's public data for network areas (www.coned.com/en/business-partners/hosting-capacity).

We created 27 different detailed energy models to predict the current hourly electricity and gas use of NYC buildings. These hourly demands were summed for each month and then compared to actual benchmarked energy use for all of the typologies listed in Table 3 except one- to four-family homes (Small Residential). Energy-use data for one- to four-family homes came from NYSERDA's 2019 Residential Building Stock Assessment (RBSA) (www.nyserda.ny.gov/About/Publications/Building-Stock-and-Potential-Studies/Residential-Building-Stock-Assessment). Our model was broken down into monthly electricity and gas data following the trends from the single-family detached house prototype energy models developed by the U.S. Department of Energy (www.energycodes.gov/prototype-building-models#Residential).

Next, the energy models, built in EnergyPlus 9.1.0 to show all 8,760 hours of the year, were calibrated to roughly match the monthly bench-marked use. The initial models were based on geometry, floor area, occupant density, thermostat setpoints, and schedules from the DOE reference building models for each typology. These were calibrated to match measured energy use by changing lighting power densities, plug load densities, envelope properties, infiltration rates and system efficiencies. Each calibrated building model was then copied with identical schedules to create electrified energy models that use heat pumps to deliver all heating, cooling and hot water.

Heat pumps were assumed to have maximum heating COPs of 3.4; split systems and semi-central VRF systems had an average heating season COP of 2.0. This estimate is conservative, since experimental research shows heating COPs can be higher, even in climates colder than New York. Cooling COPs averaged between 2.7 and 3.0. Air-to-water heat pump, chiller and cooling tower systems had average COPs of 3.1 for heating and 6 for cooling.

Two energy profiles, existing and electrified, were created for each typology. Electrified hourly profiles for a typical winter and summer day were derived from the 90th-percentile load at that hour from all days in a month. Profiles were assigned to each building across NYC, based on its building class in the Department of Planning's PLUTO database (www1.nyc.gov/site/planning/data-maps/open-data/dwn-pluto-mappluto.page). The future electrification power demands were modified depending on one of four modeled scenarios.

Baseline: Buildings use electricity for cooling, lighting and equipment, and gas is used for heating, hot water and cooking to match current use patterns.

Scenario 1: Buildings electrify their heating and hot water with heat pumps, but no other upgrades are made.

Scenario 2: Buildings electrify and make *only* energy efficiency upgrades like LED lights and roof insulation.

Scenario 3: Buildings electrify and *only* install demand flexibility controls, batteries and large water tanks for thermal storage.

Scenario 4: Buildings electrify, make energy-efficiency upgrades, *and* install demand flexibility controls and storage.

Each building's hourly power demands were then summed within geographic boundaries. The 90th-percentile demand was chosen to represent maximum possible demand—it was assumed that on extremely cold days, indoor temperatures would be lower than normal. This analysis summed loads by postal zip code and by Con Edison network area across NYC. Results were tallied in increments of 10 percent of city-wide building area. Building electrification was sequenced based on the order described on page 28 until all potential building area was electrified. Full results can be found at Urban Green's online map: maps.urbangreencouncil.org

TABLE 3

Electrification Model: Building Typologies and Systems

Data: PLUTO, LL87 audits and EnergyPlus 8760 model—annual heating COPs averaged between 2.0 (split) and 3.1 (air-to-water), annual cooling COPs averaged between 2.7 (split) and 6.1 (chiller)

Group	Description	Typology building count	Typology area (MILLIONS OF SF)	Typical existing heating system	Typical existing cooling system	Electrified heating and cooling system
1	Prewar and Postwar Small Residential	762,100	983.6	Gas boiler, steam 1-pipe	Window Air Conditioner	Split air-source heat pump
1	Modern Small Residential	99,900	214.7	Gas furnace	Split DX	Split air-source heat pump
1	Prewar Low-rise Multifamily	58,800	799.9	Gas boiler, steam 1-pipe	Window Air Conditioner	Split air-source heat pump
1	Modern Low-rise Multifamily	14,200	136.8	Gas boiler, hydronic	Through Wall Air Conditioner	Split air-source heat pump
1	Prewar Low-rise Office	4,200	62.8	Gas boiler, steam 1-pipe	Packaged Rooftop Units Air Cooled	Split air-source heat pump
1	Hotel	2,100	105.2	Gas boiler, hydronic	Chiller - Compression Water Cooled	Air-to-water heat pump and chiller
1	K-12 School	3,300	177.7	Gas boiler, steam 2-pipe	Window Air Conditioner	Split air-source heat pump
1	Restaurant (stand-alone)	600	2.0	Gas furnace	Packaged DX	Semi-central VRF air-source heat pump
2	Postwar Low-rise Multifamily	20,000	316.9	Gas boiler, steam 1-pipe	Window Air Conditioner	Semi-central VRF air-source heat pump
2	Modern High-rise Multifamily	1,700	192.9	Gas boiler, hydronic	PTAC Air Cooled	Split air-source heat pump

Group	Description	Typology building count	Typology area (MILLIONS OF SF)	Typical existing heating system	Typical existing cooling system	Electrified heating and cooling system
2	Postwar Low-rise Office	1,700	29	Gas furnace	Packaged Rooftop Units Air Cooled	Semi-central VRF air-source heat pump
2	Modern Low-rise Office	1,200	22.6	Gas boiler, hydronic	Packaged Rooftop Units Air Cooled	Semi-central VRF air-source heat pump
2	Mixed Residential and Commercial	26,200	790	Gas boiler, hydronic	DX Units Air Cooled	Semi-central VRF air-source heat pump
2	Retail (stand-alone)	1,700	196.5	Gas boiler, steam 2-pipe	Window Air Conditioner	Semi-central VRF air-source heat pump
3	Prewar High-rise Multifamily	3,400	167.1	Gas boiler, steam 2-pipe	Window Air Conditioner	Split air-source heat pump
3	Postwar High-rise Multifamily	1,100	434.5	Gas boiler, steam 2-pipe	DX Units Air Cooled	Split air-source heat pump
3	Prewar High-rise Office	200	198.2	Gas boiler, steam 1-pipe	Packaged DX	Semi-central VRF air-source heat pump
3	Postwar High-rise Office	43,700	126.4	Gas boiler, steam 1-pipe	Chiller - Compression Water Cooled	Air-to-water heat pump and chiller
3	Healthcare	1,900	109.4	Gas boiler, hydronic	Chiller - Absorption Water Cooled	Air-to-water heat pump and chiller
3	Institutional / Public Assembly	4,600	60.2	Gas boiler, steam 2-pipe	Window Air Conditioner	Split air-source heat pump
3	University	1,300	66.3	Gas boiler, hydronic	Chiller - Compression Water Cooled	Air-to-water heat pump and chiller
4	Modern High-rise Office	200	134.9	Gas boiler, hydronic	Chiller - Compression Water Cooled	Air-to-water heat pump and chiller
4	Warehouse	7,700	140.3	Gas boiler, steam 2-pipe	Packaged Rooftop Units Air Cooled	Semi-central VRF air-source heat pump
4	Industrial	4,600	60.2	Gas boiler, steam 2-pipe	Packaged Rooftop Units Air Cooled	Semi-central VRF air-source heat pump
4	Parking	6,000	31.4	Gas furnace	NA	Semi-central VRF air-source heat pump
4	Transportation / Utility / Other	3,200	55.4	Gas boiler, steam 2-pipe	Packaged Rooftop Units Air Cooled	Semi-central VRF air-source heat pump
4	Open Space / Vacant	7,200	41.1	NA	NA	NA

TABLE 4

Electrification Model: Efficiency and Flexibility Measures

Data: Energy code and EnergyPlus 8760 model

Measure	Type	Applied in these scenarios	Applied to these typologies	Description
Air Sealing	Energy Efficiency	S2, S4	All typologies	A 20% reduction in infiltration rate from baseline which reduces a building's heating and cooling loads
Roof Insulation	Energy Efficiency	S2, S4	All typologies	Roof R-value increased to 33 F ft^2-hr/Btu to cut heating and cooling loads, equivalent to 10 inches of blown-in cellulose
Window Upgrades	Energy Efficiency	S2, S4	All typologies	Window U-value decreased to 0.4 Btu/hr-ft^2 F, equivalent to low-E, double-pane and gas-filled window
Lighting Upgrades	Energy Efficiency	S2, S4	All typologies	Lighting power densities reduced by 30% in all building typologies, equivalent to full LED upgrade with some controls
EnergyStar Appliances and Plug Load Controls	Energy Efficiency	S2, S4	All typologies with varying parameters	Residential plug load densities reduced 15%, and all other typologies cut by 20%. Power reduced another 10% when unoccupied in all typologies.
Temperature Setbacks	Energy Efficiency	S2, S4	All typologies	Cooling setpoints increased 5 F and heating setpoints decreased 5 F when unoccupied.
Economizer and Energy Recovery Ventilation (ERV)	Energy Efficiency	S2, S4	Offices, Industrial, Hotels, Healthcare, Retail, Universities and Transportation	Economizer, Supply Air Temperature Reset at 60 F, Energy Recovery (ERV) Effectiveness 70%
Demand Control Ventilation (DCV)	Energy Efficiency	S2, S4	All Offices and Universities	Ventilation was reduced when a building had low occupancy.
Battery Storage	Demand Flexibility	S3, S4	All typologies larger than 2,500 SF	Batteries sized to meet peak demand for 3 hours, and they typically ran heat pumps. Batteries charge during times of low grid demand and discharge when demand is high.
DHW Storage Tanks	Demand Flexibility	S3, S4	All Residential typologies	Tank capacity sized to meet DHW demand for 4 hours. Shifts power use from morning to the overnight hours when demand is lower.
Ice Storage for cooling	Demand Flexibility	S3, S4	All High-rise Offices	Capacity of tank is equal to a building's peak hourly cooling demand multiplied by 4 hours. Ice melts to meet high cooling loads on hot summer afternoons, then it is replenished overnight.
Phase Change Materials on interior surfaces	Demand Flexibility	S3, S4	All typologies	One inch thick BioPCM layers were modeled. Phase change materials (PCMs) can absorb thermal energy and gradually release it to reduce demand on HVAC equipment during peak times.
Pre-conditioning	Demand Flexibility	S3, S4	All Offices, Universities and Schools	Heating and cooling systems turned on before occupancy to reach setpoint before high demand period
Appliance Load Shifting	Demand Flexibility	S3, S4	All Residential typologies	Up to 20 percent of EPD is shifted from peak plug load hours to nighttime.

TABLE 5

Electrification Model: New York City Network Areas

Data: Con Edison Hosting Capacity:
www.coned.com/en/business-partners/hosting-capacity

Network Type Notes
a: *Single Zone - known capacity*
b: *Double Zone - capacity split proportionally*
c: *Double Zone - capacity assumed 10% over peak*

	Current Capacity (MW)	Measured Winter Peak (MW)	Measured Summer Peak (MW)	S4 100% Power Increase Over Current Summer Peak	Total Building Area (MILLIONS OF SF)	Proportion Residential/ Commercial & Institutional
BROOKLYN						
Bay Ridge Mesh and Radial[c]	271	145	240	31%	140.1	62% / 38%
Borough Hall Mesh and Radial[a]	382	196	325	18%	142.3	59% / 41%
Brighton Beach Mesh and Radial[b]	116	66	102	47%	65.7	83% / 17%
Crown Heights Mesh[b]	252	133	207	50%	134.8	78% / 22%
Flatbush Mesh and Radial[b]	300	163	272	49%	194.5	80% / 20%
Ocean Parkway Mesh and Radial[c]	180	90	172	49%	101.8	83% / 17%
Park Slope Mesh and Radial[c]	234	108	218	50%	133.7	83% / 17%
Prospect Park Mesh[c]	75	37	66	51%	35.6	86% / 14%
Ridgewood Mesh[b]	269	139	214	45%	137.7	73% / 27%
Sheepshead Bay Mesh and Radial[c]	173	88	163	54%	110.2	85% / 15%
Williamsburg Mesh[c]	380	192	316	40%	167.7	74% / 26%
BRONX						
Central Bronx Mesh[a]	247	121	192	51%	102.4	69% / 31%
Fordham Mesh[a]	266	160	257	58%	154.9	77% / 23%
Northeast Bronx Mesh and Radial[a]	169	73	107	44%	131.0	79% / 21%
Riverdale Mesh[b]	130	59	96	53%	60.9	82% / 18%
Southeast Bronx Mesh[a]	234	125	206	43%	128.7	77% / 23%
West Bronx Mesh[b]	299	133	229	48%	125.8	66% / 34%
MANHATTAN						
Battery Park City Mesh[b]	122	48	65	-4%	21.8	46% / 54%
Beekman Mesh[a]	228	78	110	-5%	37.1	41% / 59%
Bowling Green Mesh[b]	147	74	87	-15%	32.9	30% / 70%
Canal Mesh[b]	165	75	107	7%	32.8	55% / 45%

	Current Capacity (MW)	Measured Winter Peak (MW)	Measured Summer Peak (MW)	S4 100% Power Increase Over Current Summer Peak	Total Building Area (MILLIONS OF SF)	Proportion Residential/ Commercial & Institutional
Central Park Mesh[a]	251	130	203	52%	119.2	89% / 11%
Chelsea Mesh[a]	249	140	217	7%	82.5	53% / 47%
City Hall Mesh[a]	192	89	156	0%	56.1	41% / 59%
Columbus Circle Mesh[b]	156	89	130	9%	50.8	52% / 48%
Cooper Square Mesh[a]	261	149	232	33%	92.6	71% / 29%
Cortlandt Mesh[b]	115	43	57	-9%	16.6	29% / 71%
Empire Mesh[b]	76	36	55	-14%	16.5	26% / 74%
Fashion Mesh[b]	110	39	70	-9%	20.2	21% / 79%
Freedom Mesh[b]	60	16	33	-33%	8.9	– / 100%
Fulton Mesh[a]	212	66	96	-2%	25.2	43% / 57%
Grand Central Mesh[a]	242	116	175	-15%	42.2	27% / 73%
Greeley Square Mesh[c]	66	33	56	-15%	11.5	24% / 76%
Greenwich Mesh[b]	56	30	51	7%	22.0	49% / 51%
Harlem Mesh[a]	280	126	196	35%	118.4	66% / 34%
Herald Square Mesh[a]	179	66	100	-23%	23.2	11% / 89%
Hudson Mesh[b]	88	38	62	15%	21.6	55% / 45%
Hunter Mesh[b]	80	49	68	-12%	18.7	35% / 65%
Kips Bay Mesh and Radial[c]	116	68	105	18%	34.2	68% / 32%
Lenox Hill Mesh and Radial[a]	284	159	245	31%	91.2	75% / 25%
Lincoln Square Mesh[b]	184	90	154	30%	58.2	80% / 20%
Madison Square Mesh[a]	270	139	232	11%	86.7	55% / 45%
Midtown West Mesh[b]	100	56	81	-13%	15.7	19% / 81%
Park Place Mesh[b]	121	56	81	-1%	20.8	54% / 46%
Pennsylvania Mesh[a]	263	112	180	-8%	53.4	31% / 69%
Plaza Mesh[a]	162	93	139	-7%	47.8	34% / 66%
Randalls Island Mesh[b]	24	19	19	-12%	2.1	– / 100%

	Current Capacity (MW)	Measured Winter Peak (MW)	Measured Summer Peak (MW)	S4 100% Power Increase Over Current Summer Peak	Total Building Area (MILLIONS OF SF)	Proportion Residential/ Commercial & Institutional
Rockefeller Center Mesh[b]	81	56	67	-19%	7.6	28% / 72%
Roosevelt Mesh[b]	257	61	76	27%	27.9	79% / 21%
Sheridan Square Mesh[b]	219	92	154	23%	54.2	64% / 36%
Sutton Mesh[b]	172	88	133	-6%	45.0	41% / 59%
Times Square Mesh[b]	183	93	128	-19%	42.3	19% / 81%
Triboro Mesh[a]	174	92	146	44%	72.5	74% / 26%
Turtle Bay Mesh[c]	122	76	101	-25%	18.0	9% / 91%
Washington Heights Mesh[b]	254	105	185	59%	93.8	74% / 26%
Yorkville Mesh[a]	340	183	298	48%	135.5	86% / 14%
QUEENS						
Borden Mesh[b]	162	115	161	7%	49.1	43% / 57%
Flushing Mesh and Radial[a]	511	219	371	37%	205.1	78% / 22%
Jackson Heights Mesh[b]	227	97	181	43%	93.2	79% / 21%
Jamaica Mesh and Radial[a]	492	310	461	32%	255.8	71% / 29%
Long Island City Mesh[a]	493	146	224	38%	119.5	68% / 32%
Maspeth Mesh and Radial[a]	390	142	255	41%	167.4	73% / 27%
Rego Park Mesh[b]	235	114	219	44%	127.7	80% / 20%
Richmond Hill Mesh and Radial[a]	501	199	325	39%	200.0	76% / 24%
Sunnyside Mesh[b]	82	62	81	51%	40.0	72% / 28%
STATEN ISLAND						
Fox Hills Non-network[a]	236	114	210	34%	100.9	77% / 23%
Fresh Kills Non-network[a]	212	113	170	22%	68.6	66% / 34%
Wainwright Non-network[a]	96	33	83	39%	24.0	92% / 8%
Willowbrook Non-network[a]	87	34	75	31%	39.0	78% / 22%
Woodrow Non-network[a]	172	41	115	31%	61.1	83% / 17%

GLOSSARY

Electrical Infrastructure Terms

Area substations: Local facilities that reduce the voltage of electricity supplied by transmission lines. These facilities contain many pieces of equipment—such as transformers, switches and circuit breakers—all of which either protect the network or step down power. Voltages are reduced from over 69,000 volts to 27,000 volts for Brooklyn and Queens, or 13,000 volts for Manhattan, the Bronx and most of the rest of Con Edison's territory. Power is then distributed to network areas through high-voltage feeders.

Behind-the-meter: Power equipment located inside the building and connected after the utility meter. Roof-mounted solar panels, sub-panels and home battery systems are examples of behind-the-meter (BTM) power equipment.

Distributed energy resources: A variety of modular technologies that can supply power at smaller scales, typically less than 10 MW, and closer to power demands. These could be systems that generate electricity, store energy or make energy use more efficient or flexible.

Distributed generation: A variety of technologies that generate electricity at or near where it will be used, such as solar panels, and combined heat and power. In the residential sector, common distributed generation systems include solar photovoltaic panels.

Headroom: The difference between a network area's capacity—or supply of power—and the peak power demand of that network area.

Load letter: An administrative process Con Edison customers must complete to start new electrical service or make a major upgrade to existing service. To submit a load letter, a licensed contractor submits a project's electrical drawings and load calculations. Con Edison reviews the request and notifies the customer of the necessary upgrades, inside and outside of the building, and specifications to be followed. This process ensures grid equipment around the property is properly sized to handle building loads.

Load serving entity (LSE): An organization that directly delivers electricity to retail customers. Typically, this would be the electric utility, which in New York City is Con Edison. It owns and operates the physical distribution system, measures energy use and bills customers, and plans for grid reliability and expansion.

Local distribution network: A system of interconnected local utility infrastructure—substations, feeders, transformers and wires—that distributes power to users across New York City. Traditionally, the power distributed through this network is generated outside of the local distribution network and connected to it via high-voltage transmission lines.

Network areas: Geographical regions established by Con Edison that can be thought of as "power neighborhoods." There are around 70 network areas in New York City in which power is distributed from area substations to customers through feeders, transformers and wires. Generally, power can be rerouted within a network area in order to supply the dynamic power needs of customers.

Network system: The configuration of the vast majority of Con Edison's local distribution network. The two defining features of the network system are that it is almost entirely underground, and that it includes additional redundancy—power can be rerouted within the network and it is protected against aboveground hazards like falling trees and freezing temperatures.

Non-network systems: This configuration is used for around 10 percent of Con Edison's local distribution network. It is made up of primarily traditional overhead lines, known as radial load areas, and typically provides less redundancy than the network system because power is more difficult to reroute, and power lines are vulnerable to aboveground hazards.

Non-wires solutions: Collections of distributed energy resources, like large-scale batteries, to meet growing power demands while delaying investment in traditional grid infrastructure like larger substations and new transmission lines.

On-ramps and off-ramps: Power on-ramps connect power from generation facilities to the regional transmission system. Power off-ramps move power off the transmission system into a local distribution system, or can also move power between different load pockets within a local distribution system. Both on-and off-ramps will be essential for linking NYC's local distribution system to renewable generated power.

Peaker power plants: Facilities that only generate power during times of peak power demand. Many fossil fuel peaker plants are located within New York City, and they are disproportionately in economically disadvantaged communities like Sunset Park in Brooklyn and the South Bronx.

Primary feeder: In electric power distribution, this is a large conductor, or wire, that serves as a branch of a network area. Feeders are high-voltage (over 13,000 volts) and typically run from distribution substations to local transformers.

Radial load areas: Configurations of a local distribution network where there is only one route for power to flow between the source and the end user. This configuration is common with aboveground power lines but is less reliable than a network system configuration because a power outage at one point in the system causes end users downstream to also lose power.

Redundancy: In power utilities, this is the duplication of critical components of a system to improve reliability, usually by providing backup components and alternative circuit pathways.

Transformers: Equipment that reduces the voltage of the power that runs throughout the local distribution network so it can be used by residential and commercial customers. Transformers are used throughout the local distribution system, many buried in the streets.

Energy Terms

Demand response programs/event: Set up by utilities or independent grid operators to lower demand and alleviate congestion when the grid is stressed, these programs incentivize customers to reduce their electricity use for a period of time (a demand response event) when the utility expects high power demand and grid congestion.

Energy efficiency: Building upgrades that reduce the total amount of energy that a building uses. Usually these upgrades reduce energy waste and improve efficiency by retrofitting existing systems, like adding insulation to roofs, or optimizing operations, like balancing pressures in a ventilation system.

Energy model: A set of assumptions and calculations to predict a building's actual energy use based on a full year of operation. Weather, occupancy, envelope characteristics, HVAC systems and other variables are inputs to different software applications developed to help complete these calculations.

Energy storage: The ability to stockpile energy and discharge it later when needed. Energy storage in buildings usually consists of chemical batteries for electrical storage and thermal storage tanks that can hold hot water or ice.

Peak shaving: Actions that lower the system-wide peak power demand. Peak shaving can help ensure reliability during times of high demand and reduce the need to use peaker plants.

Power demand/Peak power demand: Power demand is the amount of electrical energy required by customers over a given time period. Peak power demand occurs at the moment during a calendar year when the demand is highest. Since power supply must always meet demand, the grid is built to meet peak demand.

NOTES

1 July 2021 was 0.93 degree Celsius higher than average. The seven hottest Julys since 1880 all have occurred since 2015. NOAA National Centers for Environmental Information, State of the Climate: Global Climate Report for July 2021, published online August 2021, retrieved on August 30, 2021 from www.ncdc.noaa.gov/sotc/global/202107/supplemental/page-1

2 IPCC AR6 2021 – A.3 Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heat waves, heavy precipitation, droughts and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5: www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

3 The Northeast (CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT, WV) experienced 127 outages between 2000 and 2009 and 329 outages between 2010 and 2019. However, Con Edison's reliability metrics are typically higher than neighboring utilities—partially because most of its infrastructure is underground. Climate Central research, updated September 2020: medialibrary.climatecentral.org/resources/power-outages#methodology

Con Edison had one of the lowest outage rates of any US utility in 2020: www.eia.gov/electricity/data/eia861

4 In theory, heat pumps will have ancillary services, but that potential needs to be demonstrated experimentally at a local scale. LBNL FEB 2020 – Providing Grid Services with Heat Pumps: escholarship.org/uc/item/4w97v0wb

5 NYISO Gold Book 2021, Figure I-4: www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64

6 Con Edison's Climate Change Vulnerability Study, Appendix 1 2019. "Increased heat waves have the potential to increase NRI (and therefore decrease reliability) such that, depending on climate scenario, 11 to 28 of the 65 underground networks may exceed Con Edison's 1 p.u. standard of reliability by mid-century, without intervention or additional investment. For perspective, there are currently zero networks that exceed this standard." www.coned.com/-/media/files/coned/documents/our-energy-future/our-energy-projects/climate-change-resiliency-plan/climate-change-vulnerability-study.pdf

7 New York State's Clean Energy Fund hopes to facilitate 130,000 heat pump installations in small residential buildings on the way to achieving 3.6 TBtu savings from investor-owned utilities and 1.0 TBtu savings from the Long Island Power Authority. Clean Energy Fund: Clean Heating and Cooling Chapter: www.nyserda.ny.gov/-/media/Files/About/Clean-Energy-Fund/cef-renewable-heating-and-cooling-chapter.pdf

8 Grid-interactive efficient buildings (GEBs) package these efficiency, flexibility and control measures together. National adoption of GEBs could save hundreds of billions of dollars in power system costs, reduce carbon emissions and relieve stress on the grid. A National Roadmap for Grid-Interactive Efficient Buildings (GEBs). emp.lbl.gov/news/new-doe-report-shares-national-roadmap-grid

9 RMI compared emissions from gas furnaces to heat pumps in 48 states and found heat pumps would emit less carbon in 46 of them, including New York. rmi.org/its-time-to-incentivize-residential-heat-pumps

10 Recent projections show electric vehicle charging may only increase citywide by 200 MW, a fraction of the added demand from building electrification. Pathways to Carbon-Neutral NYC Study, April 2021. www1.nyc.gov/assets/sustainability/downloads/pdf/publications/Carbon-Neutral-NYC.pdf

11 Roughly 45 percent of New York's electricity is purchased through long-term contracts, and 51 percent is purchased through NYISO's Day Ahead Market to meet anticipated demand through the LSEs. Less than 5 percent of power is bought in real-time when demand forecasts fall short. www.ippny.org/vs-uploads/PDF/1301328531_Energy_Pricing.pdf

12 "After the Northeast Blackout of 1965, New York's seven investor-owned utility companies established the New York Power Pool (NYPP) to coordinate the reliable operation of their respective systems, which was later joined by the New York Power Authority...In 1997, the NYPP filed a proposal with FERC to form an independent system operator (NYISO). Upon approval from FERC, the NYISO officially took control of New York's electric power system on December 1, 1999, with a charge to design, deploy, administer, and monitor New York's wholesale electricity marketplace." Accessed on October 18, 2021: www.nyiso.com/faq

13 Con Edison's service territory does not include the Rockaways.

14 "Con Edison owns 62 area distribution substations located throughout New York City and Westchester County. At the end of 2020, its distribution system had over 37,000 miles of overhead distribution lines and 98,000 miles of underground distribution lines." www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_ED_2020.pdf

15 www.coned.com/-/media/files/coned/documents/our-energy-future/our-energy-projects/climate-change-resiliency-plan/climate-change-vulnerability-study.pdf

16 www.nyserda.ny.gov/all-programs/programs/ny-sun/contractors/value-of-distributed-energy-resources

17 cpowerenergymanagement.com/wp-content/uploads/2019/01/ISO_NY_CON_ED_SNAPSHOT_011319.pdf

18 Governor Hochul announced these in September 2021, and the projects are expected to eventually deliver 18 million MWh to NYC. www.nyserda.ny.gov/About/Newsroom/2021-Announcements/2021-09-20-Governor-Hochul-Announces-Major-Green-Energy-Infrastructure-Projects-to-Power-New-York-City-With-Wind

19 Con Edison will make $860M of transmission and $1,130M of distribution upgrades by 2025. Figure 1 in Utility Transmission and Distribution Investment Working Group Report (Nov 2020): documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B2794FC7E-D2A6-4C79-8834-4B60FA25ED1F%7D

20 This will start in 2023, due to the New York Department of Environmental Conservation's new rules that limit the allowable level of nitrogen oxide (NOx) emissions.

21 Electricity use in the United States declined in 1974, just when new plants were coming online to end the shortages of the 1960s and prevent massive outages like the Northeast blackout of 1965. Schewe, Philip. The Grid. Washington D.C., Joseph Henry Press: 2007.

Building analysis based on LL87 audit (2013–2018) data — 63 buildings larger than 50,000 SF use electric resistance heating. Their median age is almost 50 years, and about half of them were constructed between 1965 and 1985.

22 Based on review of NYSERDA MPP data accessed in August 2021: data.ny.gov/Energy-Environment/Multifamily-Residential-Existing-and-New-Construct/xt6e-eyna

23 Based on the 2019 NYC GHG Inventory, subways, commuter trains and streetlights consume just 5 percent of the electricity used in NYC. While our analysis examines NYC's current power needs, it does not consider any demand growth from electric cooking and plug-in vehicle charging.

24 Our typologies generally align with NYC's Technical Working Group Report. www1.nyc.gov/assets/sustainability/downloads/pdf/publications/TWGreport_04212016.pdf

25 The energy data collected through NYC's benchmarking law, Local Law 84 of 2009 (LL84), classifies buildings based on Primary Property Type, which represents the building's main purpose. We mapped typologies between those benchmarked types and PLUTO Building classes to link the datasets. Energy data for single-family homes came from NYSERDA's 2019 Residential Building Stock Assessment (RBSA), since LL84 data is limited to buildings over 25,000 SF.

26 National Renewable Energy Laboratory. Storage Futures Study Distributed Solar and Storage Outlook: Methodology and Scenarios, July 2021. www.nrel.gov/docs/fy21osti/79790.pdf

27 Based on benchmarked peak power demands in buildings larger than 25,000 SF in 2019. Just half of hotels, 19 of 37 records, have summer peaks, which could be the result of many hotels using electric resistance PTACs in their guest rooms.

28 These low-cost energy efficiency measures were chosen based on the Simple and Moderate Renovation packages designed by Community Preservation Corporation in its 2019 Underwriting Efficiency report: communityp.com/wp-content/uploads/2017/05/CPC_Underwriting_Efficiency_Handbook_Full_Interactive_FINAL.pdf

29 Climate Action Council meeting presentation on October 1, 2021: climate.ny.gov/-/media/Migrated/CLCPA/Files/2021-10-01-CAC-Meeting-presentation.ashx

30 Con Edison is already anticipating summer peak demand to grow by 700 to 900 MW by 2050 due to hotter temperatures driven by climate change. That is roughly an 8 percent increase from peak demand over the last decade. www.coned.com/-/media/files/coned/documents/our-energy-future/our-energy-projects/climate-change-resiliency-plan/climate-change-resilience-adaptation-2020.pdf

31 "Network systems are designed based on redundant facilities. Any single equipment failure will not result in service outage on the network. Each network is served by at least two primary feeders." Secondary Network Distribution Systems Background and Issues Related to the Interconnection of Distributed Resources, 2005. www.nrel.gov/docs/fy05osti/38079.pdf

32 Con Edison pays for all standard front-of-the-meter upgrades—changes to any grid infrastructure, from a building's meter out to equipment on the street and beyond—that are needed to deliver more power. Building owners are responsible for paying to upgrade the electrical circuits and equipment, like switchgears, inside their buildings.

33 Affordable housing programs preserve and provide safe homes for people with lower incomes. Government plays a major role in this process at the federal, state and local level. The NYC Department of Housing Preservation and Development (HPD) was created in 1978 with the goal of preserving affordable housing, including working with nonprofits to acquire buildings and maintain affordability, and providing tax exemptions as well as homeowner repair loans, energy efficiency updates and more.

34 Table 4 on page 36 shows electrification hitting 59 to 62 percent of buildings by 2050. Pathways to Carbon-Neutral NYC: www1.nyc.gov/assets/sustainability/downloads/pdf/publications/Carbon-Neutral-NYC.pdf

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