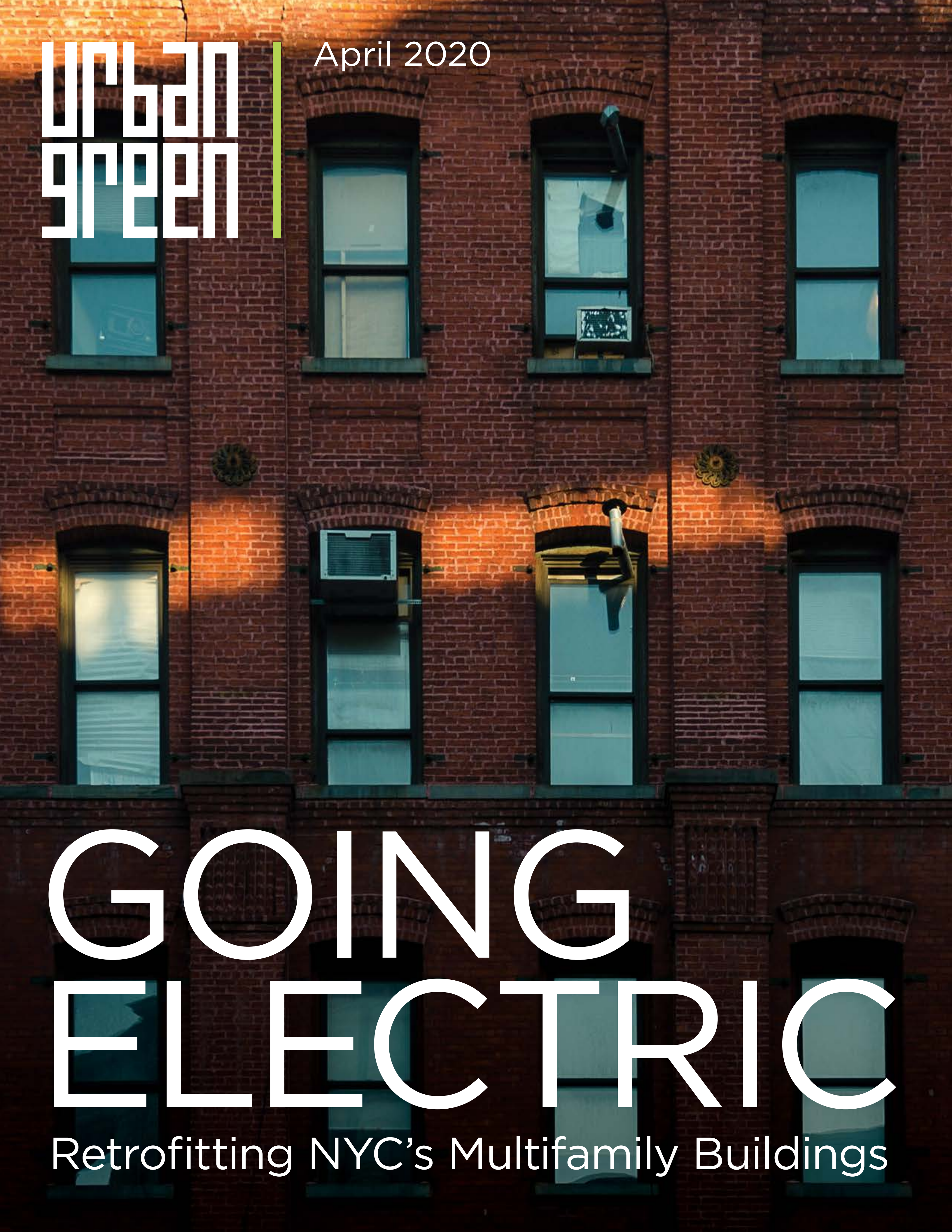

urban green

April 2020

GOING ELECTRIC

Retrofitting NYC's Multifamily Buildings

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THE SCHERMAN
FOUNDATION

GOING ELECTRIC

Heating is the largest source of emissions from NYC's buildings. Installing heat pumps would reduce the carbon footprint of most multifamily buildings today and will save even more carbon as our electricity gets cleaner in the years ahead.

EXECUTIVE SUMMARY

A heating revolution is on the horizon for NYC buildings. Electrification can drastically reduce our carbon emissions, but we must begin planning for it now.

In 2014, the City of New York (City) committed to reducing its greenhouse gas emissions 80 percent by 2050. Addressing the energy consumed by the city's buildings is critical to achieving this goal, since buildings currently account for about 70 percent of our total carbon footprint. The task is monumental, but we've already made some progress: buildings emissions are now more than 21 percent lower than 2005 levels.[1]

To date, the decline in emissions has largely been due to changes in electricity generation. Power plants across New York State have been converted to burn natural gas, a lower-carbon fuel than oil or coal. Substantial renewable energy sources have also been added to the grid, and renewables will continue to grow over the coming decades—New York law now requires that we get 70 percent of our electricity from renewable sources by 2030. But addressing emissions from the electrical grid will not be enough. New York City's low-carbon future depends on a revolution in the way we heat our buildings.

Over 40 percent of citywide emissions come from space heating and hot water systems that run on fossil fuels. We can begin to chip away at that number by improving the efficiency of these systems, but in order to make deeper, more significant cuts, we'll eventually need to transition them from burning oil and gas to using electricity. This process, known as electrification, will transform heating and cooling in New York City's multifamily buildings.

The benefits of this transition are compelling. Transforming this sector will yield enormous co-benefits for New Yorkers, including better indoor and outdoor air quality, greater access to cooling in a warming climate, and more comfortable apartments year-round. But the city's laws and infrastructure were not designed for widespread electrification, and getting there will require comprehensive planning from both government and industry.

This report provides a roadmap to advance electrification in New York City. It describes the technology behind electrification (*Understanding Heat Pumps*), examines the challenges to adopting this technology in New York's existing large multifamily buildings (*Current Challenges*), and identifies nine steps that will prepare the NYC market for large-scale multifamily electrification (*Jumpstarting Electrification*).

What Does Electrification Look Like?

Over the next thirty years, boilers and furnaces throughout New York City will need to be replaced by high-efficiency heating systems that run on affordable electricity, delivered by a grid powered with renewable energy. The technology that is best suited to usher in this heating revolution is called a heat pump. In the most basic terms, heat pumps are similar to air conditioners, but they provide heating in addition to cooling. In the winter, they pull heat from outside and disperse it indoors. In the summer, they work in reverse. Heat pumps are incredibly efficient systems that can deliver large amounts of heat, even on the coldest days, using very little electricity.

Some New York City developers and building owners are already investing in heat pumps, mostly for smaller residential buildings and some spaces within commercial buildings. But projects at this scale represent just a small piece of the emissions pie. Meaningful emissions reductions depend on NYC's existing large multifamily buildings replacing their boilers with heat pumps.[2] Except for in a few newer buildings, the large multifamily sector has made little to no progress on electrification.

What Needs to Change in the Multifamily Sector?

Heat pumps are capable of warming any New York City building to a comfortable temperature on even the coldest winter days.[3] And as mentioned previously, they can do so with great efficiency. So what's holding back the adoption of this technology in NYC? Urban Green consulted with more than 40 advisors from the real estate, energy efficiency, HVAC manufacturing, utility, and government sectors to learn why so few multifamily buildings have invested in heat pump retrofits.

This report summarizes our discussions with the advisory group. We found that the primary barriers include:

- Technical information gaps
- Substantial financial costs and planning
- Regulatory uncertainties

These obstacles are not insurmountable, but they will not subside without strategic intervention. Clearing up uncertainties and increasing confidence in heat pump solutions are essential to the future of electrification in New York City.

▶ *Turn the page for a summary of our nine electrification recommendations for NYC.*

Replacing oil and gas boilers with heat pumps will improve air quality in buildings and neighborhoods throughout the city. Young children and the elderly are especially vulnerable to pollution and will benefit most from cleaner air.

RECOMMENDED STRATEGIES FOR NYC

9 NEXT STEPS FOR ADVANCING ELECTRIFICATION IN MULTIFAMILY BUILDINGS

Electrifying our heating and hot water systems will be a multi-decade process, which is why we need to begin paving the way now. To address the barriers to electrification in large residential buildings, in the next five years we should:

1 Demonstrate the technology in NYC.

Heat pump retrofit pilot projects will shed light on options and costs for design, equipment, and labor, and also demonstrate that heat pumps are safe and work as expected. The City and State should lead by example with heat pump retrofits in government-owned buildings and by fostering pilots in the private sector.

2 Increase incentives and promote transparency.

The biggest challenge for near-term electrification is cost. Significant increases in government and utility incentive programs are necessary to encourage heat pump options for multifamily retrofits. Mandatory reporting of project details will make future electrification planning easier.

3 Harness Local Law 97 to drive electrification.

New York City's groundbreaking emissions law sets carbon caps for buildings starting in 2024. The mechanics of the law's 2030 targets will be finalized over the next three years. With the right structure, the law could be a major driver of heat pump retrofits.

4 Support heat pumps with better electricity rates.

New York City has some of the highest electricity costs in the nation. Heat pumps could help lower these costs by making better use of existing utility infrastructure. Rates that account for the value of heat pump installations could help speed adoption and strengthen the business case for electrification.

5 Enable electrification in affordable housing.

Some regulations in the affordable housing sector make heat pumps a tough sell, particularly when many building owners already struggle with thin margins and deferred maintenance. Targeted support and regulatory improvements may be necessary to spur heat pump retrofits in this large and important sector.

6 Start electrifying one step at a time.

Building owners can spread retrofit costs out over time with incremental upgrades, but they need guidance on how to plan a multi-phase heat pump retrofit. Their options include electrifying just hot water, retrofitting one portion of the building at a time, or upgrading buildings systems to be 'heat pump ready.'

7 Identify electrical infrastructure needs.

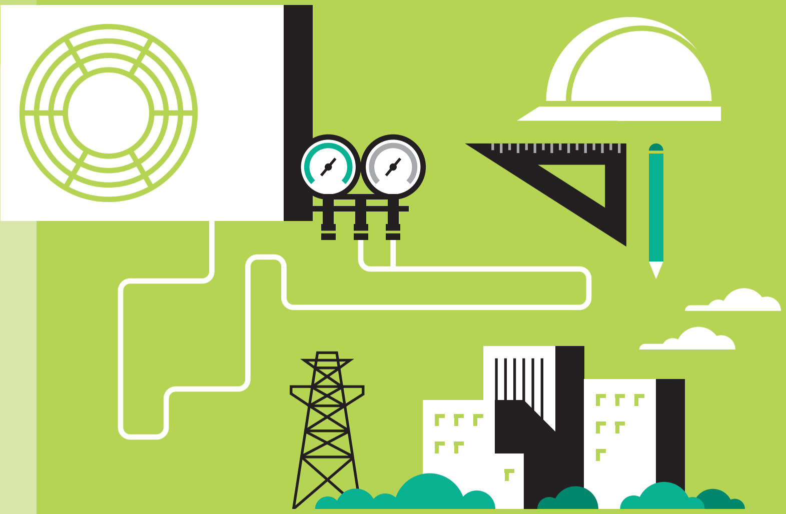
Beyond space heating, electrification also includes installing induction stoves and electric vehicle charging infrastructure. Together, these changes will require electrical upgrades in buildings and utility distribution networks. Information on current infrastructure must be collected and assessed now in order to plan for this future work.

8 Ramp up workforce training.

Architects, engineers, building operators, and contractors will need education and training to make sure they install the most effective heat pump systems and maintain them cost-effectively. Manufacturer engagement is essential since installation and maintenance procedures vary between models.

9 Launch a building electrification campaign.

Electrification is a massive shift for the New York City building sector and requires an equally sizable mobilization effort. The City should build on its experience with the Clean Heat Program and develop a large-scale, public-facing campaign to engage owners, educate residents on the benefits of heat pumps, and facilitate this long-term transition.



Heat pumps can give residents more control over the temperature of their apartments, which means more comfortable living spaces year-round. Widespread adoption of heat pumps will also expand access to cooling and reduce heat-related illnesses in a warming city.

UNDERSTANDING HEAT PUMPS

Heat pumps provide clean, comfortable, and highly efficient heating and cooling. New advances mean they can do so in cold climates while also drastically reducing emissions.

Today's oil and natural gas heating systems are more efficient than the wood and coal-fired boilers of the past, but they still have a significant carbon footprint. NYC buildings use almost twice as much energy from fossil fuels as all of the cars, trucks and buses in the city combined. Seventy-five percent of emissions from residential buildings come from burning fuel for heat, hot water, and cooking.[4]

Burning fossil fuels is not the only way to provide these essential services, and it can no longer predominate; under New York City's newly enacted Local Law 97 of 2019, building emissions will have to be drastically reduced. This means that building heating systems, especially ubiquitous steam heat, will eventually need to be replaced by heat pumps that run on electricity.[5]

This won't be the first time New York City leads an electrification movement. In 1882, the Edison Electric Illuminating Company of New York constructed a central generating station on Pearl Street to power its new light bulbs, creating the first modern electric grid. Light bulbs eventually replaced gas lamps in homes, turning them into quaint relics.

We now have another opportunity to revolutionize our buildings through electrification. Electric heat pumps can replace fossil fuel-based space heating and hot water systems. Heat pump retrofits will bring building emissions closer to zero, reduce air pollution throughout the city, and give residents more control over indoor temperatures for greater comfort.

What is a Heat Pump?

Heat pumps are electrically powered systems that move heat from one place to another. They look similar to air conditioners, and employ essentially the same technology, but work for heating as well as cooling. Each heat pump system is made of at least one loop of copper tubing containing a fluid called refrigerant that carries heat. During the summer, the system circulates refrigerant to absorb heat from inside and releases it outside. During the winter, it does the reverse; the refrigerant absorbs heat from the air outside and uses it to warm interior spaces.

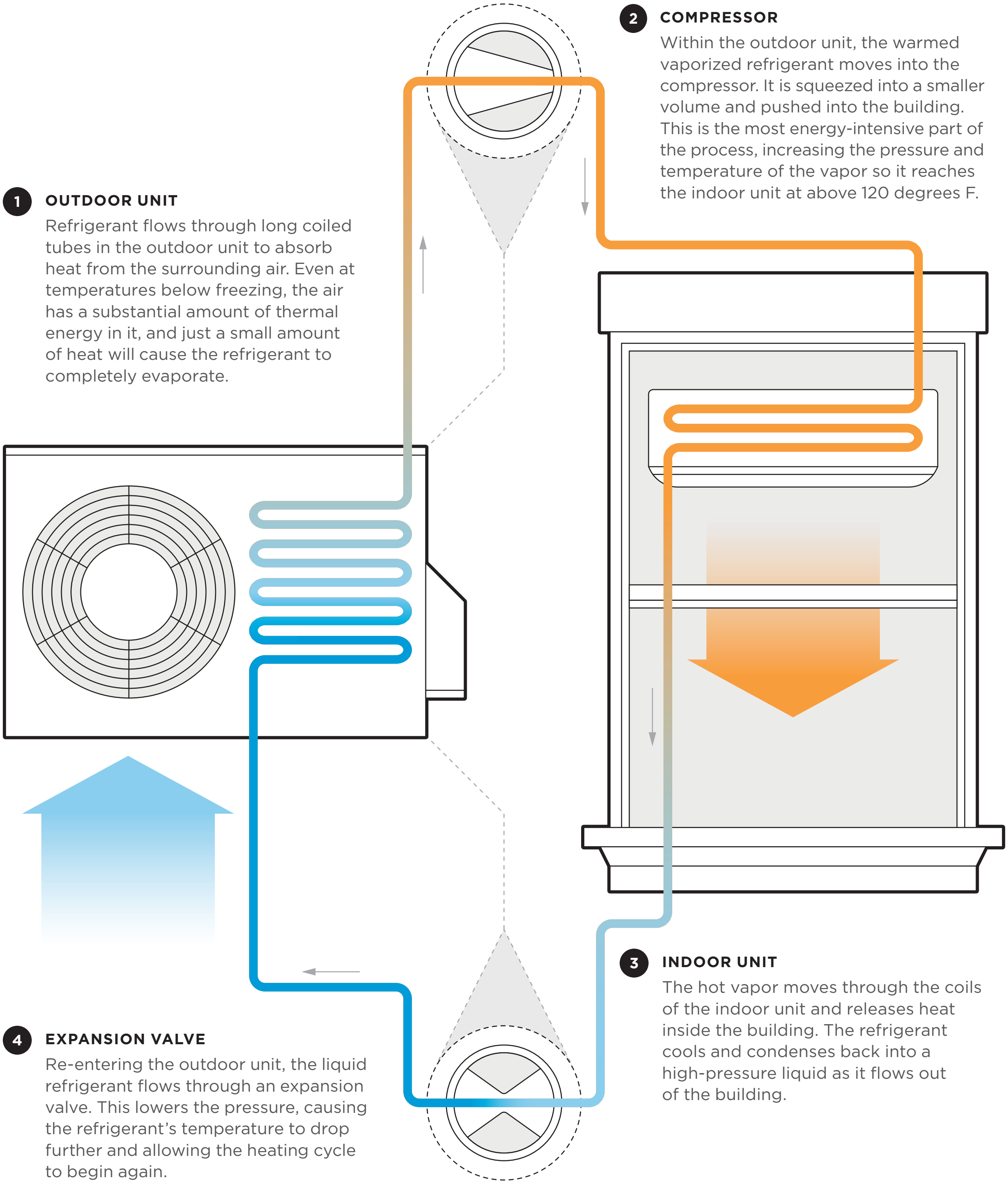
Unlike window air conditioners, heat pumps are typically split into two main components, outdoor units and indoor units. The units are connected by electrical wiring and copper tubing, also known as the line set, and contain compressors, valves, and fans. Refrigerant flows through the line set according to a thermodynamic process called the vapor compression cycle.[6]

This whole process transfers more thermal energy than it consumes in electrical energy. That means heat pumps are over 100 percent efficient.

FIGURE 1

How Does a Heat Pump Work in Winter?

Air source heat pumps capture heat from the outside air and move it inside using the vapor compression cycle. This process works even when the outdoor temperature is well below freezing. Additionally, this cycle can be reversed to cool buildings during the summer.



1 OUTDOOR UNIT

Refrigerant flows through long coiled tubes in the outdoor unit to absorb heat from the surrounding air. Even at temperatures below freezing, the air has a substantial amount of thermal energy in it, and just a small amount of heat will cause the refrigerant to completely evaporate.

2 COMPRESSOR

Within the outdoor unit, the warmed vaporized refrigerant moves into the compressor. It is squeezed into a smaller volume and pushed into the building. This is the most energy-intensive part of the process, increasing the pressure and temperature of the vapor so it reaches the indoor unit at above 120 degrees F.

3 INDOOR UNIT

The hot vapor moves through the coils of the indoor unit and releases heat inside the building. The refrigerant cools and condenses back into a high-pressure liquid as it flows out of the building.

4 EXPANSION VALVE

Re-entering the outdoor unit, the liquid refrigerant flows through an expansion valve. This lowers the pressure, causing the refrigerant's temperature to drop further and allowing the heating cycle to begin again.

Heat Pumps Aren't New, So What Changed?

The vapor compression cycle dates back to the 19th century. Originally it was only used for cooling, and early compressors were powered by steam rather than electricity. When electric heat pumps were invented, they were designed for milder climates where temperatures rarely dipped below 40 degrees F. That's why heat pumps became common in the southern United States but never took off in the Northeast. However, recent advances in technology have made them viable in colder climates like New York.

Modern heat pumps work in temperatures well below freezing due to an array of improvements. The development of smaller tubing allowed for additional coils in the outdoor units, and therefore more surface area for heat to be absorbed. Inverters, which control the power supplied to the compressor, allow heat pumps to operate at variable speeds. At faster speeds, refrigerant will flow through the system more quickly and increase overall heat transfer. New sensors and controls also communicate within the system to deliver refrigerant at precise temperatures and pressures, helping it run more efficiently.

Cold climate air-source heat pumps are already making their way into New York City buildings. They have been installed in new affordable multifamily properties, and brownstone residences in Brooklyn have completed full heat pump retrofits. An HVAC Market Report prepared for the New York State Energy Research and Development Authority (NYSERDA) found that at least 10,720 heat pumps were sold in New York State in 2018. But there's a major subset of New York City's buildings that has made little to no progress on electrification: existing large multifamily buildings.

There's good reason this sector has been slow to embrace heat pumps. A heat pump retrofit in a multifamily building is a huge project. It requires running new refrigerant and electrical lines throughout the building, installing new units in every apartment, and figuring out where to put the outdoor units, to name just a few of the challenges. Urban Green conducted extensive research to find out more about the factors holding electrification back in New York City's existing multifamily buildings. The next section describes these obstacles and others in greater detail.

Unlike the steam radiators that dominate multifamily buildings today, heat pump systems make it feasible to measure heating use, either with an electricity meter or by tracking the flow of refrigerant to an apartment.

CURRENT CHALLENGES

Facilitating widespread adoption of heat pumps will first require addressing knowledge gaps, cost barriers, and regulatory unknowns.

Modern heat pumps can efficiently heat and cool New York City's multifamily buildings. This is not just wishful thinking—it has been proven in dozens of newly constructed buildings that have already adopted the technology.[7] Many developers now recognize that heat pumps deliver higher levels of control and comfort, as well as healthier indoor environments than fossil fuel systems.

However, most New Yorkers don't live in newly constructed buildings. There are 15,000 medium and large multifamily properties that cover roughly 35 percent of NYC real estate, or 1.85 billion square feet. Most are heated by old, inefficient steam boilers that run on fuel oil or natural gas.[8] Heat pumps cannot make steam, so entire steam heating systems, from boilers to radiators, will need to be converted or replaced.

In the near term, it may be easier and cheaper for owners to update existing heating systems to improve their efficiency rather than completely replace them. But in the longer term, in order to meet our climate goals, existing buildings will have to stop burning fossil fuels.

New York City must begin preparing for this complex retrofit process now. Our interviews and forums with more than 40 advisors from the real estate, energy efficiency, utility, and government sectors revealed that there are many layers of challenges inhibiting multifamily building electrification. Some of the current impediments to heat pump retrofits include:

TECHNICAL INFORMATION GAPS

Building owners are risk averse, so they want well-tested solutions. While heat pumps have proven successful in new construction, there are limited case studies of heat pump installations in existing buildings to assuage owners' concerns. Information gaps include:

- ***System selection:*** The building industry needs to get up to speed on heat pumps to help owners choose the right system, install the equipment, and maintain it over time.

- ***Electrical capacity:*** Many multifamily buildings may require power upgrades to support the additional electrical demand from heat pumps.

SUBSTANTIAL FINANCIAL COSTS AND PLANNING

The cost of installing all new equipment, piping, and electrical lines will be hard to justify to many building owners, especially as long as natural gas remains cheaper than electricity. On top of that, retrofits may involve additional costs due to tenant disruption and changes to building maintenance.

REGULATORY UNCERTAINTIES

- ***Real and perceived refrigerant risks:***
  Heat pumps contain larger quantities of refrigerants than typical household appliances, which could cause many problems—including contributing to global warming—if they leak.

- ***New territory for the rental sector:***
  Most New York City tenants are not currently responsible for heating costs. Heat pump retrofits have the potential to change that dynamic, since they make it easier to meter and bill for heating use (while reducing rent owed). This shift could help reduce energy waste, but regulatory barriers and tenant concerns complicate the path to electrification, especially for some affordable housing.

CARBON IMPACTS

Heat pumps will reduce the carbon footprint of most multifamily buildings, even with today's largely fossil fuel-powered downstate grid. But some building experts prefer the less costly solution of improving existing systems to use natural gas more efficiently and delaying the switch to heat pumps.

Resiliency was not identified by our advisors as a concern for heat pump retrofits in multifamily buildings, but it is important to note that in the case of a blackout, heat pumps will stop working. However, this is already true for heating systems in large multifamily buildings that use electricity to run their controls, fans, and pumps, even if they burn fossil fuels for heat. Electrified or not, there will be no heat in any of these buildings if the power goes out.

Easing the financial burden of heat pump retrofits, clearing up uncertainties around safety and regulations, and increasing knowledge of and confidence in this solution are essential to the future of electrification in New York City. The following sections provide more detail about these challenges in order to illuminate potential paths forward.

Where Are the Technical Information Gaps?

Every heat pump retrofit will have unique design and engineering challenges, but two technical issues came up routinely in our discussions with advisors: choosing an appropriate system and ensuring the building's electrical capacity can accommodate the added load.

SYSTEM SELECTION: NO ONE SIZE FITS ALL

The first challenge a building owner will face when considering a heat pump retrofit is choosing a system. Heat pumps can be divided into three categories based on where they draw heat from: the air, a body of water, or the ground. For the purposes of this study, we focused on air-source heat pumps because they are the most versatile and feasible solution for the majority of existing buildings in New York City.[9]

Within the realm of air-source heat pumps, there are additional decisions building owners will have to make. First and foremost, they must choose between installing one central system or many unitary systems. Central systems utilize large outdoor units and slightly thicker refrigerant lines to provide heating and cooling to an entire building. Unitary systems, often called mini-splits or multi-splits, have smaller outdoor units that serve just one apartment, or at most a few at a time.[10]

Each system type comes with its own set of hurdles that building owners and engineers will face. The most important factors to consider in selecting a system are:

- Availability of space outside the building for outdoor units
- Potential for tenant disruption while installing indoor units
- Existing electrical capacity within the building
- Amount of heat that needs to be delivered on the coldest day

CENTRAL SYSTEMS

Installing a central heat pump system is potentially a less invasive process for tenants than unitary systems. The large outdoor units required for a central system are typically placed on the roof, but they can also go on the ground outside the building. Putting them on the roof largely hides them and makes adding electrical capacity easier, but it requires a structural analysis to ensure safety. A crane may also be useful for placement.

CASE STUDY

Heat Pump Retrofit of One Apartment

One multifamily building on NYC's Upper East Side experimented with electrification in a single apartment. The building owner decided to install a mini-split heat pump to solve a serious under-heating problem. It was a complicated retrofit: First, the existing packaged terminal air-conditioning unit was pulled out of the wall. The opening was not large enough to accommodate the mini-split, so additional bricks had to be removed from the building's façade to widen it. Then a custom grille was placed over the newly expanded opening to conceal the outdoor unit. Finally, the interior wall had to be insulated and sealed to reduce heat loss.

Unfortunately, the costs of that heat pump retrofit were high. Installing a mini-split in an existing opening can be challenging and unexpected difficulties arose. Outdoor scaffolding had to be erected in order to carefully remove bricks from the façade. Water leaked inside the outdoor unit enclosure, which delayed work and drove up costs. Many lessons were learned on how to properly retrofit an existing opening for a new heat pump, and more best practices will be uncovered with similar installations.

On the bright side, the project did achieve its goal: It realized dramatic utility cost savings, and the tenant is much warmer and happier during the winter. More projects like this are needed for the building industry to learn how to streamline the retrofit process and to convince owners that these replacements are worthwhile.

Left Image: *Upper East Side project with heat pump installed in retrofitted opening for improved aesthetics. The surrounding units have the original louvered opening for PTACs.*

Right Image: *Typical unitary heat pump installation on exterior façade.*

In a central system, the outdoor units hook up to refrigerant distribution lines that run horizontally or vertically through the core of the building. One challenge with these systems is that the connections between the refrigerant lines, indoor units, and outdoor units may span many floors and require many pipe connections.[11] The lines also hold large amounts of refrigerant as compared with unitary systems, which can make owners uneasy for reasons discussed further below.

Central systems require fewer outdoor units than unitary systems. For example, one newly constructed multifamily building in New York City that installed a central system used just one outdoor unit for every 10 apartments. Having the outdoor units in a single location may make them easier to access for maintenance, but the maintenance for these large systems is complex and will require more experienced technicians. Another potential drawback to central systems is that if outdoor units are placed on the roof, they may limit space for other improvements to the building, like solar panels. Central systems also make it more difficult to bill tenants for their actual heating and cooling energy use. If building owners wish to do so, they will need a method to track refrigerant flow to each apartment and bill tenants accordingly.

UNITARY SYSTEMS

A multifamily building with unitary heat pump systems could have as many individual systems as it has apartments. Each ductless mini-split system requires its own, small outdoor unit and independent electrical and refrigerant lines. The outdoor units can be placed anywhere around the building's exterior as long they are relatively close to their associated indoor units. These systems work well in buildings where outdoor units can easily fit on a balcony or mount on an exterior wall. Mini-splits are a good option for older multifamily buildings that do not have central shafts that can accommodate new refrigerant and electrical lines. However, older buildings may require electrical upgrades.

Unitary systems are incredibly popular outside of the U.S. and make up a majority of the Asian and European residential HVAC market.[12] Mini-splits are also growing in popularity in American single-family homes. However, high-rise building owners have been hesitant to adopt them due to the cost and the aesthetic impact on façades.

Regardless of which system they choose, owners and occupants should feel confident that heat pumps will deliver on comfort. The technology is proven to provide enough heat in the wintertime, even at very cold temperatures.[13] However, since heat pumps are still rare in New York City, building owners remain skeptical. Even when a compelling event, like a catastrophic system failure, forces building owners to find a heating replacement, they will need convincing that heat pump retrofits are worth exploring.

EXISTING ELECTRICAL CAPACITY: HOW MUCH ROOM IS LEFT?

New York City's multifamily building stock is old; more than half was built over 80 years ago. But while the frames and foundations of these old buildings are durable, the electrical service in many of them was designed long before today's modern appliances and codes. These buildings would benefit from an electrical upgrade, and many will require one if their owners decide to switch to heat pumps.

The determining factors for whether a building will need an electrical upgrade are its electrical capacity and the power requirements of the new heat pump. Capacity is based on how much electrical charge can flow through a building's wires. The flow of charge, or current, is measured in amperes (amps). Each apartment's circuit panel is rated for a certain number of amps and is wired to the main building switches in the basement. Larger wires can carry more current, and more current is needed to operate more electric appliances.[14]

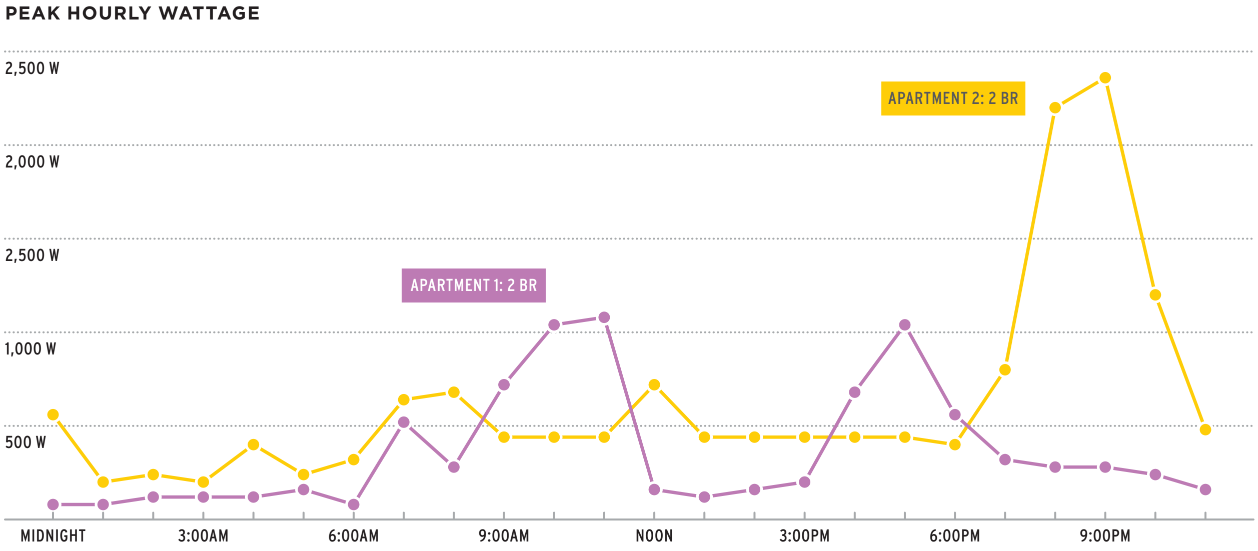
So how much capacity do apartments in multifamily buildings have? Part of the problem is there is not a lot of data on the electrical capacity of NYC buildings. One survey found that most buildings have wiring in place to provide each apartment with 40, 60, 100 or 125 amperes of electrical capacity at various voltages. Many pre-war multifamily buildings have older and smaller electrical wiring, so a 40-amp capacity may be quite common.[15]

FIGURE 2

Power Demand in Two NYC Apartments

Residential customers typically use the most electricity in the morning and evening. We analyzed power use in spring and fall, seasons with limited heating and cooling needs. The two apartments shown had the highest and lowest demand. Their peaks differ in size and timing and upgrades would help accommodate this variability.

Data: Utility electricity data voluntarily submitted to Urban Green



Forty amps is enough electricity to power simple appliances. But what about a heat pump in winter? The typical 1,000 square foot NYC apartment only needs a small unitary heat pump system, which requires about 30 amps of current at full load. Most of the time the heat pump will use fewer amps, but an apartment with low electrical capacity, like 40 amps, would still need an upgrade to meet the electrical code.[16]

Existing power demand is the other unknown in these buildings. We sampled the power use of Urban Green members and advisors and found that in direct-metered apartments, power demand peaked between 1,200 and 2,400 watts (Figure 2). An independent engineering survey found the typical peak demand is 1,600 watts in NYC apartments.[17] These peak power demands translate to between five and 11 amps of peak current for each apartment. That means for the worst-case scenario, where a low capacity circuit serves a tenant with high power demand, adding a heat pump would be pushing the limit.

When considering a heat pump installation, a building owner will have to conduct a site survey of apartments to measure available electrical capacity—how much of the total capacity remains after taking into account existing appliances and lighting. If there's not enough capacity to accommodate a heat pump and still meet current electrical code, then a building upgrade will be needed.

While that may be the case in some situations, there will also be apartments that have plenty of electrical capacity to power a small unitary system. It's unclear how many buildings in New York City will require electrical upgrades because there is limited information available on multifamily building electrical infrastructure. The building audits required by Local Law 87 of 2009 do not currently include an inventory of building electrical equipment. That is the kind of information that planners and design teams will need in order to plan out large scale electrification.

How Much Will Heat Pump Retrofits Cost?

Perhaps the biggest barrier to heat pump retrofits is the estimated high up-front cost. But the key word is "estimated," because no occupied large multifamily building in the Greater New York region has completed such a project. These retrofits certainly require intensive and careful work that is expensive to implement, but current estimates are driven up further by contractors and engineers who bake in a level of uncertainty due to the lack of real-life examples.

We collected estimates for heat pump installations from 12 NYC-based feasibility studies and project proposals from the past 10 years.[18] All of the proposals included some soft costs for design and permitting, plus contingency costs for unexpected issues that often arise when retrofitting older buildings. Eight of the plans would have replaced existing steam heat systems with centralized variable refrigerant flow (VRF) heat pump systems, and four would have replaced steam or packaged terminal air-conditioners (PTACs) with unitary mini-split heat pumps.[19] Based on this limited data set, the unitary mini-split retrofits tended to be less expensive on a per-square foot and per-apartment basis.

Total costs for each of the 12 proposals are presented in Figure 3. All but one of these projects were for buildings with steam heating systems that needed to be replaced or upgraded. Interestingly, most had had catastrophic failures, which made the cost of doing a complete heat pump retrofit comparable to upgrading the old steam system and replacing boilers and cooling towers.

Our advisory group also looked at their own project experience and estimated costs per apartment. Central systems ranged from $15,000 to $22,000 per apartment, with the potential to cost at least 15 percent more if additional functionality like simultaneous heating and cooling was needed.[20] Unitary system costs ranged from $9,000 to $12,000 for an apartment with three indoor units (one for each room), and could increase by at least 10 percent depending on whether electrical upgrades were needed.

The up-front costs of equipment and labor are the initial barrier, but current energy prices present another problem for widespread heat pump adoption. Right now, electricity costs roughly five times as much as natural gas per unit of energy. Even the most efficient cold-climate heat pumps cannot make up that big of a price difference.[21] For now, heat pumps are more expensive to operate than systems that use natural gas. But Local Law 97 penalties may change that calculus, particularly as the law's emissions factors reflect greener electricity in the future, as discussed in Section 4.

However, not every multifamily building currently uses natural gas to supply heat and hot water needs. Many buildings still burn fuel oil, use district steam, or have electric resistance systems. These options are all more expensive, per square foot, than using a heat pump, so these buildings do have the opportunity to save money with a heat pump retrofit now.

What Regulatory Questions Will Heat Pumps Raise?

REFRIGERANT SAFETY, LEAKS, AND BANS

Heat pumps use refrigerants to transport heat between outdoor and indoor units. Many different chemical compounds can serve as refrigerants, but some are toxic, flammable, or can damage the planet's atmosphere if released. Unfortunately, there is no one perfect refrigerant—each of these potential risks must be balanced—but federal policy and local building codes limit the options to compounds that are lower in flammability, non-toxic, and least harmful to the atmosphere.

Heat pumps use a larger volume of refrigerant than typical household appliances like refrigerators, and building owners may be hesitant to install a system that comes with new risks. Unitary heat pumps have an advantage in this regard because they use a much smaller amount than central systems. Refrigerant shouldn't leak from the pipes, but sometimes a combination of vibration and poor installation can lead to leaks in pipe connections.[22]

The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) sets design standards for systems that use

FIGURE 3

How Much Could a Heat Pump Installation Cost?

This collection of proposed retrofit estimates and research studies show that heat pump installations can be cost competitive with other options. All 12 estimates look at design, material and labor costs in NYC.

Data: Feasibility studies and proposals shared with Urban Green

Building Size

SMALL = LESS THAN 25,000 SF
MEDIUM = 25,000–50,000 SF
LARGE = MORE THAN 50,000 SF

	ESTIMATE DETAILS	BUILDING	COST PER SQUARE FOOT	COST PER DWELLING UNIT
1	Central VRF Proposal	Small Multifamily Built 1910s	$25.80	$18,300
2	Central VRF Proposal	Large Multifamily Built 1960s	$25.30	$30,600
3	Central VRF Research Estimate	Large High-rise Built 1950s	$25.00	$18,800
4	Central VRF Research Estimate	Large Multifamily	$21.30	$21,300
5	Central VRF Proposal	Small Multifamily Built 1920s	$18.30	$15,000
6	Central VRF Research Estimate	Large Multifamily	$17.50	$17,500
7	Central VRF Proposal	Small Multifamily Built 1910s	$17.10	$11,400
8	Unitary Mini-split Proposal	Small Multifamily	$16.00	$20,000
9	Central VRF Proposal	Large Multifamily Built 1960s	$14.60	$12,600
10	Unitary Mini-split Research Estimate	Large Multifamily	$14.00	$14,000
11	Unitary Mini-split Research Estimate	Large Multifamily	$13.00	$13,000
12	Unitary Mini-split Proposal	Large Multifamily Built 1970s	$11.20	$12,400

ESTIMATE AVERAGES	COST PER SQUARE FOOT	COST PER DWELLING UNIT
Central VRF Heat Pump System	$20.60	$18,200
Unitary Mini-split Heat Pump System	$13.60	$14,900

refrigerants, like heat pumps. ASHRAE Standard 34 limits how much refrigerant can be used within a system based on its size. If the limit is exceeded, the system must be split into smaller loops to avoid very large volumes of refrigerant. This standard has major implications for central systems. Engineers must carefully design refrigerant loops that run through occupied rooms to ensure safety.

Another risk for building owners is technological obsolescence. Scientists are trying to develop refrigerants that are safer for people and the environment, and today's offerings could eventually be phased out. However, when refrigerants have been banned in the U.S. in the past, those regulations applied to new systems, and existing systems were grandfathered in with long timelines for refrigerant service. For example, under the Montreal Protocol, an international agreement to protect the ozone layer, the U.S. began phasing out the ozone-depleting refrigerant R22 in 2003. Today, R22 is still available in limited quantities to service older equipment, and some systems in New York still use it.[23]

Finally, many engineers and climate experts are worried about the global warming potential of refrigerants. This is a valid concern since some refrigerants have 2,000 times the heat-trapping potential of carbon dioxide. Yet methane leaks are also a major source of greenhouse gases that have plagued our natural gas distribution system for decades. Gas utilities are taking steps to reduce leaks, but methane emissions from the U.S. oil and gas industry currently contribute more to global warming than refrigerant leaks on an annual basis.[24] Heat pump manufacturers and installers must seek to minimize refrigerant leaks by following best practices and adding sensors to detect them. Leakage is an issue to overcome, rather than a reason to rule out a heat pump installation.

IMPLICATIONS FOR LANDLORDS AND TENANTS

Rental units make up about two-thirds of New York City's housing stock.[25] With such a large footprint, buy-in from the rental sector is crucial to long-term electrification goals, so heat pump retrofits must make sense for both landlords and tenants.

Tenants may be resistant to heat pumps due to potential disruption from a renovation. Unfortunately, few tenants are aware of the potential benefits of heat pumps, which include improved comfort and control, better air quality, and access to cooling in the summer. But support from this sector turns most significantly on the possibility of having to pay for heating.

Unlike the steam radiators that dominate multifamily buildings today, heat pump systems make it feasible to measure heating use, either with an electricity meter (for unitary systems) or by tracking the flow of refrigerant to an apartment (for central systems). This opens the door for landlords to bill tenants for their actual heating consumption, a practice that's common in Europe, but very rare in New York City.

Shifting this cost to tenants—and in turn, reducing their rent—could be a powerful lever to encourage landlords to install heat pump systems, and provide a much-needed incentive for tenants to stop wasting energy. But current laws complicate the prospects for heat pump retrofits in the rental sector in a number of ways:

- To submeter electric heat from unitary heat pumps, a landlord of market-rate or non-rent-regulated tenants must apply for permission from the Public Service Commission and provide detailed accounting of tenant costs and associated rent reductions. This process is important, but it requires case-by-case consideration and public comment, which could be difficult to administer at scale. Some tenant advocates also question the adequacy of current tenant protections and regulatory oversight for electric submetering.

- By contrast, there appear to be no regulations directly governing submetering of a central heat pump system, which is achieved by tracking refrigerant flow instead of individual electricity use. This regulatory uncertainty could deter owners from choosing central systems, and if they do choose them, it puts market-rate and non-rent-regulated tenants at risk of being dependent on submetering of new heating and cooling technology with insufficient oversight.

- Buildings with at least one rent-regulated unit represent about 40 percent of the city's large multifamily housing stock. Under long-standing New York State Homes and Community Renewal (HCR) policy, landlords are prohibited from billing rent-regulated tenants for heat or hot water. Recent rent law reforms also significantly reduced the amount in capital expenditures that owners can recover through rent increases. And since heat pumps provide air conditioning, owners may be further dissuaded by concern about their ability to increase rents or adjust lease terms to cover the new costs of cooling.[26] Combined, these obstacles may make heat pumps a nonstarter for many building owners in this enormous sector.

- In some privately-owned buildings with subsidized affordable housing, tenants who pay their own utility bills deduct a "utility allowance" from their rent, which is based on a standard monthly cost of heat.[27] For electric heat in New York, that standard amount has historically been based on resistance heating, which is much less efficient and more expensive than heat pumps. That higher deduction penalizes owners who install heat pumps by reducing the net rent they receive from tenants.

Unless these regulatory challenges are addressed, heat pump retrofits in the rental sector will likely lag behind those in owner-occupied buildings, with the potential exception of publicly-owned affordable housing, as discussed in Section 4. Reaching long-term electrification goals depends on policy design that addresses affordability and aligns the interests of both landlords and tenants.

Will Heat Pumps Reduce NYC's Greenhouse Gas Emissions?

Building owners and other stakeholders may be skeptical that widespread heat pump retrofits will actually reduce NYC's greenhouse gas footprint. To dig a little deeper into that question, we considered three factors:

1. Emissions from existing fossil fuel-based systems based on their efficiency and the type of fuel they use,
2. The carbon intensity of NYC's electricity generation, and
3. How well heat pumps perform in New York's climate.[28]

Each of these characteristics can be modeled for a typical multifamily building in New York City.

Most of NYC's multifamily buildings have steam heat systems. This means they have a boiler in the basement that burns natural gas or fuel oil to produce steam, which is then circulated through the building, distributing heat. A typical multifamily building with steam heat uses 49 kBtu/SF of energy for heating, which translates to emissions of 2.6 $kgCO_2e/SF$ for buildings burning gas, or 3.7 $kgCO_2e/SF$ for buildings burning oil.[29] Under Local Law 97, multifamily buildings must emit less than 4.07 $kgCO_2e/SF$ by 2030, so these heating systems leave little to no room for any other energy use. But many of these systems waste a lot of energy, operating at efficiencies potentially as low as 50 percent. Upgrades would improve these systems, but achieving efficiencies greater than 80 percent is difficult.

Even though heat pumps themselves do not burn fossil fuels, New York City gets its electricity from the downstate grid where roughly two-thirds of the electricity is generated by burning oil and natural gas. The final third comes from a combination of nuclear and renewable sources, which emit almost no carbon. That will change in 2021, which is when the last nuclear plant in the downstate area, Indian Point Energy Center in Westchester County, is scheduled to shut down. With the closure looming, gas is predicted to dominate NYC's electricity supply over the next five years. Without Indian Point, the grid is expected to be 22 percent more carbon intensive than it is today. After five years, however, that trend is expected to reverse. Even the most conservative estimates predict a grid that's at least 5 percent cleaner by 2030.[30]

FIGURE 4

Transitioning NYC Buildings to Heat Pumps Cuts Carbon

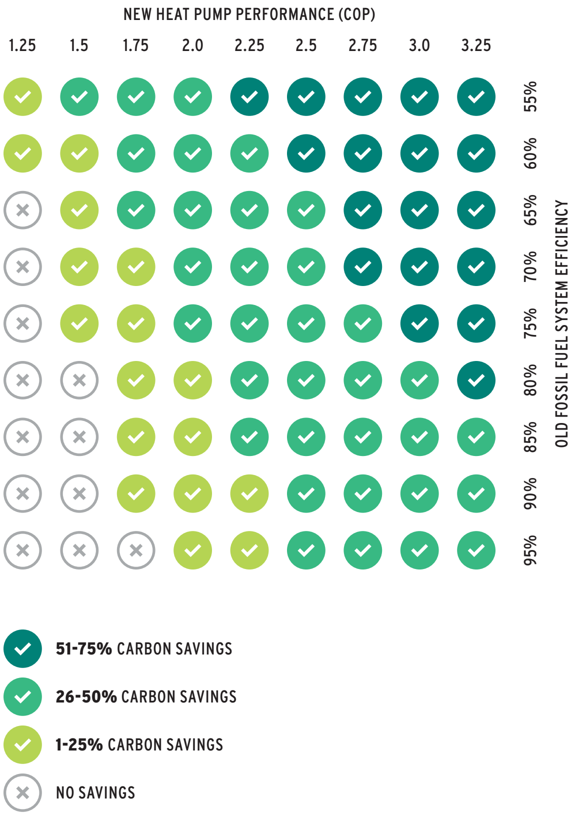
Emissions savings from electrification will vary depending on the efficiencies of the new heat pump systems and the system it's replacing, as well as the evolving makeup of the NYC electric grid. Two grid scenarios below, one dirty and the other cleaner, show the wide range of possibilities that we modeled. But in nearly all cases, emissions will be reduced.

Data: Synapse Energy Economics, Inc. (2017), NYC's Roadmap to 80 X 50

Fossil Fuel Intensive Grid as Gas Replaces Nuclear

Replacing almost any fossil fuel heating system with an industry standard heat pump will reduce carbon emissions, even as the NYC grid becomes more carbon intensive in 2021 when Indian Point closes.

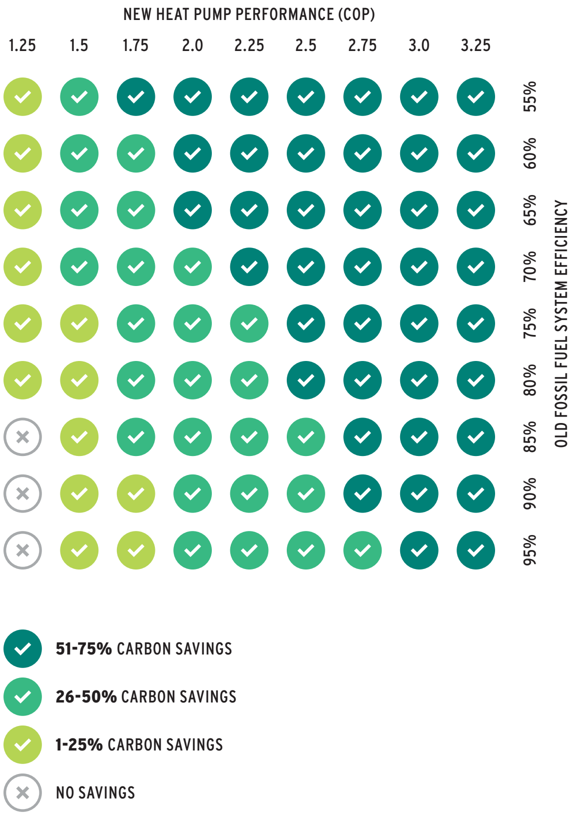
HEAT PUMP EMISSIONS SAVINGS: SHORT-TERM GRID



Cleaner Grid with More Renewable Generation

Once more renewable generation is added to the electrical grid in the 2030s and beyond, the emissions savings associated with heat pump conversions increase significantly.

HEAT PUMP EMISSIONS SAVINGS: LONG-TERM GRID



Finally, heat pump performance must be considered. This can be evaluated by the ratio of energy output to input of a given system, or the coefficient of performance (COP). A higher number means higher efficiency and lower utility costs. The range of heat pump performance is anywhere from 1.25 to 3.25 depending on winter temperatures and the quality of the system. Studies documenting the COPs of unitary heat pumps in Massachusetts, Vermont, and Minnesota during the winter have found that the average heat pump's performance is above 2.0.[31] That means the system generates two units of heat for every single unit of electricity used, or in traditional terms, it is 200 percent efficient. Since those states are even colder than New York, heat pumps should perform equally well or better here.

So where do these three considerations leave us? If New York City's electricity was generated entirely by renewables, heat pump retrofits would be a no-brainer to achieve our carbon goals. But we found that even with the current mix of fossil fuels and renewables that power our grid, multifamily heat pump retrofits could reduce residential emissions by at least 20 percent.[32] In fact, even when electricity is more carbon intensive than it is now, as it may be when Indian Point closes, our models show that heat pumps will reduce emissions in all but the most efficient multifamily buildings (Figure 4). The most common retrofit scenario will be a multifamily building with a steam heat system that's about 75 percent efficient. In this case, a heat pump only needs to perform at a COP of 1.5 to reduce the building's carbon footprint.

This means that buildings with inefficient heating systems, and/or those that burn fuel oil should begin considering heat pump replacements now. After 2025, the grid will get progressively cleaner as New York State moves toward its goals of powering the electric grid with 70 percent renewable energy by 2030, and 100 percent carbon-free energy by 2040.

New York City's mandate to reduce building carbon emissions will eventually necessitate widespread heat pump retrofits, but it's clear that we have work to do before this technology can scale. There is too much uncertainty around how owners will pay for retrofits, what these retrofits will entail, and how to ensure that tenants are protected in the process. In order for electrification to become a feasible and attractive option for the city's residents, NYC's leaders can and should begin dismantling the barriers to heat pumps now.

The final section of this report explores policies and program directions that can be implemented in the next five years to pave the way for heat pump adoption and prepare the city for 2030, when the stricter emissions targets of Local Law 97 kick in.

Heat pumps are new to many building designers, contractors, owners, managers, and operators in New York City. Education and workforce training will be essential.

JUMPSTARTING ELECTRIFICATION

Converting NYC buildings to electric heat will be a decades-long process, but several steps can be taken now to enable a faster, easier, and more efficient transition.

No industry can be transformed overnight. Electrifying heat and hot water systems in New York City's large residential buildings will be a multi-decade effort, and we must begin laying the groundwork now. Over the next five years, we can facilitate this transition through policy design that is supported by utility-sponsored programs and private sector innovation in technology and practice.

In this section we identify nine key action areas that will remove barriers to widespread heat pump retrofits and put the city on track to achieve its ambitious climate targets. In many cases, the City and/or State already has laws or programs on the books that can simply be expanded or adjusted to even the playing field for heat pump adoption.

1 | Demonstrate the Technology

INITIATE PILOT PROJECTS IN CITY- AND STATE-OWNED BUILDINGS

New York City and State have long led by example on green building. The City has implemented voluntary and legislated LEED requirements, energy benchmarking, and aggressive efficiency standards for new construction.[33] Now it should do the same with building electrification.

Government buildings can serve as a proving ground for heat pump technology and complex retrofits. City and State pilot projects would shed light on options and costs for design, equipment, and labor. They would also reveal challenges the private sector might face, facilitate workforce expertise, and demonstrate that heat pumps work as expected.

New York City Housing Authority (NYCHA) apartments are ripe for heat pump retrofits. These campuses have old and inefficient steam heating systems and a severe maintenance backlog. However, they receive lower electricity rates than the private sector and have a dedicated sustainability team that is already implementing a heat pump pilot project. Prioritizing pilots and larger-scale heat pump retrofits in NYCHA buildings will reduce the city's carbon footprint, save money on operations, and help provide cleaner, more reliable heating and cooling for some of the city's most vulnerable residents.

Outside of NYCHA, New York City should also make heat pumps part of its new Deep Energy Retrofit program, which aims to reduce building energy use by 50 percent.[34] The program will be implemented in 37 facilities, nine of which have already been chosen and include schools, homeless facilities, and a museum.

No matter how governments approach these projects, it's crucial that the strategies, costs, and lessons learned get disseminated to the private sector through workshops, case studies, and other outreach.

Pilot projects are a good start, but mandated electrification of public buildings could really move the needle. Some jurisdictions have already started down this path. For example, the Mayor of Seattle recently issued an executive order requiring that all new and substantially altered municipal buildings stop using fossil fuels.[35] In his State of the City address this year, Mayor de Blasio announced a goal to phase out fossil fuels in NYC's large buildings by 2040, starting with government buildings.[36] The New York City Council must consider how and when that target should become law.

CITY AND STATE SUPPORT FOR PRIVATE SECTOR PILOTS

City and State support for private-sector pilot projects is also critical to demonstrating heat pump retrofits in NYC's large residential buildings. NYSERDA's RetrofitNY program has already gotten the ball rolling—three of its six net-zero retrofit projects are located in the five boroughs.[37] The RetrofitNY program should be expanded and specifically seek out projects in larger multifamily buildings. It should also place more emphasis on finding the right candidates for pilot projects and communicating project results to the market.

What makes a good candidate for a heat pump retrofit pilot project in a multifamily building? There are three key characteristics. First, projects in owner-occupied properties will largely avoid issues that arise in rental buildings, such as resistance to submetering and billing directly for heating use. Condo and co-op owners have a vested interest in improving their units, and with electrification they benefit directly from improved comfort, control, and air quality in addition to lower costs after the payback period. Second, properties with expensive energy sources like fuel oil and district steam can lower their utility costs by electrifying their heating. Buildings that use electric resistance heat rank even higher, since they will not require electrical upgrades and will realize big savings from heat pumps. Lastly, buildings with systems that are hard to upgrade should be considered, such as those with one-pipe steam heating systems. These systems are typically inefficient, and there are fewer ways to improve them compared to other heating systems. Three-quarters of multifamily properties have at least one of these characteristics, and nearly 500 have all three, as shown in Figure 5.

2 | Increase Incentives and Promote Transparency

As detailed in Section 3, high up-front cost estimates are likely the single biggest challenge for near-term electrification. Significant increases in government and utility incentive programs are necessary to spur heat pump adoption in large residential building retrofits.

New York State is already working to encourage heat pumps for multifamily retrofits. In a recent breakthrough order, the Public Service Commission directed nearly $500 million to utility-run heat pump incentives through 2025, with programs to be guided by a new statewide heat pump plan.[38] As utilities expand heat pump incentives under this new plan, they must work collaboratively with stakeholders to ensure programs are designed effectively for large residential buildings.

For example, many incentive programs offer rebates, where customers front the cost and are reimbursed afterward.[39] Rebates have historically worked well for consumer appliances, but they're difficult for developers to integrate into financing at the outset of larger projects, potentially limiting their uptake. Direct discounts or upstream incentives that target distributors, installers, or manufacturers may be more effective. Incentive programs can also maximize the benefits of heat pumps by tying them to other retrofits, like building envelope improvements.

Finally, market transformation depends on knowledge-sharing. Both the pilot projects mentioned earlier and incentive programs should have mandatory reporting requirements for recipients, with non-sensitive project details made available in a public database. The Massachusetts Clean Energy Center has successfully implemented such a program and has a public dashboard that communicates costs, products, and service providers.[40]

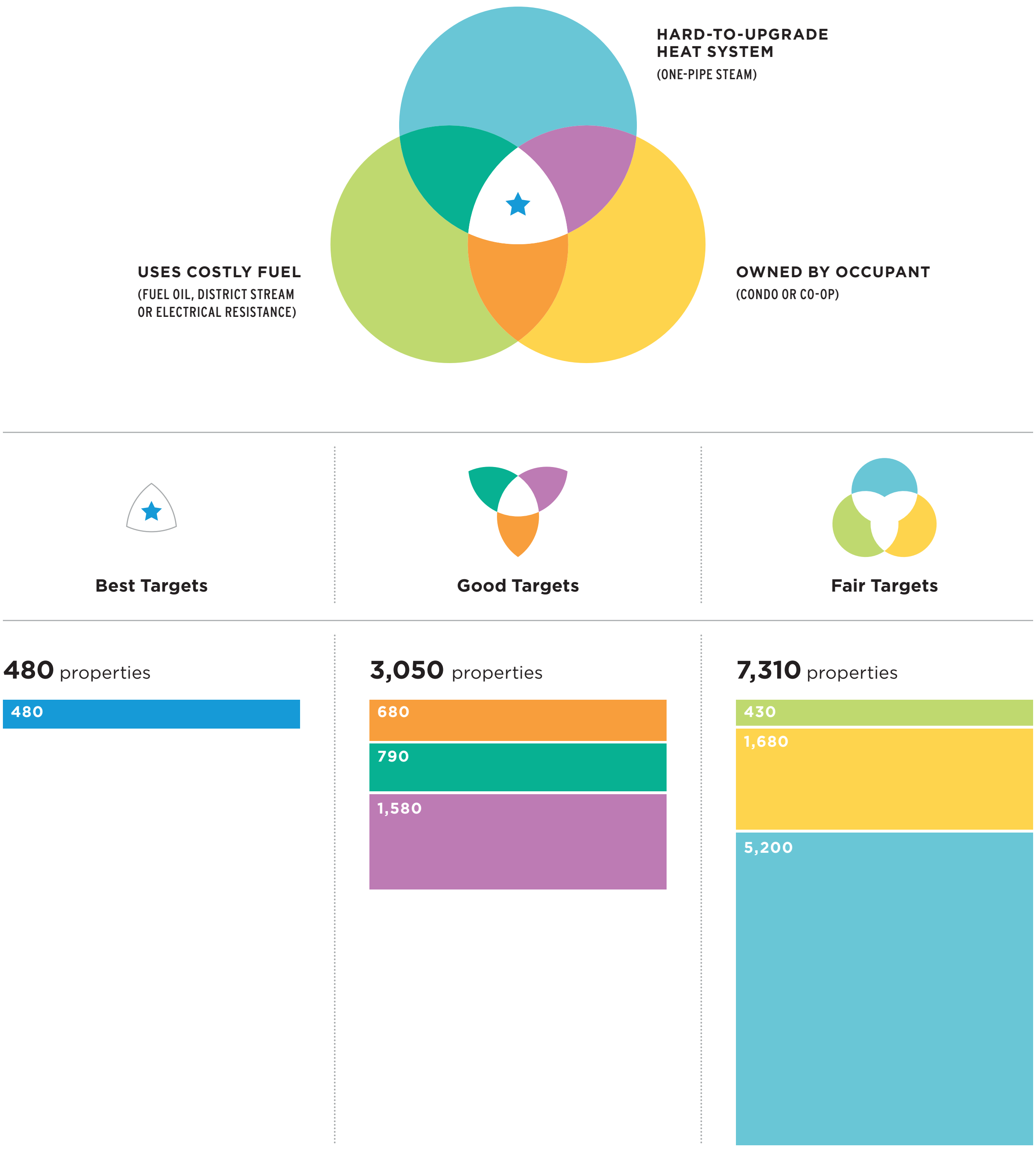
FIGURE 5

Which Buildings Should Electrify First?

The best heat pump conversion targets are owner-occupied buildings with one-pipe steam heat systems that use expensive fuels, representing 3 percent of NYC's multifamily building stock.

Data: PLUTO 2019, LL84 2017, LL87

ELECTRIFICATION PILOT COMPATIBILITY FACTORS



3 Harness Local Law 97 to Drive Electrification

New York City's Local Law 97 of 2019, which sets increasingly stringent carbon emissions limits for buildings starting in 2024, will be a major driver of retrofit activity over the next decade and beyond. The Department of Buildings, which is tasked with issuing rules and setting future emissions limits, should ensure that the law's implementation aligns with the City's long-term electrification goals and makes heat pumps an attractive option for building owners.

One way to do this is by adjusting the law's carbon coefficients. A fundamental feature of Local Law 97 is that every type of building fuel is given a coefficient—a multiplier used to calculate the emissions generated per unit of energy consumed.

For the first compliance period (2024-2029), the carbon coefficient of electricity is based on the 2016 grid. Because of the mix of energy sources powering the grid at that time, this calculation makes electricity the most carbon-intense fuel that a building can use. But as more renewables are added to the grid, that will change. Switching to heat pumps now will still reduce a building's carbon footprint, but heat pumps will appear more attractive if the carbon coefficient reflects the greener grid of tomorrow. To incentivize heat pumps as a longer-term compliance option, the coefficients for future compliance periods should align with New York's mandate to have a carbon-free grid by 2040.

Another approach is to directly incentivize heat pumps by creating a new alternate compliance option. Building owners who choose heat pump retrofits that meet certain criteria could be deemed compliant for a set period of time and not have to worry about making other upgrades.

4 Support Heat Pumps through Better Utility Rates

New Yorkers pay some of the highest electricity rates in the nation. Most Americans pay around 13 cents per kilowatt-hour of electricity used at home; New Yorkers pay closer to 20 cents.[41] The price of natural gas, on the other hand, hovers around one-fifth that of electricity. This makes heat pumps a tough sell, as owners often plan to re-coup building efficiency improvements through lower utility costs.

New York City's utility rate structures were not designed with heat pumps in mind, but there are opportunities to change the way customers are billed for energy use that both encourage heat pump retrofits and allow utilities to take advantage of their benefits to the grid.

At present, residential customers are billed for the total amount of energy they use, no matter when they use it or how much they draw, which doesn't reflect the true cost of generating and delivering electricity. It's much more expensive for utilities to provide electricity during times of peak demand, such as hot summer days when legions of air conditioners are running.[42] To prepare for those days, (and there will be increasingly more of them due to climate change) utilities regularly upgrade their transmission and distribution infrastructure. And when those peak hours hit, the least efficient and most expensive power plants have to fire up in order to keep up.

With those costs in mind, it's in a utility's interest to lower peak demand, and heat pumps can help.[43] First, they deliver more cooling using less electricity than current air conditioners. And unlike the average air conditioning unit compressor that's either on at full power or off, heat pumps are designed to stay on all day and gently ramp up as needed. These advantages will reduce the load on the grid in the summer. If utilities switched to a rate structure that recognized the true cost of energy and incentivized lower and more consistent power demand at peak times, it would give electric customers a justifiable business case to invest in electrification.

Con Edison has already gotten a head start on this. Con Edison customers with heat pumps are eligible for an optional demand-based residential electricity rate that rewards those with lower power needs. Starting in 2020, residential customers who opt into the program will be billed primarily based on their peak power demand in kilowatts. Right now participation is capped at 5,000, unless the customer has a geothermal system. If the optional rate proves to be popular and effective, then it should be made available to more customers.[44]

New York policymakers should also consider opportunities to align rules for gas and electric service connections with City and State decarbonization goals. For example, current natural gas policy encourages gas expansion; utilities are required to hook up new gas customers for free, and the cost of new service is borne by the entire customer base. Subsidizing new gas service may not make sense with a growing policy emphasis on building electrification.

5 | Enable Electrification in Affordable Housing

While NYC can lead on electrification in public housing, other types of affordable housing will face significant barriers. Private buildings with rent-regulated units, which make up about 40 percent of the city's large multifamily building area, are perhaps the most challenging to electrify.[45] Building owners in this sector face two regulatory barriers that make the cost of heat pumps much harder to justify.

First, new rent laws passed in July 2019 that were designed to protect rent-regulated tenants from undue rent hikes significantly restrict owners from increasing rents to recoup the costs of capital investments like heat pumps. Second, as noted in Section 3, heat pumps make it easier for landlords to submeter and bill tenants for their heating use. However, New York State Homes and Community Renewal prohibits landlords from charging rent-regulated tenants for heat or hot water in virtually all circumstances, even if rents are reduced to compensate for the added cost.

Given these barriers, the rent-regulated sector will need special attention in order to make heat pumps workable for both landlords and tenants. A joint City and State effort should assess how to spur electrification in this sector, first by evaluating whether it will be necessary to allow building owners to submeter and bill for heating. If so, policymakers must develop a process that's fair to tenants and works at scale, including a methodology to calculate appropriate rent reductions, adequate oversight of submetering and billing, and necessary tenant protections to ensure heat isn't cut off for missed payments.

In another type of privately-owned affordable housing—units supported by Section 8 federal rent subsidies—landlords can bill tenants for heating use. As noted in Section 3, the owners of these units face a different challenge: an outdated program for heat and hot water costs known as "utility allowances."[46] In Section 8 housing, if tenants pay their own utilities, they are allowed to deduct a standard amount from their monthly rent based on the type of heating system and the size of their apartment.

Historically, the standard monthly deductions for electric heat in New York City and State have been based on electric resistance heat, which is less efficient and much more expensive to run than a heat pump. If an owner installs heat pumps, tenant rent deductions would be much more than the actual cost of heating, and the owner would lose money. Updating these utility allowances with a heat pump-specific deduction should help open the door to electrification for this sector.

6 | Start Electrifying One Step at a Time

Heat pump retrofits are logistically challenging. One way to make the cost and disruption easier to swallow is to spread the retrofit work out over time with incremental upgrades. There are several options for multi-phase heat pump retrofits. Owners can electrify just hot water, retrofit one part of the building at a time, or upgrade buildings systems to be "heat pump-ready."

Hot water heat pump retrofits are smaller in scope and less invasive than electrifying a building's space heating. In most cases, the work will be confined to the basement and outside of the building, since the piping to deliver the hot water is already in place. The only limiting factors are cost and space, since hot water heat pumps require large storage tanks to ensure the system can meet peak demand. Most hot water systems call for thermal storage, but a heat pump system may necessitate something larger to provide a buffer on the coldest days. If owners do choose to electrify their hot water system, it may make sense for them to leave the existing hot water heater in place as a back-up for very cold days. These retrofits come with an additional benefit—hot water heat pumps can be designed to also provide common area space cooling during the summer.

CASE STUDY

Capturing the Heat from Wastewater

This report focuses on air-source heat pumps, but water-source heat pumps, which draw heat from water rather than air, could also benefit multifamily buildings. Each year, NYC multifamily buildings use over 50 gallons per square foot of water for showers, sinks and toilets. All of that water flows into the sewer system at temperatures much warmer than winter air.

Large amounts of heat could be extracted from wastewater in sewers with wastewater heat recovery technology that utilizes heat exchangers and heat pumps. However, accessing sewers without interfering with sewage treatment could be technically complicated and require review by many government agencies.[47] *A simpler and cheaper option is to tap into a building's wastewater before it reaches the sewer. This requires a large tank in the basement to collect and store wastewater long enough for a heat pump system to capture the heat and transfer it into the domestic hot water tank. Thus, the heat is recycled within the building.*

This technology has already been installed in multifamily buildings throughout North America and is a cost-effective method for reducing hot water energy use that typically offsets 20 to 40 percent of a building's overall hot water demand. The fuel savings will depend on a building's water use and tank size, but could approach 30 percent for larger and denser multifamily buildings.[48]

Image: *A wastewater heat recovery system in Vancouver. Photo courtesy of Lynn Mueller.*

Hot water heat pump retrofits are meaningful first steps, but since the fuel used to generate hot water is typically less than one-third of a building's overall fuel use, they won't result in the deep decarbonization that will eventually be necessary. However, these retrofits can yield additional savings if they are installed in tandem with wastewater heat recovery systems.

Another option that may be more accessible than a full-building retrofit is to electrify the space heating in phases. Some spaces within multifamily buildings may lend themselves to conversion first. For example, it may be easier to install unitary heat pumps in common areas and apartments on lower floors, since the outdoor units could be placed on the ground. Starting with the lower floors of a building has the added benefit of bringing cooling to offices, lobbies and recreational areas that previously might have overheated in summer.

Alternatively, owners of buildings with steam heat systems can make them "heat pump-ready" by converting to hot water, or hydronic, heating systems. This is a simpler retrofit than installing heat pumps, and has the potential to reduce building energy use by as much as 40 percent—primarily because hydronic systems operate at a lower temperature. Unlike with steam heat, it is easy to identify and fix leaks in hydronic systems, which also improves efficiency.[49]

Heat pumps are not powerful enough to replace boilers in steam heat systems, but they are capable of reaching the temperatures required to fuel a hydronic system. If building owners convert to hydronic systems first, they can eventually replace the boiler with large central heat pumps. Ideally, the heat pumps would be the final step for the building to become carbon-free. Thus, two major capital improvements would be made, saving carbon and managing costs over time.

7 | Identify Electrical Infrastructure Needs

Most of New York City's multifamily properties were built before 1940, so their electrical systems were designed for a time before widespread cooling and refrigeration. As discussed in Section 3, adding the burden of electric heating to these buildings could be a shock to their circuits. Engineers first need to know a building's electrical capacity in order to design a heat pump system that will not overload the existing wiring and electrical equipment.

In New York, city planners and building designers have little insight into multifamily building electrical capacity or the number of buildings that might need upgrades. In order to plan for heat pump retrofits, data on building electrical capacity should be collected and assessed. The City already has a law that requires owners to periodically hire experts to inventory or audit their building systems and report the findings to the City.[50] Simple changes to this law could drastically improve our understanding of electrical upgrade needs.

These audits are conducted by engineers or architects to identify which heating, cooling, and other systems a building uses in order to suggest improvements. The law does not require that any information on electricity infrastructure be collected. At a minimum, the reporting requirements should be expanded to include the electrical capacity running to apartments in multifamily buildings. This would only require visiting a few units in each building and determining the amperage rating of their circuit panels. It would also be helpful for auditors to collect the amperage rating of the building's common switches.

This data will be valuable for more than just heat pumps. Electrification also means replacing gas stoves with induction stoves and installing electric vehicle chargers. If heat pumps alone don't push a building's electrical capacity over the edge, these other changes almost certainly will. Capacity upgrades are expensive, and most multifamily properties will need them to fully electrify. More information is needed to plan and estimate the costs for this work across the city.

8 | Ramp Up Workforce Training

While heat pumps aren't new technology, they are new to many building designers, contractors, owners, managers, and operators in New York City. Education and workforce training are essential to ensure that heat pumps are adopted at scale.

Building design teams need to be more conversant in heat pump technology and know how to approach and execute retrofits for heating, cooling and hot water. Effective retrofits require a holistic approach with consideration for envelope improvements, electrical upgrades, and equipment sizing. For example, if electrification is paired with window upgrades and new insulation, designers can choose a smaller heat pump system that requires less electrical power. This will drive down costs while ensuring that the system achieves the desired thermal comfort.

Proper execution is equally important. Heat pump installations are complex, and each step of the process must be followed carefully.[51] HVAC contractors need training on best practices for mounting equipment above typical snow levels, laying out the line sets, connecting and pressure testing refrigerant tubes, and refilling the system with refrigerant. Quality pipe connections are vital to ensuring that these systems do not leak or suffer from poor performance. When systems break down or need to be refilled, poor pipe connections are usually to blame.

Larger residential systems will also need to be commissioned, or inspected by an independent expert. Design engineers need to understand how to work with independent commissioning agents to get new heat pump systems up and running quickly. Building operators must learn basic troubleshooting and ongoing maintenance procedures, such as replacing the filters in indoor units.

Training programs should begin now to ensure that all relevant professions will be able to serve a growing demand for heat pump retrofits. Manufacturers must play a strong role in implementing trainings, as installation procedures vary between makes and models. Unions are also well-suited to offer training for incumbent workers.

NYSERDA's expanded Workforce Development and Training Investment Plan will jumpstart heat pump education with new funds for curriculum development, training for contractors and heat pump installers, and support for HVAC career pathway initiatives.

9 | Launch a Building Electrification Campaign

Implementing heat pump retrofits across NYC's large residential buildings will be a long-term challenge and mark a historic transition. Disparate or ad-hoc policy approaches will not be enough. In order to truly sell New Yorkers on this shift, and to unify the eight steps discussed above, the City should develop a comprehensive outreach program to promote heat pumps for multifamily buildings.

The NYC Clean Heat program was launched in 2012 to phase out the use of dirtier heating oil in buildings, with a strong focus on improving air quality and public health.[52] The program, which is now administered by the City's Retrofit Accelerator, assists owners with the transition to cleaner heating fuels. Now that Local Law 97 is in place with a new mandate to reduce building emissions, a building electrification campaign could be the natural evolution of NYC Clean Heat—or an entirely new effort.

Either way, a large-scale, public-facing electrification program could engage building owners and help them navigate the process, educate residents on the benefits of heat pumps, and generally facilitate this critical transition. Ideally it would provide a unifying framework and dedicated staff to coordinate policy across city departments, as well as work with utilities, NYSERDA, and other agencies on the Statewide Heat Pump Implementation Plan.

The program should place a high priority on electrifying buildings in low-income communities where retrofits have lagged, and where heat pumps can deliver significant health and comfort benefits in addition to emissions savings. This would be in line with the Climate Leadership and Community Protection Act, which mandates that the state direct at least 35 to 40 percent of the program's benefits to disadvantaged communities.

It is essential that we begin taking action now to ensure that heat pumps become a viable option for large multifamily buildings. Building electrification, paired with a greener electric grid, is crucial to reducing carbon emissions from the building sector and meeting the City's Local Law 97 goals.

But as we've noted, reducing New York's contribution to global warming is not the only impetus for this transition. Replacing oil and gas boilers with heat pumps will improve air quality in buildings and neighborhoods throughout the city. Residents will gain more control over the temperature in their apartments and be more comfortable. More New Yorkers will have access to air conditioning, which is increasingly becoming a public health necessity as summer temperatures rise.

The recommendations in this report are designed to address known technical, regulatory and financial obstacles currently preventing building owners from investing in heat pumps. Each one will produce meaningful gains in the near term, while helping to prepare the city for the heating revolution to come.

NOTES

1 Local Law 66 of 2014 requires New York City to reduce citywide carbon emissions 80 percent below 2005 levels by 2050. Current progress is based on emissions from the 2005 and 2017 NYC Greenhouse Gas Emissions Inventory.

The New York City Mayor's Office of Sustainability. ***Inventory of New York City Green House Gas Emission***. https://nyc-ghg-inventory.cusp.nyu.edu/#archive

2 Over 80 percent of large multifamily buildings use steam heat, and as a sector, these buildings are responsible for at least 25 percent of NYC building emissions. Roughly 14,000 properties emitted over 8M metric tons of CO_2e in 2017 (Based on Urban Green Council's preliminary analysis of the 2017 benchmarked energy and emission data from multifamily properties larger than 25,000 SF).

3 Heat pumps have been installed in homes throughout the northeastern U.S. Northeast Energy Efficiency Partnerships (NEEP) has published a specification and product list for these cold climate air-source heat pumps. That list includes thousands of products that achieve a COP of 1.75 while operating at maximum capacity and an outdoor temperature of 5 degrees F.

Northeast Energy Efficiency Partnerships. (2019). ***Cold Climate Air-Source Heat Pump Specification (Version 3.0)***. https://www.neep.org/sites/default/files/ColdClimateAir-sourceHeatPumpSpecification-Version3.0FINAL_0.pdf

4 About 70 percent of this fuel is used for heat, according to the Technical Working Group Report of 2016. The actual emissions are based on the 2017 NYC GHG Inventory; buildings used roughly 4 TBtu of natural gas and fuel oil source energy while transportation used 2.2 TBtu of gasoline and diesel source energy. The residential sector, including multifamily and single family homes, emitted 11.9M tonnes of carbon from fossil fuels and 15.8M tonnes overall.

The New York City Mayor's Office of Sustainability. (2016). ***One City Built to Last: Transforming New York City Buildings For A Low-Carbon Future***. http://home2.nyc.gov/html/gbee/downloads/pdf/TWGreport_2ndEdition_sm.pdf

5 Based on Urban Green Council's ***Demystifying Steam: Smaller Buildings*** research, nearly 39,000 small, 6,600 medium and 6,400 large multifamily properties use steam heat in NYC. That's around 85 percent of residential buildings larger than 5,000 SF.

Urban Green Council. (2019). ***Demystifying Steam: Smaller Buildings***. https://www.urbangreencouncil.org/content/projects/demystifying-steam-smaller-buildings

6 The four thermodynamic stages of the vapor compression cycle are compression, condensation, throttling, and evaporation. Many different chemical compounds can serve as refrigerant, including carbon dioxide (CO_2) and ammonia (NH_3).

7 NYSERDA's Multifamily Programs have provided funding to 31 affordable housing new construction projects that indicated air-source heat pumps would be installed as the main heating and cooling systems.

8 ***Demystifying Steam: Smaller Buildings*** predicted that 84 percent of medium and 80 percent of large multifamily buildings use steam heat, based on a machine learning model. Overall, 82 percent of medium and large multifamily properties likely use steam heat.

9 Water-source systems, other than the boiler/tower configurations, require a river, lake or ocean nearby and ground-source heat pumps require expensive and challenging onsite drilling. This report considers modern, inverter-driven, and cold-climate air-source heat pumps. Older heat pump technologies, such as packaged-terminal heat pumps, are not considered here due to their poor performance at colder temperatures.

10 These systems deliver heat directly to indoor units without duct work, they are small in capacity (mini), and their indoor and outdoor units are separate (split). Multi-splits work similarly but use one outdoor unit to serve multiple indoor units at various setpoints. They are popular in single family homes throughout the United States: www.energy.gov/energysaver/heat-pump-systems/ductless-mini-split-heat-pumps

11 The two most common types of connections for refrigerant lines in heat pump systems are flared and brazed. Flared connections are simpler to make and much more common. They are made by using a tool to stretch the pipe opening out, and then tightening a bolt against the pipe flare and a matching fitting. Brazed connections are made using a high-temperature torch to fuse the metal surfaces together with a brazing alloy, but these require skilled contractors that usually work on very large projects.

12 New York State Energy Research and Development Authority. (2014). ***Heat Pumps Potential for Energy Savings in New York State***. https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/EERE-Potential-Studies

13 Experimental research studies of heat pumps operating in occupied buildings have confirmed that air-source pumps meet the capacities specified by manufacturers.

Schoennauer, B., Kessler, N., Bohac, D., & Kushler, K. (2016). ***Field Assessment of Cold Climate Air Source Heat Pumps***. Center for Energy and Enviroment., & American Council for an Energy-Efficient Economy. https://www.aceee.org/files/proceedings/2016/data/papers/1_700.pdf

14 Current is the rate at which electrical charge flows between points, and voltage is the difference in charge between points. Current is similar to the flow of water through a tube, and voltage is like the pressure behind that flow. Power is the product of these quantities. Current can be determined by dividing the power by the voltage needed by an appliance.

15 Taitem Engineering conducted a survey of electrical configurations in 42 buildings, 24 in NYC and 18 upstate.

Shapiro, Ian. (2019, Oct. 22). ***Electrical Service Capacity for Air Source Heat Pump Conversions [Conference session]***. Multifamily Summit. Summit conducted by New York State Energy Research and Development Authority, New York City.

16 This example would probably not pass the current electrical code (NFPA 70 - NEC). The National Electric Code has minimum ampacities for circuits based on continuous loads, non-continuous loads, and other factors.

17 Urban Green analyzed the 2019 power demand from smart meter data from 12 direct-metered apartments, 9 in NYC and 3 in Westchester County. Taitem Engineering conducted an analysis of multifamily electrical demand on 26 buildings, 17 in NYC and 9 upstate. Those peak demands were divided by the number of apartments and include common area loads like lighting and elevators.

Taitem Engineering conducted a survey of electrical configurations in 42 buildings, 24 in NYC and 18 upstate.

Shapiro, Ian. (2019, Oct. 22). ***Electrical Service Capacity for Air Source Heat Pump Conversions [Conference session]***. Multifamily Summit. Summit conducted by New York State Energy Research and Development Authority, New York City.

18 The buildings range from 15,000 SF co-ops to high-rises larger than 300,000 SF. All work was proposed in New York City within the last ten years on buildings at least 45 years old. Building characteristics and cost estimates have been modified to maintain confidentiality.

19 Most modern heat pumps, central or unitary, vary the flow rate of the refrigerant in the system—hence the acronym VRF. In central systems, the VRF label also indicates that the system is capable of heat recovery. That allows the system to move heat from one space to another within the building, which is extremely useful and efficient if some spaces need cooling while others need heating.

20 For example, in a residential building with a gym, the gym may need cooling in winter, while apartments need heat. With some additional equipment and controls, central VRF heat pump systems can move heat from the gym and use it to warm apartments.

21 Based on 2019 energy prices and average equipment efficiencies, heat pumps are currently 20 percent more expensive to operate in NYC than a steam heat system using natural gas. But they are less expensive to run than steam heat systems that use fuel oil or other expensive sources of energy.

22 Ecosystem Energy Services has installed over 300 Heat Pump systems in cold climates like Canada. Only a few have required a full refrigerant charge (~1%). In their 26 years of experience, Ecosystem estimates that annual refrigerant leakage rates were between 0.5-2% for well-installed systems, in line with the LEED standard.

23 The Montreal Protocol was originally created in 1987 to limit the use of Chloroflurocarbons (CFCs). That agreement was updated in 2016 with the Kigali Amendment which limits Hydrofluorocarbons (HFCs), including many common refrigerants used today like R134a and R410a.

24 The American oil and gas sector leaked methane equivalent to 203.3 million metric tons of carbon based on 2017 EPA estimates from the Inventory of U.S. Greenhouse Gas Emissions and Sinks. Fluorinated refrigerants (HFCs) were responsible for 168.7 million metric tons. Recent research suggests that actual methane emissions are 60 percent higher than the existing EPA estimates.

Zavala-Araiza, Daniel, Lyon, David R., Allen, David T., Barkley, Zachary R., Brandt, Adam R., Davis, Kenneth J., Herndon, Scott C., Jacob, Daniel J., Karion, Anna, Kort, Eric A., Lamb, Brian K., Lauvaux, Thomas, Maasakkers, Joannes D., Marchese, Anthony J., Omara, Mark, Pacala, Stephen W., Peischl, Jeff, Robinson, Allen L., Shepson, Paul B., Sweeney, Colm, Townsend-Small, Amy, Wofsy, Steven C. & Hamburg, Steven P. (2018). ***Assessment of methane emissions from the U.S. oil and gas supply chain***. Science, 361(6398), 186-188. 10.1126/science.aar7204. https://science.sciencemag.org/content/361/6398/186

25 NYC Rent Guidelines Board. (2019). ***2019 Housing Supply Report***. https://rentguidelinesboard.cityofnewyork.us/wp-content/uploads/2019/08/2019-HSR.pdf

26 Owners of rent-regulated housing can apply for temporary rent increases of up to two percent per year to recover the costs of building-wide major capital improvements (MCI) if the building contains more than 35 percent rent-regulated apartments. When an owner installs a new appliance, the owner may also be entitled to a rent increase called an Individual Apartment Increase (IAI), but no more than three IAI increases are allowed over 15 years. The total cost over that time cannot exceed $15,000 and the amount of the rent increase is at most 1/168th the cost of the improvement. When new services are added, such as central air conditioning, an owner can also apply to HCR for a modification to lease terms to charge tenants for that new service. For additional detail see HCR Fact Sheet #26.

New York State Division of Housing and Community Renewal Office of Rent Administration. (2019). ***Fact Sheet #26 Guide to Rent Increases for Rent Stabilized Apartments***. https://hcr.ny.gov/system/files/documents/2019/10/fact-sheet-26.pdf

27 Utility allowances apply to housing in the Section 8 Housing Choice Voucher program regulated by the U.S. Department of Housing and Urban Development.

28 A major factor in heat pump carbon savings was not included in our model—refrigerant and gas leakage. This simplification was made for two reasons. First, no reliable measurements of refrigerant leakage from heat pumps are available yet, but collecting this information would be a valuable exercise. Second, fugitive emission leaks of natural gas from transmission and distribution pipelines also cause global warming, and new research has found natural gas is a more important factor in climate change than previously thought.

Our assumption is that these two sources of greenhouse gases are roughly equal and can be ignored for this comparison.

Hmiel, B., Petrenko, V.V., Dyonisius, M.N. et al. ***Preindustrial 14CH4 indicates greater anthropogenic fossil CH4 emissions***. Nature, 578, 409–412 (2020). https://doi.org/10.1038/s41586-020-1991-8

29 These are carbon intensities. Higher numbers indicate more carbon is emitted per square foot of building area. Our calculations use the EPA's carbon coefficients for fuel, which are 0.054 kg/kBtu for natural gas and 0.075 kg/kBtu for number 2 fuel oil.

30 A 2017 report by Synapse Energy Economics estimated that Indian Point's generation will be replaced by roughly equal portions of natural gas, wind and energy efficiency. The emissions from the additional 5,100 MWh of downstate gas-fired generation in 2022 were based on existing gas plant emission rate of 0.502 tonnes CO_2e/MWh. The 2030 electricity emission intensity was taken from the high carbon scenario in NYC's ***Roadmap to 80 X 50***.

Synapse Energy Economics, Inc. (2017). ***Clean Energy for New York***. https://www.synapse-energy.com/sites/default/files/Clean-Energy-for-New-York-16-121.pdf

The New York City Mayor's Office of Sustainability. (2016). ***New York City's Roadmap to 80 X 50***. https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/New%20York%20City's%20Roadmap%20to%2080%20x%2050_20160926_FOR%20WEB.pdf

31 Figures 54 and 55 from a 2016 report by The Cadmus Group show the Average Heating COP vs Outdoor Air Tempuratures for ductless mini-split heat pumps.

The Cadmus Group, Inc. (2016). ***Ductless Mini-Split Heat Pump Impact Evaluation***. http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Mini-Split-Heat-Pump-Impact-Evaluation.pdf

Figure 3 from a 2017 report by The Center for Energy and Enviroment and the American Council for an Energy-Efficient Economy shows the COP vs Outdoor Air Tempurature for a cold climate air source heat pump.

Center for Energy and Enviroment., & American Council for an Energy-Efficient Economy. (2017). ***Cold Climate Air Source Heat Pump***. https://www.mncee.org/MNCEE/media/PDFs/86417-Cold-Climate-Air-Source-Heat-Pump-(CARD-Final-Report-2018).pdf

32 Based on 2017 LL84 Energy and Water Data Dislosure and NYC GHG Inventory data, heat pumps could cut 3 million metric tons of carbon from medium and large multifamily building emissions. We assumed that all properties electrify heat and hot water resulting in an average of 41 percent cut in natural gas emissions and 57 percent cut in fuel oil emissions.

The New York City Mayor's Office of Sustainability. (2017). ***Greener, Greater Buildings Plan: LL84 Benchmarking: Data Disclosure & Reports***. https://www1.nyc.gov/html/gbee/html/plan/ll84_scores.shtml

The New York City Mayor's Office of Sustainability. ***Inventory of New York City Green House Gas Emission***. https://nyc-ghg-inventory.cusp.nyu.edu/#archive

33 See Local Law 31 of 2016 requiring new NYC buildings to reduce energy use by 50 percent below either the energy code or the median energy use of similar buildings: https://legistar.council.nyc.gov/LegislationDetail.aspx?ID=2240482&GUID=0A9A548C-E3D9-4057-AEAC-426CA033FBBF

34 Nine of the 37 projects have been identified. Some projects are undergoing review for electrification opportunities, but it is not clear how many, if any, will ultimately include heat pump retrofits.

The City of New York Office of the Mayor. (2019, Sep. 25). ***Administration Announces City Facilities to Undergo Deep Energy Retrofits to Reduce Energy Use and Emissions***. https://www1.nyc.gov/office-of-the-mayor/news/443-19/de-blasio-administration-city-facilities-undergo-deep-energy-retrofits-reduce

35 Office of the Mayor City of Seattle. (2020, Jan.). ***Executive Order 2020-01: Advancing a Green New Deal for Seattle***. https://durkan.seattle.gov/wp-content/uploads/sites/9/2020/01/Final-Executive-Order-2020-01-Advancing-a-Green-New-Deal-for-Seattle_.pdf

36 The City of New York Office of the Mayor. (2020, Feb. 6). ***State of the City 2020: Mayor de Blasio Unveils Blueprint to Save Our City***. https://www1.nyc.gov/office-of-the-mayor/news/064-20/state-the-city-2020-mayor-de-blasio-blueprint-save-our-city#/0

37 NYSERDA RetrofitNY. ***New York's Net-Zero Pioneers***. https://www.nyserda.ny.gov/All-Programs/Programs/RetrofitNY/All-RetrofitNY-Articles/New-York-Net-Zero-Pioneers

38 State of New York Public Service Commission. (2020, Jan. 16). ***CASE 18-M-0084 - In the Matter of a Comprehensive Energy Efficiency Initiative: Order Authorizing Utility Energy Efficiency and Building Electrification Portfolios Through 2025***. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={06B0FDEC-62EC-4A97-A7D7-7082F71B68B8}

New York State Department of Public Service. (2020). ***NYS Clean Heat Statewide Heat Pump Program Implementation Plan (Item No. 227)***. http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?Mattercaseno=18-M-0084

39 Northeast Energy Efficiency Partnerships. (2019). ***Air-Source Heat Pump Program Incentive Summary***. https://neep.org/sites/default/files/resources/2019ASHPProgramSummaryUpdatedFeb2019.pdf

40 Massachusetts Clean Energy Center. ***Cost of Residential Air-Source Heat Pumps***. Median cost of heat pump installations in Massachusetts are roughly $3,700 per ton of capacity. Retrieved February 2020 from https://www.masscec.com/cost-residential-air-source-heat-pumps

41 U.S Bureau of Labor Statistics. ***Average Energy Prices, New York-Newark-Jersey City–November 2019***. Retrieved February 26 2020 from https://www.bls.gov/regions/new-york-new-jersey/news-release/averageenergyprices_newyorkarea.htm

42 The New York Independent System Operator (NYISO) and utilities have developed a framework for charging commercial and industrial customers based on their contribution to peak demand. NYISO assigns an (ICAP) tag on electricity users to determine their contribution to those requirements.

New York Independent System Operator. (2019, Sep.). ***Manual 4 Installed Capacity Manual***. https://www.nyiso.com/documents/20142/2923301/icap_mnl.pdf/234db95c-9a91-66fe-7306-2900ef905338

43 Heat pumps will benefit electric utilities in the short term, but over the next few decades, as they become more popular, they will shift building electrical demand to a winter peak, which will require substantial changes for utilities and electricity generation.

44 This demand-based rate was designed based on the rate structure of SC1 Rate IV and includes a monthly customer charge of $27. That is the full cost attributed in the ECOS study and higher than other residential rate customer charges. Con Edison has published the full details of all rates here:

Consolidated Edison Company of New York, Inc. ***Cases 19-E-0065 and 19-G-0066 ELECTRIC RATE SUMMARIES AND ESTIMATED BILL IMPACTS FOR RATE YEARS 1 TO 3***. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B8D822760-7BED-4108-B871-518D6522DA11%7D

45 Includes rent-controlled and rent-stabilized units regulated by NYS Homes and Community Renewal.

New York State Division of Housing and Community Renewal Office of Rent Administration. (2019). ***Fact Sheet #1 Rent Stabilization and Rent Control***. https://hcr.ny.gov/system/files/documents/2019/09/FACT%20SHEET%2001_0.pdf

46 Utility allowances apply to housing in the Section 8 Housing Choice Voucher program regulated by the U.S. Department of Housing and Urban Development. Standard deductions are set by public housing regulatory authorities, including the NYC Department of Housing Preservation and Development and the New York City Housing Authority.

47 With no existing sewer-level WWHR projects in New York City, the regulatory pathway to successful installation is both uncertain and challenging. Our research did not identify any prohibitions or explicit New York City or New York State regulatory requirements directly addressing sewer-level WWHR. This technology is new territory for NYC DEP, though the energy management staff has discussed the possibility of an installation with at least one consultant and one equipment manufacturer. NYC DEP has also consulted with a representative from the District of Columbia, which has installed one sewer-level WWHR project.

48 These products are available on the market as packaged combinations of heat exchangers and heat pumps that enable in-building WWHR. Multifamily properties use units of 5 to 10 tons in size that require 750 to 1500 gallons of wastewater storage capacity and can supply water at around 140 degrees F. We assumed an average COP of 4 based on manufacturer ranges of 3 to 5 on performance curves.

49 Taitem Engineering projected that steam to hydronic conversions would cut energy use by 31 percent, but completed retrofits on four buildings ended up saving over 40 percent on average.

Shapiro, Ian. (2010, May). ***Water & Energy Use in Steam-Heated Buildings***. ASHRAR Journal. https://www.taitem.com/wp-content/uploads/SteamBoilerReplacements.pdf

50 Local Law of New York City for the Year 2009 No.87 (LL87 of 2009). http://www.nyc.gov/html/planyc2030/downloads/pdf/ll87of2009_audits_and_retro-commissioning.pdf

51 NEEP offers an air-source heat pump installation guide and the North American Technician Excellence certification program helps contractors learn these procedures and offers testing and certification for air-source heat pump installers.

Northeast Energy Efficiency Partnerships. ***Air Source Heat Pump Installer and Consumer Resources***. https://neep.org/initiatives/integrated-advanced-efficiency-solutions/air-source-heat-pumps/air-source-heat-pump#Installer%20Guides

North American Technician Excellence. ***Air-To-Air Heat Pumps Service Certification***. https://www.natex.org/Portals/_Appleseed/images/default/kate_hpsv.pdf

52 In April of 2011, the New York City Department of Environmental Protection (DEP) issued regulations requiring buildings to convert from No. 6 and No. 4 heavy heating oils to cleaner fuels. The deadline for the phase out of all No. 6 heating oil was June 30, 2015, and the deadline for the phase out of all No. 4 heating oil is January 1, 2030.

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New York has $3 trillion of insured coastal property vulnerable to hurricanes and sea level rise. Widespread adoption of heat pumps can play an important role in reducing our emissions and protecting residents from the effects of climate change.

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