Buildings

HOW CAN WE RADICALLY IMPROVE EFFICIENCY IN NYC'S BUILDING STOCK?

June 29th, 2017

GETTING NYC TO

80X50

A policy forum series on NYC'S 2050 goal to reduce greenhouse gas emissions by 80% from 2005 levels

Prepared by Byron Stigge and Adam Hinge for the New York League of Conservation Voters Education Fund

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EXECUTIVE SUMMARY

In September 2014, Mayor de Blasio announced that New York City would continue its leading role in addressing climate change by committing to reducing greenhouse gases (GHG) 80 percent by 2050 (80x50). Since then, the City and numerous other stakeholders have done a tremendous amount of work to understand paths to achieve the deep carbon emissions reductions that scientists advise are necessary to limit global temperature rise to less than 2˚C. The work to date culminated in the City's *Roadmap to 80x50*, released in September 2016. Because the City's more than one million buildings cover more than five billion square feet and are responsible for 68% of citywide GHG emissions[1], dramatic changes to building energy systems and operations will be needed to reach the target. The analyses make clear that the pathways to attain 80% carbon reduction will require substantial changes in how buildings use energy.

The Roadmap presents an audacious target, aimed at driving major changes to the way buildings use energy, particularly in heating. The technical analysis and comprehensive approach highlighted in the Roadmap are demonstrations of NYC's global leadership, and in many ways, the Roadmap demonstrates a plausible path to achieve 80x50. In fact, the proposed approach is a compelling demonstration that existing, proven technologies can get us to 80x50.

However, despite the technical rigor of the Roadmap and the Technical Working Group Report, much less analysis has been presented on the economic, policy, and implementation hurdles of the proposed strategies. The effectiveness of policy activity to improve buildings' energy and emissions performance has been somewhat mixed, and building performance has not improved as rapidly as projected in earlier analyses. Achieving the target will require a mix of regulations, incentives, public support, and other activities to drive innovation and change more quickly than the historic rate of change for building systems. Significant investment and cost burdens will be required among a broad variety of stakeholders, and developing a methodology to fairly distribute the burden of effort and cost must be part of future planning processes.

The City's 80x50 target is very ambitious and has stimulated great interest in finding innovative and pragmatic ways to move toward the imperative of dramatically reduced emissions. This paper identifies hurdles that need additional attention – but 2050 is still a long way off. The 33 years between now and 2050 will allow for investment and innovation across sectors that will help us realize this goal, and many stakeholders are motivated to rise to the challenge. Considering the global imperative to solve 80x50, leadership is needed to convene the broadest possible group of stakeholders and experts to build not just a roadmap, but the road itself.

1 New York City's Roadmap to 80x50, September 2016 (p. 54): http://www1.nyc.gov/site/sustainability/codes/80x50.page

PROGRESS TO DATE

In September 2014, Mayor de Blasio announced that New York City would continue its leading role in addressing climate change by committing to reducing greenhouse gas (GHG) emissions 80 percent by 2050 ("80x50") from 2005 levels. At the time, the commitment made New York the world's largest city to commit to this ambitious target. Despite the many challenges that remain, the Roadmap has been an important step toward understanding paths to achieve the deep carbon emissions reductions that scientists advise will limit global temperature rise to less than 2˚C. Because the City's more than one million buildings cover more than five billion square feet and are responsible for 68% of citywide GHG emissions, dramatic changes to building energy systems and operations will be needed to reach the target.

For the buildings sector, the Roadmap relied on a thorough, two-year technical analysis conducted by a Technical Working Group (TWG) assembled by the City. With the availability of substantial data collected through the City's Bloomberg-era Greener, Greater Buildings Laws – including annual benchmarking, reporting of energy and water use, and required energy audits in all large buildings – and the rich detail included in the City's annual GHG inventories, the TWG was able to develop an extremely detailed picture of current building energy use and emissions and pathways to dramatically reduce those emissions. In April 2016, the TWG published its detailed findings about how New York City buildings consume energy in the report *Transforming NYC Buildings for a Low-Carbon Future*[2]. The work of the TWG was integrated with analysis on energy supply, transportation, and waste into the City's *Roadmap to 80x50*[3], released in September 2016.

The data make clear that the pathways to attain 80% carbon reduction will require substantial changes in how buildings use energy, especially for heating and hot water. The Roadmap sets an interim target of 40% GHG reduction by 2030 (a significant increase from the then-ambitious 2007 target of 30% reduction by 2030). The approach proposed in the buildings section of the Roadmap is summarized in Figure 1 and includes the following:

1. A mix of current laws and initiatives that are expected to achieve the first 23% of carbon reduction. This includes the Greener, Greater Buildings Laws, voluntary Carbon Challenges in a variety of sectors, and new initiatives identified through the de Blasio administration's *One City: Built to Last* planning process.

2. Full implementation of TWG-identified cost-saving Energy Conservation Measures (ECMs) in existing buildings, along with significantly more stringent energy codes for all new construction and major renovation. These changes are projected to create GHG emissions reductions of an additional 17%, getting to a 40% overall reduction.

3. Major shifts in the electricity generation mix throughout the region, including utility scale solar and wind developments. These shifts, along with accompanying energy storage investments, are forecasted to bring emissions down another 18% to around 58% overall for the buildings sector and are derived from New York State's Clean Energy Standard[4] commitment.

4. A shift from natural gas heating and hot water to electric-driven heat pumps for space and hot water heating in a majority of residential buildings. If this conversion and the targets for a low carbon electric grid are simultaneously achieved, then this fuel switch would reduce building sector emissions another 22%, which would reach the 80% GHG emissions reduction target.

2 One City Built to Last: Transforming New York City Buildings for a Low-Carbon Future – Technical Working Group Report, April 2016: https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/TWGreport_04212016.pdf

3 New York City's Roadmap to 80x50, September 2016: http://www1.nyc.gov/site/sustainability/codes/80x50.page

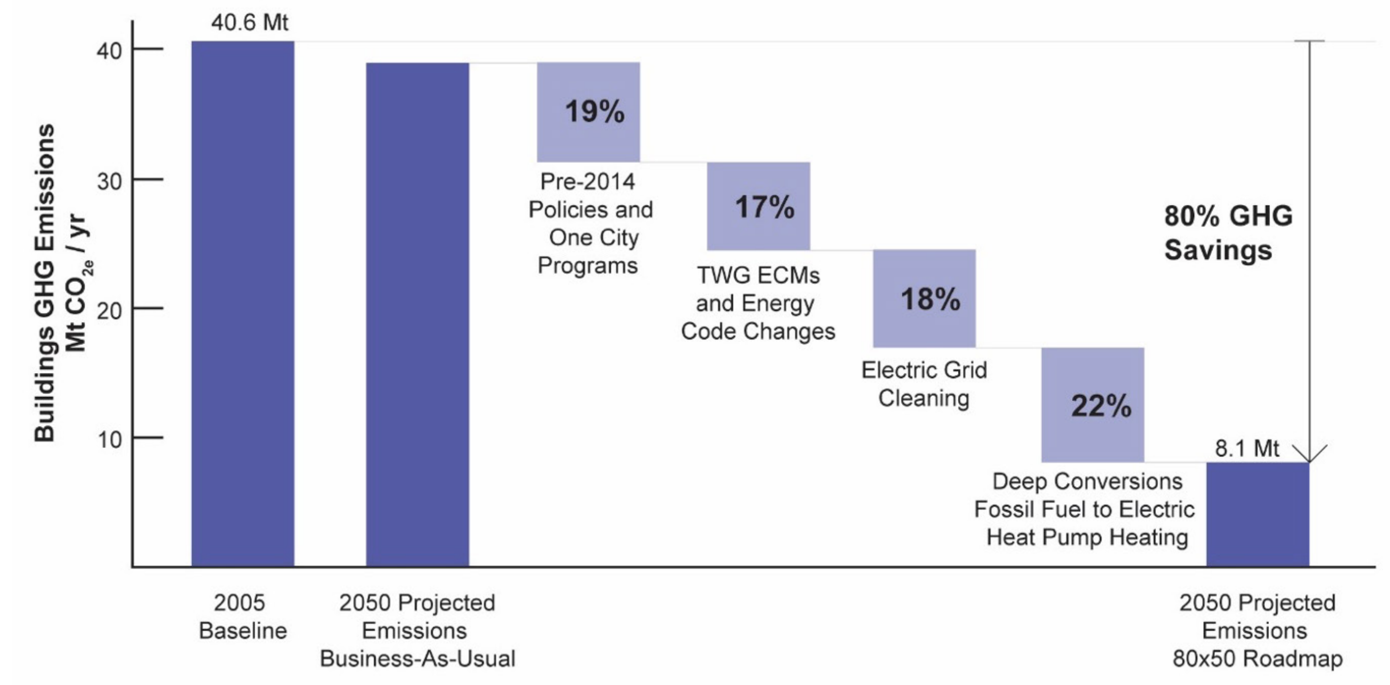

Figure 1. Simplified summary of approach to achieving 80% reductions as presented in the Roadmap

"The City's more than one million buildings cover more than five billion square feet and are responsible for 68% of citywide GHG emissions."

4 New York Clean Energy Standard. www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard

ROADBLOCKS IN THE ROADMAP

The technical analysis and comprehensive approach in the Roadmap is a demonstration of NYC's global leadership, and the 33 years to 2050 allow time for change and innovation. Only a handful of cities in the world have a document as detailed and thoughtful as the Roadmap. However, the buildings chapter is primarily a technical feasibility study rather than an implementation plan since economic and practical challenges were not presented with the same depth of analysis as the technical issues. Achieving the Roadmap targets will require capital investments above simple equipment replacement investments, particularly in the heating and hot water systems of a majority of the city's residential buildings, which with current energy prices are not cost-effective based on either up-front costs or annual operating energy costs. Even with a dramatic shift from fossil fuels to electric heat pumps for space and water heating, realizing the emissions reductions goal is dependent on an unprecedented shift to dramatically lower carbon electricity. This shift must also take place as the biggest current source of zero-carbon electricity in the region, the Indian Point nuclear plant, is scheduled to close. This paper seeks to discuss the implementation challenges and possible solutions to induce the unprecedented changes to the building and real estate industry needed to achieve the 80x50 goals.

GHG Emissions Reductions to Date: Mixed Results

The Roadmap states that with full implementation of current initiatives, the City is on track to achieve an interim target of 40 percent GHG reduction by 2030 (40x30). However, the effectiveness of policy activity to improve buildings' energy and emissions performance has been somewhat mixed and building performance has not improved as rapidly as projected in earlier analyses. According to the most recent *Inventory of New York City GHG Emissions in 2015* (report released April 2017), citywide emissions were 14.8% lower than in 2005[5], a trend that could lead to the 40x30 target if extrapolated out to 2030. However, after fairly steep improvements in the first years following 2005, building sector emissions have leveled off and were actually higher in 2013 and 2015 than in 2012.

Virtually all of the GHG reductions to date in the buildings sector are from electric grid cleaning and fuel switching, resulting from more efficient production of electricity and heating and the use of power from cleaner sources. While cleaner electricity and steam supply improvements have cut the emissions from buildings, on-site building energy consumption in NYC continues to rise. According to the 2015 Emissions Inventory, while some of the increase in the previous two years is due to growth in the building stock, NYC buildings are also seeing increased emissions in "per building area heating", which more than offsets the savings in the "per building area electricity" emissions[6].

Current policies at the city, state and federal levels are having substantial impacts on GHG emissions from some building end uses, while other consumer trends are driving up energy consumption. Building lighting energy use has been declining due to compact fluorescent lamps, LED lamps, and automated controls.

5 Inventory of New York City Greenhouse Gas Emissions in 2015, The City of New York, April 2017. http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/NYC_GHG_Inventory_2015_FINAL.pdf

6 Inventory of New York City Greenhouse Gas Emissions in 2015, The City of New York, April 2017: Figure 12 (p. 23).

Cornell Tech Residential on Roosevelt Island is being designed to Passive House standards, and when complete will be the tallest and largest residential building in the world built to Passive House standards. (photo credit: Handel Architects)

Space heating loads are trending down due to tighter envelopes and boiler/distribution efficiencies. However, air-conditioning and ventilation loads are trending up due to consumer demand for cooling and fresh air, increased residential ventilation rates due to new codes, increased IT and data cooling requirements, and the trend toward highly glazed buildings. A plethora of new and larger electronic devices in residences, and more plug loads in offices, are also pushing up electricity consumption and offsetting other efficiency gains.

While NYC buildings as a whole are not showing reduced energy consumption, larger buildings (over 50,000 square feet), which are subject to the 2009 Greener, Greater Buildings laws, are showing a more promising trend. Detailed analysis of annual benchmarking data from 2011 through 2013 shows that energy use decreased by 6% and emissions decreased by 8% in this segment of the market that participated in the City's building energy benchmarking program[7].

Additionally, there is strong progress with demonstration projects of "Passive House" development in NYC, which sets very low energy use requirements. Currently, the largest Passive House structure in the world is nearing completion as part of the Roosevelt Island Cornell Tech campus. Passive House and other market development activities show promise for new construction and retrofits of the massive existing building stock[8].

Outstanding Technical Issues to Study

In many ways the Roadmap demonstrates a plausible path to achieve 80x50. There were no proposals that require a completely new technical invention that does not currently exist, nor have dramatic improvements in equipment efficiency been relied upon to meet GHG reduction targets. In fact, the proposed approach is a compelling demonstration that proven technologies exist today that can technically get us to 80x50. Based on discussions with a variety of stakeholders, few of the proposed strategies might be called into doubt on the basis of technical feasibility.

The expansive data set of New York's building stock and energy use is far from perfect, but it is a resource that few other cities have.

7 New York City's Energy and Water Use – 2013 Report (August 2016), prepared by NYC Mayor's Office of Sustainability, Urban Green Council, and NYU Center for Urban Science & Progress. http://www.nyc.gov/html/gbee/downloads/pdf/nyc_energy_water_use_2013_report_final.pdf

8 Passive House Institute US. http://www.phius.org/home-page

Mayor Bill de Blasio signing a package of energy efficiency bills. (photo credit: NYC.gov)

A fundamental insight from the technical results of the Roadmap is that it is not possible to get to 80% GHG reduction without eliminating fuel oil and natural gas combustion from a large portion of the heating and hot water boilers that are common in NYC's residential building stock. In 2014, about 60% of GHG emissions from buildings, and nearly 30% of total citywide emissions, came from fossil fuels burned in buildings, nearly all used for space heating and hot water. The roadmap anticipates getting 50-60% of buildings to switch to electric driven heat pumps in order to meet the 80% GHG reduction target[9]. Smaller residential buildings may have fewer technical challenges for conversion to electric-driven heating, while larger residential buildings will struggle to find space for both heat pump conversion equipment as well as air-based heat sources. A few of the challenges for this monumental re-thinking are summarized below in Figure 2 along with other minor challenges identified by individuals interviewed for this paper.

Based on the analysis leading up to the Roadmap, there is little doubt that some version of the proposed technical paths could be executed by 2050 with unlimited financial resources and unlimited willingness and authority to act, though some stakeholders question the City's authority to implement some of the potential regulations. Unfortunately, even as one of the highest per-capita income cities in the world, New York City faces the same real resource constraints that all cities face.

9 NYC's Roadmap to 80x50, p. 62.

BUILDING TYPE	END-USE	STRATEGY	KEY CHALLENGES
All Building Types	Hot Water Heating	Heat pump water heaters	Heat pump water heaters are not currently common products in New York City, though they are commercially available. Large residential buildings have extreme peak hour loads, which may be difficult for air-based heat sources to keep up with in winter.
All Building Types	Hot Water Heating	Heat pump water heaters	Heat pump water heaters require a condensate drain, which may be a major plumbing retrofit in some existing buildings.
All Multi-Family	Ventilation	Reduce 'over-ventilation'	Ventilation requirement in the new ASHRAE 90.1-2016 energy code is increasing, which will further push up ventilation energy consumption well above existing building ventilation demands.
All Residential	Plug/ Appliances	Master Switch controls	Master switching and smart plugs have seen limited adoption in residential new construction and would require nearly completely new wiring in renovation.
All Residential	Lighting	Reduce lighting power density	The baseline of 0.5 W/sf is significantly lower than most residential today and achieving even lower power densities may be challenging even with LED technologies.
Tall Buildings > 12 stories	Space Heating	Electric driven heat pump	Space requirements to retrofit air-based heat source on existing large buildings would be challenging as rooftop space is already limited or occupied.
All Building Types	All	Electrifying fossil end-uses	Substantial new transmission and distribution capacity will be needed to serve the heating and water heating loads converted from gas and oil.

Figure 2: Technical challenges to specific proposals for energy efficient technologies or strategies

Economic Hurdles

Despite the technical rigor of the Roadmap and the TWG Report, much less analysis has been presented on the economic impacts of the proposed strategies. An important next step on the path to 80x50 will be to thoroughly study impacts of up-front and operational costs to residents, city government, building owners, utilities, and others. With current market costs, implementation of the ECMs identified in the TWG analysis may not be cost-effective; energy cost savings may not offset upfront capital costs. Figure 3 below presents a brief summary of some of the proposed strategies in the Roadmap that have a combination of challenging up-front costs, operational costs, owner-tenant split incentive, or transaction costs that prevent market-driven uptake in GHG reduction strategies today.

Take the simple example of converting hot water heating from a natural gas water heater to a heat pump water heater. Most existing fossil fuel-fired (natural gas or oil) water heaters in New York City will reach their useful life prior to 2050, and nearly every building – large or small, residential or commercial – will face the decision on whether to switch to electric heat pump water heaters or remain with natural gas, oil, or steam-fired equipment. The proposed switch is technically straightforward, consisting of replacing an old gas water heater or boiler with either a new high efficiency gas water heater or a heat pump water heater. New gas, oil, or steam equipment currently have slightly lower up-front costs than heat pump water heaters, though that may change over time and could create an opportunity for the City or electric utilities to provide incentives for switching to electric heating. Some retrofit configurations may have spatial planning challenges as some heat pump equipment tends to be larger than steam or gas fired equipment and would need to reject heat to outdoor air. Installing new electrical circuits or condensate drains could incur subsequent costs. Figure 4 shows the basic assumptions and results of a residential hot water heater example. GHG savings would be close to 50% with the carbon intensity of the electrical grid today, and around 80% if the grid achieved the low-carbon intensity target set in the Roadmap. But annual operating costs would likely be higher; since natural gas costs are at a historic low, this simple analysis shows an energy cost increase of 38% - although this will change along with gas and electricity prices over time.

BUILDING TYPE	END-USE	STRATEGY	KEY CHALLENGES
Multi-Family > 7 stories	Space Heating	Replace gas boiler with heat pump or VRF (variable refrigerant flow) units	Higher up front costs and operational costs for electric heat pumps compared to natural gas boilers
All Building Types	Hot Water	Replace gas water heaters with heat pump water heaters	Higher up front costs for electric heat pump water heaters compared to natural gas water heaters
All Building Types	Space Heating/ Hot Water	Replace gas fueled heating with electric driven heat pump	Natural gas prices are at a historic low while electricity prices show no sign of decreasing
Affordable Residential	All	Any ECM requiring capital investment	Capital investments can be passed down to tenants through MCI rent increases, placing cost burden on low income residents
All Building Types	All	Full achievable potential of TWG ECMs	Skepticism by many market participants about the real level of savings and cost-effectiveness of many ECMs identified in current audits and TWG report

Figure 3: Economic challenges to energy efficiency measures

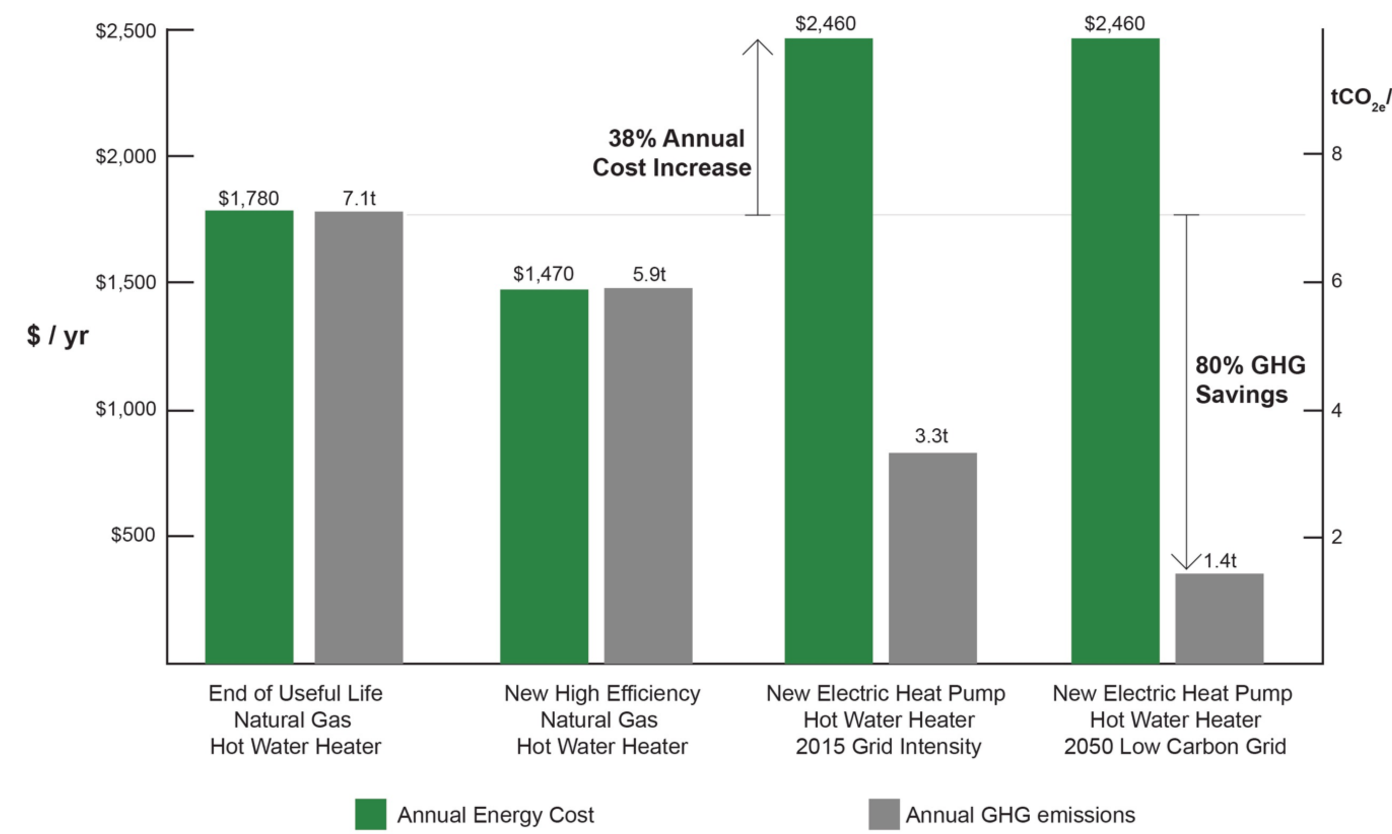

Figure 4: Example of annual energy cost and GHG emissions when considering switching from natural gas to electric heat pump hot water heating (See footnote 10 for calculation assumptions)

Considering that water heating constitutes 15% of the city's buildings-related GHG emissions, it is reasonable to assume that if most hot water heaters in New York aren't converted to heat pump water heating, there is no way to reach the 80x50 goal[11]. Aside from minor efficiency approaches in water heating, the only strategy that results in significant GHG savings is converting to electric-driven heat pump water heaters. The Roadmap does not address the difficulties of getting homeowners or residential building owners to make such a switch, nor how an increase in energy costs runs contrary to affordable housing goals of the City. Finding a clever solution to energy affordability should be a primary objective of any future working group analysis.

To remain an attractive place to live and do business, New York City needs to be economically competitive, and plans to reduce GHG emissions must fit within the broader economic goals of the City. The Roadmap did not acknowledge how many of the proposed strategies impact the current affordability crisis residents are experiencing living in New York City. Many of the proposed strategies do make economic sense, but for those that do not, such as heating and hot water fuel switching, a broad discussion of how to share the costs of achieving 80x50 goals must be conducted to move the process forward. Much more analysis, collaboration, and stakeholder engagement is needed to refine the understanding of the economics of the 80x50 Roadmap.

Implementation Challenges

Admittedly, the Roadmap was also not intended to solve the issues of how to implement the proposed strategies. Some stakeholders have raised questions about legal jurisdiction, mechanisms to induce action by city government, fair distribution of burden, and other practical concerns, which were not presented in the depth of rigor necessary for such a complex and challenging objective. Figure 5 below summarizes just a few implementation challenges discussed with various stakeholders during the research for this paper.

At the heart of much of the economic conundrum for the Buildings section of the Roadmap are the relative prices of electricity, natural gas, and oil. Firstly, none of these three fuels carry any significant externality costs for their relative impacts to climate change or relative GHG emissions (though this is accounted for in electricity markets through the Regional Greenhouse Gas Initiative, or RGGI). This means that there are no inherent pricing signals that reflect relative GHG emissions and guide economic decisions toward low GHG energy sources and away from high GHG energy sources. Secondly, the recent trend of low cost natural gas results in a significant increase in operational cost when converting to electric-driven heating and hot water. Thus, the burden of cost of this strategy will be borne by those who pay the electric bills in the buildings that convert from fossil fuels to electric heating and hot water. It is likely that many New Yorkers will likely pay more for heat and hot water in the short-term in order to achieve long-term 80x50 goals. Considering the scale of this proposal and the number of New Yorkers impacted, an informed public conversation will be necessary to ensure broad public support for 80x50 goals.

10 Assumptions: 100MMBTU annual water demand, end of life natural gas water heater efficiency: 70%, new natural gas water heater efficiency: 85%, heat pump water heater Energy Factor: 2.5 (Heat Pump Water Heater Field Evaluation of Field Installed Performance, Study by Steven Winters Associates, 2012. http://ma-eeac.org/wordpress/wp-content/uploads/Heat-Pump-Water-heaters-Evaluation-of-Field-INstalled-Performance.pdf), cost of natural gas: $12.50/MMBTU, cost of electricity: $0.22/kWh, grid carbon intensity 2017: 0.05 tCO2e/MMBTU, 2050: 0.035 tCO2e/MMBTU, natural gas carbon intensity: 0.082 tCO2e/MMBTU

11 NYC's Roadmap to 80x50, p54

BUILDING TYPE	END-USE	STRATEGY	KEY CHALLENGES
All Existing Buildings	All	Mandates to regulate existing building energy use	Aside from renovations that require filing with DOB, the legal authority for the City of New York to regulate the amount of energy an existing building uses is not clear
All Multi-Family	Space Heating	Electric heat pump or VRF	Running distribution pipes requires riser space within apartments because code does not allow pipework to run in path of egress
Affordable Residential	Space Heating	Electric heat pump or VRF	Rent Stabilized and NYCHA housing require central heating, so electrical costs to run heat pumps for heating would not be allowed to be put on a tenant meter
All Residential	Lighting	Reduce lighting power density	It is difficult to require or enforce the amount of lighting a resident installs in their home
All Building Types	All	Full achieveable potential of TWG ECMs	Tenants and building occupants are not demanding efficiency improvements, so owners make other investments that do satisfy demands – in short, it is hard to capture the limited attention of residents and managers to implement ECMs
All Building Types	Space and Water Heating	Electrifying fossil end-uses	Major shifts in revenues from natural gas/oil industry to electricity, with dramatic investment needed for distribution of new electric loads

Figure 5: Practical or implementation challenges to specific strategies in the Roadmap

MOVING FORWARD: LEVERS TO DRIVE PROGRESS AND INNOVATION

The 80x50 Roadmap sets an audacious target, designed to drive major changes in the way NYC uses energy and heats buildings. Achieving the target will require careful consideration of diverse policy levers, balancing a mix of regulations, incentives, public support, and other activities to drive innovation and change much more quickly than historic rate of change for building systems.

LEVER TO INDUCE INDUSTRY CHANGE	WHEN LEVER TENDS TO BE MOST EFFECTIVE	EXAMPLES OF RECENT DEPLOYMENT
Mandate/ Law	Strategies that are already economically rational, have broad public appeal, yet adoption is stagnant	Greener, Greater Buildings Laws of 2009 NYC Energy Code Upgrades
Incentivize	When a strategy is close to, but not yet economically rational and is likely to become rational upon broad adoption	Utility incentives NYSERDA Clean Energy Fund REV NY Prize
Price Signal	When prices do not reflect externalities, or prices do not comprise any consideration for broader policy goals	RGGI NY State REV (Reforming the Energy Vision)
Planning and Convening	Broad stakeholder input needed on complex tasks to identify gaps and opportunities	Technical Working Group 80x50 Roadmap
First Mover Proof of Concept	Group of voluntary leaders are willing to agree to an ambitious voluntary target	City Carbon Challenge Passive House
New Business Models	When an entrepreneur finds a new way to capture value that established actors are not willing or able to capture	Energy Performance Contracts
Education and Capacity Building	Market leaders have begun widespread adoption, but knowledge gaps exist among large portions of the industry	Retrofit Accelerator Building Energy Exchange

Figure 6: Levers or implementation modes to induce market changes

Balancing Different Policy and Implementation Levers

The predominant implementation mode discussed to date for getting deeper GHG reductions is mandating progress through legislation or regulation. Other modes such as those presented in Figure 6 below must be more fully considered and developed to accomplish a task as complex as this one. Some have raised concerns about the bounds of the City of New York's legal jurisdiction for mandates – these are details that need to be explored by experts. Nor was the importance of building public support or market demand for low-emission GHG buildings discussed. There was also little consideration of how to mobilize the private sector beyond the real estate community to drive rapid change in GHG reductions in the Roadmap. New York's rich ecosystem of community groups, non-profits, tech start-ups, and financial institutions could be invaluable if motivated and coordinated to address GHG emissions and climate change.

The building design and construction industry is historically slow and resistant to change, so considering how other stakeholders might drive innovation will increase the likelihood of achieving 80x50.

Driving Innovation

While the challenges on the surface can seem overwhelming, 2050 is 33 years away, and that leaves a lot of time for disruptive innovation to bring new energy and building system technologies into widespread use. Ten to fifteen years ago, who thought that driverless cars might be feasible by 2030? What does that portend for changes in buildings and energy systems by 2050? Ten years ago it would have been impossible to predict the dramatic decline in prices of LED lighting and the growth in penetration of that technology that is rapidly replacing the incandescent lights that were standard for most of the 20th century. Similarly, electric vehicle penetration has been growing faster than predictions from even three years ago, and a mix of technical and policy innovations have driven this growth.

As noted earlier, most of the technical solutions for getting to the 80x50 target are currently available, though without dramatic changes in price signals or other incentives, it is hard to see how they will be implemented as quickly as needed to achieve the goal by 2050. Achieving low carbon intensities for electricity supply also will require herculean effort to change the generation mix while maintaining reliability and affordability, especially as significant new electricity demand for space and water heating and electric vehicles grows.

Constructively balancing policy "carrots" and "sticks" will be part of the innovation challenge. In the early 1990s, as new, more efficient refrigerators were demonstrated to have technical potential, but manufacturers were hesitant to make products that consumers may not want, a group of policy makers and utilities conceived of the "Golden Carrot" award through the Super Efficient Refrigerator program[12], which led to new products on the market, rapid market growth for the new products, and the ability for the Federal government to set higher minimum efficiency standards to make the standard, lower efficiency products illegal to buy. Similar competitions might be relevant for the NYC buildings market.

There will be a need for new types of policy-oriented collaboration to accelerate the uptake of technology and drive the kinds of integrated

12 The Super Efficient Refrigerator Program: Case Study of a Golden Carrot Program: http://www.nrel.gov/docs/legosti/old/7281.pdf

designs that are currently only used on pilot projects. One example of this type of integrated design and construction innovation is the Cornell Tech Campus on Roosevelt Island, where the core academic building is targeted to be the largest net-zero energy building in the US, and the residential building the tallest in the world to achieve Passive House certification[13]. In the coming years, more of these new developments need to be proven, and new business approaches to deep retrofits of existing buildings will be needed to allow entrepreneurs to make money while cutting NYC's GHG emissions.

A healthy mix of innovative technologies was discussed in the Roadmap, but some stakeholders had actually hoped to see more. Ground Source Heat Pumps (sometimes known as 'geothermal'), Cogeneration (on-site electricity and heat production), District Energy (microgrids, neighborhood heating or cooling systems), and Advanced Lighting Controls (motion sensors, daylight controls, individual bulb control, automated shades, etc.) are all innovative building technologies that were included in the Roadmap. Considering the rate of technological change today, particularly within the realm of Internet of Things (IoT), distributed controls and data collection, mobile device interfaces, and other changes yet to be developed, we can also anticipate additional technological advancements over the next 30 years.

It would be hard to predict the extent of influence from the technology of social media, for example, which will surely evolve dramatically over the next 30 years. The ability of social media to motivate the public to change behaviors or invest in technological innovation may also help accelerate the progress to 80x50. Interestingly, though, most recent technological change has been driven by entrepreneurs uncovering latent market demand and creating new business models, not just through mandates from the public sector. This history clearly shows that there are many more roles for the City to play than just through legislative pathways.

Planning how to cut building energy consumption and change the types of systems that provide space and water heating to NYC buildings on a massive scale cannot happen without close integration with electric system planning and regulation, much of which is not led by NYC government but State regulators and the private sector. There are models of democratic policy innovations from other parts of the world that can be explored as models. Deliberative and co-governance policy development, where a mix of stakeholders have different types of responsibilities, hold promise for accelerating the changes that need to take place in the coming decades.

Sharing the Burden

Regardless of the rate of technological innovation, the ambitious targets of the 80x50 Roadmap will require significant investment and cost burdens among a broad variety of stakeholders. Developing a methodology to fairly distribute the burden of effort and cost across stakeholders was not a part of the most recent Roadmap planning and should be be part of future planning processes. To the extent any of the groups summarized in Figure 7 feel that they have borne more than their fair share of the effort or cost to achieve the 80x50 goals, they will likely oppose any major new City initiatives to pursue the plans envisioned in the roadmap. Conversations about fair distribution of cost are inextricably linked to implementation levers as well as the transparent planning process required to build consensus.

13 See https://www.nytimes.com/2017/05/29/business/energy-environment/cornells-climate-conscious-urban-campus-arises.html and http://news.cornell.edu/stories/2011/10/nyc-tech-campus-drives-sustainable-net-zero-impact

STAKEHOLDER GROUP	CONTRIBUTION TO SHARING OF BURDEN
Building Owners	Invest in new equipment, training, operations
Developers	Invest in different types of building designs and technologies
Homeowners	Investment in new equipment, burden of cost as ratepayer
Electrical Utilities	Investment in transmission/distribution (pass through to ratepayers?)
Fossil Fuel Utilities	Decline in revenues potentially causing an increase in rates to ratepayers
Independent Power Producers	Invest in new clean energy generation projects
Building Operators	Invest in training, maintenance, more and better operators
Tenants	Invest in equipment, burden of cost as ratepayer
Regulators	Include carbon and other externalities into prices
City Government	Incentives, stakeholder processes, mandates, policies
State Government	Incentives, project approvals, policies, affordable housing policies
Federal Government	Incentives, project approvals
Equipment Manufacturers	Invest in R&D for new products, expanding into new markets
Financial Institutions	Contribute to the availability of capital for investment in building energy projects that reduce GHG emissions
Advocacy Groups	Education, outreach, stakeholder process

Figure 7: Stakeholder groups and their respective burdens in achieving GHG reduction goals

NEED FOR STAKEHOLDER ENGAGEMENT

New York City has been a leader in so many societal changes in the past century, from improving building safety, to addressing low indoor air quality, to the provision of urban bicycling facilities, among many others. Current City leaders have continued this tradition through leading by example and proactively planning how to dramatically reduce GHG emissions. But the technical work over the past decade has just laid the groundwork for the even harder work still to come over the next two decades to achieve 80x50.

The same depth of rigorous technical analysis that led up to the Roadmap now needs to be applied to understanding the economic and implementation challenges of the 80x50 plan. This analysis should include another stakeholder group, with clear ground rules for decision-making defined at the outset, to engage in a multi-year, collaborative, inclusive, and data-driven problem solving exercise to address the financial, legal, and implementation challenges alluded to in this paper. Many groups and initiatives must be mobilized, motivated, and coordinated to induce the scale of GHG reduction actions. The Roadmap shows us the myriad strategies to design, build, renovate, operate, and occupy buildings differently and that everyone must be involved to achieve success. And the *process* of gaining buy-in so all stakeholders feel they share the burden of action fairly will be as important as the *product* from the next working group.

Looking back over the accomplishments of the past decade, it is also clear that there is a need to iterate on plans to evolve New York's building stock. The first set of plans in the Greener Greater Buildings Laws were a good start and the Roadmap to 80x50 is an important second step.

Although the 2016 80x50 Roadmap is not a definitive answer to a complex, and seemingly intractable problem, it is a significant step forward along the long path of innovation, collaboration, and inclusive policy-making that will result in achieving the 80x50 goals.

> "Much more analysis, collaboration, and stakeholder engagement is needed to refine the understanding of the economics of the 80x50 Roadmap."

Conclusion

The City's 80x50 target is has already begun stimulating innovative and pragmatic ways to move toward the goal of dramatically reduced emissions. While this paper has identified hurdles that need additional attention, 2050 is still a long way off and many stakeholders are motivated to rise to the challenge. Considering the global imperative to reach 80x50 and New York City's stature in the world, leadership is needed to convene the broadest possible group of stakeholders and experts to build not just a roadmap, but the road itself.

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