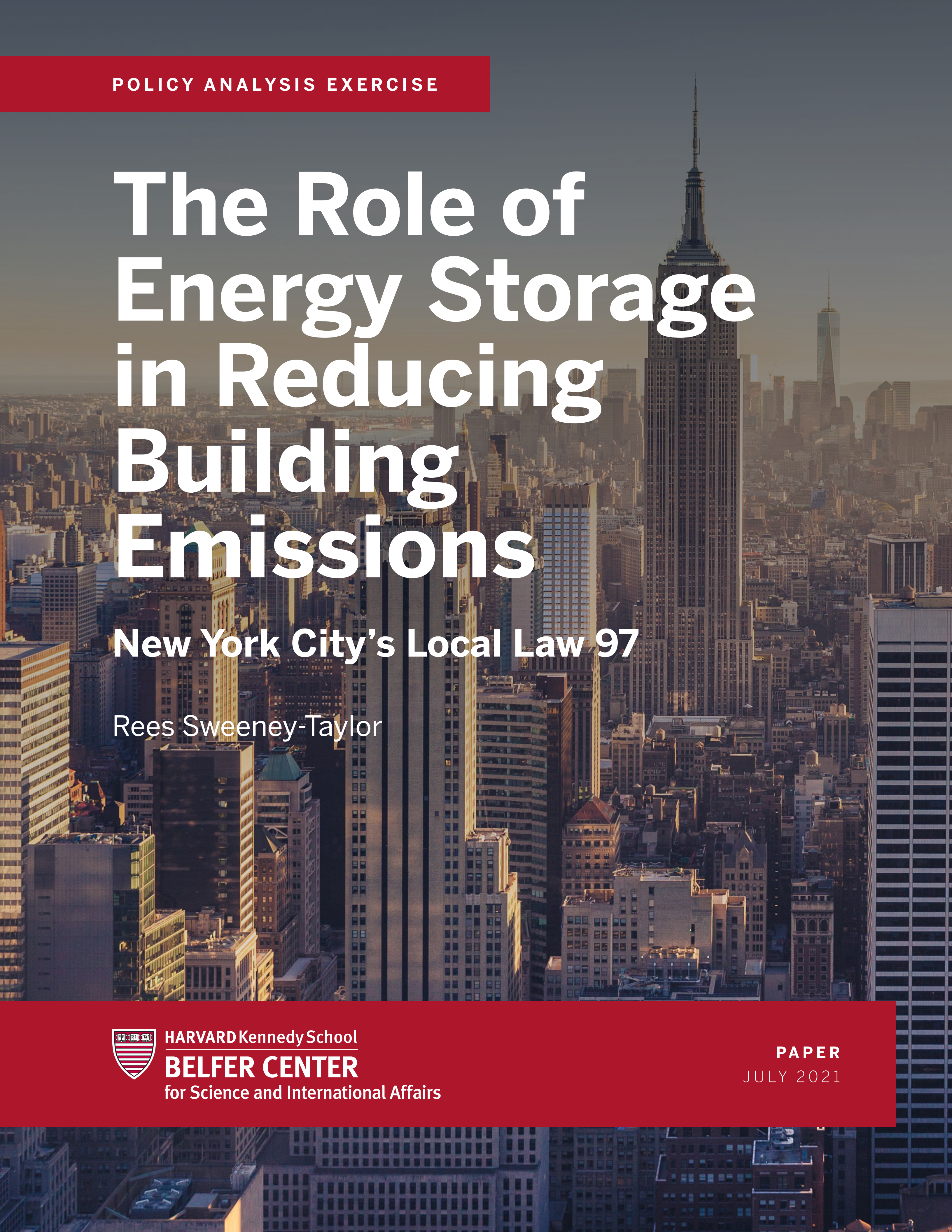

POLICY ANALYSIS EXERCISE

The Role of Energy Storage in Reducing Building Emissions

New York City's Local Law 97

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HARVARD Kennedy School
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POLICY ANALYSIS EXERCISE

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THE ROLE OF ENERGY STORAGE IN REDUCING BUILDING EMISSIONS: NEW YORK CITY'S LOCAL LAW 97

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EXECUTIVE SUMMARY

The New York City Council passed the Climate Mobilization Act in April of 2019, charting a path forward to net-zero greenhouse gas emissions by 2050. Central to the Act is Local Law 97 (LL97), which places a declining cap on emissions from the city's largest buildings and is considered "the most ambitious building emissions legislation enacted by any city in the world."[1] The building sector accounts for two-thirds of emissions in New York City,[2] and given the law's high penalty—$268 per metric ton of CO_2-equivalent (tCO_2e)—LL97 is expected to dramatically reduce those emissions over time. Buildings can pursue a variety of pathways to reduce their emissions below the cap, including changing fuels, upgrading appliances, retrofitting, reducing use, and installing distributed solar generation.

LL97 also includes specific language authorizing a deduction in emissions for energy storage based on the size of the storage system and its "ability to reduce greenhouse gas emissions during designated peak periods."[3] However, the law does not define the size or manner of the deduction that building owners will receive. Determining avoided emissions from storage proves challenging since it operates on the electric grid both as a load, potentially increasing emissions when it charges, and as a generator, potentially offsetting emissions when it discharges. Under the law, a Climate Advisory Board and its eight working groups are conducting analysis on storage emissions and other undefined aspects of the law in order to provide recommendations to the Department of Buildings (DOB) by January 1, 2023. The DOB, in conjunction with the Mayor's Office of Sustainability, will promulgate final rules in advance of the beginning of the first compliance period in 2024.

This report is designed to support the DOB as it seeks to appropriately value the avoided emissions from energy storage and encourage its deployment, helping to achieve the goals set forth in the Climate Mobilization Act and securing a renewable, reliable, and inexpensive energy future for New Yorkers.

Due to the intermittent nature of wind and solar generation, increasing energy storage deployment will be a critical element of successfully maintaining reliability while decarbonizing the electric grid. Using least-cost modeling of a future decarbonized grid, New York City and State have forecasted "astronomical" needs for storage in the city.[4]

I evaluate several policy options based on the quality of information they provide to building owners, the significance and reliability of their incentives for storage, and their short and long-term emissions impact. Based on this analysis, I make the following recommendations to the DOB:

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[1] "NYC Building Emissions Law Summary: Local Law 97" (Urban Green Council, July 2020), https://www.urbangreencouncil.org/sites/default/files/2020.07.09_urban_green_building_emissions_law_summary_revised_11.17.2020.pdf.

[2] "NYC Building Emissions Law Summary: Local Law 97."

[3] Costa Constantinides, "Local Law 97," Pub. L. No. 97 (2019), 28-320.3.6.3.2.

[4] Staff Member at Mayor's Office of Sustainability, March 12, 2021.

1. **By January 2022, establish a capacity-based deduction using reasonable assessments of the combined dispatch and investment effects of storage installed in New York City.**[5]
2. **By June 2023, establish a transparent system for time-of-use deductions and regularly publish marginal emission factors for electricity.**[6]

Recommendation 1 has the advantage of quickly providing practical, easily understood information to building owners so that they consider energy storage as they make compliance decisions. This deduction includes both the estimated short-run dispatch effects and the long-run investment effects of price-maximizing storage on the generation fleet. I estimate this capacity-based deduction as 425 to 850 tCO_2e/MW, reducing annual compliance payments for buildings above the cap by $11,500 to $23,000 for a 100kW battery. However, as noted in the report, there is reason to suspect that these numbers may actually be higher upon further analysis. Recommendation 2 provides a pathway for sophisticated storage operators to reduce emissions further by responding to real-time market signals. By providing optionality, building managers can choose the pathway that better fits their needs.

I also consider, but do not recommend three other policy options: a "Clean Peak" approach—which provides deductions for predetermined daily "peak" periods—creates undue complication while failing to drive deeper reductions in emissions; an "Average Dispatch Effects" approach—which considers only the short-run impacts of price-maximizing storage—fails to reward storage for its full emission reductions; and a blanket "Energy Use Exemption" for storage—which exempts electricity that passes through storage from the cap—creates a perverse incentivize to overutilize storage as buildings seek to direct maximum electricity through storage in order to take advantage of the exemption.

Beyond establishing storage deductions, my research suggests that the DOB should also consider these approaches to implementation:

3. **Pursue an adaptive approach to the capacity-based deduction, tracking and learning from the impact of storage on the grid.**
4. **Include energy storage in a carbon trading scheme.**
5. **Include energy storage when providing technical consultations to building owners.**

LL97 is a remarkably ambitious attempt to limit New York City's emissions and will likely serve as a model for other jurisdictions' similar attempts. Creating a framework to fairly value the short- and long-term emissions reductions from storage will help to drive deployment of a critical energy resource for our decarbonized future

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[5] A "capacity-based deduction" is an emission deduction awarded by the City based on the size of the energy storage resource rather than its discharge algorithm; "dispatch effects" are the immediate emission impacts that storage has on the grid, and "investment effects" are the long-run impacts of storage on the grid.

[6] "Marginal emission factors" convey the emission intensity of generation operating at the margin at any given time—for example, the generation source that provides electricity to a charging battery or that is displaced by a discharging battery.

I. INTRODUCTION: THE ENERGY TRANSITION

THE ROLE OF ENERGY STORAGE

In order to avoid the worst impacts of climate change and limit global warming to 1.5°C, the International Panel on Climate Change (IPCC) projects that global emissions of carbon dioxide must reach net zero by 2050.[7] This modelling has spurred goal setting at the national, state, and local levels in the United States. In Executive Order 14008, the Biden Administration recognizes the need to dramatically reduce emissions: "Responding to the climate crisis will require both significant short-term global reductions in greenhouse gas emissions and net-zero global emissions by mid-century or before."[8] Several states have also passed their own ambitious climate legislation. For instance, the Climate Leadership and Community Protection Act (CLCPA) commits New York State to generating 100% zero-emission electricity by 2040 and reducing economy-wide emissions from 1990 levels by 85% in 2050.[9]

Accomplishing such goals requires addressing numerous challenges, both through technological innovation and pioneering policy. Notably, several important transitions in how we generate and use electricity will need to occur in parallel over the coming decades. Electricity generation will need to shift from fossil fuel sources, such as coal, oil, and natural gas, to renewable energy, such as wind and solar. Simultaneously, the transportation and building sectors will need to electrify. In some regions, this shift will more than double demand for electricity.[10]

Because wind and solar power depend on intermittent sources of energy, analysts have long identified the need for large amounts of energy storage to maintain reliability of the electricity system under deep decarbonization.[11] While recent decreases in the cost of energy storage have allowed it to play an

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[7] V. Masson-Delmotte et al., "Summary for Policymakers," Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty (IPCC, 2018), 12.

[8] Joseph R. Biden, "Executive Order on Tackling the Climate Crisis at Home and Abroad," The White House, January 27, 2021, https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.

[9] "New York's Climate Leadership and Community Protection Act" (New York State, February 2020), 1, https://climate.ny.gov.

[10] "Energy Pathways to Deep Decarbonization: A Technical Report of the Massachusetts 2050 Decarbonization Roadmap Study" (Massachusetts Executive Office of Energy and Environmental Affairs, December 2020), 7.

[11] Stefan Ambec and Claude Crampes, "Decarbonizing Electricity Generation with Intermittent Sources of Energy," *Journal of the Association of Environmental and Resource Economists* 6, no. 6 (November 2019): 1107, https://doi.org/10.1086/705536.

increasing role in energy markets,[12] deployment remains well below the forecasted need to support the levels of renewable generation required to meet near and long-term decarbonization goals.

Because electricity markets tend to operate under regulated constructs, policy will play a critical role in supporting the continued research, development, and market creation for storage.[13] Properly rewarding storage for its climate benefits will help to drive storage technologies down the cost curve. Indeed, despite its importance to a clean energy future, storage has yet to receive the same sort of broad policy support that solar and wind received as those technologies matured.[14] At the Federal level, tax incentives, credits, and grants supported wind and solar generation with an estimated $51.2 billion between 2005 and 2015.[15] Additionally, states have supported renewable energy through state tax credits, renewable portfolio standards, net metering, and loan guarantees. By contrast, storage incentives are oftentimes highly restrictive, not always supporting the most recent breakthroughs in battery design.[16]

A key challenge in developing effective policy for storage is the complexity of its interaction with the grid since it acts as both a source of load and generation, alternating between utilizing and providing electricity.[17] Additionally, storage can be configured in multiple ways with respect to the grid, broadly distinguished between front-of-the-meter (FTM) and behind-the-meter (BTM). FTM energy storage discharges directly onto the grid and therefore has the potential to act as a price-setter in wholesale electricity markets. BTM storage, in contrast, discharges onto the load it is connected to, impacting the grid indirectly through lowering demand. BTM storage therefore generally acts as a passive price-taker based on a set utility tariff.[18] Figure 1 provides a helpful visual depiction of the range of services that BTM and FTM storage can provide, though in practice policy may limit those services.[19] In part because of this

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[12] "What Is Energy Transition?," S&P Global, February 17, 2021, https://www.spglobal.com/en/research-insights/articles/what-is-energy-transition.

[13] "Decarbonizing Electricity Generation with Intermittent Sources of Energy," 1124.

[14] James Temple, "Bill Gates Says It's Time to Redirect Solar and Wind Subsidies. Is He Right?," MIT Technology Review, September 17, 2019, https://www.technologyreview.com/2019/09/17/102613/bill-gates-says-its-time-to-redirect-solar-and-wind-subsidies-is-he-right/.

[15] Seth Kirshenberg et al., "Examination of Federal Financial Assistance in the Renewable Energy Mark" (Department of Energy, October 2018), ES-4, https://www.energy.gov/sites/prod/files/2018/11/f57/Examination%20of%20Federal%20Financial%20Assistance%20in%20the%20Renewable%20Energy%20Mark..._1.pdf.

[16] Lysondra Ludwig, "Battery Energy Storage Systems Integrated in Solar Facilities to Receive Tax Incentives," pv magazine, September 15, 2020, https://pv-magazine-usa.com/2020/09/15/battery-energy-storage-systems-integrated-in-solar-facilities-to-receive-tax-incentives/.

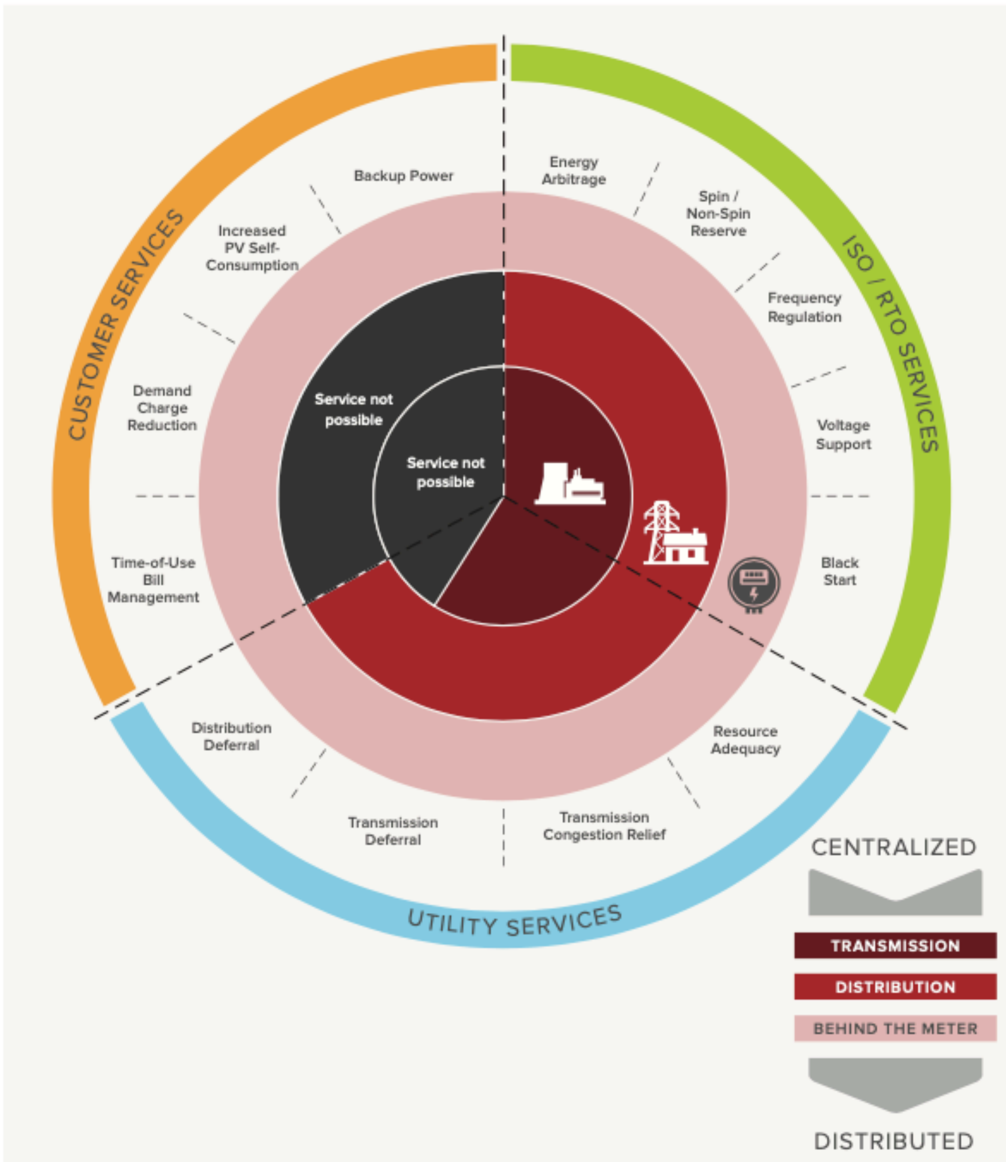
[17] Given the second law of thermodynamics, storage necessarily operates as a net load

[18] Garrett Fitzgerald et al., "The Economics of Battery Energy Storage: How Multi-Use, Customer-Sited Batteries Deliver the Most Services and Value to Customers and the Grid" (Rocky Mountain Institute, September 2015), 18, http://www.rmi.org/electricity_battery_value.

[19] Fitzgerald et al., 18.

complex relationship with the grid, energy storage is sometimes subject to market failures that prevent it from enjoying the rewards of all of the value it offers to the system as a whole.[20, 21]

FIGURE 1: BATTERIES CAN PROVIDE UP TO 13 SERVICES TO THREE STAKEHOLDER GROUPS[22]



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[20] Reza Hemmati, Hedayat Saboori, and Mehdi Ahmadi Jirdehi, "Multistage Generation Expansion Planning Incorporating Large Scale Energy Storage Systems and Environmental Pollution," *Renewable Energy* 97 (November 2016): 643, https://doi.org/10.1016/j.renene.2016.06.020.

[21] Fitzgerald et al., "The Economics of Battery Energy Storage: How Multi-Use, Customer-Sited Batteries Deliver the Most Services and Value to Customers and the Grid," 24.

[22] Fitzgerald et al., 19.

THE ROLE OF CITIES

The collective action problem of climate change—emissions and the benefits associated with them are produced locally, while the costs of those emissions are distributed globally—theoretically demands policy coordination across broad geographies. However, in part due to lack of comprehensive federal policy on climate change, states and cities have taken the lead in reducing emissions.[23] New York City is at the forefront of this trend. In April 2019, in response to the United States withdrawing from the Paris Climate Agreement and the IPCC's Special Report, the New York City Council passed the Climate Mobilization Act (CMA), charting a path forward to a net-zero New York City by 2050. Central to the CMA is Local Law 97 (LL97), which places a declining cap on emissions from the city's largest buildings.

Emission caps of the building sector modelled on LL97 may provide a powerful means for cities to reduce emissions in the future. Buildings often constitute a large portion of a city's emissions—in New York City, they account for two-thirds.[24] Additionally, with a high penalty—$268 per metric ton of CO_2-equivalent (tCO_2e) for LL97—such laws will strongly incentivize emissions reductions. Buildings have a variety of means to meet these targets including changing fuels, installing more efficient appliances, retrofitting, reducing use, and installing distributed solar generation or storage.

New York City has a history of providing blueprints for energy efficiency efforts. New York City's Local Law 84 (LL84), a predecessor to LL97, "spurred the creation of 35…laws across the United States, affecting over 11 billion square feet and more than 100,000 buildings."[25] At the state level, a New York energy policy leader noted that "as part of our buildings' stakeholder process for our Climate Action Plan we are looking towards this city model, thinking about how we can roll out something similar statewide, and how we can learn from this type of building's standard."[26] Boston recently published draft amendments to its "Building Energy Reporting and Disclosure Ordinance" with declining emission standards modeled off LL97.[27] The impact may well be felt internationally too; the Organization for Economic Co-operation and Development noted the significance of LL97 in its report *Managing Environmental and Energy Transitions for Regions and Cities*.[28] Given the likely reach of the law's precedent, properly addressing key questions regarding the implementation of LL97 are critical to similar efforts in the future.

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[23] Wyman, Katrina M.; Spiegel-Feld, Danielle, "The Urban Environmental Renaissance," *California Law Review*, April 2020, 326, https://doi.org/10.15779/Z38DZ0325P.

[24] "NYC Building Emissions Law Summary: Local Law 97."

[25] "Local Law 97: A Complete Guide to Preparing for NYC's Most Ambitious Building Emissions Legislation" (EnergyWatch, November 2020), 1.

[26] Energy Policy Leader in New York State, March 11, 2021.

[27] "Amendments to Building Energy Reporting and Disclosure Ordinance Including a Building Performance Standard," City of Boston, January 27, 2021, https://www.boston.gov/sites/default/files/file/2021/01/Boston%20Emissions%20Performance%20Standard%20Draft%20Policy%20Summary%2001-27-21.pdf.

[28] OECD, *Managing Environmental and Energy Transitions for Regions and Cities*, 2020, 80.

ENERGY STORAGE IN CITIES

The role that storage and cities play in the energy transition converge in LL97. In general, given their limited jurisdictions and inability to effectively regulate power plants, cities tend to focus climate mitigation policy on reducing consumption through energy efficiency or reduced use.[29] In contrast, storage increases the net load of a building and city. However, it offers operators the opportunity to strategically reduce load at key times, responding to and, to some extent, shaping the larger grid. Storage can charge during off-hours such as the middle of the night or midday and then discharge during the morning or evening peaks. This has the effect of displacing polluting, fossil-fuel "peaker" plants. Peaker plants tend to be aging, inefficient, and heavily polluting plants that the grid relies on to meet its peak demands.[30] Replacing peakers has important benefits in air quality and emission reductions. Additionally, by increasing demand during lulls, storage can incentivize the deployment of greater renewable resources. Indeed, the myriad services that storage provides can be particularly beneficial in urban environments, given transmission constraints, lack of space for renewable generation, and the negative health impacts on large population centers from fossil fuel plants.[31] Thus, energy storage in cities provides an opportunity for buildings to better match their "demand with conditions on the grid such as overall system demand, carbon intensity, and cost, [so that] the built environment can transform from contributing to the problem to a critical part of the solution."[32]

However, since storage is not in and of itself a source of clean energy, it does not guarantee emission reductions; indeed, as discussed below in greater detail, depending on the specific mix of the grid and the dispatch algorithm of the battery,[33] energy storage may well increase emissions. LL97 acknowledges this ambiguity by legislating that buildings can reduce their emissions by installing storage, with that deduction "based on the size of the resource and its ability to reduce greenhouse gas emissions during designated

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[29] Wyman, Katrina M.; Spiegel-Feld, Danielle, "The Urban Environmental Renaissance," 342.

[30] "New York State Peaker Power Plants: Energy Storage Replacement Opportunities" (PSE Healthy Energy, June 2020), 2.

[31] "Massachusetts Peaker Power Plants: Energy Storage Replacement Opportunities" (PSE Healthy Energy, May 2020), 4.

[32] Cathy Higgins, Alexi Miller, and Stacey Hobart, "The Arc of Progress: Getting to Zero Energy and Zero Carbon in the 21st Century," *New Buildings Institute*, Summer Study on Energy Efficiency in Buildings, Summer 2020, secs. 7–194.

[33] There are numerous ways that buildings can store energy. Innovative engineering allows buildings themselves to serve as massive forms of energy storage, trapping heat on winter afternoons and cool air on summer nights to reduce energy costs. In the future, this kind of thermal energy storage will be an essential design feature of buildings, providing more efficient heating and cooling than electric storage combined with heat pumps. Generally speaking, this paper focuses instead on commercially available electric batteries, such as lithium-ion or absorbed glass mat. For further insights on the future of building-level energy storage, see Mark M. MacCracken, "Using Yesterday's Waste Energy for Tomorrow's Heating: Electrification, Heat Pumps and Thermal Energy Storage," The American Society of Heating, Refrigerating, and Air-Conditioning Engineers Journal, July 2020.

peak periods."[34] However, this ambiguity is difficult to resolve due to the complex interaction between storage and the grid. One energy policy leader described the significance of this work: "How to treat storage both from a long-run policy perspective as well as short-run market signals is absolutely one of the trickiest topics within, I would say, the next five to ten years of climate planning and decarbonization of the grid."[35]

Properly valuing these avoided emissions from storage is essential to deploying socially beneficial levels of energy storage. Overvaluing storage will induce unnecessary, redundant development; undervaluing it will prevent buildings from pursuing a promising means of reducing emissions. Low deployment of storage may also incur higher future system costs in transmission and distribution investments as well redundant renewable generation in order to maintain reliability on a decarbonized grid. Given this challenge, thoughtful analysis of these questions will support the overall effectiveness of LL97:

1. **How should the New York City Department of Buildings calculate the avoided emissions from storage?**
2. **What practical hurdles to beneficial storage deployment do building owners face, and how can LL97 play a role in removing those barriers and incentivizing reasonable deployment of storage?**

This paper explores these questions in further detail. **Section II** provides a background on energy storage in New York State and New York City, the mechanics of Local Law 97, and the key questions that remain for the law's implementation with regard to storage. **Section III** outlines the available options for treating avoided emissions from storage under the law. **Sections IV and V** present the criteria and methodology used to evaluate those options. **Section VI** describes the key findings from this research, and **Section VII** makes several recommendations for how the City and other stakeholders should proceed.

[34] Constantinides, Local Law 97, 28-320.3.6.3.2.

[35] Energy Policy Leader in New York State, interview.

II. BACKGROUND

THE MECHANICS OF LOCAL LAW 97

LL97 represents a significant increase in New York City's ability to drive meaningful reductions in emissions. Previously, LL84 and Local Law 87 required building owners to report annual energy consumption data for benchmarking purposes and conduct energy audits once per decade. These audits, while mandatory, resulted in energy-use reductions of only "2.5% for multifamily residential buildings and 4.9% for office buildings," indicating that audits alone are unable to reduce emissions in line with the City's goals.[36] In order to accelerate these reductions, the City Council passed LL97, which the Urban Green Council, a major advocate for building efficiency in the city, describes as "the most ambitious building emissions legislation enacted by any city in the world."[37]

An antecedent to LL97 is the Tokyo Cap-and-Trade Program (TCTP), established in April 2010, which mandates emission reductions for Tokyo's largest 1,400 energy consumers and about 40% of the total emissions from the Commercial and Industrial Building sector.[38] The TCTP is largely regarded as a success, achieving a 27% emissions reduction in targeted buildings by 2017.[39] In comparison, LL97's reach is much larger, including the residential sector and extending to roughly 50,000 of New York City's largest buildings, or 60% of the city's building area. It establishes a citywide goal of a 40% reduction in emissions by 2030 and 80% by 2050 relative to 2005 levels. That amounts to a total reduction of 5.3 million tCO_2e of annual emissions in covered buildings from current levels.

The law, which applies to most buildings over 25,000 square feet, reduces emissions through assigning greenhouse gas coefficients or "emissions factors" to different fuel sources, including electricity, and placing an emissions limit per square foot for each building code occupancy group (e.g. "Mercantile," "Residential," "Factory"). While LL97 set a static emission factor for electricity, Local Law 147 (LL147) amends the original law to allow the Department of Buildings (DOB) to promulgate variable, time-of-use emissions factors for electricity.[40] As discussed below, the emissions intensity of the grid can vary widely based on the specific generation mix producing electricity.

[36] Constantine E. Kontokosta, Danielle Spiegel-Feld, and Sokratis Papadopoulos, "The Impact of Mandatory Energy Audits on Building Energy Use," *Nature Energy* 5, no. 4 (April 2020): 309, https://doi.org/10.1038/s41560-020-0589-6.

[37] "NYC Building Emissions Law Summary: Local Law 97."

[38] Steven Nadel and Adam Hinge, "Mandatory Building Performance Standards: A Key Policy for Achieving Climate Goals," *American Council for an Energy-Efficient Economy*, June 2020, 5.

[39] Nadel and Hinge, 6.

[40] Costa Constantinides, "Local Law 147," Pub. L. No. 147 (2019), § 28-320.3.1.1.1.

The first compliance period runs from 2024 to 2030, at which point the cap is significantly diminished, such that emissions are scheduled to be between 20% and 34%—varying by building occupancy group—below current sector levels by 2030. Approximately 20% of buildings are currently over the 2024 limit; 75% are over the 2030 limit.[41] From 2024 onward, in order to encourage compliance, the law imposes the \$268/tCO_2e penalty on buildings that exceed their designated cap. Given that this penalty is very high relative to many other carbon pricing schemes—in the most recent auction conducted by the Regional Greenhouse Gas Initiative, of which New York State is a part, the market cleared at \$7.41/tCO_2—many observers believe that LL97 will precipitate a significant reduction in emissions.

LL97 IMPLEMENTATION PROCESS

While passage of LL97 is a major accomplishment and establishes significant authority for reducing emissions, there is a great deal that requires further clarification prior to the first compliance period in 2024. Uncertainty remains, for example, as to whether the policy will allow buildings to trade emission credits as the TCTP does, how the time of use of electricity will be considered, and methods for calculating compliance. The law creates a sixteen-member Climate Advisory Board to provide advice and recommendations by January 1, 2023, to the DOB's newly created Office of Building Energy and Emissions Performance, which, in consultation with the Mayor's Office of Long-Term Planning and Sustainability (MOS), will ultimately resolve the law's outstanding uncertainty. The Climate Advisory Board has, in turn, created eight working groups to focus on particular questions of implementation: Building Technologies & Pathways (Multifamily Buildings), Building Technologies & Pathways (Commercial Buildings), Carbon Accounting, Energy Grid, Economic Impact, Hospitals, Communications, and Implementation.

As noted above, among the many complex questions that remain unresolved is the capacity-based deduction that buildings will receive for each kW of installed energy storage. It remains unclear how significant that deduction will be and how narrowly the "ability to reduce greenhouse gas emissions" will be defined. Determining these deductions touches on numerous other aspects of the law, and therefore several working groups are actively engaged with these questions.

ENERGY STORAGE IN NEW YORK STATE AND CITY

There is wide agreement on the need to promote energy storage in New York State and City. New York State's Governor, Legislature, and Public Service Commission (PSC) "have solidified the role of energy storage as an important foundation of the state's transition to a clean energy-powered future,"[42] and have set one of the highest procurement targets for energy storage in the country with a commitment to deploy

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[41] "NYC Building Emissions Law Summary: Local Law 97."

[42] Will McNamara, "New York Energy Storage Policy" (Department of Energy, Office of Electricity, Global Energy Storage Database, August 19, 2019), 2.

1,500MW statewide by 2025 and 3,000MW by 2030.[43, 44] Studies show that without storage, decarbonization costs increase dramatically, and the resulting redundant renewable generation suffers significant curtailment.[45] Energy storage helps to reduce these costs;[46] for example, the New York State Energy Research and Development Authority (NYSERDA) estimates that deployment of 3,600MW of energy storage by 2030 could result in over $3 billion in ratepayer benefits, in particular by lowering distribution and capacity market investments.[47] Nonetheless, storage in the state remains "in the early stages of development."[48]

In its *Energy Storage Roadmap*, the New York Department of Public Service (DPS) notes the importance of investing in storage to realize those benefits: "Through lowering the cost and speeding the deployment at scale of storage solutions and drawing on innovation and investment from all sectors, energy storage will create the most value for customers and the state's energy system in the new energy paradigm."[49] Significantly, the *Roadmap* goes on to note that since not all future values of storage are available today, "this presents a significant barrier to unlocking the full potential of energy storage. Thus, the Roadmap's recommended actions aim to enable the realization of storage value, now and over time, while also reducing barriers and costs."[50]

In addition to the general orientation towards promoting energy storage in the state, the New York Independent System Operator (NYISO), NYSERDA, and the DPS have all identified a particular need to advance storage downstate, in New York City and its environs. NYISO, for example, has identified a major challenge to decarbonization in the transmission constraints between an upstate surplus of clean energy supply and high downstate demand that still relies on fossil-fuel generation at peak hours (See Figure 2).[51]

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[43] "By comparison, California has a 1,300 MW by 2020 target." McNamara, 2.

[44] "Energy Storage," NYSERDA, accessed March 27, 2021, https://www.nyserda.ny.gov/All-Programs/Programs/Energy-Storage.

[45] Maryam Arbabzadeh et al., "The Role of Energy Storage in Deep Decarbonization of Electricity Production," *Nature Communications* 10, no. 1 (December 2019): 1, https://doi.org/10.1038/s41467-019-11161-5.

[46] Mehdi Jafari, Magnus Korpås, and Audun Botterud, "Power System Decarbonization: Impacts of Energy Storage Duration and Interannual Renewables Variability," *Renewable Energy* 156 (August 2020): 11, https://doi.org/10.1016/j.renene.2020.04.144.

[47] "New York State Energy Storage Roadmap" (New York Department of Public Service, June 21, 2018), 6.

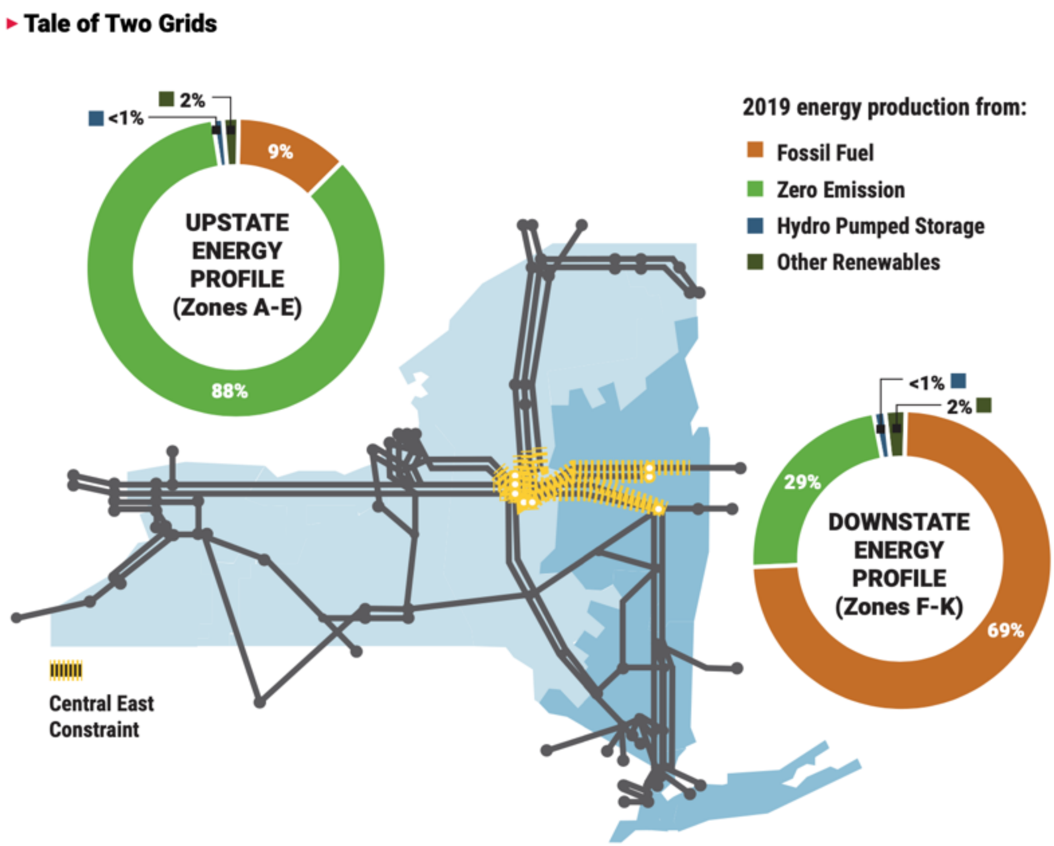
[48] McNamara, "New York Energy Storage Policy," 2.

[49] "NYS Energy Storage Roadmap," 4.

[50] "NYS Energy Storage Roadmap," 8.

[51] "Power Trends 2017: New York's Evolving Electric Grid," The New York ISO Annual Grid & Markets Report (New York ISO, 2017), 8.

FIGURE 2: TALE OF TWO GRIDS[52]



In its analysis of the CLCPA, NYSERDA concludes that "nearly all of the roughly 22,500 GWh of electricity generated within New York City was from fossil fuel-fired generation. Without displacing a substantial portion of the fossil fuel-fired generation currently operating within Zone J, the statewide 70 by 30 Target [70% of electric load met by renewable generation by 2030] will be difficult to achieve."[53] The report also notes that additional upstate renewables alone will not necessarily be sufficient to enable statewide compliance with the 70 by 30 Target.[54] To address this problem, a NYSERDA study finds that "storage can play a critical role in peaker replacement,"[55] suggesting that a two-pronged strategy of increasing storage

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[52] "Power Trends 2020: The Vision for a Greener Grid," The New York ISO Annual Grid & Markets Report (New York ISO, 2020), 9.

[53] "White Paper on Clean Energy Standard Procurements to Implement New York's Climate Leadership and Community Protection Act" (NYSERDA, June 18, 2020), 45.

[54] "CES Procurements," 46.

[55] Acelerex, "NYSERDA/DPS Energy Storage Study Results" (New York State Public Service Commission, May 2018), 17.

in and around New York City and adding additional renewables may be necessary to substantially lower New York State's overall emissions.

The *Carbon Neutral NYC Study*, a forthcoming report from the City and its utilities, will provide forecasts of energy storage needs out to 2050. As an MOS staff member notes, the report, which "is intended to inform the LL97 working groups,…is a super granular analysis of what we're anticipating out to 2050 and what we need to do to meet our decarbonization goals, and the anticipated energy storage needs are pretty astronomical…"[56] The PSC's *Zero Emissions Study*, which models least-cost pathways, forecasts a need for "7,300 MW in New York City and Long Island by 2040 in order to fully decarbonize the grid."[57] This modeling "reinforced what the *Energy Storage Roadmap* showed us, which is that there's a lot of value to energy storage everywhere, but we especially need it downstate. So we need to figure out ways of properly valuing it."[58]

Additionally, while the focus of this paper is on the emission impacts of storage, researchers and policymakers have noted the many other localized co-benefits of installing storage in New York City, particularly through displacing local peaker plants. These peaker plants, one-third of which are located in environmental justice communities,[59] can have significant negative impacts on local air quality and the health of residents. Closing a substantial portion of the state's peaker plants would enable "$360M in environmental and health savings."[60] Accordingly, the CLCPA requires the PSC to: "specify that a minimum percentage of energy storage projects should deliver clean energy benefits into NYISO zones that serve disadvantaged communities. "[61]

Despite the clear benefits of installing storage in New York City, as of April 2020 no projects in the city had been awarded NYSERDA incentives.[62] This is likely the result of several factors particular to the city. Given high building density, energy storage often cannot be paired with renewable generation, which precludes "projects from qualifying for the materially valuable [investment tax credit] that requires direct charging of batteries from renewable generators."[63] Standalone energy storage projects are more common in New

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[56] Staff Member at Mayor's Office of Sustainability, interview.
[57] Johannes Pfeifenberger et al., "Initial Report on the New York Power Grid Study" (New York State Public Service Commission, January 19, 2021), 5.
[58] Energy Policy Leader in New York State, interview.
[59] An environmental justice community is "characterized as communities with 51.1 percent or more of the population reporting as non-white in urban areas (more than 33.8 per- cent in rural areas) and/or 23.59 percent or more of the population in households with incomes below the federal poverty level." "New York State Peaker Power Plants: Energy Storage Replacement Opportunities," 1–3.
[60] Scott Burger and Isabella Ragazzi, "Solving the Clean Energy and Climate Justice Puzzle: How Multi-Day Energy Storage Can Cost-Effectively Replace Long-Running Peakers in New York State" (Form Energy, July 2020), 2.
[61] "New York State Climate Leadership and Community Protection Act," Pub. L. No. S. 6599 (2019), sec. 66-p (7) (a).
[62] "State of Storage in New York," Annual Energy Storage Deployment Report Pursuant to Public Service Law §74 (Department of Public Service, April 1, 2020), 19.
[63] "State of Storage in New York," 19.

York City, but currently suffer from high charges under current Con Edison tariffs.[64] Furthermore, additional barriers "have held back what has otherwise been a hugely fertile state for clean energy."[65] These barriers include zoning restrictions, the Fire Department of New York's (FDNY) concerns about the flammability of indoor battery systems, and high interconnection costs.[66]

Given this context of the benefits of storage and the forecasted needs by state and city energy policy leaders, I consider various options for valuing storage under LL97 and the key considerations that the Advisory Board, working groups, and ultimately the DOB should take into account in appropriately incentivizing energy storage deployment in New York City.

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[64] "State of Storage in New York," 19.

[65] Andy Colthorpe, "Energy Storage Fire Safety Codes to Go into Effect in New York next Month," Energy Storage News, October 21, 2019, https://www.energy-storage.news/news/energy-storage-fire-safety-codes-to-go-into-effect-in-new-york-next-month.

[66] "State of Storage in New York," 19.

III. POLICY OPTIONS

Policy options for determining the emission deduction buildings can receive for storage under LL97 were developed through an iterative process of conversations with stakeholders, analysis of analogous policies adopted elsewhere, and academic research. The following five potential policies were considered.

CLEAN PEAK

A 2018 Massachusetts law established the Clean Peak Energy Standard (CPS) for the state. Run by the Massachusetts Department of Energy Resources (DOER), the CPS "is designed to provide incentives to clean energy technologies that can supply electricity or reduce demand during seasonal peak demand periods."[67] The DOER designates four-hour long daily windows as "peak" (4 to 8 p.m. in the winter, spring, and fall, and 3 to 7 p.m. in the summer).[68] Qualified clean resources, including energy storage that charge from non-emitting resources, are awarded monetizable credits for providing energy during those peak hours. Adapted to LL97, energy storage could receive set emission deductions based on charging and discharging during certain pre-determined daily windows that would seek to maximize emission reductions from storage.

AVERAGE DISPATCH EFFECTS

This approach examines the short-term emission impacts of storage that uses a dispatch algorithm to maximize revenue without concern for its emissions impact. Estimating the average impact of this storage, a uniform capacity-based deduction is granted to each kW of installed energy storage in the city, without consideration for the particular dispatch algorithm of that energy storage system (ESS). Adjustments could be made, however, based on other factors such as the duration of the ESS and the utility tariff it falls under, though these specifics are not analyzed in this paper.

AVERAGE DISPATCH AND INVESTMENT EFFECTS

In this scenario, building owners receive the estimated value of the long-term investment effect of the ESS in addition to the short-term dispatch effect. Whereas the dispatch effect captures the immediate impact of an ESS to the grid, the investment effect considers the long-term effects of storage in driving others' investment decisions. Storage systems that maximize profit by increasing load midday and displacing load during evening peaks may not simply reduce emissions in the near term. Rather, through market impacts they may cumulatively drive investment in resources that can generate electricity cheaply mid-day (e.g., upstate solar) and disinvestment in more expensive resources that currently generate electricity during

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[67] "Clean Peak Energy Standard," Mass.gov, accessed March 27, 2021, https://www.mass.gov/clean-peak-energy-standard.

[68] Jeffrey G Shrader et al., "(Not So) Clean Peak Energy Standards," December 10, 2019, 3.

peak hours (e.g., downstate peaker plants). Building owners would receive the value of both dispatch and investment effects, without consideration of their dispatch algorithm.

TIME-OF-USE DEDUCTION

Under this approach, building owners receive deductions based on the marginal emission factor (MEF) of the grid as they charge and discharge. As opposed to the average emission factor (AEF), which represents the average emission intensity of the grid over a set period of time, the MEF captures the emissions of the marginal unit of generation that must generate electricity for each marginal increase of load on the grid. This is an important and often overlooked aspect of emissions on the grid, since the MEF dictates the actual short-run emissions generated or avoided from an intervention. Using this metric, storage would receive its emission deduction based on the specific marginal emissions incurred when charging and the marginal emissions avoided when the storage discharges. For maximum precision, this information would need to be calculated and communicated in real time and in short intervals such as five-minute increments. Alternatively, this approach could be used on a day-ahead basis according to forecasts of the MEF for the next day, sacrificing some accuracy of the actual emissions avoided but providing building owners the certainty to schedule their dispatch algorithm ahead of time.

ENERGY USE EXEMPTION

An energy use exemption for storage would exempt any electricity used to charge storage from the emissions cap, preventing an unintended penalty for storage. This is the approach, for example, that the working groups may consider for electric vehicle charging ports in order to ensure that buildings are not disincentivized from installing charging ports onsite.

While this exemption makes sense in order to avoid penalizing existing storage, it does nothing to incentivize reductions in emissions. Furthermore, taken to an extreme, it over-incentivizes storage, as buildings would seek to direct maximum electricity through storage in order to exempt as much electricity as possible. Therefore, this paper does not further consider a blanket energy use exemption as a standalone option.

There may, however, be a role for a limited energy use exemption to ensure that storage is not perversely disincentivized and the options above accurately reward avoided emissions. This limited energy use exemption would likely be in the form of a specified annual kWh of charge per installed kW of storage.

Using the criteria presented in the following section, I analyze each of the first four options, which are not mutually exclusive, but, when feasible, can be integrated to build on the strengths of each and provide optionality to owners. Generally, providing optionality has helped to win support for the law. As a senior member of the Mayor's administration observed about passage of the original law, "Everyone wanted more flexibility in complying."[69] Providing optionality of compatible solutions may help reduce the cost of compliance and the political repercussions of implementation.

[69] Senior Member of the Mayor's Administration, January 6, 2021.

IV. CRITERIA

In order to evaluate the first four options presented above, I use a model for investment and change in the real estate sector that Joseph Allen and John Macomber propose in *Healthy Buildings: How Indoor Spaces Drive Performance and Productivity*. While their research focuses on healthy buildings, their model for why investments lag behind rational optimization also applies to suboptimal installation of novel energy storage technologies for buildings. Allen and Macomber observe that "lack of market response comes down to four factors: *information, inertia, incumbents,* and *incentives.*"[70] They point out that the industry suffers from a pervasive lack of information or even erroneous information.[71] In addition to this information gap, the "real estate and construction industry is one of the largest business sectors and investment classes in the world…The industry is also very complex. Scores of entities are involved in almost every building project…These factors contribute to an industry that is capital intensive, fragmented…and risk averse."[72] Therefore, inertia and incumbents tend to drive investment decisions. Finally, incentives can often be misaligned or unclear, producing suboptimal outcomes.[73]

Since the second and third factors—inertia and incumbents—are difficult for policymakers to address directly, particular attention should be paid to providing transparent, timely, and practical information as well as significant and reliable incentives to shift the inertia of incumbents towards deploying energy storage. Therefore, the first two criteria I use in evaluating the options above are *information* and *incentives*. Under the criterion of information, I consider whether the information in the rulemaking is timely, transparent, and practical so that building owners can make meaningful use of that information. I have assessed incentives both in terms of their size relative to the cost of energy storage and their "bankability," or how "well understood" and "reliable," the incentives are—key determinants in the ability of developers to finance projects.[74]

In addition to *information* and *incentives*, the actual *impact* on emissions from the policy path chosen comprises a third and critical criterion. I evaluate short- and long-term impacts.

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[70] Joseph G. Allen and John D. Macomber, *Healthy Buildings: How Indoor Spaces Drive Performance and Productivity* (Cambridge, Massachusetts: Harvard University Press, 2020), 71.

[71] Allen and Macomber, 80.

[72] Allen and Macomber, 72.

[73] Allen and Macomber, 81.

[74] Matthew Wolfe, "MA Clean Peak Energy Standard," *Next Grid Markets* (blog), April 9, 2020, https://nextgridmarkets.com/2020/04/09/does-the-new-massachusetts-cps-get-energy-storage-over-the-hump/.

V. METHODOLOGY

QUALITATIVE RESEARCH

I conducted interviews with fifteen primary sources from November 2020 through March 2021 to inform practical considerations regarding the timeline and complexity of the implementation process. My interviews were intended to cover a wide range of stakeholders and experts, drawn from New York City and State energy policy experts, the Climate Advisory Board and its working groups, carbon accounting and energy storage businesses, academia, advocacy, and building management. Appendix B contains a full list of interviewees and common interview questions.

I also reviewed numerous secondary sources, including existing news coverage of the law, as well as substantial academic research analyzing the impacts on emissions of storage deployment. This literature provides key considerations for calculating emissions reductions from storage. Applying those insights to the specifics of New York City provided a foundation for my quantitative research below.

Finally, I qualitatively evaluated the four options across the three criteria. While the City may determine that developing a quantitative scoring system is useful for considering the range of options, I found that it introduced an exaggerated degree of precision, requiring further research to justify. Instead, I have relied on assessing the clear qualitative strengths and weaknesses of each approach in order to recommend what, with the limited information currently available, constitutes the most promising path forward for New York City.

QUANTITATIVE RESEARCH

I used the platform *Station A* to estimate the existing capacity for profitable deployment of storage in New York City. *Station A* uses publicly available geographic and energy data to assess opportunities for profitable renewable energy and storage development. Using their proprietary algorithm based on likely electricity costs, annual peak load, average hourly load, ratio of peak-to-average load, unobstructed parcel square footage, and available incentives, I conducted an analysis of buildings over 25,000 square feet (the threshold for coverage by LL97) to understand the current available capacity for profitable storage deployment in the city.

In order to calculate the necessary value to meaningfully incentivize storage, I drew primarily on my interview with Joshua London, Senior Vice President of Glenwood Management, a major New York City property owner, developer, and manager. London oversaw installation of dry absorbed glass mat batteries at fifteen Glenwood properties in the city. Taking his quotes of average storage costs, energy savings from storage, and payback period, I calculated a reasonable minimum incentive that would still qualify as "significant."

Finally, in order to analyze the emissions impact of the policy options, I drew on calculations from existing modeling in the research papers mentioned above. In particular, I build off the insights from two papers: "How much wind and solar are needed to realize emissions benefits from storage?" by Naga Srujana

Goteti, Eric Hittinger, and Eric Williams and “Emissions impacts of future battery storage deployment on regional power systems,” by John E. T. Bistline and David T. Young. Goteti, Hittinger, and Williams analyze the dispatch impacts of storage in the NYISO region based primarily on 2015 data. Their paper examines the change in emissions when modeling different amounts of storage on the grid. To calculate the average avoided emissions per installed megawatt of storage, I divided the total emissions reduction they modeled in the NYISO region by the number of megawatts of storage assumed in the model.

Bistline and Young’s paper analyzes the changes in emissions due to storage from both short-term dispatch effects and long-run investment decisions. Unfortunately, due to restrictions related to the COVID-19 pandemic, the results specific to New York State that are visually represented (along with numerous other regions) in Figure 6 (p. 33) are inaccessible at this time. The author instead pointed to Figure 6 as an indication of the order of magnitude of investment effects in relationship to dispatch effects. While there is clearly considerable variation across regions and scenarios, I assume for the purposes of my calculations that investment effects are five to ten times larger than dispatch effects. Multiplying the low and high ends of this range with the estimated dispatch effect observed in the paper above, I established a first-order approximation for the range of long-term emission impacts.

In order to more accurately determine the emission impacts of storage, further analysis could be done of New York City specifically, perhaps using a capacity planning and dispatch model such as the Electric Power Research Institute’s (EPRI) U.S. Regional Economy, Greenhouse Gas, and Energy (REGEN) model that Bistline and Young employed in their work.

VI. FINDINGS

Table 1 presents the high-level findings from my research, discussed in greater detail below.

TABLE 1: SUMMARY FINDINGS

	Criteria		
Policy Options	**Information**	**Incentives**	**Emissions Impact**
Clean Peak	Low	Medium	Medium
Dispatch Effects	High	Low	Low
Dispatch and Investment	Medium	High	Medium
Time-of-Use Deduction	Low	Medium	High

CRITERIA 1: INFORMATION

Information, in this context, primarily refers to the information included in the evenutal rulemaking that resolves the ambiguity around how storage will be valued for building owners.

There is a real danger that, even with the high penalties for non-compliance, many building owners will simply pay fines rather than undertake the time-consuming task of assessing buildings' energy use, comparing alternative pathways to compliance, and executing a plan for emissions reduction specific to each property. For example, Joshua London suspects that "there's going to be quite a number of buildings that just say, 'you know what, my fine is going to be $650,000 dollars a year, I'm going to pay it.'"[75] Additionally, some building owners feel that they have exhausted all reasonable compliance pathways available to them.[76, 77]

Unfortunately, because of existing law, alternative compliance payments will likely go into the City's general fund, and not necessarily target emissions reductions elsewhere. As John Mandyck, CEO at Urban Green Council and a major advocate of the law, notes, "Building owners can pay fines, but that doesn't get us the carbon reduction that we need."[78] A lack of access to information on cost-effective approaches

[75] London.
[76] David Chiu, "Local Law 97: Buildings Must Meet Greenhouse Limits Starting in 2024," The Cooperator New York, September 2019, https://cooperator.com/article/local-law-97.
[77] Will Bredderman and Daniel Geiger, "Footing the Green Bill: Legislation to Cut Carbon Emissions Will Cost Property Owners Billions," *Crain's New York Business*, April 22, 2019.
[78] Justin Gerdes, "After Pandemic, New York's Buildings Face Daunting Decarbonization Mandate," Greentech Media, April 23, 2020, https://www.greentechmedia.com/articles/read/new-york-citys-ambitious-building-emissions-law-turns-one.

to reducing emissions will certainly exacerbate this problem. While previous efforts in New York City to use energy reporting to encourage buildings' energy efficiency failed to drive significant reductions on their own, my research nonetheless suggests that providing timely, transparent, and practical information to property owners will be critical to the success of LL97.

In fact, given the aforementioned inertia of the real estate industry, it is likely that batteries *already* would be profitable for many building owners but are not installed due to a lack of clear information. London notes that Glenwood has installed fifteen batteries at its properties, and the payback period has "ranged between three and a half and five years," which he considers a worthwhile investment.[79] According to my analysis using Station A, an estimated 191MW of distributed BTM energy storage could already be profitably deployed on buildings covered by LL97. However, the total installed storage capacity to date in the city is only 14 MW.[80] As London observes, "a lot of people, when they weren't compelled, [didn't invest in batteries]; it's a different story now with people looking for what they are going to do about Local Law 97."[81]

LL97 therefore provides an opportunity to nudge buildings towards profitable investments in storage, benefitting their bottom line while also supporting the city's energy future as a whole. Fortunately, the law includes a natural pathway for this information through a provision requiring the DOB to offer technical assistance to building owners.[82] Of course, if energy storage is not included in that technical assistance, buildings may be less likely to pursue it as a means of compliance. Highlighting case studies of storage successes, such as Glenwood's profitable deployment of batteries, may encourage installation of profitable energy storage systems.

Finally, while it is beyond the policy options considered here, there was broad agreement among stakeholders of the importance of ongoing streamlining of the battery permitting process as well. To date, New York City has taken strict precautions due to the high density of buildings and concerns of thermal runaway in some batteries. However, substantial efforts are underway in this regard. Given the clear importance of storage to New York City's energy future, the MOS has prioritized safely streamlining the permitting process. An MOS staff member explained, "we're working with the Fire Department, the Department of Buildings, and the Department of City Planning to identify the best ways that the City can encourage energy storage deployment at scale."[83] In a promising development, "FDNY is undertaking a fire code revision...and they are taking seriously the idea of figuring out pathways for battery storage to be allowed indoors in specific situations."[84]

[79] London.
[80] "Distributed Energy Resources Portfolio Manager," NYSERDA, April 3, 2021, https://der.nyserda.ny.gov/portfolio-manager/?p=NqvcD5L8.
[81] London, interview.
[82] Constantinides, Local Law 97, 28-320.4.
[83] Staff Member at Mayor's Office of Sustainability, interview.
[84] Staff Member at Mayor's Office of Sustainability.

TIMELINESS OF INFORMATION

To successfully leverage LL97 as an opportunity for buildings to adopt storage, however, the emission deduction for storage must be determined soon. Generally speaking, providing ample materials to building owners in the near term is critical to the law's actual success in reducing emissions. As Richard Yancey, Executive Director of the Building Energy Exchange, observes, "one year after the passage of Local Law 97, there is still much work to be done to engage and educate building owners. There's a broad group of people who, quite frankly, still don't really know what this is."[85] If information about how energy storage will be considered under the law is delayed until 2023, which is when the Advisory Board's report to the DOB is due, many buildings' compliance decisions will have already been made, possibly leading to investments in more expensive alternatives. As London notes, until the rules are promulgated, it's unlikely that batteries will be deployed: "We're eagerly awaiting [the rulemaking]…As property owners and operators, we're kind of in limbo…People are probably going to wait before saying, 'Oh, batteries are one of my tools that I'm going to use.'"[86]

TRANSPARENCY OF INFORMATION

In addition to urgency, stakeholders made clear that the algorithm determining emission reductions from storage must also be transparent. A state energy leader raised concerns about the City outsourcing this work to a private company, "it's tough to think about having a private company who would have some type of proprietary analysis, which then they couldn't share. It would just be kind of a magical 'trust us.'"[87] A carbon accounting entrepreneur agrees that "transparency is one of the biggest issues in today's carbon accounting world; no one really knows how the emissions are calculated and the underlying assumptions; it's often average emissions data based on annual static data."[88] The chosen policy option should therefore provide sufficiently transparent accounting systems to allay these concerns.

PRACTICALITY OF INFORMATION

Finally, in order to decrease the friction and cost of determining a low-cost means of complying with the law, information provided to building owners must be easily put to use. A key finding is that buildings' appetite for information complexity may vary widely by the size of the property and technical expertise of the building manager. Owners of small buildings will likely prefer simple, easily implemented solutions that will guarantee emission reductions since they "have more difficulty calculating abatement costs."[89] For example, Timothy Grogan, the managing agent of a 300-unit co-op, is concerned that he does not

[85] Gerdes, "After Pandemic, New York's Buildings Face Daunting Decarbonization Mandate."

[86] London, interview.

[87] Energy Policy Leader in New York State, interview.

[88] That same entrepreneur observed that there may well be private solutions that could help the City expedite this process: "a private company won't necessarily be less transparent than the City and consultants; it really depends on the approach that you're taking." Carbon Accounting Entrepreneur, March 17, 2021.

[89] Danielle Spiegel-Feld, "Local Law 97: Emissions Trading for Buildings," *New York University Law Review Online* 94 (December 2019): 158.

have access to a simple means of calculating options to reduce emissions further.[90] With respect to battery storage, building owners may be expecting a simple, easily understood figure. For instance, when imagining storage deductions in the law, London suggests that "the Advisory Board will probably list an amount per kilowatt or per kilowatt hour or per megawatt hour per year that they will assign that would be an offset,"[91] rather than a more complicated or grid-dependent deduction. William Acker, Executive Director of New York Battery and Energy Storage Consortium, observes, "buildings' ability to respond is constraining; the more textured and real-time you make the signal, the more difficult for the building to take advantage of it."[92]

In contrast, mangers of high-tech buildings may prefer a more precise approach that allows for emissions maximization. For example, the Bank of America Tower is the first skyscraper to receive a "platinum" rating from the U.S. Green Building Council's Leadership in Energy and Environmental Design program. However, based on the company's calculations, due to heavy, round-the-clock use, LL97 may cost the building $2.5 million in yearly fines beginning in 2024.[93] Such a property may find more complex and nuanced information agreeable if it helps to maximize emission reductions. Therefore, the chosen policy should ideally include a range of pathways, responsive to the capacity of the building owner.

EVALUATION OF POLICY OPTIONS ON CRITERIA 1: INFORMATION

CLEAN PEAK	Establishing peak windows should be a straightforward process given existing policy examples; however, determining a reasonable size of the deduction during those peak windows will require greater analysis that may take some time. Furthermore, the benefits from the policy may not be immediately clear to building managers. This approach also requires considerable ongoing information sharing in order to track the timing and amount of charging and discharging storage.
AVERAGE DISPATCH EFFECTS	The simplicity of a dispatch-only deduction lends itself to quick implementation using a transparent calculation, such as the one I have provided below, and with immediate practical value to building managers and financiers.
AVERAGE DISPATCH AND INVESTMENT EFFECTS	This approach is somewhat more complex than the dispatch figure alone, requiring more challenging and time-consuming analysis to determine a reasonable long-term investment effect. However, once established, it shares the benefit above in terms of transparency and practicality.
TIME-OF-USE DEDUCTION	This approach presents the most challenges to timely, transparent, and practical information. Given that MEFs are constantly changing, even once the system is implemented, it will require further analysis on the part of building owners to calculate potential values of energy storage. It also requires ongoing information-intensive work

[90] Chiu, "Local Law 97: Buildings Must Meet Greenhouse Limits Starting in 2024."
[91] London, interview.
[92] William Acker, March 25, 2021.
[93] Bredderman and Geiger, "Footing the Green Bill: Legislation to Cut Carbon Emissions Will Cost Property Owners Billions."

	in order to adjust dispatch algorithms. Overcoming these information barriers could prove resource-intensive for building owners; however, larger and more technically complex building managers may be willing to make this tradeoff if it brings with it higher emission deductions, as explored below.

CRITERIA 2: INCENTIVES

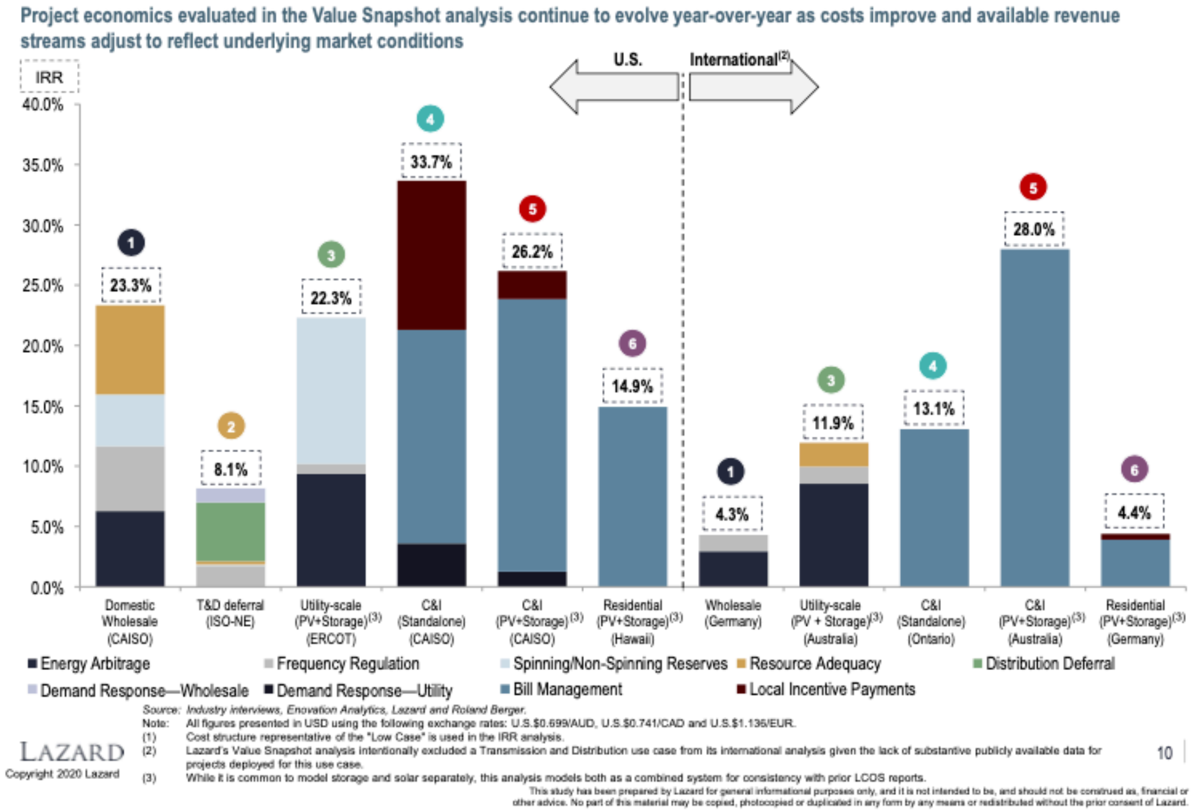
Based on the considerations of cost of compliance in Appendix A, it is clear that pursuing energy efficiency and retrofits alone will incur high overall social costs for reducing emissions. Therefore, energy storage could play a role in reducing overall compliance costs. Adequately incentivizing storage is critical to the City's overall energy goals, and LL97 may prove a useful means for doing so. As a member of MOS noted, "The Office's perspective on storage is we need a lot of it, and we'd like to see a lot more of it built not just for the grid benefits, but also for the resiliency benefits."[94]

To achieve profitability, batteries often use an approach called "value stacking," combining streams of revenue by offering numerous services to the grid. Figure 3 shows examples of how different batteries combine revenue streams. LL97 provides two means of incentivizing storage: a time-of-use benefit based on the MEF of electricity and the undefined "capacity-based deduction" cited above. As the MOS staff member noted, these two can work in concert to properly incentivize storage on the grid: "To the extent that [storage owners are] not receiving the right compensation for the value that they're providing, there's this capacity-based deduction that can potentially be used to figure out what the right compensation should be."[95]

[94] Staff Member at Mayor's Office of Sustainability, interview.

[95] Staff Member at Mayor's Office of Sustainability, interview.

FIGURE 3: VALUE SNAPSHOT CASE STUDIES—SUMMARY RESULTS[96]



Currently, there may be unmeasured factors disincentivizing sufficient battery deployment. Storage often suffers from market failures that reduce the value streams from services it provides. For example, as noted above, storage can indirectly improve air quality from reduced peaker plant operation. When determining the capacity-based deduction for storage under LL97, some of the emission reductions that storage offers are similarly overlooked. For example, Dr. John Bistline notes that even when accounting for both the dispatch and investment impacts of storage, it is possible to still underestimate the averted emissions from storage due to the fact that "emissions from startups of fossil units…are not easy to account for…in a linear optimization model."[97] Authorizing energy storage projects in the near term may expedite future buildout when significant and rapid investment in energy storage is necessary to maintain reliability. This kind of early public investment in technologies can be critical to lowering the long-term costs for society.[98]

Nonetheless, there may be a need for additional targeted policies to incentivize storage beyond LL97. As a state energy policy leader notes, "not every policy mechanism has to value everything. We can have

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[96] Mark Wilson, "Lazard's Levelized Cost of Storage Analysis—Version 6.0," *Lazard*, 2020, 10.

[97] John Bistline, "Research on Energy Storage Investment Effects," February 3, 2021.

[98] Terence Conlon, Michael Waite, and Vijay Modi, "Assessing New Transmission and Energy Storage in Achieving Increasing Renewable Generation Targets in a Regional Grid," *Applied Energy* 250 (September 2019): 1096, https://doi.org/10.1016/j.apenergy.2019.05.066.

different levers."[99] For example, a future carbon pricing scheme in NYISO, which has recently been under consideration, would effectively incentivize storage to reduce emissions on the grid outside of the context of LL97.

Furthermore, the City is actively considering whether the law should include a trading system in its implementation. Developing an emissions trading system under LL97 presents an opportunity to reduce compliance costs, allowing buildings with deep reductions to trade avoided emissions to buildings that have difficulty reducing their emissions. As Zach Livingston, Head of Sales at the carbon accounting company ClearTrace, observes, "LL97 shouldn't be pushing companies to just hit that threshold, but should be incentivizing companies to go well under that threshold…Real estate companies…that are able to go well under that threshold can then look to trade that with companies that are over that threshold, giving another offset potential outside of just RECs."[100]

Proponents of storage note that including bulk FTM storage in the trading scheme could help buildings reduce their emissions offsite when it is challenging and expensive to do so onsite. For example, the New York City Council recently passed legislation to close the jail complex on Riker's Island and explore installing a large renewable energy center in its place. Such projects could provide useful sites for large-scale FTM storage that could be included in a trading scheme, providing cost-effective compliance opportunities for highly efficient buildings that nonetheless have difficulty staying below their caps, such as data centers or a trading floor.[101]

The key question in analyzing incentives is: given timely, transparent, and practical information, do the emission deductions awarded to an ESS, combined with existing value streams for storage, justify the costs of installing and operating that ESS in terms of time, complexity, and money? Emission deductions must be both significant, avoiding substantial costs, and reliable, providing financial certainty.

SIGNIFICANCE OF INCENTIVES

Naturally, the size of the deduction provided to storage will impact how much storage is deployed in response to LL97. As London observes, if the incentive is not significant "people may shy away from it. You know, it's not cheap. It's about $350,000 for a 100kW system."[102] In his own calculations of a 100kW battery's performance, the revenue has been significant enough to make it worthwhile: each battery lowers the building's electricity costs "14% or 15% a year, with the main function being demand peak shaving. [When] you take 14-15% off an $800,000 electric bill, it is significant."[103] Combining these two figures from London, roughly $112,000 in annual revenue justifies an upfront investment three times that. Considering that the value from LL97 can be "stacked" with other value streams such as the ones that

[99] Energy Policy Leader in New York State, interview.

[100] Zach Livingston, January 29, 2021.

[101] Gerdes, "After Pandemic, New York's Buildings Face Daunting Decarbonization Mandate."

[102] London, interview.

[103] London.

London describes, I set a minimum threshold of 15% of the revenue required to finance one of Glenwood's batteries, or roughly $170/kW/year, to consider an incentive "significant."

RELIABILITY OF INCENTIVES

The other major consideration in designing the incentives for batteries is how dependable or "bankable" the incentive is. The project's value streams must be reliable and likely to remain consistent year after year in order to limit the risk of the investment.

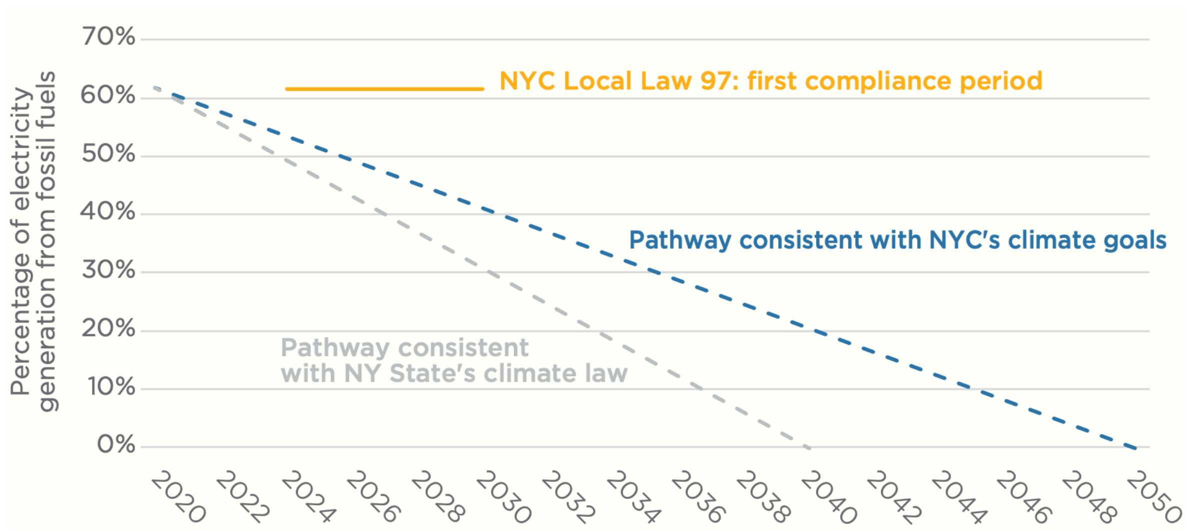
EVALUATION OF POLICY OPTIONS ON CRITERIA 2: INCENTIVES

CLEAN PEAK	The significance of a clean peak incentive is quite flexible. In Massachusetts, the value of the credits are now around $100,000/MW/year or only $100/kW/year, failing to meet the threshold of significance; however, it is likely that this will increase over time as the standard becomes more exacting.[104] As for bankability, analysts remain uncertain whether this financial stream is secure enough to make projects "financeable" or if it simply qualifies as an "upside."[105] It is likely that a clean peak program could be designed in such a way that the incentive is both significant and relatively reliable. Doing so, however, would raise questions of efficacy; for, as explored below, the impact of the clean peak approach probably does not justify a high financial reward.
AVERAGE DISPATCH EFFECTS	A straightforward benefit for the "dispatch effect" is likely to fail the threshold of significance. As shown below, a reasonable estimate for the avoided emissions of this pathway is 85 tCO_2e/MW/year. Translated into avoided alternative compliance payments, this equals $23/kW/year. This incentive is, however, highly reliable since it is not based on the grid composition or the dispatch algorithm of the ESS.
AVERAGE DISPATCH AND INVESTMENT EFFECTS	An incentive based on both dispatch and investment effects is reliable for the same reasons as the dispatch-only approach. Based on the avoided emissions calculations below, a reasonable range for the incentive is $115 to $230/kW/year, straddling the $170/kW/year threshold of significance. It should be noted that this approach, as with the dispatch-only approach above, would require a limited energy use exemption for buildings to realize these full incentives. The exemption is justified up to a reasonable level because the dispatch and investment effects already account for the emissions from charging.
TIME-OF-USE DEDUCTION	Currently, the emissions factor for electricity in LL97 is based on the historical generation mix for New York City and does not account for the planned decarbonization of New York State's electricity grid over the coming decade (Figure 4).

[104] Wolfe, "MA Clean Peak Energy Standard."
[105] Wolfe.

	This keeps the emissions factor higher than it likely actually will be.[106, 107] If the emissions factor for electricity is based on the evolving generation mix and varies with time of use, then this disincentive on storage will be reduced. Until these new emissions factors are released, it is difficult to affix a value per installed kW of storage. Based on a recent report from RMI on the impacts of demand response on marginal emissions in New York City, it is likely that that value will vary widely over time and depend upon the characteristics of the battery and building.[108] Therefore, incentives will likely range both above and below the threshold of significance. Given its variability, this value is, however, less bankable than the others.

FIGURE 4: FUEL SOURCES FOR NEW YORK CITY-AREA ELECTRICITY SYSTEM[109]



[106] Noah Kaufman and Yu Ann Tan, "New York City's Building Emissions Law Shows the Importance of Economywide Climate Policy," *Columbia School of International and Public Affairs, Center on Global Energy Policy*, October 2020, 1.
[107] Kaufman and Tan, 3.
[108] Cara Carmichael et al., "The Carbon Emissions Impact of Demand Flexibility" (RMI, 2021).
[109] Kaufman and Tan, "New York City's Building Emissions Law Shows the Importance of Economywide Climate Policy," 4.

CRITERIA 3: IMPACTS

Measuring the impacts of energy storage on emissions is complex, requiring extensive technical modelling, such as that provided by EPRI's REGEN. Storage tends to "have complex and diverse cost, value, and performance characteristics that make [it] challenging to model."[110] Moreover, "there is limited guidance about best practices and research gaps for energy storage analysis."[111] EPRI concludes that many models "do not adequately model the potential benefits" of energy storage.[112] Overall, the potential of storage and other demand response tools to support compliance with LL97 is significant. A recent report from RMI calculates that demand flexibility in buildings can provide a 3% emission reduction currently but could exceed 10% as buildings electrify their operations.[113] Even a 3% emission reduction city-wide, would reduce emissions by roughly 1 million tCO2e annually, or nearly 20% of the reduction required by 2030. Of course, many buildings cannot support energy storage on site, but the potential for emission reductions citywide may nonetheless be large. Before providing further estimates for the impact of storage, two important modelling considerations are paramount: grid-level characteristics and ESS-level characteristics.

GRID-LEVEL CHARACTERISTICS

In order to properly understand the impact of storage on emissions, it is critical to distinguish between marginal and average emissions factors, as described above.[114] This distinction is, in fact, significant for understanding the emissions impact of any decarbonization effort on the electric grid, including renewable energy deployment or efficiency measures.[115] As RMI researchers note in their analysis of the impacts of demand flexibility on LL97: "Annual average emissions only encourage behavior that reduces energy consumption over the year. This limits the impact of the law because it does not value behavior that is optimized around the timing of electricity consumption."[116] One study found that using AEFs

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[110] John Bistline et al., "Energy Storage in Long-Term System Models: A Review of Considerations, Best Practices, and Research Needs," *Progress in Energy* 2, no. 3 (July 24, 2020): 1, https://doi.org/10.1088/2516-1083/ab9894.

[111] Bistline et al., 1.

[112] Udi Helman, "Pumped Storage Hydro in Resource Planning in the United States: A Survey of Recent Results and Methods," July 2019, 12.

[113] Carmichael et al., "The Carbon Emissions Impact of Demand Flexibility," 14.

[114] Kyle Siler-Evans, Inês Lima Azevedo, and M. Granger Morgan, "Marginal Emissions Factors for the U.S. Electricity System," *Environmental Science & Technology* 46, no. 9 (May 2012): 4742, https://doi.org/10.1021/es300145v.

[115] K. Siler-Evans et al., "Regional Variations in the Health, Environmental, and Climate Benefits of Wind and Solar Generation," *Proceedings of the National Academy of Sciences* 110, no. 29 (July 16, 2013): 11768, https://doi.org/10.1073/pnas.1221978110.

[116] Carmichael et al., "The Carbon Emissions Impact of Demand Flexibility," 6.

instead of MEFs can underestimate the impact of emission reduction efforts by 50% or overestimate them by 100%.[117]

For New York City specifically, the MEF may be particularly important due to the local grid composition because, while "most electricity demand is met by efficient natural gas," which is therefore weighted more heavily in the AEF, "if the petroleum plant is the marginal plant, it is the one that would actually decrease its electricity output and would be the one whose emissions are avoided due to the intervention."[118] To address this issue, LL147 amended the original law to allow for time-of-use emission factors for electricity, which the City is currently developing. However, calculating MEFs can be challenging, since "there are different ways of accounting for marginal emissions based on different assumptions."[119] Further complicating matters, NYISO does not currently publish MEFs, making it difficult to estimate what precisely the benefits of storage responding to MEFs would be.[120]

ESS-LEVEL CHARACTERISTICS

The composition of the specific ESS is the other major factor dictating the impact on emissions. Under current market structures, storage is not necessarily rewarded for unique characteristics, such as its rate of discharge or its duration. In New York City, there is compelling evidence that long-duration storage may play an important additional role in helping to replace local peaker plants. Modeling shows that a combination of short- and long-duration energy storage **"**can economically replace—one-for-one—up to 83% of New York [State]'s peakers." Including long-duration storage on the grid, "enables the economic replacement of more than 4x more peakers than lithium ion alone."[121] Therefore, the composition of the ESS should ideally be considered when attempting to calculate its emissions impact.

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[117] Courtney N. Smith and Eric Hittinger, "Using Marginal Emission Factors to Improve Estimates of Emission Benefits from Appliance Efficiency Upgrades," *Energy Efficiency* 12, no. 3 (March 2019): 585, https://doi.org/10.1007/s12053-018-9654-4.
[118] Smith and Hittinger, 587.
[119] Carbon Accounting Entrepreneur, interview.
[120] Siler-Evans, Azevedo, and Morgan, "Marginal Emissions Factors for the U.S. Electricity System," 4747.
[121] Burger and Ragazzi, "Solving the Clean Energy and Climate Justice Puzzle: How Multi-Day Energy Storage Can Cost-Effectively Replace Long-Running Peakers in New York State," 2.

EVALUATION OF POLICY OPTIONS ON CRITERIA 3: IMPACTS

CLEAN PEAK	A clean peak approach fails to capture the full dynamism of MEFs on the grid. Despite its focus on adding clean energy to predetermined peak windows, in practice this approximation can prove too blunt to achieve meaningful emissions reductions, reflecting average emissions more than marginal emissions.[122] Prior to the actual launch of CPS in Massachusetts, modeling suggested that the "Clean Peak only achieves about a 5% reduction in emissions relative to our no-policy baseline."[123] Notably, this 5% refers to the reduction in dispatch emissions caused by storage—that is, even with the CPS in place, the model suggests that the short-term emission impacts from storage in Massachusetts is net positive. This result is due in part to the specific grid composition in Massachusetts which often causes storage to both charge from natural gas plants and discharge to displace natural gas, leading to an increase in emissions due to less than 100% round-trip efficiency. Furthermore, results from modeling the policy did not show evidence of a significant shift from the counterfactual dispatch algorithm.[124] Remarkably, applying a carbon price of even \$1/tCO_2e was found to be as effective as the CPS.[125] Of course, these results were only obtained through a model and could change over time as the grid composition in Massachusetts changes. However, the results suggest that a clean peak model under LL97 may not significantly shift the dispatch algorithm of storage. In that case, its effect on emissions is likely to be small compared to what is already achieved through a simple price-maximizing algorithm under the current market construct.
AVERAGE DISPATCH EFFECTS	As seen in Massachusetts, in many cases energy storage can increase short-term emissions.[126, 127] Given the importance of energy storage to decarbonization, this result may be counterintuitive. Nevertheless, based on the generation mix, the round-trip efficiency (RTE) of storage, and the current market structure that rewards energy arbitrage by cycling large amounts of energy to take advantage of small fluctuations in price, the net effect of many storage systems is to increase the level of emissions.[128] Researchers have also demonstrated that "in many US regions, marginal storage-induced CO_2 emissions can be decreased significantly (25-50%) with little effect on revenue (1-5%)."[129] However, since power generation is not targeted directly by LL97,

[122] Shrader et al., "(Not So) Clean Peak Energy Standards," 2.

[123] Shrader et al., 3.

[124] Shrader et al., 3–4.

[125] Shrader et al., 4.

[126] Laura M. Arciniegas and Eric Hittinger, "Tradeoffs between Revenue and Emissions in Energy Storage Operation," *Energy* 143 (January 2018): 1, https://doi.org/10.1016/j.energy.2017.10.123.

[127] Eric S. Hittinger and Inês M. L. Azevedo, "Bulk Energy Storage Increases United States Electricity System Emissions," *Environmental Science & Technology* 49, no. 5 (March 3, 2015): 3203, https://doi.org/10.1021/es505027p.

[128] Arciniegas and Hittinger, "Tradeoffs between Revenue and Emissions in Energy Storage Operation," 8.

[129] Arciniegas and Hittinger, 1.

	and electricity from emissions is currently assigned a single factor, the law will not correct this market failure without further clarification. What, then, is the current dispatch effect of storage in New York City? In a 2015 study of bulk energy storage in the U.S., Hittinger and Azevedo find that, for NYISO, there were "small increases in emissions…as a result of storage additions." However, subsequent work by Hittinger concludes that this had changed based on lower natural gas prices, which allowed storage charged from natural gas to displace coal plants. In this subsequent modeling of the New York grid, storage operating without an emissions signal but in a purely arbitrage manner appears to, in fact, reduce emissions.[130] I use these more recent results to compute the short-term impacts of storage. The paper observes 84,559 tCO_2e annually through dispatch from 1,000MW of storage in NYISO or roughly 85 tCO_2e/MW/year in average dispatch effects. This represents a lower bound on the impact of storage in New York City in the future, given that storage in the city should reduce emissions more than storage elsewhere in the state due to the local MEFs noted above. Furthermore, the paper found that as more renewables enter the grid, emissions reductions from storage tend to increase.[131]
AVERAGE DISPATCH AND INVESTMENT EFFECTS	There are also long-term impacts of energy storage that must be considered to accurately assess the total emission reductions from storage. As an energy policy leader at the state level observed, "I think people have been critical of some subsidies around batteries because [the batteries] potentially could, in the short run, raise emissions, but that absolutely loses sight of the long run benefit that we know that we need."[132] Bistline and Young find that long-run investment effects tend to dominate the emission impacts from energy storage rather than the short-term dispatch effects.[133] Overall, their study suggests that "existing literature likely underestimates the potential emissions reductions from battery storage deployment."[134] See Figure 6 for a visual representation of this difference between short-term and long-term effects. Estimating investment effects as five to ten times the size of dispatch effects, the long-term impact of storage operating in NYISO is between 425 tCO_2e/MW and 850 tCO_2e/MW in annually avoided emissions. However, the actual impacts of this approach for each kW of installed storage should be the same as the approach above; the difference recorded here is purely one of

[130] Naga Srujana Goteti, Eric Hittinger, and Eric Williams, "How Much Wind and Solar Are Needed to Realize Emissions Benefits from Storage?," *Energy Systems* 10, no. 2 (May 2019): 452, https://doi.org/10.1007/s12667-017-0266-4.

[131] Goteti, Hittinger, and Williams, 457.

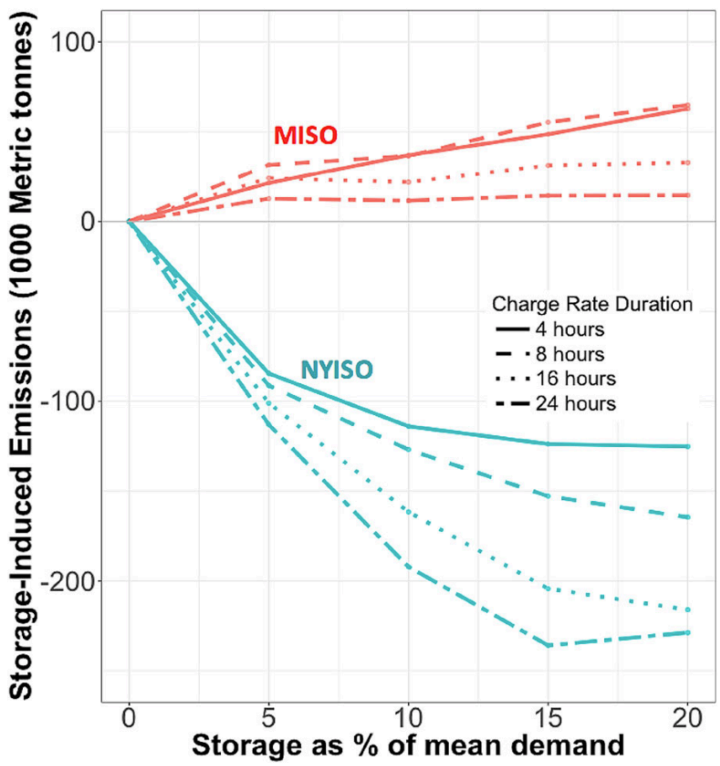
[132] Energy Policy Leader in New York State, interview.

[133] Bistline and Young, 11.

[134] Bistline and Young, 11.

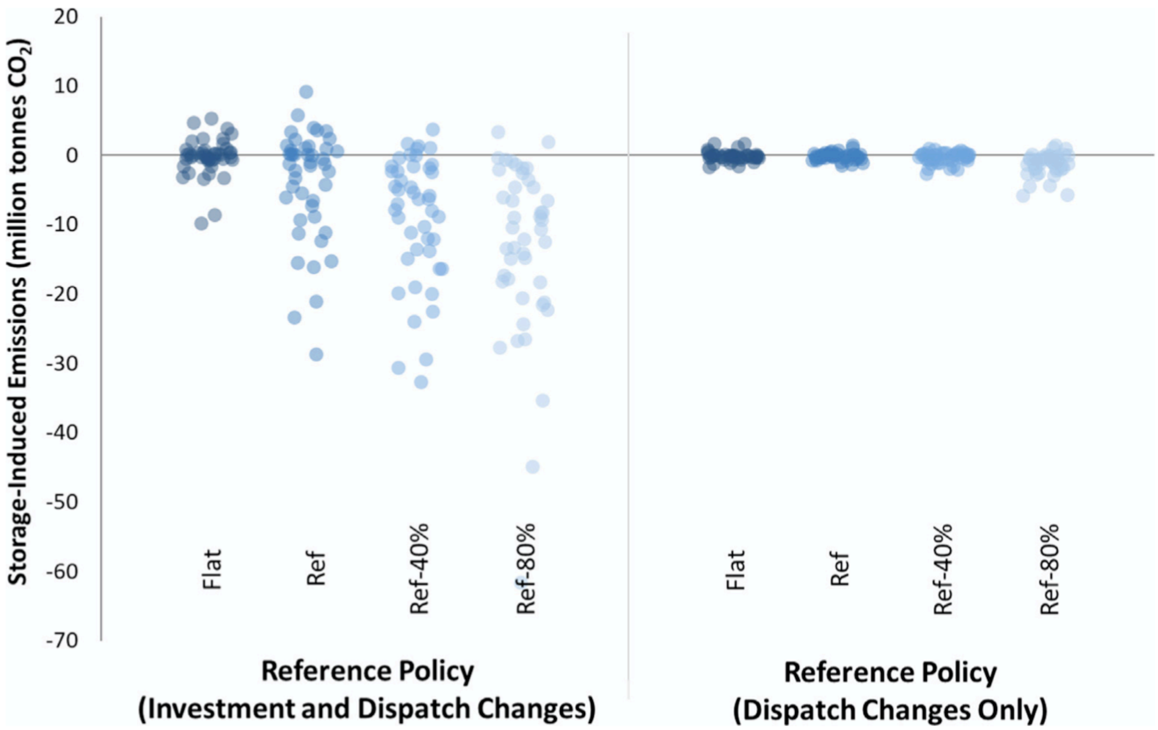
	accounting: this method includes the full long-term impacts rather than just the short-term effects. That being said, because this approach would induce greater storge deployment (since the capacity-based deduction is larger), it should lead to greater storage deployment and a larger total emission reduction at the system level.
TIME-OF-USE DEDUCTION	In terms of actual emissions reduced, a time-of-use deduction will yield the highest short-term emission reductions, since it will significantly impact the dispatch algorithm of storage to minimize emissions. It should also lead to long-term emission reductions of at least the size of those calculated above. Further modeling is needed to determine the actual emissions reductions from storage using a dispatch algorithm based on MEFs.

FIGURE 5: ANNUAL STORAGE-INDUCED EMISSIONS IN NEW YORK ISO (NYISO) AND MIDCONTINENT ISO (MISO). THE STORAGE CAPACITIES ARE VARIED BETWEEN 0 AND 20% OF THE AVERAGE DEMAND, WHICH IS 3000–12,000 MW IN MISO, AND 1000–4000 MW IN NYISO. THE ESTIMATED STORAGE-INDUCED EMISSIONS ARE GIVEN IN METRIC KILO TONS OF CO_{2E}.[135]



[135] Goteti, Hittinger, and Williams, "How Much Wind and Solar Are Needed to Realize Emissions Benefits from Storage?," 451.

FIGURE 6: REGIONAL STORAGE-INDUCTED EMISSIONS (MILLION METRIC TONS CO_2) IN 2050 WITH BOTH INVESTMENT AND DISPATCH CHANGES (LEFT PANEL) AND DISPATCH CHANGES ONLY (RIGHT PANEL) UNDER WIND/SOLAR COST SENSITIVITIES. POINTS REPRESENT INDIVIDUAL REGEN MODEL REGIONS UNDER DIFFERENT NATURAL GAS PRICE SENSITIVITIES.[136]



[136] Bistline and Young, "Emissions Impacts of Future Battery Storage Deployment on Regional Power Systems," 11.

VII. RECOMMENDATIONS

Given these findings, I make the following recommendations to the Department of Buildings.

By January 2022, establish a capacity-based deduction using reasonable assessments of the combined dispatch and investment effects of storage installed in New York City. Providing a capacity-based deduction within the coming year rather than in 2023 puts storage on the same footing as other compliance pathways in giving building owners timely, transparent, and practical information during the window when they are making compliance decisions for 2024. While assessing the investment effects will require more time than assessing the dispatch effects alone, it is justified in guaranteeing a more significant incentive for storage projects that remains bankable. While the emissions impacts in the short-term are less than a time-of-use approach, the long-term impacts of storage are captured, supporting the City in its energy goals.

Based on my research, a reasonable range for this value is between 425 tCO_2e/MW and 850 tCO_2e/MW. As noted in the section on incentives above, in order for this approach to be fair, the Department of Buildings should also establish a limited energy use exemption for storage. This could be based on expected annual kWh charge and discharge per installed kW to ensure that storage captures the established capacity-based deduction in emissions.

By June 2023, establish a transparent system for time-of-use deductions and regularly publish marginal emission factors for electricity. If storage operators prefer, they can adopt the time-of-use approach instead. This recommendation allows sophisticated storage operators to pursue greater reductions in emissions. In order to qualify, storage operators must relinquish both the dispatch incentive and the energy use exemption, instead maximizing the differential in real-time marginal emissions. Since this approach does not include the long-term investment effects of storage, they should still be rewarded that portion of the capacity-based deduction.

I am not recommending the "Clean Peak" approach because, while further evidence may suggest otherwise, its modeled lack of efficacy raises concerns about its ability to substantially reduce emissions in New York State. I also do not recommend the "Average Dispatch Effects" because this approach does not fairly value the long-term impacts of storage.

Beyond establishing storage deductions, the Department of Buildings should consider these other policies:

Pursue an adaptive approach to the capacity-based deduction, tracking and learning from the impact of storage on the grid. The capacity-based deduction, while guaranteed for the project life of storage built by 2024, should be flexible going forward to adjust to observed impacts of storage on the grid. Using the most advanced carbon accounting systems, the City should track the detailed impact on the grid of several representative storage units. This information should be shared publicly to inform other cities as they learn from the successes and failures of the pioneering work of LL97 and understand how to value storage locally. As a state leader in energy storage noted, "Local Law 97 is cutting edge. And so, like any new policy, they're going to have to be mistakes that they're going to make and we're all going to get to learn from."[137] Storage deployment should also be tracked against the need forecasted in the forthcoming *Carbon Neutral NYC Study* to see if additional incentives are necessary.

Include energy storage in a carbon trading scheme. If the City does decide to pursue a carbon trading scheme, it should include bulk FTM storage installed in New York City or serving the city's grid in that scheme. This storage, owned and operated by a single entity and dispatching based on marginal emissions factors, should be able to sell its clean storage credits to building owners as a form of compliance.

Include energy storage when providing technical consultations to building owners. In providing consultations to building owners on how to comply with the law, the City should be certain to provide expertise on energy storage in addition to information on building retrofits and other energy efficiency measures. It could also consider collecting data on these interventions to evaluate the efficacy of providing this information on eventual storage deployment.

LL97 is a remarkably ambitious attempt to limit New York City's emissions and will likely serve as a model for other jurisdictions' similar attempts. Creating a framework to fairly value the short- and long-term emissions reductions from storage will help to drive deployment of a critical energy resource for our decarbonized future.

[137] Energy Policy Leader in New York State, interview.

APPENDICIES

APPENDIX A: COST OF COMPLIANCE

In order to reduce political resistance and leakage, cost-effective implementation is critical to the law's success and longevity. One study observes that "fines could reach as high as $5 million annually for individual buildings."[138] Cost projections for LL97 compliance based solely on retrofits are alarming. Urban Green estimates that if only retrofits and energy efficiency measures are used to comply with the law, it will cost $16 to $24 billion over the coming decade. By comparison, current spending on energy-saving retrofits in the city is only $235 million annually, or 10-15% of the expected future outlay required.[139] Dividing even the low-end of this estimate by the 5.3 million tCO_2e reduction required by 2030 means that the *average* cost of retrofits would be over $3,000/$tCO_2e$. Given the $268/$tCO_2e$ compliance penalty, this would make the payback period more than 11 years. Assuming that the *marginal* cost of some retrofits is significantly higher, payback periods may well run to multiple decades to achieve some of the necessary carbon reduction.

Of course, energy retrofits are sometimes able to provide additional revenue through lowering energy costs for building owners, though oftentimes it is the renter that benefits from this cost reduction while the building owner may only see secondary benefits. However, building owners' ability to pass on these expenses is in some cases constrained. In order to ensure that LL97 does not disproportionately impact low-income tenants, New York State's 2019 "Housing Stability and Tenant Protection Act" reduces allowable rent increases for rent-regulated tenants from 6% to 2% for Major Capital Improvements.[140] Passage of this law was part of a series of negotiations between City and State officials and advocates for low-income renters that allowed amendment of LL97 to cover buildings with up to 35% affordable housing.[141]

Further complicating compliance, since the passage of LL97 in 2019 New York City's real estate industry has sustained major revenue losses and uncertainty due to the impacts of the COVID-19 pandemic. With many New Yorkers moving out of the city, median rents in Manhattan fell 20% between March and November of 2020 and the value of real estate sales decreased 50% in 2020.[142] Additionally, as people return to office buildings after COVID-19 restrictions are lifted, there will likely be efforts to increase

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[138] Gerdes, "After Pandemic, New York's Buildings Face Daunting Decarbonization Mandate."
[139] "Retrofit Market Analysis" (Urban Green Council, June 18, 2019), https://www.urbangreencouncil.org/sites/default/files/urban_green_retrofit_market_analysis.pdf.
[140] "Housing Stability and Tenant Protection Act of 2019" (n.d.), 25.
[141] Senior Member of the Mayor's Administration, interview.
[142] Stefanos Chen, "The Real Estate Collapse of 2020," New York Times, December 29, 2020, https://www.nytimes.com/2020/12/25/realestate/nyc-real-estate-market.html.

ventilation for health reasons, further increasing demands on buildings' energy systems.[143] Nonetheless, there is no indication that the City intends to push the first compliance period of LL97 back.

These considerations are important since overburdening the real estate industry could reduce the law's effectiveness, either through a successful legislative campaign to amend and weaken it or leakage of emissions to other jurisdictions through energy-intensive industry relocating or increased urban sprawl.[144] In order to support building owners' ability to make the necessary improvements, at the same time that the City Council passed LL97, it also passed Local Law 96, which establishes a Property Assessed Clean Energy (PACE) program, providing low-cost loans for cost-saving clean energy investments that typically make such investments net-positive for building owners. PACE financing will be available for both energy efficiency improvements and renewable energy system installations, including energy storage systems, potentially dramatically reducing the cost of compliance with LL97 for many building owners.[145] However, PACE financing has been slow to gain adoption in other jurisdictions.[146]

APPENDIX B: INTERVIEW FORMAT, QUESTIONS, AND INTERVIEWEES

FORMAT AND QUESTIONS

Most of the interviews were recorded video calls over Zoom. A few, as noted below, were in writing and focused on a narrower set of questions. Generally, interview questions evolved over the course of my research as my knowledge of the subject deepened, and the focus of each interview shifted with the subject matter expertise of the interviewee. Below are the interview questions I set out with when beginning my research, and which provided the departure point for future interviews.

- Legislative Process
    - What were some of the highlights and key decisions in passing LL97?
    - Who were the critical stakeholders for gaining support?
- Energy Storage and DERs
    - Do the working groups have a plan for how to address the emission reduction from energy storage and distributed energy resources?
    - Can remote batteries count towards reducing emissions?
    - Can other remote DERs count towards reducing a building's emissions?
- LL97 and New York State Energy Policy

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[143] Anca Gagiuc, "Conquering Local Law 97 Post-Pandemic," Commercial Property Executive, July 20, 2020, https://www.cpexecutive.com/post/conquering-local-law-97-post-pandemic/.
[144] Spiegel-Feld, "Local Law 97: Emissions Trading for Buildings," 154–55.
[145] Sage Lincoln, "Picking Up the PACE: NYC LL96 Final Rules Expected Soon," Urban Green Council, March 10, 2021, https://www.urbangreencouncil.org/content/news/picking-pace-nyc-ll96-final-rules-expected-soon.
[146] Lincoln.

- What will the relationship be between VDER and LL97?
    - How will Tier 4 RECs and LL97 work together?
    - How will transmission constraints affect the implementation and compliance with LL97?
- Compliance
    - How many MWs of clean energy/storage need to be built for buildings to be in compliance?
    - How will EV charging be considered under LL97?
- Follow up
    - How can my research help you?

INTERVIEWEES

- William Acker, Executive Director, New York Battery and Energy Storage Technology Consortium
- John Bistline, Principal Project Manager, Electric Power Research Institute (written correspondence only)
- Zach Livingston, Head of Sales, ClearTrace
- Nick Lombardi, Senior Manager of Business Development, Enel X
- Joshua London, Senior Vice President, Glenwood Management Corporation
- John D. Macomber, Senior Lecturer of Business Administration, Harvard Business School
- Michael Macrae, Senior Manager Regulatory Affairs, Enel X (written correspondence only)
- Danielle Manley, Associate Manger of Policy, Urban Green Council
- Carbon Accounting Entrepreneur
- Climate Advisory Board Member
- Energy Policy Leader in New York State
- Senior Member of the New York City Mayor’s Administration
- Staff Member at New York City Department of Buildings
- Staff Members at New York City Mayor’s Office of Sustainability

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