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Connecting the Dots for NYC Clean Power: The Case of NineDot Energy

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Introduction

On July 27, 2023, Con Edison (ConEd), the major energy provider in New York City, sent mass text messages and emails to New Yorkers: "We're preparing for the heatwave in your area," it read. "Please limit your energy use between 2pm and 10pm to keep service reliable."[1]

The risk was twofold. In the worst-case scenario, high demand from energy-intensive air conditioning units and other appliances could overwhelm the power grid and trigger a blackout. But New York has seen only a few blackouts in the past several decades, and the most recent citywide outage was in 2003.[2] It was more likely that the utility company would respond to high demand by firing up so-called peaker plants, outdated oil-powered and natural gas–powered facilities recognizable by their telltale smokestacks, which belch pollutants into the atmosphere.[3]

New York City has approximately 15 peaker plants, and they only operate for about 500 hours each year during heat waves, cold snaps, and other times of high demand. Although they're only used approximately 6% of the time, the city spends heavily to keep these plants open: Between 2010 and 2019, New York ratepayers spent an estimated $4.5 billion to maintain the facilities.[4] A peaker plant's presence in a neighborhood tends to correlate with increased rates of respiratory illness among residents.

The heatwave was a test for NineDot Energy, a clean energy developer that had begun building basketball court–sized battery storage sites throughout the city to store energy from cleaner sources of power and overnight, when there's excess power available. The idea was that clean battery power could one day replace peaker plants when ConEd needed additional electricity to keep the lights on. That summer, the goal was more modest: If they worked, the

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batteries could replace the smaller diesel generators ConEd typically used in periods of high demand. On July 27 and 28, as temperatures soared above 100°F, the company's first battery site came online.

Co-founder and Chief Technology Officer Adam Cohen was on a lobbying trip to Washington, DC, when the call from ConEd came. He scrambled to his hotel room to make sure everything was ready to go.

The Energy Transition

For the first time ever, in 2023, global investors were expected to spend more money on solar power than drilling for oil.[5] The costs of solar power, wind power, and lithium-ion battery cells had all plunged in the past 20 years, and in many parts of the world, it was already cheaper to build and run solar and wind power plants than nuclear, coal, or gas facilities.[6] The transformation had happened with breathtaking speed. In 2005, just 0.8% of energy in North America came from wind and solar sources. By 2022, the number had climbed to 13.5%.[7]

The progress was encouraging, but the world needed to move even more quickly to halt carbon emissions and minimize the catastrophic impacts of climate change. In 2015, government leaders from around the world met in France and agreed to a goal of limiting the rise in average temperature to 1.5°C (2.7°F) above preindustrial levels. To hit that target, the ambitious Paris Agreement would require a 50% reduction in global emissions by 2030.[8]

In the United States, President Biden signed several laws that encouraged heavy government spending in support of various clean energy initiatives, including building infrastructure for charging electric vehicles, offering tax breaks to homeowners who invested in energy-efficient upgrades, and developing carbon-capture technology. These new incentives led to an estimated $230 billion in US manufacturing investments in 2023, including a solar cell plant in Georgia, an electric truck factory in Nevada, and a battery factory in Oklahoma.[9]

It was against this backdrop that NineDot realized the ideas they had been working on for years to achieve their mission of fighting climate change were ready for prime time. For nimble companies that could successfully navigate the complex web of local, state, and federal regulations while taking maximum advantage of the tax breaks and other incentives on offer, going green was finally a financially viable goal.

Energy in New York

New York City is fueled by a hodgepodge of sources including wind, nuclear, natural gas, hydroelectric power, and solar energy.[10] The whole system is calibrated by a seven-person team in Albany that monitors statewide electricity usage and tweaks the mix of power sources based on what's cheapest and where it's needed.[11] It's a taxing, high-pressure job, and the control room operators undergo psychological evaluations to ensure they're up to the task.

Electricity generated upstate is carried south to the city along more than 10,000 miles of power lines, which can get congested during times of high demand. When the lines are overwhelmed, control room operators may opt to turn on peaker plants or spend more on sources of power closer to New York City. The power grid can get very dirty in the summer, when heatwaves result in heavy air conditioning usage, but surprisingly, it can also be stretched in the winter, when much of the available natural gas is used to heat buildings, and operators turn to generators powered by dirty petroleum to meet electricity demand.

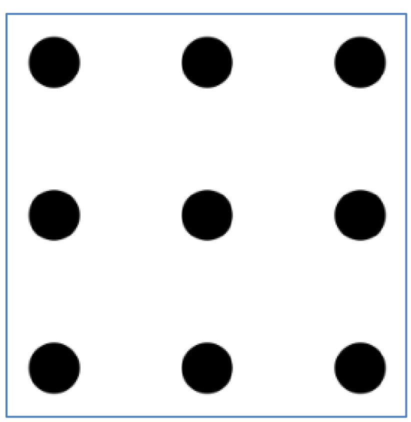
Building more power lines would go a long way in solving congestion issues, but increasing transmission line capacity is politically fraught—no one wants one running through their yard. And although a project that will bring hydropower underground from Quebec to New York City has been in the works since 2008, it isn't likely to open until 2026.[12]

Despite these infrastructure obstacles, the state of New York has set a goal of using 100% zero-emission electricity by 2040.[13] The plan includes phasing out peaker plants and building energy storage facilities like NineDot's battery sites, offering alternative sources of electricity in times of power line congestion. NineDot is on track to meet or exceed its goal for 400 megawatts (MW) in operation, construction, or development by the end of 2026. New York City is pursuing similar ambitious energy goals that complement the state's plan.[14] The state and the city are offering various subsidies and tax breaks to developers of energy storage and solar power projects that can help reach those targets.

The ambitious plan—in particular, the phaseout of peaker plants—has generated some concern about potential blackouts. In July 2023, two days before the ConEd text message, the editors of the conservative paper *The New York Post* penned an op-ed warning that "the state's loony green agenda" could stress the city's power grid by shuttering fossil fuel facilities before renewable energy sources are operating at scale. "Constituents better keep some candles handy," the *Post* warned.[15]

NineDot: Origins

The nine dot (or nine dots) puzzle is simple. Picture three dots in a row. Now picture three rows of three dots, all stacked on top of each other so that they form a grid.



The challenge is to connect all nine dots using four straight lines without lifting the pen. The problem can only be solved by *thinking outside the box*.

It was the appeal of outside-the-box climate solutions that brought the three founders of NineDot Energy together. In the early 2010s, Adam Cohen, a physicist by training, accepted a postdoctoral position at the US Department of Energy working on renewable energy. "One of the first things I learned in my first week as a postdoctoral fellow is that the really hard parts about making clean energy get deployed at scale have almost nothing to do with science and technology: they have to do with sort of human decision-making and regulations and permitting," he said.[16]

Cohen began to focus on so-called soft costs of clean energy: the planning, sales, and deployment expenditures that eclipsed the cost of hardware. At the time, he said, a physical solar panel might have cost approximately $2 per watt of energy produced. (The cost has since come down to approximately $0.25.) Yet the cost of a residential solar installation was more like $7 per watt. The *soft* costs were the $5 in non-hardware costs, and they included interconnection, market research, and customer acquisition. The goal was to bring those soft costs down to $2 per watt. Cohen launched a research program focusing on social and behavioral science with the aim of developing techniques to reduce soft costs and speed up the adoption of green energy technologies.

It was at his Department of Energy cubicle that Cohen met his future co-founder, David Arfin, who was working as a consultant to the department at the time. Arfin had recently left SolarCity, a solar panel installation company founded by Elon Musk's cousins Lyndon and Peter Rive and later acquired by Tesla.[17] At SolarCity, Arfin patented[18] a business model that leased residential solar panels to customers, allowing them to install the hardware without footing the bill for the up-front costs. Arfin remained interested in dreaming up clean energy financing arrangements that made the adoption of renewables cheap and easy for households.

Cohen and Arfin hit it off, united in the idea that *cool business models* could reduce soft costs and hasten the adoption of renewable energy. They met their third business partner, Nalin Kulatilaka, when Arfin was a peer reviewer on an academic paper Kulatilaka published on quantifying and shifting risks in clean energy business models.

"We liked talking about new ideas, and new businesses, and how to actually make progress and not just have things that sit on a shelf or in a laboratory—but rather developing projects that get deployed," Cohen said.[19]

Developing the Idea

In 2015, the three co-founders launched CertainSolar. "Our first foray into business was a financial model that actually made it so that the end user, the customer, the individual household was always 'in the money' for adopting clean energy," Cohen said.[20] With research funding from the Department of Energy, they were hoping to provide consumers a way to lease solar panels while guaranteeing savings.

The team quickly pivoted to focusing on community solar operations. These were projects that weren't connected to specific homes or businesses; rather, they fed into the power grid from an off-site location. Buying into these distributed clean energy projects held promise for customers, who could cancel their subscriptions without risk of being left with a useless solar panel on their roof.

The obvious choice of location was New York, which had just codified rules for community solar. The team looked into building solar farms in the city but quickly realized the obvious: There aren't many 30-acre parcels of undeveloped land in New York City that could function as a cost-effective solar farm.

That's when the founders decided to think outside the box and hatched plans to build fuel cell sites instead of solar farms and changed their company's name to NineDot Energy. Instead of a mythical 30-acre plot of land that could house a solar farm in New York City, they just needed to find a 10,000 square-foot space, approximately the size of two basketball courts.[21] Fuel cells weren't as clean as solar energy—they use natural gas to create electricity—but they were approximately 40% cleaner than the power grid, Cohen estimated.[22]

"The pieces just started fitting," Cohen recalled. "We were like, 'Oh, we understand how electricity is priced, we understand the financing, we understand the customers and what they want, and now we have the technology that actually works in the most vibrant energy market in the country'."[23] Between 2017 and 2020, the small team managed to build three projects.

Soon, the rules were adjusted to include battery energy storage in addition to fuel cells. This was promising because batteries were not reliant on natural gas. Battery installations could theoretically charge up using excess clean energy, then deploy the power during peak times. It would also be possible to plug electric vehicles into the battery projects to charge or feed electricity back into the grid, a technology known as *vehicle-to-grid*, or *V2G*. "It turns out the market is expanding so quickly, the technology is getting so much better, that you could build hundreds of these projects," Cohen said.[24]

NineDot had found its niche. In a handful of years, the founders had moved from a community solar business model to a fuel-cell and battery-powered development strategy. Cohen described the business model as "vanilla … with add-ons." NineDot buys energy through the power grid, then later sells that energy back into the power grid. Off-site subscribers pocket the difference in price that is available because of how the various regulations are encouraging the upgrade of New York's energy infrastructure, and NineDot takes a share of the savings. "We are sort of a real estate company, we're also a finance company, we're also a technology company, an engineering company, a construction company, and a sustainability company," Cohen said. "You have to do all of these different things to make a project work. And so we're not any one thing."[25]

Scaling Up

NineDot's new strategy was to build battery energy storage sites in locations of need throughout New York City. Nature doesn't conform to the nine-to-five workday, and wind farms and solar panels tend to produce the most electricity when the wind is blowing and the sun is shining. By storing clean power, the batteries could help address the mismatch between downstate electricity demand and upstate energy production. The potential was huge: As residents shifted toward driving electric vehicles and powering their homes with heat pumps, demand for electricity could double or triple. By late 2024, NineDot had plans to develop hundreds of MW of battery storage. The company's projections suggested that demand would reach 6,000 MW by 2030 and potentially 17,000 MW by 2050.[26] "We're just scratching the surface of this market, or this need," Cohen said.[27]

A single large battery is slightly larger than a sports utility vehicle (SUV) or small pickup truck, and it holds one megawatt of energy (see Exhibit 1). A typical NineDot project is a five-unit group of these truck-sized installations. A five-megawatt project can power approximately 5,000 New York City homes for about four hours on a hot summer day.

New York City uses 5,500 MW of power each day. In the summer, demand can rise to 10,000 megawatts.[28] In other words, although each NineDot installation storing 5 MW of power contributes to the energy grid, to make a significant dent in the city's electricity demand, NineDot needed to build hundreds of these battery installations. To do so, it would need to dramatically expand its team and capital base.

Help came in the form of an investment from Carlyle Group, a private equity firm that poured a total of $100 million into NineDot and V2G charging company Fermata in early 2022. Carlyle and a new investor, Manulife, invested a further $225 million in 2024. The hope was for NineDot to build 400 MW (1,600 MW-hours [MWh]) of clean energy storage by 2026.[29]

By fall 2024, the team comprised 65 employees. To cut the tape on hundreds of battery projects, they'd need to scout thousands of potential locations, and most would not work out. It would be a challenge, but the regulatory environment in New York kept getting friendlier and friendlier. "The state has doubled down increasing the goals and the incentives for this market, the city has made permitting easier. The utility has made interconnection easier. And the federal government has passed the Investment Tax Credit that expanded to standalone storage," Cohen said in August 2023. "And we built the business model without the need for that. And so it was kind of just like a lot of goodness happened."[30]

Since summer 2023, New York State had made several concrete steps toward reducing carbon emissions from its grid. It approved a 6-gigawatt roadmap with $1.3-2.0 billion in funding for energy storage deployment through 2030, and as of fall 2024, there was a pipeline of 1.4 gigawatts of community-scale projects in ConEd territory. New York City also passed *City of Yes for Carbon Neutrality*, which allowed for batteries to be installed in all zoning districts in the city.

The Way Forward in New York and Beyond

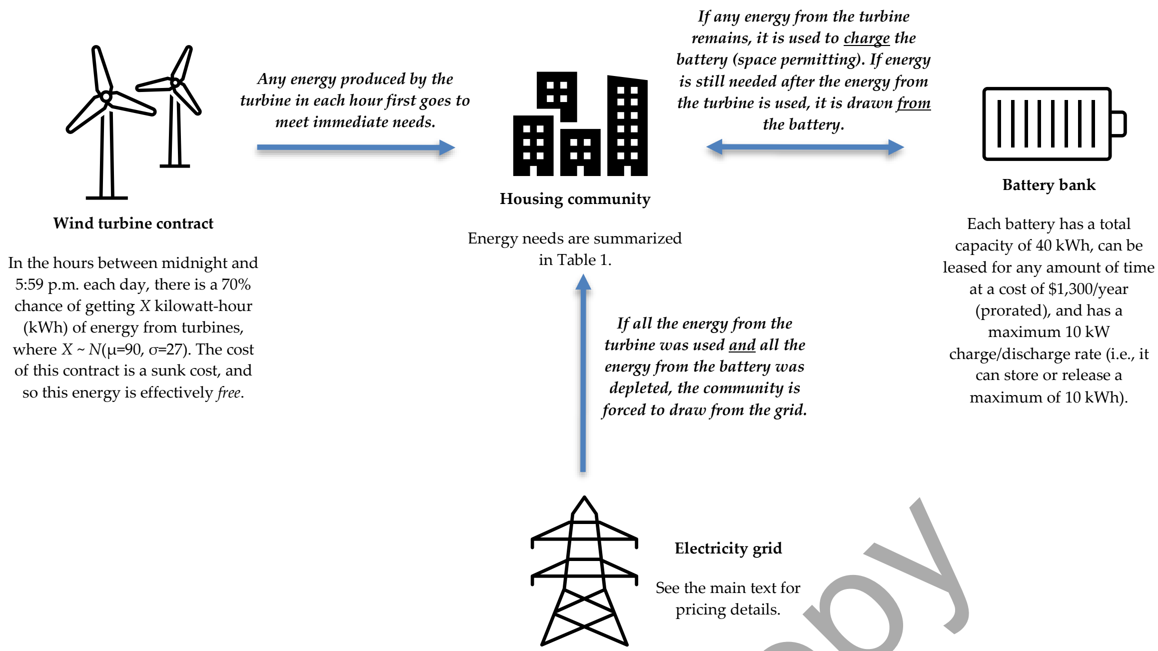
NineDot's aspirations did not stop at New York. They were convinced that if they could make it in New York, they could make it anywhere. The *city that never sleeps* ran on electricity and was also one of the most challenging places in the world to deploy the kind of technology with which NineDot was working. A plethora of agencies had to approve every step of every project, and New York's fire department had world-leading standards for reviewing and approving lithium-ion batteries. Given New York's pioneering work in the field, NineDot was convinced that other cities around the world would look to New York as an inspiration to clean up their own grids. If NineDot succeeded in New York, they would be able to make it anywhere.

Heading into the hot July of 2024, NineDot had the wind at its back. It had the money and the know-how to replicate its battery installations all over the city. But the heady ideas and boundless optimism were about to run up against the messy, glitchy reality of the New York City power grid. The company's entire business model was built around softening the blow of a late-summer heat wave. The founders were about to find out whether eight years of meticulous planning and intensive data analysis would pay off.

An Enormous Logistical Challenge

There are many logistical challenges inherent in NineDot's vision. How large should NineDot's battery banks be? How does the transient nature of some renewable energy sources affect the operation and profitability of these batteries? And what kinds of savings can they hope to achieve?

To illustrate the analytic techniques that can be used to answer these kinds of problems, we will run a small-scale simulation that will illustrate some of these tradeoffs. This problem will consider a small housing community (a far smaller setting than the one NineDot actually operates) contending with a far simpler energy landscape (either drawing energy from the grid or drawing energy from a modest contract with a wind turbine provider, with a battery bank used for auxiliary storage) during an average July day. The following figure illustrates the simplified case we will consider:



The housing community has a source of wind energy that is clean and inexpensive but unpredictable. Rather than draw from the grid whenever wind energy is unavailable, they choose to invest in a battery bank to store wind energy when it is plentiful and then draw from it when needed. The challenge is to decide how many batteries to include in this battery bank.

The community's needs are large enough that they can be reliably estimated by a normal distribution, with means and variances listed in Table 1.

We now discuss approaches to estimate the price of electricity from the grid and its greenhouse gas impact. Figure 1 summarizes historical data on both metrics. Each point in both graphs corresponds to a single hour in July in a specific year.

Figure 1 (left) reveals that the energy wholesale price per MWh grows *exponentially* with load. This makes intuitive sense. When the load is low, cheaper energy sources can be leveraged. When the load increases, energy sources become increasingly scarce and increasingly expensive. Note that in addition to this wholesale price, our community must pay a *delivery cost* of $0.17/kWh.[i] Using data such as these, we can use a *best fit* line to obtain the following relatively accurate model of price as a function of load our apartment community faces.

$$\text{Price per MWh (\$)} = \exp\left(2.23 + 0.03 \times \text{apartment community load} + \varepsilon\right) + 170$$

where ε is a normally distributed random variable with mean 0 and standard deviation 0.16, capturing random fluctuations in electricity price.

[i] This is a simplification; the full complexities of calculating delivery costs are beyond the scope of this case.

We finally turn our attention to the *dirtiness* of energy provided from the grid. This is an altogether more difficult proposition because electricity supplied to New York City comes from myriad sources, which vary in importance from hour to hour. We rely on estimates from the environmental nonprofit singularity.energy (modified and simplified for this case) to estimate the amount of CO_2 produced per MWh as a function of load in New York City.[ii] These are plotted in Figure 1 (right). The plot reveals an approximately linear pattern between the load and the amount of CO_2 produced *per MWh*. For this reason, to a first approximation, we will estimate the amount of CO_2 produced in any given hour as:

$$\text{energy used} \times \text{CO}_2 \text{ per unit energy used} \approx \text{energy used} \times \text{load on grid in that hour}$$

Note that because this is only an approximation, the resulting number will not directly be interpretable as an amount of CO_2, but instead it will give us an indication of the *order of magnitude* of CO_2 released. These numbers will be useful in comparing the carbon impact of various options without necessarily giving us an accurate number for the amount of CO_2 released.

[ii] Although we do not use it in this case, it is interesting to note that New York City's Department of Buildings has developed the world's first Hourly Marginal Emission Rate Calculator precisely to determine the greenhouse gas reduction value of local battery energy storage. This pioneering work is part of the city's Climate Mobilization Act (also known as Local Law 97).

Hour of Day	Mean (kWh)	Standard Deviation (kWh)
0	66.471	6.893
1	63.566	6.549
2	61.349	6.284
3	59.883	6.102
4	59.295	6.034
5	60.219	6.252
6	63.217	7.038
7	67.443	8.147
8	71.354	8.952
9	74.669	9.452
10	77.313	9.709
11	79.452	9.902
12	81.037	10.098
13	82.127	10.219
14	82.985	10.237
15	83.622	10.286
16	84.043	10.29
17	83.666	10.205
18	81.504	9.668
19	79.216	9.2
20	77.495	8.82
21	76.324	8.49
22	73.601	7.937
23	70.068	7.326
0	66.471	6.893

Table 1: Energy demand in our housing community during one day in July are normally distributed with the parameters listed in this table in each hour of the day.

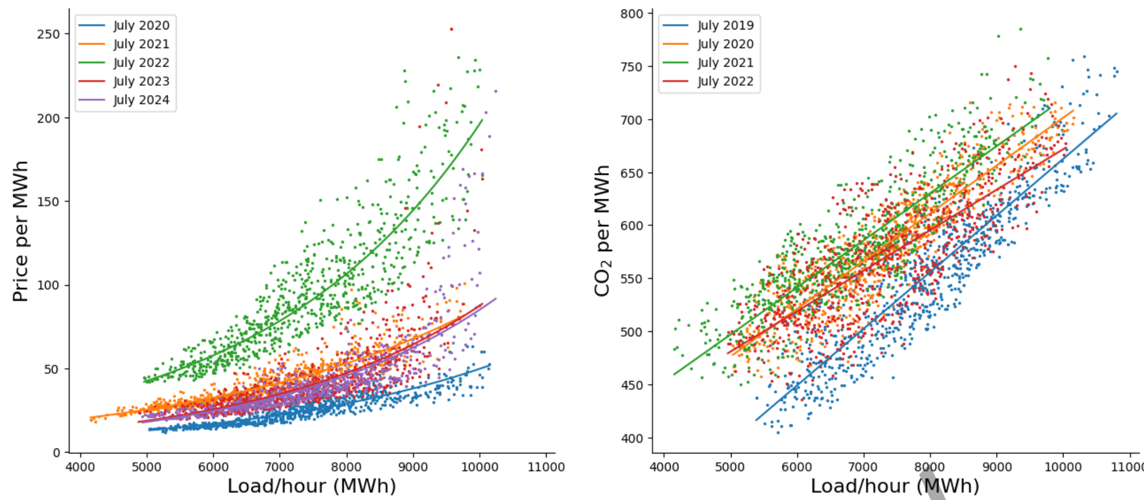


Figure 1: Hourly electricity loads in New York City plotted against wholesale electricity prices (left) and CO_2 produced (right). CO_2 figures are sourced, modified, and simplified from singularity.energy. Best-fit curves superimposed on points.

Before class, consider the following questions:

- At a high level, how would you approach the task of evaluating the potential benefit for the community of installing a single battery? What about multiple batteries?
- More specific questions:
  - Suppose that at the start of any given hour, the battery bank has stored 10 kWh of energy. The community ends up needing 16 kWh in that hour, and the turbine generates 2 kWh. How much energy will the community draw from the grid in that hour? How much energy will be left in the battery at the end of that hour?
  - More generally, suppose that at the start of any given hour, the battery bank has stored S kWh of energy. The community ends up needing E kWh in that hour, and the turbine generates W kWh. How much energy will the community draw from the grid in that hour? How much energy will be left in the battery at the end of that hour? How does the number of batteries B figure in this calculation?
  - What are the sources of randomness in this calculation? Do you think the randomness could be ignored? For example, the turbine generates on average 90 kWh of energy 70% of the time. Could we assume the turbine generates a constant $90 \times 0.7 = 63$ kWh?

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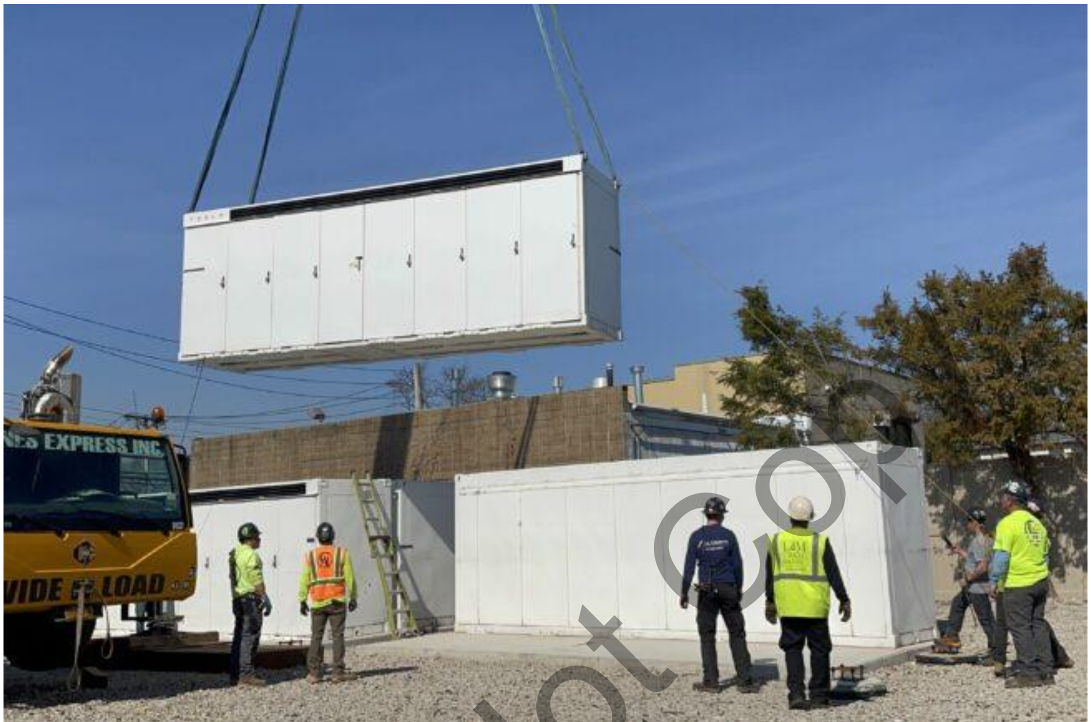
Exhibits

Exhibit 1: Batteries Being Installed (*Rigged*) at a New Site in Staten Island, New York City



Source: NineDot

Exhibit 2: Cohen and Arfin at a Completed Battery Site in the Bronx, New York City. Batteries on the left, utility interconnection equipment on the right, and solar panels in the background on the canopy.

Source: NineDot

Exhibit 3: NineDot's V2G Project in Brooklyn, New York City. This facility uses power from electric car batteries during peak times to help the ConEd power grid.

Endnotes

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