How New York City Gets Its Electricity

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When you turn on a light or charge your phone, the electricity coming from the outlet may well have traveled hundreds of miles across the power grid that blankets most of North America — the world's largest machine, and one of its most eccentric. Your household power may have been generated by Niagara Falls, or by a natural-gas-fired plant on a barge floating off the Brooklyn shore. But the kilowatt-hour produced down the block probably costs more than the one produced at the Canadian border. Moreover, a surprising portion of the system is idle except for the hottest days of the year, when already bottlenecked transmission lines into the New York City area reach their physical limit. "We have a system which is energy-inefficient because it was never designed to be efficient," said Richard L. Kauffman, the state's so-called energy czar, who is leading its plans to reimagine the power grid. It's like a mainframe computer in the age of cloud computing, Mr. Kauffman added, and with climate change, the state has that basic architecture." But how does it work now?

Cranking Out Power

In 1882, heaps of black coal were hauled by horse-drawn wagons to the Edison Electric Illuminating Company of New York's powerhouse on Pearl Street in Lower Manhattan, where "jumbo" steam-powered engines (named after P. T. Barnum's elephant) spun generators. These created electricity, which traveled to homes and businesses within about one square mile, illuminating drawing rooms without the use of a match for the first time. A few years later, a hydroelectric station on the Niagara River using Nikola Tesla's designs and equipment supplied by George Westinghouse helped turn Buffalo into an industrial force. Today hundreds of plants, mostly privately owned, pump out power. Each one varies in its cost to build and operate, how much power it can produce, how quickly and how efficiently. Unlike other states, which do not have access to such a diversity of resources, New York has a full menu of options. Coal, the original fuel, is on the way out. The state has announced plans to close the remaining plants or convert natural gas, which is currently cheap and plentiful. In 2015, 64 plants that use natural gas produced almost half the electricity in the state, said the New York Independent System Operator, a nonprofit that runs the state's grid and power markets. Four nuclear plants accounted for about a third of it. Though disposing of nuclear waste remains a concern, the state wants to subsidize nuclear plants upstate because of the steady, carbon-free power they provide. But Gov. Andrew M. Cuomo's recent decision to force the closing of the Indian Point power plant in suburban Westchester County has raised questions about the state's ability to meet its clean energy goals and how it will make up for the energy the plant provides. In New York there are 180 hydroelectric facilities, which produced 19 percent of the state's electricity, and which remain crucial to clean power production. By 2030, Mr. Cuomo wants half of the electricity consumed in the state to come from renewable sources produced here or imported from places like Canada and New England. According to the latest figures, less than a quarter of the electric energy produced in New York came from renewables. According to the latest figures, less than a quarter of the electric energy produced in New York came from renewables. While there are tens of thousands of residential and commercial solar energy systems, only one utility-scale solar photovoltaic power plant is included in the Nyiso's estimates of solar production. Large-scale wind has had more success, and the state is pushing for more; about 30 wind farms are planned upstate. And the state recently approved the nation's largest offshore wind farm, which could power 50,000 homes on Long Island by the end of 2022. A second site near the Rockaway Peninsula in Queens is in the works but is years

away. The cost of building wind and solar plants has fallen, but these power sources are intermittent. Until more storage is plugged into the grid, like batteries or pumped hydro plants, which pump water into reservoirs to store power for later use, other generators must be available to supplement solar and wind power. A standard part of the electric arsenal are generators called “peakers,” which are needed to keep the grid reliable but might run only a few days a year. New York City has about 16 such plants, mostly around the waterfront, which spring into action on the hottest days of the year or if transmission lines or power plants upstate malfunction. Some sit on barges, and all are designed to switch on quickly. The trade-off for the rapid response is usually higher costs and carbon emissions. As a result, customers pay for plants and wires that “a lot of the time are hardly used,” said Mr. Kauffman, the energy czar. The entire system was designed to meet demand extremes and handle the worst-case situation.

The Delicate Art of Balancing the Grid

Inside a $38 million control room near Albany, a team of seven employees of the New York Independent System Operator is always on duty, monitoring electricity zooming through the state’s grid and coming in from and out to neighboring grids. Nyiso (pronounced NIGH-so) is one of 36 entities responsible for the Eastern Interconnection, one of the country’s three main grids extending from the Rockies to the East Coast in the United States and Saskatchewan to Nova Scotia in Canada. Unlike water, electricity can’t be stored in a bucket. While batteries are improving, most electricity is used the instant it is created. The team constantly calculates how much power is needed and which plants can produce it at the lowest cost. Every five minutes, a computer system directs plants to dial up or scale down production to ensure enough electricity is available to keep the lights on without overloading transmission wires. If the system is out of balance or the flow of electricity is destabilized, it can damage equipment or cause power failures. Operators undergo psychological evaluations to ensure they can handle stress, and they spend weeks every year inside simulation labs preparing for a hurricane or cyberattack. Still, the No. 1 enemy is tree branches, as Gretchen Bakke pointed out in her book, “The Grid: The Fraying Wires Between Americans and Our Energy Future.” In 2003, the country’s worst blackout started with a sagging power line in Ohio that shorted out after touching a tree branch. A series of human errors and a computer problem plunged about 50 million people into darkness from New York City to Toronto and cost the United States economy about $6 billion. Jon Sawyer, the chief system operator for Nyiso, said that today, computer systems receive 50,000 data points about every six seconds, and operators monitor regional activity on a 2,300-square-foot video wall. Mandatory reliability standards have been put in place for the thousands of entities involved in the operation of the country’s electric systems. The biggest daily variable is weather. Storms can flood equipment, and bright, hot days can cause transformers to overheat and customers to crank up air-conditioners. Leaning on solar and wind means a greater dependence on weather, just as weather patterns have become less predictable. Nyiso has developed sophisticated tools using climate data to predict how much power each wind farm will generate and to find ways to balance the system if the wind suddenly dies down, Mr. Sawyer said. It is working on methods to track cloud cover and other conditions that affect the output of solar panels.

Transmitting Power Efficiently

The system’s backbone is the 11,124 miles of high-voltage lines running overhead and underground that carry electricity to local utilities. Unlike water pipes, transmission lines are not hollow, and they can overheat or shut down if too much power flows through them. Since most power is generated in

less populated areas, certain lines that carry it downstate during times of peak demand can become gridlocked. Nearly 60 percent of the state's electricity is consumed in the New York City area, where only 40 percent of it is made. "New York is the poster child for congestion," said Bill Booth, a senior adviser to the United States Energy Information Administration. To get around bottlenecks, grid operators may turn on more expensive or less efficient generators closer to where the demand is. Think of it as paying more for a carton of milk at the bodega next door than at the supermarket 12 blocks away. The state is prioritizing projects to bring more power downstate from wind farms and hydro plants. The need is even more urgent with plans to close Indian Point as soon as 2021, as it supplies about one-fourth of the power consumed in New York City and Westchester County. But building new power lines is fiercely unpopular. Residents don't want high-voltage lines in their backyards, and local power generators dislike competition from cheaper power brought in from farther away. Even if the lines are below ground, like the ones that bring power to Manhattan from New Jersey through the muck of the Hudson River, securing federal and state permits can take years. One project to bring hydropower from Quebec to New York City under Lake Champlain and the Hudson has been in the works since 2008. Despite enhancements, the transmission grid is aging. More than 80 percent of the lines went active before 1980, and Nyiso estimates that almost 5,000 miles of high-voltage transmission lines will have to be replaced in the next 30 years at a cost of about $25 billion.

Delivering Power to Your Home

Consolidated Edison's system, which originally covered about a square mile in Lower Manhattan, now stretches out over 660 square miles in the city and Westchester. There are about 200 networks that operate independently to balance and regulate the flow of electricity in dense areas. Manhattan alone has 39 networks; Rockefeller Center, for example, has its own. In all, there are 129,935 miles of cables snaking underground and overhead, enough to reach more than halfway to the moon. The largest of the state's six electric utilities, Con Ed spends millions of dollars a year to open utility holes and dig into streets crowded with gas mains, fiber-optic cables, steam pipes and subway lines to make repairs and upgrades to its vast underground network. Partly as a result, its customers pay among the highest electricity rates in the country. Operators in Con Ed's energy control center, housed in a location the utility will not disclose, ensure that enough power flows through its network to serve more than nine million people, even during a heat wave. Much of the year, peak demand is around 5 p.m., when evening rush subways and elevators take commuters home, children turn on video games and families open refrigerator doors to start dinner. In summer, it is around 3 p.m., when air-conditioners are blasting. While Con Ed's system is among the most reliable in the country, the company cannot prevent squirrels from chewing wires or transformers. But it is working to prepare for disastrous weather. Since Hurricane Sandy in 2012, the utility has spent about $1 billion to raise, waterproof or build walls around equipment in lower elevations and to carve up distribution networks so that smaller sections can be shut off remotely when floodwaters rise.

With the proliferation of residential and commercial solar installations, customers are now feeding power back to the grid. Robert Schimmenti, who leads Con Ed's electric operations, said it was developing systems to integrate the increasing numbers of devices on the other side of the meter, like fuel cells and batteries, which are sometimes linked in a microgrid, that the utility does not control. In May, Con Ed will begin installing "smart meters" in businesses across the city, and, in July, at homes on Staten Island, giving customers detailed summaries about consumption and helping operators diagnose problems without dispatching a truck. To help finance the $1.3 billion project and

to modernize its distribution networks, Con Ed requested a rate increase, which the state approved in January. After a nearly five-year freeze, customers will see a raise of 2.3 percent to 2.4 percent in the next three years. A typical city resident who uses 300 kilowatt-hours per month would see an increase from $78.52 to $80.30.

What's Next?

Instead of moving power from large, central generating stations, where energy flows in only one direction and about 5 percent vanishes in transit (more during peak times), more power will be generated and distributed locally. In the same way that cloud computing and smartphones have revolutionized how consumers get and store information, smaller-scale generation and storage devices throughout the grid will make the system more efficient and resilient, Mr. Kauffman said. Although energy use is projected to flatten or decrease in the next decade, thanks in part to more efficient appliances and better insulated buildings, peak demand will continue to grow, according to Nyiso. Mr. Kauffman said focusing on reducing demand on the system, especially at peak times, would be crucial to meeting New York's clean energy goals. The state is using financing and competitions as incentives for the private sector to develop sensors and software to make transmission more efficient, batteries that will make better use of renewable energy, or "smart appliances," like washing machines or dishwashers that will delay a cycle until demand is lower, like the middle of the night. Central to this transformation is overhauling the rules governing utilities. Mr. Kauffman compared the utilities to the hotel industry, which has been disrupted by upstarts like Airbnb. Traditionally, utilities have been largely indifferent to how much power customers consume. They receive a fixed rate of return (9 percent in 2016) on the infrastructure they build and their cost to upgrade and maintain networks. But the state is seeking to create ways for utilities to make money by teaming up with companies and customers to install software solutions to control electricity use or to add solar panels more affordably, instead of building billion-dollar substations. Ultimately, consumers will have more choices about where and how their power is made and how it's consumed. But as more people create their own power and use less from their utility, because of the way electricity rates are structured a smaller percentage of consumers could end up paying more to build and maintain transmission wires and equipment. Audrey Zibelman, the departing chairwoman of the New York Public Service Commission, which sets consumer rates, said moving toward a system that reduced carbon emissions did not necessarily mean higher costs. "It actually means lower prices if we do it right," Ms. Zibelman said. The state has promised that the poorest New Yorkers will pay no more than 6 percent of their household income on energy costs, and it also plans to spend about $1 billion to make rooftop and community solar installations more accessible and affordable. New York is taking lessons from California, Germany and other clean energy pioneers. "Building a modern energy infrastructure that's clean and resilient," Governor Cuomo said, "is critical to attracting new investments and growing a green economy across New York, while helping us combat climate change, maintain our air quality and keep our communities healthy for generations to come." Despite President Trump's skepticism of climate change and support of the coal industry, the state says it will forge ahead. Mr. Kauffman said New York was enacting these policies "through its own authorities and is not reliant on the federal government to advance our clean energy agenda." Still, he said, reinventing a system that originated more than a century ago will take time. "It is not flipping a switch," he said.

Source: https://www.nytimes.com/interactive/2017/02/10/nyregion/how-new-york-city-gets-its-electricity-power-grid.html