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Electric Power & Natural Gas

A 2040 vision for the US power industry: Evaluating two decarbonization scenarios

To get a sense of how far and how fast the United States is likely to reduce power-sector emissions, watch PJM, the country's largest system.

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February 2020

In the absence of clear federal action, a number of American states are taking the lead on reducing CO_2 emissions. California and New York, in particular, have set ambitious targets of 100 percent carbon-free power by 2045 and 2040, respectively. But these two states account for only about 3.2 percent of CO_2 emissions in the US power sector.

By contrast, the Midcontinent Independent System Operator (MISO)[1] market, which covers 15 states, accounts for 22 percent of US power-sector emissions, and the PJM Interconnection, a 13-state market,[2] accounts for 21 percent.[3] If the MISO and PJM states do not act, it will be that much more difficult to constrain climate change to 1.5 or 2.0 degrees above historical averages.

This article focuses specifically on PJM, the country's largest single power system[4] in generation (Exhibit 1). By comparing its current emission trajectory with a hypothetical deep-decarbonization scenario, we show just how important PJM is to the effort to cut CO_2 emissions in the United States. We also evaluate what PJM needs to do, and how much it could cost, to aggressively reduce emissions.

There are four reasons that PJM could be a bellwether of the speed and depth of decarbonization in the United States.

— **Its size.** Only five countries produce and consume more power than PJM, which serves 65 million people.[5] PJM states emitted 989 million tons of CO_2 in 2017, 37 percent from power generation and the rest from other sectors, such as transportation, building heating, and industry.[6]

— **Its connectivity.** With more than 30 gigawatts of transmission links,[7] PJM trades power with neighboring markets. Its actions have consequences beyond its borders.

— **Its similarity to the rest of the country.** In the past decade, PJM has seen a substantial decrease in the use of coal and a fast uptake in natural gas, a trend that has redefined the US power market as a whole. In per capita emissions and the price of delivered power, PJM is near the US average.

— **Its upcoming power-plant retirements.** In the next five years, about eight gigawatts of capacity, mostly coal-fired, will be retired in PJM markets, and even more nuclear power could retire if plants aren't extended beyond their typical 60-year life. PJM will need to replace these sources with conventional fuels, renewables, nuclear power, or some combination of all three. Those decisions will go a long way toward determining its emission trajectory.

Two scenarios for PJM

A number of state governments within PJM, including Delaware, Maryland, New Jersey, Pennsylvania, and Virginia, have announced decarbonization policies. Some are specific to the power sector; others are economy-wide. We estimate that these policies, as well as initiatives in other states, could reduce PJM's emissions by 49 percent by 2040 (relative to 2017) and economy-wide emissions in these same markets by 26 percent. We call this the status quo scenario.

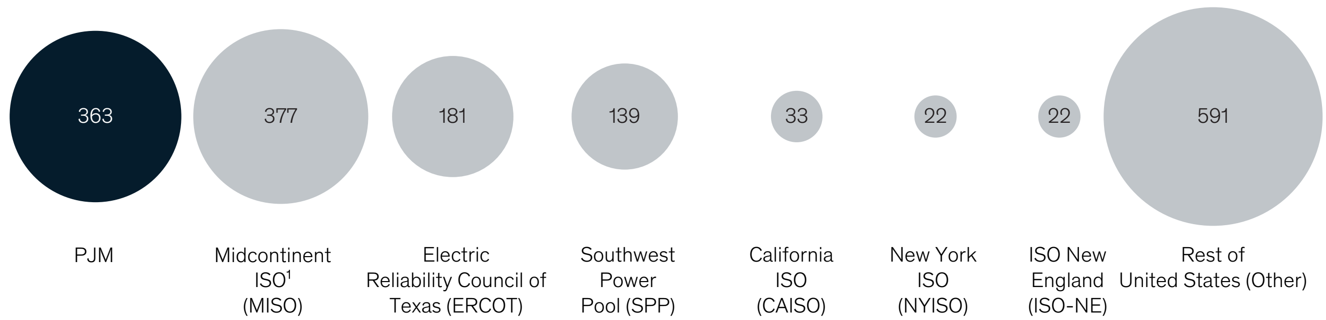
We also devised a second, hypothetical scenario that envisions PJM markets reducing emissions by 95 percent by 2040, and economy-wide emissions by 80 percent by 2050. We call this the deep-decarbonization scenario.

[1] MISO serves some or all of Arkansas, Illinois, Indiana, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, North Dakota, South Dakota, Texas, Wisconsin, and the Canadian province of Manitoba.
[2] PJM serves some or all of Delaware; Illinois; Indiana; Kentucky; Maryland; Michigan; New Jersey; North Carolina; Ohio; Pennsylvania; Tennessee; Virginia; Washington, DC; and West Virginia.
[3] Although MISO and PJM are, strictly speaking, the names of the organizations that run power markets in these regions, we use the terms to refer to the regions themselves.
[4] The term "system" is used to refer to the country's seven competitive wholesale power markets. Each is run by an independent system operator (ISO) or a regional transmission organization (RTO). CAISO = California Independent System Operator and NYISO = New York Independent System Operator.
[5] IEA Atlas of Energy, International Energy Agency, energyatlas.iea.org.
[6] This calculation is based on the assumption that PJM decarbonizes by 80 percent relative to its 2017 emissions.
[7] ABB Energy Velocity Suite, ABB, new.abb.com.

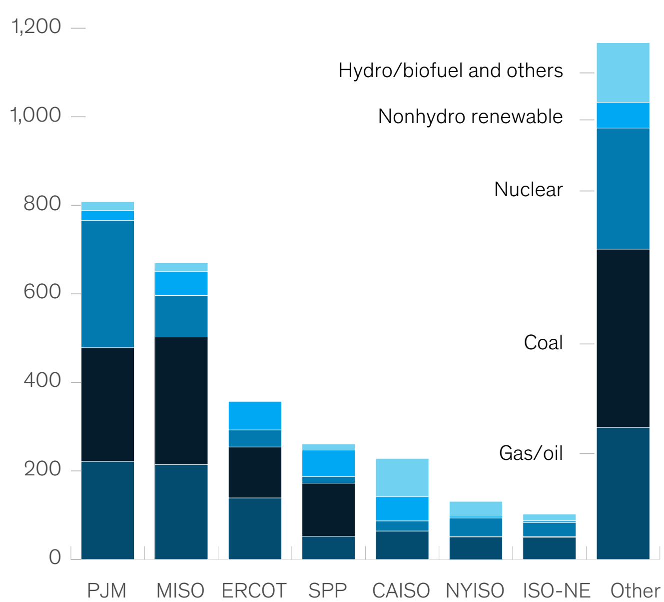
Exhibit 1

PJM generates the most power in the United States, and it emits the second-most greenhouse gases.

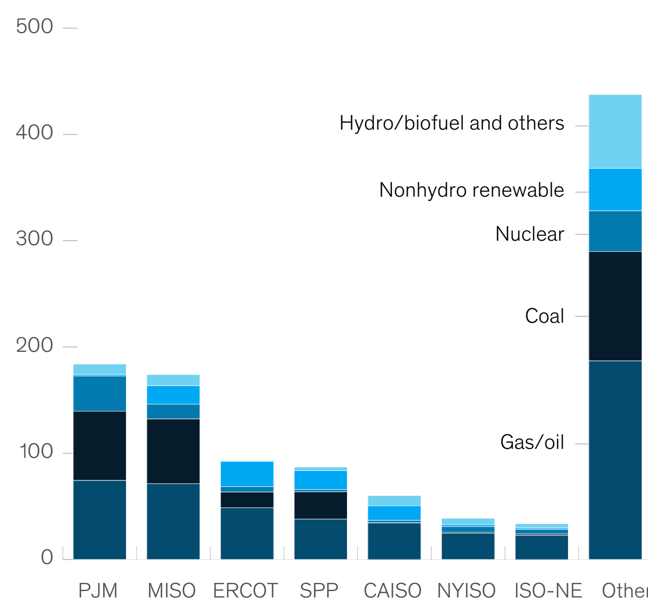
US power-sector CO_2 emissions in 2017, millions of metric tons



US power generation in 2017, terawatt-hours



US generating capacity in 2017, gigawatts



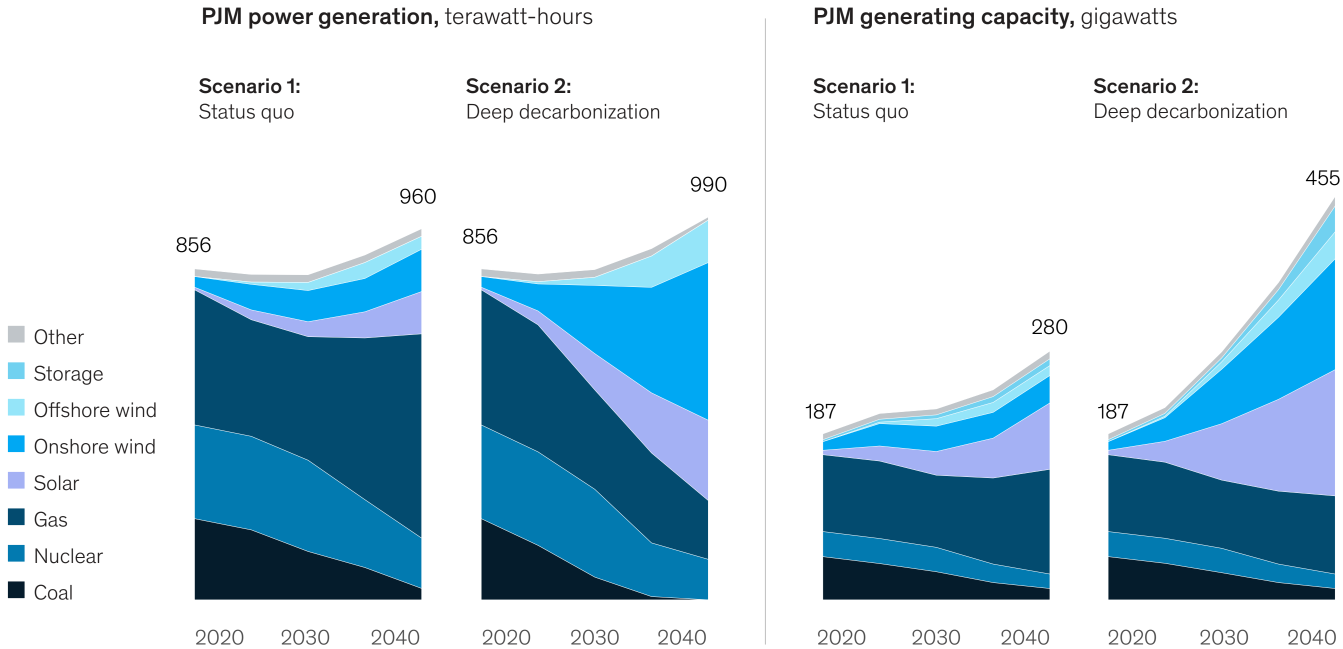
[1]Independent System Operator.
Source: ABB Energy Velocity Suite; independent system operators; US Energy Information Administration

To evaluate the implications of these two scenarios for PJM, we estimated the likely effects of implementing decarbonization policies, such as energy-efficiency and demand-response programs. We also looked at technology, including power generation (both conventional and renewables), the transmission grid, batteries and other forms of storage, and vehicle-to-grid options. Finally, we took into account known variables, such as the retirement of generation assets, the weather, electricity-demand profiles, and the effects of electrification of heating and transport.

We also modeled PJM's neighboring regions to understand power flows and interdependencies.

Exhibit 2

Gas generates more than three times as much power in the status quo scenario, compared with deep decarbonization.



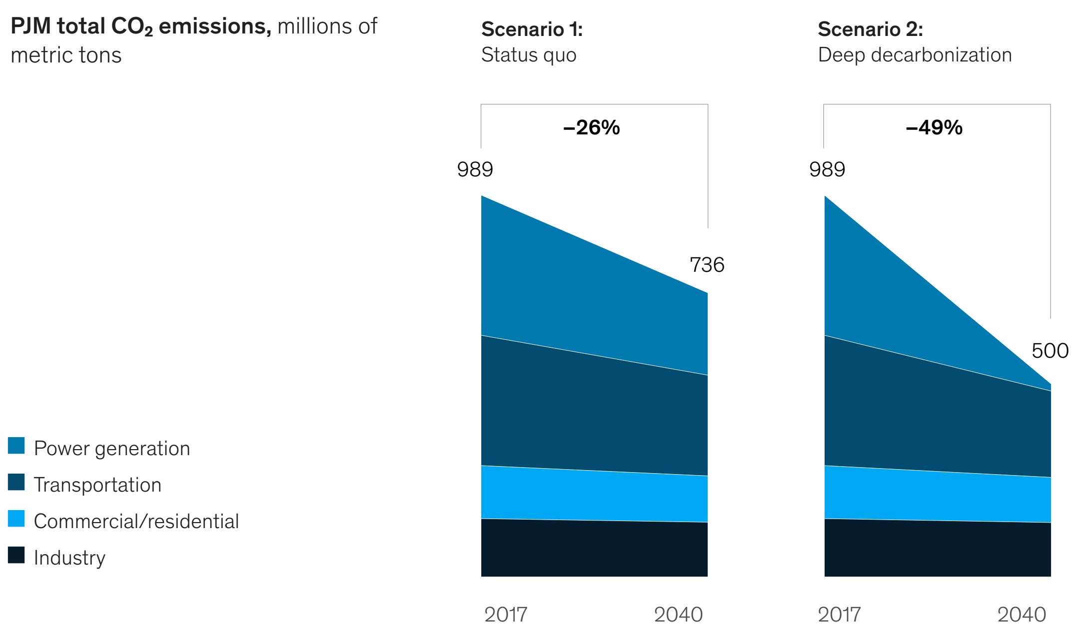
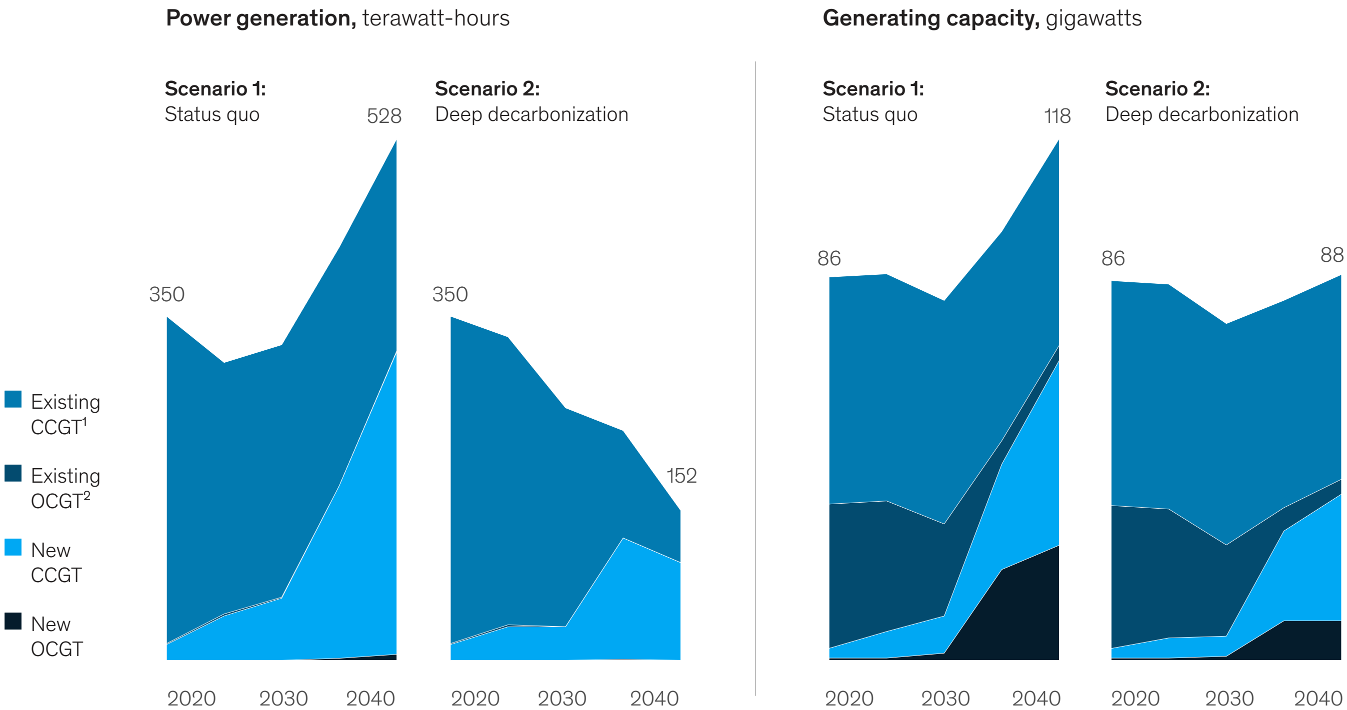
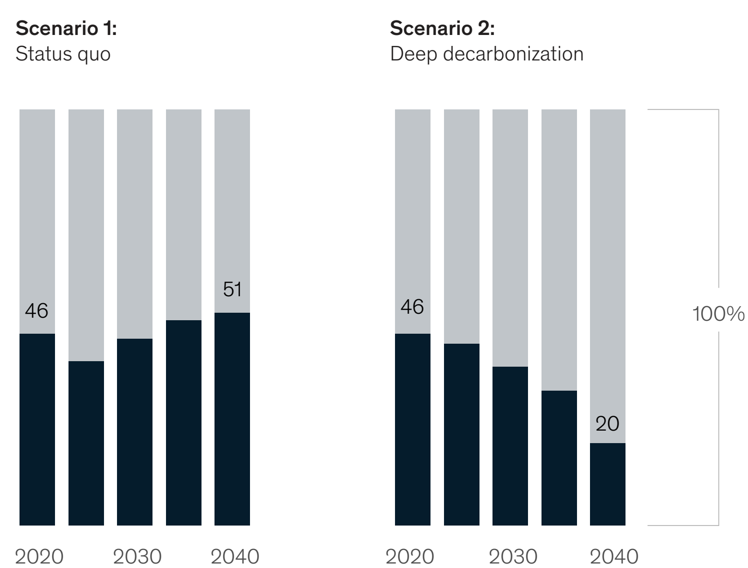


Exhibit 3

In both scenarios, more gas will come online, but how much is used will be very different.



Estimated load factors for CCGT plants, %



[1]Combined-cycle gas-turbine plants.
[2]Open-cycle gas-turbine plants.

In 2019, for example, the state of New York passed a law mandating the total decarbonization of its power system by 2040; because this commitment has already been made, it is part of the status quo scenario, even though the result is one of deep decarbonization.

The difference between the two scenarios is stark (Exhibit 2). Under the first, or status quo, scenario, renewable power grows relatively slowly, and the overall capacity of fossil-fuel-fired power doesn't change much, though the composition does, as lower-cost natural gas displaces coal.

Under the hypothetical deep-decarbonization scenario—one that could occur if state and national governments decide to take much more aggressive action on greenhouse-gas emissions—the grid shifts much more quickly toward renewable power, particularly the use of onshore wind. There is also significant investment in flexibility—the capabilities required to manage the intermittent output of renewable power. Coal all but disappears, given the limitations on emissions placed on the system. As a result, by 2040, emissions from the power sector decline 95 percent. The transition is costly, however, requiring an estimated additional $193 billion in investment over 20 years.

Looking at these two scenarios, eight important questions emerge. How PJM answers them will go a long way toward determining how far and fast it will decarbonize.

1. What is the role of gas-fired generation?
In both scenarios, power companies build new gas-fired power plants (Exhibit 3). But in deep decarbonization, much less new capacity is installed (38 gigawatts compared with 68 gigawatts), and average utilization—the percentage of time the power plant is actually in use—falls from roughly 50 percent to 25 percent. At such low utilization, revenues would fall, impairing the economic sustainability of much of the natural-gas industry.

It bears remembering, though, that gas plants can do more than provide power. Specifically, they can ramp production up and down quickly to balance the intermittent generation from renewable power. As renewable generation grows—something that happens in both scenarios—this capability will be critical to ensure reliability (Exhibit 4). If gas plants are to be economically viable in a deep-decarbonization scenario, new market structures may be needed to pay the industry for this flexibility in load balancing, even as natural gas's contribution to power generation declines. Other assets, such as nuclear and emerging technologies like battery storage and demand-response programs, can also provide load-balance services. They may also require different compensation mechanisms as the share of renewables grows.

2. How fast will renewable power grow?
Under the status quo scenario, we assume that the cost of wind and solar power continues to fall, and that installed capacity rises an additional 102 gigawatts by 2040, supported by $98 billion in investment. This would make PJM one of the country's largest renewable power markets.

In the deep-decarbonization scenario, restrictions on emissions would force the retirement of fossil-fuel plants, and their replacement by renewables, sooner than would happen based solely on cost. The result would be a near tripling in renewable generation, capacity installation, and investment (to $291 billion) by 2040 (Exhibit 5). Achieving this would also require dramatic increases in supply-chain capacity, qualified workers, land, transmission capabilities, and flexibility.

3. Will PJM continue to export power?
Under the status quo scenario, PJM supports decarbonization in New York (and, to a lesser extent, New England) as its resources are used to balance the intermittency of these markets' growing fleet of renewables. If New York's future distributed-solar and offshore-wind assets produce more than the system needs, for example, PJM could absorb the excess power. And when New York's production falls short, PJM could also export power. In effect, PJM acts like a giant battery that New York can draw on, a role it now plays.

Exhibit 4

In both scenarios, the role of gas changes, and the use cycles become extreme.

Hourly annual gas-plant usage by scenario, megawatts (illustrative)

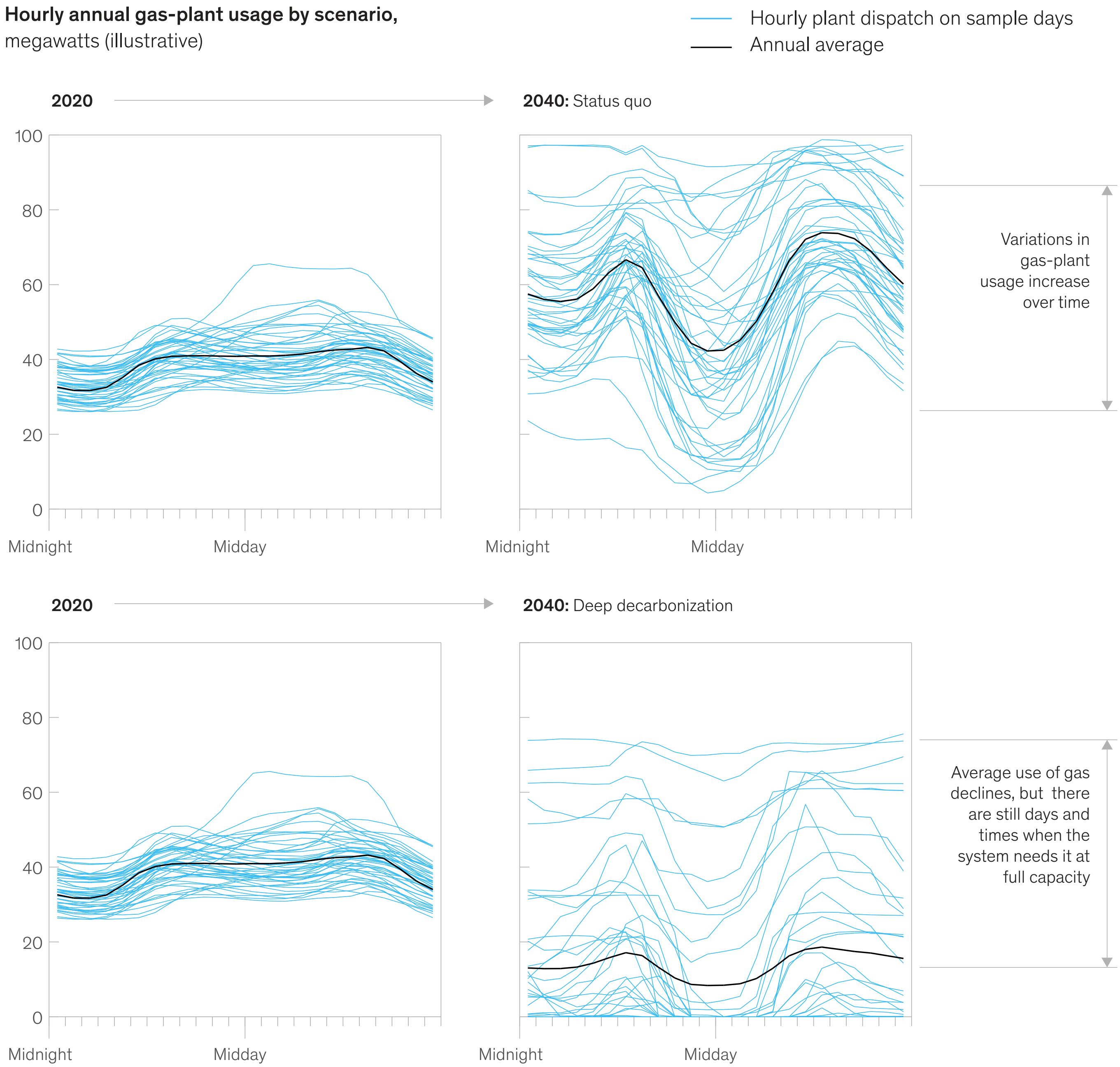
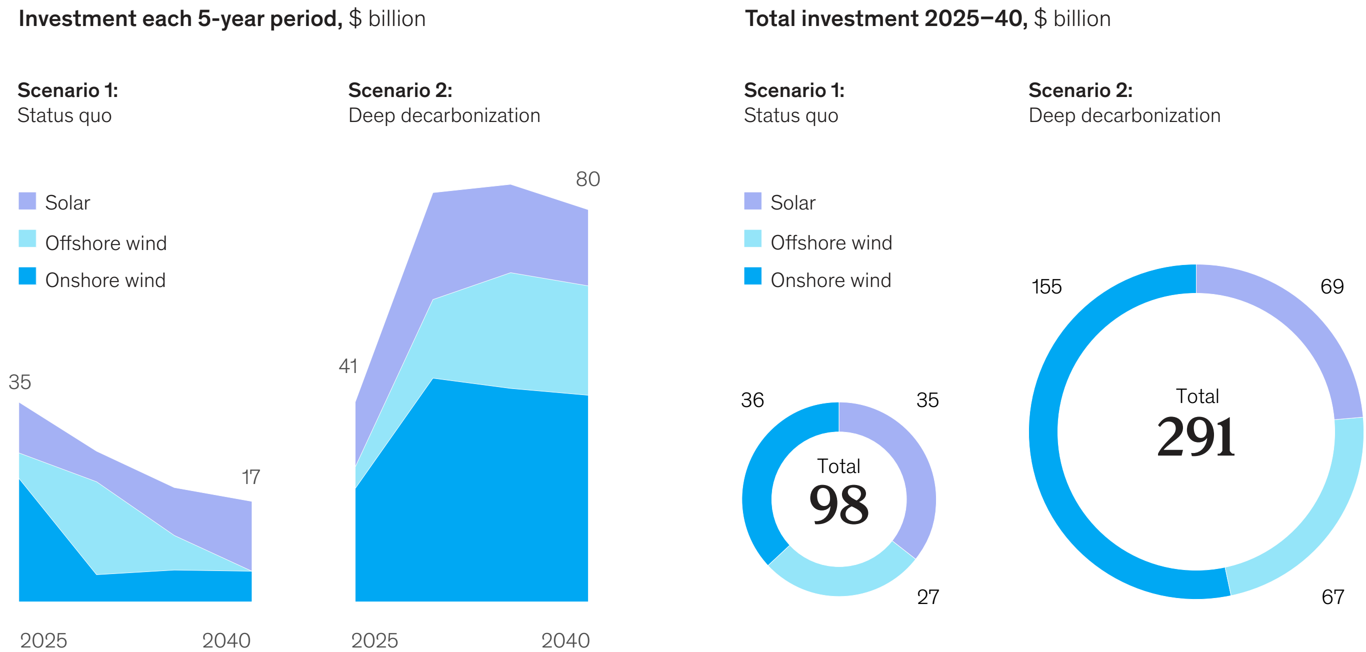


Exhibit 5

Under deep decarbonization, almost three times as much money is invested in renewables.



Under deep decarbonization, however, PJM could become a net importer of power (Exhibit 6). New York has committed to building nine gigawatts of offshore wind by 2035. At that level, New York will sometimes have excess electricity that it can export, so that PJM would not have to build its own assets.

4. What is the role of offshore wind?

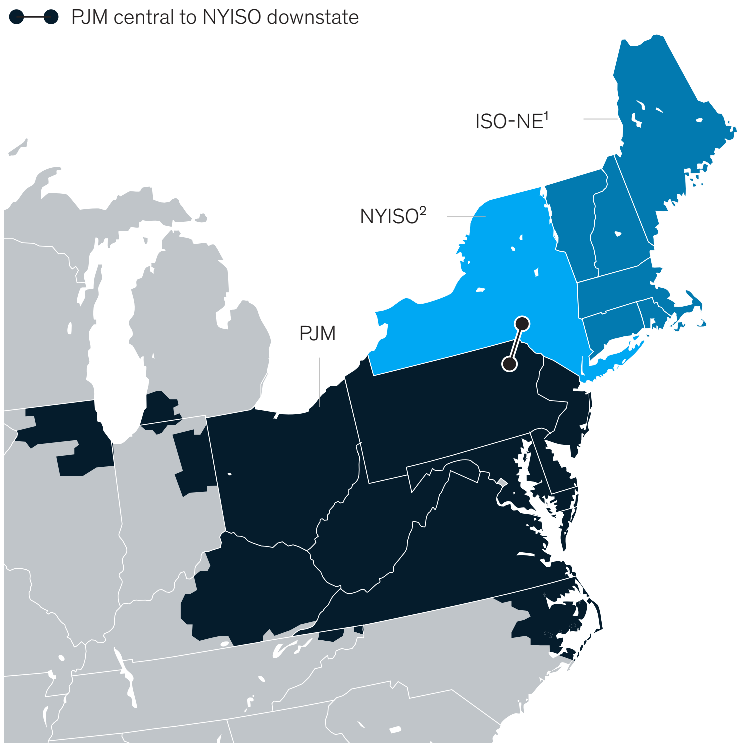
Three PJM states—Maryland, New Jersey, and Virginia—have announced plans to build 11.2 gigawatts of offshore wind by 2035; none have any at the moment. In deep decarbonization, this figure could jump to 30 gigawatts. Timing is important. If offshore wind begins to expand relatively soon, PJM won't need to build as many fossil-fuel plants that could later become idle or underused as more renewables come online. There are also knock-on effects to consider. In the deep-decarbonization scenario, PJM no longer serves as a battery for New York and New England. Therefore, our model shows that those independent system operators (ISOs) would likely have to build an additional 12 to 15 gigawatts of offshore wind, plus the associated flexibility investments.

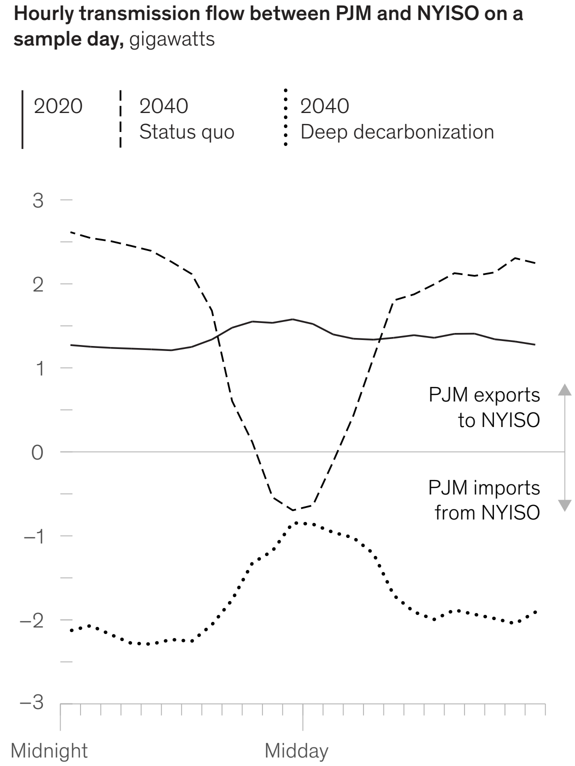
5. What about nuclear power?

PJM's nuclear-power plants account for 35 percent of generation, and they provide carbon-free, reliable power, 24/7. Keeping these plants online as long as they are safe appears to make sense, in both economic and environmental terms. If the nuclear fleet were to be retired early, by 2030, we estimate that PJM would incur an additional $13 billion to $42 billion in costs, depending on the scenario. In the status quo scenario, this would also likely result in higher emissions, as more gas is used. The discussion about nuclear will likely intensify, as the subsidies for many of the region's nuclear plants expire in the mid-2020s.

Exhibit 6

Under deep decarbonization, regional power flows could change substantially.





[1]ISO-NE = (Independent System Operator) New England.
[2]New York Independent System Operator.

6. If PJM opts for deep decarbonization, what happens to electricity demand?
If PJM opts for deep decarbonization, we estimate that PJM's electric demand would grow 14 percent (or 104 terawatt-hours) by 2040, compared with 2017. In non-PJM markets that are already actively pursuing aggressive decarbonization, though, the figure is much higher. In New York, for example, we estimate that electricity demand will rise 33 percent; in California, 56 percent.

PJM's electric load increases modestly under deep decarbonization, compared with California and New York, because its power generation is more emission intensive, accounting for 37 percent of total emissions in its territory. In California, the figure is 10 percent, and for New York, 17 percent. Greening the PJM power system, then, has a bigger impact on economy-wide decarbonization goals than in California or New York. Those states will have to rely more on electrification in the transportation, building, and industrial sectors to reach their decarbonization targets, therefore increasing their electric load.

7. What role will battery storage play?
Under the status quo scenario, we estimate that PJM could have 117 gigawatts of renewable power online by 2040. At that level, less than ten gigawatts of storage will be needed to balance PJM's grid, because there will be natural-gas plants available. In the deep-decarbonization

scenario, with 297 gigawatts of renewables online and much less natural-gas capacity, about 30 gigawatts of storage would be required.

Getting there will not be easy. The difficulty is not so much economic as structural; battery storage will require new market and policy mechanisms to create a sustainable business model. In 2018, the Federal Energy Regulatory Commission (FERC) promulgated Order 841; its goal was to increase storage in wholesale-electricity markets. Order 841 gave considerable leeway in how to go about it. Even so, FERC has not, so far, accepted PJM's plans, citing the high duration requirements imposed on storage assets seeking to participate in markets. This debate illustrates how challenging it will be to integrate storage and other emerging technologies into power markets.

8. How will state and federal regulation affect the evolution of power markets?

Federal and state regulators and the ISOs are likely to have differing views on the best way to structure electricity markets. FERC, for example, recently directed PJM to expand its minimum offer-price rule (MOPR), a mechanism to counteract subsidies that individual states offer to various forms of generation (typically nuclear and renewables). In FERC's view, such support distorts the larger regional market. The ruling comes after more than a year of debate, which caused PJM to delay its auctions for new generation capacity. In another example of tension between state and federal policy (with ISOs caught in the middle), New York is asking FERC to exempt battery storage from a New York Independent System Operator (NYISO) market mechanism that the state says would make batteries less competitive in capacity auctions.

PJM's decisions will have a profound effect on how fast and far the United States decarbonizes. More than any other single market, its actions will influence the growth of renewable power, the role of gas-fired generation, the development of new market mechanisms, and the evolution of regional dynamics. If PJM charts a feasible path to power-sector decarbonization, the rest of the United States is more likely to do so. If PJM cannot, then the prospects diminish. In a sense, as PJM goes, so goes the country.

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The authors wish to thank Andrea Grass and Chad Powers for their contributions to this article.

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