

## Reliable Service, Equal Access, Lower Prices

The interstate high-voltage electric transmission system is the essential link between the sources of electricity and the consumers who rely on it. It's also the foundation of PJM, which was created in 1927 to realize the benefits of interconnecting the transmission system and sharing generating resources across Pennsylvania, New Jersey and Maryland.

Today, PJM Interconnection oversees the round-the-clock generation and transportation of electricity and the planning and enhancement of the transmission system for more than 65 million people in 13 states and the District of Columbia, representing nearly 25 percent of the electricity in the U.S.

PJM works cooperatively with transmission owners, who maintain the equipment. PJM operates a power system of more than 84,000 miles of transmission lines across 369,089 square miles of territory and 6,650 substations, interconnecting with more than 180,086 MW of power generation.

## Transmission Today: The Great Equalizer

Transmission is the great equalizer, connecting generation, no matter how it is fueled, over small and vast distances to ensure that consumers, no matter where they are, have access to reliable electricity at the lowest possible cost.

Over the last century, society has grown to rely more and more on electric-powered machinery, technology and appliances. As a result, consumption of electricity has grown and the transmission system has evolved to keep pace.

Transmission also serves as the foundation for facilitating competition among power producers through access to PJM's wholesale electricity markets. Competition has lowered prices, increased efficiency and allowed new, innovative power resources equal access to consumers across the states in the PJM region.

PJM's operations save approximately \$2.8 billion to \$3.1 billion per year through reliable and efficient management of power resources to meet customer demand. This benefit can only be realized through the centralized dispatch of generating resources and a high level of integration and coordination of the interconnected transmission grid.

## The Evolution of Transmission for Tomorrow

The demand for electricity is no longer growing as quickly as in the past, while the mix of generation resources keeps changing. The consumption of electricity is also changing, incorporating new technology like electric vehicles, smart homes, massive new data centers and shale gas processing facilities.

## Next Steps

This brief introduction to the transmission system in PJM touches on its history, value and continued evolution.

In spring 2019, PJM will release a detailed analysis quantifying the value of transmission, which will include:

- Impact of transmission projects on congestion, generator production costs and customer payments
- Quantity and cost of electricity flowing between PJM and adjoining transmission systems
- Efficiencies in system operations that reduce the need for controlling actions, including power transfer curtailment (a last resort)
- Investment in new transmission needed to address PJM's shifting generation fleet, the increase of renewables, aging infrastructure and generator deactivations
- Savings in the capacity market resulting from increased generator diversity, reduced installed reserve margin and electricity transfers across PJM's borders
- Changes in transfer capability on reactive interfaces



Behind the scenes, transmission is evolving to serve these new needs while maintaining the same reliable, continuous supply of electricity customers expect.

### Transmission Delivers Power Reliably, Where and When It Is Needed

The transmission system is the best way to move the most power to the most people in the most reliable, efficient way. Generators operate at their best when they are built at or close to the source of their fuel, such as coal mines, natural gas wells and hydroelectric dams. The farther the fuel is from a generator, the more costly and time-consuming it is to get it there. Wind and solar farms are no exception. They need to be located where the wind blows most or the sun shines most and they need transmission lines to carry their electricity to where it is used. Transmission enables the development of all forms and sizes of generation and connects it with consumers across the PJM region.

### Transmission Enables Reliability at Fair Prices

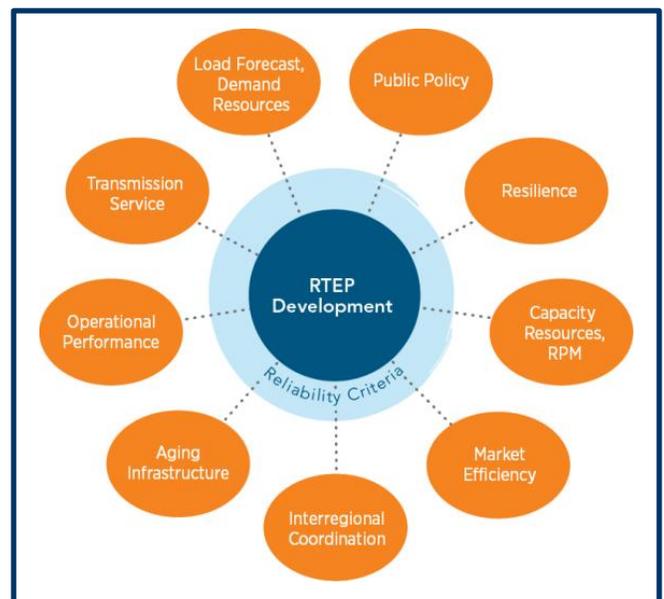
Transmission enables the lowest-cost power to reach the greatest number of people. PJM operates the grid by scheduling and directing the lowest-cost power resources to generate electricity first, incrementally adding more expensive resources as they're needed and saving the highest-cost resources for relatively brief periods of peak customer demand.

Throughout the year, as the price of fuels fluctuate, as generation resources go in and out of service for maintenance, and as new generation resources are commissioned and old ones retire, the economics of the market can shift. The transmission system enables PJM to handle this fluid wholesale energy market, transporting the lowest-cost power across the region and giving all generation resources, regardless of fuel type, access to the market.

### An Evolving Electric System Needs Evolving Transmission

Transmission continues to evolve as the grid and consumer needs change. In the PJM region, old generators, particularly coal units, are retiring due to competition from newer technology and low natural gas prices. From 2010 to 2017, nearly 27,000 MW of PJM's oldest generators, averaging 46 years of age, retired. They were replaced by more than 32,000 MW of new resources, including natural gas-fired generators, demand response and renewables like solar, wind and battery storage.

The size of generation is also shifting, with some much larger and many much smaller generators coming on-line than in the past. The electric industry and its customers have historically benefited from economies of scale. For new generators designed for increasingly high levels of output, a robust high-voltage transmission system continues to support this economic benefit. However, power generation is also more widely distributed, with older generators often being replaced by hundreds of smaller, less-centralized generators — some as small as 1 MW. These dynamic factors, along with additional distributed energy resources on the grid, result in geographic shifts in the flow of electricity. The transmission system continues to adapt to these ever-changing conditions.



### Enabling the Decrease of Emissions and the Rise of Renewables

The transition to more natural gas-fired, wind and solar generation, as well as energy-efficient on-site generators, more efficient homes and appliances, and “behind the meter” generation such as rooftop solar, have reduced emissions in PJM’s footprint drastically over the last 15 years. PJM’s current generation mix is 30 percent less carbon-intensive than 10 years ago. A flexible, robust transmission system has assisted this reduction by enabling the entry of new, competing technologies such as demand response and renewable generation.

As of 2017, there were nearly 40 million MWh of renewable generation in PJM. That number has kept pace with the renewable portfolio standards of most states in the PJM region. One way transmission enables the growth of renewables is by transporting electricity from more remote pockets of generation to the grid. Without transmission, much of the electricity generated by wind, for example, would not be able to make it to consumers as wind-powered generators are clustered in remote areas that are most suited to their operations. As more renewable generation comes on-line in PJM, the transmission system will continue to evolve to enable that change.

### Planning for Change

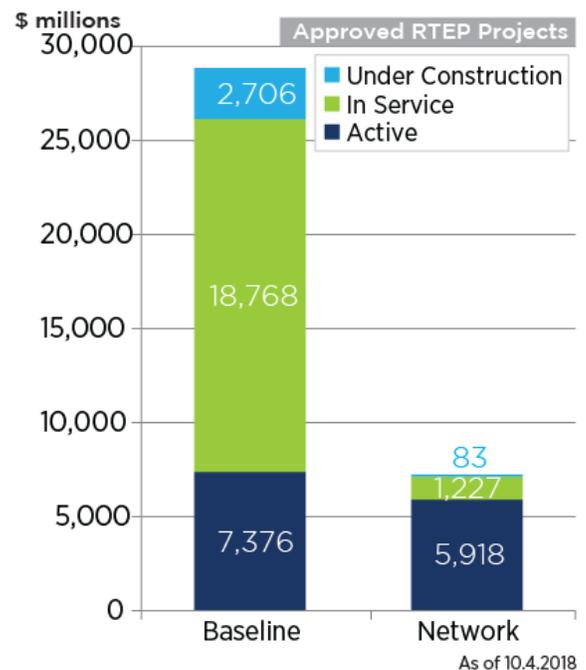
Maintaining a reliable and efficient transmission system in this fluid environment requires extensive planning. PJM’s comprehensive long-term regional transmission expansion planning process identifies the need for changes and additions to the system up to 15 years in the future. The long planning horizon gives the developers who take on these projects time to marshal resources and gain state and local approvals to build the infrastructure.

Under authorization from the Federal Energy Regulatory Commission (FERC), PJM oversees transmission facilities that are, for the most part, 100 kV and above. In response to identified regional reliability, market efficiency or public policy needs, PJM staff recommends projects to include in the regional transmission expansion plan, which then must be approved by the PJM Board of Managers.

Roughly 20 percent of all PJM-approved transmission projects over the last 20 years have been undertaken to enable approximately 84,200 MW of new generation to reliably connect to the system. The other 80 percent have been undertaken to evolve the transmission system to meet changing needs. These are called “baseline projects.” These projects ensure the round-the-clock reliability that we all expect.

The owners of transmission in the PJM region manage the existing transmission equipment under authorization from FERC. They continually invest in the transmission system and replace and upgrade aging equipment to keep it in good condition. Transmission owners focus on evaluating the equipment condition, performance and risks in order to prevent failures that could impact grid stability, customer reliability and public safety. These are called transmission owner-identified or “supplemental” projects. The transmission owners’ efforts are an important complement to the PJM regional transmission expansion plan.

National, regional and local reliability and safety standards ensure that the transmission system is built to protect against large-scale power outages, which can take a huge societal and economic toll.



### Equal Access to Less Expensive Power

Baseline projects can be used to relieve congestion. Congestion is one of the culprits that causes wholesale power prices to vary from community to community within PJM. It is caused by limitations (also called constraints) on the transmission system, which can limit the lowest-cost power from reaching all areas. When these bottlenecks occur, PJM must ask higher-cost generators to meet customer demand in those constrained areas. Investing in transmission to reduce congestion ensures that consumers have access to lower-cost power.

If congestion in one area is persistent, PJM can authorize “market efficiency” projects to address the problem and help keep costs down. Until they are built, these PJM Board-approved projects are re-evaluated each year to ensure that they will continue to provide economic benefits. A market efficiency project’s economic benefits must exceed its costs by at least 25 percent to remain on the regional transmission expansion plan. Planned upgrades are calculated to have saved more than \$94 million in congestion costs in 2018 and will save more than \$107 million in 2022. There are additional cost savings that have resulted from transmission upgrade projects beyond market efficiency, which will be quantified in the spring 2019 paper.

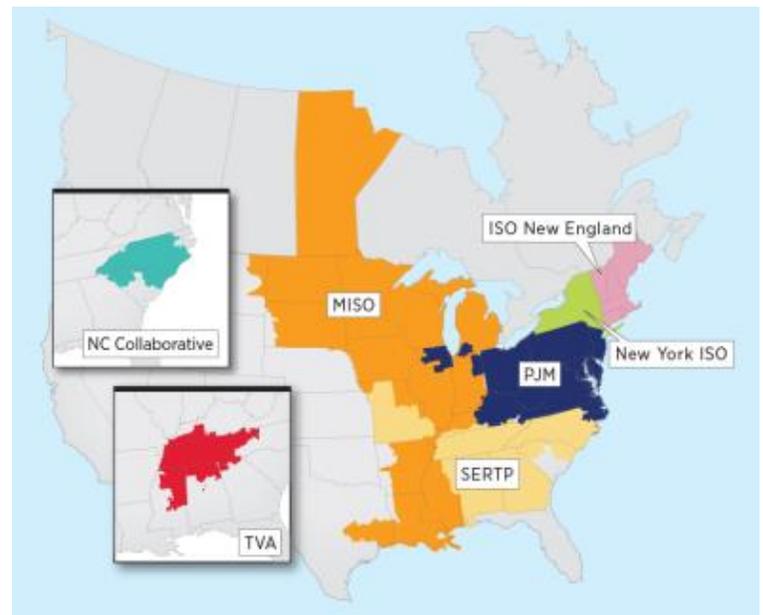
### Regional Perspective Means Region-Sized Benefits

PJM’s regional perspective allows for the long-term coordination of the flow of electricity over vast areas, across state boundaries and into and out of neighboring regions. PJM’s large footprint makes the electric system more effective thanks to economies of scale and considering the region as a whole, rather than as individual states or separate transmission zones.

Since 2002, PJM has added many transmission zones to its footprint, enabling the addition of 112,000 MW of generation and 95,000 MW of peak customer demand. The result has been increased competition in the wholesale markets and lower prices.

The additions have also increased reliability. With more transmission zones, the diversity of customer demand across PJM increased from 1 percent to 3.5 percent. Diversity in this case means that different transmission zones experience their highest demand at different hours or even on different days, so extra generation from a lower-demand zone can be sent to a higher-demand zone where it’s needed.

The increased number and locations of generators that PJM can call on also lowers outage risks by spreading the risk across many more generators. The combination of these factors has meant that PJM can carry a lower level of installed reserves – reduced from about 20 percent in 2002 to about 16 percent today – which, in turn, reduces costs to consumers.



Linking the transmission zones in PJM has also meant that less power generation is needed to serve the whole system reliably. PJM estimates that 27,000 fewer megawatts are needed across the region because of the interconnected system.

Interregional planning can play a critical role in expanding economic opportunities for power transactions, balancing power between regions and positioning neighboring regions to help one another in emergencies.

PJM’s regional planning process is open and transparent, offering a clear view into PJM’s analysis and process for all, including regulatory agencies, utilities, consumer

advocates, state and federal legislators, generation owners, transmission companies and anyone else with an interest in the future of the electric system.

### Transmission Is Key to Resilience

Under traditional planning, grid operators have designed and operated the transmission system to federally mandated reliability standards and “N-1 criteria,” which means that the system will continue to function even if a major generating facility or major transmission line is lost.

Reliability is about designing, operating and maintaining electricity supply to provide an adequate, safe and stable

flow of electricity. In everyday life, that means the lights come on, refrigerators are working and businesses continue to hum around the clock.

Resilience is directly linked to the concept of reliability. You cannot be resilient if you are not first reliable. But resilience encompasses additional concepts – preparing for, operating through and recovering from significant disruptions, no matter what the cause. It is about the ability to withstand extreme or prolonged events. PJM is working with its stakeholders to further develop and incorporate resilience concepts into its planning process.

### Modernizing the Transmission System

The regional high-voltage transmission system is aging. Many facilities were placed in service in the 1960s or earlier and are deteriorating and reaching the end of their useful lives. Within PJM, nearly two-thirds of all bulk electric system assets are more than 40 years old and more than one-third are more than 50 years old. Some local lower-voltage equipment, especially below 230 kV, is approaching 90 years old. The vast majority of this equipment is outdoors and made of combinations of wood, glass, steel, iron and a variety of composite materials, all of which deteriorate with age.

Maintaining older equipment means higher costs and greater risk of outages. As the system continues to age, the approach must shift from simply maintaining assets to

modernizing them. Asset modernization often goes beyond simply installing similar equipment. Replacement projects offer the opportunity to learn from history and adopt knowledge, capabilities and technologies that did not exist when the original facilities were built.

Modernizing the existing transmission system will provide a multitude of benefits, including incorporating designs that can withstand more extreme events, lower frequency and shorter duration of outages, reduced public and employee safety risks, and use of advanced technology to improve system operability, efficiency and security.

However, the cost of new transmission is significant and must be balanced with the benefits it brings.

## Conclusion

The high-voltage transmission system is essential to our society. It reliably transports electricity to the people who need it, at the speed of light, and provides equal access to low-cost electricity for all consumers. To keep pace and continue to serve consumers in the face of rapid changes in generator technology and location, changing consumer behavior patterns, and aging equipment, the transmission system must evolve. That means phasing out old infrastructure, reducing congestion and planning for a more resilient, flexible and efficient future. This is a brief overview of the history, value and continued evolution of the transmission system in PJM. PJM will release a detailed analysis quantifying the value of transmission in spring 2019.