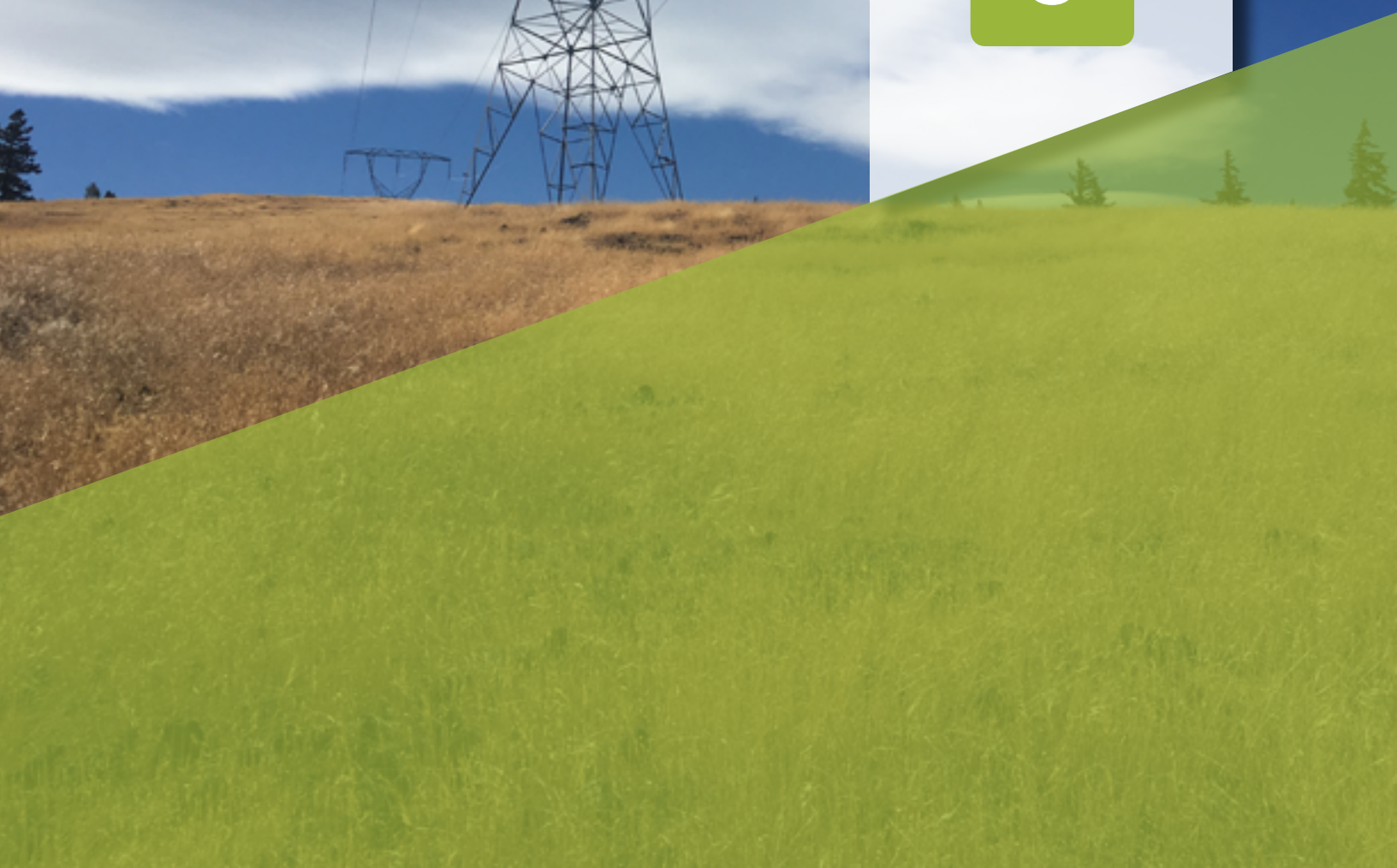




Energy





EXECUTIVE SUMMARY

In a digital, connected world, Americans increasingly rely on readily available and uninterrupted electricity. Over the last four years, transmission and distribution and reliability-focused pipeline investments have increased, and outages have declined slightly. Annual spending on high voltage transmission lines grew from \$15.6 billion in 2012 to \$21.9 billion in 2017, while annual spending on distribution systems — the “last mile” of the electricity network — grew 54% over the past two decades.¹ Utilities are taking proactive steps to strengthen the electric grid through resilience measures. However, weather remains an increasing threat. Among 638 transmission outage events reported from 2014 to 2018, severe weather was cited as the predominant cause.² Additionally, distribution infrastructure struggles with reliability, with 92% of all outages occurring along these segments.³ In the coming years, additional transmission and distribution infrastructure, smart planning, and improved reliability are needed to accommodate the changing energy landscape, as delivery becomes distributed and renewables grow.

CONDITION, CAPACITY, OPERATIONS & MAINTENANCE Electricity

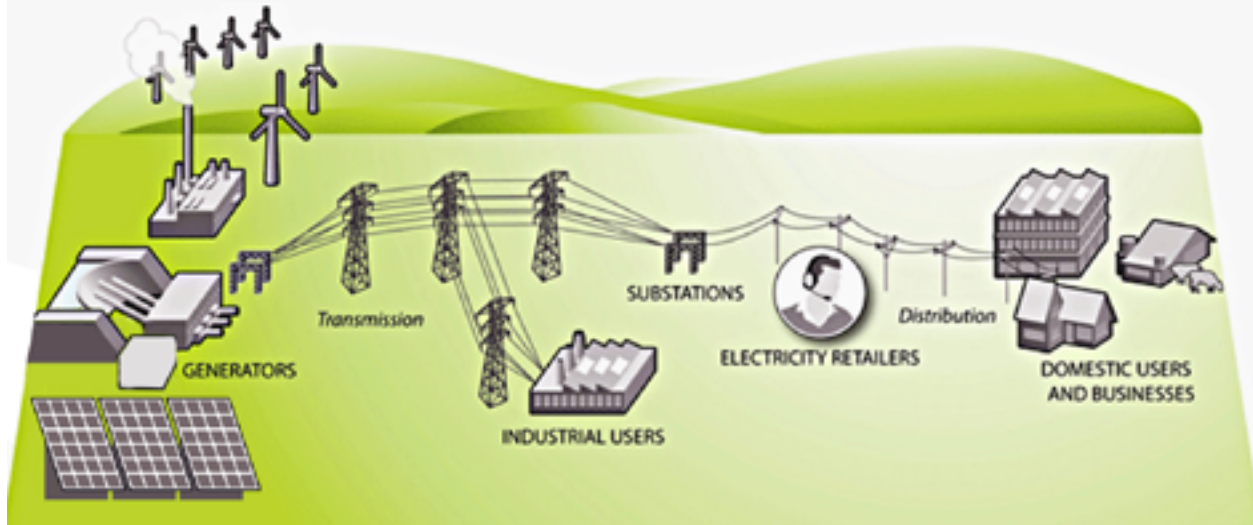
Energy infrastructure in the U.S. is used to generate, transmit, and distribute electricity. The electric industry has invested significantly to meet customers’ demands, but transmission and distribution (T&D) systems still struggle with reliability. This problem is likely to accelerate as the impacts of climate change persist and the public’s expectation of more reliable, “always-on” electricity increases.

Electricity delivery in the U.S. depends on an aging and complex patchwork of power generation facilities, 600,000 miles of backbone transmission lines (240,000 miles of which are considered high-voltage lines or \geq 230 Kilovolts), and around 5.5 million miles of local distribution lines that operate within federal, state, tribal, and local regulatory jurisdictions.⁴ This system is responsible for providing safe, reliable, and cost-effective electricity to customers. Each type of infrastructure may be owned by an investor or public utility, independent power producer,

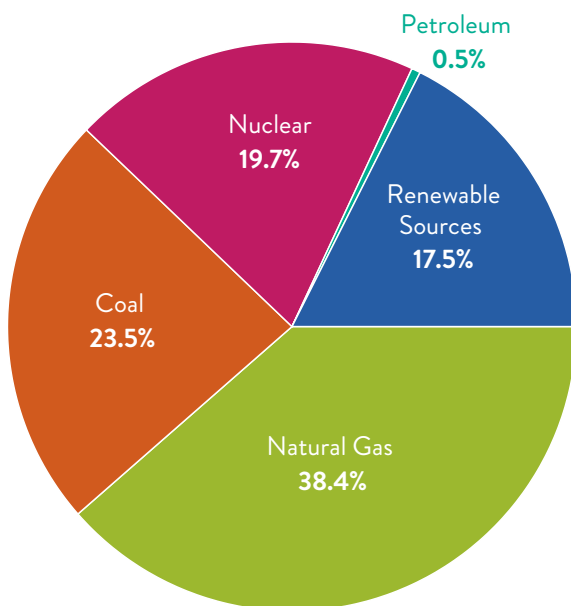
or governmental agency. While investor-owned utilities (IOUs) make up only 6% of the number of electricity providers, they serve 72% of U.S. electricity customers.⁵

The majority of the nation’s grid is aging, with some components over a century old — far past their 50-year life expectancy — and others, including 70% of T&D lines, are well into the second half of their lifespans. The transmission system, which can be thought of as the “interstate highway” of electricity delivery, is regulated by the Federal Energy Regulatory Commission (FERC), and mostly consists of high voltage transmission lines that carry electricity across the country. The distribution system, the “last mile” of the electric delivery system, is regulated by the states and consists of lower voltage lines that act as the local roadways, carrying electric power to neighborhoods and communities. The distribution system also includes substations, individual customer services and meters, as well as other components.⁶

These costly transmission and distribution problems, such as those from weather-related events and other causes, result in power outages that are estimated to cost U.S. households \$28 to \$169 annually.



U.S. Electricity Generation by Energy Source



U.S. Energy Information Administration 2019

Distribution is a key failure point in the electric grid in terms of system reliability. The distribution system accounts for 92% of all electric service interruptions, a result of aging infrastructure, severe weather events, and vandalism.⁷

These costly transmission and distribution problems, such as those from weather-related events and other causes, result in power outages that are estimated to cost U.S. households \$28 to \$169 annually. For an increasingly critical sector, U.S. data centers, on which many industries rely, the cost of outages grew from \$505,000 in 2010 to \$740,000 in 2016, which equates to \$8,851 per minute that the electricity grid is malfunctioning.⁸

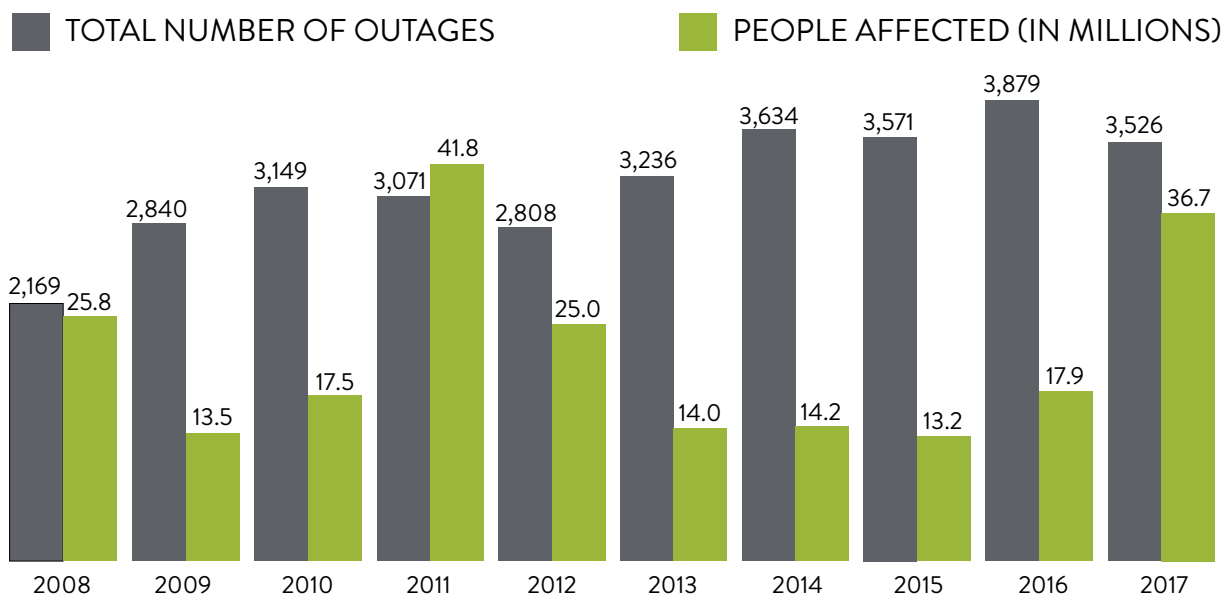
For the first time, renewables (solar, wind, biomass, geothermal, and hydropower) accounted for the largest portion of new generating capacity in 2020.⁹ Renewables' share of the generating capacity is on track to increase significantly between now and 2023.¹⁰

Electricity generation from renewable energy sources rose from 18% in 2019 to 20% in 2020 and is expected to rise to 22% in 2021, continuing to expand their lead

over coal (20.1%).¹¹ Additionally, U.S. energy production exceeded annual U.S. energy consumption in 2019 for the first time since 1957.¹² Near-term, U.S. energy systems are projected to deliver sufficient energy to meet national demands, although increasing electrification — particularly of the transportation sector — could have a significant impact. Electric vehicles (EV) are continuing to penetrate

the market. EV charging stations within the United States has grown from 6,900 chargers in 2012 to approximately 61,000 by the end of 2017 for all vehicles. While demand-related impacts due to electrification is uncertain, it is expected that utilities will implement rates that will drive charging to non-peak hours, affecting most passenger vehicles and light duty trucks.¹³

Number of Outages Over Time



2017 Eaton Blackout Tracker

Oil and Gas

Although traditional fossil-fuel-using sectors such as transportation and space heating are transitioning to electrification, there is still dependence on existing oil and gas supply and recovery, processing, and pipeline delivery. Much like the electric grid, the nation's pipelines are also aging, as witnessed by increasing failures and leakage events, thus driving a need to employ improved inspection techniques, preservation technologies, and sound decision-making for upgrades and replacements.¹⁴ America's more than 190,000 miles of oil pipelines and 2.4 million miles of gas pipelines connect sources such as wells and port terminals to refineries/processing facilities and consumers.¹⁵ Together, oil and natural gas supply 65% of the energy we use.¹⁶ Similar to electricity, much of the oil and gas infrastructure is privately owned, operated at near full-time capacity, and publicly regulated.¹⁷ Over half of the natural gas

transmission and distribution network was installed before 1960, with urban systems being among the oldest.¹⁸ System improvements are principally funded by regulated owner rates and limited recovery; as such, modernization and upgrade investments are typically driven by urgency and necessity rather than through asset management and life-cycle cost-based planning. The risks of aging infrastructure have been witnessed even as recently as 2020 through damaging pipeline events in Baltimore, New York City, and Philadelphia, and failed transmission and distribution lines from Hurricanes Laura and Sally.¹⁹

New technology improvements have contributed to design, construction, and maintenance methods of oil and natural gas pipelines and improved asset integrity, cost-efficiency, and extended service life expectations.

These new technologies have also greatly eliminated incidents in newer systems.²⁰

Critical infrastructure bottlenecks also exist, including the gas delivery constraints to New England and New York and challenges with urban infrastructure upgrades. According to the U.S. Energy Information Administration, the nation's 135 oil refineries are operating at or near capacity with 2019's production rate approaching

a record 19 million barrels per day and only one new refinery coming online. While production has kept up with demand, outage-driven commodity price spikes are often experienced due to the capacity limitations and lack of geographic diversity of the oil and gas sector, as many systems are along the Gulf of Mexico, frequently exposed to extreme storms.

FUNDING & FUTURE NEED

All three major components of the electric grid (generation, transmission, and distribution) have an investment gap. To meet the latest state-driven Renewable Portfolio Standards in generation infrastructure, the gap is projected to grow to a cumulative \$197 billion by 2029.²¹

Despite the large gap, transmission infrastructure has benefited from increased investment. Transmission spending in the U.S. increased from \$15.6 billion in 2012 to \$21.9 billion in 2017, driven by a desire to provide access to clean energy and to increase the grid's reliability, security, and resilience.²² Spending also reduced congestion, lowered resource pricing, and renewed the focus on meeting customer needs.²³ Across all regions of the country, factors such as upgrades and replacements of aging transmission infrastructure, system hardening, and resilience measures that minimize impacts from catastrophic events, improvements to comply with evolving transmission reliability and security compliance standards, and expansion of the transmission system to integrate renewables and natural gas have contributed to the increase in transmission spending.²⁴ As wind and solar generation grow, new T&D lines are required to link these renewable resources to customers. Doing so allows owners to make investments that "harden" the grid and reduce outage frequency and duration.

Spending on electricity distribution systems by major U.S. electric utilities — representing about 70% of the



total U.S. electric load — has risen 54% over the past two decades, from \$31 billion to \$51 billion annually.²⁵ This increase has been anchored by capital investment from utilities that are working to upgrade aging equipment. Poles, wires, and substation transformers are being upgraded with advanced materials and new technology to better withstand extreme weather events, to allow easier frequency and voltage control during system emergencies, and to accommodate greater use of variable renewable generation.²⁶

In the past decade, investment in overhead poles, wires, devices, and fixtures such as sensors, relays, and circuits has risen by 69%, while spending on substation transformers and other station equipment increased by 35%.²⁷ Investment in customer meters has more than doubled over the past decade as utilities have upgraded traditional meters to smart meters that can be accessed remotely, communicate directly to utilities, and support smart consumption and pricing applications using real-time or near real-time electricity data. However, there will be additional required investment to maintain these wires and poles, transformers, meters, and similar equipment, which are usually the responsibility of the local utility.²⁸

The National Environmental Protection Act (NEPA), which directs agencies to consider environmental impacts in decision-making, was updated by Executive

Order in 2020.²⁹ Changes are expected to expedite the permitting process to no more than two years for most transmission and distribution projects. Reducing delays in the permitting process would facilitate the expansion of the nation’s energy infrastructure to increase its capacity. However, these efforts must be made with safeguards in place to protect the natural environment.

Investment in oil and gas infrastructure is driven by changing sources, increasing demand, and pricing fluctuations, in addition to physical condition, failure events, and regulation. Where demand approaches or exceeds existing supply in geographic regions, commodity pricing is elevated, and funding is justified. When commodity pricing is low, infrastructure investment declines. Through 2035, investment in oil and gas infrastructure is expected to contribute \$1.50 to \$1.89 trillion to U.S. GDP, or between \$79 billion and \$100 billion annually.³⁰ This investment produces positive impacts on the economy, from employing individuals to fostering delivery of lower cost energy to households and businesses.

The recent Keystone XL Pipeline permit rescindment will have a future impact on America’s pipeline infrastructure. In addition to the significant number of jobs lost, the precedent of rescinding already granted permits is concerning and could harm future investment in all energy infrastructure.

<i>ASCE 48: Design of Steel Transmission Pole Structures</i>	Provides a uniform basis for the design, detailing, assembly, fabrication, testing, and erection of steel tubular structures for electrical transmission poles ³¹
<i>ASCE 10: Design of Latticed Steel Transmission Structures</i>	Provides requirements for the design of guyed and self-supporting latticed steel electrical transmission structures ³²
<i>ASCE Manual of Practice 74: Guidelines for Electrical Transmission Line Structural Loading</i>	Provides most relevant and updated information related to transmission line structural loads and has been updated to address impacts of climate change ³³
<i>ASCE Manual of Practice 104: Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures</i>	Details best practices for the use of fiber-reinforced polymer (FRP) composite poles and crossarms in resilient conductor support applications ³⁴
<i>ASCE Manual of Practice 123: Prestressed Concrete Transmission Pole Structures</i>	A complete engineering reference on static-cast and spun-cast prestressed concrete poles for electric distribution and transmission power lines ³⁵
<i>ASCE Manual of Practice 141: Wood Pole Structures for Electrical Transmission Lines: Recommended Practice for Design and Use</i>	Provides comprehensive knowledge of the principles and methods for the design and use of wood poles for overhead utility line structures ³⁶

Preserving the nation's energy infrastructure requires balancing the affordability and access to delivered energy products (e.g., electricity and natural gas) with maintaining reliable and resilient service as well as

RESILIENCE & INNOVATION

While weather has always been the number one threat to the energy sector's reliability, climate change has only exacerbated the frequency and intensity of these events and associated costs.³⁷ The Department of Energy (DOE) found that power outages are costing the U.S. economy \$28 billion to \$169 billion annually.³⁸

Rather than focusing on repairing the grid after a major disaster, more utilities are taking proactive steps to adapt to climate change, by strengthening the grid through resilience measures and incorporating consensus-based standards during long- and short-term planning.

Incorporating these consensus-based standards in the design and construction of T&D infrastructure, which should be used for all overhead infrastructure (transmission, distribution, and communication) will improve the physical strength of the systems and allow them to better withstand natural disasters. The cost to properly design a typical distribution line by following the applicable standards increases by only \$681 per mile.³⁹ This is not only considered cost-effective, but also could prevent the loss of life.⁴⁰

Many of the nation's 8,625 power plants were deliberately

PUBLIC SAFETY

Pipeline incidents impacting people or the environment have declined by 20% in the past five years, while national pipeline capacity has grown by 12%. Pipeline and Hazardous Materials Safety Administration (PHMSA) statistics indicate that the frequency of significant pipeline incidents has fluctuated between 291 to 308 incidents in 2017 to 2019.⁴⁵ Each incident typically results in some injury or death as well as property damage in excess of \$50,000 per event. Since 2017, significant pipeline incidents have caused over \$3 billion in property damage. Clearly, continued upgrades and improvements are needed but must be balanced against the advancement of electrification and demand shift, among other factors.

reducing the carbon footprint. This is readily addressed through life-cycle cost analysis, wherein technology improvements and best and sustainable practices to replace aging infrastructure can be confirmed.

sited near shorelines to have access to water. As a result, when hurricanes strike, power plants face significant flooding damage. During Hurricane Harvey in Houston, Texas, in 2017, wind and catastrophic flooding knocked down or damaged more than 6,200 distribution poles, and 21.4 gigawatts of generation were affected by wind damage, flooding damage, fuel supply issues, or evacuations and shutdowns.⁴¹ As sea levels rise, storm surges would hit further inland, causing more coastal flooding to transmission, distribution, and generation infrastructure.⁴²

Electric companies have invested more than \$285 billion in T&D since Superstorm Sandy, partially to harden the energy grid and make it more resilient to future storms, including investing in new and upgraded T&D infrastructure, improving efficiency and reliability, and enhancing protection to enable a more secure, flexible, and resilient electric system.⁴³

Other ways utilities have incorporated resilience are through increased utilization of microgrids and battery storage.⁴⁴ Innovations support decarbonization, electrified transportation, remote pipeline inspections, and also include smart technologies such as T&D line sensors.

Beyond just the inconvenience of having no lights or internet, prolonged power outages have significant consequences for everyone. Nearly every other part of our infrastructure relies on electricity.

Communications are the first to be impacted; public and private transportation is immediately affected; water and wastewater cease to operate; gas stations and grocery stores cannot sell the goods that they have due to our digital economy; and commercial activity immediately terminates as even cash transactions require electric registers. The public's health is in danger as medical devices could be shut off, water contaminated, and food spoilage will begin.⁴⁶

With new technologies deployed by the transmission system, power outages also bring increasing risks in cyber and physical security. Consumers depend on electricity constantly, and the grid's reliability can be impaired by cyberattacks on information technology systems that support its operations, with the potential to cause power outages. The electric grid is becoming more vulnerable to cyberattacks via industrial control systems, consumer Internet of Things devices connected to the grid's distribution network, and the global positioning system (GPS). From 2014 through 2018, grid owners

and operators reported 17 events to DOE that were initially believed to be caused by cyber-related activity. Further analysis of the 17 events shows only four were determined to be related to cybersecurity, and none disrupted the reliability or availability of the grid or resulted in a power outage.⁴⁷ But cyberattacks will only increase and the possibility of a major breach on part of the U.S. grid is always a risk.

Select energy systems, such as the transmission grid, are also exposed to low-probability severe threats, such as geomagnetic pulse, which could have a significant impact on public safety and the economy. The DOE released a Cybersecurity Strategy to strengthen the resilience and cybersecurity of the nation's energy infrastructure.⁴⁸ Additional actions by both FERC and the North American Electric Reliability Corporation (NERC) have focused on increasing physical resilience, enhancing cybersecurity, and bolstering the interdependence of the nation's energy and telecommunications infrastructure.⁴⁹



Photo courtesy of FirstEnergy Corp

CONSTRUCTION UNDERWAY ON FIRSTENERGY TRANSMISSION LINE UPGRADE IN NORTHEAST OHIO



Energy



RECOMMENDATIONS TO RAISE THE GRADE

- Adopt a federal energy policy that provides clear direction for meeting current and future demands factoring in technology change, carbon reduction, renewables and distributed generation, state and market-based factors, and rate affordability.
- Require the adoption of consensus-based standards for all overhead T&D lines, structures, and substations to ensure safety and increase reliability.
- Improve grid and pipeline reliability by increasing frequency and effectiveness of critical asset inspections and focusing on robust risk mitigation; consider life cycle costs and technology impacts during system upgrades and replacements.
- Develop a national hardening plan that considers investment in production/generation and delivery (T&D, pipelines) to enable rapid restoration of energy systems after natural and/or manmade disasters.
- Consolidate federal, state, and local environmental reviews and permitting processes so new T&D and pipelines can be funded, create jobs earlier, and modernize energy infrastructure faster — while ensuring environmental and community impacts are fully vetted and considered.
- Design energy infrastructure including life-cycle cost analysis and construction of additional transmission grid infrastructure to efficiently deliver power from generation sources to regions with greatest demand requirements.

SOURCES

1. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, Today in Energy, “Major Utilities Continue to Increase Spending on U.S. Electric Distribution Systems,” July 20, 2018.
2. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
3. U.S. Department of Energy (DOE), “Economic Benefits of Increasing Electric Grid Resilience to Weather Outages,” 2013.
4. U.S. Department of Energy, “Dynamic Line Rating: Report to Congress,” June 2019.
5. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, Today in Energy, “Investor-Owned Utilities Served 72% of U.S. Electricity Customers in 2017,” August 15, 2019.
6. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
7. Institution of Engineering and Technology, Generation, Transmission & Distribution, 2019, Vol. 13 Iss. 5, pp. 717-723. “Distribution system versus bulk power system: identifying the source of electric service interruptions in the US.”
8. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
9. Federal Energy Regulatory Commission (FERC), “Office of Energy Projects, Energy Infrastructure Update,” April 2020.



Energy



SOURCES (Cont.)

10. Federal Energy Regulatory Commission (FERC), “Office of Energy Projects, Energy Infrastructure Update,” July 2020 and August 2020.
11. Federal Energy Regulatory Commission (FERC), “Office of Energy Projects, Energy Infrastructure Update,” July 2020 and August 2020.
12. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, “U.S. Energy Facts Explained.”
13. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
14. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), “Gas Transmission Integrity Management Reporting: GT IM Performance Measure,” 2021. (<https://www.phmsa.dot.gov/pipeline/gas-transmission-integrity-management/gt-im-performance-measures>)
15. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), “PHMSA Regulations,” 2020.
16. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), “General Pipeline FAQs,” 2018.
17. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, “Natural Gas Explained.”
18. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, “Natural Gas Explained.”
19. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), “Cast and Wrought Iron Inventory.”
20. National Petroleum Council, “Dynamic Delivery: America’s Evolving Oil and Natural Gas Transportation Infrastructure,” 2019.
21. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
22. Edison Electric Institute, “2018 Financial Review: Annual Report of the U.S. Investor-Owned Electric Utility Industry,” pp 52-53, 2018.
23. Edison Electric Institute, “2018 Financial Review: Annual Report of the U.S. Investor-Owned Electric Utility Industry,” pp 52-53, 2018.
24. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, Today in Energy, “Major Utilities Continue to Increase Spending on U.S. Electric Distribution Systems,” July 20, 2018.
25. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, Today in Energy, “Major Utilities Continue to Increase Spending on U.S. Electric Distribution Systems,” July 20, 2018.
26. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, Today in Energy, “Major Utilities Continue to Increase Spending on U.S. Electric Distribution Systems,” July 20, 2018.



Energy



SOURCES (Cont.)

27. U.S. Energy Information Administration (EIA), Independent Statistics and Analysis, Today in Energy, “Major Utilities Continue to Increase Spending on U.S. Electric Distribution Systems,” July 20, 2018.
28. Edison Electric Institute, “Smarter Energy Infrastructure: The Critical Role and Value of Electric Transmission,” 2019.
29. National Environmental Policy Act, “Executive Orders.”
30. American Petroleum Institute, “U.S. Oil and Gas Infrastructure Investment Through 2035: An Engine for Economic Growth,” 2017.
31. ASCE 48: Design of Steel Transmission Pole Structures.
32. ASCE 10: Design of Latticed Steel Transmission Structures.
33. Manual of Practice 74: Guidelines for Electrical Transmission Line Structural Loading.
34. ASCE Manual of Practice 104: Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures.
35. Manual of Practice 141: Wood Pole Structures for Electrical Transmission Lines: Recommended Practice for Design and Use.
36. Manual of Practice 113: Substation Structure Design Guide.
37. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
38. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
39. Lynch, O, P.E., “But it’s Just a Distribution Line!” Electrical Transmission and Substation Structures, 2012 Conference.
40. McKinsey and Company, “Why, and How, Utilities Should Start to Manage Climate-Change Risk,” April 24, 2019.
41. McKinsey and Company, “Why, and How, Utilities Should Start to Manage Climate-Change Risk,” April 24, 2019.
42. American Society of Civil Engineers (ASCE), “Failure to Act: Electric Infrastructure Investment Gaps in a Rapidly Changing Environment,” 2020.
43. Edison Electric Institute, “Smarter Energy Infrastructure: The Critical Role and Value of Electric Transmission,” 2019.
44. U.S. Department of Energy, “How Distributed Energy Resources Can Improve Resilience in Public Buildings: Three Case Studies and a Step-by-Step Guide,” 2019.
45. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, “Pipeline Incident 20 Year Trends.”
46. Federal Emergency Management Association, “Power Outages.”
47. U.S. Government Accountability Office, “Critical Infrastructure Protection: Actions Needed to Address Significant Cybersecurity Risks Facing the Electric Grid,” August 26, 2019.
48. U.S. Department of Energy, “Cybersecurity Strategy 2018-2020.”
49. Federal Energy Regulatory Commission, “Cyber and Grid Security,” 2020.