



December 2022

TENNESSEE VALLEY AUTHORITY

Additional Steps Are Needed to Better Manage Climate- Related Risks

Accessible Version

GAO Highlights

Highlights of [GAO-23-105375](#), a report to congressional requesters

Why GAO Did This Study

More frequent extreme weather events and other risks associated with climate change could cost utilities and customers billions of dollars from power outages, disruptions to electricity generation capacity, and infrastructure damage. Enhancing climate resilience means taking actions to reduce potential future losses by managing climate-related risks. TVA is a federal corporation and the nation's largest public power provider. TVA provides electricity to about 10 million customers in seven states, including 153 local power companies and about 60 large industrial customers and federal facilities.

GAO was asked to examine U.S. energy infrastructure resilience. This report examines (1) climate-related risks to TVA's operations; and (2) steps TVA has taken to manage climate-related risks, and additional steps needed. GAO analyzed relevant reports and financial disclosure documents; and interviewed TVA officials and knowledgeable stakeholders from consumer groups and DOE national laboratories.

What GAO Recommends

GAO is making three recommendations, including that TVA conduct an inventory of assets and operations vulnerable to climate change and develop a resilience plan that identifies and prioritizes resilience measures. TVA neither agreed nor disagreed with our recommendations.

View [GAO-23-105375](#). For more information, contact Frank Rusco at (202) 512-3841 or RuscoF@gao.gov.

December 2022

TENNESSEE VALLEY AUTHORITY

Additional Steps Are Needed to Better Manage Climate-Related Risks

What GAO Found

The Tennessee Valley Authority (TVA) faces several climate-related risks to its operations. Increasing temperatures and other climate-related risks are expected to affect TVA's ability to generate and transmit electricity, according to reports reviewed and stakeholders interviewed by GAO. For example, in 2007, 2010, and 2011, TVA had to reduce power generation at its Browns Ferry Nuclear Plant because river temperatures were too high to receive discharge water from the plant without raising ecological risks. Climate-related effects, such as heavy precipitation and flooding, could also create added costs to TVA's operations—such as for infrastructure investments—that could affect TVA's ability to keep electricity rates low. For example, in 2010, a TVA substation was submerged in over 5 feet of water when 15 inches of rain fell in 2 days. TVA relocated the substation to higher ground, at a cost of about \$9 million.

Tennessee Valley Authority's Browns Ferry Nuclear Plant in Alabama



Source: Tennessee Valley Authority. | GAO-23-105375

TVA has taken several steps to manage climate-related risks. For example, TVA identified risks, such as flooding and drought, in its 2021 *Climate Action Adaptation and Resiliency Plan* and implemented several resilience measures, such as relocating certain infrastructure. However, TVA has not conducted an inventory of assets and operations vulnerable to climate change or developed a resilience plan that identifies and prioritizes resilience measures to address specific risks. According to the Department of Energy's (DOE) *Guide for Climate Change Resilience Planning*, conducting an inventory of assets and operations vulnerable to climate change can help utilities more accurately identify relevant hazards and the potential severity of disruptions to operations or damage to related infrastructure. This, in turn, would better position TVA to plan and implement appropriate actions to address climate change vulnerabilities as they become more acute, and as new and better information becomes available. In addition, developing a resilience plan that includes a portfolio of resilience measures could help TVA identify available options and determine whether mitigating certain risks is worth the investment. Doing so would help TVA better fulfill its mission of providing reliable and affordable power to its customers.

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Abbreviations

DOE	Department of Energy
ISO	International Organization for Standardization
TVA	Tennessee Valley Authority

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December 30, 2022

The Honorable Tom Carper
Chairman
Committee on Environment and Public Works
United States Senate

The Honorable Joe Manchin III
Chairman
Committee on Energy and Natural Resources
United States Senate

Climate change is expected to have far-reaching effects on every aspect of the electricity grid—from generation, transmission, and distribution, as well as consumer demand for electricity—as we reported in March 2021.¹ In that report, we found that these effects could result in costs to utilities and customers in the billions of dollars, including the costs of disruptions to electricity generation capacity; power outages and infrastructure damage; operational challenges; and the need for capital investments. The nature and extent of climate change effects on the grid will vary by geographic location, energy source, condition of grid infrastructure, and other factors.

The Tennessee Valley Authority (TVA) is a federal corporation and the nation’s largest public power provider. TVA provides electricity to about 10 million customers and has a service area that covers 80,000 square miles, including most of Tennessee and parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina, and Virginia. TVA operates generating assets that include 29 hydropower plants, 17 natural-gas and/or oil-fired plants, 13 solar installations, five coal-fired plants, and three nuclear plants.² TVA also purchases some power from other producers. TVA owns and operates more than 16,000 miles of transmission lines and 500 substations. Because TVA is the nation’s largest public power provider, potential climate change effects on TVA’s

¹GAO, *Electricity Grid Resilience: Climate Change Is Expected to Have Far-reaching Effects and DOE and FERC Should Take Actions*, [GAO-21-346](#) (Washington, D.C.: Mar. 5, 2021).

²TVA’s power operations produce waste stored in facilities operated by TVA.

infrastructure and operations could have significant economic and social consequences.

You asked us to examine efforts to enhance U.S. energy infrastructure resilience to climate change. This report examines (1) the risks that climate change poses to TVA's operations; and (2) steps that TVA has taken to manage climate-related risks, and additional steps needed to manage these risks.

To conduct our work, we interviewed officials from the Department of Energy (DOE), the Federal Energy Regulatory Commission, and TVA. To examine the risks that climate change poses to TVA's operations, we reviewed the U.S. Global Change Research Program's *Fourth National Climate Assessment*;³ National Academies of Sciences, Engineering, and Medicine reports;⁴ DOE and national laboratory reports; prior GAO, Congressional Research Service, and Congressional Budget Office reports; and TVA reports and assessments. We identified these reports by (1) conducting a literature search, (2) asking TVA officials and stakeholders for recommendations, and (3) reviewing prior GAO work.

We also reviewed TVA's 2021 Annual Report to the U.S. Securities and Exchange Commission. We interviewed four knowledgeable stakeholders from actuarial, reinsurance, and credit rating entities to obtain their perspective on how climate-related risks could affect TVA's financial condition. We identified these stakeholders through a review of related reports and by asking for recommendations for other stakeholders and organizations to interview. We selected stakeholders based on their knowledge about TVA, and their expertise related to risk management and TVA's credit rating and financial condition. We generally asked the same questions during each interview (e.g., how climate change could affect TVA's financial condition) but also discussed individual stakeholders' perspectives, as appropriate. We also asked for recommendations for other stakeholders and organizations we should interview. Findings from our selected stakeholders cannot be generalized

³U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. 2 (Washington, D.C.: 2018).

⁴National Academies of Sciences, Engineering, and Medicine, *Attribution of Extreme Weather Events in the Context of Climate Change* (Washington D.C.: 2016); and National Research Council of the National Academies, *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change, Adapting to the Impacts of Climate Change* (Washington, D.C.: 2010).

to those we did not include in our review; rather, our interviews provide insights into how selected stakeholders viewed the various topics.

To examine the steps that TVA has taken to manage climate-related risks, we reviewed relevant TVA plans and annual reports, such as TVA's 2021 *Climate Action Adaptation and Resiliency Plan*.⁵ We compared the steps that TVA has taken to GAO's *Enterprise Risk Management Framework* to assess the extent to which TVA is managing climate-related risks and to identify additional steps needed.⁶ In addition, we interviewed 11 knowledgeable stakeholders from consumer and environmental groups, as well as a consultant, and staff from an industry association and five DOE national laboratories.⁷ We identified these stakeholders through a review of related reports and by asking for recommendations for other stakeholders to interview. We selected stakeholders based on their knowledge of TVA and their expertise related to electricity and climate change. Findings from our selected stakeholders cannot be generalized to those we did not include in our review; rather, our interviews provide insights into how selected stakeholders viewed the various topics. We generally asked the same questions during each interview, including asking for recommendations for other stakeholders and organizations we should interview.

We also reviewed GAO's *Disaster Resilience Framework* to identify opportunities to manage climate-related risks and enhance the resilience

⁵According to TVA's 2021 *Climate Action Adaptation and Resiliency Plan*, every investment in mitigating greenhouse gas emissions is also an investment in climate adaptation. Tennessee Valley Authority, *Climate Action Adaptation and Resiliency Plan* (August 2021). In this report, we focus on TVA's efforts to enhance the resilience of its operations, also referred to as "adaptation," and we did not review TVA's emission reduction efforts.

⁶GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, [GAO-17-63](#) (Washington, D.C.: Dec. 1, 2016).

⁷The five laboratories included Oak Ridge National Laboratory, Argonne National Laboratory, Pacific Northwest National Laboratory, National Renewable Energy Laboratory, and Idaho National Laboratory.

of TVA's infrastructure and operations to the effects of climate change.⁸ Given our methodology, we may not have identified every step that TVA could take to better manage climate-related risks, but we provide examples of steps that TVA could take.

We conducted this performance audit from August 2021 to December 2022, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

This section describes (1) legislation and TVA governance, (2) TVA's operations and planning, and (3) climate resilience and risk management.

Legislation and TVA Governance

TVA is an independent federal corporation established by the TVA Act for purposes including to improve the quality of life in the Tennessee River Valley by improving navigation, promoting regional agricultural and economic development, and controlling the floodwaters of the Tennessee River.⁹ From its inception in 1933 through fiscal year 1959, TVA received annual appropriations to finance its cash and capital requirements. In

⁸In October 2019, GAO issued our *Disaster Resilience Framework* to serve as a guide for assessing federal actions to facilitate and promote resilience to natural disasters. The principles in this framework can help identify opportunities to enhance efforts to promote disaster resilience, including building resilience to climate change. The framework is organized around three broad, overlapping principles—information, incentives, and integration—and a series of questions to guide analyses that can help agencies and other users consider opportunities for enhancing federal efforts to promote disaster resilience. GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, [GAO-20-100SP](#) (Washington, D.C.: Oct. 23, 2019).

⁹Pub. L. No. 73-17, 48 Stat. 58 (1933) (codified as amended at 16 U.S.C. §§ 831–831ee). In its 2018-2022 strategic plan, TVA established four strategic imperatives: (1) maintain low rates, (2) live within its means, (3) manage assets to meet reliability expectations and provide a balanced portfolio, and (4) be responsible stewards of the region's natural resources. Tennessee Valley Authority, *TVA Strategic Plan FY2018-2022* (February 2018).

1959, however, Congress amended the act and provided TVA with the authority to finance its power program through revenue from electricity sales and borrowing, and required TVA to repay a substantial portion of the annual appropriations it had received to pay for its power facilities. Under the act, TVA must design its rates to cover all costs and also keep rates as low as feasible. TVA must charge rates for power that will produce gross revenues sufficient to provide funds for its costs, including administrative, capital investment, and operations and maintenance support. TVA can borrow money by issuing bonds and notes to finance its power program, an authority set by Congress that cannot exceed \$30 billion at any given time.¹⁰

A nine-member Board of Directors nominated by the President and confirmed by the U.S. Senate administers the TVA. The board sets TVA's goals and policies, appoints the CEO, and approves rate changes. TVA files publicly available quarterly and annual financial reports with the U.S. Securities and Exchange Commission.

TVA's Operations and Planning

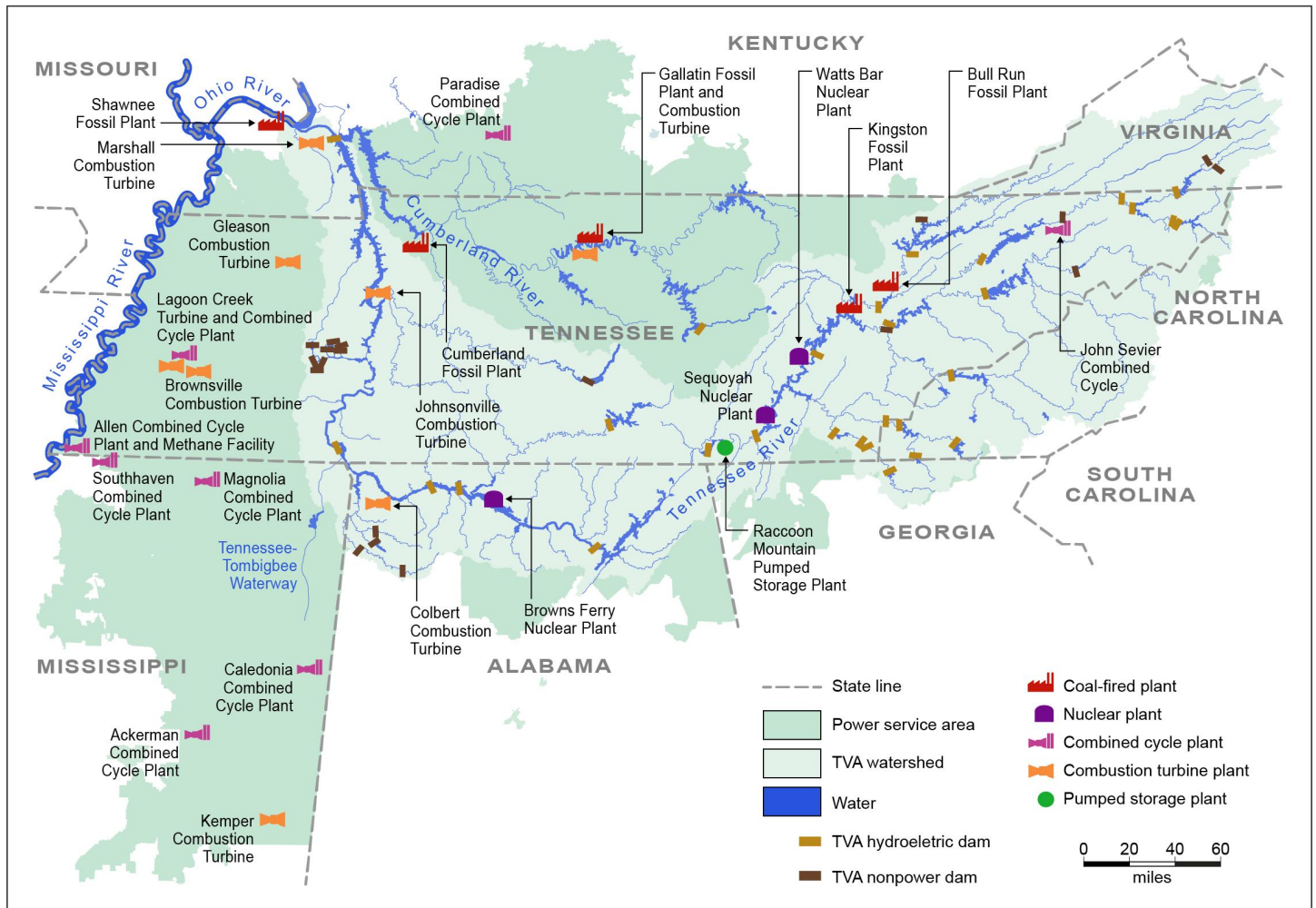
TVA's mission focuses on three key areas: (1) energy—delivering reliable, low-cost, clean energy; (2) environment—caring for the region's natural resources; and (3) economic development—creating sustainable economic growth. TVA has an extensive power generation and transmission system and supporting infrastructure that includes TVA's generation facilities and transmission infrastructure, such as substations, towers, and control centers. TVA's fiscal year 2021 power generation portfolio consisted of 41 percent nuclear, 21 percent natural gas and/or oil-fired, 15 percent coal fired, 10 percent hydropower, 8 percent purchased power (nonrenewable), and 5 percent purchased power (renewable).¹¹

¹⁰According to the Congressional Research Service, TVA pays for its debt primarily by using bonds. TVA's debts are not guaranteed by, nor are they obligations of, the federal government. Congressional Research Service, *Privatizing the Tennessee Valley Authority: Options and Issues*, R43172 (Washington, D.C: July 29, 2013).

¹¹TVA's nonhydropower renewable resources from TVA facilities are less than 1 percent of all electric power that TVA generated and purchased in fiscal year 2021 and, therefore, are not included. Purchased power (renewable) includes the majority of TVA's nonhydropower renewable energy supply. Tennessee Valley Authority, *TVA Annual Report to the U.S. Securities and Exchange Commission*, 10-K (Sept. 30, 2021).

TVA has constructed dams and hydropower facilities on the Tennessee River and its tributaries. TVA manages and maintains 49 dams, which comprise TVA's integrated reservoir system. This system provides approximately 800 miles of commercially navigable waterways, as well as significant flood reduction benefits both within the Tennessee River system and downstream on the lower Ohio and Mississippi Rivers. The reservoir system also provides a water supply for residential and industrial customers and cooling water for some of TVA's coal-fired and nuclear power plants. A portion of energy generated by nine U.S. Army Corps of Engineers' dams on the Cumberland River system contributes to TVA's power system. TVA purchases hydropower from these dams from the Southeastern Power Administration—a federal power marketing agency. See figure 1 for a map of TVA's service area and power generation assets.

Figure 1: Tennessee Valley Authority’s Service Area and Power Generation Assets



Source: Tennessee Valley Authority (TVA). | GAO-23-105375

TVA sells electricity to 153 local power companies and about 60 large industrial customers and federal facilities.¹² TVA had revenues of about \$10 billion in fiscal year 2021 from the sale of electricity. TVA generally uses debt financing for capital investments in new generation capacity and environmental controls; it uses revenues for operations and maintenance of its power system assets and to service its bonds’

¹²Approximately 93 percent of TVA’s revenue from sales of electricity comes from local power companies. TVA also sells electricity directly to industrial companies, federal agencies, and others. Federal facilities include military installations and a national laboratory.

principal and interest. TVA can borrow funds at competitive interest rates because of its triple-A credit rating, which is based, in part, on the fact that it is a federal corporation.

TVA periodically develops an integrated resource plan to guide its decisions about the resources needed to meet forecasted future demand for electricity and to determine the most cost-effective ways to prepare for the future power needs of its customers. To forecast the demand for electricity in its service area for the next 20 or more years, TVA employs a set of models. Forecasting beyond a few years into the future, however, involves great uncertainty. Utilities deal with uncertainty, in part, by producing a range of forecasts based on demographic and economic factors and by maintaining excess generating capacity, known as “reserves.” Models help utilities choose the least-cost combination of power-generating resources to meet electricity demand. If demand forecasts are unreasonably high or low, a utility could end up with more or less generating capacity than it needs to serve its customers reliably, or end up with a mix of generating capacity that is not cost effective. Either outcome can affect electricity rates, as well as the utility’s financial situation.

Climate Resilience and Risk Management

Enhancing climate resilience means taking actions to reduce potential future losses by managing climate-related risks—planning and preparing for potential climate hazards, such as extreme rainfall, drought, and other events.¹³ Moreover, according to the *Fourth National Climate Assessment*, enhancing climate resilience entails a continuing risk management process through which individuals and organizations become aware of, and assess the risks and vulnerabilities from, climate and other drivers of change, take actions to reduce those risks, and learn over time. As we and others have reported, investing in resilience can

¹³For purposes of this report, we use the definition of “resilience” in Presidential Policy Directive 21, which establishes national policy for critical infrastructure security and resilience. Specifically, Presidential Policy Directive 21 defines “resilience” as the ability to prepare for and adapt to changing conditions and withstand, and recover rapidly from, disruptions, including naturally occurring threats or incidents. Presidential Policy Directive 21, *Critical Infrastructure Security and Resilience* (Feb. 12, 2013).

reduce the need for more costly steps in the decades to come.¹⁴ However, evaluating resilience investments can be challenging and the benefits difficult to quantify.¹⁵ Moreover, utilities must balance the need to enhance resilience with the associated costs, which could result in increases to the rates charged to consumers. In addition, increases in rates could disproportionately affect low-income populations that spend a greater portion of their income on energy expenses.

Enterprise risk management can help entities identify, assess, and manage risks, such as preparing for and responding to climate change.¹⁶ In addition, enterprise risk management can help these entities' leaders make better, more effective decisions when prioritizing risks and allocating resources to manage risks. In 2016, we identified six essential elements of enterprise risk management.¹⁷ See figure 2.

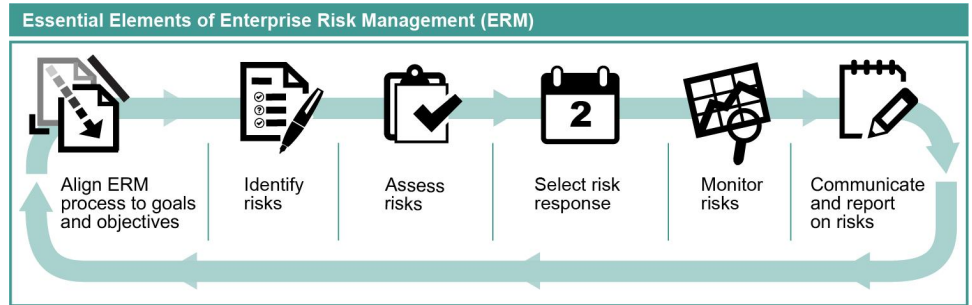
¹⁴GAO, *Climate Change: Opportunities to Reduce Federal Fiscal Exposure*, [GAO-19-625T](#) (Washington, D.C.: June 11, 2019); and *Climate Change: Selected Governments Have Approached Adaptation through Laws and Long-Term Plans*, [GAO-16-454](#) (Washington, D.C.: May 12, 2016). National Research Council of the National Academies, *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change*.

¹⁵[GAO-21-346](#).

¹⁶GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, [GAO-17-63](#) (Washington, D.C.: Dec. 1, 2016). According to the National Academies of Sciences, Engineering, and Medicine, climate resilience actions should address climate hazards that are acute—more frequent or intense extreme weather—and chronic—gradual, long-term changes, such as ecosystem shifts or sea level rise. National Research Council of the National Academies, *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change*. Similarly, according to International Organization for Standardization (ISO) Standard 14090, an organization's assessment of how it will be affected by climate change should consider chronic, slow-onset impacts, as well as acute, sudden impacts from extreme events. International Organization for Standardization, ISO 14090:2019, *Adaptation to Climate Change—Principles, Requirements and Guidelines* (June 2019). The International Organization for Standardization is a worldwide federation of national standards bodies.

¹⁷[GAO-17-63](#).

Figure 2: GAO’s Enterprise Risk Management Framework



Source: GAO. | GAO-23-105375

The six essential elements of enterprise risk management are generally consistent with the steps outlined in several resilience planning frameworks that we reviewed, including DOE’s *Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning*, and international standards.¹⁸

Increasing Temperatures, Heavy Precipitation, and Other Climate-Related Effects Pose Risks to TVA’s Operations

Increasing temperatures, heavy precipitation and flooding, drought, extreme weather events, and other effects of climate change pose risks to TVA’s operations, according to reports we reviewed, and stakeholders we interviewed.

Increasing temperatures. Increasing temperatures may create greater demand for electricity and affect TVA’s power plant operations, ability to generate power, the efficiency of TVA’s transmission and other critical infrastructure, and the health of TVA’s outdoor workers. For example, increasing temperatures may result in increased electricity demand for cooling. This could require TVA to purchase power from other power

¹⁸U.S. Department of Energy, Office of Energy Policy and Systems Analysis, *Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning* (September 2016); International Organization for Standardization, ISO 14090:2019, *Adaptation to Climate Change—Principles, Requirements and Guidelines* (June 2019); and ASTM International, Standard ASTM E3032-15e1: *Guide for Climate Resiliency Planning and Strategy* (2016). ASTM International develops voluntary consensus industry standards.

producers at relatively higher prices to meet customer demand. Furthermore, according to DOE's *Guide for Climate Resilience Planning*, increasing temperatures may result in a reduction in thermoelectric plant efficiency and available generation capacity. Increasing temperatures may also result in reductions in hydropower generation.¹⁹ Moreover, according to the *Fourth National Climate Assessment*, the Southeast United States has been warming at an accelerated rate since the 1960s.

Increasing temperatures may trigger environmental requirements that could force a power plant to shut down or reduce power generation. For example, in 2007, 2010, and 2011, TVA had to reduce power output from its Browns Ferry Nuclear Plant because river temperatures were too high to receive discharge water without raising ecological risks.²⁰ Figure 3 shows TVA's Browns Ferry Nuclear Plant in Alabama.

Figure 3. Tennessee Valley Authority's Browns Ferry Nuclear Plant in Alabama



Source: Tennessee Valley Authority. | GAO-23-105375

¹⁹As we reported in 2014, rising temperatures can reduce the amount of water available for hydropower—because of increased evaporation—and degrade habitats for fish and other wildlife. Hydropower production is also highly sensitive to changes in precipitation and river discharge. GAO, *Climate Change: Energy Infrastructure Risks and Adaptation Efforts*, [GAO-14-74](#) (Washington, D.C.: Jan. 31, 2014).

²⁰To prevent hot water from harming fish and other wildlife, power plants typically are not allowed to discharge cooling water above a certain temperature. When power plants reach those limits, they can be forced to reduce power production or shut down.

Additionally, increasing temperatures could negatively affect the efficiency and capacity of TVA's transmission lines and other critical power equipment. For example, higher temperatures cause the expansion of transmission line materials, causing lines to sag. Sagging can cause permanent damage to the lines, increasing the likelihood of power outages when the lines make contact with other lines, trees, or the ground.²¹ Moreover, one stakeholder we interviewed told us that increasing temperatures could negatively affect transformer operations and add extra pressure from increased consumer use for air conditioning. The additional burden and high temperatures can shorten the lifespan of transformers—a critical component of the transmission system—which are expensive and difficult to replace, according to this stakeholder.²²

Finally, higher temperatures can negatively affect the health of TVA employees who work outdoors. According to TVA's 2021 *Climate Action Adaptation and Resiliency Plan*, 61 percent of large Southeast cities are exhibiting some aspects of worsening heatwaves, which is a higher percentage than any other region of the country.²³ Heat-related health threats are a risk in outdoor jobs and activities.²⁴

Heavy precipitation and flooding. Increased risk of flooding associated with heavy precipitation events can damage or otherwise negatively affect TVA's generation and transmission infrastructure, which can lead to outages and costly repairs. Furthermore, heavy precipitation events pose inland flooding risks for electricity assets and supporting infrastructure along riverbanks or in floodplains (including other energy systems and critical transportation links between fuel supplies and generation

²¹[GAO-21-346](#).

²²Similarly, according to one report by Oak Ridge National Laboratory, transformers and power lines are particularly vulnerable to high temperatures. Persistent extreme temperatures can lead to deratings—reductions in power generation—shorter lifetimes, and abrupt failure of these components. M.R. Allen-Dumas et al., *Extreme Weather and Climate Vulnerabilities of the Electric Grid: A Summary of Environmental Sensitivity Quantification Methods*, Oak Ridge National Laboratory, ORNL/TM-2019/1252 (Oak Ridge, TN: Aug. 16, 2019).

²³Tennessee Valley Authority, *Climate Action Adaptation and Resiliency Plan* (August 2021).

²⁴According to the *Fourth National Climate Assessment*, by 2090, under a worst-case scenario, the Southeast is projected to have the largest heat-related impacts on labor productivity in the country.

facilities).²⁵ According to the *Fourth National Climate Assessment*, heavy precipitation events have increased in frequency and intensity in the Southeast, and there is high confidence they will continue to increase in the future.²⁶

Furthermore, TVA's 2019 *Integrated Resource Plan Final Environmental Impact Statement* states that greater precipitation during storms will increase flood risk, expand flood hazard areas, increase the variability of stream flows (i.e., higher high flows and lower low flows) and increase the velocity of water during high flow periods, thereby increasing erosion.²⁷ According to TVA documents, in May 2010, 15 inches of rain fell in 2 days, causing substantial flooding of one of TVA's substations, covering it with over 5 feet of water.²⁸ According to a TVA official, some local power companies were unable to receive power as a result.

Drought. Drought could reduce the water available for TVA's power plants that rely on water for their power generation operations. According to the *Fourth National Climate Assessment*, intra-annual droughts in the

²⁵U.S. Department of Energy, Office of Energy Policy and Systems Analysis, *Climate Change and the Electricity Sector*.

²⁶According to TVA's *Climate Change Adaptation and Resiliency Plan 2020 Update*, four major inland flood events occurred in just 3 years (2014–2016) in the Southeast, causing billions of dollars in damages and loss of life.

²⁷According to TVA's 2019 *Integrated Resource Plan Final Environmental Impact Statement*, these changes will have adverse effects on water quality and aquatic ecosystem health. Climate change also has the potential to affect outdoor recreation, including reservoir and stream-based recreation, according to the document. Tennessee Valley Authority, *2019 Integrated Resource Plan, Volume II—Final Environmental Impact Statement* (Knoxville, TN: June 2019).

²⁸Substations provide crucial links for electricity generation and serve as key nodes for linking transmission and distribution networks to end-use customers. Additionally, a substation generally contains transformers, protective equipment (e.g., relays and circuit breakers), switches for controlling high-voltage connections, electronic instrumentation to monitor system performance and record data, and fire-fighting equipment in the event of an emergency. U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability, *United States Electricity Industry Primer*, DOE/OE-0017 (July 2015).

Southeast are expected to become more frequent in the future.²⁹ In addition, droughts may last longer, according to TVA's analysis. In TVA's region, an inadequate supply of water could reduce generation at TVA's hydropower plants and at its coal-fired, natural gas, and nuclear plants, which depend on water from nearby river systems for cooling.³⁰ This could require TVA to purchase power from other producers or to rely on more costly power generation options. For example, the 2007 to 2008 droughts in the TVA area were among the worst on record, according to a 2017 DOE and Department of Homeland Security report.³¹

Even as the drought began to ease in early 2008, TVA's hydropower generation was only at 49 percent of normal operation. During the drought, coal prices more than doubled, forcing TVA to rely on additional natural gas purchases to meet generation needs. In October 2008, TVA raised rates by 20 percent in order to absorb more than \$2 billion in increased costs for coal, natural gas, and purchased power, according to the report.

Extreme weather events. Extreme weather events, such as high winds, thunderstorms, heat waves, intense cold periods or ice storms, and extreme rainfall, could threaten TVA's operations and damage

²⁹According to the U.S. Environmental Protection Agency, although rainfall during spring is likely to increase in Tennessee during the next 40 to 50 years, the total amount of water running off into rivers or recharging ground water each year is likely to decline 2.5 percent to 5 percent, as increased evaporation offsets the greater rainfall. Droughts are likely to be more severe because periods without rain will be longer, and very hot days will be more frequent. U.S. Environmental Protection Agency, *What Climate Change Means for Tennessee*, EPA 430-F-16-044 (August 2016).

³⁰According to TVA's September 2021 Annual Report to the U.S. Securities and Exchange Commission, periods of either high or low levels of rainfall may impede river traffic, impacting barge deliveries of critical items, such as coal and equipment for power facilities.

³¹U.S. Department of Homeland Security and U.S. Department of Energy, *Dams and Energy Sectors Interdependency Study, an Update to the 2011 Study* (2017).

infrastructure, which could have negative financial implications.³² According to *the Fourth National Climate Assessment*, extreme weather events, such as tornadoes, hail, and thunderstorms are exhibiting changes that may be related to climate change, and modeling studies consistently suggest that the frequency and intensity of severe thunderstorms in the United States could increase with climate change. Furthermore, according to one stakeholder we interviewed, there could be an increase in tornado activity in the TVA area, which could damage transmission infrastructure.³³ If that happens, TVA may need to rebuild damaged infrastructure, which would affect TVA's operations and financial condition, according to this stakeholder.

For example, in April 2011, several TVA customers lost power because of the destruction caused by a series of storms and tornadoes that passed through the region. Redstone Arsenal—a United States Army base—lost electricity for a week on account of severe damage to TVA equipment and facilities throughout northern Alabama. According to a stakeholder we interviewed, a tornado from the same storm system struck a transmission line that served one of TVA's industrial customers, causing the customer's facility to lose electricity for about 30 days while TVA rebuilt the transmission line in the area. Furthermore, because of extreme cold conditions in January 2014, TVA experienced all-time record

³²According to the *2017 Quadrennial Energy Review* and the U.S. Global Change Research Program's *Fourth National Climate Assessment*, the leading cause of power outages in the United States is extreme weather. Quadrennial Energy Review (QER) Task Force, *Transforming the Nation's Electricity System: The Second Installment of the QER* (January 2017). According to a report by Moody's Investors Service, extreme weather associated with climate change can increase the financial risk to utilities by contributing to sharp increases or declines in demand for electricity. Sharp volatility in demand could affect liquidity because utilities will need to buy or sell power or natural gas as demand fluctuates. Also, extreme weather conditions require more backup generation, which increases costs and can heighten the risk of system stress and service interruptions, according to this report. This may raise electricity prices as utilities add capacity to meet demand, thereby increasing costs to consumers. Moody's Investors Service, *Regulated Electric Utilities in the United States: Intensifying Climate Hazards to Heighten Focus on Infrastructure Investments* (January 2020).

³³Trends and future projections for some extreme events, including tornadoes, lightning, and wind storms, are still uncertain. However, these types of events provide insight into the potential climate-related vulnerabilities that the United States faces. According to the National Academies of Sciences, Engineering, and Medicine, severe storms—those that produce strong winds, hail, tornadoes, extensive lightning, or heavy precipitation—are the most challenging weather events to attribute to climate change, because these events are poorly observed, cannot be simulated in climate models at present, and have a complex and subtle relationship to climate change. National Academies of Sciences, Engineering, and Medicine, *Attribution of Extreme Weather Events*.

demand and subsequently requested that customers reduce electricity use to avoid power outages. In addition, according to TVA, frozen switches and limited gas capacity forced TVA to mobilize crews and work under frigid conditions. TVA also had to purchase power to meet demand during this event.

More frequent wildfires. Wildfires could also affect TVA's operations. As we reported in March 2021, more frequent wildfires threaten critical transmission infrastructure, including transmission towers.³⁴ In particular, according to the *Fourth National Climate Assessment*, rising temperatures and increases in the duration and intensity of drought are expected to increase the occurrence of wildfires and reduce the effectiveness of prescribed burns in the Southeast.³⁵ According to a report by Oak Ridge National Laboratory, large fires can cause a range of physical impacts on transmission and distribution systems, including damage to towers and poles leading to potential collapse of power lines.³⁶ Additionally, the transmission capacity of a line can be affected by the heat, smoke, and particulate matter from a fire, even if there is no actual damage to the physical structure. For example, the insulators that attach the lines to the towers can accumulate soot, creating a conductive path and causing leakage currents that may force utilities to shut down the line. TVA has one of the largest transmission systems in North America,

³⁴GAO-21-346. In its fiscal year 2021 *Transmission System Vegetation Management Final Environmental Assessment*, TVA states that the reliability of TVA's transmission system is extremely important because interruptions can cause widespread and extended outages. For example, one high-voltage transmission line can support a primary substation, but if an interruption occurs on this transmission line, all other substations that depend on the primary substation also will be interrupted. The other secondary substations distribute power to homes, businesses, hospitals, and safety devices, such as traffic lights. Therefore, the loss of one primary substation can affect thousands of people. Tennessee Valley Authority, *Fiscal Year 2021 Transmission System Vegetation Management, Final Environmental Assessment* (Chattanooga, TN: November 2020).

³⁵Prescribed burns entail using deliberate, planned fires to restore or maintain desired ecosystem conditions and reduce fuels.

³⁶M.R. Allen-Dumas et al., *Extreme Weather and Climate Vulnerabilities of the Electric Grid*.

and wildfires pose a financial threat to the utility sector because utilities can be liable for fires caused by their power lines.³⁷

TVA Has Taken Several Steps to Manage Climate-Related Risks but Has Not Conducted an Inventory of Assets Vulnerable to Climate Change or Prioritized Resilience Measures

TVA has taken several steps to manage risks posed by the effects of climate change. However, TVA has not conducted an inventory of assets and operations vulnerable to climate change, or identified and prioritized resilience measures to address these climate change vulnerabilities.

TVA Has Taken Several Steps to Manage Climate-Related Risks

TVA has taken several steps to manage climate-related risks to its operations, including identifying and assessing risks, among others. See table 1 for examples of steps that TVA has taken to manage climate-related risks as they relate to the six elements of enterprise risk management.

³⁷According to TVA's *2020 Climate Change Adaptation and Resiliency Plan*, wildfires may affect biodiversity and air quality, but the plan does not discuss how wildfires may affect TVA infrastructure. Furthermore, TVA's *2021 Climate Change Adaptation and Resiliency Plan* does not mention wildfires, but TVA's 2021 Annual Report to the U.S. Securities and Exchange Commission identifies wildfires as a potential risk. According to the *Fourth National Climate Assessment*, although the total area burned by wildfire is greatest in the western United States, the Southeast has the highest number of wildfires. A 4-month seasonal drought in the fall of 2016 collectively produced the worst wildfires the region has seen in a century, according to the *Fourth National Climate Assessment*.

Table 1: Tennessee Valley Authority (TVA) Steps Taken to Manage Climate-Related Risks

Enterprise Risk Management element ^a	TVA step taken
<p>Align enterprise risk management process with goals and objectives <i>Ensure the enterprise risk management process maximizes the achievement of agency mission and results.</i></p>	<ul style="list-style-type: none"> Established an Enterprise Risk Council to oversee TVA's management of enterprise risks and establish an appropriate tone for a risk management culture throughout TVA.^b Issued a statement on climate change adaptation to (1) recognize that adaptation is a complement to mitigation or lowering emissions and that both are necessary to address the causes and potential consequences of climate change; (2) ensure that TVA executes its mission and operations safely, securely, effectively, and efficiently as the climate continues to change; and (3) establish a TVA-wide directive to integrate climate change adaptation planning and actions into existing and future planning processes.^c
<p>Identify risks <i>Assemble a comprehensive list of risks, both threats and opportunities, that could affect the agency from achieving its goals and objectives.</i></p>	<ul style="list-style-type: none"> Identified risks to operations, including rising temperatures and number of days exceeding 95 degrees Fahrenheit; flooding; changes in reservoir operations and hydropower generation because of increased demands for water and changes in precipitation patterns and evaporative losses; and increased frequency of extreme weather events, including extreme precipitation events and drought.^d Identified potential financial risks, including extreme temperatures that may increase demand for power and require TVA to purchase power from other producers at relatively higher prices to meet customer demand.^e
<p>Assess risks <i>Examine risks and consider both the likelihood of the risk and the impact of the risk on the mission to help prioritize risk response.</i></p>	<ul style="list-style-type: none"> Collaborated with Oak Ridge National Laboratory to assess climate change vulnerabilities and evaluate the costs and benefits of certain resilience investments in TVA's Cumberland River basin.^f Assessed how climate change would affect TVA's ability to meet power commitments through its integrated resource planning process. Specifically, TVA ran a climate sensitivity model to reflect the potential for a rise in temperatures, seasonal drought, and flooding conditions. TVA concluded that its system would become summer peaking because of climate change and estimated an increase of billions of dollars in related costs.^g Completed a study with the University of Tennessee to test the resilience of TVA's reservoir system in the face of extreme drought and partnered with Oak Ridge National Laboratory to assess how rising temperatures could affect electricity demand forecasting. Began assessing how extreme flooding may affect infrastructure built near the Tennessee River. Began working with Oak Ridge National Laboratory to assess climate change projections and potential effects on six key river management area uses, including power generation and flood protection. Evaluated the vulnerability of all of TVA's substations and switching stations from flooding events, although TVA used flood maps that did not consider climate change.
<p>Select risk response <i>Select a risk treatment response (based on risk appetite) that includes accepting, avoiding, reducing, sharing, or transferring risk.</i></p>	<ul style="list-style-type: none"> Purchased insurance and implemented resilience measures, such as relocating and hardening infrastructure. For example, TVA relocated a substation to higher ground. Increased TVA's winter reserve margin—the percentage of power plant capacity above expected demand—from 20 percent to 25 percent to better ensure uninterrupted service during extreme cold events. Replaced wood poles with steel for new construction and installed a series of modifications at four dams to manage potential flooding events. Established a regional transformer exchange program to share information among utilities on spare transformers available in case of an emergency, according to TVA officials.

Enterprise Risk Management element ^a	TVA step taken
Monitor risks <i>Monitor how risks are changing and if responses are successful.</i>	<ul style="list-style-type: none"> Routinely updated its climate adaptation plans to reflect new science information (e.g., National Climate Assessment) and funded climate change research efforts.
Communicate and report risks <i>Communicate risks with stakeholders and report on the status of addressing the risks.</i>	<ul style="list-style-type: none"> Periodically reported on the status of TVA's efforts to address climate-related risks and how these risks are changing through TVA's climate adaptation plans.^b Collaborated with federal agencies, such as through the Flood Resilience Interagency Working Group, and supported state, local, tribal, and private sector efforts to build climate resilience.ⁱ For example, according to TVA officials, in 2021, TVA collaborated with the city of Chattanooga on its regional resiliency planning effort, helped inform the city of Knoxville's 2021 Energy & Sustainability Work Plan, and contributed to the Tennessee Advisory Commission on Intergovernmental Relations report on improving community resilience to natural disasters.

Sources: GAO analysis and TVA documents. | GAO-23-105375

^aGAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, GAO-17-63 (Washington, D.C.: Dec. 1, 2016).

^bTVA, *Climate Action Adaptation and Resiliency Plan* (Aug. 16, 2021).

^cTVA, *Statement on Climate Change Adaptation* (June 1, 2011).

^dTVA, *Climate Action Adaptation and Resiliency Plan* (Aug. 16, 2021); *Climate Change Adaptation and Resiliency Plan 2020 Update* (July 15, 2020); and *Climate Change Adaptation Action Plan 2016 Update* (June 30, 2016).

^eTVA, *TVA Annual Report to the U.S. Securities and Exchange Commission, 10-K* (Sept. 30, 2021).

^fThe Oak Ridge National Laboratory study focused on evaluating the risks associated with extreme heat wave and drought conditions that are projected to affect TVA's Cumberland region by midcentury. Melissa Allen et al., *Assessing the Cost and Benefits of Investments in Climate Resilience: Tennessee Valley Authority Case Study*, Oak Ridge National Laboratory, ORNL/TM-2017/13 (Oak Ridge, TN: January 2017).

^gTVA, *2019 Integrated Resource Plan, Volume I—Final Resource Plan* (2019); and *2019 Integrated Resource Plan, Volume II—Final Environmental Impact Statement* (Knoxville, TN: June 2019). TVA estimated an increase of \$3 billion in total resource costs from the increased summer peak and thermal derates. When cooling water intake temperatures are high, power plants must reduce power production (derate) or use cooling towers (if available) to reduce the temperature of the discharged water and avoid noncompliance with thermal limits. Also, if intake water temperatures reach their design limits, the Nuclear Regulatory Commission requires nuclear plants to shut down.

^hGAO reviewed TVA's 2012, 2014, 2016, 2017, 2018, 2020, and 2021 climate change adaptation plans.

ⁱThe Flood Resilience Interagency Working Group—co-led by the Council on Environmental Quality, the Office of Management and Budget, and the Federal Emergency Management Agency—was formed by the White House Climate Policy Office in response to Executive Order 14030 on Climate-Related Financial Risk. According to TVA officials, the Interagency Working Group is developing flood standards that will consider climate change risks. TVA's flood risk management and historical flood risk mapping experience in the Tennessee River Valley provides valuable input to this group, according to TVA officials.

In addition, TVA has taken steps to respond to climate-related risks by investing in resilience measures and relocating and hardening

infrastructure.³⁸ According to its 2021 Annual Report to the U.S. Securities and Exchange Commission, TVA has spent \$155 million since 2009 to protect certain nuclear assets from extreme flooding. TVA also relocated a substation to higher ground and evaluated the vulnerability of all substations and switching stations from flooding events. According to TVA officials we interviewed, it cost about \$9 million and took approximately 4 years for construction to start to relocate the substation. According to these officials, it took TVA an additional 3 years to construct and transfer power to the new substation.³⁹ TVA has also replaced wood poles with steel for new construction and preventative maintenance, and installed a series of modifications at four dams to manage potential flooding events.⁴⁰ Finally, according to its 2019 *Integrated Resource Plan Final Environmental Impact Statement*, TVA installed additional cooling capacity at its Browns Ferry Nuclear Plant to address the risks associated with increasing temperatures.⁴¹

³⁸Resilience measures include nature-based solutions. In its fiscal year 2021 Sustainability Report, TVA states that it aims to be a leader in nature-based climate solutions to mitigate climate change and build resilience. TVA plans to plant 500,000 trees and restore 15 acres of wetlands by 2035, according to the report. Tennessee Valley Authority, *TVA Sustainability Today. Tomorrow. Together.* (May 2022). As we reported in 2019, natural infrastructure can be designed and developed for flood risk reduction purposes. For example, wetlands have the potential to reduce the risks of inland flooding. GAO, *Army Corps of Engineers: Consideration of Project Costs and Benefits in Using Natural Coastal Infrastructure and Associated Challenges*, [GAO-19-319](#) (Washington, D.C.: March 2019). In addition, according to a report by the National Academies of Sciences, Engineering, and Medicine, restoring coastal wetlands may reduce an area's vulnerability to coastal storms but could also provide co-benefits, such as increasing biodiversity by creating new breeding grounds for fish and improving recreation and tourism amenities, thereby expanding the total potential benefits of a project. National Research Council of the National Academies, *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change*.

³⁹Officials told us that TVA did not relocate the substation all at once. Instead, it took years to relocate sections to avoid any power disruptions.

⁴⁰According to TVA officials, TVA also works with federal agencies on resilience efforts. For example, TVA participates with the Federal Emergency Management Agency and other federal agencies on its annual national exercises around managing natural disasters, such as flooding.

⁴¹The 2019 *Integrated Resource Plan Final Environmental Impact Statement* also recognizes that further adaptation, such as installing increased cooling capacity at other thermal plants, may be necessary, given the forecasted long-term increases in temperature. Tennessee Valley Authority, *2019 Integrated Resource Plan, Volume II—Final Environmental Impact Statement*.

TVA Has Not Conducted an Inventory of Vulnerable Assets or Identified and Prioritized Climate Resilience Measures

TVA has not conducted an inventory of assets and operations vulnerable to climate change or developed a resilience plan that identifies and prioritizes resilience measures to address climate-related risks.

Risk management involves identifying and assessing risks to better understand the likelihood of impacts and their associated consequences.⁴² According to DOE's *Guide for Climate Change Resilience Planning*, taking inventory of assets and operations vulnerable to climate change can help utilities more accurately identify relevant hazards and the potential severity of disruptions or damages to infrastructure and operations.⁴³ In addition, TVA's 2016 *Climate Change Adaptation Action Plan* states that each major TVA planning process should identify any significant climate risks—those with the potential to substantially impair, obstruct, or prevent the success of agency mission activities, in the near term and the long term, in particular.⁴⁴ However, TVA has not assessed the risks that climate change poses to all major

⁴²[GAO-17-63](#).

⁴³According to DOE's *Guide for Climate Change Resilience Planning*, utilities undertaking a comprehensive vulnerability assessment may benefit from a complete, system-wide understanding of climate hazards. One critical input to the vulnerability assessment is an inventory of the assets and operations that could be affected by climate-related threats. Identifying, characterizing, and inventorying a utility's assets and operations will provide useful insights on the various ways in which climate impacts may disrupt services and how best to prioritize and implement operational resilience measures.

⁴⁴Tennessee Valley Authority, *Climate Change Adaptation Action Plan 2016 Update*.

planning processes or assets.⁴⁵ For example, TVA did not consider climate change in assessing the risk that flooding poses to its substations. According to DOE, relying solely on historical data puts a utility at risk of underestimating its vulnerability to future climate change effects.⁴⁶ In addition, TVA has not assessed how potential changes in the frequency of wildfires may affect TVA's power assets and operations.⁴⁷

TVA officials we interviewed told us that identifying climate-related risks and potential effects is challenging because of the long time frame involved and the inherent uncertainty in climate models.⁴⁸ TVA officials identified other challenges to managing climate-related risks, such as obtaining comprehensive and timely data, and understanding potential

⁴⁵According to GAO's Enterprise Risk Management Framework, entities should assemble a comprehensive list of risks, both threats and opportunities, that could affect the entity from achieving its goals and objectives. Furthermore, categorizing risks can help agency leaders see how risks relate and to what extent the sources of the risks are similar. Risks are linked to relevant strategic objectives and documented in a risk register or some other comprehensive format that also identifies the relevant source and a risk owner to manage the treatment of the risk. Comprehensive risk identification is critical, even if the agency does not control the source of the risk. [GAO-17-63](#). Similarly, according to ASTM International, creating a comprehensive list of risks based on available climate information is critical, because if a risk is not identified at this stage, it will not be included in further analysis. Further analysis could entail conducting a risk analysis to determine whether certain risks need to be treated (some identified risks may not require treatment at all because they fall within the agency's risk appetite, defined as how much risk the organization is willing to accept relative to mission achievement). ASTM International, Standard ASTM E3032-15e1: *Guide for Climate Resiliency Planning and Strategy* (2016).

⁴⁶U.S. Department of Energy, Office of Energy Policy and Systems Analysis, Partnership for Energy Sector Climate Resilience, *A Review of Climate Change Vulnerability Assessments: Current Practices and Lessons Learned from DOE's Partnership for Energy Sector Climate Resilience* (May 2016).

⁴⁷TVA officials we interviewed told us that TVA considers wildfires to be a rare occurrence, and TVA is focused on the most pressing and imminent risks.

⁴⁸In October 2019, we reported that there are several ways to account for uncertainty about the specific nature of future climate risks when making decisions about which projects to prioritize. This includes, for example, prioritizing projects that provide benefits under a wide range of future climate scenarios or prioritizing projects that can be modified if future climate conditions are different than expected. GAO, *Climate Resilience: A Strategic Investment Approach for High-Priority Projects Could Help Target Federal Resources*, [GAO-20-127](#) (Washington, D.C.: Oct. 23, 2019).

technological advances.⁴⁹ Despite these challenges, conducting a comprehensive inventory of assets and operations vulnerable to climate change would better position TVA to plan and implement appropriate actions to address climate change vulnerabilities. This is particularly important as these vulnerabilities become more acute and as new and better climate information becomes available, thereby reducing uncertainty.

According to DOE's *Guide for Climate Change Resilience Planning*, once utilities have identified assets and operations vulnerable to climate change, they should develop a resilience plan that includes a portfolio of resilience measures and an action plan that specifies which risks to address, as well as how and when to do so. TVA has not developed such a plan. Instead, according to a TVA official, TVA maintains a collection of resiliency documents. However, these documents do not include a portfolio of resilience measures or an action plan that specifies which risks to address, as well as how and when to do so. Once TVA develops a resilience plan, TVA should routinely reassess it by incorporating both information on implemented resilience actions, as well as updated information about climate change, resilience technologies and planning tools, and connected infrastructure vulnerabilities.⁵⁰ Developing a resilience plan that includes a portfolio of resilience measures could help TVA identify what options exist and determine whether mitigating certain risks is worth the investment. This, in turn, would help TVA fulfill its mission of providing reliable and affordable power to its customers.

⁴⁹TVA officials we interviewed told us that TVA participates in the Federal Geographic Data Committee—the lead entity for the development, implementation, and review of policies, practices, and standards related to geospatial data. This committee is currently developing a Climate Resilience Information System. The U.S. Global Change Research Program and the National Oceanic and Atmospheric Administration are taking the lead on this development. Federal Geographic Data Committee, *Advancing the Nation's Geospatial Capabilities to Promote Federal, State, Local, and Tribal Climate Planning and Resilience. A Report to the National Climate Task Force* (Reston, VA: October 2021).

⁵⁰Connected infrastructure can include fuel suppliers, telecommunications providers, and transmission operators, among others. According to DOE's *Guide for Climate Change Resilience Planning*, utilities should reassess their plans at least as frequently as major climate change assessment reports are produced by the Intergovernmental Panel on Climate Change—a United Nations body that assesses scientific and other aspects of climate change—or the U.S. Global Change Research Program that produces the U.S. National Climate Assessment every 4 years. U.S. Department of Energy, Office of Energy Policy and Systems Analysis, *Climate Change and the Electricity Sector*.

Conclusions

Climate change effects on TVA's operations could have significant economic and social consequences because TVA is the nation's largest public power provider, serving about 10 million customers. TVA's extensive service area—covering over 80,000 square miles—and extensive infrastructure—including hydropower plants; coal, natural gas, and oil-fired plants; nuclear power plants; and renewable energy sites—make TVA particularly vulnerable to the potential effects of climate change.

TVA has taken several steps to manage climate-related risks. However, TVA has not conducted an inventory of assets and operations vulnerable to climate change. According to DOE's *Guide for Climate Change Resilience Planning*, conducting an inventory of assets and operations vulnerable to climate change can help utilities more accurately identify relevant risks and the potential severity of disruptions or damages to infrastructure and operations. By conducting such an inventory, TVA could better plan and implement appropriate actions to address climate change vulnerabilities.

TVA has also not developed a resilience plan that identifies and prioritizes measures to address climate change vulnerabilities. According to DOE's *Guide for Climate Change Resilience Planning*, once utilities have identified assets and operations vulnerable to climate change, they should develop a resilience plan that includes a portfolio of resilience measures and an action plan that specifies which risks to address and how and when to do so. Developing such a plan could help TVA identify what options exist and determine whether mitigating certain risks are worth the investment. As we and others have reported, investing in resilience can reduce the need for more costly steps in the decades to come.

Further, establishing a plan to routinely reassess the resilience plan and incorporate information about implemented resilience actions, as well as updated information about climate change, resilience technologies and planning tools, and infrastructure vulnerabilities, would help TVA fulfill its mission of providing reliable and affordable power to its customers.

Recommendations for Executive Action

We are making the following three recommendations to TVA:

- The TVA Chief Executive Officer should direct TVA staff to conduct an inventory of assets and operations vulnerable to climate change that includes analyzing the likelihood and degree of damage or disruption from climate change and the likely consequences if specific climate effects were to occur. (Recommendation 1)
- Once TVA staff identifies vulnerable assets and operations, the TVA Chief Executive Officer should direct TVA staff to develop a resilience plan that identifies and prioritizes measures to address climate change vulnerabilities and that includes a portfolio of resilience measures and an action plan that specifies which risks to address and how and when to do so. (Recommendation 2)
- TVA's Chief Executive Officer should direct staff to establish a plan to routinely reassess the TVA resilience plan and incorporate updated information about implemented resilience actions, as well as updated information about climate change, resilience technologies and planning tools, and connected infrastructure vulnerabilities. (Recommendation 3)

Agency Comments and Our Evaluation

We provided a draft of this report to TVA for review and comment. We received written comments from TVA, which have been reprinted in Appendix I. TVA also provided technical comments, which we incorporated as appropriate.

In its written comments, TVA neither agreed nor disagreed with our three recommendations.

In response to our first recommendation that TVA conduct an inventory of assets and operations vulnerable to climate change, TVA stated that while the agency does not have one report or one "inventory" that documents all assets or operations, TVA continually evaluates climate-related risks to each area of its operations. However, TVA has not assessed the risks that climate change may pose to all major planning processes or assets. For example, TVA did not consider climate change in assessing the risks that flooding poses to substations. In its written

comments, TVA said that the agency had begun a corporate-level initiative this year to examine resilience holistically and potentially identify methods to monitor resiliency efforts across the enterprise. TVA also stated that TVA would review the best path forward to implementing an enterprise inventory. We continue to believe that our recommendation that TVA conduct an inventory of assets and operations vulnerable to climate change is valid and will help TVA better plan and implement appropriate actions to address climate change vulnerabilities.

In response to our second recommendation that TVA develop a resilience plan that identifies and prioritizes measures to address climate change vulnerabilities, TVA stated that it issues and regularly updates a climate adaptation report. In addition, in its written comments, TVA stated that TVA's Enterprise Risk Management business unit provides TVA with a comprehensive risk perspective to identify and manage risks, capitalize on opportunities, and improve risk management behaviors. While TVA's climate adaptation reports highlight certain risks and resilience measures, the reports do not outline a portfolio of resilience measures or identify an action plan that specifies which risks to address, as well as how and when to do so. We continue to believe that our recommendation would help TVA identify what options exist to determine whether mitigating certain risks are worth the investment.

In response to our third recommendation that TVA establish a plan to routinely reassess its climate resilience plan and incorporate updated climate information, TVA stated that it is already doing this through its climate adaptation reports and periodic updates that are submitted to the Office of Management Budget and the Council on Environmental Quality as required by executive order since 2011. In addition, TVA stated that the climate risks that have been identified by individual business units are reviewed as part of TVA's Enterprise Risk Management's annual risk assessment process. In our report, we acknowledged that TVA routinely updates its climate adaptation reports and includes updated information about climate change in doing so. However, as stated in our report, TVA's climate adaptation reports do not identify and prioritize resilience measures, or include a plan that specifies which risks to address and how and when to do so. Therefore, while TVA has a mechanism to routinely update its climate adaptation reports, the reports do not include information that could help TVA determine whether mitigating certain climate risks are worth the investment.

Lastly, TVA stated that our recommendations should be directed to TVA's Chief Executive Officer. We revised our recommendations accordingly.

As agreed with your offices, unless you publically announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies of this report to the appropriate congressional committees, TVA's Chief Executive Officer and Board of Directors, and other interested parties. In addition, the report will be available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix II.

A handwritten signature in black ink that reads "Frank Rusco". The signature is written in a cursive style and extends across the width of the page with a long horizontal stroke at the end.

Frank Rusco
Director, Natural Resources and Environment

Appendix I: Comments from the Tennessee Valley Authority

**Appendix I: Comments from the Tennessee
Valley Authority**



1101 Market Street, Chattanooga, Tennessee 37402

December 8, 2022

Mr. Franklin W. Rusco
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street Northwest
Washington, DC 20548

Dear Director Rusco:

**GAO DRAFT REPORT: ADDITIONAL STEPS ARE NEEDED TO BETTER MANAGE
CLIMATE-RELATED RISKS**

Thank you for the opportunity to provide Tennessee Valley Authority's comments on the draft report of TVA's management of climate-related risks. TVA appreciates the U.S. Government Accountability Office's (GAO) collaboration and professionalism in conducting its review.

Next year, TVA will commemorate its 90th anniversary serving the great people of the Tennessee Valley. TVA has a long and storied history managing risks to the Valley and its residents. In fact, one of TVA's primary objectives when it was established nearly a century ago, was to create an engineered system of dams and reservoirs to reduce flooding in the Valley and the risks associated with the flooding.

TVA is both fundamentally and operationally focused on the potential for impacts to its system due to climate-related risks. We appreciate the GAO's recognition that TVA has taken several steps to "manage climate-related risks [including identifying] risks, such as flooding and drought in its 2021 Climate Action Adaptation Plan, and [has] implemented several resilience measures to address specific risks."

The GAO's recommendations to TVA for improvement are appreciated. It is important, however, to note as it relates to these recommendations, that TVA utilizes a constant, ongoing risk process to ensure that each TVA major business unit identifies significant climate change risks on an ongoing basis. Significant climate change risks are those identified risks with the potential to substantially impair, obstruct, or prevent the success of agency mission activities, both in the near-term and particularly in the long-term, using the best available science and information.

Risks, including climate-change risks, are identified through major planning processes such as annual strategic planning, annual risk review and enterprise risk management (ERM), transmission reliability and resiliency planning, emergency exercises, cybersecurity efforts, and partnerships with other federal entities like National Weather Service, U.S. Army Corps of Engineers, Division of Homeland Security, and the Federal Emergency Management Agency.

The GAO report first makes a recommendation to "conduct an inventory of assets and operations vulnerable to climate change that includes analyzing the likelihood and degree of

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Valley Authority**

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damage or disruption from climate change, and the likely consequences if specific climate effects were to occur.” While TVA does not have one report or one “inventory” that documents all assets or operations, we continually evaluate climate-related risk to each area of operations (and those risks can be quite different from one business unit to the next).

TVA has worked to advance best practice research and tools toward a comprehensive asset-specific inventory risk assessment with Oak Ridge National Labs, Electric Power Research Institute (EPRI), Department of Energy (DOE) and others. In addition, a corporate-level initiative began this year to examine resilience holistically and potentially identify methods to monitor resiliency efforts across the enterprise. TVA will continue efforts to ensure assessments can be completed in an ongoing and operationally informative manner and will review with the TVA resiliency team the best path forward to implementing an enterprise inventory.

The report’s second recommendation is to “develop a resilience plan that identifies and prioritizes measures to address climate change vulnerabilities and includes a portfolio of resilience measure and an action plan that specifies which risks to address and how and when to do so.” As the GAO is aware and as recognized in the draft report, TVA issues a Climate Adaptation report and updates it regularly.

In addition, Enterprise Risk Management is a strategic business function that provides TVA with a comprehensive risk perspective to identify and manage risks, capitalize on opportunities, and improve risk management behaviors more effectively. The Chief Risk Officer heads TVA’s Enterprise Risk Management business unit, with responsibilities that include establishing enterprise risk management policies and guidelines as well as performing frequent risk assessments across all TVA business units. At TVA, we work around-the-clock to monitor and protect our assets and the people of the Valley. We collaborate with other government agencies as well as industry groups and neighboring utilities.

Finally, the report recommends to “routinely reassess the TVA resilience plan and incorporate updated information about implemented resilience actions as well as updated information about climate change, resilience technologies and planning tools, and connected infrastructure vulnerabilities.” This is being done already through TVA’s Climate Adaptation reports and periodic updates, which are submitted to the Office of Management Budget and the Council on Environmental Quality as required by executive order since 2011. TVA’s Climate Adaptation Statement dictates when those updates occur. In addition, climate risks that have been identified by individual business units are reviewed annually as part of TVA’s Enterprise Risk Management’s annual risk assessment process. This helps to ensure identified risks and risk mitigation actions are properly managed based on a probability and impact assessment.

TVA is unique among federal agencies in that it files U.S. Securities and Exchange Commission (SEC) reports as well as Federal Sustainability reports under E.O. 14057. TVA has been carefully observing emerging actions under each best practice to ensure clear reporting under both.

We suggest that any GAO recommendations be worded for the TVA Chief Executive Officer (CEO) to direct TVA staff. While the TVA Board establishes the broad strategies, goals, and polices of TVA, the CEO undertakes the day-to-day operations of the company including TVA’s risk and resiliency programs. This structure was put into place by Congress when the TVA Act

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was amended. The CEO recommends action to the TVA Board of Directors. Examples include TVA's Environmental Policy, Biodiversity Policy, and strategic planning reports. (See [fy-2022---2026-strategic-plan5be28920-60e0-4839-b86b-608794f85519.pdf \(azureedge.net\)](#).)

Thank you again for the opportunity to review this report and provide these comments. TVA appreciates GAO's recommendations on these important matters.

Sincerely,



Rebecca C. Tolene
Chief Sustainability Officer

Accessible Text for Appendix I: Comments from the Tennessee Valley Authority

December 8, 2022

Mr. Franklin W. Rusco
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street Northwest
Washington, DC 20548

Dear Director Rusco:

GAO DRAFT REPORT: ADDITIONAL STEPS ARE NEEDED TO BETTER MANAGE CLIMATE-RELATED RISKS

Thank you for the opportunity to provide Tennessee Valley Authority's comments on the draft report of TVA's management of climate-related risks. TVA appreciates the U.S. Government Accountability Office's (GAO) collaboration and professionalism in conducting its review.

Next year, TVA will commemorate its 90th anniversary serving the great people of the Tennessee Valley. TVA has a long and storied history managing risks to the Valley and its residents. In fact, one of TVA's primary objectives when it was established nearly a century ago, was to create an engineered system of dams and reservoirs to reduce flooding in the Valley and the risks associated with the flooding.

TVA is both fundamentally and operationally focused on the potential for impacts to its system due to climate-related risks. We appreciate the GAO's recognition that TVA has taken several steps to "manage climate-related risks [including identifying] risks, such as flooding and drought in its 2021 Climate Action Adaptation Plan, and [has] implemented several resilience measures to address specific risks."

The GAO's recommendations to TVA for improvement are appreciated. It is important, however, to note as it relates to these recommendations, that TVA utilizes a constant, ongoing risk process to ensure that each TVA major business unit identifies significant climate change risks on an ongoing basis. Significant climate change risks are those identified risks with the potential to substantially impair,

obstruct, or prevent the success of agency mission activities, both in the near-term and particularly in the long-term, using the best available science and information.

Risks, including climate-change risks, are identified through major planning processes such as annual strategic planning, annual risk review and enterprise risk management (ERM), transmission reliability and resiliency planning, emergency exercises, cybersecurity efforts, and partnerships with other federal entities like National Weather Service, U.S. Army Corps of Engineers, Division of Homeland Security, and the Federal Emergency Management Agency.

The GAO report first makes a recommendation to “conduct an inventory of assets and operations vulnerable to climate change that includes analyzing the likelihood and degree of damage or disruption from climate change, and the likely consequences if specific climate effects were to occur.” While TVA does not have one report or one “inventory” that documents all assets or operations, we continually evaluate climate-related risk to each area of operations (and those risks can be quite different from one business unit to the next).

TVA has worked to advance best practice research and tools toward a comprehensive asset- specific inventory risk assessment with Oak Ridge National Labs, Electric Power Research Institute (EPRI), Department of Energy (DOE) and others. In addition, a corporate-level initiative began this year to examine resilience holistically and potentially identify methods to monitor resiliency efforts across the enterprise. TVA will continue efforts to ensure assessments can be completed in an ongoing and operationally informative manner and will review with the TVA resiliency team the best path forward to implementing an enterprise inventory.

The report’s second recommendation is to “develop a resilience plan that identifies and prioritizes measures to address climate change vulnerabilities and includes a portfolio of resilience measure and an action plan that specifies which risks to address and how and when to do so.” As the GAO is aware and as recognized in the draft report, TVA issues a Climate Adaptation report and updates it regularly.

In addition, Enterprise Risk Management is a strategic business function that provides TVA with a comprehensive risk perspective to identify and manage risks, capitalize on opportunities, and improve risk management behaviors more effectively. The Chief Risk Officer heads TVA’s Enterprise Risk Management business unit, with responsibilities that include establishing enterprise risk management policies and guidelines as well as performing frequent risk assessments across all TVA business units. At TVA, we work around-the-clock to monitor and protect our assets and the people of the Valley. We collaborate with other government agencies as well as industry groups and neighboring utilities.

Finally, the report recommends to “routinely reassess the TVA resilience plan and incorporate updated information about implemented resilience actions as well as updated information about climate change, resilience technologies and planning tools, and connected infrastructure vulnerabilities.” This is being done already through TVA’s Climate Adaptation reports and periodic updates, which are submitted to the Office of Management Budget and the Council on Environmental Quality as required by executive order since 2011. TVA’s Climate Adaptation Statement dictates when those updates occur. In addition, climate risks that have been identified by individual business units are reviewed annually as part of TVA’s Enterprise Risk Management’s annual risk assessment process. This helps to ensure identified risks and risk mitigation actions are properly managed based on a probability and impact assessment.

TVA is unique among federal agencies in that it files U.S. Securities and Exchange Commission (SEC) reports as well as Federal Sustainability reports under E.O. 14057. TVA has been carefully observing emerging actions under each best practice to ensure clear reporting under both.

We suggest that any GAO recommendations be worded for the TVA Chief Executive Officer (CEO) to direct TVA staff. While the TVA Board establishes the broad strategies, goals, and policies of TVA, the CEO undertakes the day-to-day operations of the company including TVA’s risk and resiliency programs. This structure was put into place by Congress when the TVA Act was amended. The CEO recommends action to the TVA Board of Directors. Examples include TVA’s Environmental Policy, Biodiversity Policy, and strategic planning reports. (See [fy-2022--- 2026-strategic-plan5be28920-60e0-4839-b86b-608794f85519.pdf](#) (azureedge.net).)

Thank you again for the opportunity to review this report and provide these comments. TVA appreciates GAO’s recommendations on these important matters.

Sincerely,

Rebecca C. Tolene
Chief Sustainability Officer

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, (202) 512-3841 or ruscof@gao.gov

Staff Acknowledgments

In addition to the contact named above, the following individuals made key contributions to this report: Janice Ceperich (Assistant Director), Celia Rosario Mendive (Analyst in Charge), Will Horowitz, and Anne Kolesnikoff. Also contributing to this report were Ben Atwater, Alicia Puente Cackley, Miriam Carroll Fenton, Nirmal Chaudhary, John Delicath, Philip Farah, William Gerard, Cindy Gilbert, Paige Gilbreath, Lijia Guo, Susan Irving, Rona Mendelsohn, Dan C. Royer, and Joe Thompson.

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