

SEE ENERGY BRIEF

Monthly Analysis

High-Temperature Impacts on Energy
Infrastructure and the Need to Maintain
System Operation



Introduction

High temperatures are emerging as one of the most significant threats to the reliability, efficiency, and resilience of modern energy infrastructure. As global temperatures continue to rise and extreme heat events become more frequent and prolonged, energy systems are increasingly exposed to operational stress and physical degradation. High temperatures reduce the efficiency of electricity generation, transmission, and distribution assets while simultaneously increasing electricity demand due to the widespread use of cooling technologies. These combined effects place considerable strain on power systems, increasing the risk of equipment failures, service interruptions, and higher operating costs.

The impact of extreme heat extends across the entire energy value chain, affecting thermal and renewable power generation, electrical grids, fuel transportation, and energy storage systems. Thermal power plants often experience reduced cooling efficiency and lower generation capacity, while transmission lines and transformers suffer from overheating, increased electrical resistance, and accelerated material aging. Renewable energy technologies are also vulnerable, as elevated temperatures can reduce the performance of photovoltaic panels and alter the availability of energy resources. Understanding the vulnerabilities of energy infrastructure to high-temperature conditions is therefore essential for developing effective adaptation strategies, improving system resilience, and ensuring a secure and sustainable energy supply under a changing climate.

Impacts on Energy Infrastructure Components

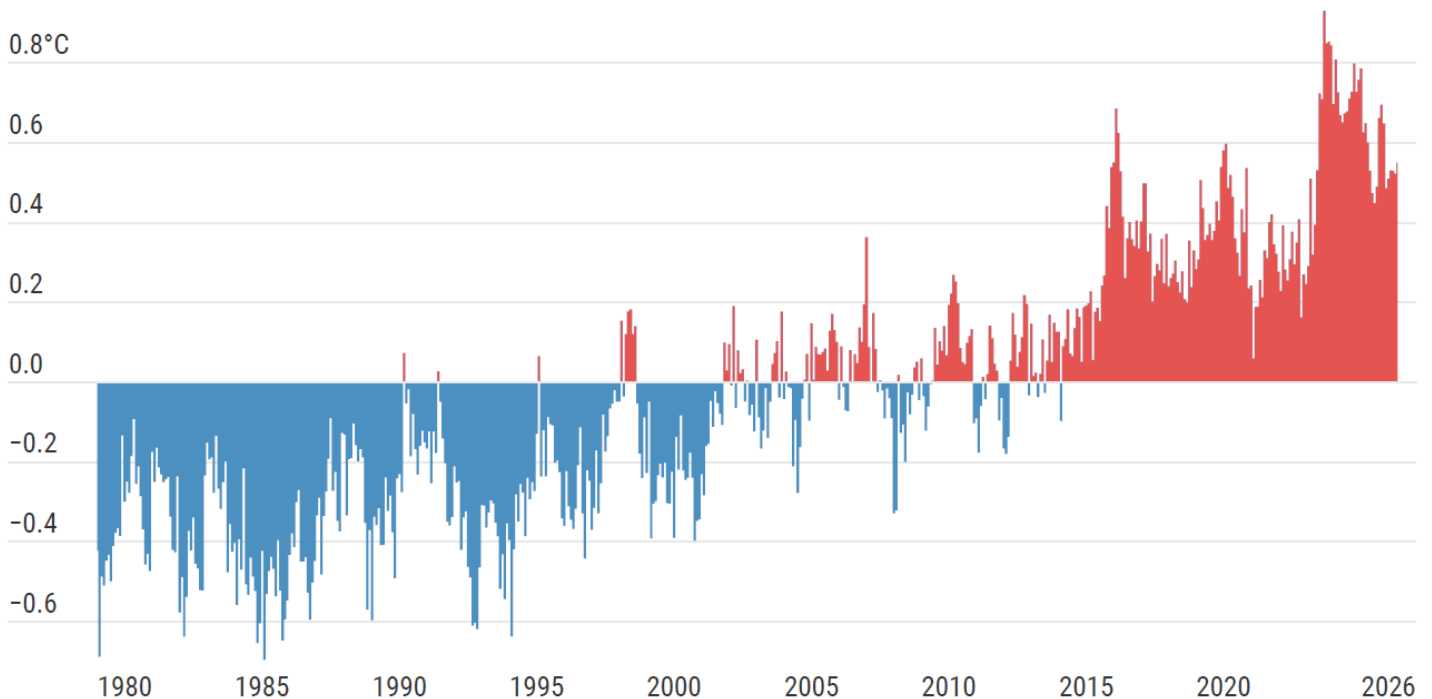
High temperatures have significantly influenced the performance, reliability, and operational lifespan of energy infrastructure. As heatwaves become more frequent and intense, energy systems are increasingly subjected to environmental conditions that surpass the limits for which they were originally designed. Elevated ambient temperatures directly influence the physical properties of electrical and mechanical equipment, reducing operational efficiency while accelerating material degradation. Consequently, utilities and infrastructure operators face increasing maintenance costs, reduced system reliability, and a greater likelihood of service interruptions. [\(1\)](#)

Electricity generation facilities are among the most vulnerable assets. Conventional thermal power plants, including coal, natural gas, and nuclear facilities, depend heavily on water for cooling. During periods of extreme heat, higher intake water temperatures reduce cooling efficiency, limiting the plant's ability to reject waste heat and often forcing operators to reduce power output or temporarily suspend operations to comply with environmental regulations. Hydroelectric power stations may also experience reduced generation capacity due to lower reservoir levels and decreased river flows associated with prolonged hot

and dry conditions.

It is becoming clearer by the day that renewable energy systems are not immune to high-temperature impacts. Although solar irradiance generally increases during hot weather, photovoltaic (PV) modules become less efficient as cell temperatures rise. Every degree above the standard testing temperature reduces electrical conversion efficiency, resulting in lower power output. Wind energy production can also decline during heatwaves because hot air has lower density, reducing the aerodynamic efficiency of wind turbines despite favorable wind speeds. (2)

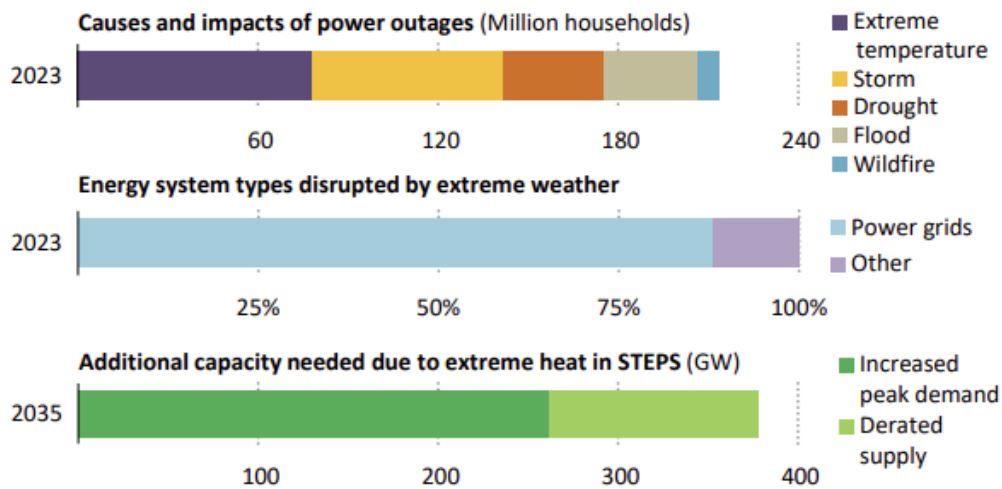
Figure 1: Global Surface Air Temperature, January 1979-May 2026



Source: Copernicus (3)

Extreme weather events are increasingly affecting the reliability and resilience of energy systems, leading to more frequent service disruptions and higher costs for energy providers and consumers. Damage to energy infrastructure, increased maintenance requirements, and rising insurance expenses contribute to higher electricity delivery costs. Based on recent IEA data (4), nearly 300 disruptions to critical energy infrastructure were recorded in 2023. Transmission and distribution networks were the most affected components, with damage to power lines accounting for approximately 85% of all reported incidents. Additional impacts include reduced hydropower generation caused by drought-induced water shortages, precautionary power shutoffs to reduce wildfire risks, and damage to solar PV installations from severe hailstorms. As economies become increasingly dependent on electrification and digital technologies, the economic consequences of power outages continue to grow, highlighting the need for more resilient energy infrastructure.

Figure 2: Impacts of Extreme Weather Events in 2023 and Additional Power Capacity Needed From Extreme Heat in the STEPS, 2035



Source: IEA World Energy Outlook 2025

Recent observations indicate that several types of extreme weather events are occurring with greater frequency and severity, with extreme heat representing one of the most significant challenges for energy systems. Rising ambient temperatures substantially increase electricity demand as households, commercial buildings, and industries rely more heavily on air conditioning to maintain indoor comfort. This growing dependence on cooling systems primarily affects peak electricity demand, placing considerable stress on power networks. Future projections suggest that increased adoption of air conditioning, driven by economic growth and rising living standards, will significantly raise peak electricity demand over the coming decades. Long-term increases in average temperatures and more frequent heatwaves are expected to further intensify these demand peaks, particularly during exceptionally hot years when electricity consumption can surge well beyond historical levels.

The effects of extreme heat are further intensified by its impact on electricity supply and power infrastructure. Prolonged droughts can reduce hydropower generation by limiting water availability, while extended periods of low wind speeds may decrease electricity production from wind farms. Conventional thermal power plants are also vulnerable, as elevated temperatures reduce cooling efficiency, increase mechanical stress on equipment, and lower overall generation efficiency. When these supply-side constraints occur simultaneously with sharply rising electricity demand during heatwaves, the reliability of power systems is significantly challenged. The combined effects of reduced generation capacity and increased peak demand narrow available operating reserves, emphasizing the importance of incorporating future high-temperature scenarios into long-term energy system planning, capacity adequacy assessments, and climate resilience strategies.

As energy storage technologies become more common, especially batteries, it is important to study how high temperatures are impacting the operation of these systems. Energy storage technologies generally experience performance degradation under sustained high temperatures. Lithium-ion batteries, widely deployed in grid-scale and distributed energy storage applications, exhibit accelerated chemical aging, reduced cycle life, and an increased likelihood of thermal runaway when operating outside recommended temperature ranges. These limitations reduce storage reliability precisely when electricity demand peaks during extreme heat events.

Moreover, high temperatures can significantly affect oil and gas infrastructure by reducing the efficiency and reliability of production, processing, transportation, and storage facilities, while accelerating the deterioration of critical equipment and materials. Prolonged heatwaves also increase operational risks by causing thermal expansion in pipelines, placing additional stress on compressors and cooling systems, and elevating the likelihood of equipment failures, maintenance requirements, and supply disruptions.

Operational Challenges and Adaptation Strategies

The impacts of high temperatures extend beyond individual infrastructure components and affect the overall operation and resilience of energy systems. Heatwaves typically coincide with substantial increases in electricity demand due to the widespread use of air conditioning and cooling technologies in residential, commercial, and industrial sectors. This simultaneous increase in demand and reduction in supply capacity creates a critical imbalance that places exceptional stress on power grids.

Peak electricity demand during extreme heat events often requires utilities to operate aging power generation plants, activate reserve capacity, or import electricity from neighboring regions. However, these options may be limited when large geographical areas experience concurrent heatwaves, reducing regional electricity availability. Grid operators must therefore carefully balance supply and demand while maintaining system frequency and voltage stability. Failure to manage these conditions effectively can lead to voltage reductions, controlled load shedding, or widespread blackouts.

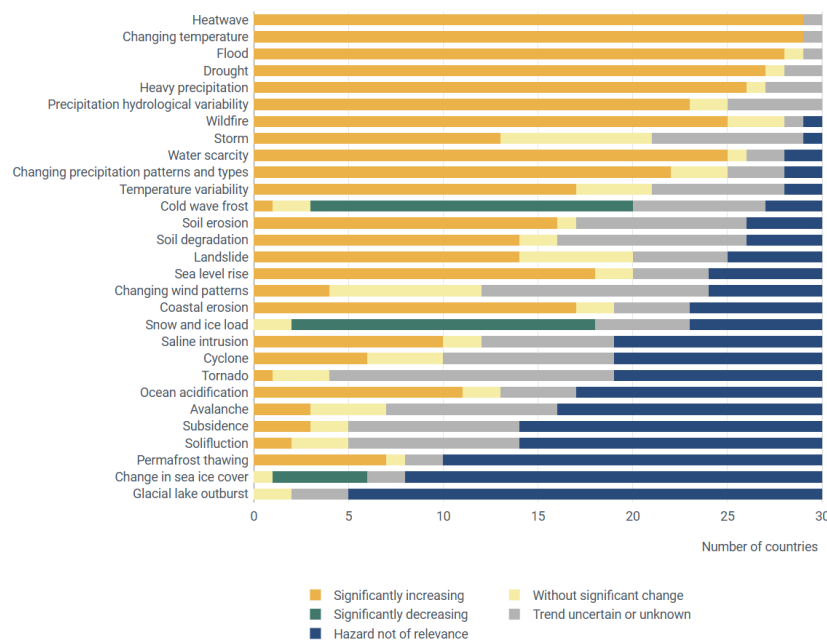
In addition, we have the experience of Greece and Bulgaria, where the Transmission System Operators (TSOs) are obliged to ditch substantial amounts of RES produced electricity in order to maintain the balance of the system. Infrastructure resilience is further challenged by the cumulative effects of repeated heat exposure. Materials such as polymers, insulation systems, lubricants, and electronic components degrade more rapidly under elevated temperatures, increasing maintenance requirements and reducing asset reliability. Prolonged exposure also increases the probability of simultaneous equipment failures, complicating restoration efforts and extending outage durations.

To address these challenges, energy utilities are increasingly implementing adaptation measures designed to improve system resilience. Infrastructure modernization includes replacing aging conductors with high-temperature, low-sag transmission lines, installing advanced transformer cooling systems, and deploying temperature-resistant materials capable of maintaining performance under extreme environmental conditions. Smart grid technologies provide real-time monitoring of equipment temperatures, enabling predictive maintenance and dynamic power flow management before failures occur.

Moreover, high temperatures create significant operational challenges for oil and gas infrastructure by reducing the efficiency of processing facilities, increasing thermal stress on pipelines, compressors, pumps, and storage systems, and accelerating equipment degradation, which can lead to higher maintenance requirements, operational downtime, and supply disruptions. To address these challenges, operators are adopting adaptation strategies such as upgrading cooling systems, implementing continuous condition monitoring and predictive maintenance, using heat-resistant materials and coatings, enhancing pipeline integrity management, and incorporating climate risk assessments into infrastructure design and operational planning to improve long-term resilience under increasingly extreme temperature conditions.

Diversification of electricity generation also enhances resilience. Increasing the penetration of renewable energy sources, supported by advanced battery storage systems and flexible demand-response programs, reduces dependence on centralized thermal generation that is vulnerable to cooling constraints. Distributed energy resources, including rooftop solar systems and microgrids, improve local energy security and reduce transmission congestion during periods of peak demand. (5)

Figure 3: Key Future Hazards Reported in 2025



Source: European Environment Agency (6)

Long-term adaptation requires integrating climate projections into infrastructure planning, engineering standards, and investment decisions. Designing energy assets for future temperature extremes rather than historical climate conditions will improve operational reliability and reduce lifecycle costs. Furthermore, coordinated policies that promote energy efficiency, sustainable cooling technologies, and climate-resilient infrastructure investment will play a critical role in ensuring that energy systems remain secure, efficient, and capable of supporting economic development under increasingly warmer climatic conditions.

Discussion

The growing frequency, intensity, and duration of high-temperature events have exposed significant vulnerabilities across the energy sector, highlighting the strong interdependence between climate conditions and energy system performance. Extreme heat affects both the supply and demand sides of the energy system by reducing the operational efficiency of power generation and transmission infrastructure while simultaneously increasing electricity consumption for cooling. Thermal power plants experience reduced cooling efficiency and lower generation capacity, transmission lines suffer from increased electrical resistance and conductor sag, and transformers and other electrical equipment are subjected to accelerated aging. At the same time, prolonged heatwaves substantially increase peak electricity demand, placing additional stress on already constrained power systems. These combined impacts increase the likelihood of equipment failures, supply interruptions, and higher operational costs, demonstrating that high temperatures represent not only an environmental challenge but also a critical risk to energy security and economic stability.

Addressing these challenges requires a comprehensive approach that integrates climate resilience into energy planning, infrastructure design, and system operation. Modernization of electricity networks through the deployment of advanced monitoring technologies, high-temperature-resistant materials, smart grid applications, and distributed energy resources can improve the ability of power systems to withstand extreme heat events. Furthermore, incorporating climate projections into long-term infrastructure planning will enable utilities and policymakers to design assets that remain reliable under future climate conditions rather than historical weather patterns. Investments in energy efficiency, demand-side management, renewable energy integration, and energy storage technologies can further reduce system vulnerability by limiting peak demand and increasing operational flexibility. Collectively, these adaptation measures will strengthen the resilience of energy infrastructure, ensuring a secure, reliable, and sustainable energy supply in an increasingly warming climate.

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IENE SEE ENERGY BRIEF MONTHLY ANALYSIS - Issue No. 466 – ISSN:179-9163

Contributed by IENE’s Research Team

Monthly Analysis is published by the INSTITUTE OF ENERGY FOR SOUTH-EAST EUROPE (IENE)

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