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National Trust

Section 12: Utilities and Services

Power Generation

Climate change vulnerability: Low

Power generation – introduction

Electricity powers everything we do. From lighting and heating our historic places, and preserving rare collections to keeping cafes running, a dependable electricity supply underpins the day-to-day running of the National Trust. Power infrastructure, especially where it is connected with on-site renewables, is critical to achieving our environmental goals and net zero ambitions.

This chapter of the National Trust's Climate Change Adaptation Guidance for Utilities and Services focuses specifically on power generation infrastructure. It is designed to help property teams, consultants and project managers to understand how climate hazards may impact both conventional and renewable energy systems across our estate, and what options to adapt exist. It outlines the vulnerabilities, potential impacts, thresholds for change and practical responses applicable to electrical power whether it is supplied via the national grid, generated on site or stored locally. As we decarbonise our energy use and shift to more distributed, renewables-based systems, this guidance supports a proactive approach to ensuring a resilient, safe and sustainable energy supply for our people, places and collections.

Image credit:
Wimpole solar PV (©National Trust Images/James Dobson)

Power generation – why does it matter?

Electricity keeps the National Trust running. It does this quietly and constantly. It lights and heats our historic places, safeguards rare collections, and powers the systems that run our cafes, tills, car chargers and digital infrastructure. It brings winter light trails to life and ensures our places are welcoming, comfortable and safe all year round.

The shift from fossil fuels to renewables brings both benefits and new risks to manage. On-site generators, solar photovoltaic (PV) arrays, hydroelectric schemes, battery systems and private wire networks increase energy independence and carbon savings, but they also introduce new asset types that must be managed and resilient to climate hazards.

Failure of power supply can compromise conservation environments, digital infrastructure, and accessibility – especially for sites relying on electrically powered mobility aids – visitor management systems and environmental controls. In our larger properties, a loss of power affects income, reputation and the safety of people and collections.

Our aging power systems were never designed for climate extremes. Many of the traditional electricity supply networks rely on overhead lines, which are prone to storm damage, or low-lying substations that are vulnerable to flooding. Off-grid sites that rely on generators face difficulties with fuel delivery as a result of changing weather or market volatility, which reduces supply.

Renewable energy systems are increasingly deployed across National Trust sites, but, they too are not immune to climate-related risks. For example, equipment can fail under heat stress – especially during prolonged hot weather – and moisture ingress – caused by driving rain, flooding or high humidity – which can corrode connectors and degrade insulation.

Structures must also be designed for increasing flood risk and wind loading, particularly at exposed or coastal sites. As storm intensity and wind gust variability is predicted to rise, PV mounting systems, for example, need to be engineered for uplift, fatigue and lateral force resistance. The design of future systems must account for these climatic pressures from the outset to ensure that they remain robust, adaptive and low-maintenance throughout their lifecycle.

Image credit:
Solar PV installation (©National Trust Images/Linda Goudie)

Power generation – hazards, impacts and options

Hazard	Impacts	Options
Extreme heat	Overheating of panels reduces output. Overheating of associated components, such as inverters, batteries, transformers and switchgear, may lead to fire risk and/or accelerated wear of components.	Use passive/active cooling, fire-retardant mounts, buffer zones, heat-rated materials and ventilate installation locations. Avoid siting sensitive equipment in areas prone to heat build-up, such as enclosed loft spaces or south-facing facades, and prioritise high-quality, tested materials suited to elevated temperatures.
Increased frequency and/or intensity of storms or high winds	More frequent and intense storms can cause structural damage, water ingress, electrical faults and accelerated wear across power systems. Wind uplift, lightning strikes and driving rain increase the risk of outages, equipment failure and loss of generation.	Use wind-rated and vibration-resistant fixings for inverters, generating equipment and enclosures, with anchoring systems designed for cumulative loading over time. Reinforce mounting frames. Relocate or shield vulnerable equipment from prevailing winds, where feasible. Fit surge protection to safeguard against lightning strikes. Specify corrosion-resistant materials in coastal or high-rainfall zones and build in regular inspection and maintenance cycles to address accelerated weathering and mechanical stress.
Flooding (fluvial, pluvial and groundwater)	Flooding causes water ingress and corrosion that affects substations, switchgear, inverters, cabling and generating equipment. More intense rainfall events and shifting flow regimes, especially in upland and riverine areas, are accelerating natural landscape changes. These include bank erosion, siltation and changes to riverbed profiles and sediment movement.	Elevate or relocate assets. Use ingress protection (IP) rated enclosures, seal ducts and drainage. Avoid flood-prone siting and monitor moisture. To manage increased erosion and geomorphological change, install debris and sediment traps, and diversion barriers upstream of intakes to reduce blockage risk. Use engineered bank reinforcement where appropriate, such as riprap or natural stabilisation techniques like willow spiling, to help protect vulnerable riverbanks from collapse or scouring. Survey intake structures periodically and reprofile to reflect changes in riverbed conditions; where feasible, design or retrofit to tolerate shifting sediment loads. Establish routine geomorphological monitoring to enable early intervention before problems escalate.
Drought	Drought can cause soil shrinkage, cable damage, risk of overheating and fire hazards. Reduced river flows cause low power production in hydropower, which results in less revenue generation.	Use flexible/deep cabling, clear vegetation, adapt hydro abstraction (for example, engineering modifications to intakes), ventilate enclosures and inspect ground for soil movement.
Humidity and moisture	Condensation and damp can cause corrosion in switchgear, inverters and battery enclosures; also insulation breakdown and electrical faults.	Use moisture-sealed enclosures, anti-condensation heaters, breathable housing designs and humidity monitoring. Inspect regularly.

Power generation – options and thresholds

Climate change affects the performance and resilience of both conventional and on-site renewable power systems.

Higher temperatures, stronger storms and wetter or drier conditions can accelerate equipment failure, which increases maintenance needs and poses safety risks. While some adaptations can be incorporated at design stage, many sites will need to respond over time as thresholds are reached.

Power system adaptations are often site specific and should be developed with input from electrical and renewable energy specialists, conservation teams and estate managers. For historic buildings or remote landscapes, options must balance resilience, access, aesthetics and significance.

Options for adaptation include:

Ventilation and cooling – introduce passive or active cooling for inverters, switchgear and battery systems, particularly in enclosed plant rooms or roof spaces.

Raise or relocate installations – move substations, switchgear or enclosures above flood level or away from exposed slopes or ridgelines.

Moisture and corrosion protection – use IP-rated equipment, sealed cable ducts and anti-corrosion treatments for coastal or high-humidity locations.

Flexible or deep cable routing – accommodate soil shrinkage or freeze-thaw in underground cabling and protect joint integrity.

Vegetation and fire-risk management – maintain clearance around power infrastructure to reduce the likelihood of fire in drought-prone sites.

Hybrid and storage solutions – add battery systems or low-carbon backup generators to mitigate outages or curtailment risk during extreme weather.

Monitoring and control – integrate remote diagnostics, fault alerts and environmental sensors (heat, humidity and water ingress) into infrastructure planning.

Thresholds & tipping points

What triggers a change in design, investment or maintenance approach?

- Frequency of electrical faults, trips or outages exceed acceptable operational limits.
- Overheating, flooding or storm damage leads to repeated component failure.
- Equipment inspection reveals accelerated corrosion or loss of integrity.
- Battery performance degrades under high heat or repeated cycling.
- Maintenance interventions become disproportionately frequent, costly or unsafe.
- Risk to significance (for example, fire near historic structures or cable routing through sensitive archaeology) outweigh current system benefits.
- Changes in local climate projections render existing design inadequate.

Image credits:

Inverters and solar panels (©National Trust Images/James Dobson)

Power generation – worked pathway example

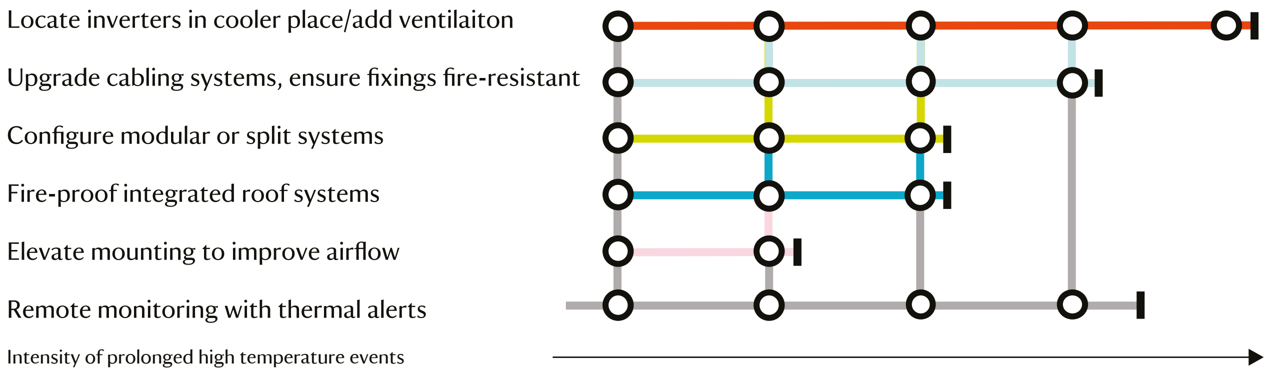
This application of pathways and thresholds to a hypothetical site shows how and when you might wish to make changes to your adaptive response as climate hazards evolve.

Dynamic Adaptive Policy Pathways (DAPP)[1] is a decision-making approach used in climate adaptation planning to manage long-term uncertainty. Rather than relying on a single fixed strategy, DAPP maps out a sequence of possible actions and decision points over time, based on how future conditions unfold. It allows organisations like the National Trust to make low-regret investments, while keeping future options open and identifying clear thresholds for when changes in strategy are needed.

Why DAPP is relevant to power generation projects

Power infrastructure is increasingly sensitive to climate-related risks, but also to other factors such as technological change, policy shifts and landscape sensitivities. Systems such as solar PV, batteries, substations, inverters and cabling are vulnerable to extreme heat, moisture, flooding, wind loading and fire risk. In the context of historic sites, these systems must also respect setting, fabric and visitor experience. DAPP provides a framework for balancing performance, resilience and conservation.

The options listed previously must not be selected in isolation from the unique characteristics, significance, vulnerabilities and land use of your specific site, and this may mean that different adaptive pathways apply in each specific context. The worked example below is based on a typical roof mounted solar PV system, owned by the National Trust, and is a hypothetical example demonstrating potential measures and thresholds rather than an actual dynamic adaptive policy pathway. These assets are already experiencing issues with increased wind loading and increases in rainfall affecting the roof structures. The pathway below is an example of assessing the options to ensure solar PV remains a viable option on buildings that are increasingly subject to extreme temperature conditions. To realise any options in practice, natural environment, sustainability and access considerations would also need to be taken into account.



The specific trigger points are partially dependent on permissions from the planning authorities, Historic England/Cadw and other demands on local resources. This pathway chart shows a set of adaptive options for managing the impact of increasing high-temperature events on rooftop power systems. Actions are sequenced over time and triggered by observed thresholds, such as inverter performance issues, battery overheating or fire risk. Options earlier in the chart represent low-regret measures, while later stage responses may be more disruptive or require planning approval. See the Introduction to Climate Change Adaptation for further information on Dynamic Adaptive Policy Pathways and how to choose pathways from the range of options.

[1] Dynamic Adaptive Policy Pathways approach (Haasnoot, Kwakkel, Walker & Ter Maat, 2013)

Case studies, signposting and references

Orford Ness is off-grid and powered by solar and diesel generation. Exposed to the elements on the eastern coast of England, the island is subject to rising sea levels and inundation, which cause an increased risk of flooding.

On the remote, ecologically significant shingle spit of Orford Ness in Suffolk, the National Trust has delivered a pioneering off-grid renewable energy system. This system exemplifies how historic landscapes can adapt to a changing climate while reducing reliance on fossil fuels. Orford Ness lost its grid connection in 2013 following storm damage to ageing Cold War-era infrastructure. The site, a nationally designated nature reserve and former military testing ground, had been reliant on diesel generators but this system was inefficient and risked polluting surrounding water due to the regular ferry deliveries of oil across the River Ore. Faced with rising fuel costs, operational risk from logistics and carbon reduction targets, the National Trust sought a flexible, flood-resilient solution that was rooted in renewable energy.

System design

The resulting system comprises a 30kW solar PV array, a 100kWh lithium-ion battery storage system and a trailer-mounted 45kVA backup generator, which are all coordinated by an intelligent power management system. Designed and installed by Bouygues Energies & Services, the system is entirely off-grid and transportable when needed, which is critical in a landscape prone to flooding and erosion.

While the PV array is ballast-mounted to avoid disturbance to ground archaeology and wildlife, the PV can be raised to avoid flood levels. The battery and generator can be relocated at short notice, while preserving their functions in the face of extreme weather or changing land conditions.

A major strength of the system lies in its adaptability. The entire infrastructure is modular and removable. This design acknowledges both the site's vulnerability to coastal processes and the National Trust's operational need for flexibility in asset deployment. It also reflects a more pragmatic and site-sensitive approach to long-term climate adaptation that balances environmental stewardship with functional resilience.

Signposting & additional guidance

Flood Risk Mapping (Environment Agency-England) https://flood-map-for-planning.service.gov.uk/

Flood Risk Mapping (Natural Resources Wales) https://naturalresources.wales/flooding/check-your-flood-risk-on-a-map-flood-risk-assessment-wales-map/?lang=en

National Trust Renewable Energy Programme https://www.nationaltrust.org.uk/our-cause/nature-climate/climate-change-sustainability/solar-power-at-our-places

BS EN IEC 62485-1:2018 Safety requirements for secondary batteries and battery installations – General safety information https://knowledge.bsigroup.com/products/safety-requirements-for-secondary-batteries-and-battery-installations-general-safety-information-2

Historic England guidance on installing solar panels https://historicengland.org.uk/advice/technical-advice/building-services-

Image credits:

Mobile battery store (© National Trust Images/Dee Nunn)

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Case studies, signposting and references

Hafod y Llan is a remote hydroelectricity scheme in Eryri (Snowdonia), which is increasingly exposed to convective storms and at risk from lightning-induced surges.

On the slopes of Yr Wyddfa, Hafod y Llan Hydro generates 660kW of renewable electricity. As climate change drives more frequent and intense storm events in upland Wales, the risk from lightning strikes is predicted to increase, which poses risks to safety, operational continuity and telemetry – the remote measurement and transmission of data.

Key risks include damage to turbine controllers, telemetry and power electronics, especially given the isolated location and long lead-in times for repair. These events prompted lightning protection modifications as a climate adaptation measure to ensure that critical infrastructure is safeguarded during extreme weather events.

System design

The hydro scheme has, until recently, relied on an industry standard set up. Surge protection devices were installed at two key points: one at the intake (where the water enters the system) and one at the powerhouse (where electricity is converted and managed). These devices are designed to intercept electrical surges, which are sudden spikes in voltage that can happen when lightning strikes nearby. Surges can travel along cables and damage sensitive equipment like the hydro control panels and sensors.

This set up was based on 'Type 2 protection', which is suitable for areas where a direct lightning strike is considered unlikely and aligns with Lightning Protection Zones – a framework for assessing the exposure of parts of a system to lightning.

Climate change is shifting those assumptions. What used to be rare is now becoming more likely. Rather than wait for further damage or prolonged downtime, the National Trust decided to act pre-emptively. Lightning protection specialists were brought in to assess the system's vulnerability under current and future storm conditions. Based on their advice, a more resilient system has been proposed.

The proposed system shifts the focus from sufficiency to increased resilience. The work was delivered with input from lightning protection specialists and the National Trust specialist renewables team. By anticipating future climate risks now, Hafod y Llan will continue to avoid costly equipment loss and downtime. The planned upgrade will ensure the site continues to operate reliably, even as extreme weather becomes more frequent. The upgrade is part of the National Trust's wider approach to climate risk reduction across its hydro estate.

Signposting & additional guidance

UK Climate Projections https://www.metoffice.gov.uk/research/approach/collaboration/ukcp

National Trust Renewable Energy Programme https://www.nationaltrust.org.uk/visit/wales/craflwyn-and-beddgelert/renewable-energy-at-craflwyn-and-beddgelert

BS EN IEC 62305-1:2024- TC Protection against lightning – General principles https://knowledge.bsigroup.com/products/protection-against-lightning-general-principles-3

Image credits:

Hafod y Llan weir (© National Trust Images/John Miller)