Call for Evidence on Critical National Infrastructure and Climate Adaptation by the Joint Committee on the National Security Strategy

About the Institution of Engineering and Technology (IET)

The IET is one of the world's largest engineering institutions with over 158,000 members in 150 countries. Our aim is to inspire, inform and influence the global engineering community to engineer a better world. We are a diverse home across engineering and technology and share knowledge to engineer solutions to global challenges like climate change. With our roots in electrical engineering, we have been championing engineering solutions and the people who deliver them for 150 years. The IET provides independent, impartial, and expert advice, spanning multiple sectors including Energy, the Built Environment, Transport, Manufacturing and Digital. On behalf of the profession, the IET strives to inform and influence government on a wide range of engineering and technological issues. The organisation's membership spans a broad range of professional knowledge, and regularly offers unbiased, independent, evidence-based advice to policymakers via several channels. We believe that professional guidance, especially in highly technological areas, is critical to good policymaking.

Introduction

The IET welcomes the opportunity to respond to the consultation by the Joint Committee on National Security Strategy into the Critical National Infrastructure (CNI) and climate adaptation. Whilst this response will largely consider the energy sector, it is important to apply systems thinking across sectors and apply learning where possible. The sectors within the CNI are intrinsically linked and it is important to recognise that failure within one sector can have a detrimental effect on others. The committee should therefore consider overarching regulatory oversight of the CNI to ensure a standard of resilience across different sectors. It also enables transfer of knowledge and experience of dealing with major events.

The IET has expertise across a range of subject areas, relevant to the management of the critical national infrastructure and would be happy to provide further input in due course. In addition to the sectors listed within the CNI, **the IET recommends that manufacturing is added as the fourteenth CNI sector.** Manufacturing supply chains were adversely affected during the pandemic and there needs to be a greater understanding of what effects there might be on other sectors if there were prolonged and severe shortages of materials.

Resilience

Engineers recognise that most systems lie on a spectrum with *resilient* at one end and *brittle* at the other. Those nearer the *resilient* end can cope with component malfunctions and external events beyond their design specification; those nearer the *brittle* end can fail catastrophically as a result of a minor malfunction.

Many of the complex socio-techno-economic systems that underpin everyday life can be placed on this spectrum. Such systems play an increasingly important part in people's lives: supply chains providing fresh food from around the world to local supermarkets; power systems extracting energy from wind, sunshine, tides, biomass and fossil fuels, and making it available 24/7 in sockets around our homes; interconnected healthcare, international data networks connecting phones, computers, search engines and media; the financial system allowing international credit card usage and providing finance for business and industry – the list of complex systems essential to modern life is long and continually growing.

Some complex systems are *engineered* (planned), the participants are known in advance and there are protocols and regulations in place. A city metro system may be complex, but there is little ambiguity over its geographical extent, assets, operations, or responsibility for the safety of the network. Other complex systems can be *ad hoc* – there is no central authority, players join and leave at will and regulation may be covered by multiple jurisdictions.

Occasionally, a complex interconnected *system-of-systems* will fail which may not have been obviously connected. In 2015, Storm Desmond took out the electricity system in Lancaster, many were surprised to find that phones, health and social care, lifts and water supplies in tower blocks, cash machines, card payments, petrol stations, garage doors …, … were all affected.[1] Many of these are complex systems in their own right and no-one had anticipated the interactions between them would be affected by the loss of a key component to the system. **Having a body that has responsible oversight for the system of systems would benefit contingency planning and resilience.**

Tension between resilience and efficiency

The cost of resilience can often be prohibitively high and the move towards efficiency can make a system more cost effective. This itself comes at a price as the system moves towards the brittle end of the resilience scale. For example, the removal of the train line to Manchester from Euston via Crewe, from Marylebone via Nottingham, or from St Pancras via Derby has reduced the costs of the network and increased efficiency. However, it has also meant that when there is a fault, there is limited contingency in place.

The UK's drainage and sewage systems rely heavily on legacy infrastructure, much from the Victorian era, since when the population has more than doubled.[2] The greater throughput in the same infrastructure has led to a more 'financially efficient' system (*making the assets sweat*) but has reduced the margins to cope with unanticipated events, which represents a loss of resilience and contributed to the many thousands of releases of untreated sewage.

Furthermore, the communications network is increasingly moving towards a reliance on electricity due to efficiencies and new technology. Despite improving efficiency, it could prove to be vulnerable if the energy sector experiences a major event, especially as these changes mean that communication is more reliant on systems which do not necessarily have the same level of backup and resilience designed in. Electrification of large parts of our vehicle fleet will also increase reliance on electricity.

Electricity Infrastructure

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[1] *Living without electricity – One city's experience of coping with loss of power.* Royal Academy of Engineering, ISBN 978-1-909327-26-9, May 2016

[2] *The Cambridge Economic History of Modern Britain*, Cambridge University Press, 2008.

Overhead line components are designed to a factor of safety of between 2.3 and 3.5 based on the worst credible storm conditions, therefore, the lines should be sufficiently robust to withstand the effects of climate change. However, as witnessed recently through Storm Arwen, a consequence of abnormally high wind and gust speeds, combined with saturated ground conditions, can lead to mature trees being uprooted and falling across overhead lines causing extensive and widespread damage. Climate change might increase the frequency and severity of windstorms. Whilst some measures can be taken to reduce frequency and duration of supply interruptions due to tree-related faults on overhead lines, felling trees within falling distance of lines would be environmentally unacceptable whilst widescale undergrounding would be prohibitively expensive and largely impracticable (UK has approximately 280,000 km of overhead line distribution) and could create other reliability issues, including longer repair times of underground cables are damaged by other parties.

An indirect consequence of climate change arises from the displacement of traditional fossil-fuelled 'synchronous' generation with inverter-connected wind and solar PV generation. The result is declining levels of system inertia which increases the risk of rapid frequency collapse in the event of a major loss of grid infeed (e.g. a major generator or interconnector). The current emphasis focusses on procuring new frequency response products (Dynamic Containment, Frequency Moderation and Frequency Regulation). Dynamic Containment (typically provided by grid-scale batteries) relies on fast injection of real power, but this does not confer inertia in the true sense (inertia is a natural physical attribute conferred by large rotating synchronous generators due to their electromagnetic coupling with the power system, and has the inherent benefit that inertia conferred due to a fall in frequency is proportional to the rate of fall in frequency). The ability to restart the grid served by a higher proportion of non-synchronous generation in the event of a national shutdown is a matter currently receiving attention, including through a project known as Distributed ReStart which seeks to ascertain the feasibility of initially creating local power islands on electricity distribution systems independently from the national transmission system as part of the restart procedure.

Increased likelihood of coastal or fluvial flooding due to increased rainfall is a further threat to the electricity power system (as was demonstrated by events in Lancaster in 2011)[3]. **Substation susceptibility to flooding will need to be continuously reassessed, and appropriate mitigation in terms of flood defences installed – or relocation of infrastructure in extreme cases.**

Reliance on electricity

There has been a considerable advancement in technology in recent decades and with it there has been a greater move towards reliance on electricity. With this move comes greater risk to the system of systems if the electrical network fails. In future there will be even more people relying on electrical vehicles for transport, heat pumps for their homes and electricity for their communications network.

For example, the only available communication network in Lancaster during the power outage in 2011 was the Public Switched Telephone Network (PSTN) powered from batteries at the phone

[3] *Living without electricity – One city's experience of coping with loss of power.* Royal Academy of Engineering, ISBN 978-1-909327-26-9, May 2016

exchange. However the PSTN is closing on 31 December 2025.[4] The move towards efficiency of this part of the system needs to also ensure that a replacement would also have the capacity to keen running for a short amount of time if there was a black start of the electricity grid, as its predecessor could.

Another communications system that proved useful during Storm Desmond was *Bay Radio*. At the time, this was a radio station that operated locally and with valuable local knowledge supporting the flood response. Subsequently, it has been taken over by a syndicated network based in Birmingham with fewer local resources to enable it to provide a similar service. Increasingly, radio and TV are being transferred from the radio spectrum to internet-based communication. With the decline of MW transmitters that, in an emergency, could be run by a local diesel generator, it was possible for people to hear important news anywhere in the UK with a small radio and a few cheap batteries. However, internet-based broadcasting requires power supplies to equipment cubicles in the street and routers in people's homes – much less resilient. **When making advancements in efficiency and technology, it is also important to consider the resilience of the system as a whole and mitigate where possible.**

Electricity network operators are aware that in future we will be more dependent on parts of the electricity system which were built when reliability was not so critical. Given that losing power for some days in a totally electrified home could result in loss of power, heating, external communications, and vehicle transport, a conversation needs to start about what Value of Lost Load will be acceptable in future, which any changes to standards might cost, and how they will be paid for.

Contingency planning and local resilience

It is possible to improve local resilience with contingency planning, however this is a short term solution. Availability of generators, water, food, LED lights and batteries combined with local knowledge and technology will support preparedness for extreme weather events.

There should also be greater responsibility for distribution system operators and transmission system operators to ensure that networks they are developing and maintaining are suitable for extreme events, especially with an increase in renewables. Renewable developers should demonstrate that their technology will remain operational through extreme events.

The advent of energy communities and microgrids provides some potential opportunity for resilience of electricity supply in the event of grid failure provided the technically complex challenge of maintaining system frequency, voltage and sufficient fault-level can be managed. However, we must take care that in extreme events, these microgrids do not become 'islanded', with communities isolated as a result.

V2X technology might also provide a limited opportunity for customers to maintain their essential house supplies in the event of a prolonged grid failure. However, an increase in electric vehicle usage will need to take into account prioritising power for emergency service vehicles in the event of an outage. The rapid charging network may become critical infrastructure when regions seek to

[4] Wilding, K. *The closure of the public switched telephone network*, Crown Commercial Service, November 2020. Accessed 21.12.21 https://www.crowncommercial.gov.uk/news/the-closure-of-the-public-switched-telephone-network

recover from severe weather events. We have seen how even rumours of fuel shortage drive consumer behaviour even when supply is available.

There should be greater use of energy storage for back up power in extreme events. This could be achieved via battery or hydrogen technology, for example. The sectors within the CNI will also need to consider back up power through energy storage.

Extreme weather

Extreme weather is one of the biggest threats to the energy system in terms of climate change. Resilience is the capability of a system to cope with unplanned and unexpected events. Aside from the deteriorating resilience of some infrastructure, the UK is subject increasingly regular extreme weather events that will test resilience in many more systems.

The high rate of Arctic heating is likely to result in melting glaciers, leading to locally reduced salinity that has the potential to weaken the *Atlantic Meridional Overturning Circulation* (AMOC)[5], but no-one can predict with certainty how this will affect Britain's climate. From 12 to 26 January 2009, there were anticyclonic conditions over much of Northern Europe, resulting in almost no output from Britain's wind farms. From late June to mid-July 2021, there was a heat dome over the western side of North America, with temperatures approaching 50°C in locations normally reckoned to have a temperate climate. From 22 to 28 January 2018, Britain suffered from *The Beast from the East* when the combined use of electricity and gas exceeded 250 GW. If this becomes the new norm, the target set in the 10-point plan[6] that aims to increase the installed capacity of offshore wind to 40 GW by 2030 and the closure of most fossil-fuelled power stations will be inadequate, even if accompanied by a largescale investment in energy storage.

A credible consequence of climate change is that the gulf stream weakens or changes its route affecting UK wind patterns and sea level. This could lead to weather-blocking events wherein UK could experience several consecutive days of anticyclonic conditions and hence minimal output from wind farms. Again, this would require hugely expensive (long-duration) energy storage to fill the energy gap. Also, a weakening gulf stream could lead to colder winters in UK and hence higher demands for (increasingly electric) domestic space and water heating.

The UK should be planning for these events to occur on a frequent basis. Furthermore, it is important to **plan for the eventuality that these events will occur in quick succession on occasion.** Planning for unusual weather behaviour should also be considered for example anticipating a storm from a different direction could be mitigated in the standard tree management policy; no longer identifying these situations as 'low probability'.

Technology

At low voltage (LV), the use of aerial bundled conductor (in lieu of the traditional vertical 4-wire bare conductor configuration) eliminates the risk of conductor clashing due to tree contact, and even in

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[5] *What is Atlantic Meridional Overturning Circulation?* Accessed 21.12.21 https://www.metoffice.gov.uk/weather/learn-about/weather/oceans/amoc

[6] *The ten point plan for a green industrial revolution*. Department for Business, Energy and Industrial strategy Accessed 21.12.21 https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution/title

the event the conductor is brought down by a falling tree, the conductor insulation minimises danger to the public; and due to the cable's 'weak link' pole attachment, the poles will generally remain upright, facilitating a faster repair. Whilst the overall circuit length of the UK LV overhead line network is relatively short (around 65,000km) it often causes a small groups of customers to remain off supply for over 24 hours in extreme weather conditions due to the sheer number of individual faults.

At high voltage (HV), insulated conductor designs can reduce faults due to tree branches and wind-borne material, and the increasing application of remote control, automation, auto-reclosers and auto-sectionalisers helps minimise the number of customers affected by a fault (other than by short-duration interruptions).

In exceptional cases, selective diversion or undergrounding of high voltage lines might be justified, provided in the latter case a feasible cable route is available which can also accommodate any ground-mounted substations required to replace pole-mounted transformers and switchgear. It may also have its own reliability issues as well as agricultural and environmental impacts, particularly when done piecemeal.

These solutions however come at a cost that needs to be carefully balanced against the benefit. Whilst undergrounding high voltage lines can lead to other reliability issues (in addition to environmental and agricultural impacts) especially if done piecemeal, for example, inserting sections of underground cable in a predominantly overhead line circuit.

Conclusion

The Joint Committee on the National Security Strategy should consider the system of systems that interlink the CNI. Brittle infrastructure in one can impact negatively on another during an emergency. The IET recommends regulatory oversight of the CNI as a whole, which would also allow learning to be transferred across sectors to become more robust in future. It also recommends that manufacturing is added to the CNI sector list.

It is often the case that increases in efficiency can cause vulnerabilities in the system which moves it towards the brittle end of the spectrum, with the inevitable loss of resilience. These decisions should be carefully considered in the planning stage and mitigated where appropriate. Measures can be taken to prepare for extreme events, such as storms impacting the energy sector, however these come at a cost and investment will be required to ensure robustness when dealing with the impact of climate change.

The IET would welcome the opportunity to discuss the impact of climate change on the critical national infrastructure further. Please contact sep@theiet.org.uk