Mobile RAN power resilience

Technical Report and CFI Update

Non-confidential version for publication

Report

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Annex

1. Overview

1.1 This report sets out the results of our modelling and analysis of the resilience of mobile networks in the event of a sustained UK—wide power outage, in particular the resilience of the masts and the associated radio access network (RAN). It then considers the further measures necessary to meet resilience goals as well as additional benefits that may result from using new approaches to supporting mobile connectivity during power outages.

1.2 In December of 2023, we published a Call for Inputs (CFI) with the aim to promote a discussion about what power backup mobile network operators (MNOs) can, and should, provide for their networks and services. Since then, we have publicly stated a desire to better understand the extent of existing power backup in more granular detail.[1] We explained that it may allow us to more accurately assess whether and where power backup may be required, and what magnitude of costs are likely to be required to meet the estimated level of need. In our September Resilience Statement, we explained that we would work with government in this respect, and this report forms part of that engagement process.

1.3 In general, telecommunications services in the UK are reliable, but nevertheless do suffer from outages from time to time for different reasons, geographic extent and durations.[2] Given the reliance of consumers and business on telecoms networks and services, failures can be particularly challenging, and our dependence on telecommunications' networks and services is likely to increase further in the coming years.

1.4 The UK's reliance on mobile connectivity has been brought to sharp relief in recent years when parts of the country experienced extreme weather events (such as storm Arwen in 2021). The widespread loss of power to communities coupled with the consequential loss of mobile network services in these areas highlighted the challenge of maintaining the availability of communications networks in the face of such events along with the need to prepare for, and improve response times to, such situations to mitigate their negative effects.

1.5 An estimate published in the CFI, suggested that the costs of providing one hour of backup across all four mobile networks would be £0.9 - £1.8bn. However, this estimate was derived from a high-level understanding of the total number of masts that all MNOs have deployed across the country, with adjustments to reflect 2022 Connected Nations data on existing power backup and an assumption to account for feasibility.[3]

1.6 This report seeks to set out our assessment and understanding of mobile RAN resilience derived through a quantitative examination of the current mobile infrastructure provided to us by the MNOs as part of Ofcom's Connected Nations infrastructure reporting programme. This data includes specific mast site information, geographic coverage and existing power backup capabilities. We have also incorporated our own estimates of power backup facilities and other associated information to aid our modelling.

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[1] Ofcom, 2024: Statement on Network and Service Resilience Guidance: paragraph 8.12.

[2] Ofcom, 2023: Connected Nations 2023 - UK report, Section 4: 'Network security and resilience'

[3] Ofcom, 2023. Resilience guidance consultation and Call for Input on mobile RAN power back up

1.7 Details of MNO mast locations, capabilities, resilience provision and coverage are commercially confidential information and therefore maps, figures and tables within this report should be considered to be confidential even at the aggregate level as it may be possible to identify specific MNO information from them.

Summary of findings

1.8 The output from the modelling and analysis suggests that:

a) For short duration power outages up to around 1 hour, around two thirds of the population[4] would be able to make emergency calls. This level of protection is enabled through the power back-up of around 20% of all mast sites in the UK up to at least one hour, coupled with the fact that mobile phones will roam[5] onto available networks to make an emergency call, so are not dependent on their home network.

b) As the duration of an outage increases fewer consumers can make emergency calls: only around [✂] could make an emergency call in the event of a power outage lasting up to 6 hours. This is because far fewer (5%) sites [✂] have backup facilities of at least 6 hours.

c) We estimate that the costs to upgrade mobile networks to ensure almost everyone can maintain access to the emergency services for up to 4 hours would be approximately £1 billion.[6] As we noted in our CFI,[7] Ofgem data indicates that the majority (approximately 90%) of power outages last between 3mins and 3 hours.

d) Further enhancements or network hardening[8] to increase the duration of protection and/or to allow more services (such as data connectivity or the ability to make calls to any number rather than simply 999) would incur significantly higher costs.

e) Technological innovation may provide alternative solutions to maintain connectivity, such as the increasing availability of 'Direct to Device' satellite communication. The geographic extent, capacity and timescales of such approaches need further investigation before they can be considered viable alternatives to current mobile backup measures.

f) Internationally we have not seen a common consensus emerge on how to ensure resilience on the RAN, with individual countries adopting different positions depending on their circumstances. For example, challenging weather conditions prompted Australia and Norway to implement mobile network power backup, with Australia taking a voluntary approach (12 hours for a limited number of sites) and Norway mandating it (2 hours, with 4 hours in rural areas), while Switzerland has considered plans to mandate up to 72 hours of backup with potential service restrictions.

1.9 The data and insights contained in this report do not form a cost/benefits analysis (CBA) and do not quantify the value of different levels of resilience considered. This information is

[4] For this report, we have used premises as a proxy for citizens/consumers, and that is what the numbers in this report refer to.
[5] The ability for mobile handsets to roam onto an alternative network in order to make an emergency call is known as 'Limited Service State'.
[6] Includes both capital costs and multiple years of additional operating costs - explained further at paragraph 6.5
[7] Ofcom, 2023. Resilience guidance consultation and Call for Input on mobile RAN power back up Annex 2.
[8] In the context of this report, "hardening the network" refers to a set of measures and strategies implemented to improve the network's ability to withstand disruptions and recover quickly from an electrical mains power outage.

offered to inform further discussion on power resilience in the mobile network and power backup of MNO mast sites in particular. These discussions would need to consider:

- What should be an acceptable level of resilience to power outages, both in terms of coverage and duration generally, but also the extent to which services must be available (such as general telephony and data/internet services).
- The optimum balance between enhanced power supply reliability and telecoms-provided backup power facilities. Additionally, what steps could be taken to improve communication and coordination between the telecoms and electricity sectors to maximise resilience, avoid investment duplication and facilitate faster power restoration.
- The ongoing costs and operational challenges associated with battery or generator backups at mobile mast sites, such as servicing, fuelling, building restrictions for installation, theft/damage and wider environmental considerations.
- Should additional resilience solutions (such as generators) be targeted to where long-duration power outages are more likely and if so, how would these areas be identified and what level of resilience would be considered appropriate? Such consideration would greatly benefit from coordination with the energy sector, as working in partnership will help prioritise investment in the telecoms sector.
- What additional or alternative approaches could be considered to supplement existing resilience solutions or avoid the need for further deployment? This may include taking advantage of future investments into satellite phone services (and if so, it would need to consider how this would be achieved in practice) or leveraging the enhancements to the Emergency Services Network (ESN) to offer enhanced services to the public.
- In the event that further investment in MNO backup provision is considered necessary, how should this be funded, through which mechanism and what implications may result?

1.10 This report does not directly address these considerations but does aim to inform the debate and highlight the trade-offs and opportunities that may exist. We anticipate and welcome further discussions with MNOs, representatives from government and the energy sector, in particular, Ofgem, DESNZ and the relevant electricity supply and distribution organisations, to explore the above matters. We would particularly welcome MNO involvement in some of these discussions as they are best placed to understand their own network capabilities and opportunities (for example identifying which sites may be more or less suitable for power backup).

1.11 The scope and timing of any possible next steps will aim to include the above discussions.

1.12 We may separately consider scoping work on how power outages may affect fixed voice and broadband networks in the UK to provide a holistic view of power resilience of telecoms.

2. Background to this report

Summary

2.1 This section outlines the context and rationale for the preparation of this report.

2.2 Consumers and businesses in the UK are increasingly using communications networks and services for all aspects of their lives either at home, work or on the move. As a result, there is a greater public expectation that these networks will be resilient and generally available. However, there have been, and continue to be, incidents rendering mobile networks unavailable leading to widespread disruption.

2.3 In Ofcom's recently updated resilience guidance, we did not include measures relating to power resilience of mobile networks as we needed to identify measures that were appropriate and proportionate. We therefore opened a debate, through our CFI, into whether and how the resilience of mobile networks could be enhanced. We have shared further below what stakeholders have said to date on what is important to them when outages occur. We have also provided findings from our modelling exercise and other activities that should help inform what options are available to policy makers when considering how to respond to the challenges of ensuring resilience on these networks.

Ofcom's CFI on power resilience in RAN

2.4 Providers of public electronic communications networks and services (PECN/S) are under a duty to take appropriate and proportionate measures to identify, prepare for and reduce the risk of security compromises, which includes anything that compromises the availability, performance or functionality of the network or service. In December 2023, we issued a consultation ('*the Consultation*'), seeking views on proposals to update guidance available to PECN/S, on how they could comply with their resilience-related security duties. Ofcom's aim when providing updated guidance was to improve transparency and understanding of Ofcom's expectations around the relevant resilience-related security duties.

2.5 All networks are dependent on electrical power to function, and outages can cause significant and extensive service disruption for consumers. At that stage, we did not include specific measures relating to the provision of additional power backup up at the mobile RAN in the proposed guidance. This was because our work to that point suggested the high costs involved in providing a universally-available power backup solution meant that it was not possible to determine whether this would be a proportionate measure. Given the risk that any mobile RAN site might be affected by a power outage, we stated that a minimum level of one hour back-up at all mobile sites, allowing uninterrupted communication services, would cost £0.9 - £1.8bn across the industry.[9]

[9] Paragraph 5.23 of the CFI. The indicative data we had gathered suggested that a minimum of 1 hour power backup at a given RAN site would address the majority of customer hours lost in energy outages (where energy customers are a proxy for access networks). See Annex A2 of the CFI. This would reduce disruption and harm to consumers from the loss of communications services.

2.6 We therefore did not include a measure, and instead issued a CFI inviting stakeholders to input on what services consumers should be able to expect during a power outage, and what a more cost-effective solution could look like to address potential consumer harm.

Context for running the CFI

Power related incidents reported to Ofcom

2.7 Ofcom's own incident reporting shows that between 2020 and 2022, 693 out of 2735 (25.3%) of the reported incidents for fixed and mobile networks were caused by power related issues. Furthermore 245 days' worth of incidents out of a total of 1393 days (17.6%) were power related.

The consequences of energy outages are becoming more acute

2.8 We explained in the CFI that the UK's energy network is generally resilient, but communications providers can, and do, experience power cuts. We noted that the UK's growing use of, and reliance on, communications services means that the consequences of energy outages, which in turn compromise the availability, performance or functionality of networks and services, are increasingly acute. People now access a wide and increasing range of online services across mobile networks and services. This includes gaming, banking, remote working, e-commerce, video-on demand/streaming, as well as government services.[10] As a result, we have become reliant on digital communications as a society, with nearly all (94%) UK adults using an online communications service for making voice/video calls or sending messages in 2022.[11]

2.9 Mobile networks play a critical role in the event of an emergency. 41.9million 999/112 calls were made in 2023, of which 79% were from a mobile and 15% from a landline.[12] In March 2023, the UK Government launched its Emergency Alert service,[13] which was then trialled in April 2023. It is designed to warn people if there is a danger to life nearby, in the case of events like severe flooding, fires and extreme weather. Under the system, mobile phone masts in the surrounding area broadcast an alert, with every compatible mobile phone or tablet in range getting the alert if they are using a device on a 4G or 5G network.

Climate change is leading to more uncertain and severe weather conditions

2.10 Climate change is having an increasingly adverse impact on the UK's Critical National Infrastructure (CNI), and this is set to worsen substantially in the future under all reasonable climate change scenarios. The Joint Committee on the National Security

[10] Ofcom, 2023.*Online Nation 2023*, pp.12
[11] Ofcom Online Nation 2022 report
[12] DCMS, HO, DHSC, 2023. *999 and 112: the UK's national emergency numbers*. 999 and 112: the UK's national emergency numbers - GOV.UK [accessed 22 November 2024]
[13] About Emergency Alerts - GOV.UK

Strategy has identified that UK telecoms infrastructure is particularly at risk from severe flooding, high winds, and lightning strikes because of climate change.

2.11 Severe weather that results in the loss of mains power or direct physical damage to telecoms infrastructure (such as downed overhead cables) can significantly disrupt or damage telecoms networks. In 2021, the impact of Storm Arwen left over 74,000 customers without mains electricity supply for over 48 hours.[14] Mobile communications were also affected by the storm, as thousands of mobile cell sites were disrupted by the same power outages, affecting all four MNOs.[15]

The closure of the PSTN places more focus on the reliability of mobile networks

2.12 The migration of landline users from PSTN to VoIP technology means that some will become more reliant on mobile networks in the event of a power outage that reduces availability of fixed networks. We are likely to see a further shift of consumers from traditional landlines to VoIP-based telephone services that use a broadband connection.[16] Ofcom's existing guidance under General Condition A3.2(b) states that fixed providers must have at least one solution available that enables access to emergency organisations for a minimum of one hour in the event of a power outage at the customer's premises. This solution should be offered free of charge to landline dependent premises.

2.13 In response, fixed providers are deploying a number of solutions including in-home battery backup units. Some fixed providers are providing 'hybrid handsets' that rely on a mobile signal to make calls, including those to emergency services, in the event of an outage. This means that an increasing number of consumers relying on VoIP technology, will likely turn to their mobile network in the event of a power outage, including to make an emergency call.

Ofcom's work since the CFI

2.14 We used the CFI to start a discussion about what power backup MNOs can and should provide for their networks and services to address the problems discussed above. The learnings from the CFI could be used to implement guidance in the future, and/or working with industry and government to identify and pursue other ways to ensure resilience across the RAN.

2.15 Following the conclusion of the CFI, we have focussed on:

1) Considering the responses to the CFI, and
2) modelling and analysing the power back up data from MNOs in more granular detail.

[14] https://assets.publishing.service.gov.uk/media/629fa8b1d3bf7f0371a9b0ca/storm-arwen-review-final-report.pdf

[15] https://assets.publishing.service.gov.uk/media/629fa8b1d3bf7f0371a9b0ca/storm-arwen-review-final-report.pdf pp.16

[16] Connected Nations UK report 2024: "As the switch-off of the legacy public switched telephone network (PSTN) progresses, PSTN connections now account for just over a quarter of all residential landline connections (27%)."

2.16 We received 60 responses, ranging from MNOs, industry groups, local authorities, and members of the public. A number of respondents noted that the challenges required a cross-sector response from the energy and communications sectors. Respondents provided insights into the types of harms that may result from mains outages to the RAN, ranging from limits to 999 access, to the need for local authorities and family members to contact individuals (including vulnerable people).

2.17 MNOs outlined the practical, technical, and environmental challenges of enhancing the level of power backup in the RAN. For example, the particular challenges in rural areas where infrastructure can be more vulnerable to extreme weather and where distances can impact repair response times. Stakeholders were supportive of targeting improvements to areas of most need.

2.18 This document includes the outputs of a modelling exercise that seeks to help us understand the extent of existing power backup in more granular detail, and provides early sight of the potential scale of the gap between current levels of power resilience and potential consumer needs during power outages. We expect this approach can evolve to help answer a more complex set of policy questions, such as the identification of approaches targeted at where backup is most needed and their costs.

2.19 The rest of the document is structured as follows:

i) In section 3 we cover stakeholder's views on the importance of backup and consumer harms/ impacts from power loss, and how these insights may shape policy objectives in this area.
ii) In sections 4-6, we describe the modelling work we carried out, the results on levels of existing backup and some initial estimates on the costs associated with hardening the MNOs' RAN sites to support continued provision of various levels of service during power outages.
iii) In section 7 we summarise the arrangements other countries have adopted to address the problems of outages at the mobile RAN.
iv) In section 8, we set out some considerations for DSIT to possibly explore when planning potential next steps.

3. Key themes emerging from the CFI

Summary

This section outlines the potential harms identified by respondents to Ofcom's December 2023 CFI. These insights could be used to inform policy direction on what mobile services could be prioritised during an outage, what duration of backup may be needed, and where consumers are most likely to need connectivity during an outage.

Limited ability to contact emergency services

3.1 Nearly all stakeholders emphasised the critical importance of maintaining access to emergency services, such as 999, during power outages.[17] Vodafone stated that access to emergency services "should be the priority" over other services due to the seriousness of the harms associated with it.[18] We noted that access is especially crucial for vulnerable groups, including those with impaired hearing who rely on emergency SMS and emergency video relay.[19] The potential failure of alternative emergency contact methods, such as panic alarms and smart home devices, during power outages further underscores the necessity of reliable mobile network access for emergency calls.

Limited ability to contact relatives and/or dependents

3.2 Orkney Islands Council stated that "safety should be paramount" and "at the very least, consumers should be able to access voice services to call emergency services and be able to contact family members".[20] Vodafone also suggested that consumers "would benefit from continued access to friends and family".[21] Contacting relatives and/or dependents may be useful during a power outage as non-emergency situations can arise.

3.3 Evidence cited by the Institute of Electrical and Electronics Engineers suggests that during emergency situations, people want to be able to ensure that their family and friends are safe with the first point of contact being able to get in touch with them.[22]

[17] Highlands & Islands Enterprise response to CFI, pp.11; Joint Radio Company response to CFI, pp.5); Scottish Borders Council response to CFI, pp.5

[18] Vodafone response to CFI, pp.2

[19] Ofcom: Emergency video relay: *how it will work*

[20] Orkney Islands Council response to CFI, pp.4

[21] Vodafone response to CFI, pp.5

[22] Stiegler, R., Tilley S., Parveen T., 2011. *Finding family and friends in the aftermath of a disaster using federated queries on social networks and websites.*

Limited ability to contact telecare providers

3.4 Stakeholders highlighted the importance of maintaining telecare access for vulnerable individuals, especially those reliant on mobile networks. [23] We note that some telecare providers use roaming SIMs to enable devices to connect to different networks during outages, potentially mitigating the impact of power disruptions.

Limited access to information sources

3.5 [✂] suggested that certain individuals may experience harm from not having access to information about an unexpected power outage. "During a power outage, people want information: to understand how long they will be affected and what impact it will have on their activities".[24]

3.6 A stakeholder cited a Royal Academy of Engineering report highlighting the significant challenges faced by a Lancaster community during a major power outage in 2015.[25] Key issues included limited access to reliable news sources, hindered communication for journalists, and the proliferation of misinformation.

Limited communication between communities, services, and staff

3.7 The loss of communication during a power outage can significantly impair the ability of communities, services, and staff to coordinate effective responses.[26] While emergency services may have access to dedicated networks, other crucial bodies like Local Resilience Forums and local councils often rely on ordinary means of communication.

3.8 The 2015 Lancaster outage highlighted the challenges posed by information gaps, such as uncertainty regarding school openings and public service appointments. This underscores the importance of reliable communication channels to ensure the smooth functioning of essential services and community resilience.

Broader economic and financial harm

3.9 [✂] mentioned that "there may be an economic impact too if mobile phones are out of action for a lengthy period" as people "rely on them for business and personal reasons".[27] As more of our economic activity shifts online, an outage of communications services has the potential to cause broad economic harm if alternatives are not available.

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[23] Highlands & Islands Enterprise response to CFI, pp.11
[24] [✂] to CFI, pp.3
[25] Royal Academy of Engineering: Living without electricity, *One city's experience of coping with loss of power (May 2016)*
[26] Lanarkshire Local Resilience Partnership response to CFI pp.3. They cited a best practice guide, prepared by central government, suggesting that local authorities "ensure that they can continue to exercise their functions in the event of an emergency. Ministry of Housing, Communities & Local Government, 2018, page 8: *Local authorities' preparedness for civil emergencies*.
[27] [✂] to CFI, pp.3

Outage length and rural locality could aggravate harms

3.10 Stakeholders noted several factors that could exacerbate the harms noted above. Lanarkshire Local Resilience Partnership suggested the length and geographic scope of a power outage significantly influences the severity of its consequences. Prolonged outages can exacerbate harm, increase demand on emergency services, and extend recovery time.[28]

3.11 Stakeholders noted that rural areas, with their remote infrastructure and potential transportation challenges, are more susceptible to power outages. These outages can have a more severe impact on rural communities, as they may be more isolated and rely on essential services that are harder to restore.[29]

Potential policy objectives

3.12 Based on the harms outlined above, we have grouped potential policy objectives below, into:

a) 'access emergency communications';
b) 'the ability to contact others'; and
c) 'the ability to go online'.

Table 1: Breakdown of high-level potential policy objectives and specific expectations

Potential policy objectives	What mobile services should consumers be able to expect during a power outage?
Emergency communications	To make a 999 call
	To receive emergency alerts
	For telecare users to contact, and be contacted by, their providers
	For deaf consumers to use emergency video relay
Contacting others	to send an SMS (inc. to 999)
	to make voice calls (to relatives, vulnerable people, Local Resilience Forums dialing in)
	to use one-to-many messaging e.g. WhatsApp, email
Going online	to access information online? (social media, news websites etc.)
	to conduct economic activity? (mobile banking, remote working etc.)

3.13 Each of the above potential policy objectives may require different technical requirements and additional resilience measures which would then result in different costs for meeting those objectives. This could depend on the coverage and capacity backed-up sites can currently provide. We consider below how networks could deliver these potential policy objectives. We have grouped them into four categories to reflect the step-change in costs for each category as well as the three categories of harm:

[28] Lanarkshire Local Resilience Partnership response to CFI pp.3
[29] Beatrice Wishart MSP response to CFI; Highlands and Islands Enterprise response to CFI, pp. 5; Rural Services Network response to CFI; Orkney Islands Council response to CFI

1. Ability to contact emergency services (emergency roaming on any network);
2. All MNOs providing access to all voice and SMS services;
3. All MNOs providing access to voice services and limited data capability; and
4. All MNOs providing access to voice and data services.

3.14 Providing more reliable services during an outage can vary on the number of sites with power backup available for consumers to access. With more backed-up sites within a specified area, there is less chance for sites to become congested and therefore be able to provide more reliable services during an outage. We have outlined what each category of design may entail in the table below.

Table 2: Implications on network design and protection for each policy objective (category)

Category	Network Design Implications
Ability to contact emergency services (emergency roaming on any network)	Because handsets can roam onto other networks when making an emergency call, the minimum number of sites to be backed-up would be sites that provide enough coverage to access 999 services by at least one MNO. Note that our analysis considers the coverage of networks to support calls, but not the capacity/bandwidth of the networks to support all emergency callers simultaneously.
All MNOs providing access to all voice and SMS services	Providing voice services would require all MNOs to have backed-up sites. Enough sites would need to be backed-up to provide sufficient access to voice services across the UK
All MNOs providing access to voice services and limited data capability	More sites would be required to be backed-up to ease congestion across sites. This should allow greater capacity from sites for data services to be accessed. However, this is not guaranteed and is dependent on a variety of factors.
All MNOs providing access to voice and data services	This is the level of service if there were no power outage. Both voice and data services would be functioning as if there was no power outage

3.15 Combing both the potential policy objectives and the design of network sites equipped with power backup, we have set out what objectives may be achieved during a power outage in the table below.

Table 3: Potential for policy objectives to be achieved for different network designs and capabilities

	During a power cut, is it possible…	All MNOs providing access to voice and data services	All MNOs providing access to voice services and limited data capability	All MNOs providing access to all voice and SMS services	Ability to contact emergency services (emergency roaming on any network)
Emergency	To make a 999 call?	Yes	Yes	Yes	Yes
	To receive emergency alerts?	Yes	Yes	Yes	Yes
	For a telecare provider to contact a customer?	Yes	Yes	Yes	No
	For deaf consumer to use emergency video relay?	Yes	Maybe	No	No
Contacting others	to send an SMS (inc. to 999)	Yes	Yes	Yes	No
	To make voice calls (to relatives, vulnerable people, Local Resilience Forums dialing in)	Yes	Yes	Yes	No
	To use one-to-many messaging e.g. WhatsApp, email	Yes	Maybe	No	No
Going online	To access information online? (social media, news websites etc.)	Yes	Maybe	No	No
	To conduct economic activity? (mobile banking, remote working etc.)	Yes	Maybe	No	No

3.16 With regards to emergency roaming, two scenarios could exist, either:

a) MNOs co-ordinate the resilience they provide in specific areas so that at least one operator would still be available in the event of a power outage, but the detail of which MNO deploys resilience at which site would be for the MNOs to decide and will differ from place to place; or

b) one MNO could be designated a 'network of last resort' with expectations/obligations/requirements to deploy resilience at sufficient sites to provide emergency call service to consumers on behalf of all other mobile networks.

3.17 With fewer sites available during a power outage, the sites with power backup may become more congested, and services, in particular data services that are sensitive to the effects of network congestion, may reduce in quality. For example, real-time services such as video calling or high bandwidth services such as film viewing. Increasing the number of sites with power backup however could reduce congestion and increase consumers' ability to use these services, albeit at higher costs.

Providing access to Emergency Communications

3.18 Several stakeholders have highlighted the need for consumers to have access to emergency services during a power outage, and for it to be provided "as a minimum".[30] Restricted access to telecare providers was another harm raised by stakeholders that would fall within the scope of emergency communication, especially for the most vulnerable. The policy of providing access to emergency communications would see consumers having sufficient access to 999 services and telecare.

3.19 Access to emergency video relay (emergency services for deaf or hearing-impaired individuals) cannot be guaranteed under a network of last resort as data services would not be provided to all consumers that roam on to networks, they are not contracted to. Emergency SMS cannot be guaranteed to work either, as the individual would also be required to be connected to their contracted network.

3.20 Since 2023, the UK Emergency Alerts System enables all compatible phones connected to a 4G or 5G network to receive emergency alerts to warn people if there is a danger to life nearby.

Contacting others

3.21 The ability to contact others was identified by stakeholders to be beneficial during a power outage. Contacting others could range from communicating with family/dependants, local councils contacting vulnerable consumers, or enabling Local Resilience Forums to mobilise.[31]

3.22 The ability to contact others would be difficult to achieve on a network of last resort due to consumers requiring access to multiple MNOs. However, this policy outcome could be achieved on a network design that ensures enough sites are backed-up to provide sufficient voice coverage across all MNOs.

Going online

3.23 Accessing online services is important for daily life as so many key services are available this way. Notably, access to 'real time' information (e.g. outage status, or services impacted)

[30] Highlands and Islands Enterprise response to CFI, pp.11; Scottish Borders Council response to CFI: Vodafone response to CFI.

[31] Lanarkshire Local Resilience Partnership response to CFI, and Orkney Islands Council response to CFI

can be found via online sources. [✂] suggested that during a power outage, consumers would want to know how it would affect them and for how long.[32]

3.24 The policy of enabling consumers to access online services would require a large number of sites to have power backup to provide effective data coverage. It would be worth noting that due to Net Neutrality rules, it is unlikely that it would be possible to enable one set of online services to have priority of others, for example, online communications services (e.g. WhatsApp) over other online services such as entertainment (music and video platforms).

Network of last resort for 999

3.25 As noted above, to support emergency calls across the UK requires either a co-ordinated optimisation of power resilient UK emergency call coverage, which would require battery backup across different MNO sites or, one MNO could be designated as network of last resort to provide emergency call service to consumers.

3.26 During a power outage, either of the above options would aim to provide the minimum service required for consumers to access 999 services. Only emergency calls can be made provided there is coverage from an MNO site.

3.27 The policy of ensuring consumers have access to 999 calls will help mitigate the harms that might result from not having access to these services e.g. impaired ability to request an ambulance or report a fire. However, emergency services other than 999, such as emergency video relay or emergency SMS, may not be accessed due to either insufficient capacity or coverage from a consumer's contracted provider.

3.28 This policy will also allow for emergency alerts to be sent if the MNO site is providing 4G signalling. Emergency alerts could be a method to mitigate against some harms that may result from not having access to information. It may also be possible for telecare providers to be contacted. This is dependent on whether a telecare device has a roaming SIM.

3.29 By providing access to 999, sites are also providing access to all other services. This allows for consumers who are connected to their contracted MNO to be able to send SMS texts, make standard voice calls, and use data. However, the recipient for any calls and texts must also be connected to their contracted MNO to receive them. It is worth noting that while a consumer may attempt to use data, voice calls are prioritised. With a smaller number of sites available and a larger number of devices connected to one site than normal, a site may become congested and provide a more contended data service than normal.

All MNOs providing voice services

3.30 This objective would require all MNOs to have enough backup to provide adequate voice coverage for their customers and require a larger number of sites to have power backup.

3.31 Providing access to voice coverage from all MNOs would allow consumers to make voice calls and send SMS texts to others, mitigating against some harms such as being unable to contact relatives/dependents. Local Resilience Forums (LRFs) and local councils could also

[32] [✂] response to CFI

benefit as they could use voice networks when co-ordinating responses and carrying about their duties. It would still allow consumers to access 999 services.

3.32 This level of coverage would enable limited access to data services for consumers. While increased backup sites could alleviate network congestion, the primary focus on voice services would not guarantee reliable data connectivity.

All MNOs: voice and 'limited' data capability

3.33 This objective would involve providing a limited data service to consumers, in addition to voice services. This may require a larger number of sites to be backed up to reduce data congestion across sites.

3.34 Providing access to data services may help mitigate against harms that result from not having access to information. For example, having access to news websites, social media, and official websites with useful information (e.g. local council websites, NHS websites, government websites etc.) may allow consumers to find information about the outage and/or related events, empowering consumers to prevent potential further harm.

3.35 Data services can also be used to mitigate other potential harms. For example, data can facilitate the use of a wider range of communication methods, such as instant messaging, potentially improving contact with relatives, dependents, and between communities, services, and staff.

3.36 An increase in the number of backed-up sites may potentially alleviate congestion at specific locations. However, the efficacy of this approach in mitigating congestion for particular data services remains uncertain. While net neutrality regulations are likely to prevent MNOs from throttling specific internet services, consumers may still use bandwidth-intensive services (e.g., video streaming, large file downloads, online gaming), potentially impacting other users' access to data services. Given the limited research on consumer behaviour during power outages, it is difficult to predict how users might respond and the subsequent impact on data service usage patterns.

All MNOs: data and voice services

3.37 This objective would envisage the same services being available would be available if there was no power outage. It should mitigate against all harms of a power outage, as services would be fully operational.

3.38 Sites would still be subject to the same congestion they experience without a power outage and any issues that arise separate from a power outage. This level of coverage and capacity would be expected to provide the most effective level of mitigation against economic and financial harm compared to other network designs.

4. Evaluating Existing Power Resilience

Summary

4.1 This section outlines our post CFI study to better understand the current level of mobile RAN resilience. By analysing detailed information from MNOs, we have significantly improved our understanding of mobile RAN resilience. This study allows us to refine our previous estimate of the UK wide costs associated with hardening the network to prepare for various outage scenarios.

The objectives of the Power Resilience Study

4.2 As outlined in the CFI, the amount of existing power backup within the mobile RAN varies. Some MNOs have a small number of cell sites with days' worth of power backup, often at remote sites or 'hub' cell sites, which other 'child' cell sites rely on. Some, but not all, operators also have battery backup in some form at all of their sites (of a minimum of 10-15 minutes).

4.3 We have previously signalled our plan to conduct a study to better understand the extent of existing power backup in more granular detail.[33] We were keen to understand:

1) what level of power resilience is currently being provided by MNOs;
2) how the existing level of resilience helps address what respondents have told us is necessary to prevent harms during an outage;
3) whether and where power backup may be required; and
4) what magnitude of costs is likely to be required to meet the estimated level of need.

4.4 This report seeks to address the first two questions outlined above. We will be considering scope of work to address answering questions three and four. Though we have updated our estimate of the costs associated with backing up the whole of the UK for one hour using a more sophisticated data set, we can also provide costs for backing up all of the UK's network for more than just one hour.

4.5 We developed a geospatial model to assess the current resilience of mobile services nationwide. This model helped us estimate the gap between current resilience and potential consumer needs during outages. We used these modelling outputs to approximate the costs of implementing additional power backup across the UK's mobile network.

4.6 In future, with more comprehensive datasets, we could potentially refine the model to analyse resilience at a more granular geographic level, including specific rural or vulnerable areas. Additionally, incorporating power outage information may allow us to better target possible solutions and estimate costs.

[33] Statement on Network and Service Resilience Guidance: September 2024, paragraph 8.12-8.13.

The steps taken to prepare this report

4.7 The modelling exercise was carried out to understand the extent of 'current' backup across the four mobile networks at a more granular level. The model captures where masts are backed up and how an outage is likely to impact mobile connectivity per UK premise. For example, if there is an outage, connectivity may be lost immediately, after a set time period and/or partially (so only certain services are available, such as access to emergency calls). This analysis has been done on a UK-wide basis, so the number or percentage of premises impacted will be apparent.

4.8 To achieve this, we requested information from all four MNOs on where they have masts, and what backup, if any, they have at those particular sites.[34] The data was collected in October 2024.

4.9 The model assesses the coverage available to all premises (business and residential), and how that coverage is affected in the case of a mains power outage, based on mast backup and the duration of the outage. This provides an estimate for how many premises might lose mobile connectivity when power is lost for extended periods.

4.10 We noted several key limitations of the datasets available at this time, so we had to make some fundamental assumptions in the modelling process, including:

a) Mobile coverage data: We used data from the MNOs to analyse the predicted mobile coverage, based on the best serving footprint, available to each premise.[35] This data only tells us about the strongest signal from the mast in each area, not about other coverage that might be available in the same area. This makes it difficult to model how different masts overlap and work together, which is a crucial part of designing mobile networks.
b) Power outage data: Ofcom does not have access to information about historical, localised power outages. In the absence of this key dataset, we model a power outage at a UK level only.
c) Premises as a proxy for consumers: as described above, consumers and businesses in the UK are increasingly using communications networks and services for all aspects of their lives either at home, work or on the move. Therefore, it's hard to know where they will need to use a network at any given moment. Premises have been used as a proxy for the impact of loss of coverage for consumers. We recognise that consumers may need coverage away from a premise during a power outage, and that this assumption means some areas (roads and rural areas) where there are no premises will be underrepresented.
d) Consumer behaviour: we do not have data on if, and how, consumer behaviour may change during a power outage. Ideally, consumers connected to a site that has power back up should be able to use all the services, such as voice and data, as normal. However, in practice, more users in the area may connect to these sites as their handsets attach to the remaining (protected) site, thus deteriorating the overall user experience. Modelling the user experience in these situations is complex and hence to keep the analysis simple, we have assumed that the user experience does not change.

[34] Through Ofcom's 2024 Connected Nations process. This process relies on Ofcom's statutory information gathering powers.
[35] Showing coverage at a resolution of 100 metres by 100 metres.

4.11 The modelling helped us to develop a better understanding of the impact of the current level of power back at mobile RAN sites on consumer services. We looked at the impact on both access to emergency services as well as voice and data services that are required to enable the potential policy objectives as set out above. The key findings from the modelling are presented in Section 5.

4.12 When considering any further work, we could potentially work with stakeholders to help improve the modelling parameters and get access to some key data sets (such as localised power cut information). As set out in this report there are a number of sources of uncertainty in our analysis, and this improved information should enable us to improve accuracy of our estimates, and develop more targeted solutions.

5. The outputs of our modelling exercise

Summary

5.1 This section sets out the key findings from our analysis looking into the current backup provisions being provided by MNOs and its impact on consumers in accessing services during a power cut.

Current level of power backup per MNO

5.2 In 2024, Ofcom collected information from all the four MNOs about the location of their masts and the levels of backup provision at those sites.

5.3 At a high level, the provision of power backup provided by MNOs varies significantly between individual MNOs. The table below provides a summary of the current level of power backup in the UK mobile networks.

5.4 [✂]

Table 4: The current level of power backup in the UK mobile networks based on 2024 data per MNO

[✂]

5.5 Looking at the aggregate number of sites may not provide an accurate picture of the power backup provision. For example, many sites are shared between MNOs so the total number of unique sites is [✂]. Ofcom has collected more detailed information that has helped develop a much better understanding.

5.6 [✂]

Table 5: Duration of power backup at mobile sites, based on 2024 data, per MNO

[✂]

5.7 There are various factors that may influence the decision of an MNO to invest in power backup at a mobile site. The responses to our CFI shed some light on some of the reasons for an MNO to choose a site for power backup provision.

5.8 Vodafone explained that sites at the greatest risk of power loss and which benefit less from overlapping coverage should remain the primary focus of power autonomy innovation and improvements. They state they already take this approach on a more informal commercial basis today, factoring in the utilisation of the site, the space available and the frequency of

power disruption. In practical terms, this means the sites (usually in rural areas) that are prone to more power outages, have longer power autonomy factored into site design.[36]

5.9 BT/EE say the market has evolved over recent years with new services introduced that increase data consumption and with legacy technologies retired. They go on to explain 'As a result of these market dynamics, BT has already taken measures to provide power resilience in line with our obligations and to meet customer demand where it exists. As commercial organisations in a highly competitive market where network quality is a key feature to compete effectively, MNOs have an incentive to offer a reliable mobile network connection to its customers including –to an extent– during power outages.'[37]

The impact of current levels of power backup on accessing emergency services

5.10 The analysis we undertook was focused on mobile services required for consumers to access emergency services and on understanding the impact of a power outage on premises that have existing access to it.

5.11 There are various ways consumers can contact emergency services. In 2023, 41.9 million 999/112[38] calls were made in the UK, of which 79% was from a mobile device and 15 % using a landline connection.[39]

5.12 Consumers in the UK can benefit from the Emergency Mobile Roaming whereby if a mobile phone is used to make an emergency call and the provider's own network is not available, the call will automatically roam on to another network that is available in the area. This has a significant bearing on the ability of consumers to access emergency calls despite the coverage or availability of their own network provider in an area.

5.13 To factor in emergency mobile roaming in our analysis, we have combined the mobile coverage provided by all mobile operators to calculate the emergency services coverage.

5.14 As set out in the previous section, we have used the number of premises in the UK as a proxy for the number of consumers. Based on the latest predicted mobile coverage estimates from the mobile operators, almost all of the circa 32 million premises in the UK have coverage from at least one MNO and hence can access emergency services using mobile services.

5.15 The following table sets out the percentage of premises, where consumers of any of the four MNO networks there can access emergency services after different duration of power outage.

Chart 1: Percentage of premises with 999 coverage with respect to power outage duration

[✂]

[36] Vodafone response to CFI, pp. 12.
[37] BT response to CFI, pp. 13.
[38] 999 and 112 is the national emergency response service in the UK. 112 is the pan-European equivalent to 999 and can be used in the UK.
[39] https://www.gov.uk/guidance/999-and-112-the-uks-national-emergency-numbers#the-statistics---2023

5.16 [✂]

5.17 The following images show how access to emergency services through all four mobile networks will change with time in the event of a nationwide power outage. Note that in Northern Ireland phones may be able to roam onto networks deployed in the Republic of Ireland, although we have not considered this in our analysis.

[✂]

5.18 The analysis was based on a network setup that allowed consumers to use voice calls to access emergency services. However, this mobile network configuration does not support certain other use cases, such as emergency video relays for deaf consumers and telecare providers contacting their customers.

The impact of current level of power back on coverage provided by each MNO

5.19 Consumers rely on mobile services for more than just gaining access to emergency calls (999). They will use mobile services to contact friends and family, access crucial information about essential services, and coordinate community responses. To stay connected and access online services, consumers need voice and/or data services provided by their network provider. Unlike emergency services, consumers cannot automatically roam onto another network to access these essential services.

5.20 This means that the power backup provided by each individual MNO is key in enabling its customers (direct or indirect)[40] to access these services in the event of a power outage. [✂]

Chart 2: Percentage of premises with coverage from each MNO with respect to power outage duration

[✂]

5.21 [✂]

5.22 [✂]

5.23 [✂]

5.24 [✂]

[✂]

5.25 [✂]

[40] Some customers may have contracts directly with an MNO but others may be contracted with an Mobile Virtual Network Operator (MVNO), and the latter would rely on the former to provide services.

Subnational breakdown for percentage of premises with 999 coverage

5.26 In addition to a UK-wide perspective of the resilience provided by MNOs, we have also considered how access to 999 services during an outage may vary across different regions and geographic classifications.

Chart 3: Extent of 999 access provided to premises with respect to power outage duration by Nation

[✂]

5.27 [✂]

Chart 4: Extent of 999 access provided to premises with respect to power outage duration by English regions

[✂]

5.28 [✂]

Chart 5: Extent of 999 access provided to premises with respect to power outage duration by rural/urban classifications[41]

[✂]

5.29 [✂]

[41] Classifications derived from Bluewave Geographics: Microsoft Word - LOCALE_Suite_BWG.docx

6. The estimated costs of improving mobile RAN power backup

6.1 In light of the updated modelling data presented in previous sections, the estimated costs for installing power backup on the mobile network have been reassessed. We describe the steps we have taken to derive these estimates.

Stakeholder views on costs to improve RAN power resilience

6.2 Mobile UK argued that economies of scale may be limited as longer power backup requires larger batteries which may not be accommodated within existing street furniture thus requiring additional land.[42] Vodafone explained that sites with under-utilised space, i.e. those most likely to accommodate power backup, may not be the sites that need it.[43]

6.3 The MNOs commented on some additional factors that could influence costs. Three said we should reflect the cost of:

a) a battery refresh programme;
b) replacing stolen batteries and repairing any associated equipment damage; and
c) any additional security measures required to protect the energy asset.[44]

6.4 VMO2 and Vodafone also highlighted the additional costs due to increased risk of fire and theft, as well as the negative impact on the environment[45]. VMO2 noted that costs and feasibility will vary significantly across sites, tight timescales would increase costs, and new build is easier than retrofitting sites[46]

Estimates on the 'per site' cost to improve RAN power resilience

6.5 Our estimates include the cost of replacing batteries, but they may not fully include all the additional costs from increased risk of theft and equipment damage. Given that it is not our area of expertise, we have not factored in the environmental impact but note that there are greener solutions to battery backup (although we do not know the cost for these greener solutions).

6.6 Using our formal powers to request information required to perform our duties, we obtained various cost estimates from the four MNOs for battery-based power backup.

[42] Mobile UK response to CFI, paragraph 16.
[43] Vodafone response to Q.8 of the CFI, page 11.
[44] Three response to Q.1 of the CFI, page 9.
[45] Vodafone response, page 6.
[46] VMO2 response, page 6.

Using this information we have estimated the following lifetime costs[47] per site to install additional power backup (in 2024 prices):

Table 6: Lifetime costs per site to install additional power backup

Battery Duration	15 mins	1hr	2hr	4hr
Average cost per site	£[✂] k	£[✂] k	£[✂] k	£[✂] k
Low-capacity site cost (as a proxy for rural)	n/a	£[✂] k	£[✂] k	£[✂] k

6.7 We found a publicly available source[48] on the potential cost for installing a generator in the US, but they may not be applicable to UK MNOs and were estimated in 2014. Based on this source and applying a consistent methodology for calculating total capital and operating costs over the economic life of a mobile site, we estimate a cost per site to install 3 days of generator power backup of £55k (2024 prices).

6.8 However, it is unclear how these costs may have changed over the last 10 years (we simply inflated by CPI), costs may vary in the UK, and for high capacity (i.e. high power) sites, the duration is likely to be closer to 1-2 days. Finally, there are significant feasibility/practical issues involved with installing generators at a mobile radio access site, e.g. weight and space limitations for some sites.

Estimated 'aggregate' costs to improve RAN Resilience

6.9 We used the 'per site' costs estimates, along with the new modelling data, to update the aggregate costs likely to be incurred to improve resilience across all four MNOs. This includes estimated costs to apply power backup for several time durations. These estimates assume that all sites would be backed up on a UK wide basis, beyond those already backed up.

Table 7: Cost estimates for UK wide power backup for all 4 MNOs

Power backup duration	Scenario	Cost (£million, 2024 prices)
15 minutes	Upper estimate	500
	Lower estimate	250
1 Hour	Upper estimate	2200
	Lower estimate	1100
2 Hours	Upper estimate	3400

[47] These costs are in cash terms (in 2024 prices) and include both capital costs and multiple years of additional operating costs modelled over the economic life of the cell sites.

[48] Backup Power Cost of Ownership Analysis and Incumbent Technology Comparison

Power backup duration	Scenario	Cost (£million, 2024 prices)
	Lower estimate	1700
4 Hours	Upper estimate	4400
	Lower estimate	2200

6.10 These updated estimates tend to align with that included in the CFI. Specifically, we suggested in the CFI that to install a minimum *one hour* of battery power backup across all MNO's RAN sites, where power backup is likely to be feasible, could cost in the region of £0.9 - £1.8bn (in 2023 prices, and based on older power backup and site information).[49] However, we have also provided estimates to improve resilience across all sites beyond one hour and now present costs required for up to 4 hours.

6.11 We have also prepared estimated costs incurred to improve RAN resilience on an individual MNO basis across several time durations in the table below. These estimates reflect the number of sites that are currently backed up.

Table 8: Cost estimates for UK wide power backup for each individual MNO over several time durations (Rounded cost estimates in £m and 2024 prices)

Power backup duration	Vodafone	O2	EE	Three	Total
15 minutes	[✂]	[✂]	[✂]	[✂]	500
1 Hour	[✂]	[✂]	[✂]	[✂]	2200
2 Hours	[✂]	[✂]	[✂]	[✂]	3400
4 Hours	[✂]	[✂]	[✂]	[✂]	4400

[49] Ofcom CFI, 2023. Paragraph 5.23.

7. International comparators

Overview

7.1 Power backup for RAN sites is common practice in many countries, employed for various reasons. To inform our wider understanding on these issues, we conducted an international review, examining how other countries have considered the power backup requirement, the factors influencing these decisions, and the specific details of these requirements, such as the duration of backup and the types of sites covered.

7.2 We briefly cover three diverse countries—Australia, Switzerland, and Norway. These nations, while facing similar challenges as the UK, have adopted distinct approaches to power backup implementation. By touching upon these examples, we can appreciate the various pathways and requirements for deploying effective power backup solutions. Additionally, we provide a brief overview of international standards and regulations pertaining to power backup systems.

Australia

7.3 In response to a particularly devastating bush fire season in 2019-2020, the Australian Government launched its Mobile Network Hardening Program to "strengthen the resilience of telecommunications facilities to allow them to operate for longer during natural disasters".[50] The first round of funding, launched in February 2022, targeted 467 mobile base stations for a minimum of 12 hours of battery backup and 532 upgrades. This consisted of new portable and permanent generators, increasing power backup capacity, improving transmission resilience in network clusters to reduce single points of failure, and physical hardening against bushfire damage.[51] All of these sites were part of the Australian Government's Mobile Black Spot Program.[52]

7.4 More recently, in its second round of funding announced in September 2023, the Mobile Hardening Program looks at improving resilience across multiple sites. The second round of funding specifically looks at "upgrading power capacity to a minimum of 12 hours" and "delivering emergency power solutions, including generators".[53] It specifically targets more rural sites and those that are at risk of natural disasters.

7.5 In some countries, power backup is required either through regulation or legislation (see 7.13). However, in Australia there is no legal requirement for MNOs to provide mobile sites with power backup. To promote the installation of power backup, the Australian Government provides grants to MNOs who fulfil a criterion in each round of funding. The criteria in the previous rounds of funding have targeted specific sites in areas which are

[50] https://www.infrastructure.gov.au/media-communications-arts/phone/mobile-network-hardening-program
[51] https://www.infrastructure.gov.au/media-communications-arts/phone/mobile-network-hardening-program
[52] https://www.infrastructure.gov.au/media-communications-arts/phone/mobile-services-and-coverage/mobile-black-spot-program
[53] https://www.infrastructure.gov.au/sites/default/files/documents/MNHP-Round-2-Grant-Opportunity-Guidelines-final-31-aug.pdf

more likely to be impacted by power outages and natural disasters.[54] However, there is a legal requirement for communication service providers to ensure access to the emergency call service which may lead to some MNOs having power backup in place already due to the rurality of some parts of Australia.[55]

Norway

7.6 Similar to Australia, Norway's plans to introduce power backup for RAN sites started with natural disasters. During storm Dagmar in 2011, 40,000 users were unable to use their mobile networks due to the damage caused by the storm. The then Chief of Nkom, Torstein Olsen, stated that Norwegians were unable to reach health services and municipalities were unable to implement their emergency coordination.[56]

7.7 The decision to implement power backup was taken in 2014 by Nkom, the country's telecommunications regulator. Nkom has powers to implement power backup through regulation via the Electronic Communications Act 2003, which states that providers shall implement measures related to security and preparedness, which may include the "introduction of special functions and services in electronic communications networks".[57] In 2015, the Norwegian Government upheld Nkom's decision after minor adjustments over the implementation period. The Norwegian Government also upheld the decision that MNOs must pay for the upgrades themselves.[58]

7.8 The regulation requires a minimum of 2 hours of backup on cell sites and 4 hours of backup for sites in more rural areas.[59] Since 2015, backup has been installed at all sites that NKOM have deemed to be eligible. In terms of funding, MNOs are expected to cover the costs themselves. However, a government funded program was created to reinforce specific sites of importance (e.g. in municipality and city centres) beyond the obligations already set out.[60]

Switzerland

7.9 The Swiss Federal Office for Civil Protection carries out and maintains a national risk analysis of disasters and emergencies in Switzerland. This is a compilation of the broad range of disasters and emergencies Switzerland can face, scenarios associated with them, and assessing the likelihood of these scenarios.[61] Scenarios in the risk catalogue provided the basis for requiring power backup on RAN sites.

7.10 In November 2023, Bakom, the Swiss regulator, launched a consultation on introducing secondary legislation, amending the Ordinance of 9 March 2007 on Telecommunications

[54] https://www.infrastructure.gov.au/media-communications-arts/phone/mobile-network-hardening-program

[55] Telecommunications (Emergency Call Service) Determination 2009.

[56] https://www.aftenposten.no/norge/i/GGRrJ/post-og-teletilsynet-vil-ha-reservestroem-til-mobilnettene (in Norwegian)

[57] Electronic Communications Act 2003, Section 2-10

[58] https://www.regjeringen.no/contentassets/0c8cc18666a1468889983a5a5b8aa303/vedtakklage28042015.pdf (in Norwegian)

[59] Nkom's IRG survey response

[60] https://nkom.no/sikkerhet-og-beredskap/nkoms-program-for-forsterket-ekom

[61] The National Risk Analysis of Disasters and Emergencies in Switzerland (admin.ch)

Services. The amendment would require MNOs to establish power backup on RAN sites to provide access to emergency calls, public telephones services, and internet access for a continuous 72 hours (or 14 days for cyclical blackouts).[62] The legislation also featured the power for MNOs to restrict telecommunication traffic, specifically data-heavy internet services for the use of entertainment.[63]

7.11 The Provisions allow five years for MNOs to provide emergency calls, and a further three years to guarantee access to telephone and internet services, with the costs of the transition borne by operators.

7.12 Responses to the consultation were mostly positive, particularly from emergency services. However, MNOs had a generally negative response due to the cost of installing power backup, estimated to be around CHF145 million per year.[64] This has left open the question of funding and whether MNOs will have to pass prices onto consumers or if there would be a government scheme available. As the policy is yet to be decided, this is subject to change.

The Wider Landscape

7.13 The following table provides a comprehensive overview of countries with existing requirements or schemes for power backup on RAN sites. It highlights key differences in regulatory requirements, implementation methods, underlying motivations, pre-existing infrastructure, and funding responsibilities across various nations. The information was gathered from a mix of desk research and engagement with other regulators.

Table 9: Summary of international approaches to RAN power resilience

Country	Hours of backup required through legislation or regulation	Hours of backup known if no requirement specified	Implemented through	Causes for introducing requirement	Pre-existing infrastructure	Responsibility for funding
Australia	No obligation	12 hours (for a limited number of sites)	Government scheme	Natural disasters	Some rural sites had power backup	Government
Austria	No obligation	30 mins – a few hours	MNOs	Not available	N/A	MNOs
Belgium	Not specified[65]	1 – 2 hours for most sites	MNOs	Not available	N/A	MNOs

[62] https://www.bakom.admin.ch/bakom/en/homepage/ofcom/organisation/legal-framework/consultations/consultation-resilience-mobile-networks.html
[63] https://www.bakom.admin.ch/bakom/en/homepage/ofcom/organisation/legal-framework/consultations/consultation-resilience-mobile-networks.html
[64] https://www.bakom.admin.ch/bakom/en/homepage/ofcom/organisation/legal-framework/consultations/consultation-resilience-mobile-networks.html ; https://www.swissinfo.ch/eng/swiss-politics/swiss-telecoms-firms-fight-demand-for-blackout-coverage/72635774
[65] There is not an obligation specifically for power back-up but there is a legislative requirement to provide uninterrupted access to emergency services and to take appropriate measures (derived from EECC art.40)

Country	Hours of backup required through legislation or regulation	Hours of backup known if no requirement specified	Implemented through	Causes for introducing requirement	Pre-existing infrastructure	Responsibility for funding
Bulgaria	No obligation	4 – 24 hours (depending on rurality)	MNOs	Issues with the power network	N/A	MNOs
State of California	72 hours (high-risk fire areas)[66]	N/ A	Regulation	Wildfires	Not available	MNOs
Estonia	≥3- ≥6 hours (depending on rurality)[67]	N/A	Legislation	Natural disasters and security	Not available	MNOs
Finland	≥2- ≥6 hours (depending on rurality, with exceptions) [68]	N/A	Regulation	Natural disasters	Not available	MNOs
Greece	Not specified[69]	Varied	Legislation	Security	N/A	MNOs
Hungary	Not specified[70]	Varied	Legislation	Security	N/A	MNOs
India	No obligation	Varied[71]	MNOs	Issues with the power network	N/A	MNOs
Ireland	Not specified[72]	10 mins – 8 hours (site dependent) [73]	Legislation	Security of networks	N/A	MNOs

[66] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M343/K979/343979403.PDF
[67] https://www.riigiteataja.ee/akt/126022021011?leiaKehtiv (in Estonian)
[68]https://www.kyberturvallisuuskeskus.fi/sites/default/files/media/regulation/Regulation_on_resilience_of_communications_networks_and_services_and_of_synchronisation_of_communications_networks.pdf
[69] There is no specific legislation for power back-up but instead legislation for protections against interruptions or disruptions from the public energy supply network. Decision of ADAE 28/2024 "Regulation on the security of electronic communications networks and services" (in Greek).
[70] There is no general legal or regulatory obligation for MNOs to have back-up power in their RAN. However, MNOs are required to identify if specific elements are critical infrastructure. If so, MNOs must plan mitigations against risks which may include, but not required, providing power back-up.
[71] https://economictimes.indiatimes.com/keeping-india-connected/articleshow/51596388.cms?from=mdr [Accessed December 2024]
[72] MNOs have no specific obligation for power back-up but are required to take appropriate measures to manage risks posed to the security of networks and services under the Communications Regulation and Digital Hub Development Agency (Amendment) Act 2023.
[73] Climate Change and its Effect on Network Resilience – A study by Frontier Economics | Commission for Communications Regulation (comreg.ie). New study due early 2025.

Country	Hours of backup required through legislation or regulation	Hours of backup known if no requirement specified	Implemented through	Causes for introducing requirement	Pre-existing infrastructure	Responsibility for funding
Japan	Minimum 24 hours near Government offices[74]	4 – 72 hours (depending on site)[75]	Regulation and MNOs	Natural disasters	Separate base stations specifically for emergencies	MNOs
Malta	No obligation	30 mins – 3 hours	MNOs	Not available	N/A	MNOs
Norway	≥ 2 hours - ≥ 4 hours (depending on rurality)	N/A	Regulation	Natural disasters	Some rural sites had power backup	MNOs[76]
Romania	1 - 3 hours (depending on rurality, 6 hours for hub sites)[77]	N/A	Regulation	Issues with power network	All MNOs have backup installed already	MNOs
Slovenia	2 hours[78]	N/A	Legislation	Security and business continuity plan	Not available	MNOs
South Africa	No obligation	~8 hours[79]	MNOs	Issues with the power network	N/A	MNOs
Sweden	≥1- ≥ 4 hours (dependent on rurality)[80]	N/A	Regulation	Issues with the power network	Not available	MNOs[81]
Switzerland	Under discussion	N/A	Legislation	Security	N/A	MNOs

[74] MNOs are required to provide power back-up near government offices through the Standards for Safety and Reliability of Information and Communications Networks: https://www.soumu.go.jp/menu_seisaku/ictseisaku/net_anzen/anshin/ (in Japanese)

[75] Levels of backup vary between operators. For example, https://www.softbank.jp/en/sbnews/entry/20220318_01

[76] There is a government funded program aimed at reinforcing important coverage sites (e.g. in municipality and city centres). This funding is not directed at meeting the power back-up obligations, but rather for increasing general service availability for the population.

[77] https://www.ancom.ro/formdata-1130-48-2289 (in Romanian)

[78] For voice and SMS services only: https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina/2023-01-2991/splosni-akt-o-varnosti-omrezij-storitev-in-podatkov (in Slovenian)

[79] now.vodacom.co.za/article/how-is-vodacom-affected-by-load-shedding

[80] https://pts.se/regelbibliotek/foreskrifter-och-allmanna-rad-202211-om-sakerhet-i-nat-och-tjanster/ (in Sweden)

[81] Funding was provided by the government through the Swedish regulator to improve resilience on the island of Gotland due to its distance away from the mainland and historical power outages.

8. Key considerations for improving power resilience on the RAN

Overview

8.1 The previous sections have set out the key findings from our analysis. We now turn to what implications these insights might have for a consideration of power resilience on the RAN. This section sets out the areas and factors to which further consideration needs to be given, these include:

- Defining critical needs during power outages, encompassing both coverage and duration, and determining the essential services to maintain, such as 999 access;
- The extent to which MNOs may improve resilience without regulatory intervention;
- The enhancements to the Emergency Services Network (ESN) and how these may affect general network availability;
- The current and planned investments in electricity supply and restoration;
- The potential gains to be had from improved communication and coordination between the power and telecoms sectors;
- The wider impacts resulting from improvements to power resilience, such as environmental and operational factors; and
- The potential role for new technology and solutions (such as satellite) in improving overall resilience.

8.2 The scope and timing of any possible next steps will aim to include the following discussions.

To what extent should resilience on the RAN be hardened to enable 999 access?

8.3 Respondents to the CFI highlighted reliable access to emergency services, such as 999, as a critical need during power outages.

8.4 Based on available data, approximately two thirds of UK premises can maintain emergency mobile connectivity for up to one hour during a power outage.

8.5 [✂]

8.6 Given [✂], it is worth considering if additional hardening of the network is required, and if so, how should that be done.

8.7 It is currently uncertain whether further hardening of the mobile network, to enable access to 999 services during an outage, is necessary for all premises. A significant portion of UK premises, potentially the majority, may rarely experience power outages, and the cost of

providing backup power to masts serving these premises may outweigh the potential benefits. Premises being serviced by mast sites with existing levels of backups may well have been deliberately targeted as they are located in areas with known or predicted outage risks.[82] Further data identifying locations most susceptible to outages could inform questions about the strategic hardening of the existing network.

8.8 Some MNOs suggested that rather than hardening the mobile network to ensure consumers can contact 999 services during an outage, that more could be done to improve 'in home' resilience.[83] In particular, the provision of a battery backup unit (BBU) to service the broadband router may allow consumers with a Digital landline replacement Voice over IP (VoIP) service to make calls in the event of a power outage. However, the duration for which this facility is available will depend on the power resilience of the in-home battery, any street cabinets that are used to support the broadband service and that of the exchange (or similar site). We plan to explore the possibility of analysing the resilience of fixed networks to power failure as part of future work in this area.

8.9 It is also unclear how long networks should be able to withstand disruptions. However, data from Ofgem on national power outages may provide some valuable insights. Approximately 60-70% of domestic outages last between 3 minutes and 1 hour. Moreover, roughly 90% of domestic outages are less than 3 hours, and 93% are less than 4 hours. This could suggest that backing up masts for longer than this time, may not be necessary in all cases. However, we note that several respondents to the CFI did highlight that their own experience of actual outages tended to be measured in days and weeks rather than hours. Vodafone noted that longer outages, such as those experienced with Storm Arwen, are unlikely to benefit from MNO battery investment, and tactical emergency generator deployment is more effective to ensure power is maintained.[84]

8.10 In addition to identifying where, and for how long, the network needs to be strengthened, it is useful to consider what might be the most effective approach for improving resilience. In section 3 above, reference was made to a 'network of last resort' that would be an arrangement put in place to ensure all consumers (or premises) could access 999 services for a given duration during an outage. This could either be a:

a) a co-ordinated optimisation of power resilient UK emergency call coverage, which would require battery backup across different MNO RANs; or
b) one MNO, with power backup, could be designated a network of last resort to provide emergency call service to consumers.

8.11 We do not currently have the data available to estimate the costs involved in providing the first option. We have estimated the cost of the second option, which we suggest would be in the region of £1bn to improve power backup for one of the MNOs to reach all of the masts in the UK.

[82] Vodafone Response to CFI, response to question 10.
[83] Vodafone Response to CFI, response to question 2.
[84] Vodafone response to CFI, paragraph 11.

To what extent should the RAN be hardened to enable Business as usual (BAU) services

8.12 Respondents to the CFI pointed out that, while access to emergency services was the priority, users would experience harm if they did not have access to other mobile services during an outage, such as the ability to make normal (non-999) calls to friends and family, send messages using data services and be able to use the internet to access information.

8.13 All non-999 services would require users to be connected to their own mobile operator. Unlike emergency calls, these services would not allow roaming onto other MNOs' networks.

8.14 [✂]

8.15 A major concern is the potential impact on vulnerable users who rely on video text relay services to contact emergency services. During and post the first hour of an outage, these users would encounter substantial difficulties in accessing critical emergency assistance. Additionally, emergency SMS services would be disrupted.

8.16 Hardening the mobile RAN to ensure uninterrupted BAU services for all UK premises during outages would incur significant costs. We estimate that upgrading all networks to provide 4 hours of BAU service across the UK would cost approximately £4.4bn.

Does the market provide an adequate level of resilience?

8.17 The MNOs suggested that the mobile market correctly values power backup. Three, Vodafone and VMO2 indicated that, in general, consumers are not willing to pay a higher price for enhanced power backup, particularly in an environment where services are generally resilient.[85] BT explained that it has already implemented power resilience measures to meet consumer demand where it exists as MNOs have an incentive to offer a reliable mobile service.[86]

8.18 Three said that DNOs already provide high levels of availability, the costs to back up are prohibitive and short-term power outages are de-minimis in comparison to the overall network availability and any other outages due to planned activity. In areas of high population density, where the impact of short-term power loss is most felt, there is overlapping coverage from adjacent sites. Thus, a loss of power at one cell site does not necessarily imply a total loss of service.[87]

8.19 Stakeholders indicated there may be consumer groups who would particularly value power backup, including businesses, vulnerable consumers and customers affected by extreme weather events. However, there are not enough of these customers to fund additional battery investment.

8.20 It is not clear if the market provides a level of resilience that meets consumers' needs. Further analysis would be needed before reaching such conclusions, including an

[85] Vodafone, VMO2 and Three response to Q9 in CFI.
[86] BT EE response to Q9 in CFI.
[87] Three response to Q2 in CFI

assessment of any positive externalities that might go beyond the scope of the telecoms regulator. However, due to behavioural biases, we might speculate that resilience may not always factor into consumers' purchasing decisions even though it is something that consumers may value when a power outage occurs. This may particularly be the case where a customer loses access to 999 services because of a power outage given the infrequency of such an event and yet the potentially very large harm.

Funding and impact on mobile investment

8.21 MNOs argued that the commercial value for improved resilience is not sufficient to allow them to fund additional investments in power backup. VMO2 argued that consumers would be unwilling to pay for significant investments in power backup, particularly when the mobile market is highly competitive with many MNOs facing insufficient returns.[88] Vodafone argued that most consumers would willingly opt for a lower cost service from a mobile provider with less power backup.[89]

8.22 We note that even if consumers are not willing to pay for the additional costs from improving power backup, this might be due to behavioural biases such as present bias which could justify a market intervention. In the event a minimum requirement for power backup was introduced for all MNOs, there is a high likelihood that the cost of any investments by MNOs could be pushed onto consumers by raising prices, even in a competitive market.

8.23 MNOs also argued that improving battery backup would divert funding from 5G rollout or other innovations.[90] They therefore suggest a range of alternative funding options for additional power backup, e.g. Annual Licence Fee reform or a cross-sector fund or state funded.

The planned enhancements to the Emergency Services Network (ESN).

8.24 The current analysis does not take into account potential enhancements to the ESN. The ESN is a dedicated mobile network in the UK designed specifically for use by emergency services and other authorised first responders. The ESN was built by EE by upgrading around 19,500 of its existing sites, deploying 650 more 4G masts in rural areas and building new sites.[91]

8.25 We note that the Home Office has agreed a new contract with BT and EE to continue the development of the Emergency Services Network (ESN).[92] The published communications on these developments state that the ESN requires greater resilience than is generally provided by a commercial network to ensure that the mission critical communications are always available. The published update also states that new contractual arrangements

[88] VMO2 response to Q9 in CFI.
[89] Vodafone response to Q9 in CFI.
[90] VMO2 response to CFI pp 6; Vodafone response to 11 in CFI.
[91] https://business.ee.co.uk/large-business/esn/
[92] https://www.find-tender.service.gov.uk/Notice/024046-2024?origin=SearchResults&p=1

involve the installation of generators and batteries to certain sites (noting that the EE have currently fitted c. 800), to ensure that there are backup power sources.

8.26 These developments could provide a significant improvement to the existing level of resilience of the network that has not been taken into account in this analysis as it is not available. To understand the nature and extent of these potential improvements and how they may affect forward-looking perspectives on resilience, it may be helpful to incorporate likely plans into our models as such details become available.

The investment in the power grid in the medium term

8.27 The MNOs were particularly keen to ensure that this whole discussion should involve greater engagement with the energy sector. [93] They emphasised that mains power is a critical input to all types of communications services and yet MNOs had limited control on the resilience of the grid itself. They argued that focus should be placed on the resilience of Distribution Network Operators (DNOs) to reduce the frequency and duration of outages.

8.28 Despite this, the MNOs noted that the power grid is relatively reliable, referring to the range of 'customer minutes lost per annum' for different DNOs from Ofgem data. Mobile UK noted the average 'customer minutes lost' (CML) across the UK was 32 minutes in 2022.[94] Vodafone noting the best performing DNOs experience an average of around 13 customer minutes lost per annum (and 15 customer interruptions per 100 customers).[95] Mobile UK stressed the significant geographical variations. For example, they quote Ofgem data on DNO reliability that suggests in 2021/22 that Scottish Hydro reported 57 customer interruptions per 100 customers and 56 minutes lost per customer, whereas London Power Networks reported 15 customer interruptions per 100 customers and 13 customer minutes lost.[96]

8.29 Attention was drawn to Ofgem's five-year plan (published in June 2022 as part of its draft plans for its electricity distribution price control, or RIIO-ED2) to enable £20bn to be spent on improvements to the reliability and speed of restoration of the power network.[97]

8.30 We recognise the efforts of the energy industry – including through further investment in the upcoming RIIO-ED3 processes – to improve the resilience of electricity networks.[98] Ofgem have noted that this will, among other things, boost resilience to prevent power

[93] Including Vodafone, VM02 and Three
[94] Mobile UK response to CFI, pp 1.
[95] Vodafone response to CFI, paragraph 10.
[96] https://www.ofgem.gov.uk/sites/default/files/2022-11/RIIO-ED2%20Final%20Determinations%20Core%20Methodology.pdf
[97] Ofgem stated that the 2023 to 2028 plan will boost grid capacity, improve customer service and resilience to prevent power outages, and prepare the way for increases in the generation of cheaper, greener, home-grown energy to bring down bills in the long-term. https://www.ofgem.gov.uk/publications/ofgem-reveals-landmark-five-year-programme-deliver-reliable-sustainable-energy-lowest-cost-consumers
[98] Ofgem's RIIO-ED3 is a regulatory framework for the electricity transmission, gas transmission, and gas distribution networks in the UK. It sets out how network companies will be allowed to recover their costs and make a fair return on their investments during the period 2026-2031. https://www.ofgem.gov.uk/decision/riio-3-sector-specific-methodology-decision-gas-distribution-gas-transmission-and-electricity-transmission-sectors

outage.[99] We recognise that even with further investment in resilience, energy networks may still be subject to outages, for example during extreme weather.

The benefits and opportunities for collaboration, information sharing and coordination between mobile operators and DNOs when outages occur

8.31 Respondents to the CFI suggested improved collaboration across the energy and telecoms sectors. Some highlighted the Electronic Communications Resilience & Response Group's (ECRRG) Post Incident Review following the 2022 storms[100] which included a recommendation for improved communication & collaboration between the sectors.[101]

8.32 The key opportunities for closer collaboration we have noted from the CFI responses included:

a) Prioritising the restoration of power to mobile sites as quickly as possible. Respondents pinpointed areas with no overlapping coverage or those serving as network hubs. This would enable effective communication between power companies, service providers, and consumers, as well as ensuring access to emergency services and loved ones[102];
b) Sharing of information about the location of power outages and recovery timescales, including a single source of outages database;[103] and
c) A more concerted effort to learn from previous power outages by collecting, examining and sharing:

   i) data on historical power outages,[104]
   ii) any relevant research and reports[105], and
   iii) useful advice for communities and local authorities on power resilience.

8.33 We agree that this issue requires cross sector collaboration. This report, and any next steps, are intended to facilitate open, wider discussion across relevant stakeholders about how to address any potential harms resulting from a lack of power resilience to the mobile sector.

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[99] Ofgem press release, 29 June,2022. https://www.ofgem.gov.uk/press-release/ofgem-reveals-landmark-five-year-programme-deliver-reliable-sustainable-energy-lowest-cost-consumers

[100] The EC-RRG is an industry group that takes the lead in developing and maintaining cooperation between the communications sector and the government on issues regarding resilience and emergency planning.

[101] BEIS, DCMS/DSIT, Ofcom, Ofgem, CP's & Distribution Network Operators (DNO's).

[102] Vodafone noted in their CFI response (paragraph 12) that they were trialling a priority site restoration exercise with National Grid In Cornwall.

[103] BT highlighted two of the key actions in the ECRRG Post Incident Review focused on improved information from the energy sector to make informed operational decisions and a higher level of priority for info sharing for CNI providers. Specifically, the development of a single source power outages map, covering the entire UK would enable operators to take decisions on deploying generators and engineer deployments.

[104] Consumer Scotland suggested in order to a make a granular risk assessment, it would be important for Ofcom and MNOs to access sufficiently detailed data on power cuts for sites and regions to be prioritised.

[104]Azenby suggested that MNOs should have visibility of the government's predictions on power availability year on year in additional to historical data.

[105] For example, Consumer Scotland noted the Storm Arwen Review Final Report recommendation for Energy Emergencies Committee to conduct a review with Ofgem into the 'worst served customers' process can be expanded to include a framework to conduct community risk and contingency assessments, prioritising those communities judged to be at high risk of disruption.

8.34 We will continue to work with energy and telecoms sectors, through well- established mechanisms, such as ECRRG and discussions with Ofgem, to support further collaboration. However, we recognise that legislative changes, required for example to enable priority of mobile site restoration, remain matters for the government.

Environmental considerations

8.35 MNOs noted have existing net-zero commitments that must be considered when planning power resilience solutions.[106] [107] Several MNOs also raised the concern surrounding the usage of diesel generators, due to the level of emissions and noise pollution that they can create[108]. Others noted that, while generators are typically diesel-powered, biofuel alternatives can reduce environmental impact. [109]

8.36 Concerns were raised over the environmental impact of battery technology, citing unsustainable mineral sourcing and toxic disposal challenges.[110] The MNOs proposed utilising more renewable backup power, citing their investment in self-powered masts as an example.[111]

Feasibility and implementation considerations

8.37 VMO2 proposed a site audit of all sites to assess the feasibility of backup solutions. Site types, particularly rooftops and monopoles, will significantly impact the suitability of different solutions due to the wide range of locations.[112]

8.38 MNOs also noted that battery backup systems, while essential, pose risks such as fire and theft. Mandating minimum battery life could inadvertently increase theft risk, as these batteries are valuable and sought-after for solar energy storage. This could lead to increased damage and service disruptions.

8.39 The real threat of theft is evidenced by past targets like street cabinets and cell sites. Increasing security can be costly and potentially damage sites, harming customer service. Additionally, power outages could exacerbate the risk of battery theft due to increased demand.

8.40 MNOs highlighted several challenges that could delay the deployment of power backup solutions. These include limited supply chain capacity for hardware, particularly batteries; a shortage of skilled staff to implement the changes, which could drive up costs and timelines; complex commercial negotiations and planning permissions; and technical feasibility constraints. Additionally, physical limitations, such as limited space or capacity at

[106] Vodafone stated that they have “very clear fiduciary and environmental commitments that would make it difficult for us to adopt certain technology approaches”: Vodaphone response to CFI paragraph 22
[107] VMO2 suggested that “environmental matters and commitments to net zero ought to be a factor” when suggesting measures: VMO2 response to CFI pp.8
[108] Vodafone, VMO2, Cellnex, and Mobile UK responses to CFI
[109] Cellnex response to CFI pp.3
[110] BT response to CFI pp.4
[111] Vodafone response to CFI paragraph 22
[112] VMO2 response to CFI answer to question 5

many sites, could require significant retrofitting work, increasing costs and potentially making deployment impossible in certain locations, especially roadside and rooftop sites.

The potential for satellite D2D capabilities in the UK

8.41 Satellite technology is evolving, enabling Direct-to-Device (D2D) communication through existing mobile phone bands. This complements terrestrial networks, offering potential benefits in remote and underserved areas. The Ofcom team have been looking into the potential benefits of these D2D developments and have set out an explanation of our current thinking in annex A1 and we would encourage readers to examine these initial observations in detail.

A1. Direct-to-Device Satellite communications

Background

A1.1 Satellites have long provided voice calls and data using spectrum allocated internationally by the International Telecommunication Union (ITU) for Mobile Satellite Services (MSS).[113] These services were traditionally costly and targeted enterprise use cases. However, Direct-to-Device (D2D) MSS is now available for some mass market consumer handsets, e.g., Apple 14 and more recently Pixel 9, primarily limited for messaging services. Recent technology developments and the launch of new satellites has enabled D2D using spectrum used by the Mobile Network Operators (MNOs) bands and has the potential to serve existing 4G and 5G mobile devices.

A1.2 Owing to advancements in satellite launch technology, satellite antenna systems, and computational power, satellite D2D technology is undergoing active development within the 3GPP[114] standards as a solution to complement and supplement terrestrial mobile networks, enhance service continuity, and extend outdoor coverage to mobile devices in remote and hard-to-reach regions.

A1.3 D2D can be provided from Geostationary Earth Orbits (GEO) or Non-Geostationary Orbits (NGSO), such as Low Earth Orbits (LEO) and Medium Earth Orbits (MEO). LEO satellites, due to their proximity to the ground, offer lower latency and propagation losses; however, they require large-scale constellations for continuous coverage.

A1.4 Satellite networks, including D2D, consists of three segments: 1) a user terminal which is a mobile handset in the context of D2D; 2) a satellite in orbit, providing service access and connecting user terminals and the gateway; and 3) a gateway that offloads user traffic from the satellite to the core network and then routed to data networks or the internet.

A1.5 Given the growing interest in D2D, we ran a Call for Input (CFI) over the summer seeking stakeholder views on the potential benefits of D2D services (and other MSS services) in the UK and industry interest in offering these services. The CFI, responses, statement, and next steps can be found on the Ofcom website.[115] The CFI identified industry interest in expanding existing MSS services and introducing D2D in mobile bands. Some of the responses highlighted the role D2D could play in improving the resilience of services delivered over terrestrial mobile networks, although capacity limitations were acknowledged. Following our CFI and consideration of these responses, we consider that there is scope for improved connectivity from the sky and space to support economic growth and enable a number of potential citizen and consumer benefits in the UK. We plan to consult on specific proposals to authorise Direct to Device satellite services in mobile

[113] The ITU defines MSS in Article 1.25 of the Radio Regulations.
[114] 3rd Generation Partnership Project (3GPP) is a collective of standards organisations which develop system description for mobile telecommunications, including radio access, core network and service capabilities.
[115] https://www.ofcom.org.uk/spectrum/space-and-satellites/improving-mobile-connectivity-from-the-sky-and-space/

bands in the UK in early 2025. Subject to consideration of stakeholder responses and our final decisions this could enable such services to be offered to consumers later in 2025.

D2D vs terrestrial networks

A1.6 It is too early to establish a view on the exact role D2D will play and by when, since this will depend on the techno-economics, actual deployment timelines, and configurations by satellite network operators, such as the number of satellites, orbits, and gateways. While we can form some expectations based on international filings through the ITU and FCC,[116] these expectations will require constant monitoring until we have factual data to back any alternative views.

A1.7 Terrestrial mobile networks remain essential for mobile service access in the UK, covering 95% of the landmass with 4G and providing 5G coverage for 95% of outdoor premises.[117] Given the larger scale of terrestrial 4G and 5G networks, and the shorter distances between base station and mobile handsets compared to non-terrestrial networks, they offer greater network capacity.

A1.8 Compared to terrestrial mobile networks, D2D satellites deliver lower data rates because of the higher propagation losses between satellites and mobile devices on the ground and because there are generally fewer D2D satellites covering the same region due to their larger service area of each D2D satellite. As such this makes them useful for providing extended coverage rather than a capacity rich solution that might replace terrestrial infrastructure.

A1.9 Different solutions for network resilience have different outcomes, such as redundancy in infrastructure, geographical diversity, and technology fallback options, addressing different mean times between failures across the network. While D2D can provide a fallback option when the terrestrial network is unavailable, its traffic must be offloaded from satellites to gateways and routed through terrestrial networks. Regional power outages or natural disasters may affect both terrestrial base stations and satellite gateways.

A1.10 With fewer satellites and even fewer gateways, in the short and medium terms, especially in the hardest-to-reach, resilience measures should be considered carefully to avoid substituting a single point of failure with another. This can be mitigated by incorporating redundancy in network nodes, power backups, enabling technologies like inter-satellite links, or by having multiple D2D constellations establish roaming agreements to enhance service resilience. Assessing the D2D potential benefits requires benchmarking against existing network infrastructure to determine the most effective outcomes and solutions for each region.

Factors affecting D2D service support in the UK

A1.11 The support of D2D for communications services, including emergency services, depends on the type of service (messaging, voice, video) and the availability of network resources, including deployment scenarios, scale, technology implementation, device support, and

[116] ITU filings are available at BR IFIC or ITU Space Explorer. FCC filings are available at IBFS.

[117] https://www.ofcom.org.uk/phones-and-broadband/coverage-and-speeds/connected-nations-2024/

spectrum availability. This section will focus on the deployment and technology aspects of D2D in supporting these services and providing simultaneous coverage in time and space.

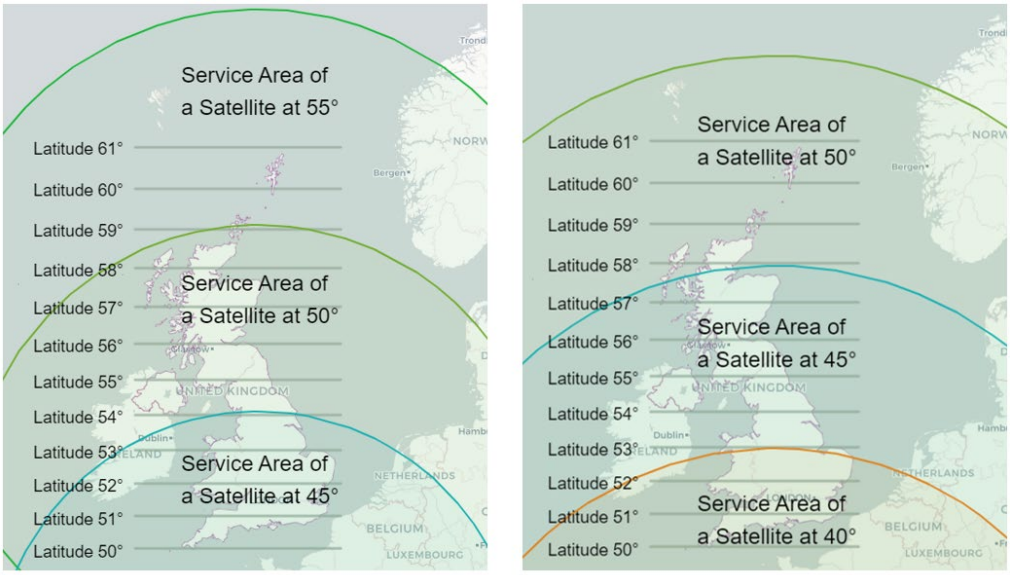
Deployment scenarios

A1.12 D2D coverage from LEO in the UK depends on satellite constellation variables, including orbital parameters,[118] and deployment scale. The number of satellites passing over the UK[119] alongside their technology implementation will have direct impact on the service area, continuity, and reliability, especially for voice and video calls. Note that the majority of the world population lives between ±50° latitudes,[120] outside the UK's latitudes 50°-61°. Therefore, satellite network providers may optimise their constellations for these regions, resulting in fewer satellites passing over the UK.

A1.13 Given the UK's northern location, spanning latitudes 50° to 61°, satellites with inclination angles between 50° and 90° provide good visibility for user terminals, as shown in Figure 1, which is essential for coverage and service continuity. Consequently, satellite coverage during the day may be limited especially in the northern parts and must be assessed case-by-case.

[118] Orbital parameters refer to satellite orbit height and inclination angle, which is the angle of a satellite's orbit relative to the equator.
[119] For LEO satellites, inclination angle of a satellite controls its trajectory. 0° inclination means the orbit is exactly above the equator, while 90° inclination means the orbit passes over the north and south poles.
[120] SEDAC Gridded World Population Density – Earth.Gov

Figure 1 Satellite Service Area from orbits relevant to the UK achieved from various inclinations. A satellite with a service beamwidth of 116°, placed at an inclination of 50° or higher can provide good visibility and coverage in the UK, including the northern parts. The service area is dependent on orbit height as well. Instantaneous service area of satellites changes dynamically with respect to their relative position - the presented plots show the service area limits for the specified inclination angles and heights over the UK.



Satellite Height: 550km Satellite Height: 730km

Source: Ofcom

Technology implementation and service support

A1.14 Terminal design specifications directly impact service reliability. Key parameters include antenna systems' performance, mobile devices' power limits, spectrum plans (MSS or MNOs), terminal receiver sensitivity, and end-to-end network capacities. Satellites differ by antenna design, such as regenerative,[121] transparent, [122] and their use of inter-satellite links (ISL). Larger antenna arrays allow smaller beams, better spectrum reuse and coverage, while ISL can improve service handover, continuity and resilience.

A1.15 Spectrum plans impact D2D accessibility, as handset compatibility depends on the spectrum used. Existing mobile phones can use D2D services in MNO spectrum without modifications. However, D2D in MSS spectrum is limited and may require hardware or firmware updates, depending on the RF chipsets used. Therefore, D2D in MSS spectrum may require customers migrating to newer models with D2D capabilities.

A1.16 In the northern parts of the UK with limited number of satellites, D2D may be limited to messaging. While conversational voice can be supported from LEO, availability during the day and call durations depend on the number of satellites in relevant orbits to handle handover and ensure service continuity. The same challenge applies to video calling, with

[121] A regenerative satellite regenerates incoming signals with digital signal processing techniques such as demodulation, decoding, switching, encoding, and modulation.
[122] A transparent satellite can only amplify, forward, and switch the frequency bands of the incoming signals without digitisation, advanced detection, and transmission techniques.

an additional challenge of uplink limitations due to mobile devices' finite power budgets leaving no sufficient margin for service protection and stability. D2D provision from GEO will suffer more from the finite power budget on mobile devices as the greater altitude of these orbits imposes higher propagation losses and latency.

Simultaneous coverage and capacity trade-off

A1.17 Satellites over southern parts of the UK provide optimal coverage and capacity locally but providing coverage to northern areas is suboptimal, costly and reduces availability in the south as excessive resources are reallocated in a zero-sum fashion to offset even higher propagation losses due to steeper service angles. In the short and medium terms, D2D will be likely limited to messaging and emergency alerts due to tight network capacity constraints.[123] Dynamic and time-varying capacity management becomes essential to prioritise critical services and regions. In the long term, denser satellite constellations in the orbits relevant to the UK could enhance D2D by enabling more simultaneous service availability in time and space.

[123] Of note, in October 2024, the FCC granted Starlink temporary authority to operate on T-Mobile's spectrum in hurricane-impacted Florida, supporting emergency alerts to all networks and SMS for T-Mobile subscribers, but not voice or video calls due to limited satellite coverage.