Economic rationale for enabling Smart Grid functionality of the UK energy system via a Private Radio Frequency-based enhanced Operational Communications Solution

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Gemserv

1. Executive Summary

The UK electricity system is changing, shifting from a simple passive energy network where energy flows from centralised generation through progressively smaller capacity wires until it reaches the consumer, to a vastly more complex and dynamic system. In addition, as we transition to Net Zero, energy networks will need to be more flexible as renewable energy generation, energy storage systems, and millions of low carbon devices such as electric vehicles, heat pumps and micro-generation are connected across every tier of the network.

To support an affordable transition, Distribution Network Operators (DNOs) are being challenged as Distribution System Operators (DSOs) to use a broader range of tools to manage and operate networks as efficiently as possible1. These tools include enhanced monitoring & planning; real-time network reconfiguration; actively managing system voltages; and using commercial arrangements to balance the electricity system generation with demand and to manage system constraints. These operations all have one thing in common: they require access to a resilient and reliable communications solution to plan, monitor, control and protect networks whilst addressing an increasingly complex and fragmented demand profile from consumers.

A dynamic electricity network requires a more sophisticated control and monitoring system that will allow greater network visibility and flexibility, allowing real-time management of the UK energy system.

The UK gas system is also changing, injecting biomethane into the gas networks[2] and providing support for hydrogen as part of the Prime Minister's Ten Point Plan for a Green Industrial Revolution[3]. Successes in early trials of blending hydrogen into the gas distribution system are already being reported[4]. These new opportunities also require gas distributors to introduce enhanced operational control capability across their networks to be able to monitor and control the gas blend in real-time. Although we consider that smart gas grids could deliver benefits, especially when hydrogen or biogas is injected into gas networks, we have omitted these from our analysis as 1) the scale is uncertain and likely to be insignificant compared to electricity, 2) including these benefits is not necessary to justify smart grids for utilities, and 3) the decision to use Private Radio Frequency in preference to other communications solutions would not be affected.

The analysis undertaken here indicates that up to £12.7bn of benefits could be delivered through implementation of a smart grid, as shown below:

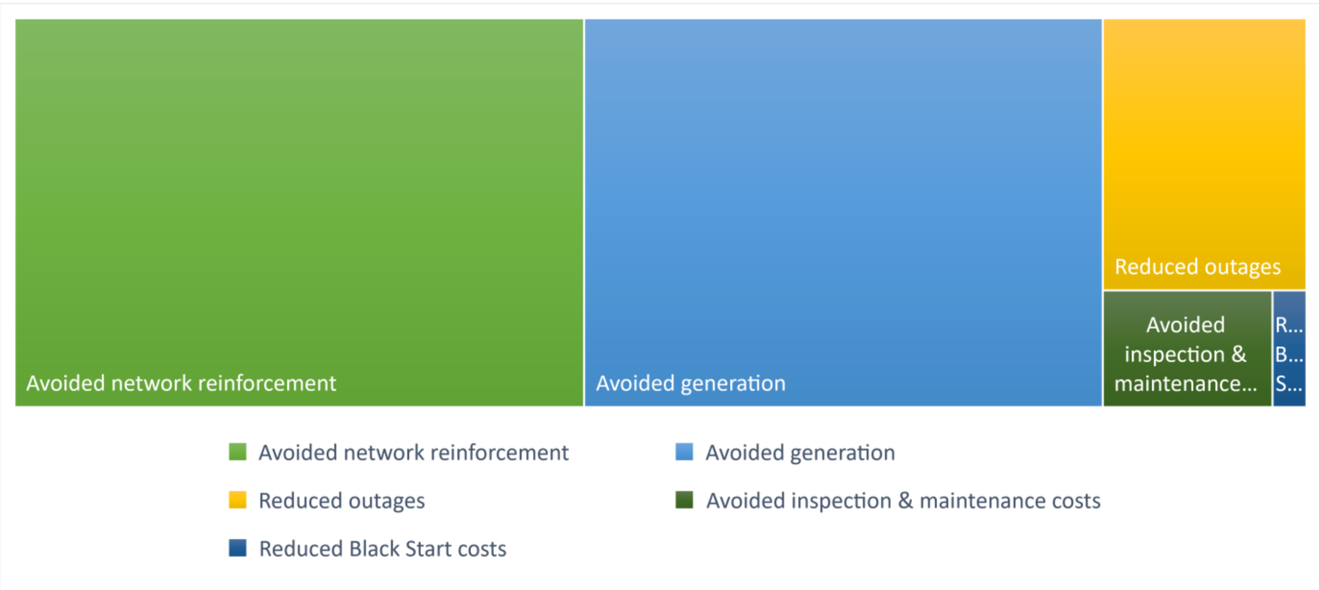

Figure 1: £12.7bn Net Benefits of a Smart Grid Enabled by RF Communications

[1] Ofgem (2019) Ofgem-BEIS Joint Open Letter to the ENA Open Networks Project
[2] SGN Biomethane
[3] BEIS (2020) The Ten Point Plan for a Green Industrial Revolution
[4] HyDeploy (2021) First UK trial of hydrogen blended gas hailed a success

- **Avoided network reinforcement**[5]: This benefit is mainly achieved through improved visibility of the network, reducing peak loads, increasing network utilisation, and avoiding or deferring network reinforcement.
- **Avoided generation**: Achieved by shifting peak loads and effective utilisation of Distributed Energy Resources (DERs), meaning that capital costs for generation can be avoided.
- **Reduced outages**: Early visibility of potential issues, visibility of excess network loading, and automated recovery from failure reduce the number of interruptions and duration of outages impacting consumers.
- **Avoided inspection & maintenance costs**: Targeted, data-driven inspection and maintenance regimes reducing the level of unnecessary site visits.
- **Reduced Black Start costs**: Using a smart grid to allow DERs to compete to offer Black Start services and avoiding the costs of ensuring thermal generation readiness.

If these savings are passed onto the consumer, this would enable a reduction in network charges of £25 for every bill payer per year.

The need to rapidly improve operational control capability through enhanced communications across the energy networks is widely accepted, however the best means of achieving this transformation are currently uncertain. This paper sets out the economics of alternative smart grid connectivity solutions and confirms the case for a Private Radio Frequency (RF) based solution at the core of facilitating future smart energy networks.

Our analysis concludes that:

1. All smart grids enabled by enhanced communications capability enable significant network reinforcement costs to be avoided.
2. Smart operational control capability using a public mobile network would entail higher cost, increased risk and uncertainty whilst use of hybrid public/private fibre is considered unfeasible due to prohibitive cost.
3. Our detailed economic analysis confirms that a Private Radio Frequency-based solution with designed-in resilience to address the needs of the Energy Network Operators provides, by a significant margin, the most economically efficient solution amongst the smart communications infrastructure options considered.

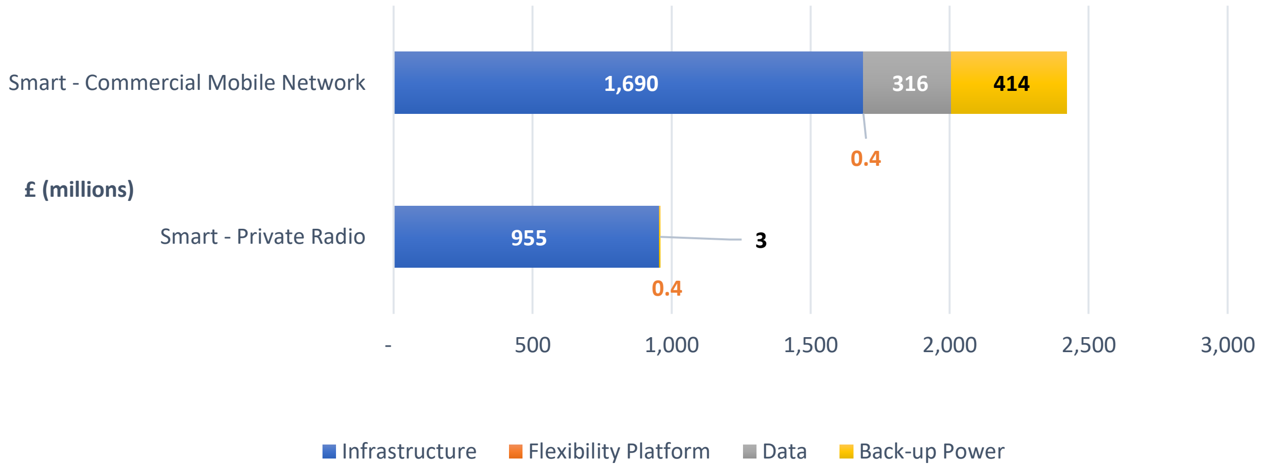

Figure 2: Net Present Value of Smart Communications Infrastructure Costs (£m)

[5] All values quoted in this report are Net Present Value to 2050 (other than section 5.3 Communications Cost5.3 and the data tables in the annex)

CONTENTS

2. Communication options

Three types of smart communications solutions have been considered to support the enhanced operational control capability envisaged to determine the most economic solution. For each solution we have considered the technical feasibility and economic considerations.

Public and Private Fibre Communications:

Fibre takes its name from the type of cable used to transmit a superfast internet signal. Optical fibre cables can transmit data over long distances and when the cables are buried have a long lifetime and require minimal maintenance. We have assumed that the lifetime of the communications infrastructure exceeds 30 years, meaning no replacement over the timeframe we are considering.

A dedicated private fibre network is theoretically possible however it would take years to build out and the investment required is prohibitive. Public fibre has not yet achieved the level of geographical coverage that would be required, and there is no certainty that it will do in future[6].

We have therefore modelled the cost of building a hybrid communications network of public (utilising cables installed as part of the UK fibre roll out) and private or dedicated fibre. We consider this cost to be approximately £51bn, making a dumb reinforcement approach significantly more economic than developing a smart grid using fibre communications.

Additionally, partial or entire reliance on public communications networks would require assurance that:

- The level of resilience would meet the standard required for Critical National Infrastructure, which may be particularly challenging for fibre networks as any repairs will require civil engineering works.
- The level of resilience in the event power failure would meet the standard required. Additional costs would be incurred if active electronics are involved in the end-to-end service. We have assumed this is passive and that no extra costs would be incurred and hence are not included.
- Cyber security standards for Critical National Infrastructure can be met, including effective separation from the internet.
- Other standards of performance (such as latency - time taken to transfer data) will be met.

Private Radio Frequency Communications:

Radio spectrum is currently used for a range of services in the UK including commercial mobile operators, emergency services, Broadcast Television and Radio and the military, amongst others.

We have considered that a Private Radio Frequency-based network could deliver the services required to achieve the main operational control characteristics of a smart grid. The service benefits from designed-in resilience, security and allows the Energy Sector to manage technology risk and obsolescence. The main points to note are:

[6] House of Commons Library (2021) Gigabit-broadband in the UK: Government targets and policy

- We have assumed a five-year period to build out a solution.
- A Private Radio Frequency-based network would rely on Ofcom awarding spectrum for the private use of utilities. The appropriate spectrum would be sub-1 GHz, ideally at around 400-470MHz, which is of no relevance to commercial service providers.
- The specific amount of spectrum in these bands being targeted is 2 x 3MHz or 2 x 5MHz as the applications under consideration have relatively low data requirements – these channel sizes are considerably smaller than those being targeted by the mobile operator community as they would not provide sufficient bandwidth to support mobile broadband services.
- We note that other jurisdictions, such as Germany[7] have awarded spectrum for “critical infrastructures that will help to pave the way for the digitisation of the energy transition. Spectrum is particularly suitable for use in building a highly available and blackout-resilient nationwide wireless network infrastructure for sectors such as electricity, gas, wastewater, water and district heating”.

Commercial Mobile Networks:

Ofcom awards spectrum to Mobile Network Operators (MNOs) on the basis of auctions that include conditions such as coverage requirements, licence fees, data throughput commitments and roll-out obligations.

The MNOs (EE, Three, O2 and Vodafone in the UK) sell voice and data services to consumers using their network infrastructure and the radio spectrum acquired by them from Ofcom.

These services are optimised to be efficient and to provide low-cost mobile telecoms coverage on a ‘reasonable endeavours’ basis, but this optimisation means that they are not designed to address all of the requirements set out in section 5.2 for the Critical National Infrastructure which depends on these smart and resilient communications.

Each generation of mobile communications is eventually superseded by future generations, with the spectrum repurposed.

Commercial mobile phone networks could potentially deliver the services required to achieve the main benefits of a smart grid and the time to implement the solution would be similar to that required for Private Radio Frequency communications.

However, the costs of a commercial mobile solution to the Energy Sector would be significantly higher than a Private Radio Frequency solution due to two principal factors: the rip and replace nature of these solutions causing additional customer premises equipment (CPE) costs and the need to invest in power resilience.

Commercial Mobile Networks could provide the necessary service assuming sufficient investment by the service providers to:

- Provide assurance that commercial mobile networks will achieve the low latency required for network protection. Our modelling has assumed this is possible, although there is little evidence available.
- Ensure resilience against power outages. Typical existing arrangements will ensure that mobile communications will operate on back-up power for three hours during a power outage. This is considered sufficient at present to support non-critical services such as consumer Mobile Broadband but were the electricity network to become more actively managed via such a solution, this would present an unacceptable level of risk to the operational integrity of the Energy Networks. Additionally, Black Start using

[7] President's Chamber of German Utilities (2020) Notice to award spectrum

DERs will be entirely dependent on operational communications after a significant power outage. Our analysis has included an estimated cost for enhancing power resilience to address such a requirement.

- Guarantee standards of performance (for resilience, latency, and availability), which DNOs have stated would be necessary during our interviews. We highlight this as a further risk to the adoption of this solution but have not adjusted the costs as we have no data to quantify the extra cost of gaining necessary guarantees or ensuring sufficient operational safeguards are enabled.

There would also need to be:

- Acceptance that the longevity of any generation of mobile solution cannot be guaranteed. Each generation of mobile communications is ultimately replaced by future generations, and communications equipment will need to be replaced ahead of any switch-off as enhancements to standards are implemented which are not backwards compatible. Our analysis has assumed a 10-year lifetime for a commercial mobile network, based on analysis of previous mobile generations and after seeking technical input from industry.
- Acceptance that a lack of control of the communications networks means that services and costs may change over the lifetime. This may be manifest as price rises to support technology, changes to service levels, etc. We highlight this as a risk to this option and note that we have not included any additional costs as we have no data to quantify any extra costs or reduced benefits.

3. The Distribution System

The UK electricity system is rapidly changing from a broadly unidirectional system where centrally dispatched generators produce electricity, and it is transported via the transmission and distribution systems to the end customer who consumes the electricity.

The distribution networks are adapting to enable DERs, including generators and storage providers, to connect to the distribution system economically and without risk to the network, and to enable consumers to adopt low carbon technologies including electric vehicles, heat pumps and domestic battery storage.

The diagram below, from Western Power Distribution[8], illustrates some of the additional complexity.

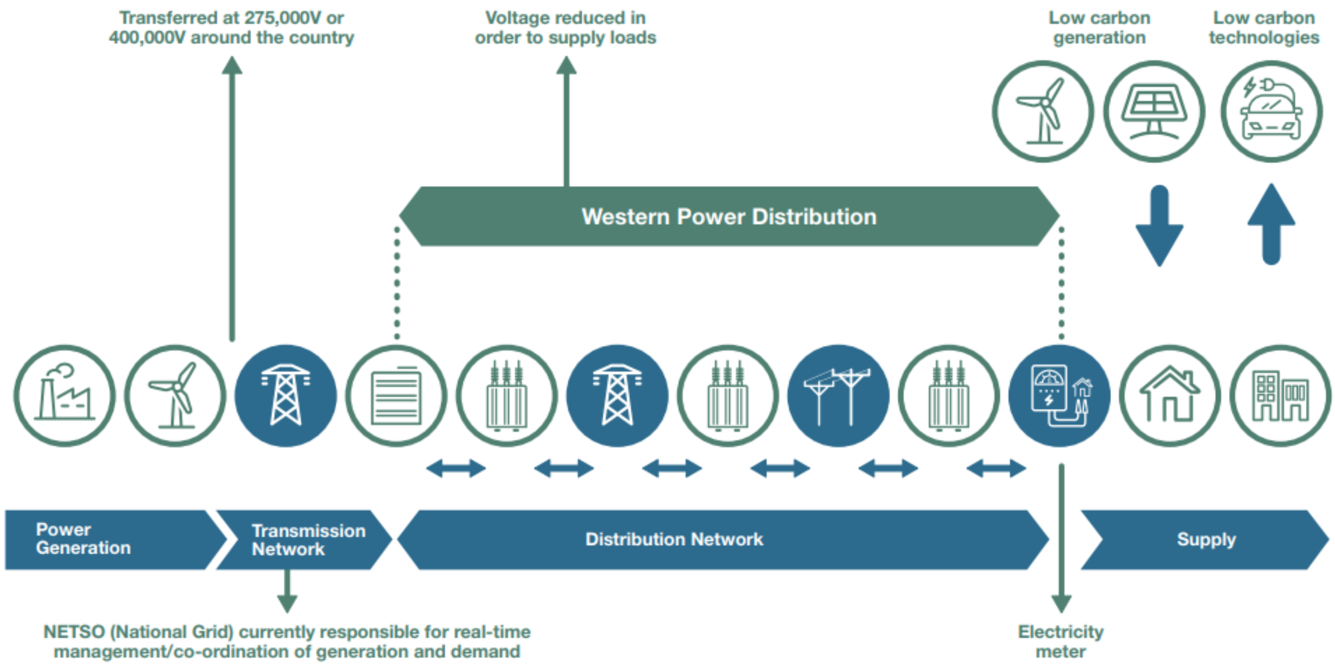

Figure 3: Increasing complexity of the distribution system

The transition to net zero presents a substantial opportunity to renew our electricity system and deliver green growth, with the renewable energy economy sector in 2018 having generated over £46.7 billion of turnover[9]. Over the coming decade the UK's burgeoning low carbon economy is expected to grow at a rate that exceeds traditional industries[10].

Progress in decarbonising the power sector has helped to position the UK as an international climate change leader. COP President Alok Sharma has highlighted the opportunities that arise from the transition to low-carbon technology[11] and nowhere is the opportunity more obvious than the continued focus on decarbonisation of the power sector. Continued support for renewables and the subsequent opportunities to electrify emission-intensive transport and heating all signal an exciting transformation ahead. Indeed, the UK Government has signalled its intentions by developing an offshore wind sector deal, communicating a key role for electric vehicles in the Transport Decarbonisation Plan[12], and funding electrical heat pumps via the Clean Heat Grants Scheme.

[8] Western Power Distribution (2020) DNO Transition to DSO
[9] ONS (2020) Low carbon and renewable energy economy, UK: 2018
[10] HM Government (2018) Clean Growth Strategy
[11] BEIS (2020) COP26 President Alok Sharma's briefing to UN member states
[12] DfT (2020) Decarbonising Transport – Setting the Challenge

The National Grid Electricity System Operator (NG ESO) Future Energy Scenarios (FES) 2021 data[13], demonstrates the extent to which low carbon technologies will affect distribution networks over the next 10 years. FES impacts are highlighted in the figure below.

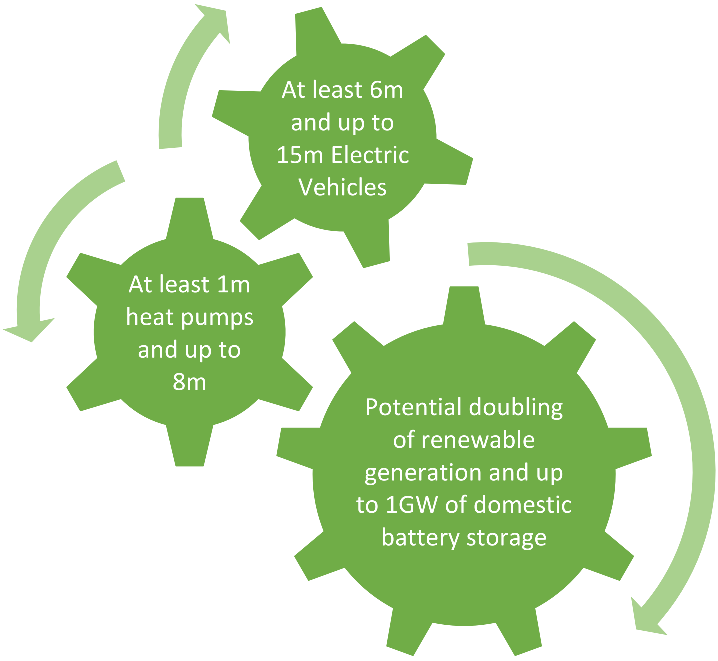

Figure 4: Transformation of Electricity Networks by 2030

To support this increasingly complex environment, distribution system operators need capabilities that are enabled by a reliable and robust operational control capability facilitated by an enhanced communications system. These capabilities include:

- Managing more granular data from more network assets regarding the operation of their networks, to gain visibility of network utilisation and facilitate more effective network planning, operation and enhanced asset utilisation.
- Enabling the near real time ability to reconfigure parts of the network to better manage energy flows, or to isolate faults, etc.
- Real time operational technology to protect the network in certain fault circumstances.
- Receiving and acting upon alerts from network assets to warn of potential and actual network faults.
- Communicating with generation, storage or consumption for system balancing or voltage management.
- The opportunity to use embedded generation to facilitate the Electricity Restoration Process.
- Enable local market mechanisms to be established for energy provision.
- Establish mechanisms for balancing locally.

[13] National Grid ESO (2021) Future Energy Scenarios Data Workbook

4. The Case for Smart Grids

4.1. KEY BENEFITS OF A SMART GRID

Our analysis has utilised published information from reputable sources to support quantification of the benefits, supplemented by interviews with DNOs. The DNOs either provided additional data or have helped to verify that the benefits are attainable using each of the communication solutions considered.

The key benefits total £12.7bn, and how we have determined these are set out below:

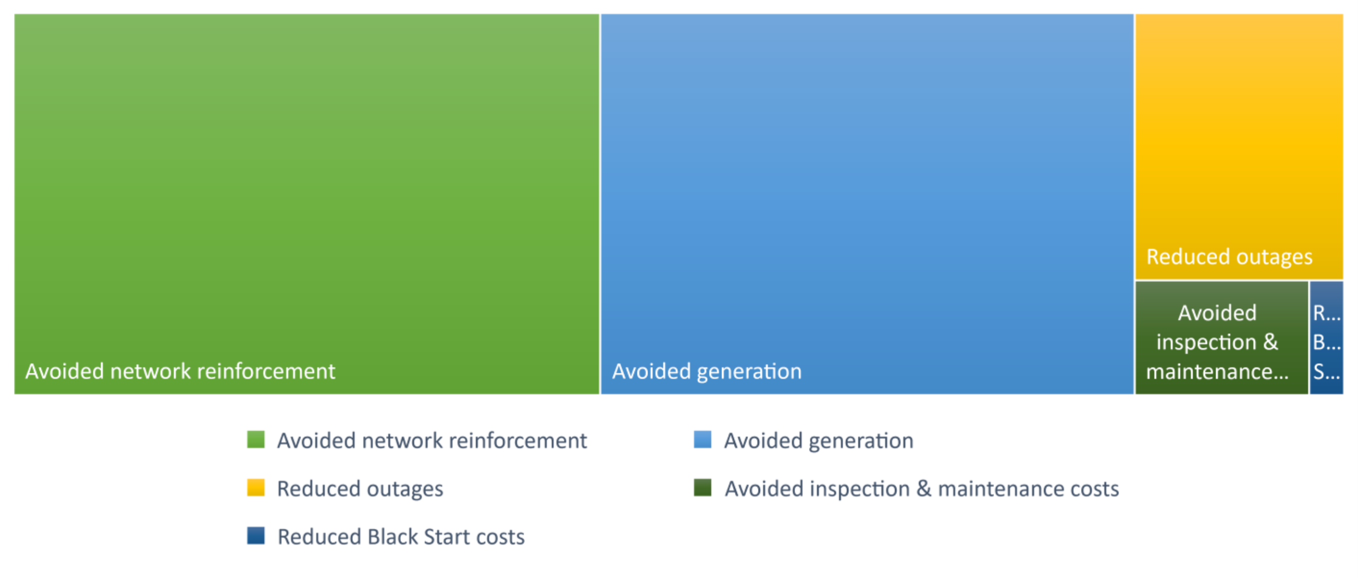

Figure 5: £12.7bn Net Benefits of a Smart Grid Enabled by RF Communications

Avoided network reinforcement: £5.6bn

Supporting the information set out above in NG ESO's Future Energy Scenarios, the Committee on Climate Change (CCC) also sets out predictions for electrification and the impact on the GB electricity system[14], including estimated costs for the reinforcement needed to support this electrification.

This benefit is mainly achieved through improved visibility and control of the network (such as dynamic load ratings, voltage management, and managing thermal constraints), along with reducing peak loads using demand- (and generation-) side response. These activities help to avoid or defer network reinforcement and increase network asset utilisation.

We have assessed the extent of avoided network reinforcement based on information published by the Carbon Trust / Imperial College London Consultants[15] and by UK Power Networks[16].

Avoided generation: £5.1bn

Alongside the CCC's Sixth Carbon Budget, the CCC publishes[17] a dataset including electricity generation estimates. We have used the dataset for the 'Balanced Pathway'.

Smart grids support shifting peak loads, as explained above, alongside increasingly effective utilisation of DERs to address energy demand, the total electricity generation capacity and associated capital costs can be reduced.

[14] CCC (2019) Accelerated electrification and the GB electricity system
[15] Carbon Trust / Imperial College London Consultants (2021) Flexibility in Great Britain
[16] UKPN (2014) Future Energy Scenarios Annex 9: Smart Grid Strategy
[17] CCC (2021) Sixth Carbon Budget Dataset

We have used the Carbon Trust / Imperial College London Consultants report on Flexibility in Great Britain[15] to quantify this benefit in energy terms. Noting that a portion of these benefits can be achieved without a smart grid (i.e., existing load data would be sufficient to derive some of these benefits), we have scaled down the benefits attributable to smart grids and associated communications. We have applied the Contracts for Difference (CfD) auction clearing price for Delivery Year 2023/24[18] to develop a value for the avoided cost of new generation.

Reduced outages: £1.4bn

We have used the data published by Ofgem[19] to establish a baseline for the impact on customers of outages, using Customer Minutes Lost (CML) and Customer Interruptions (CI), along with the associated penalty or reward values. This related to the RIIO-ED1, so we have taken this as the basis when using a (largely) dumb distribution network.

We recognise that there is debate in industry whether Value of Lost Load, CML and CI adequately value the social and economic cost of outages, although we have no agreed basis for revising any of these values and have therefore not assumed any uplift.

Smart grids provide distribution businesses several tools that will reduce the frequency and duration of outages and interruptions. These include better planning information leading to more targeted, and timelier asset / network maintenance / reinforcement or active management, real-time warnings from network assets, enhanced visibility of excess network loading, voltage and thermal rating data, ability to reconfigure the network, and automated fault protection and recovery in the event of failure.

We have estimated the reduction in CML and CI, and the associated cost, based on RIIO-ED2 submissions and from our interviews with distribution businesses.

Avoided inspection & maintenance costs: £0.5bn

We have determined the value of avoided inspection and maintenance visits based on information shared with us by distribution businesses that supports their RIIO-ED2 submissions. They have provided details of the infrastructure that they plan to make smart during RIIO-ED2 along with the benefit in avoided inspection and maintenance costs. We have then scaled this up to determine the benefit from a fully smart grid.

These benefits are achieved through better targeted inspection and maintenance regimes informed by enhanced data. For instance, data regarding transformer loading and thermal rating information can inform decisions on maintenance visits and oil changes, etc. More effective and efficient operation of the network based on data can reduce the potential to cause issues, and monitoring warnings and load data help determine the need for inspection and maintenance (or lack thereof).

Reduced Black Start costs: £0.1bn

National Grid is currently running a programme[20] to develop and prove the ability to restore the power to customers following a blackout. This entails coordinating a number of DERs to provide a safe and effective Electricity System Restoration service. This will increase competition in the market, and deliver cost and carbon emissions reductions

The business case for the project states that "there is potential for customers to save at least £115m by 2050, if a GB wide implementation can take place from 2025, with 810 kT of avoided CO_2". These benefits are largely achieved through the increased volume of assets that will be able to provide these services bringing down costs

[18] KPMG (2019) CfD Round 3
[19] Ofgem (2021) RIIO-ED1 Annual Report 2019-20 Supplementary Data
[20] National Grid (2018) Black Start from Distributed Energy Resources

through competition and avoiding the costs of keeping thermal assets ready to perform Black Start. We have used the benefits set out in the business case for the programme.

4.2. COST COMPONENTS

The costs of smart grid communications vary significantly, with private fibre costs being prohibitively high owing to the cost of the civil works. Whilst a Private Radio Frequency communications solution or alternatively a commercial mobile network-based solution are more comparable. Nevertheless, the Net Present Cost of providing a Private RF solution is around £1.7bn less than a commercial mobile based alternative.

The main cost components are set out below:

Communications Infrastructure:

- Private RF (£955m): comprising base stations, core systems & software, equipment installed on distribution network assets, and voice platform to provide PSTN replacement.
- Public Mobile (£1.7bn): comprising equipment installed on distribution network assets. This is the NPV of initial installation and two replacement cycles for all CPE, each with an undiscounted cost of £846m.
- Private / Public Fibre (£39.3bn): primarily consisting of the cost of laying fibre optic cables, with the wide range owing to the range of estimated extension required to connect distribution assets to private fibre (on the basis that they will not be covered by the public fibre network).

Flexibility Platform:

- All Communications Systems (£0.4m): the cost of the flexibility platform required to deliver the benefits achievable (such as those dependent on load shifting).

Data:

- Private RF (N/A): Zero cost as this data would be included in the operational cost of the Private Radio Frequency Network solution.
- Public Mobile (£316m): a yearly data charge for use of the commercial mobile network.
- Private / Public Fibre (£11.5bn): this includes a yearly data and main link connection charge for use of the public fibre network.

Backup Power:

- Private RF (£2.8m): We have assumed funding for installing backup power for 100 sites that make use of public infrastructure. We assume that no additional backup power is required to maintain the communications system for 72 hours after power failure for infrastructure situated on existing DNO assets.
- Public Mobile (£414m): the calculated cost of providing battery storage at each macro site for a Single commercial mobile network solution, capable of maintaining mobile communications operational for 72 hours in the event of a mains power failure.
- Private / Public Fibre (N/A): Assumed to be zero cost on the basis of an entirely passive fibre network being able to maintain communications after power failure. This assumption would require further investigation, as active electronics within the end-to-end system may require backup power sources for resilience.

We set out further detail on the costs of each communications option in section 5.3.

5. Communications Requirement

5.1. INTRODUCTION

DNOs have traditionally managed a very stable unidirectional flow of energy from generator to consumer with relatively limited asset monitoring and control requirements – only monitoring a few key locations and controlling a low volume of remote switchgear and plant.

As electricity networks develop to support low carbon technologies at grid and consumer sites, and DNOs transition to DSOs, a far greater need develops to monitor more sites / assets in greater detail, to automate more systems, and to provide real-time management, control and protection.

Smart grid communications will have an integral role in ensuring the safe, reliable, and efficient operation of this Critical National Infrastructure over the long term.

5.2. COMMUNICATIONS REQUIREMENTS

In assessing the communications solution, we have sought to ensure that the different options address a number of high-level requirements that would ensure delivery of the expected benefits. We have not undertaken a detailed technical assessment and have relied on published information and the interviews we have conducted.

Coverage & Volumetrics

The volume of data required is very low compared to most system requirements and each of the communications technologies can easily support the requirement.

The number of remote sites that are to be considered, which are determined using current and projected electricity grid supply points, bulk supply points and substations, and gas distribution sites, are also relatively low (in the tens of thousands). The key factor here is the impact the number of sites has on the civil engineering cost for a fibre network.

Geographic coverage is assumed for all solutions, although 'not spots' cannot be ruled out if using a commercial mobile network.

Latency

DSO services have differing requirements for latency (the time taken for a communication to reach its destination), with network protection having the greatest need for low latency. We understand that there are some limitations with commercial solutions, as they are not necessarily designed for lowest latency, and hence struggle to address this requirement. However, we have modelled that each solution can deliver the full benefit of smart grids and have not reduced the benefit that can be realised if latency requirements were not to be achieved.

Reliability & Resilience

Availability and up-time will become increasingly important as the complexity of the grids increases. Having near-real time information to manage constraints, being able to operate switchgear, and being confident that automated operation and protection will be available when the grid is fully smart and operated at higher utilisation will be critical, whereas today these are relatively unimportant requirements whilst most of the grid relies on excess capacity to operate within tolerance. Although there is some concern that commercial operations may not meet reliability requirements, we have modelled that each solution can deliver the full benefit of smart grids and have not reduced the benefit that can be realised if reliability and resilience requirements were not met.

Resilience, including resilience in the event of power outage, becomes critical as smart power grids develop, particularly as the scale and complexity of the energy system expands over time. If communications are not resilient in the event of power outage, restoration of services and Black Start becomes difficult, manually intensive, time-consuming, and potentially unsupportable.

Security

Security of the Critical National Infrastructure is paramount, and a topic that has been raised by each organisation that we have interviewed. Private networks have been regularly stated as a preference, as placing reliance on commercial organisations, who are potentially not geared up for CNI requirements, and whose business is dominated by non-mission critical applications, e.g., streaming content and social media, is called out as a risk. We have modelled that each solution can deliver the full benefit of smart grids and have not reduced the benefit that can be realised if security requirements could not be addressed. In reality, we would expect this requirement to significantly increase the cost of providing the service and would therefore increase the cost to electricity and gas distribution businesses.

Other Services

Other telecommunications applications have been identified by the distribution businesses, all of which are assessed to be supported by each of the communications platforms options considered. These include: mobile voice communications, security (CCTV), and fixed voice (to replace landline communications when PSTN is switched off).

5.3. COMMUNICATIONS COST

The cost of different communication systems has been estimated using data provided by DNOs which has then been scaled to deliver a cost estimate for delivering the solution across the entire Great British network.

Scenario 1: Private Radio Frequency Network

Item	Explanation	Unit Cost (£)	Quantity	Total Cost (£)
CPE – Primary Substation	Radio	£5,337	4,800	£25,617,600
CPE – Distribution Substation	Radio	£3,567	230,000	£820,410,000
eNB	Base station	£45,534	2,000	£91,068,000
Core	Brains of system	£1,964,758	13	£25,541,854
OMC	Software	£2,500	26	£65,000
VOLTE	Voice platform	£1,888	50,000	£94,400,000
Training		£157,954	6	£947,724
Backup Power	Battery backup	£30,730	100	£3,072,985

Table 1: Cost components of Private Radio Frequency Communications

Scenario 2: Commercial Mobile Network

Item	Unit Cost (£)	Quantity	Total Cost (£)
Annual data charge per site	£88.24	234,800	£20,719,000
CPE – Primary	£5,337	4,800	£25,618,000
CPE - Distribution	£3,567	230,000	£820,410,000
Battery Backup	£30,730	15,000	£460,947,778

Table 2: Cost components of Commercial Mobile communications

In the Commercial Mobile scenario, we assume that replacement is required after 10 years and therefore the capital costs are incurred three times over the period up to 2050. These costs also don't include the costs associated with reinforcing the macro cellular sites to provide the power resilience required in electricity grids.

Scenario 3: Public and Private Fibre Network

Item	Value	Unit
Private fibre		
Number of end points	600,000	#
Average length of fibre link to each end point	10	km
Proportion of fibre network that is private	15	%
Total length of fibre required	900,000	km
Cost per km for fibre	£52,000	£
Estimated capital cost of private fibre network	£46.8bn	£bn
Openreach/3rd party fibre		
Proportion of fibre network that is public	85%	%
Installation cost per site	£1,848	£
Annual data charge and main link charge per site	£3,555	£

Table 3: Cost components of Private Fibre communications

The fibre scenario has been estimated by considering the length of fibre that would be required to replicate the other smart scenarios. We have assumed that 85% of the network could be serviced using public fibre networks[21] with a short private link and the remaining 15% would be delivered by a private solution. There is some uncertainty over this estimate, however the costs of fibre mean this scenario will always be significantly more expensive than either of the other smart scenarios.

[21] House of Commons Library (2021) Gigabit-broadband in the UK: Government targets and policy

6. Summary and Conclusions

6.1. COST BENEFIT ASSESSMENT

The costs and benefits of the four scenarios have been evaluated using a discounted cash flow model. This model assumes that costs begin from 2022 and benefits begin to accrue from 2023. The model is run up to 2050 and discounted at rate of 3.5%. As shown on table 4, the benefits of pursuing either a Private Radio Frequency network or commercial mobile network for distribution network operational control communications far outweighs the costs. The Net Present Cost of providing a Commercial Mobile based solution is around £1.7bn higher than a Private Radio Frequency-based alternative and would be subject to achieving the same levels of reliability, resilience, and security as a Private Radio Frequency solution – hence consideration should also be given to the qualitative factors outlined in section 6.2 when comparing these options.

Scenario	Net Present Cost of Grid Improvements for a Low Carbon Future (£)	Saving vs Dumb Reinforcement Scenario (£)
Dumb reinforcement	£23.9bn	
Targeted reinforcement plus smart grid managed via Radio	£10.7bn	£13.2bn
Targeted reinforcement and smart grid managed via Fibre	£61.3bn	-£37.3bn
Targeted reinforcement and smart grid managed via Commercial Mobile	£12.2bn	£11.7bn

Table 4: Cost benefit assessment of smart & dumb networks

6.2. RISKS AND QUALITATIVE FACTORS

The service provided by public communications networks (cellular or fibre) currently does not include any guarantee of continued operation during power outages, or quality of service or availability. This will be a key requirement of a smart grid solution as the electricity system transitions from large, centralised generation to smaller, decentralised, and intermittent renewables. Returning the system to operation following an outage becomes much more challenging as we decarbonise electricity and will require network operational communications systems to have power resilience for up to 72 hours. A cost of including power resilience in the commercial mobile scenario has been applied, although there is uncertainty as to whether this is something one of the MNOs would be willing to invest in. Noting that only one network would need power resilience a monopoly would be created. It is highly likely that in this scenario Ofcom or Ofgem would regulate this monopoly to avoid excessive prices being charged by the Commercial Mobile Network operator. We anticipate that this is something mobile networks would want to avoid and if offered, prices may be higher due to the additional administration costs associated with regulation.

There are significant benefits of DNOs having complete control of the communications network. In a RIIO-ED2 business plan submission, one DNO stated that the use of 3rd party commercial telecommunication services would increase the risks in meeting key DNO criteria i.e., always delivering the best network availability. In addition to the risks concerning power resilience there are concerns over the level of cyber security that would be offered by 3rd parties. As key pieces of infrastructure, distribution networks are susceptible to attacks. The cost of achieving guarantees of service when using a commercial mobile network are likely to significantly increase the modelled costs of this scenario.

Reliance on Commercial Mobile Network Operators introduces a technology obsolescence risk as each generation of mobile communications is eventually superseded by future generations, with the spectrum repurposed. This forces users to replace previously installed CPE ahead of the sunset of the previous generation. We have assumed a replacement cycle of 10 years for each generation of mobile communications, at an undiscounted cost of nearly £850m each time for the nearly 235,000 distribution assets. Examples of this technology obsolescence risk include the sunset of 2G & 3G mobile communications[22, 23], T-Mobile's court case to delay KPN switching off the copper PSTN network in the Netherlands[24], and the replacement of the Airwave network, which is used by Great Britain's emergency services, by the Emergency Services Network[25] (ESN).

Public communications operators (cellular and fibre) are private companies with a profit motive which, combined with the lack of a Universal Service Obligation, has led to limited network coverage in sparsely populated regions due to lower returns of network investment. However as regulated entities, DNOs have a statutory obligation to offer the same high quality of service for every property. DNOs are unlikely to be able to achieve this using public mobile networks due to limited coverage in rural locations. Furthermore, a regulatory failure would occur if DNOs were to face large fines for aspects of their business that are out of their control such as the availability and reliability of third-party communication networks.

6.3. CONCLUSIONS

The challenges of electricity distribution will increase significantly as we transition from large, centralised fossil fuel generation to smaller, decentralised and intermittent renewables. Furthermore, the increasing deployment of demand side low carbon devices such as heat pumps and electric vehicles will exacerbate these challenges in ensuring a safe, reliable and resilient electricity system.

This analysis shows that implementation of enhanced operational telecommunications capability by the networks businesses can deliver significant benefits over a dumb network scenario in which there is very limited remote operational control of assets. The analysis has shown a present value of benefits of £12.7bn could be achieved by smart grid solutions, which could be delivered with an investment of £1bn in a Private Radio Frequency Network. The modelled benefits in order of magnitude are avoided reinforcement, avoided generation, reduction in outages, reduction in maintenance and enhanced Electricity Restoration Service capabilities.

Our analysis finds that:

- Similar benefits can be achieved using either a Private Radio Frequency network or commercial mobile network-based solution.
- The cost of deploying a Private Radio Frequency network is significantly less than that of a commercial mobile network alternative, whilst the cost of a private fibre network (or public / private hybrid) is uneconomic.
- There are significant risks (and potential additional costs) involved if using a commercial mobile network scenario, that we have been unable to price-in and would therefore be in addition. These include:
  - ensuring quality of service, reliability, availability, and resilience of the network
  - a commercial mobile network would limit the availability of operational communications across all distribution network assets unless additional radio sites were deployed due to poor coverage 'nots spots' in sparsely populated regions
  - reliability would be affected by DNOs not having control of planned or unplanned maintenance
  - uncertainty over the level of power resilience MNOs would be willing to offer
  - securing guarantees of performance from mobile network operators is likely to be expensive, if possible at all, as this represents increased risk for the MNOs, for which they will require compensation.

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[22] Pangea 2G & 3G article: UK 2G & 3G sunset information
[23] Public Technology article: government commitment to clear roadmap for downsizing 2G & 3G mobile networks
[24] Comms Update: T-Mobile files court action to slow down KPN copper switch-off
[25] NAO Report: Progress Delivering the Emergency Services Network

Data and Results Tables

Scenario	Item	Value (£)	Source
All	Distribution network reinforcement costs*	£36,150m	CCC/Imperial College
All Smart	Flexibility dispatch platform with APIs	£0.4m	DNO data
Private RF	Capital cost	£1,058m	Scaling of DNO data
	Backup power battery and infrastructure cost	£3.0m	ICIS
	Annual Backup power operational cost	£2-6k	BEIS
Fibre Network	Capital cost of public and private fibre	£47,169m	Analysis of DNO data
	Annual data charges and main link connection	£710m	DNO data
Commercial Mobile	Capital cost	£2,538m	Analysis of DNO data
	Annual data charges	£21m	Analysis of DNO data
	Backup power battery and infrastructure cost	£444m	ICIS
	Annual Backup power operational cost	£0.3-1m	BEIS

Table 5: Costs of network reinforcement and smart grid upgrades

* Midpoint of core and high headroom rapid EV + HHP scenario

Some numbers in tables 5 and 6 have been rounded, more detail of costs can be seen in section 5.4.

Benefit	Item	Value	Unit	Source	Additional info
Black Start	Annual benefit of Black Start capability	£7.5m	£m	National Grid	Using distributed restart project NPV of £115m
Avoided generation	Reduction in generation assets required	2%	%	Carbon Trust	Scaled down from 4% estimate in the report
	Electricity generation	306-612	TWh	CCC	Balanced Pathway generation between 2021 and 2050
	Value of avoided generation	£39.65	£	KPMG	Strike price of offshore wind in CfD round
Outages	Reduction in customer interruptions	15%	%	DNO data	Consumer Engagement Group document
	Reduction in customer minutes lost	25%	%	DNO data	Consumer Engagement Group document
Maintenance	Annual avoided maintenance per primary substation	£280	£	Analysis of DNO data	ED2 plan from a DNO
	Annual avoided maintenance per distribution substation	£140	£	Analysis of DNO data	ED2 plan from a DNO
Reinforcement	Reduction in network reinforcement for smart grid	25%	%	UKPN / Carbon Trust	Both show 25% reduction in distribution network reinforcement

Table 6: Benefits of a smart grid

Methodology Note

MODELLING APPROACH

A discounted cash flow model is used to evaluate the costs and benefits of four scenarios:

1. Dumb Reinforcement

2. Private Radio Frequency

3. Fibre

4. Commercial Mobile

The dumb reinforcement scenario assumes that distribution network reinforcement continues its current trajectory with no additional communication system investment. Whereas the three smart scenarios assume that all primary and distribution substations are connected by the communication system in question to deliver a smart network.

A discount rate of 3.5% is applied to reflect the decreasing value of future cash flows, this follows the governments guidance on discount rates[26].

The net present costs of the three smart scenarios are then compared to the dumb reinforcement scenario to estimate the saving from delivering a smart network.

COSTS

The only modelled cost that applies to all scenarios is distribution network reinforcement costs, although this varies between smart and dumb scenarios. Network reinforcement costs are assumed to fall evenly throughout the modelled period.

The smart scenarios also include the costs of the communication system as outlined in the communications cost section (5.4) and the cost of a flexibility dispatch platform with APIs. The communication system costs are assumed to fall evenly over the first five modelled years for the Private Radio Frequency Network, Commercial Mobile and public part of the Fibre scenario with the private fibre estimated to take 10 years to deliver.

To enable a fair comparison between smart scenarios the costs of power resilience has been included in the Commercial Mobile scenario to ensure that this option would enable Black Start capability from distributed generation. This has been estimated by including the costs of batteries at all the macro sites on one of the mobile networks as a proxy for one of the four networks pursuing power resilience. We have also assumed power resilience would be required on 5% of the base stations (100 sites) in the Private Radio Frequency scenario, these have been costed in the same way as in the Commercial Mobile scenario.

The dumb reinforcement scenario also faces higher costs due to the increasing number of outages due to higher penetration of renewable energy and increasing electrification. These costs are assumed to be of the same magnitude as the benefit of reduced outages in the smart scenarios below.

[26] HM Treasury (2020) The Green Book (2020)

BENEFITS

The benefits arising from the three smart scenarios are assumed to be the same magnitude, however the fibre scenario has slightly lower overall benefits due to a longer build out time. Benefits of communications systems on the distribution network are:

1. Avoided reinforcement

Avoided reinforcement is estimated using a carbon trust report[27] and UKPN smart grid strategy[28] that states flexibility and smart networks can reduce network reinforcement required by 25%.

2. Avoided generation

Avoided generation is estimated using a carbon trust report which states flexibility can reduce electricity demand by 4%[29]. There are challenges in knowing how much of this can be attributed to the communication system, as such Gemserv have applied a multiplier of 0.5 to this assumption to scale down this benefit to a 2% reduction in electricity generation. There is some uncertainty around this benefit, however as all smart scenarios experience this it does not impact the findings materially. The 2% reduction is then applied to the electricity demand data in the Balanced Pathway of the CCC's Sixth Carbon Budget[30]. Combining this avoided generation with a price of electricity of £39.65/MWh[31] each year gives a monetary value of this avoided generation.

3. Reduction in outages

The benefit of reduced outages has been estimated using a DNO Customer Engagement Group Network Investment Strategy RIIO-ED2 submission to Ofgem. This states the aim to reduce customer interruptions (CI) by 15% and customer minutes lost (CML) by 25% through smart solutions. These outage reductions are assumed hold for the whole network and are applied to the unplanned outage performance of each DNO[32]. The reward that would be gained from Ofgem for achieving this is then calculated. This reward is assumed to be the monetary value of a reduction in outages.

4. Reduction in maintenance

The delivery of one DNOs communications plan over RIIO-ED2 is estimated to reduce maintenance costs by £820,000 per year. This avoided maintenance is then scaled to reflect the benefit of a communication system that covers the entire distribution network.

5. Black Start capabilities

The value of Black Start has been estimated using a National Grid report titled "Black Start from Distributed Energy Resources"[33]. This estimates the value of Black Start from distributed generation at a net present benefit of £115m by 2050 through increased competition and lower costs associated with large generator readiness. This benefit is assumed to apply to the three smart scenarios in this analysis, although benefits in the fibre scenario are slightly lower due to the longer time taken to deliver this solution.

[27] Carbon Trust / Imperial College London Consultants (2021) Flexibility in Great Britain
[28] UKPN (2014) Annex 9: Smart Grid Strategy
[29] Carbon Trust (2021) Flexibility in Great Britain
[30] CCC (2021) The Sixth Carbon Budget Dataset
[31] KPMG (2019) Blown away, CfD Round 3 delivers record low price for offshore wind
[32] Ofgem (2021) RIIO-ED1 Annual report 2019-20 supplementary data file
[33] National Grid (2018) Black Start from distributed energy resources

Document Control

CHANGE HISTORY

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0.1	Draft	15/09/2021	Phillip Twiddy & Jamie Mitchell	For peer review
0.2	Draft	16/09/2021	Phillip Twiddy & Jamie Mitchell	For internal review
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REVIEWERS

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