Tillbridge Solar

Tillbridge Solar Project
EN010142

Volume 7
Statement of Need

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ES1 This Statement of Need provides relevant legal, policy, and industry evidence in support of the urgent need for decarbonisation and action to support security of electricity supplies in the UK. It also provides evidence in support of ground mounted solar electricity generation generally, and Tillbridge Solar Farm (the 'Scheme') specifically, in relation to the benefit brought against the UK's critical strategic needs.

ES2 This Statement of Need concludes that the decarbonisation, security of supply and affordability benefits delivered by the Scheme to the national urgent need for low-carbon generation, should be accorded very significant weight when assessing the planning balance.

ES3 Urgent and unprecedented actions are required on a global scale to halt climate change. A rapid increase in the supply of low carbon electricity is needed for the UK to meet its climate change targets. Solar generation is a critical part of the UK's strategy to achieve net zero by 2050, a key step towards which is the government's aim to achieve full decarbonisation of the GB electricity system by 2035.

ES4 The National Policy Statements (NPSs) which are important and relevant to the Scheme confirm that large-scale ground mounted solar farms have a critical role to play in achieving the government's aims, and the government has determined that there exists a critical national priority (CNP) for low-carbon infrastructure, including large-scale solar farms, because of the decarbonisation, energy security and affordability benefits that they deliver.

ES5 The NPSs also confirm that assets which provide flexibility to the national electricity system, or to the energy system generally, are also needed to achieve the government's decarbonisation and energy security aims. The government is supportive of solar that is co-located with storage to maximise the efficiency of land use. The Scheme, which is a large-scale solar plus energy storage scheme, is therefore fully aligned with the government's aims.

ES6 Decarbonisation will increase demand for electricity and policies and strategies are already in-flight which are increasing, or are set to increase, electricity demand. Therefore, a significant number of new low-carbon electricity schemes, including this Scheme, are required to meet that demand and support the delivery of net zero.

ES7 Progress has been made in the development of different low-carbon electricity generation technologies. However, many of the technologies with potential to play a role in the delivery of a net zero energy system have uncertain delivery timescales. Developments with the proven ability to achieve carbon savings comfortably within in the next decade are essential to keep the UK on its legally binding carbon reduction path. Large-scale solar is one of the most likely technologies to be deliverable at scale against the timeframes required to support net zero.

ES8 The NPSs explain that the availability of grid connection, suitable irradiance levels and local topography are key inputs to the selection of sites suitable for large-scale solar generation developments. The number of locations within the UK at which large-scale solar generation is suitable is therefore likely to be limited, and this is a material issue when considering how the UK is to meet the urgent need for low-carbon generation as is set out in the NPSs.

ES9 Many factors are important in the design of a large-scale solar scheme within the context of a particular location, and flexibility in design is important to allow for the scheme to be designed in to optimise its benefits. Optimising the use of existing and available grid connections is necessary in the next decade to meet the government's aims for a zero-carbon electricity system by 2035.

ES10 The proposed location of the Scheme enables the Scheme to deliver against the urgency of need, in relation to decarbonisation, security of supply and affordability. No adverse grid operability effects are anticipated as a result of connecting the Scheme to the National Electricity Transmission System at the proposed location.

ES11 Solar generation contributes to security of supply. Aggregated generation output from portfolios which consist of different renewable technologies, including solar, is more predictable and less variable than single-technology portfolios. Solar generation is needed to support a high level of generation adequacy and generation dependability within the GB electricity system.

ES12 Solar facilities are already among the cheapest form of electricity generation in the UK and Government forecasts indicate that costs will continue to reduce in the future. By generating low carbon electricity at a low marginal cost, large-scale solar power reduces the energy generated by more expensive and more carbon intensive forms of generation. Solar therefore decarbonises the electricity system and lowers the market price of electricity.

ES13 In summary, a significant capacity of low-carbon solar generation is urgently needed in the UK. Developing this Scheme will be an essential step in meeting the government's objectives of delivering sustainable development to enable decarbonisation. By doing so, the Scheme will address the climate change emergency that affects everyone's lives and the environment, by ensuring our energy supply is secure, low-carbon and low-cost.

1. Overview

1.1 Document purpose

1.1.1 Tillbridge Solar Limited (the Applicant) is seeking a Development Consent Order (DCO) for a large-scale solar plus storage development, connecting to the National Electricity Transmission System (NETS) at National Grid's Cottam 400kV Substation (the Scheme).

1.1.2 This Statement of Need for solar generation describes how and why the Scheme addresses all relevant aspects of government policy, including the National Policy Statements EN-1 and EN-3. These Statements were published by the government in November 2023 and designated on 17th January 2024 (Ref. 1, Ref. 2). NPS EN-1 establishes a critical national priority for nationally significant low-carbon infrastructure, the definition of which includes solar PV..

1.1.3 NPS EN-1 explains that:

“The urgent need for CNP Infrastructure to achieving our energy objectives, together with the national security, economic, commercial, and net zero benefits, will in general outweigh any other residual impacts not capable of being addressed by application of the mitigation hierarchy. Government strongly supports the delivery of CNP Infrastructure and it should be progressed as quickly as possible” (Ref. 1, Para 3.3.63).

1.1.4 This Statement of Need demonstrates the important contribution the Scheme will make to the three national energy policy aims:

a. Net zero and the importance of urgently deploying low-carbon generation assets at scale

b. Security of supply (geographically and technologically diverse supplies)

c. Affordability and reducing exposure to volatile international markets

1.1.5 This Statement of Need for the development of large-scale solar generation demonstrates why the Scheme is urgently needed at the scale proposed; why the proposed location is highly suitable for such a scheme; and how the Scheme addresses all relevant aspects of established and emerging government energy and climate change policy and commitments.

1.1.6 This Statement of Need reflects government policy that solar is a key part of the government’s strategy for low cost decarbonisation of the energy sector. It calls on established and emerging primary analysis and opinion by qualified third parties, to support the need case for the Scheme. The Scheme is required to ensure that the UK remains on track to meet its legally binding carbon emissions reduction targets, while enhancing national security of supply, and at a cost which, in relation to other electricity generation infrastructure developments, provides value for money for end-use consumers.

1.2 Document Overview

1.2.1 This Statement of Need provides relevant legal, policy, and industry evidence in support of the urgent need for decarbonisation and action to support security of electricity supplies in the UK.

1.2.2 This Statement of Need also provides evidence in support of ground mounted solar electricity generation generally, and the Scheme specifically, in relation to the benefit brought against the UK's critical strategic needs.

1.2.3 This Statement of Need should be read in conjunction with international and national policy context relevant to the need for and benefits of this Scheme.

1.2.4 Chapter 2 of this Statement of Need explains that urgent and unprecedented actions are required on a global scale to halt climate change. A critical step in the strategy to fight climate change, is a full decarbonisation of the GB electricity system by 2035.

1.2.5 Chapter 3 of this Statement of Need summarises those National Policy Statements (NPSs) which are important and relevant to the Scheme. These NPSs provide that there is a critical national priority (CNP) for nationally significant low carbon infrastructure, including solar development, for both energy security and Net Zero, and that grid connection, irradiance and site topography are key inputs to the selection of sites suitable for large-scale solar generation developments.

1.2.6 Chapter 4 provides evidence that decarbonisation will increase demand for electricity and describes the policies and strategies already in-flight which are increasing, or are set to increase, electricity demand.

1.2.7 Chapter 5 provides an overview of progress in the development of different technologies with potential to play a role in the delivery of a net zero energy system. It highlights the uncertainty of delivery timescales for many technologies, and the opportunity brought forward by developments with the proven ability to achieve carbon savings comfortably within in the next decade. Storage assets will support the operation of low-carbon generators to achieve carbon savings.

1.2.8 Chapter 6 provides evidence on technical considerations associated with the development of solar in the UK including principles associated with the siting and location of large-scale solar schemes and describes factors which are important in the design of a scheme within the context of a particular location.

1.2.9 Chapter 7 sets out the benefits of the proposed location of the Scheme in relation to decarbonisation, security of supply and delivering against the urgency of need. The chapter also provides evidence on the suitability of the proposed location from a grid operability perspective.

1.2.10 Chapter 8 provides evidence that solar generation contributes to security of supply as part of a multi-technology aggregated generation portfolio. Whereas Chapter 5 demonstrates the need for storage facilities to be developed as renewable generation capacity grows, Chapter 8 describes how co-located solar plus storage schemes can deliver flexibility.

1.2.11 Chapter 9 provides evidence that solar facilities are already among the cheapest form of electricity generation in the UK and the development of more solar schemes will help to reduce the cost of wholesale electricity.

1.2.12 Chapter 10 provides the overall conclusions of this Statement of Need which are that a significant capacity of low-carbon solar generation is urgently needed in the UK. Developing this Scheme will be an essential step in meeting the government's objectives of delivering sustainable development to enable decarbonisation. By doing so, the Scheme will address the climate change emergency that affects everyone's lives and the environment, by ensuring our energy supply is secure, low-carbon and low-cost.

1.3 Scheme Description

1.3.1 The Tillbridge Solar Project (the Scheme) will comprise the construction, operation (including maintenance), and decommissioning of ground-mounted solar photovoltaic (PV) arrays. The Scheme will also include associated development to support the solar PV arrays.

1.3.2 The Scheme is made up of the Principal Site, the Cable Route Corridor and works to the existing National Grid Cottam Substation. The Principal Site comprises the solar PV arrays, electrical substations, grid balancing infrastructure, cabling and areas for landscaping and ecological enhancement.

1.3.3 The associated development element of the Scheme includes but is not limited to access provision; a Battery Energy Storage System (BESS), to support the operation of the ground mounted solar PV arrays; the development of on-site substations; underground cabling between the different areas of solar PV arrays; and areas of landscaping and biodiversity enhancement.

1.3.4 The Scheme also includes a 400kV underground Cable Route Corridor of approximately 18.5km in length connecting the Principal Site to the National Electricity Transmission System (NETS) at the existing National Grid Cottam Substation. The Scheme will export and import electricity to the NETS.

1.3.5 A full description of the Scheme is included in **Chapter 3: Scheme Description of the Environmental Statement [EN010142/APP/6.1].** An overview of the Scheme and its environmental impacts is provided in the **Environmental Statement Non-Technical Summary [EN010142/APP/6.4].**

2. Legal and policy background supporting the need for urgent decarbonisation

2.1 Chapter summary

2.1.1 This chapter describes the global context of international climate change aims, commitments and actions taken to date, and future actions needed to limit global temperature increase to 1.5°C above pre-industrial levels.

2.1.2 It is important to emphasise the urgency of the need to decarbonise UK energy generation in order to meet national climate change target and climate budgets.

2.1.3 The urgency required of actions to deliver decarbonisation globally is increasing. Carbon has a cumulative warming effect, and it is well understood that decarbonisation progress to date must accelerate in all countries in order to limit the temperature increase to 1.5°C above pre-industrial levels.

2.1.4 Actions to decarbonise the UK must also accelerate for the UK to keep on track with meeting its five-yearly carbon budgets, its 2030 Nationally Determined Contribution (NDC), and its net zero target by 2050.

2.1.5 The need for and the scale of future carbon reduction actions is increasing. The only way that need and scale will decrease in the future, while still limiting global temperature increases, is by delivering actions like the Scheme without undue delay.

2.2 Global decarbonisation

2.2.1 The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12th December 2015. It entered into force on 4th November 2016.

2.2.2 The overarching goal of the Paris Agreement is to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels."

2.2.3 In October 2018, following the adoption by the UN Framework Convention on Climate Change of the Paris Agreement, the Intergovernmental Panel on Climate Change (IPCC), which is the United Nations body for assessing the science related to climate change, published a Special Report on the impacts of global warming of 1.5°C above pre-industrial levels. This report concluded that human-induced warming had already reached approximately 1°C above pre-industrial levels, and that without a significant and rapid decline in emissions across all sectors, global warming would not be likely to be contained, and therefore more urgent international actions to decarbonise would be required.

2.2.4 NDCs are at the heart of the Paris Agreement and the achievement of its long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate, and maintain successive NDCs that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

2.2.5 The IPCC Working Group III (IPCC WG3) published its Summary of Climate Change as part of the IPCC's Sixth Assessment Report in April 2022, (Ref. 3). The IPCC WG3 report notes that although the rate of growth of average global annual greenhouse gas (GHG) emissions was lower between 2010 and 2019 than in the previous decade, average global annual GHG emissions during the last decade were higher than in any previous decade on record.

2.2.6 The IPCC WG3's global GHG emissions for four modelled scenarios are included in Figure 2-1 below. The red band shows global annual GHG emissions considering global decarbonisation policies which at the time of writing the report had been implemented. Implemented policies are likely to slow the historical increase in annual emissions but are not yet sufficient to reduce them. That is to say, policies which have already been implemented mean that global GHG emissions will continue at their current level through to 2050.

2.2.7 The purple, green, and blue bands show the IPCC's conclusions on different decarbonisation pathways, which must be followed to meet three scenarios of global temperature increases.

2.2.8 The purple band shows the decarbonisation path achieved by NDCs to 2030 followed by the decarbonisation path required to limit temperature increase to 2°C above pre-industrial levels with a probability of at least 67%. The red band is higher than the purple band, which implies that policies implemented to date are not yet sufficient to meet 2030 NDC commitments.

2.2.9 The green band shows the decarbonisation path which will achieve the same outcome as the purple path, by increasing actions in the 2020s and overshooting current NDCs. By urgently increasing decarbonisation actions now, future year-on-year carbon reductions to meet the same outcome can be lower and therefore are likely to be more achievable.

2.2.10 The cumulative warming effect of carbon means that not delivering against plans set out for the 2020s will lead to a greater scale and urgency to future plans and their delivery in order to meet the temperature increase limit set by the Paris Agreement. Delaying decarbonisation actions increases the risk of losing the fight against climate change, whilst in the meantime ongoing climate change events and impacts are unlikely to slow or decrease, putting lives and livelihoods at risk.

2.2.11 The blue band shows the decarbonisation path which will meet the commitments of the Paris Agreement with a probability of 50%.

2.2.12 Conclusions arising from Figure 2-1 are:

a. Global climate change commitments are not yet sufficient to meet nor sustain a (likely) successful track towards containing global temperature rise below 1.5°C; and

b. Policies implemented to date fall short even of those commitments

2.2.13 The IPCC WG3 report findings also imply that mitigation after 2030 can no longer establish a pathway which will likely not exceed 1.5°C global temperature increase vs. 1990, during the 21st Century.

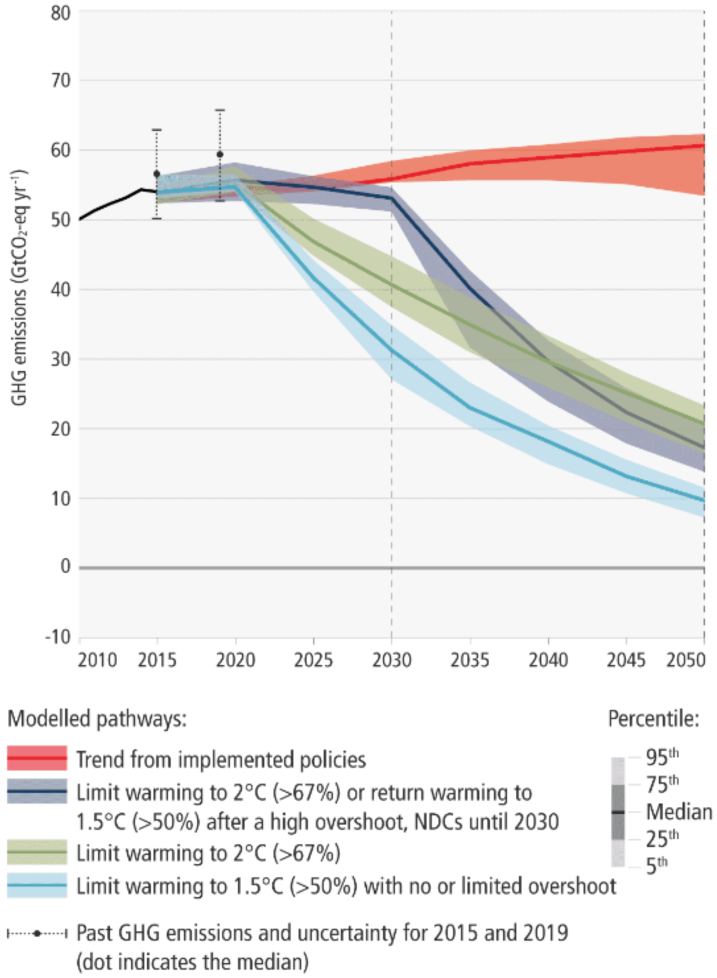

Figure 2-1 Representation of global GHG emissions of modelled pathways (Ref. 3)

2.2.14 The compelling need for global action to decarbonise continues to be reinforced. On 20th March 2023, the IPCC published its 2023 assessment of global climate change. The report concludes that the world is likely to pass a dangerous temperature threshold within the next 10 years, pushing the planet past the point of catastrophic warming — unless nations drastically transform their economies and immediately transition away from fossil fuels (Ref. 4).

2.2.15 In an April 2023 press release which accompanied his State of the Global Climate 2022 report, the World Meteorological Organisation's (WMO) Secretary General stated that *"WMO is sounding the alarm that we will breach the 1.5C level on a temporary basis with increasing frequency"* (Ref. 5). This implies that sufficient progress on fighting climate change has not yet been made and more needs to be done in both mitigation and adaption.

2.2.16 The 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28) was held in Dubai in December

2023. At the closing statement, the UN Climate Change Executive Secretary celebrated strides made at COP28, including agreement among the parties, to *"tripling renewables and doubling energy efficiency"* as well as signalling *"the beginning of the end"* of the fossil fuel era.

2.2.17 However, on a global basis, COP28 concluded the requirement for action to abolish carbon emissions is more urgent now than ever it has been. The same is true for the UK. (Ref. 6).

2.3 Decarbonisation in the UK

2.3.1 As a result of its commitments to the Paris Agreement, in June 2019 the UK became the first major economy to legislate for a 2050 net zero GHG emissions target through the Climate Change Act 2008 (2050 Target Amendment) Order 2019 (Ref. 7).

2.3.2 Decarbonisation is therefore a UK legal requirement.

2.3.3 In December 2020, the UK communicated its NDCs under the Paris Agreement to reduce GHG emissions by at least 68 per cent from 1990 levels by 2030. In April 2021, the government legislated for the Sixth Carbon Budget (CB6), which requires the UK to reduce GHG emissions by 78 per cent by 2035 compared to 1990 levels.

2.3.4 UK Government objectives are to ensure the supply of energy to the national energy system always remains secure, reliable, affordable, and consistent with meeting legally binding GHG emissions including the NDC. The government has identified that this will require a step change in the decarbonisation of the UK's energy system (Ref. 1, Para 2.2.3), and large-scale ground mounted solar has an important role to play in the UK.

2.3.5 The Climate Change Committee, a national independent advisory committee, made clear in its Progress Report to Parliament in 2019 (Ref. 8(2019)), that the UK is not on track to meet its fourth (2023-2027) or fifth (2028-2032) carbon budget.

2.3.6 This position was reinforced in the latest 2023 report which states that:

"Our confidence in the achievement of the UK's 2030 target and the Fifth and Sixth Carbon Budgets has markedly declined from last year" (Ref. 8(2023), p8)

and

"To achieve the NDC [Nationally Determined Contribution – 2030] commitment of at least a 68% fall in territorial emissions from 1990 levels, the rate of emissions reduction outside the power sector must almost quadruple." (Ref. 8(2023), p13)

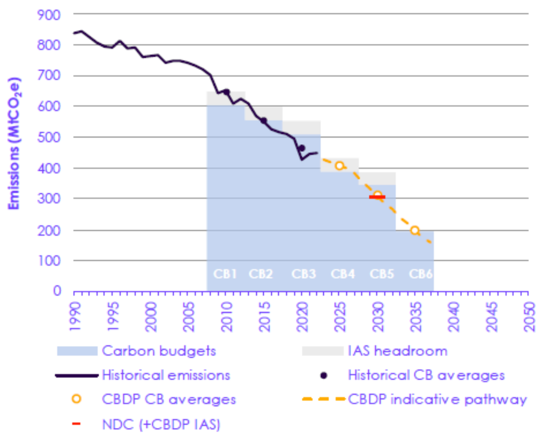

Figure 2-2: UK historical emissions, the government's pathway and the UK's targets (Ref. 8)

2.3.7 Emissions in the UK have steadily fallen over the last three decades and in 2022 were 46% below 1990 levels. The UK met its first two carbon budgets and the CCC report that it is likely to have met its third, which ran from 2018 to 2022, although a full assessment will be made in 2024 (Ref. 8(2023)).

2.3.8 Figure 2-2 shows historical emissions and performance against historical Carbon Budgets. The CCC's Carbon Budget Delivery Plan (yellow) for Carbon Budgets 4 to 6 are also shown, as is the UK Government's NDC in 2030.

2.3.9 The CCC conclude that progress must be made in further reducing the emissions associated with electricity supply while accelerating emissions reductions in other sectors for the UK to meet its 2030 NDC and the Sixth Carbon Budget (Ref. 8(2023), p82). Chapter 4 shows that decarbonisation of other sectors is largely dependent on the availability of sufficient quantities of low-carbon electricity as a substitute for carbon-emitting fuels. It therefore follows that the development of new low-carbon electricity generation infrastructure also needs to accelerate.

2.3.10 Maintaining progress in decarbonisation of electricity supply must, according to the CCC, now focus on *"phasing out unabated gas generation, while also keeping pace* with growing electricity demand" (Ref. 8(2023), p83).

2.3.11 Without adequate supply of low-carbon electricity, the urgent requirement for a rapid decarbonisation of other sectors (as will be required to meet future Carbon Budgets) is unlikely to be achieved.

2.4 The UK's strategic plan for decarbonisation

2.4.1 The UK chose to largely decarbonise its power sector by adopting low carbon sources quickly, and invited industry to bring forward new low carbon developments to meet the twin challenge of energy security and climate change (Ref. 1, Para 3.3.5).

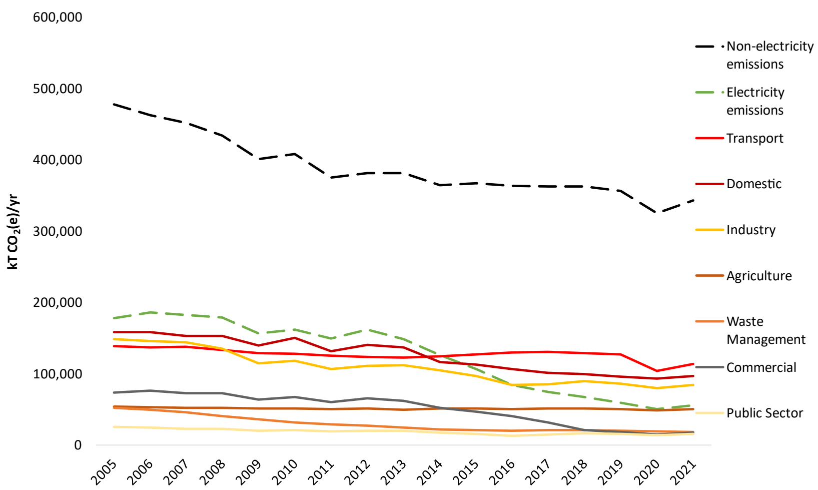

Figure 2 3: National (UK) District GHG Emissions 2005 - 2021 (LULUCF net benefits small and not shown (Ref. 9)

2.4.2 Implementing this strategy by closing generation capacity with high carbon emissions and replacing it with low-carbon renewable energy has delivered significant decarbonisation benefits in the UK to date.

2.4.3 Figure 2-3 shows that carbon emissions associated with the UK's electricity system (green dashed line) have reduced by over 50% between 2005 and 2021 (the most recent year for which data is available from this source). Non-electrical emissions have also reduced but by a lower percentage.

2.4.4 Those sectors with the highest carbon emissions in 2021 were the transport and domestic sectors. Fossil fuels remain a major source of energy to these sectors. Critically the percentage reductions of emissions in those sectors between 2005 and 2021 was lower than national average emission reduction (at 18% and 39% respectively) and was 19% in the domestic sector excluding domestic electricity use.

2.4.5 Figure 2-3 suggests that the transport, domestic and industrial sectors require a significant intervention to reduce carbon emissions, and that the reduction of emissions from those sectors will be critical if net zero 2050 is to be reached.

2.5 The Energy White Paper

2.5.1 The Energy White Paper (Ref. 10), published in December 2020, outlined a strategy to transform the energy system, tackling emissions while continuing to ensure secure and reliable supply, and affordable bills for households and businesses.

2.5.2 Solar has helped increase UK renewable capacity five-fold between 2010 and 2020 (Ref. 10, p40).

2.5.3 A low-cost, net zero consistent system is likely to be composed predominantly of wind and solar (Ref. 10, p43).

2.5.4 Onshore wind and solar will be key building blocks of the future generation mix, along with offshore wind. We will need sustained growth in the capacity of these sectors in the next decade to ensure that we are on a pathway that allows us to meet net zero emissions in all demand scenarios (Ref. 10, p45).

2.5.5 Solar plays an increasingly important role in supporting an affordable and fair energy system by displacing price-setting gas from the electricity system (Ref. 10, p30).

2.6 Net Zero Strategy – Build Back Greener

2.6.1 The Net Zero Strategy (NZS) (Ref. 11), published in October 2021, set out a long-term plan for the economy-wide transition to net zero that will take place over the next three decades.

2.6.2 The NZS's key policy is for the UK to be powered entirely by clean electricity by 2035, subject to security of supply (Ref. 11, p20).

2.6.3 Government committed to accelerate deployment of low-cost renewable generation, such as wind and solar, to meet their key policy aim (Ref. 11, p94).

2.6.4 A sustained increase to the deployment of land-based renewables such as locally supported onshore wind and solar in the 2020s and beyond is required to meet CB6 (Ref. 11, p103).

2.6.5 The NZS includes up-to-date evidence of the low cost of large-scale solar globally, which is supporting the necessary increase in capacity of large-scale solar builds in the UK (Ref. 11, p312).

"Gas will continue to play a role in setting the electricity price for some years to come but, over time, will do so less frequently, as more and more low carbon generation (such as wind and solar) connect to the electricity system … This will help put downward pressure on wholesale electricity prices" (Ref. 11, p337).

2.7 The British Energy Security Strategy

2.7.1 The British Energy Security Strategy, published in April 2022, set out the immediate need to manage the financial implications of soaring commodity prices in the near term and also the long-term goal of "address[ing] our underlying vulnerability to international oil and gas prices by reducing our dependence on imported oil and gas" (Ref. 12, p6).

2.7.2 The British Energy Security Strategy recognises the critical role of renewables in accelerating the transition away from fossil fuels (Ref. 12, p16).

2.7.3 The British Energy Security Strategy introduced the government's increased ambition for solar generation, supporting a five-fold increase in deployment of solar technology by 2035, recognising the abundant source of solar energy in the UK and an 85% reduction in cost of solar power over the last ten years. (Ref. 12, p19). The online British Energy Security Strategy includes an explicit ambition for up to 70GW of British solar on roofs and on the ground by 2035.

2.7.4 For ground-mounted solar, the strategy indicates a future consultation on planning rules to strengthen policy in favour of development on non-protected land, while ensuring communities continue to have a say and environmental protections remain in place. (Ref. 12, p19).

2.7.5 Critically, the British Energy Security Strategy includes actions such as the bringing forward electricity into home heating and supporting the rollout of electric vehicles (EVs) as part of Government's Electric Vehicle Infrastructure Strategy, which will increase demand for electricity in future years, from potentially as early as the mid-2020s.

2.8 Mission Zero – the Skidmore Review

2.8.1 Mission Zero was published in January 2023 by Rt Hon Chris Skidmore MP, Chair of government's Independent Review of Net Zero. The report was commissioned to ask how the UK might deliver its own net zero targets in a manner that was more affordable, more efficient, and in a pro-business and pro-enterprise way. Mission Zero recognises the importance of taking action on net zero. It also recognises the fact that the energy transition is a new economic reality, particularly amid the global reality of the energy security crisis and rising gas and fossil fuel prices in 2022.

2.8.2 Mission Zero reconfirms the global importance of the UK's commitment to achieve net zero and makes recommendations which should be taken forwards now, alongside other wider recommendations. It states that the UK should be proud of the steps it has taken so far to achieve net zero, and that climate change and the economy are intertwined. The UK must however move quickly, not only to protect and secure delivery of our national climate commitments but also deliver the economic benefits of moving away from a carbon economy. The review finds that *"The benefits of net zero will outweigh the costs"* and believes that *"This is too important to get wrong"* (Ref. 13, p8).

2.8.3 Mission Zero makes the following recommendations which are relevant to the growing need for large-scale ground mount solar to be deployed in the UK:

a. Priority Mission no. 2: "Full-scale deployment of solar including a rooftop revolution to harness one of the cheapest forms of energy, increase our energy independence and deliver up to 70GW of British solar generation by 2035";

b. Priority Mission no. 8: "Working towards gas free homes by 2035 [or earlier]" and Recommendation 1 is to set a legislative target for gas-free homes and appliances;

c. Recommendation 15 is the swift delivery of Zero Emissions Vehicles and the ZEV mandate to apply from 2024. Powering Up Britain (see following) remains ambitious and forward-thinking in its targets for the decarbonization of light road transport, but is less explicit in regard to associated timelines – noting the practical requirement to remain compatible (from a supply chain / industry change perspective) with the wider European position: "Between 2030 and 2035, new cars and vans will only be able to be sold if they offer significant zero emission capability" (Ref. 14, p27);

d. Priority Mission 8 and Recommendations 1 and 15 add weight to the argument for rollout of solar and other renewable generation to meet the growing demand which will arise from their delivery;

e. Priority Mission no. 9 is to "Embed nature and habitat restoration … maximising co-benefits for climate and nature wherever possible." Ground mount solar can deliver on this Priority Mission through delivering biodiversity net gain because of development;

f. Recommendation 11 is to "Set up taskforce and deployment roadmaps in 2023 for solar to reach up to 70GW by 2035." This Recommendation recognises that the current pipeline for solar projects in the UK, and the most ambitious industry projections for solar deployment, are not yet of sufficient scale to meet the government's ambition without undue levels of risk associated with the deployment of other technologies; and

g. Mission Zero recognises the importance of local action and local plans to the achievement of net zero. People and places must be empowered to deliver net zero through a full alignment on a local level with a net zero future through the introduction of a 'net zero test'. All local authorities will be required to play their part in achieving carbon neutrality in the future. Ground-mounted solar (at both Nationally Significant infrastructure and local planning authority scale) is a leading deliverable low-carbon generation technology which will enable local authorities to deliver against plans to decarbonize on a local level.

2.9 Powering Up Britain

2.9.1 The UK Government's Powering Up Britain Strategy, Powering Up Britain: Energy Security Plan and Powering Up Britain: Net Zero Growth Plan set out how the UK will achieve energy security, promote green growth and meet its net zero targets.

2.9.2 Powering Up Britain was published in March 2023 to present the most up to date information on the government's energy strategy, explaining *"how the Government will enhance our country's energy security, seize the economic opportunities of the transition* [to renewables]*, and deliver on our net zero commitments"* (Ref. 14(1), p6), and observes that *"The* [Mission Zero] *Review was unequivocal in its assessment that the plan set out in the Net Zero Strategy was the right one, whilst providing recommendations to strengthen delivery."* (Ref. 14(1), p16)

2.9.3 Powering Up Britain concludes that *"We need investment at scale … to rapidly rollout existing technologies … at pace to meet our ambitions for decarbonising power and* [lower] *wholesale UK electricity prices."* (Ref. 14(1), p9) and observes that *"a significant proportion of technologies we will need for 2050 are currently at the demonstration or prototype phase"* (Ref. 14(1), p9). This implies that while we should continue to strive for innovation, waiting for novel technologies to deliver comes with risk (as some technologies may not deliver) and therefore the Government's strategy to deliver a rapid rollout of existing technologies while continuing to invest in new technologies is of critical importance in the fight against climate change.

Ground-mounted large-scale solar is a mature technology which is capable of delivering a reliable and rapid rollout once projects are consented.

2.9.4 Powering Up Britain recognises the huge potential solar generation can have in decarbonisation. Large-scale ground-mounted solar is a mature technology which is capable of delivering a reliable and rapid rollout once projects are consented and is one of the cheapest forms of electricity generation that is readily deployable at scale.

2.9.5 Powering Up Britain therefore includes the acceleration of renewables deployment as a critical to support the delivery of the Government's plans: *"Our goal is to develop up to 50GW of offshore wind by 2030 and to quintuple our solar power by 2035"* (Ref. 14(1), p7), noting that 14GW of solar is already installed in the UK (Ref. 14, p19).

2.9.6 Powering Up Britain's Energy Security Plan confirms that the government is *"aiming for 70GW of ground and rooftop capacity together by 2035 … We need to maximise deployment of both types of solar to achieve our overall target"* (Ref. 14(5), p37)

2.9.7 In support of the emphasis Powering Up Britain places on the need to maximise the deployment of ground-mounted solar, the strategy states that the *"Government seeks large scale solar deployment across the UK, looking for development mainly on brownfield, industrial and low/medium grade agricultural land. The government will therefore not be making changes to categories of agricultural land in ways that might constrain solar deployment"* (Ref. 14(1), p20).

2.9.8 Powering Up Britain makes it clear that the government expects the operational capacity of both large-scale and rooftop solar to grow in pursuit of net zero. In other words, that development on agricultural land is also anticipated.

2.10 Climate Change Committee Progress Report to Parliament, 2023

2.10.1 The Committee on Climate Change published the 2023 edition of their annual Progress Report to Parliament in June 2023. The report noted the lack of urgency in the delivery of decarbonisation in the UK.

2.10.2 The Committee's summary comment was that the UK should stay firm on existing commitments and move to delivery. The report stated that "*To achieve the NDC* [2030] *commitments the goal of at least a 68% fall in territorial emissions from 1990 levels, the rate of emissions reduction outside the power sector must almost quadruple from what has been achieved so far*" … but "*Some of the key planks of the UK Net Zero Strategy have substantial lead-times*" (Ref. 8(2023), p13).

2.11 Energy Act 2023

2.11.1 In October 2023, the Energy Act 2023 (EA 2023) came into law. The EA 2023 aims to strengthen energy security and support the delivery of net zero and affordable energy bills for households in the long term.

2.11.2 Government's press release at the time of Royal Assent (Ref. 15) describes the key elements of the EA 2023.

2.11.3 The EA 2023 brings heat networks into the remit of the Office for Gas and Electricity Markets (Ofgem), further supporting the UK's whole-system approach to energy, and updates their remit further so that the Office considers net zero targets as part of its everyday decisions.

2.11.4 New measures will also support consumers in their transition to 'smart products' which will pave the way to the automatic response of UK electricity demand at times of abundance or potential scarcity – a key measure if households are to deliver flexibility to the UK's energy system.

2.11.5 On the energy supply side, the EA 2023 legislates for the regulation of nuclear fusion, an important enabler of the UK's prototype fusion ambitions for 2040.

2.11.6 The EA 2023 also introduces a new licensing framework for CO_2 and hydrogen transport and storage to help deliver the UK's first carbon capture and hydrogen production sites.

2.11.7 Further provision is made within the EA 2023 to support the growth of offshore wind while ensuring that compensation for any adverse environmental effects is delivered strategically as opposed to being delivered on a scheme-by-scheme basis.

2.11.8 The EA 2023 should therefore be seen as enabling legislation which will support the UK to deliver on technology development to achieve net zero by 2050. Further discussion on those technologies is included in Chapter 5 of this Statement of Need.

2.12 Connections Action Plan

2.12.1 Securing a timely grid connection is a critical enabler for low carbon infrastructure to contribute towards a zero-carbon electricity system by 2035 but grid connection availability is currently constrained.

2.12.2 Ensuring assets can connect to the electricity network where and when they need to is crucial to achieving net zero, as well as to delivering affordability for consumers and maintaining security of supply

2.12.3 In November 2023, DESNZ and Ofgem jointly published a Connections Action Plan which states:

"Nearly half of transmission generation projects have a connection date at least five years from now, with some scheduled to wait ten years or more. This is simply too slow and remains the biggest risk to our ability to decarbonise our power system by 2035 …

The Plan is aimed at getting a significant majority of projects connected by their requested connection date, up from 14 per cent today, and to reduce the average delay a project faces in connecting to the transmission network from five years to six months" (Ref. 16, p7)

2.12.4 The Connections Action Plan includes reforms to the connections process which have been designed to enable viable projects to connect in a timely and cost-effective manner. The reforms are:

a. Raising entry requirements, including evidence of landowner permission, to deter speculative connection applications

d. Removing stalled projects to release capacity for more viable projects

e. Better utilising existing network capacity to reduce connection timelines, and

f. Allocating available network capacity to connect projects that are readier to progress and are able to quickly make use of capacity

2.12.5 The Plan explains that the efficient utilisation of existing networks can defer or negate the need for expensive new infrastructure, which takes time to deliver (Ref. 16, pp26&27) and that ensuring that existing and future capacity is allocated efficiently will allow timely connection offers, aligned with net zero objectives.

2.12.6 In relation to increasing network capacity, the Plan describes that there are two approaches. The first is to increase network build and the second, which is described as *“more efficient”* and *“typically lower cost”*, is to *“maximise the use of the currently available and planned network capacity”* (Ref. 16, pp40&41)

2.12.7 Capacity allocation is defined in the Plan as an approach to *“maximise the benefits of available capacity such that projects that are more ready and able to connect can do so ahead of those which are stalled, while maintaining appropriate opportunities for technologies with varying lead times, in line with net zero pathways”* (Ref. 16, p44)

2.12.8 Schemes which propose to develop technology which will support the move to net zero (such as solar and storage schemes) are therefore aligned with the government’s aims and strategy. Schemes which propose to connect to existing and available connection capacity are aligned with the Connections Action Plan reforms.

2.12.9 This Scheme proposes to connect a large-scale solar plus storage asset to the National Electricity Transmission System via an existing and available point of connection. Through the design of the Scheme, the Applicant seeks to maximise use of the connection capacity available. This Scheme is therefore fully aligned with the direction of travel of relevant policy and action plans in support of achieving Government’s aims of a zero carbon electricity system by 2035.

2.13 Conclusions on decarbonisation policy context

2.13.1 Urgent and unprecedented action is needed on an international scale to meet the commitments established through the Paris Agreement for urgent actions to decarbonise society and stop global warming.

2.13.2 The UK has legally binding targets to decarbonise and is developing new, and enhancing existing, policies to ensure that those targets are met in a secure and affordable fashion.

2.13.3 However, policies are not yet sufficient to deliver to those national commitments, and delivery against those UK policies is further behind.

2.13.4 Without a rapid increase in the supply of low-carbon electricity, the urgent requirement to decarbonise other sectors (as will be required to meet future Carbon Budgets) is unlikely to be achieved.

2.13.5 Solar generation is increasing in both scale and importance within emerging government policy. Not only for the benefits it delivers to decarbonisation, but also because of the need for secure and affordable energy supplies.

2.13.6 Government is currently targeting 70GW of solar to be operational in the UK by 2035, including both ground mount and rooftop installations.

2.13.7 To achieve Government's target, the equivalent of approximately one solar scheme of a scale similar to the Scheme would need to be switched on each and every month between now and 2035.

2.13.8 The Scheme will, if consented, make an important and significant contribution towards achieving Government's current targets.

3. National Policy Statements

3.1 Planning policy for Nationally Significant Infrastructure Projects

3.1.1 The legal requirement to achieve net zero underpins the urgent need for the delivery of large capacities of consentable and affordable electricity generation schemes which make best use of GB's natural low-carbon energy resources and available grid connection points.

3.1.2 The NPSs were established against obligations made as part of the Climate Change Act 2008 (CCA2008) and were first designated in June 2011. Following a period of revision and consultation, a revised suite of NPSs were designated by the government on 17th January 2024.

3.1.3 The NPSs include the government's conclusion that there is a critical national priority (CNP) for the provision of nationally significant low-carbon infrastructure, which includes large-scale solar farms, because a combination of many or all types of such infrastructure is urgently required for both energy security and Net Zero.

3.1.4 The overarching National Policy Statement for Energy (NPS) EN-1 (Ref. 1) sets out national policy for energy infrastructure in England and Wales. It has effect, in combination with NPS EN-3 (for renewable energy infrastructure) (Ref. 2) and NPS EN-5 (for electricity networks) (Ref. 17), on recommendations made by the appointed Examining Authority (ExA) to the relevant Secretary of State (at the time of submission, the SoS for Energy Security and Net Zero) on applications for energy developments that fall within the scope of the NPSs (Ref. 1, Para 1.1.1).

3.1.5 NPS EN-1, when combined with the relevant technology-specific energy NPS, provides the primary basis for decisions by the SoS for developments that fall within the scope of the NPSs.

3.1.6 NPS EN-3 covers those technologies which, at the time of publication, were technically viable at generation capacities of over 50MW onshore and 100MW offshore. Critically, this includes solar generation, and as such the need for this technology is fully covered by the NPSs.

3.1.7 By virtue of intended generating capacity of the Scheme, the NPSs are relevant and applicable to the Scheme.

3.1.8 This Statement of Need for the development of large-scale solar generation reflects the government's policy that there is a critical national priority for nationally significant low-carbon infrastructure, including solar generation, and that solar is a key part of the government's strategy for low cost decarbonisation of the energy sector. It builds upon the arguments made in the NPSs to demonstrate why the Scheme is urgently needed at the scale proposed; why the proposed location is highly suitable for such a scheme; and how the Scheme also addresses all relevant aspects of established and emerging government energy and climate change policy and commitments.

3.1.9 S104 of the Planning Act 2008 makes clear that where an NPS exists relating to the type of development applied for, the SoS must have regard to it as a relevant NPS, and must decide the application in accordance with that NPS. The NPSs provide specific policy in relation to solar development, and the policies set out in NPS EN-1, 3 and 5 therefore apply as 'relevant' NPSs under s104.

3.1.10 The urgent national need for energy generating stations set out in both NPS EN-1 and EN-3 is of great significance to the determination of the Scheme. The NPSs establish that:

"Subject to any legal requirements, the urgent need for CNP Infrastructure to achieving our energy objectives, together with the national security, economic, commercial, and net zero benefits, will in general outweigh any other residual impacts not capable of being addressed by application of the mitigation hierarchy" (Ref. 1, Para 3.3.63).

3.1.11 There is a presumption under the NPSs that the urgent need for CNP infrastructure will outweigh any residual effects in all but the most exceptional cases. This presumption does not apply to residual impacts which present an unacceptable risk to, or interference with, human health and public safety, defence, irreplaceable habitats or unacceptable risk to the achievement of net zero. Where no such residual impacts exist, the presumption weighs in favour of the need for CNP infrastructure.

3.1.12 Policies within NPSs EN-1, EN-3 and EN-5 are relevant to this Scheme and those in accordance with which this Application must be decided are set out in Section 4.2.

3.1.13 The urgency of the need nationally significant low carbon infrastructure established in the NPSs requires actions to be taken in the near-term in order for that need to be met and therefore the urgent need for the Scheme is demonstrated by the urgent need for new energy infrastructure as set out in NPS EN-1. *"Government strongly supports the delivery of CNP infrastructure and it should be progressed as quickly as possible"* (Ref. 1, Para 3.3.63).

3.1.14 The urgent national need for energy generating stations means that significant weight should be attributed to the Scheme's ability to contribute to meeting that need.

3.2 A synthesis of National Policy Statement EN-1 (2023)

3.2.1 The fundamental need for the large-scale infrastructure, which NPS EN-1 considers, recognises the UK's legal commitment to decarbonise to net zero by 2050 and so contribute to holding the increase in global average temperature due to climate change, to well below 2 degrees above pre-industrial levels. The NPS states that:

"Using electrification to reduce emissions in large parts of transport, heating and industry could lead to more than half of final energy demand being met by electricity in 2050, up from 17 per cent in 2019,

representing a doubling in demand for electricity. Low carbon hydrogen is also likely to play an increasingly significant role" (Ref. 1, Para 2.3.7).

3.2.2 Government direction is to develop an integrated energy system which relies on low-carbon electricity generation for a significant proportion of its supply. As a consequence:

"Demand for electricity is likely to increase significantly over the coming years and could more than double by 2050 as large parts of transport, heating and industry decarbonise by switching from fossil fuels to low carbon electricity. The Impact Assessment for CB6 shows an illustrative range of 465-515TWh in 2035 and 610-800TWh in 2050" (Ref. 1, Para 3.3.3).

3.2.3 Government's objectives for the energy system are *"to ensure our supply of energy always remains secure, reliable, affordable, and consistent with meeting our target to cut GHG emissions to net zero by 2050"* (Ref. 1, Para 2.3.3).

3.2.4 Meeting this objective, Government states, will require a step change in the decarbonisation of our energy system, in particular to deliver a dramatic increase in the volume of energy supplied from low carbon sources (Ref. 1, Para 2.3.5).

3.2.5 The security, reliability and affordability of energy supplies is also of critical importance because of the role energy plays in delivering economic prosperity and social well-being (Ref. 1, Para 2.5.1).

3.2.6 Accelerating deployment of renewables, nuclear, hydrogen, CCUS and network infrastructure will help address the UK's current vulnerability to international energy prices through the supply of clean, secure and affordable UK-sourced power on a route to achieving net zero (Ref. 1, Para 2.5.6).

3.2.7 Government sees a need for significant amounts of new large-scale infrastructure to meet its energy objectives and considers that the need for such infrastructure is urgent (Ref. 1, Para 3.1.1).

3.2.8 There must always be sufficient electricity to meet demand, with margin to accommodate unexpectedly high demand, unexpected plant closures or extreme weather events and NPS EN-1 explains that the larger the margin, the more resilient the system will be with dealing with those types of events (Ref. 1, Para 3.3.1 & 3.3.2).

3.2.9 No single type of electricity infrastructure will be able to meet Government's objectives in isolation, so new generators of varied technology, assets that provide flexibility and new networks will all be needed (Ref. 1, Para 3.3.4). However, the government has concluded from its analysis that *"a secure, reliable, affordable, net zero consistent system in 2050 is likely to be composed predominantly of wind and solar"* (Ref. 1, Para 3.3.20).

3.2.10 Government's view is also that decentralised and community energy systems, which by definition would include rooftop solar installations, could lead to some reduction in demand on the main transmission system, but *"the government does not believe they will replace the need for new large-scale electricity infrastructure to meet our energy objectives."* NPS EN-1 goes on to explain that the connection of large-scale generation facilities via high voltage transmission systems enables the pooling of generation and demand and enables the efficient bulk transfer of power between areas with surplus and areas in deficit (Ref. 1, Para 3.3.12).

3.2.11 Government also considers that *"it is prudent to plan on a conservative basis to ensure that there is sufficient supply of electricity to meet demand across a wide range of future scenarios"* (Ref. 1, Para 3.3.10).

3.2.12 To hit the target of UK commitments to decarbonise the power sector by 2035 (Ref. 18), the NPSs conclude that it is necessary to bring forward new renewable electricity generating projects as soon as possible. The need for new renewable electricity generation projects is therefore urgent.

3.2.13 The Secretary of State has therefore determined that substantial weight should be given to this need when considering applications for development consent under the PA2008, and is not required to consider separately the specific contribution of any individual project to satisfying the need established in the NPS (Ref. 1, Paras 3.2.7 & 3.2.8).

3.2.14 NPS EN-1 explains that large capacities of low-carbon generation will be required to:

a. Ensure that there is sufficient electricity to meet increased demand;

b. Replace output from retiring plants;

c. Ensure there is sufficient margin in our supply to accommodate unexpectedly high demand; and

d. Mitigate risks such as unexpected plant closures and extreme weather events (Ref. 1, Section 3.3).

3.2.15 The government has concluded that national energy security and net zero ambitions will only be delivered through the development of new low carbon sources of energy at speed and scale (Ref. 1, Para 4.2.2) and therefore that there is a critical national priority (CNP) for the provision of nationally significant low carbon infrastructure (Ref. 1, Para 4.2.4). Low carbon electricity generation infrastructure is described as *"all onshore and offshore generation that does not involve fossil fuel combustion"* (Ref. 1, Para 4.2.5) and as such large-scale solar generation is classified as CNP infrastructure under NPS EN-1.

3.2.16 Government expects that *"For projects which qualify as CNP Infrastructure, it is likely that the need case will outweigh the residual effects in all but the most exceptional cases"* (Ref. 1, Para 4.1.7).

3.2.17 The Scheme meets the definition of CNP Infrastructure because it is for the development of greater than 50MW capacity of a low carbon source of energy. As CNP infrastructure, the urgent need for the Scheme to achieving the UK's energy objectives, together with the national security, economic, commercial and net zero benefits, will in general outweigh any other residual impacts not capable of being addressed by application of the mitigation hierarchy (Ref. 1, Para 3.3.63).

3.2.18 In noting the crucial national benefits of increased system robustness through new electricity network infrastructure projects, NPS EN-1 also recognises the particular strategic importance in the next decade of the role of solar generation in the UK's generation mix.

"As part of delivering [a secure, reliable, affordable, net zero consistent system in 2050], government announced in the British Energy Security Strategy an ambition to deliver up to 50GW of offshore wind by 2030 … and the requirement in the Energy White Paper for sustained growth in the capacity of onshore wind and solar in the next decade" (Ref. 1, Para 3.3.21).

3.2.19 The siting of new solar capacity is therefore important and the location of points of connection to existing networks to enable that capacity to come forwards, are an important consideration.

3.2.20 In relation to integration technologies, NPS EN-1 states that:

"New generating plants can deliver a low carbon and reliable system, but we need the increased flexibility provided by new storage and interconnectors (as well as demand side response …) to reduce costs in support of an affordable supply. Storage and interconnection can provide flexibility, meaning that less of the output of plant is wasted as it can either be stored or exported when there is excess production." (Ref. 1, Paras 3.3.5 & 6).

3.2.21 NPS EN-1 goes on to explain that storage is needed to reduce the costs of the electricity system and increase reliability by storing surplus electricity in times of over-supply, to provide electricity when demand is higher. Section 5.11 of this Statement of Need explains that storage can achieve the benefits set out in the NPS from stand-alone facilities or facilities co-located with renewable generation facilities.

3.2.22 The local and national benefits which storage assets can provide are also referenced in NPS EN-1 (Ref. 1, Para 3.3.6), being:

a. Maximising the usable output from intermittent low carbon generation
b. Reducing the total amount of generating capacity required to meet peak demand
c. Reducing the need for new network infrastructure
d. Providing a range of balancing services to help operate the electricity system, and
e. Reducing constraints on the electricity network

3.2.23 The role of 'low-carbon hydrogen' is also signalled as likely growing in significance in the future GB energy system, and therefore supports the need for infrastructure which can generate low-carbon electricity to produce low-carbon hydrogen (Ref. 1, Paras 2.3.5 - 2.3.7).

3.3 A synthesis of National Policy Statement EN-3 (2023)

3.3.1 NPS EN-3 (Ref. 2) covers nationally significant renewable energy infrastructure which includes solar photovoltaic (PV) at more than 50 MW in England and more than 350MW in Wales (Ref. 2, Para 2.6.1).

3.3.2 NPS EN-3 bolsters the support for solar development in the UK that was previously provided in the draft 2021 versions, now stating that it has *“committed to sustained growth in solar capacity to ensure that we are on a pathway that allows us to meet net zero emissions. As such solar is a key part of the government’s strategy for low-cost decarbonisation of the energy sector”* (Ref. 2, Para 2.10.9).

3.3.3 The statement goes on to re-iterate the contribution that solar generation is expected to make to achieving net zero targets and the energy security goals set out in the British Energy Security Strategy, of *“a five-fold increase in combined ground and rooftop solar deployment by 2035 (up to 70GW)”* (Ref. 2, Para 2.10.10).

3.3.4 Because *“Solar farms are one of the most established renewable electricity technologies in the UK and the cheapest form of electricity generation.”* (Ref. 2, Para 2.10.13), solar is also expected to bring forwards affordability benefits for consumers.

“Solar farms can be built quickly and, coupled with consistent reductions in the cost of materials and improvements in the efficiency of panels, large-scale solar is now viable in some cases to deploy subsidy-free.” (Ref. 2, Para 2.10.14)

3.3.5 NPS EN-3 also establishes that energy storage, if proposed as part of a solar farm proposal, may be treated as associated development to that proposal (Ref. 2, Para 2.10.16).

3.3.6 Grid connection, and in particular the likely proximity of schemes to suitable connection points on the transmission network, is also addressed:

“The connection voltage, availability of network capacity, and the distance from the solar farm to the existing network can have a significant effect on the commercial feasibility of a development proposal.”

“To maximise existing grid infrastructure, minimise disruption to existing local community infrastructure or biodiversity and reduce overall costs applicants may choose a site based on nearby available grid export capacity.” (Ref. 2, Paras 2.10.24&25)

3.3.7 NPS EN-3 also lists irradiance and site topography as key inputs to site selection (Ref. 2, Paras 2.10.19 & 20).

3.3.8 NPS EN-3 suggests anticipated levels of land efficiency for solar generation, recognising both the land take which schemes such as this one requires, but also that evolution in the technology is anticipated and this may bring about efficiency benefits through the life of the Scheme:

“Along with associated infrastructure, a solar farm requires between 2 to 4 acres for each MW of output. A typical 50MW solar farm will consist of around 100,000 to 150,000 panels and cover between 125 to 200 acres. However, this will vary significantly depending on the site, with some being larger and some being smaller. This is also expected to change over time as the technology continues to evolve to become more efficient.” (Ref. 2, Para 2.10.17)

3.3.9 The degradation of solar efficiency over time is addressed in NPS EN-3 (Ref. 2, Para 2.10.55), suggesting that developers may need to account for the light-induced degradation effects on solar panels by overplanting solar panel arrays.

3.3.10 The design life of solar panels should also be considered "*when determining the period for which consent is required. An upper limit of 40 years is typical, although applicants may seek consent without a time-period or for differing time-periods of operation.*" (Ref. 2, Para 2.10.65).

3.4 A synthesis of National Policy Statement EN-5 (2023)

3.4.1 NPS EN-5 covers new, non-exempt above ground electricity lines over 2km in length whose nominal voltage is expected to be 132kV or above and other kind of electricity infrastructure in England which is constituted as associated development for which consent is sought along with an NSIP (Ref. 17, Para 1.6.2).

3.4.2 NPS EN-5 explains that *"significant new electricity networks infrastructure is required"* (Ref. 17, Para 2.2.3).

3.4.3 NPS EN-5 acknowledges that the siting of new electricity transmission infrastructure is determined by *"the location of new generating stations or other infrastructure requiring connection to the network, and/or system capacity and resilience requirements determined by the Electricity System Operator"* (Ref. 17, Para 2.2.2).

3.4.4 If the UK's Centralised Strategic Network Planning process identifies strategic investments intended to facilitate achieving net zero and decarbonisation targets, *"the Secretary of State should have regard to the need case for new electricity networks infrastructure set out in Section 3.3 of NPS EN-1"* (Ref. 17, Paras 2.8.2&3).

3.4.5 The proposed connection to an existing and available grid substation is a significant benefit of the Scheme within the context of the significant need for new electricity networks infrastructure. This Statement of Need does not synthesise further the contents of EN-5.

3.5 Conclusion

3.5.1 The Applicant considers that NPSs EN-1, EN-3 and EN-5 are relevant to the Scheme for the purposes of s104 of the PA2008, and as such the DCO application for the Scheme must be determined in accordance with their policies.

3.5.2 Solar generation is expected to make an important contribution to the UK's renewable energy generating capacity towards 2050.

3.5.3 The NPSs demonstrate that:

a. The need for solar technology (as a renewable source) in GB is urgent and significant and has increased, with nationally significant solar technology now defined as CNP infrastructure;

b. Large-scale solar is technically and economically feasible;

c. Large-scale solar can and will bring benefits for the UK; and

d. Integration technologies will play an essential role in full decarbonisation of the whole GB energy system, enhancing the benefits brought by low-carbon generation.

3.5.4 These factors manifest in terms of material contribution to the UK's legal decarbonisation targets; enhancement of security of supply; and managing the affordability of electricity for GB consumers.

3.5.5 NPS EN-3 provides that grid connection, irradiance and site topography are key inputs to the selection of sites suitable for large-scale solar generation developments.

3.5.6 Therefore, the number of locations at which large-scale solar generation is suitable is likely to be limited, and this is a material issue when considering how the UK is to meet the urgent need for low-carbon generation as is established in the current NPSs.

4. Estimating future electricity demand

4.1 Chapter summary

4.1.1 This chapter provides information to support and quantify the policy position that future electricity demand will need to grow to a very significant degree in order to achieve net zero. As set out in NPS EN-1:

"[Government] expect[s] that demand for electricity is likely to increase, as significant sectors of energy demand (such as industry, heating and transport) switch from being powered by fossil fuels to using electricity. As a result of this electrification of demand, total electricity consumption ... could double by 2050." (Ref. 1, Para 3.3.14).

"Whilst no such projections of the UK's future energy mix can be definitive, they illustrate the scale of the challenge the UK is facing." (Ref. 1, Para 3.3.21).

4.1.2 Energy consumption in the UK in 2022 at 1,498TWh, with 19% (283TWh) in the form of electricity (Ref. 19, Table 1.1au). Electricity demand is expected to grow significantly in the future as carbon-intensive sources of energy are displaced by electrification of other industry sectors, or production of non-carbon energy vectors by use of electricity, although energy efficiency measures may mean that UK energy consumption decreases in the future, such that future energy consumption may be lower than current levels.

4.1.3 The annual National Grid ESO (NGESO) Future Energy Scenarios (FES) documents provide important and relevant information on these points. The FES are discussed in more detail in the following sections.

4.2 Introducing the FES

4.2.1 NGESO's FES (Ref. 20) are widely recognised and regular publications which indicate whether particular future pathways for electricity generation can be successful against a current national policy perspective.

4.2.2 Trends in the data help identify which pathways are more likely to be successful than others in achieving net zero, and this includes indications of the relative contribution of (therefore related to need for) different generation technologies in meeting projections of future demand.

4.2.3 The FES are an important point of view, which contributes to an objective assessment of the need for, and scale of, how much energy GB might need and where it could come from, to build a picture of the ways in which net zero could be reached.

4.2.4 NGESO recommend that "*Benefits to the whole energy system must be considered to optimise the cost of delivering net zero technology and infrastructure,*" and that "*Strategic coordination and whole energy system thinking across all sectors is required to achieve decarbonisation targets,*" (Ref. 20(2023), p11). This means a consideration of all aspects of energy demand and supply as an interconnected system, rather than thinking about electricity, transport or heat separately. Strategic coordination and whole system thinking, especially between the electricity and hydrogen sectors, is required to achieve decarbonisation targets and deliver more effective initiatives to fight climate change while maximising affordability.

4.2.5 Recent editions of the FES have addressed delivery of the British Energy Security Strategy as well as further increases in the urgency of action against climate change. The FES have now a greater emphasis on interim milestones such as carbon-free operation of the NETS by 2035 and a deeper insight into how the whole energy system works together.

4.2.6 The FES includes four modelled scenarios, or pathways. Three pathways involve radical change across many industry sectors, and will deliver the required 100% reductions in carbon emissions by 2050. One pathway will not.

4.2.7 Two of the pathways (Consumer Transformation and System Transformation) meet the net zero target in 2050. A third, Leading The Way, meets net zero in 2046. The fourth pathway, Falling Short, only achieves emissions levels of 80% of 1990 levels by 2050 – the original objective of the Climate Change Act 2008, but not sufficient to secure net zero 2050.

4.2.8 The net zero commitment underpins the urgency for new low carbon generation infrastructure to be built and commissioned, and government support for such developments is critical.

4.2.9 The key observation is that in all lower-carbon futures, the electricity sector will not operate in isolation from other energy sectors. Rapid decarbonisation is required across all areas of demand – including residential, transport, industrial and commercial. Deep electrification of all of those areas is required in order to meet net zero, and until widespread electrification is achieved, the need for urgent electrification will increase year-on-year.

4.2.10 The 2023 FES includes an Energy Background Document in which it is stated that:

“A range of technologies with different characteristics can, in combination, help deliver secure, affordable low carbon electricity supplies and harness the potential of domestic renewable resources. More electricity from wind and solar is vital to help UK meet its target for net zero by 2050” (Ref. 21, p16).

4.2.11 The Energy Background Document also provides an example of how strategic coordination and whole system thinking can deliver a secure and affordable energy system built largely on renewables and hydrogen, although in reality, the need for low carbon electricity generation capacity is, based on currently known and deliverable technologies, independent of the scale of adoption of hydrogen in the UK.

“Producing hydrogen via electrolysis can create additional demand when needed to avoid curtailing wind and solar generation and this hydrogen can then be used to generate power at times of peak demand or low renewable output” (Ref. 21, p20).

4.2.12 In scenarios which meet net zero, the FES foresee future consumers / typical homeowners will use an electric heat pump with a low temperature heating system and an Electric Vehicle (EV). Consumers will be highly engaged in reducing and managing consumption, while hydrogen, electrolysed from excess renewable generation, will decarbonise industrial processes.

4.2.13 NGESO's analysis draws them to conclude that, as well as helping to deliver net zero, high levels of renewables will also help to address the cost-of-living crisis and contribute to the future affordability of energy supplies. The greater the capacity of electricity generation capacity added in near-term, the faster emissions from electricity reduce, and the quicker the decarbonisation of other sectors can be delivered (Ref. 21(2023), Tables NZ03 & NZ04).

4.2.14 This is important because the FES also conclude that negative emissions are already needed to help deliver net zero, and that a reliance on gas will make net zero later, or unachievable, within statutory timeframes. Wind and solar together comprise the backbone of Great Britain's electricity supply infrastructure in net zero compliant FES scenarios.

4.2.15 Chapter 9 of this Statement provides evidence that solar generation is, based on current economics, likely to be one of the cheapest sources of electricity in both the 2020s and 2050 energy mix. A diverse mix of low-carbon generation will be required to meet national decarbonisation targets.

4.3 The past and the future of UK electricity demand

4.3.1 In the 1990s and early 2000s, GB electricity demand grew only slowly, but from 2005 electricity demand has fallen year-on-year due to:

a. A decline in economic growth rate (particularly with the recession of 2009);

b. A reduction in the level of electricity intensity as the economy has shifted to less energy-intensive activities;

c. The introduction of energy efficiency measures including more efficient lighting and technology development more generally (Ref. 22, p28 & 23, p48); and

d. The COVID-19 pandemic (2020-2021) and cost of living crisis (2022-2023).

4.3.2 Today's view of future GB electricity demand is, however, one of returning growth, for the same reasons as those stated in the 2011 NPS EN-1 (Ref. 1):

a. The switching of sources of final-use power for heating and transport from carbon-intensive sources to electricity, the generation of which can be decarbonised using technologies already available today, will put upward pressure on demand;

b. The least-cost energy efficiency measures, such as introduction of low-voltage LEDs for lighting, have now been implemented across business and domestic sectors, and

c. Economic restructuring in GB away from manufacturing to a service-based economy has largely occurred, however the growth of new high-technology and highly skilled manufacturing, both contributing to national economic growth and prosperity, is likely to place additional pressures on the electricity sector.

4.3.3 The FES shows that electricity demand will need to increase if net zero is to be achieved, but crucially year-on-year by more than had previously been considered. Consequentially, low-carbon electricity supply will need to increase further to meet that demand, including the potential for increased anticipated demand for green hydrogen, which could be produced using renewable electricity to electrolyse water with zero carbon emissions.

4.3.4 The majority of industry projections of GB electricity demand to 2050 are for a significant increase from today's level of circa 300TWh. The amount by which forecasts increase varies according to the level of decarbonisation of non-energy sector demand, and the source of that decarbonisation. For example, hydrogen is an important energy vector which may be able to help decarbonise hard to reach sectors of transport, space heating and heavy industry. Off-grid hydrogen production would require the generation of low-carbon power, but this would be counted outside of the transmission system demand projections for 2050 (i.e. in addition to the views included in the following list):

a. The NPSs foresaw a doubling of current demand (Ref. 1, Para 2.2.22), i.e. to circa 600TWh;

b. NGESO present a range from 570TWh (for a scenario which does not meet net zero) to 726TWh (Ref. 20(2023), Table ED1);

c. The National Infrastructure Commission forecasts 465 – 595TWh Ref. 24, p35);

d. The Energy Systems Catapult forecasts 525 – 700TWh (Ref. 25, pp23&27);

e. The CCC's sixth carbon budget presents a range from 550 – 680TWh (Ref. 26, Table 3.4.a);

f. Government's impact assessment for Carbon Budget 6 (CB6) presents a range from 610 – 900TWh (Ref. 27, p29);

g. The 2020 Energy White Paper presents a range from 575 – 665TWh (Ref. 10, p42);

h. Mission Zero suggests that "electricity demand by 2050 could be roughly double today's level of total electricity demand" (Ref. 13, Paras 287 & 299); and

i. The Connections Action Plan projects electricity demand of between 570-770 TWh by 2050 depending on how net zero is met (Ref. 16, pp68-70).

4.3.5 The increasing level of future demand is relevant to the need for low carbon generation capacity because sufficient capacity must be developed to meet that demand. Further, as indicated in Mission Zero and borne out historically by industry data, in the future, demand on winter days "could be double that of milder days" (Ref. 13, Para 299). Therefore, timing demand to periods of high supply, or with supply, will be important, as will building sufficient generation capacity to meet demand under a variety of weather conditions. The government states that "it is prudent to plan on a conservative basis to ensure that there is sufficient supply of electricity to meet demand across a wide range of future scenarios" (Ref. 1, Para 3.3.10)

4.3.6 Figure 4-1 shows how NGESO's forecasts for electricity demand in Great Britain have developed since 2012. Each annual forecast is represented as a shaded area ranging from the lowest forecast demand scenario to the highest scenario per delivery year. Historical demand is shown as purple columns. Prior to the UK's 2019 commitment to net zero, as GB electricity demand reduced year-on-year, so too did future demand forecasts, converging towards a range from 350 – 400TWh.

4.3.7 Since the net zero commitment was made, forecasts for future GB electricity demand have increased significantly. To highlight this, NGESO's forecasts dated 2020 to 2023 have been shown in blue, with the 2023 forecast bordered in dark blue for emphasis. Increased electrification of transport, heat, and industrial demand is essential for the achievement of net zero and is a key driver for the increase in future electricity demand.

4.3.8 The range of demand provided by recent sources shows a shallow increase in forecast GB electricity demand over the coming five years as the aforementioned policies start to take hold. The forecasts then ramp up significantly around the end of the 2020s and thereafter.

4.3.9 Since the UK made its 2019 commitment to net zero, forecast GB electricity demand in 2050 has converged towards a range from 650 – 700TWh.

4.3.10 It is implicit that the trajectories shown in Figure 4-1 can only be met (and therefore net zero achieved) if there is sufficient operational low-carbon electricity generation capacity to generate the low-carbon energy demanded by consumers.

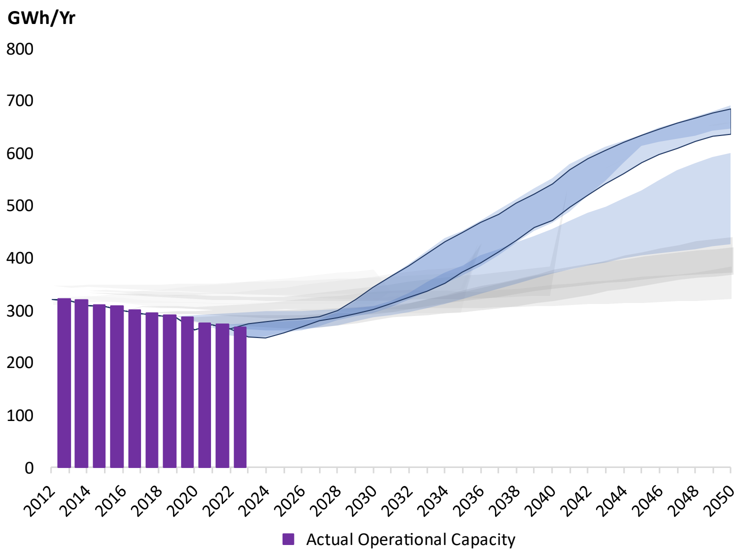

Figure 4-1: Evolution of UK electricity demand projections (2012 – 2023) (Ref. 20)

4.4 Transport policies underpin a growth in future electricity demand

4.4.1 Surface transport is currently the largest source of UK GHG emissions (surface transport accounted for just under one quarter of the UK's 2019 and 2020 emissions, (Ref. 25, p115, and Ref. 8(2022), Executive Summary Data Tables). A rapid shift to low emission vehicles will give a significant boost to UK decarbonisation.

4.4.2 Growth in the use of EVs is expected to create significant new demands on the electricity network. Government proposed a ban on the sale of all new petrol and diesel vehicles to be effective from 2030 (Ref. 28) alongside a ban on sales of new hybrid vehicles by 2035, although the Energy White Paper (Ref. 10, p92), proposed to bring the date for phasing out petrol and diesel cars and vans (including hybrids) forwards to no later than 2032. The aims included in Powering Up Britain were less explicit but remain ambitious and forward-thinking as well as being compatible (from a supply chain / industry change perspective) with the wider European position: "*Between 2030 and 2035, new cars and vans will only be able to be sold if they offer significant zero emission capability*" (Ref. 14(1), p27).

4.4.3 In September 2023, consistent with the groundwork laid in Powering Up Britain, the then Prime Minister Rishi Sunak announced that the UK's ban on the sale of new petrol and diesel cars would be pushed back to 2035, allowing petrol and diesel cars to be purchased new up to that date, and permitting second hand trades thereafter. Despite a delay to the ban, Government subsequently confirmed that the majority of new cars sold in the UK will have to be fully electric by 2030, suggesting a market and manufacturer, rather than regulation, led approach to electrification (Ref. 29). The zero emission vehicle mandate was introduced by the government on 1st January 2024. It demands that at least 22% of all cars and 10% of all vans sold in Britain in 2024 are pure electric, rising to 80 percent by 2030.

4.4.4 The Society of Motor Manufacturers and Traders reported a 17.8% increase in Battery Electric Vehicle (BEV) sales in the UK in 2023 versus 2022, and 16.5% of all new vehicle purchases in the UK in 2023 were BEV (Ref. 30).

4.4.5 Three major UK vehicle manufacturers – Mini, Jaguar Land Rover and Nissan – have stood fast in their drives to become 100% electric brands from 2026, 2025 and 2030 respectively (Ref. 31).

4.4.6 The September 2023 Prime Ministerial speech on net zero announced a *"more pragmatic, proportionate, and realistic approach to meeting net zero that eases the burdens on working people"* (Ref. 32) without abandoning any targets of commitments. Reducing costs and an improving range of EVs, together with growing charging infrastructure are expected to encourage consumers still to choose EVs over petrol and diesel cars, even in the absence of government regulations.

4.4.7 The eventual and necessary transition of all cars from fossil fuels to support net zero will continue due to their lower run costs, improving performance, increasing model choices, and zero emission capability.

4.4.8 The FES suggest that EVs will increase annual electricity demand in the UK by between 16TWh and 38TWh in 2030 and by between 90TWh and 123TWh by 2050. (Ref. 20(2023), Table ED1).

4.4.9 The government is facilitating the adoption of electricity into transport through its Electric Vehicle Infrastructure Strategy (March 2022) (Ref. 33) which sets out the expectation, by 2030, of there being around 300,000 public charge points as a minimum in the UK, up from just 53,677 on 1st January 2024 (Ref. 34).

4.4.10 The UK has put leadership of a low-carbon transport revolution at the heart of its Industrial and Clean Growth strategies and regards EVs as a critical new technology which will be vital in the fight against climate change. The government's commitments to invest in "gigafactories" for the mass production of batteries and EV supply chain, (Ref. 35, Ref. 36 & Ref. 37) provide evidence that, despite Government relaxing the end-date to sales of new petrol and diesel cars, there is strong political support for the rapid development and rollout of EVs, with which will come significant additional electricity demand. Indeed, as the SMMT data shows, the rollout of EVs has already begun.

4.4.11 To support efforts in the decarbonisation of heavier transport (e.g. road freight, rail and air), Government pledged to invest £140 million in 2021/22 across hydrogen-powered freight trials and the delivery of 4,000 zero emission buses (Ref. 10, p94). The application of hydrogen as a fuel for flight and rail, and in industrial energy-intensive processes, is also progressing.

4.5 Energy policies for homes underpin a growth in future electricity demand

4.5.1 The domestic sector accounts for approximately one third of the UK's electricity demand and 40% of the UK's demand for natural gas (Ref. 15).

4.5.2 Government-backed energy efficiency schemes seek to improve the insulation of the UK's homes as well as reduce demand from lights, appliances and services.

4.5.3 Reducing UK domestic electricity demand will support the move to a zero-emissions electricity system, and flexibility in consumption, either through variable 'time of use' tariffs or demand flexibility schemes may allow consumers to support the flexibility needs of a low-carbon electricity system.

4.5.4 Improved insulation and improved boiler efficiency may help reduce domestic demand for gas and thereby reduce carbon emissions associated with the use of gas in the home. However, the domestic use of gas must be substituted out for either electricity or hydrogen for domestic carbon emissions to fall to zero or very close to zero.

4.5.5 The Energy White Paper sets out Government's aim to increase the rate of installation of home electric heat pumps from 30,000 per year to 600,000 per year by 2028. The British Energy Security Strategy aims to ensure that by 2050 all UK buildings will have low-carbon heating, and reconfirms (Ref. 12, p12) the government's intent to phase out the sale of new and replacement gas boilers by 2035 – an intent which was replicated in Powering Up Britain and confirmed by the Prime Minister's speech in September 2023, which confirmed as 2035, the date beyond which certain gas boiler replacements would no longer be permitted.

4.5.6 FES 2023 predicts that by 2030, residential demand may have increased by up to 12% vs. 2022 levels, while in 2050 residential demand may have increased by between 64% and 96% vs. 2022 levels, primarily due to the electrification of home heat and cooking.

4.6 Peak electricity demand is also expected to grow

4.6.1 The future daily profile of electricity demand is less easy to forecast, but estimated peak demand remains a key determinant of required installed generation capacity.

4.6.2 Figure 4-2 illustrates National Grid ESO's forecast of peak GB power demand (using NGESO's Average Cold Spell methodology) out to 2050. In the four scenarios, peak demand is anticipated to range between 63GW and 69GW by 2030 (2022, for comparison, was 58GW); between 86GW and 107GW in 2040, and between 98GW and 113GW in 2050 (Ref. 20(2023), Figure ES.03).

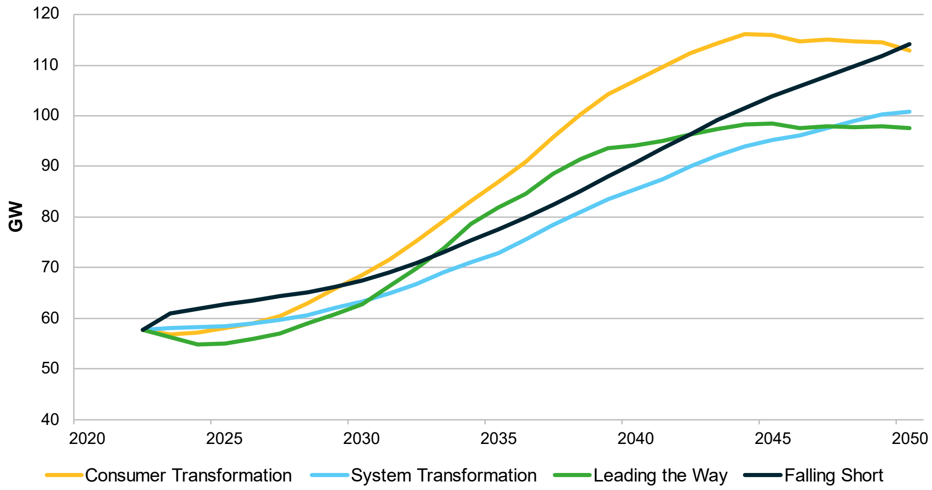

Figure 4 2: Future net peak electricity demand (Ref. 20)

4.6.3 Despite peak demand being anticipated to drop between now and 2025 in some scenarios, all scenarios show an increase in peak demand thereafter, driven by underlying industrial and commercial demand growth (through substitution of other energy sources) and the electrification of heating and transport.

4.6.4 EVs and hydrogen vehicles will require the deployment of additional electricity generation capacity and may also act as integration measures for renewable and baseload generation, capable of shifting load from when demand is high, to periods where supply is higher.

4.6.5 Sufficient electricity generation capacity will need to be deployed to be able to meet forecast peak load, as well as forecast annual demand, under normal and unfavourable weather conditions, supporting the need for significant growth in UK low-carbon electricity generation capacity.

4.7 Conclusions

4.7.1 Policies are already in place to substitute electricity for fossil fuel as a source of energy in non-traditional sectors in the UK, and many of those policies have started to deliver both on a national and local basis.

4.7.2 GB electricity demand will therefore start to increase during the 2020s as a result of this substitution, supporting the urgent need for new low-carbon electricity generation facilities to come forward to meet demand.

4.7.3 Peak electricity demand is uncertain but is likely to grow. Significant capacity of new, low-carbon generation will be required to meet peak demand against a wide range of weather conditions, and the anticipated increase in electricity consumption due to electrification of non-traditional sectors.

4.7.4 Without a rapid increase in low-carbon supply, decarbonisation of other sectors is unlikely to occur. Further, UK-located low-carbon generation must increase to prevent an increase in UK electricity demand from increasing GB consumers' exposure to volatile energy prices and reducing GB security of supply.

4.7.5 The Scheme will contribute to meeting GB's growing electricity demand and will therefore be a critical enabler of achieving the UK's decarbonisation and energy security aims.

5. Developing new technologies to deliver net zero

5.1 Chapter summary

5.1.1 This chapter reviews selected current policy support and development / delivery in technologies which are being tasked to support the delivery of net zero.

5.2 Current and future generation mix

5.2.1 The Net Zero Strategy's key policy is for the UK to be powered entirely by clean electricity by 2035, subject to security of supply (Ref. 11, p20).

5.2.2 Electrification is a key strategy to deliver decarbonisation in the UK and Government is targeting a zero-carbon electricity system by 2035 (Ref. 18). By growing the UK's low-carbon electricity generation capacity, the carbon emissions associated with the electricity we use to light our homes and power our appliances will decrease.

5.2.3 By growing the UK's low-carbon electricity generation capacity further, electricity can be used instead of carbon emitting fuels in other non-traditional sectors (e.g. petrol in transport) and further decarbonisation can be achieved. The decarbonisation of all sectors is essential for the UK to meet net zero.

5.2.4 To decarbonise the UK's electricity system, less electricity must be sourced from carbon emitting generation capacity. Low-carbon generation capacity must therefore be developed both as a substitute for carbon emitting capacity, and to increase the amount of electricity generated to meet additional, non-traditional demand.

5.2.5 It is important to clarify that this Statement of Need does not seek to justify, or promote the exclusion of, any other generation technologies from the future GB generation mix.

5.2.6 Figure 5-1 below shows historical electricity generation in the UK from 1996 to 2022 by fuel source, measured in terawatt hours (TWh, 1 TWh = 1,000,000 MWh), and the resulting average grid carbon intensity, measured in $gCO_2(e)/kWh$.

5.2.7 Figure 5-1 shows that Coal + Oil generation reduced from approximately a one-half share of UK generation in 1996 to nearly zero by 2022.

5.2.8 Low-carbon generation, including renewable wind and solar, increased from near zero in 1996 to over 40% of UK generation in 2022.

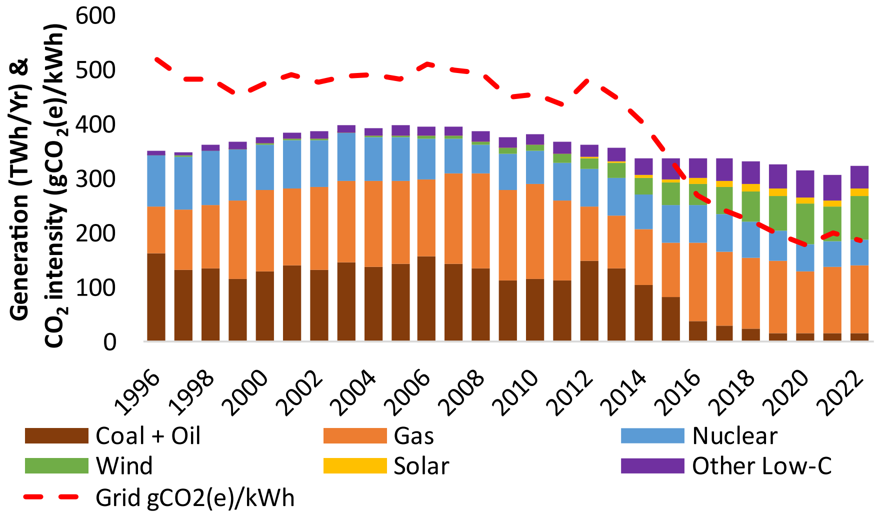

Figure 5-1: Historical Electricity generation (TWh/Yr) and carbon intensity (gCO2(e)/kWh) (Ref. 19)

5.2.9 Nuclear has reduced from generating over one quarter of the UK's electricity needs in 1996, to just 15% in 2022. Gas has contributed approximately 40% of UK generation each year throughout the period shown. GB Grid carbon intensity has reduced from over 500 gCO2(e)/kWh in 1996 to 186 gCO2(e)/kWh in 2022, a reduction of 65%, while electricity generation has reduced by only 7% over that period.

5.2.10 The carbon intensity of the GB Grid has reduced since 1996 due to a regulatory increase in the cost of emissions from high-carbon intensity generation assets, the subsequent closure of all but one coal plant in the UK, and a significant increase in low-carbon, low-marginal cost generation (predominantly wind and solar) since 2010. Section 9.2 of this Statement of Need explains how GB electricity market arrangements support this essential shift.

5.2.11 As well as providing projections of national demand, the FES provide projections for how that demand will be met. Figure 5-2 below shows projected electricity generation in the UK from 2022 to 2050 by fuel source, measured in terawatt hours under NGESO's 'System Transformation' scenario, and the resulting average grid carbon intensity, measured in $gCO_2(e)/kWh$.

5.2.12 The 'System Transformation' scenario shown in Figure 5-2 projects that wind generation will increase from 101TWh in 2022 to 566TWh in 2050. Nuclear generation more than doubles from 41TWh to 87TWh over the same timeframe. Solar generation increases nearly four-fold, from 13TWh to 52TWh.

5.2.13 These low-carbon generation sources, if delivered, will provide the much-needed electricity required to reduce grid carbon intensity from current levels around 186 $gCO_2(e)/kWh$ to zero in 2035, aligned with government decarbonisation targets.

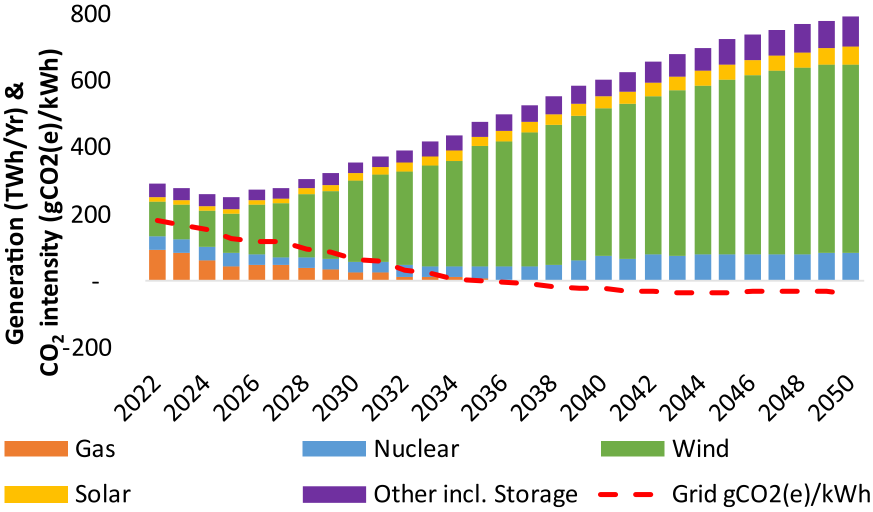

Figure 5-2: Projected electricity generation (TWh/Yr) and carbon intensity (gCO2(e)/kWh) (Ref. 20)

5.2.14 Critically, grid carbon intensity reaches zero at the same time as unabated gas generation ceases. Carbon Capture, Usage and Storage (CCUS) technology must be deployed at scale and integrated into the existing gas generation network, for gas technology to have a role in the future electricity system. Abated gas generation (i.e. gas plus CCUS) is included in the purple 'Other' category in Figure 5-2.

5.2.15 The UK is also pursuing a strategy of interconnection with other markets. Interconnectors are physical cables through which energy can flow in either direction. Market forces determine which direction the energy flows, from low price to high price markets.

5.2.16 Interconnectors can support energy security but, as the British Energy Security Strategy states, "*If we're going to get prices down and keep them there for the long term, we need a flow of energy that is affordable, clean and above all, secure. We need a power supply that's made in Britain, for Britain*" (Ref. 12, p3).

5.2.17 The UK has traditionally been an importer of energy from European markets, all four of National Grid scenarios project that the UK will be a net exporter of energy from the 2030s, however interconnectors may play an important role in meeting UK electricity demand at certain times of the day or year. For simplicity, interconnector flows have been excluded from Figure 5-2.

5.2.18 It is important also to note that although the share of UK electricity generation which is to be met by wind power (itself a combination of offshore and onshore deployments) is projected to increase from 34% in 2022 to over 70% by 2050, the UK's approach to electricity supply is very much a multi-technology approach. A multi-technology approach will be more resilient to and secure against – among other things – variations in the weather, technical failures and market forces.

5.2.19 NPS EN-1 states that "We need to ensure that there is sufficient electricity to always meet demand; with a margin to accommodate unexpectedly high demand and to mitigate risks such as unexpected plant closures and extreme weather events" (Ref. 1, Para 3.3.1)

5.2.20 NPS EN-1 also articulates the Government's view that it is prudent to plan infrastructure development on a conservative basis "to ensure that there is sufficient supply of electricity to meet demand across a wide range of future scenarios" (Ref. 1, Para 3.3.10). Prudence would imply not over-relying on technologies which are yet to be proven, have long development lead-times, or which have historically experienced funding difficulties.

5.2.21 The expected growth in electricity demand leads to a need for increased capacities of electricity generation. The national shift from dispatchable carbon-emitting generation to low-carbon renewable generation also implies a growth in electricity generation capacity.

5.2.22 To improve the likelihood of being able to ensure system adequacy from renewable generators in all but the most unlikely of meteorological situations, a large capacity of interconnected assets from as broad as possible a range of technologies and geography may be beneficial.

5.2.23 Figure 5-3 shows, for the same 'System Transformation' scenario, the projected and significant increase in installed capacity of each technology required to meet the output projections shown in Figure 5-2 above.

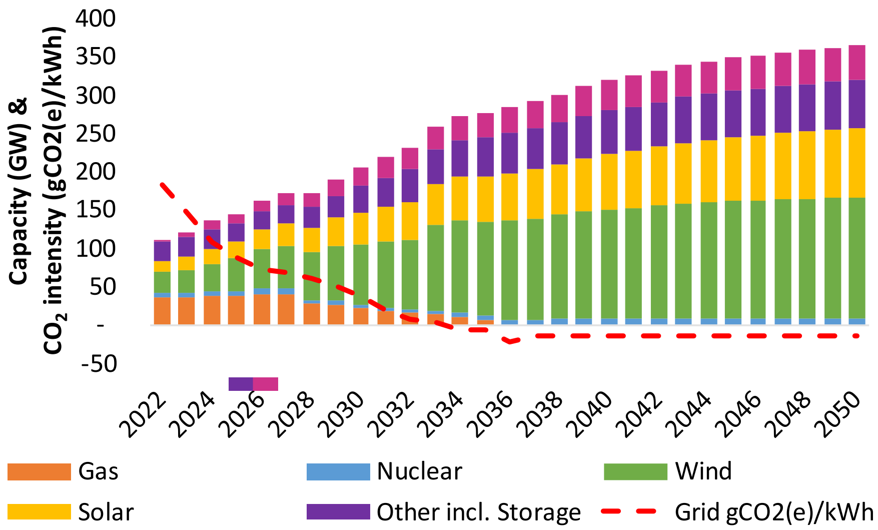

Figure 5-3: Projected electricity generation capacity (GW) and carbon intensity ($gCO_2(e)/kWh$) (Ref. 20)

5.2.24 Figure 5-3 shows that electricity generation capacity will need to increase to between three and four times current installed capacity in order to generate sufficient output to meet demand in 2050.

5.2.25 The National Infrastructure Commission scenarios anticipate that 129 – 237GW of renewable capacity must be in operation by 2050, including 56 – 121GW of solar, 18 – 27GW of onshore wind, and 54 – 86GW of offshore wind. (Ref. 24, p19).

5.2.26 The ESC anticipates broadly similar generation capacities. 165 – 285GW of capacity will be required in 2050, including 18 – 80GW of solar (Ref. 25, pp23&27). The ESC has higher expectations of future nuclear capacity than other analyses, anticipating 20 – 38GW of nuclear versus 5 – 16GW (NGESO) and just 5GW (NIC).

5.2.27 Approximately ten percent of NGESO's projected capacity in 2050, or 30GW, is expected to be short duration storage, shown in pink in Figure 5-3. Long Duration Storage, including Pumped Hydro and hydrogen, is included within the purple 'Other' data series. Further information on electricity storage is included at Section 5.11.

5.2.28 The quantity of new generation capacity required in the UK to meet its net zero targets is enormous, and unprecedented in relation to capacity growth seen at any previous time. Such an expansion of capacity, across many technologies, does not come without risk and it is very possible, if not probable, that one or more technologies will miss their targets. This would increase the need for technologies which are successfully being deployed to accelerate their deployment further.

5.2.29 Challenges will come not only in international competition in supply chains, technology and labour markets, but also in grid connection. FES 2023 reiterates the obvious point that *"sufficient electricity connection capacity is vital"* to support capacity projections (Ref. 20(2023), p132).

5.2.30 Grid is a finite but critical enabler to decarbonisation both in terms of absolute scale and timing to connect. NPS EN-3 recognises the benefit to decarbonisation and consumers of using already available grid infrastructure:

"To maximise existing grid infrastructure, minimise disruption to existing local community infrastructure or biodiversity and reduce overall costs applicants may choose a site based on nearby available grid export capacity" (Ref. 2, Para 3.10.38)

5.2.31 The CCC have also identified grid connection as a potential brake to beating climate change and delivering energy security): "There is an immediate need for policy to move ahead with ensuring adequate network capacity an*d connections"* (Ref. 8(2023), p28), the implication of which is that network capacity and connections are not currently adequate to meet UK needs.

5.2.32 Put simply, to fight climate change, we need to make the most of the infrastructure we have available, and we will need to build more. This context provides further support for the Applicant's proposal to use the available grid capacity at Cottam. Chapter 7 provides more information on this point.

5.3 Development Pipelines

5.3.1 The following sections in this chapter provide additional evidence in relation to the main categories of renewable generation technologies tasked to support the delivery of a low-carbon and secure electricity system by 2035, and their contribution to decarbonisation, security of supply and affordability.

5.3.2 New energy projects follow a uniform high-level development process.

a. The first step is to secure a grid connection offer and define the project cognisant of technical, environmental, land and planning constraints. Data on current and potential future connections for large-scale projects is available on National Grid's Transmission Entry Capacity (TEC) Register (Ref. 38);

b. The second step is to apply for and obtain planning consent. The government's Renewable Energy Planning Database (REPD) (Ref. 39) provides insight into determined and yet to be determined renewable energy projects at all scales nationally; and

c. The third step is to secure revenues for the project. System adequacy is primarily managed through GB's Capacity Market in which eligible assets compete at annual auctions for capacity payments in return for providing an equivalent firm supply of capacity to the electricity system.

5.3.3 Wind and solar technology were first included as eligible technologies in the Capacity Market in 2019, however the Capacity Market is not open to assets which already hold Contracts for Difference (CfD) contracts (and vice versa). The inclusion of renewable generation technologies in the Capacity Market underlines the contribution renewable energy can make to system adequacy and system security:

"The system is typically better off with intermittent capacity than without it – wind farms, for example, can contribute to overall security of supply" (Ref. 40, p114).

5.3.4 The CfD scheme remains the Government's main mechanism for supporting low carbon electricity generation.

5.3.5 The CfD scheme was introduced under the Energy Act 2013 to incentivise investment in renewable energy by providing developers of projects with high upfront costs and long lifetimes with direct protection from volatile wholesale prices. CfDs also protect consumers from paying increased support costs when electricity prices are high.

5.3.6 Renewable generators located in Great Britain that meet the eligibility requirements can apply for a CfD by submitting bids into CfD Allocation Rounds, in which a range of different renewable technologies compete directly against each other for a contract.

5.3.7 The Low Carbon Contract Company's CfD Register (Ref. 41) and the EMR Delivery Body's Capacity Market Registers (Ref. 42) hold data on contract award.

5.3.8 Although lists and registers provide important evidence towards current and future generation capacities, the listing of a scheme on any grid connection register, a planning database or a commercial contract register, does not guarantee that the scheme will come forwards.

5.3.9 For example, in February 2023 National Grid ESO shared their analysis that 30-40% of projects listed on their TEC Register did not make it through to operation (Ref. 43). Section 3.12 of this Statement describes reforms being taken under the Connections Action Plan to deter speculative connection applications and remove stalled projects from the connections queue.

5.3.10 Of the 205GW of projects of all technologies listed on the REPD, just 50.1GW are operational and 42.1GW will not move forwards due to having been refused planning consent, being abandoned (by the developer), or planning permission having expired.

5.3.11 Analysis of the CfD Register (Ref. 41) shows that even projects which have achieved consent, and a revenue contract are not guaranteed to deliver. 43 projects with CfDs have registered a reduction to the capacity of the CfD Unit or have had their CfD terminated:

a. Offshore wind: 99MW reduction on 10 projects still going forwards;

b. Onshore wind: 69MW reduction on 12 projects still going forwards;

c. Biomass / Waste / CHP projects: four projects (166MW) terminated, 13MW reduction on one project still going forwards;

d. Solar PV: one project (12MW) terminated, 40MW reduction across six projects still going forwards; and

e. Advanced conversion technology: nine projects (124MW) terminated.

5.3.12 NPS EN-1 articulates the Government’s view that infrastructure development should be planned on a conservative basis (Ref. 1, Para 3.3.10), without over-relying on technologies which are yet to be proven, have long development lead-times, or which have historically experienced funding difficulties.

5.3.13 This analysis suggests that it is not prudent to assume the full delivery of pipeline projects listed on various registers, because it is highly unlikely that a significant proportion of that capacity will be commissioned.

5.4 Offshore Wind

5.4.1 The UK is a world-leader in offshore wind technology with ambition to deliver 50GW of operational capacity by 2030, up from 13.4GW operational in 2022 (Ref. 20(2023), Table ES1).

5.4.2 None of National Grid’s 2023 FES projections for offshore wind capacity meet Government’s 2030 50GW target, highlighting the massive scale of renewable infrastructure required to meet net zero. Of the three scenarios which are consistent with net zero 2050, offshore wind capacity in 2030 ranges between 40.7GW and 48.4GW, generating between 165TWh and 206TWh of low-carbon energy each year.

5.4.3 Offshore wind is expected to produce a significant proportion of the UK’s future low-carbon electricity needs, however the government proposes a multi-technology approach to the future electricity system, in part to provide security of supply through variable weather conditions.

5.4.4 Offshore wind is not tasked with meeting, and cannot be expected to meet, future UK electricity needs on its own.

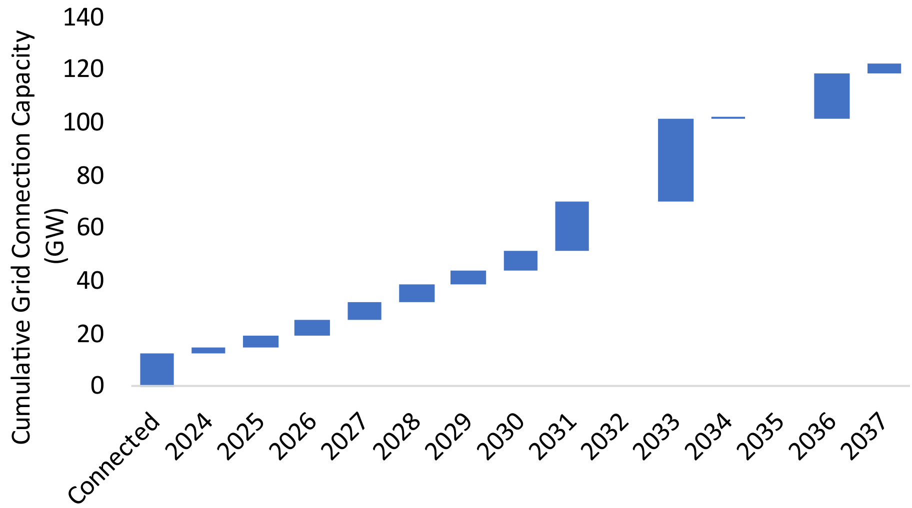

Figure 5-4: Current and potential future connected capacity of offshore wind technology (Ref. 38)

5.4.5 National Grid's TEC Register (Ref. 38) lists projects which have accepted a connection offer, and Figure 5-4 shows the grid connection capacity of potential future Offshore Wind projects and their contracted year of connection.

5.4.6 Of the total offshore wind (including floating wind) pipeline shown, which amounts to 119GW of capacity, 6GW, all connecting in 2036, proposes a mix of technologies while 113GW is proposed to be stand-alone offshore wind. The TEC Register records the connection capacity for the development and does not identify the proposed capacity for any of the technologies proposed to be installed.

5.4.7 Figure 5-4 should therefore be interpreted as an approximation rather than a precise view of the offshore wind development pipeline, but as described previously, not all of that capacity will deliver.

5.4.8 At the time of submitting this Statement, the TEC register lists a total of 33.9GW of capacity which has not yet connected but is scheduled to connect before 2030 bringing the UK's total operational offshore wind capacity to 49.3GW in 2030, if all of the pipeline delivers. This is broadly in line with both the most ambitious FES projection and the government's target of 50GW in 2030.

5.4.9 The connection of many projects with connection agreements in the late 2020s and beyond will be dependent on a significant number of onshore and offshore transmission network reinforcement works. The Connections Action Plan makes clear the level of network development required to facilitate the connection of up to 50GW of offshore wind to the UK electricity network by 2030 and the risks associated with the delivery of these pipelines should not be understated.

5.4.10 While it is not a given, there is potential for any network development delays to affect multiple offshore wind projects, particularly because National Grid's approach to offshore transmission development is currently favouring a network of connections with transmission assets being shared by multiple projects where previously offshore transmission assets have been developed for individual projects (Ref. 16, p62).

5.4.11 When a grid connection has been secured, projects are prepared for planning consent submission and appear on the government's Renewable Energy Planning Database (Ref. 39). The relationship between projects listed on the TEC Register and projects listed on the REPD is not one-to-one because developers may take different approaches to planning and delivery for example in the phasing of projects for consent and delivery.

5.4.12 The TEC Register lists 25 offshore wind projects comprising 24.9GW proposing to connect in the period 2024 – 2027. In order to meet these dates, it is likely that planning consent must have already been secured. The REPD lists 20 offshore wind projects comprising 20.6GW in 'awaiting construction' or 'under construction' status. It is therefore possible that offshore wind delivery is already set to be at least 4.3GW lower than the pipeline shown in Figure 5-4 by 2027.

5.4.13 On receipt of planning consent, offshore wind developers are then eligible to compete with other projects for CfDs.

5.4.14 15.2GW of offshore wind projects have secured but not yet commenced their CfDs. Many of these projects are still in construction, but approximately 4GW are already operational. Some contracts have not yet commenced for commercial reasons, however contracts for 11.2GW of offshore wind are expected to commence in the coming years.

5.4.15 The data therefore suggests that of the 25GW of offshore wind which is not yet operational but has an agreement with National Grid to connect by 2027, approximately 20GW has secured planning consent, and approximately 55% of that capacity (11.2GW) has secured a CfD.

5.4.16 However, the number of projects which have secured funding and commenced construction still does not indicate a commitment by or obligation on the promoter to deliver that project at all or, if it does, at a particular generation capacity.

5.4.17 In July 2023, for example, developer Vattenfall announced that it was halting development of its Norfolk Boreas wind farm (1.8GW) because it *"no longer made financial sense to continue"* (Ref. 44). Vattenfall is also reviewing its other UK-based offshore wind projects in the face of rising costs.

5.4.18 In summer 2023 Government held CfD Allocation Round 5 (AR5). The Allocation Rounds follow a competitive process, so information on project prequalification for the allocation round is not published. When AR5 results were published in September 2023, however, no contracts had been awarded to offshore wind projects.

5.4.19 The Allocation Round Price Cap for AR5 was £44/MWh in 2012 money (equivalent to approximately £64/MWh in 2023). One possible conclusion of the AR5 result, is that developers require a strike price of more than

£64/MWh to make their projects economically viable, yet could not be awarded a contract at a higher value than the Price Cap and therefore no contracts were awarded to offshore wind projects in AR5.

5.4.20 The effect of the AR5 outcome on the future development of offshore wind remains to be seen although in November 2023 the government increased the Administrative Price Cap for offshore wind in advance of CfD AR6 which opens in March 2024. It would therefore seem that the likely impact of the AR5 result is a delay in the construction of projects which have already secured planning, while developers wait until AR6 to attempt to secure revenues before breaking ground.

5.4.21 A further knock-on effect on offshore wind delivery is also possible as future Allocation Rounds risk becoming over-subscribed with projects unsuccessful in previous rounds and projects which have recently secured planning competing for contracts. Greater competition in future rounds may drive price down, but only to a level of commercial acceptability.

5.4.22 As offshore wind capacity grows, projects may be located further from shore, or in deeper water, or incorporate new technology – for example floating platforms – which may all increase future development costs over those achieved within the technology class to date.

5.4.23 The UK’s current offshore wind pipeline shows great potential to deliver significant decarbonisation and energy security benefits. However, it is clear from recent project and contracting progress that delivery of the pipeline should not be taken for granted.

5.4.24 With some projects under construction currently paused, a temporary hiatus in securing revenue contracts for projects which have already secured planning consent and overcome significant complexity in associated grid connection works, it may be prudent to assess the risk of non-delivery of offshore wind capacity as increasing versus an assessment undertaken even 12 or 18 months ago.

5.4.25 Any shortfall in the delivery of offshore wind projects against National Grid’s scenarios will need to be made up for instead by other technologies.

5.5 Onshore Wind

5.5.1 The REPD (Ref. 39) shows that, at the time of submitting this statement, the UK has 13.9GW of operational onshore wind.

5.5.2 In 2015 the then Conservative Government placed an effective moratorium on further onshore wind development in England. According to the REPD, onshore wind capacity in the UK increased by just 0.4GW between the end of 2015 and July 2023.

5.5.3 National Grid FES (2023) net zero consistent scenarios include a range of 21 – 27GW of onshore wind operational by 2030, which increases to 29 – 44GW by 2050 (Ref. 20(2023), Table ES1).

5.5.4 In September 2023, the government announced a lift on the ban on onshore wind in England, by introducing changes to the National Planning Policy Framework (NPPF) that will allow local authorities to give the go-ahead to onshore turbine proposals where the impacts are (or can be made) acceptable and the proposal has community support (Ref. 45, Footnote 54). At the time of application of this scheme, the National Infrastructure Planning Portal lists no applications for onshore wind developments so the moratorium effectively remains in place.

5.5.5 NGESO forecast only up to 2GW of newly installed capacity between now and 2030 to be located in England and Wales (of a total ranging from 8GW to 14GW), but after 2030, onshore wind in England and Wales is forecast to become a greater proportion of new UK installations, as many of the currently available sites in Scotland may by then have already been developed.

5.5.6 Whilst the changes to the NPPF sought to reverse the onshore wind moratorium, the requirement to demonstrate acceptability and community support means that it is unlikely that this technology class will play any meaningful part in decarbonisation in the short term. With the moratorium having been in place for such a long time, onshore wind development pipelines in England are currently thin.

5.5.7 National Grid's TEC Register (Ref. 38) shows that there will be no new onshore wind projects in England and Wales connecting to the Transmission system before 2025, and only 3.2GW hold agreements to connect before 2030. Other projects totalling approximately 2.2GW have been accepted to connect to the English and Welsh electricity distribution networks, however the REPD shows that the onshore wind project pipeline for England and Wales is virtually empty. Further, just one 35MW development in Wales secured a CfD as part of Allocation Round 5, for delivery in 2027/28.

5.5.8 Data from the REPD also shows that onshore wind projects that achieve planning consent in Great Britain take between four and five years to pass through the planning system (average duration between commercial operations date and planning application submission date, for successful onshore wind projects listed on the REPD). Pre-application development may last for two or more years beforehand although this will be highly project dependent.

5.5.9 It is therefore not a given that the changes to the NPPF will deliver the required generation capacity to meet even its share of National Grid's least optimistic projections for the technology class.

5.5.10 The UK will therefore need to look to Scotland to deliver an increase in onshore wind capacity through the next circa five years.

5.5.11 The REPD pipeline for Scotland shows 7.1GW of consented projects which are not yet operational (just 1.6GW of these are listed as under construction) as well as 7.1GW of applications in Scotland which have not yet been determined.

5.5.12 The REPD also shows that of the total capacity of Scottish onshore wind projects listed in the REPD as having been determined, only 53% has been consented (15.8GW consented of 29.9GW determined). If historical consent rates continue into the future, the Scottish pipeline of onshore wind projects is not of a sufficient scale to deliver the range of onshore wind required by 2030 in National Grid's net zero compatible scenarios.

5.5.13 Therefore, relying on Scottish onshore wind to deliver against the National Grid's projections is also not a prudent approach to delivering progress against the UK's decarbonisation and energy security targets.

5.5.14 Any shortfall in the delivery of onshore wind projects against National Grid's scenarios will need to be made up for instead by other technologies.

5.6 Nuclear

5.6.1 GB operational nuclear capacity is, at the time of submission of this report, at 6GW, down from over 9GW in 2020. Two stations (2.4GW) are due to close in March 2026 (Ref. 46) and a further two stations (also 2.4GW) are due to close in 2028. Operator EDF is investigating the possibility of extending operation of the existing stations for as long as possible but as with all nuclear facilities, continued operation is dependent on stringent operational inspections continuing to yield satisfactory results (Ref. 47),

5.6.2 Therefore, by as early as 2029, only one currently operational nuclear power station, Sizewell B (1.2GW) will continue to operate in the UK. Operator EDF is seeking permission to extend the life of this reactor by 20 years to 2055. A 60-year operational lifetime is commonplace for the nuclear technology in use at Sizewell B.

5.6.3 Nuclear power is a low-carbon power source, therefore the likely closure within the next five years of 4.8GW of capacity, which has historically generated c.30TWh/year of low-carbon electricity, will need to be made up by other low-carbon sources of electricity, just to keep grid carbon intensity from increasing over the next five years.

5.6.4 New nuclear has been a part of the government's energy strategy since the mid-2000s and many barriers to nuclear development have been removed over the last decade. For example, site selection (the National Policy Statement for Nuclear Power Generation, although this now is due to be replaced), early regulatory approval of reactor designs (the Generic Design Assessment (GDA) process) and revenue and back-end cost certainty through the CfD, a key element of the 2013 Electricity Market Reform, and the Funded Decommissioning and Waste Management Plan. The Energy Act 2013 also created a body corporate, the Office for Nuclear Regulation (ONR) to regulate, in Great Britain, all nuclear licensed sites.

5.6.5 The nuclear development process is neither easy, nor short. Nuclear projects have long development and construction lead times with many regulatory and commercial approvals and decision points along the way. Hinkley Point C development started in earnest in the late 2000s and civil site construction commenced in 2016. Hinkley Point C is still under construction, and it was announced in January 2024 that the plan to start commercial operations has been further delayed to between 2029 and 2031 (Ref. 48).

5.6.6 In the 2020 Energy White Paper, the government stated its aim *"To bring at least one large scale nuclear project to the point of Final Investment Decision by the end of this Parliament* [i.e. in 2024]*, subject to clear value for* *money and all relevant approvals."* (Ref. 10, p16). Sizewell C, which is proposed to be a replica of Hinkley Point C, received a Development Consent Order in July 2022.

5.6.7 In November 2022, Government announced that it would take a £700 million stake in Sizewell C and so would become a 50% shareholder in the project's development with EDF. A further £511 million has been made available *"to continue project development and prepare the Suffolk site for construction"* (Ref. 49). As of September 2023, Government and EDF have been working together to raise private capital investment for the project. In December 2023, the government invested an additional £1.3 billion in the project, consolidating its position as the majority shareholder (Ref. 50).

5.6.8 If a Final Investment Decision is taken before the end of 2024, and construction commences soon afterwards, overlaying Hinkley Point C's construction programme would see first commercial operation at Sizewell C well into the second half of the 2030s. Construction efficiencies may be secured through replication of construction methods from Hinkley Point C to Sizewell C, but are not guaranteed.

5.6.9 Government launched Great British Nuclear (GBN) in 2023, as an 'arms-length body' with its first priority being to *"administer a competitive process to select the best small modular reactor (SMR) technologies from around the world. This SMR technology selection process will underpin government's commitment to two nuclear Project Final Investment Decisions during the next Parliament, with at least one of these being into an SMR project"* (Ref. 51).

5.6.10 SMRs are nuclear facilities which are proposed to achieve economies of scale through multiples of projects, rather than the size of a single project. Modular construction of nuclear facilities is largely anticipated to be factory based, requiring only the installation of prefabricated components in situ. In this way, learning can be applied during subsequent manufacturing in a controlled environment, delivering anticipated rewards in terms of construction duration, cost and quality.

5.6.11 The first SMR designs are now being assessed under GDA by the ONR, a process which has previously taken three or more years. Critically however, SMRs will require the construction and approval of manufacturing facilities prior to delivery of the first unit. Although SMRs may bring decarbonisation and energy security benefits to the UK in time, the first SMR unit is very unlikely to be operational in the UK within this decade.

5.6.12 In October 2023, GBN down-selected six companies through the initial stage of a nuclear technology competition, successful companies were considered to *"offer the greatest confidence in being able to make a final investment decision in 2029"* and be *"most able to deliver cutting-edge technology by* [the] *mid-2030s"* (Ref. 52).

5.6.13 Companies will bid for government development support contracts – to be awarded in summer 2024 – which will cover technology-dependent site-specific design, access to GBN's developer capability, and support in accessing suitable development sites.

5.6.14 Any reactor which succeeds in becoming commercially operational, whether large or small, will need to pass through GDA, be allocated an approved site, secure grid connection and secure a Development Consent Order. Manufacturing facilities may also require nuclear-level consenting and approval. Reactor operating companies will need to secure a Nuclear Site Licence and become both intelligent customer and controlling mind of the end-to-end design, operation and decommissioning of the site.

5.6.15 Revenue mechanisms will also need to be developed, funding secured, and then the process of construction and installation commenced, and facilities commissioned.

5.6.16 NGESO's 2023 FES assumes the early closure of two existing nuclear stations and the early commissioning of one Hinkley Point C reactor (i.e. both before 2028) in their net zero consistent scenarios. However, in none of these three scenarios does nuclear capacity rise between the full commissioning of Hinkley Point C (in 2028) and the possible first SMRs in 2034 or later. NGESO's latest projections for nuclear capacity growth were made in July 2023 and in February 2024 they already may be unachievable.

5.6.17 It is clear that nuclear development does not come without risk, however, as evidenced by the late shelving of two mature GW-scale reactor projects in the UK in the 2010s. At that time, three nuclear projects progressed towards Financial Investment Decision, but only one, Hinkley Point C (EDF, 3.2GW) has been taken forwards to construction. The other two (Wylfa and Moorside) were discontinued in 2019 and 2017 respectively, due primarily to commercial matters.

5.6.18 It is therefore not yet the case that the existence of a governmental plan for nuclear, and companies currently participating in that plan, can be relied upon to deliver its potential benefits.

5.6.19 Further, this analysis suggests that no nuclear facility other than Hinkley Point C is able to join the existing Sizewell B reactor on the grid before 2035, the date that Government is targeting for full decarbonisation of the electricity system.

5.6.20 All four scenarios anticipate that Sizewell C will go ahead, but operation is not forecast to be until 2037 in the most optimistic scenario and 2039 in the least optimistic. Figure 5-5 shows the average and the range of the annual nuclear capacity projections for National Grid's net zero compatible FES projections.

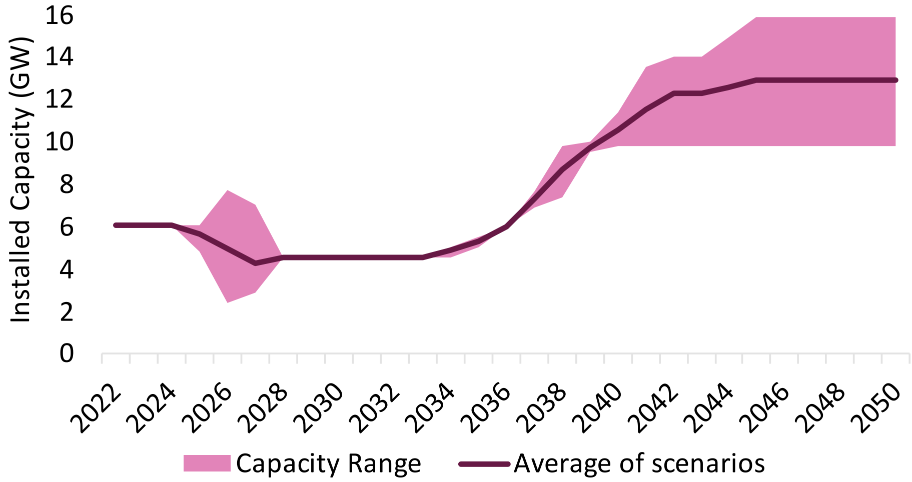

Figure 5-5: FES future nuclear capacity 2022-2023 and scenarios for 2024-2050 (GW) (Ref. 20)

5.6.21 In October 2023, the government also published 'Towards Fusion Energy 2023', the next stage of the UK's nuclear fusion energy strategy (Ref. 53).

5.6.22 The UK's nuclear fusion strategy sets out two objectives. Firstly, a UK demonstration of commercial viability of fusion from a UK prototype plant which delivers net energy, and secondly the development of a world-leading fusion industry.

5.6.23 Not detracting from the important activity of fusion research and development, it is relevant for the purpose of examination of this scheme to place this exciting prospect in the UK into context. In support of the first objective:

"the STEP Programme will design, develop and build, by 2040, a prototype fusion power plant capable of delivering net energy" (Ref. 53, p20).

5.6.24 EA 2023 legislates for fusion regulation, an essential pre-requisite for developers to plan prototype projects.

5.6.25 Any possible decarbonisation contribution from nuclear fusion will therefore not materialise in time to support Government's target to decarbonise the electricity system by 2035, and it is not yet clear that achieving Government's fusion targets, including a successful demonstration STEP project, will enable nuclear fusion to make a net contribution to decarbonisation from any facilities following STEP, prior to 2050.

5.7 Unabated Fossil Fuels and Abatement technology

5.7.1 National Grid's FES shows that 28.4GW of CCGT (Combined Cycle Gas Turbine) generation capacity is currently operational in the UK, and in 2022 this capacity contributed over 30% of the UK's total annual generation output. 7.9GW of gas-fired generation capacity, including Open Cycle Gas

Turbines, smaller gas reciprocating engines and gas-fired combined heat and power is also currently operational (Ref. 20(2023), Table ES1).

5.7.2 Currently CCGT (and other gas-fired) capacity is fully unabated, meaning that the CO_2 emitted as a by-product of the electricity generation process is released to the atmosphere and contributes to global warming. Progressing towards a zero-carbon electricity system by 2035 requires the decarbonisation of these assets, or the replacement of that generation capacity with alternative low-carbon sources. The most significant decarbonisation requirement is on the CCGT fleet.

5.7.3 Decarbonisation of the fuel used to generate electricity in the CCGT fleet can be achieved by burning hydrogen. Capturing carbon emissions and storing them away from the atmosphere would also decarbonise the assets and is dependent upon the deployment at scale of Carbon Capture Usage and Storage (CCUS).

5.7.4 National Grid's FES show that by 2030 emissions from up to 7% of CCGT capacity should be captured by CCUS, rising to between 21% and 37% by 2035. Deploying CCUS more quickly will provide a greater capacity of low-carbon dispatchable generation to the market to complement renewable generation assets in meeting demand.

5.7.5 CCUS is also required to facilitate BECCS, as described in Section 5.9 below.

5.7.6 Powering Up Britain includes an aim to deliver four operational CCUS clusters to capture and store 20-30 million tonnes of carbon dioxide ($MtCO_2$) by 2030 (Ref. 14(1), p21). The Prime Minister's September 2023 speech on net zero (Ref. 32) also confirmed the government's continued support for four CCUS clusters by 2030.

5.7.7 CCUS has a key role in the UK's Net Zero Strategy. It is a prominent feature of the National Infrastructure Strategy (Ref. 54), Energy White Paper (Ref. 10) and Industrial Decarbonisation Strategy (Ref. 55). The government has previously recognised that *"the technology has not been delivered at scale and significant risks remain"* (Ref. 54, p53) but recent progress has been made in developing and consenting projects as well as developing a commercial framework to support the technology. The government's CCUS Deployment Pathway seeks to secure an option to deploy CCUS at scale during the 2030s, subject to costs coming down sufficiently.

5.7.8 Government is taking a cluster approach to CCUS deployment with Track 1 and Track 2 projects now identified and under development.

5.7.9 Government has selected eight projects from its Track 1 cluster sequencing process for CCUS to proceed to negotiations for government support. Three are part of the East Coast Cluster and five are part of the HyNet Cluster. Both clusters have previously been identified as funding recipients.

5.7.10 HyNet report the potential to reduce CO_2 emissions by 10 million tonnes every year by 2030 by producing and transporting hydrogen to end users through a network of dedicated pipes, while also capturing the associated CO_2 emissions and piping them in a separate pipe to an undersea storage facility. The HyNet Carbon Dioxide Pipeline Development Consent Order was granted in March 2024, the Hynet North West Hydrogen Pipeline planning application is expected to be submitted to the Planning Inspectorate in 2025.

5.7.11 The East Coast Cluster aims to capture and store an average of around 23 $MtCO_2$ per year by 2035, with three selected Track 1 projects aiming to connect to the cluster by 2027.

5.7.12 The Net Zero Teesside project, a Track 1 CCGT + CCUS project with associated CO_2 transportation infrastructure, which is part of the East Coast Cluster, was granted a Development Consent Order in February 2024. In the Decision Letter, the Secretary of State recognised the urgent need for gas-fired electricity generation with CCS infrastructure as set out in EN-1 and determined that the project would help deliver the Government's net zero commitment by 2050. Therefore, the project would be in line with Government's wider policy statements on energy and climate change.

5.7.13 A planning application for a second part of the East Coast Cluster, the Humber Low Carbon Pipelines project, was withdrawn by previous developer National Grid Carbon Limited in January 2024. The project was to construct CO_2 and hydrogen transportation pipelines to connect various emitters and generators in the Humber region and is now being taken forward under a separate DCO application by new owner, Northern Endurance Partnership.

5.7.14 Both HyNet and East Coast Clusters provide the possibility of directly capturing and storing emissions from CCGT and Biomass electricity generation facilities located close to the clusters as well as the opportunity to decarbonise heavy industry in the areas local to the proposed pipelines.

5.7.15 Progress has been made on project definition, design and consenting in recent years. EA 2023 provides a licensing framework for CO_2 transport and storage, but business models to secure future revenues are still in development. These will be a critical input to future Final Investment Decisions both at the cluster level, and at the level of the projects of which they are comprised.

5.7.16 The Cluster approach, when it is delivered, will provide abatement for a significant proportion of the UK's operational CCGT fleet and other industrial carbon emissions. However, an extension of the UK's CCUS or hydrogen pipelines will be required to take emissions out of the many CCGT facilities which are not near to an existing or proposed cluster. Yet the government is aiming that, by 2035, the UK electricity system will be operating with zero emissions.

5.7.17 The government's principle of adopting a prudent approach to future energy supply suggests that the full decarbonisation of the existing UK CCGT fleet should not be assumed by 2035, and therefore that other low-carbon supplies may be required to make up for facilities which have by 2035 not yet been abated.

5.8 Hydrogen

5.8.1 The government's 2021 UK Hydrogen Strategy (Ref. 56, p2) explains that hydrogen has *"the potential to overcome some of the trickiest* *decarbonisation challenges facing our economy"*, especially in enabling the decarbonisation of industry and land transport, and as a potential substitute for current carbon-intensive marine and aviation fuels.

5.8.2 Currently most hydrogen is produced by converting methane to hydrogen and carbon dioxide (this is known as 'blue hydrogen'). As blue hydrogen production emits carbon as a by-product, the development of blue hydrogen facilities will require CCUS capability to achieve net zero carbon. CCUS clusters with hydrogen and carbon dioxide pipelines are hoped to become operational in the second half of the 2020s.

5.8.3 Hydrogen can also be produced through the electrolysis of water (this is known as 'green hydrogen'). The 'green' label for electrolysed hydrogen presumes that the input electricity used in the hydrogen production process is itself low-carbon, therefore, there are no carbon emissions associated with the process.

5.8.4 Green hydrogen production therefore relies on considerable amounts of renewable energy to electrolyse water. Electrolysis currently accounts for approximately 1% of global hydrogen production. However, a growth in electrolysis capability and capacity opens out the prospect of using renewable generation to produce hydrogen, in potentially significant quantities.

5.8.5 Powering Up Britain confirms the Government's ambition of up to 1 GW of electrolytic hydrogen and up to 1GW of CCUS-enabled hydrogen in operation or construction by the end of 2025, subject to affordability and value for money. (Ref. 14(1), p22). Progress in the government's Hydrogen Allocation Rounds (HARs) for electrolytic hydrogen (Ref. 57) implies that this ambition is unlikely to be met. Government expects to *"award contracts totalling up to 250MW of capacity from HAR1, subject to affordability and value for money. We aim for contracts to be awarded in Q4 2023, with first projects becoming operational in 2025"* and *"intends to launch the second allocation round (HAR2) in Q4 2023 and aims to award contracts to up to 750MW of capacity in early 2025, subject to affordability and value for money"*.

5.8.6 The consultation document related to market engagement for HAR 2 (Ref. 58) describes that, despite the government's aim to deliver 1GW by 2025, projects will be able "to select a delivery year between March 2026 until March 2029" (Ref. 58, p8). This suggests that the Government's Hydrogen capacity aims will not be met, and the potential for demonstration Hydrogen projects delayed as well as those fully commercial projects which will follow to secure benefits for the UK in terms of decarbonisation, energy security, and cost certainty for consumers.

5.8.7 Industry is more optimistic of progress, and the Hydrogen Energy Association reports that "The first wave of large-scale electrolytic hydrogen projects will be in operation in 2025", including pioneering projects located in Wales, Scotland and East Anglia totalling over 1GW of hydrogen electrolysis capacity (Ref. 59).

5.8.8 Hydrogen remains an interesting and valuable technology to support net zero. Once hydrogen has been produced, it can be stored, transported, and used in a range of applications as a substitute for natural gas or other carbon intensive fuels. EA 2023 lays the foundations for a future which includes hydrogen technology by creating provisions for business modes for hydrogen production, transport and storage.

5.8.9 NGESO's FES 2023 estimates that between 127 and 213TWh of electrical energy will be required annually in the UK by 2050 to produce hydrogen through electrolysis to meet its many potential end-uses (Ref. 20(2023), Table ES.B). The wide range of future demand estimates is due to different net zero compatible scenarios producing hydrogen in different ways. The Energy System Catapult foresee the need for *"a new low carbon hydrogen economy … delivering up to 300TWh per annum, roughly equivalent to electricity generation today"* and concluding that *"electricity generation itself may have to double, or even treble if most hydrogen is to be produced by electrolysis"* (Ref. 25, pp6 & 36)

5.9 Biomass

5.9.1 National Grid's FES (2023) (Ref. 20(2023) Table ES1) advised that 4.4GW of Biomass generation was operational in the UK in 2022, producing nearly 16TWh of low-carbon electricity.

5.9.2 The government's Biomass Strategy, published in 2023 reaffirmed that *"Only biomass use that complies with strict criteria is considered to be low carbon and to deliver genuine CO2 emissions savings"* (Ref. 60, p6).

5.9.3 Building on the already green credentials of the technology, the Biomass Strategy sets a vision to continue to use sustainable biomass in power generation in the 2020s. By 2035, the government's aim is to transition away from unabated uses of biomass by 2035 by incorporating, where possible and with priority, Bioenergy with Carbon Capture and Storage (BECCS) to make biomass use net negative carbon emissions.

5.9.4 Recognising that *"Biomass can play a significant role in decarbonising nearly all sectors of the economy"* the government has also stated that *"Biomass is not a silver bullet, and neither is carbon capture. We will rely on a range of solutions to achieve net zero"* (Ref. 60, p4).

5.9.5 BECCS is not currently operating at scale in the UK, however demonstration and commercial scale plants are operational in other countries. Active work is therefore being undertaken in Government and industry to develop business models which support biomass and the delivery of low-carbon electricity as well as negative emissions through the deployment of CCUS to deliver BECCS in the UK.

5.9.6 The government is considering whether new or refurbished biomass plants must, on commissioning, be fit to deploy carbon capture in the future.

5.9.7 Against the backdrop of national biomass capacity reducing as existing plant reach the end of their commercial life, National Grid anticipate that BECCS will come online progressively from 2030, to reach an operational capacity from 1.6 – 4.6GW by 2035 and 2.2 – 8.8GW by 2050 (Ref. 20(2023), Table ES1). Neither the REPD nor the TEC Register yet list any future biomass projects in the UK.

5.9.8 BECCS will be dependent upon the delivery of CCS infrastructure to support the capture of emissions, and any shortfall in the delivery of onshore wind projects against National Grid's scenarios will need to be made up for instead by other technologies.

5.10 Solar Power

5.10.1 The government's solar photovoltaics deployment information resource (Ref. 61) records installed and operational solar capacity in the UK. The government's data shows that 15.4GW was operational at the end of August 2023.

5.10.2 Solar generated between 11 and 12 TWh of power in each of 2019 – 2021. Generation increased to nearly 13TWh in 2022 (Ref. 20(2023)). UK solar generation makes an important and reliable annual contribution to meeting national demand. Solar is well placed to play the role that recent government papers have ascribed to it, including those summarised in Chapter 2 of this report.

5.10.3 Figure 5-6 following shows how solar capacity has grown in the UK each year since the records began in 2010.

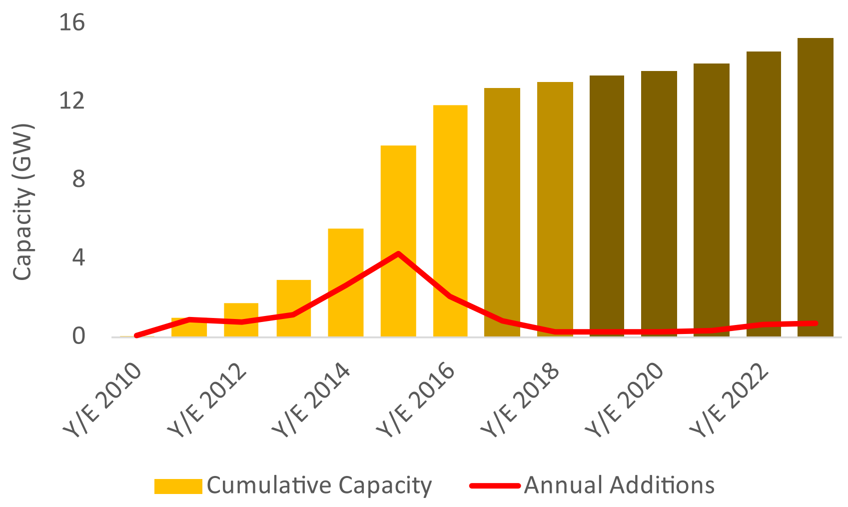

Figure 5-6: Cumulative installed solar capacity in the UK and annual additions 2010-2023 (Ref. 61)

5.10.4 Growth in UK solar capacity has been characterised by two phases, the first was supported by the Feed in Tariff (FiT) scheme, that entered into law by the Energy Act 2008 and took effect from April 2010. This phase is denoted by the yellow columns in Figure 5-6. The FiT scheme paid a revenue to owners of solar installations (and other renewable generation assets) with a capacity lower than 5MW.

5.10.5 Figure 5-6 shows that the scheme was effective in increasing solar capacity over the period 2010 to 2015. A tariff reduction was announced in December 2015, reflecting reducing installation costs and therefore less of a requirement to incentivise new installations. Annual installations reduced over 2017 and 2018 as capacity accredited by the scheme before the 2015 tariff announcement was built out.

5.10.6 The FiT scheme closed to new applicants in 2019, and solar capacity growth since 2019 has been supported by market revenues only.

5.10.7 Annual installations peaked at 4GW in 2015 and averaged 1.1GW over the period 2010 to 2023.

5.10.8 Solar has undergone significant technological advances in scale and commercial efficiency, and the UK has many areas of commercially viable solar irradiation. It is therefore for GB to make best use of this natural, renewable energy resource in order to meet its legal carbon emission reduction obligations.

5.10.9 The government has stated that it expects a 5-fold increase in the deployment of solar by 2035 (Ref. 12, p19) equivalent to 70GW of operational capacity by the same date.

5.10.10 Importantly, in order to achieve the government's 2035 aim, solar capacity installations will have to achieve over 4GW each year starting from 2024, i.e. annual installations will have to be higher for a decade, compared to the UK's previous single highest rate of annual installation.

5.10.11 National Grid's FES net zero compatible pathways include solar capacities in 2030 of 25 – 42GW, in 2040 of 43 – 68GW, and in 2050 of 57 – 92GW (Ref. 20(2023), Table ES1). In every scenario, a pathway to net zero includes a significant future increase in solar capacity beyond that which is installed or in development today, as shown in Figure 5-7.

5.10.12 Figure 5-7 superposes FES forecast ranges for solar capacity from 2012 through to 2023, with each range shown as a shaded area covering the

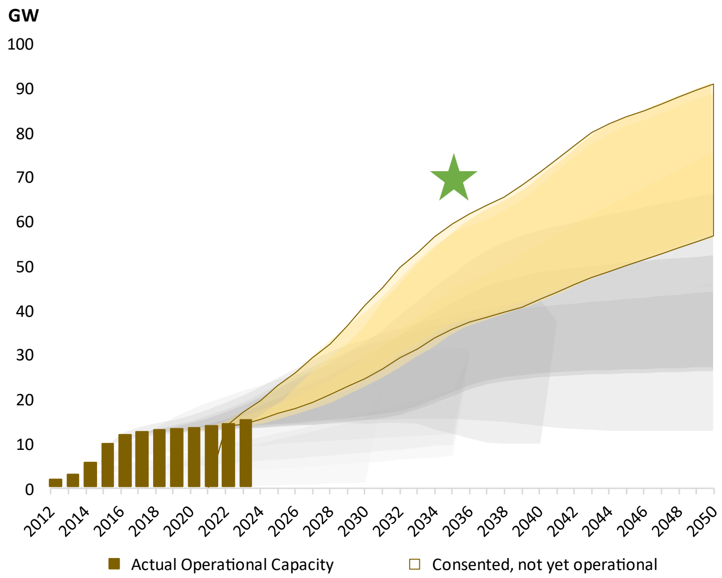

Figure 5-7: Evolution of future solar capacity forecasts in the UK, 2012 – 2023 (Ref. 20)

pathway with the lowest forecast capacity to the highest capacity in each year. Historic installed capacity (consistent with that shown in Figure 5-6) is shown by the brown columns.

5.10.13 Figure 5-7 shows that in each year since 2013, the future range of solar capacity for different FES pathways has increased over the previous year's range, including for pathways which are not compatible with net zero.

5.10.14 The UK's net zero commitment in 2019 has manifested in subsequent FES pathways as a further increase in solar capacity, shown by the yellow ranges in Figure 5-7 (the 2023 forecast shows the greatest installed capacity and is bordered in brown)

5.10.15 Year-on-year cost reductions have made solar technology progressively more attractive (and now preferential) compared to many other forms of electricity generation, promoting the commercial rationality for the UK to prioritise the development of solar capacity in order to address energy affordability challenges (see Chapter 9) irrespective of the already urgent need for schemes to come forwards to support decarbonisation and energy security aims.

5.10.16 Each of the annual ranges of future installed solar capacity in Figure 5-7 may be explained by the extent to which other low carbon technologies including onshore and offshore wind, nuclear, CCUS and BECCS, are deployed in the UK. Delays or shortfalls in the deployment of any technologies versus their FES pathways will require a compensatory acceleration or expansion in the deployment of other technologies for the UK to remain on track to achieve net zero.

5.10.17 In this context, the urgent development of large capacities of technologies which are proven in development and operation is clearly a prudent approach and is consistent with the government's conservative approach to infrastructure development (Ref. 1, Para 3.3.10)

5.10.18 The solar sector is proven in operation with over 15GW of installed capacity reliably delivering zero-carbon electricity to the UK's electricity system. The solar sector is also proven in delivery because of its short development duration and is therefore well placed to deliver to the urgent need for low-carbon generation.

5.10.19 Data from the REPD (Ref. 39) quantifies the average duration from planning submission to operation of a solar farm in the UK is 1.3 years (over an average of 1,259 projects) with a 0.9 year construction timeframe. Larger projects may take longer. The 12 solar projects listed as operation on the REPD which are over 40MW in capacity took on average 1.9 years from planning submission to operation, of which construction lasted on average 1.3 years.

5.10.20 It is however important to recognise that many large-scale schemes have operational dates which are determined by available grid connection dates. Large-scale schemes may therefore follow a development plan to coordinate with those dates. Larger schemes of over 50MW capacity are also required to apply for development consent under the PA2008, with different statutory timelines to smaller schemes, which may affect the time elapsed from planning submission to operation.

5.10.21 At first view, solar pipelines look healthy but must be viewed with caution, particularly in relation to the analysis included at Section 5.3 of this

Statement regarding the attrition of projects and capacity from pipelines and registers prior to commercial operation.

5.10.22 Solar schemes can be developed stand-alone or co-located with storage or other generation technologies. Both stand-alone and co-located schemes play essential roles in contributing to the three pillars of energy policy: decarbonisation, security of supply and affordability.

5.10.23 Section 5.11 of this Statement explains that storage is an essential part of the future energy system. Section 6.8 explains that the co-location of storage with renewable generation has benefits, however it is not necessary (and nor is it a policy requirement) that all renewable energy schemes are co-located with storage.

5.10.24 Stand-alone solar schemes (and schemes using other renewable generation technologies) are already prevalent and will likely continue to be prevalent in the UK's future electricity system.

5.10.25 Figure 5-9 shows that in each of the three FES pathways which are compatible with net zero, the capacity of solar generation always outstrips that of storage. It is therefore anticipated by the Electricity System Operator, that the future electricity system will consist of both stand-alone solar (and other renewable) projects, as well as co-located projects.

5.10.26 Stand-alone renewable schemes generate, from a renewable source, zero-marginal carbon electricity. Therefore, stand-alone schemes also provide an essential contribution to reaching net zero.

5.10.27 The TEC Register (Ref. 38) lists 3.3GW of stand-alone solar and 37.1GW of co-located solar projects with connection dates prior to 2030. The TEC register does not record the capacity of individual technology types within an application. Therefore, it is more precise to state that solar technology is proposed to be installed at projects which comprise a total of 37GW of connection capacity to the NETS prior to 2030.

5.10.28 Embedded Capacity Registers (Ref. 62) list a total of 42.1GW of solar projects with a status of ‘Accepted to connect’. The data does not indicate when connections will be available.

5.10.29 A point of connection is absolutely necessary for a developer to secure for a development to be viable to take forwards and in many cases grid connection can be secured prior even to engaging local landowners. The current scarce nature of grid connections in GB, coupled with expectations of large capacities of connections being required in the future, prioritises the procurement of grid capacity as a critical project development activity.

5.10.30 The cost of securing and holding a grid connection for a potential project is also not prohibitive in relation to development costs as a whole. It is therefore as expected that the capacity of projects listed on ‘connection queues’ is currently very high. This does not necessarily mean that those projects will make it to commercial operation.

5.10.31 Planning consent is required for all projects greater than micro-scale. The REPD lists 1.6GW of projects under construction and 9.9GW of consented projects awaiting construction.

5.10.32 The REPD also lists 4.4GW of Nationally Significant Infrastructure Projects (all with grid connections proposing to connect in the 2020s). 15 large-scale solar or solar plus storage schemes are listed as being at Pre-Application stage on the National Infrastructure Planning Portal. Grid connection dates for these projects range from 2025 to 2033 and the total capacity associated with these facilities is anticipated to be circa 7GW.

5.10.33 At best, therefore, approximately one third of the capacity of solar projects with agreements to connect to the NETS prior to 2030 have so far engaged with the Planning Inspectorate and it is possible that only a percentage of that capacity will come forwards to the development consent stage.

5.10.34 The REPD also lists 7GW of Local Planning Authority level solar facility planning applications as ‘submitted’ but not yet determined. If successful, it is possible that a proportion of these could deliver prior to 2025 although the REPD does not include an ‘Operational Date’ against 6GW of these projects.

5.10.35 Of the circa 80GW capacity currently listed on connection registers with connection dates earlier than 2030, just 21GW has progressed to the planning stage, although a further 7GW has registered its intent to submit a planning application ‘at a later stage’.

5.10.36 In relation to revenue contracting, the pipeline is even further constrained. Just 4.3GW of solar schemes have secured CfDs to deliver the majority of the capacity from October 2024 (2GW) and October 2027 (1.4GW) (Ref. 41).

5.10.37 The data also suggests that an attrition or stall rate could be significant. Under 5% of potential pre-2030 connected capacity has yet passed through planning and secured a revenue contract for the electricity generated.

5.10.38 It is the view of this author, that if a significant capacity of solar generation is not built out to a scale comparable with the projections provided by NGESO and others, then the UK will be highly unlikely to continue to reduce its carbon emissions over the coming decade, and ultimately meet its legally binding decarbonisation targets.

5.10.39 A significant proportion of low-carbon schemes currently listed on registers will not become operational, and with that as context, bringing the Scheme forwards will be a critical step in the development and delivery of large-scale solar capacity in the UK.

5.11 Flexibility

5.11.1 The National Infrastructure Commission (NIC) describe the need for flexibility in the UK’s future energy system, stating that:

“It is key that, alongside deploying renewables, the UK continues to drive innovation in the power sector to effectively build a flexible electricity system. Storage technologies, flexible demand, efficient interconnectors, and other innovations are also needed to support renewables and maintain the security of the electricity system.” (Ref. 63, p6)

5.11.2 Flexibility is delivered through interactions between both supply (generation) and demand (consumption) to help the national energy system function safely and efficiently. The full operation of flexible assets within that system requires them to both store energy from (or save) and release energy to (or use more) the energy system in response to market drivers, as will subsequently be explained.

5.11.3 The overriding themes for the GB electricity market in the coming decade are those of decarbonisation through an increase in deployment of renewable generation, and higher demand due to the electrification of heat, transport, and industrial demand, while meeting Security of Supply standards and affordability aims.

5.11.4 This means a move away from dispatchable fossil-driven assets and towards renewable plant: a theme which will alter the needs of the GB electricity system. System security of supply will need to address:

a. Changing patterns of, and variability in, residual demand (demand net of renewable output)

b. A reduction in the proportion of synchronous plant connected and available to support system frequency, and

c. A shift in the location of generation reflecting resource (wind and solar) distribution

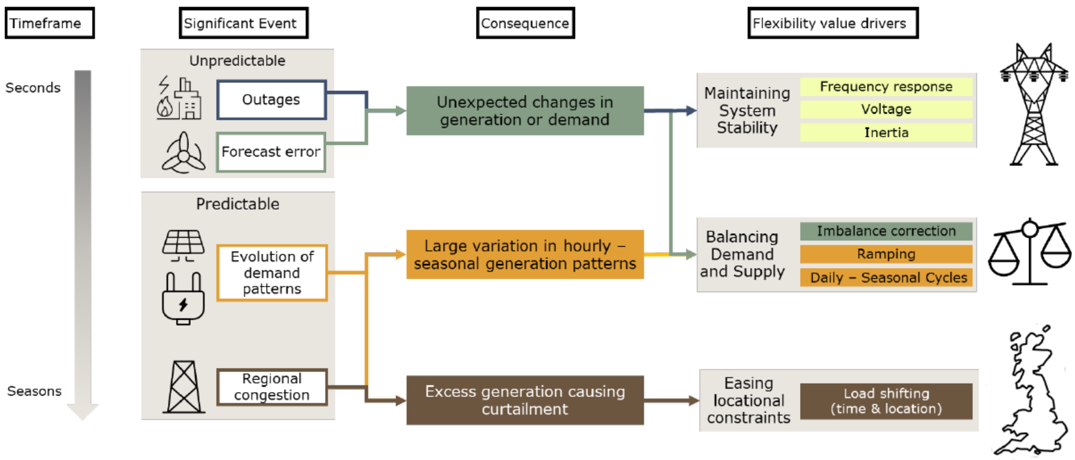

Figure 5-8: Drivers of Flexibility Requirements (Ref. 64)

5.11.5 Figure 5-8 above illustrates the events, consequences and value drivers over different timeframes for flexibility in the GB electricity market. Greater variability in residual demand (i.e. demand net of renewable generation supplied) will increase the need for flexibility solutions across multiple timeframes.

5.11.6 Flexibility is needed to maximise the use of renewables when there is an abundance of generation, and to fill the supply gaps in periods of shortfall.

5.11.7 Storage provides flexibility. Flexibility is the ability to shift in time or location the consumption or generation of energy. Flexibility is also the ability to shift energy from one medium (vector) to another, e.g. electrical energy to gravitational potential energy through Pumped Storage schemes, and back again.

5.11.8 NPS EN-1 sets out the policy position in favour of electricity storage:

“Storage has a key role to play in achieving net zero and providing flexibility to the energy system, so that high volumes of low carbon power, heat and transport can be integrated.” (Ref. 1, Para 3.3.25)

5.11.9 Storage facilities need to be able to import energy and export energy. Sources of energy import are discussed later in this section.

5.11.10 Storage has the capability to deliver flexibility over different timeframes and can be categorised as:

a. Short Duration Storage (SDS) with durations of four hours or lower, suited to addressing short duration balancing needs
b. Medium Duration Storage (MDS) with durations of over four hours, up to 12 hours, suited to addressing within day balancing; and
c. Long Duration Storage (LDS) with durations of over 12 hours, required for multi-day and seasonal balancing needs

5.11.11 Here, ‘Duration’ refers to the amount of energy a storage facility can hold, rather than the time for which energy can be efficiently stored between import (charge) and export (discharge).

5.11.12 Short Duration Storage addresses the increasing need for flexibility in matching supply with demand within-day, i.e. balancing increasing levels of renewable electricity supply with demand and providing system services to support the operation of a high-renewable electricity system.

5.11.13 Long Duration Storage addresses the view that, in the future, the electricity system is expected to exhibit greater seasonal variability and provide for the potential of periods of days or weeks where there may prolonged excesses, or shortfalls, of renewable output.

5.11.14 Extreme but rare extended periods of low renewable generation (sometimes referred to as ‘*Dunkelflaute’* events) possibly lasting up to several weeks have the potential to pose a security of supply risk. There is still considerable uncertainty around forecasting when these events will occur and how long they will last, so there is a need for both sufficient storage capacity and generation capacity to manage security of supply through these periods while also supporting decarbonisation targets.

5.11.15 Conversely, enduring periods of high renewable generation can better contribute to overall electricity system decarbonisation if abundant generation can be stored rather than curtailed.

5.11.16 Long Duration Storage assets are an important part of the anticipated solution to help manage both types of events, but these are not the events which Short Duration Storage assets, such as those which form part of the Scheme, are designed to address.

5.11.17 National Grid ESO’s 2023 FES indicates that storage and interconnection (flexibility) capacity will need to increase (from 12.7GW in 2022) to 28.6 – 46.4GW in 2030 and 49.3– 78.9GW by 2050 to balance supply and demand both within the GB system and across borders, in those FES pathways which are compatible with net zero. NGESO forecast an increase in Short Duration Storage (including Battery Energy Storage Systems (BESS), compressed air, pumped hydro and liquid air technologies, versus 2022 installed capacity) to between 16.9GW and 29GW by 2030 and between 33.4GW and 52.1GW by 2050 for scenarios which are compatible with net zero 2050 (Ref. 20(2023), Table ES1).

5.11.18 There are many technologies which have potential to provide grid scale electricity storage functions, ranging from pumped storage hydro schemes (a technology which has been in existence for over 50 years), through BESS, which are becoming increasingly commonplace in the UK, to more novel technologies such as liquid air storage, compressed air storage for SDS or hydrogen with potential for LDS application, which at the time of writing this Statement are now being designed, developed with varying timescales for deployment.

5.11.19 Key differentiators between storage technologies are not only how energy is stored but is also how much energy can be stored, and for how long it can be stored, from both a technical and commercial basis.

5.11.20 NPS EN-3 also describes Government's support for solar which is co-located with storage (Ref. 2, Para 2.10.2).

5.11.21 Storage systems which are co-located with solar in the UK have so far tended to be SDS systems.

5.11.22 Currently, SDS systems complement the generation profile of solar facilities and provide system functions which support the operation of the solar facility by (among other functions) balancing supply with demand.

5.11.23 The co-location of MDS or LDS systems with solar has not yet been proposed in the UK but future advances in technology may make this a viable possibility.

5.11.24 BESS are short duration electricity storage systems.

5.11.25 Two important operational parameters which describe the size of a BESS are its power capacity and its energy capacity.

5.11.26 Power capacity is measured in megawatts (MW) and describes the maximum instantaneous level of power export or import achievable by the BESS. This is analogous to the power capacity of a conventional generator.

5.11.27 Energy capacity describes how much energy the BESS can store. Energy equals power multiplied by time. Energy capacity is measured in megawatt hours (MWh) and can be described as MWh, simply hours, or by a C-rate.

5.11.28 For clarity, energy capacity does not relate to how long energy can be stored for (elapsed time between charge and discharge) although different technologies may have different technical or commercial factors which provide a practical limit to that elapsed time.

5.11.29 As renewable generation capacity increases on the GB electricity system, so too will the total capacity of operational storage systems to balance an increasingly variable supply portfolio with demand across timeframes ranging from milliseconds to seasons.

"Storage and interconnection can provide flexibility, meaning that less of the output of plant is wasted as it can either be stored or exported

when there is excess production. They can also supply electricity when domestic demand is higher than generation, supporting security of supply. This means that the total amount of generating plant capacity required to meet peak demand is reduced" (Ref. 1, Para 3.3.6).

5.11.30 Figure 5-9 shows anticipated future solar capacity and future short duration storage capacity for each year to 2050. The annual projections for short duration storage capacity (y-axis) are plotted against the annual projections for solar capacity (x-axis) for each of the three scenarios listed. The data has been re-cast to show increases versus a 2022 baseline. Therefore, Figure 5-9 shows anticipated growth in short duration storage capacity as a function of anticipated increase in solar capacity.

5.11.31 Data from each of the *"three* [FES] *pathways involving radical change across many industry sectors, which will deliver the required 100% reductions in carbon emissions by 2050"* are shown on Figure 5-9. The one FES pathway which will not deliver net zero is not shown.

5.11.32 Each pathway tracks a similar trend. An increase of 20GW of solar (i.e. increasing GB installed solar capacity from c.15GW as at the time of submission to c.35GW) corresponds to a projected increase of c.15GW of Short Duration Storage (i.e. increasing GB installed storage capacity to c.20GW). An increase of 40GW of solar capacity corresponds to an increase of c.25GW of Short Duration Storage.

5.11.33 Although the data shows that National Grid expect Short Duration Storage capacity to increase by c.600MW as solar capacity increases by c.1GW on a nearly linear basis it will not be solely a growth in solar capacity, but more likely a growth in the capacity of all renewable generation, which drives the requirement to increase capacity of many types of storage technology.

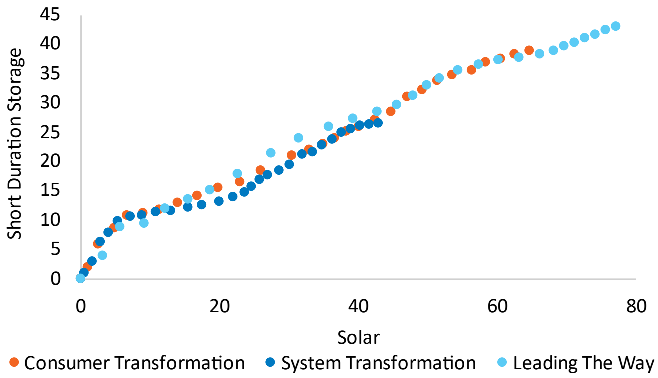

Figure 5-9: Growth in Short Duration Storage capacity vs. Solar Capacity, 2023 – 2050 (Ref. 20)

5.11.34 As both renewable generation capacity and storage capacity are expected to increase, projects which seek to connect to grid connection points which can accommodate storage facilities may propose to bring forwards co-located storage facilities as Associated Development to the main (renewable generation) development, as envisaged by NPS EN-3 (Ref. 2, Para 2.10.16).

5.11.35 As described in Section 5.10 above, storage facilities may also be developed as stand-alone from any renewable generation schemes.

5.11.36 Developments may identify location-specific reasons why storage schemes will not be co-located with renewable generation schemes, but it is important to recognise that stand-alone storage schemes are already commonplace in GB. Such schemes have already and are likely to continue to come forwards, delivering decarbonisation and energy security benefits as part of the UK's electricity system through their own grid connections. It is not necessary (nor is it a policy requirement) that all storage is co-located with a renewable energy scheme but as NPS EN-1 makes clear, co-location is an approach which the government supports because it can help to maximise the efficiency of land used by a scheme.

5.11.37 Figure 5-9 shows that in each of the three FES pathways which deliver net zero, the capacity of solar generation outstrips that of storage capacity at all times. It is therefore anticipated by the Electricity System Operator, that the future electricity system will consist of both standalone solar schemes (and by extension other renewable schemes), as well as co-located schemes.

5.11.38 However, where available grid connections enable the co-location of renewable generation with storage, a scheme which includes both may be proposed and by doing so would – among other reasons – ensure that the greatest use can be made of that available grid connection infrastructure.

5.11.39 Projects which are being brought forwards as stand-alone generation schemes still play an essential role in contributing to the three pillars of energy policy: decarbonisation, security of supply and affordability, because of their critical ability to generate, from a renewable source, zero-marginal carbon electricity – which is something that storage, on its own, cannot do.

5.11.40 The size of the import connection secured by connection agreement with National Grid at the point of connection is an important input into the maximum power capacity of the BESS proposed at a facility. Other physical parameters may limit specific elements of the scheme, including parameters which will have the effect of capping the energy capacity of the proposed BESS.

5.11.41 Given the need for flexible sources of generation to support the rollout of renewable generation capacities onto the NETS, it follows that where the deployment of storage facilities is acceptable in a planning sense, that the consent process does not impart any conflicting or arbitrary caps on either energy or power capacity of an installed storage facility. Developers may therefore approach consent in such a way that secures flexibility in design (by way of a 'Rochdale envelope' approach) in order to allow provision in the DCO for technological innovation and improvements that may be realised at the time of procurement and construction, in order to ensure that it can construct the Scheme taking advantage of innovation, safety improvements and cost-efficiencies.

5.11.42 The following examples describe how the Operational parameters for the size of the BESS are related to each other, using as an illustration, a 100MW, 200MWh Li-Ion system.

5.11.43 A BESS with 100MW power capacity would, at any specific moment, be able to import, or export (not both) up to 100MW of electrical power.

5.11.44 If that BESS was able to store enough energy to export at full capacity for one hour, it would have an energy capacity of 100MWh (100MW x 1h).

5.11.45 A BESS with two hours of energy capacity would be able to store 200MWh (100MW x 2h). This energy could be exported to grid at its maximum power rate (100MW) for two hours.

5.11.46 Once fully depleted (i.e. all stored energy has been exported from the BESS), the BESS would take two hours at full import power rate (also 100MW) to reach a full state of charge. The state of charge (SoC) can be measured as an absolute number (e.g. when full, the state of charge in this example would be 200MWh) or as a percentage of the energy capacity of the BESS (e.g. when full, the state of charge would be 100%).

5.11.47 The battery C-rate describes the ratio of the power capacity and energy capacity, and the C-rate is the inverse of the number of hours required fully to charge the BESS from empty to full. This example describes a 0.5C BESS which takes at least two hours to discharge all of its energy from full (100% SoC) to empty (0% SoC).

5.11.48 In reality, BESS are not normally operated across the full 0% - 100% range of state of charge, instead cycling across 80% to 90% of that range (i.e. from c.10% SoC to c.90% SoC) to preserve battery cell life. Neither are BESS 100% efficient, and a Round Trip Efficiency (RTE) measure describes the percentage of energy which has been imported to the BESS is then available for export. A current typical RTE value is 88%.

5.11.49 In the examples following, to simplify the explanation given on how BESS may operate, both round trip efficiency and operation range of state of charge have been ignored.

5.11.50 BESS provide flexibility to the electricity systems because they are able to import power when national supply outstrips demand, and export power when demand outstrips supply. BESS are also able to provide Ancillary (Balancing) Services.

5.11.51 Typically, BESS (as opposed to other forms of storage, e.g. pumped hydro, or in the future hydrogen) are used to balance supply and demand over short time periods (e.g. milliseconds to days). BESS may import energy at times of low demand (e.g. overnight) or high supply (e.g. the middle of a sunny day, or when wind generation is high) and release that energy when demand is high.

5.11.52 In the UK, demand currently tends to be higher in the morning (e.g. 07:00 to 09:00) and in the early evening e.g. 17:00 to 19:00) than it is at other times of the day, although it is conceivable that the daily shape of national demand will trend towards the daily shape of national supply through the implementation of smart meters, time of use tariffs, electric heating and transport needs in domestic and commercial properties.

5.11.53 Ancillary (Balancing) Services are procured by NGESO and under these contracts, operators respond to NGESO’S requests to import or export power. Ancillary (Balancing) services are important because supply of and demand for electricity must be matched at all times, and the electricity system needs to be kept in balance and within statutory control parameters. Ancillary (Balancing) Services are used by NGESO to do this.

5.11.54 Table 5-1 describes the potential contributions made by a storage asset as part of the Scheme to the GB electricity market. This includes the role of the storage asset in supporting the operation of the solar asset by directing energy from times when generation is in abundance to times when it is needed, and its ability to provide ancillary services which support the operation of the solar asset as part of a decarbonised GB electricity system. Further explanation of the associated nature of the storage development is included in **Planning Statement [EN010142/APP/7.2].**

5.11.55 Table 5-1 describes on each row, the different types of service, or commercial application, available to BESS. The second column provides an explanation of the service. The third column addresses the applicability of each service to either solar, storage or both (whether co-located or not).

Table 5-1: The potential contribuions of a storage asset within the Scheme to the GB electricity market, including ancillary service provision

Service	Explanation	Applicability	Service Type	Connection
Trading	Forward balancing of anticipated energy supply with energy demand	Solar assets generate energy. Storage helps by directing energy from when it is produced to when it is needed. Storage can be co-located with solar assets, or developed independently.	Other	
Balancing Mechanism	Being available to NGESO to balance supply and demand at delivery	Solar will provide downward flexibility, if needed, but at the 'cost' of low-carbon energy unless that energy is instead stored. Co-located RES and storage can provide both upward and downward flexibility, and operating storage in support of a RES asset avoids the loss of any low-carbon energy generated by that asset. Stored energy can be dispatched over milliseconds to days, depending on technology and need.	Other	
Frequency Response	Changing output over seconds / minutes to help maintain national system frequency at the statutory level of 50Hz		Ancillary	Both
Reserve Operation	Changing output over minutes / hours to re-balance supply and demand following a fault or other event on the electricity system			
Reactive Power	Locational service which supports the 'flow' of power from source to destination	A mandatory service for all transmission-connected assets, delivered by solar, other RES and storage assets	Ancillary	Export
Inertia	Helps to slow the rate of change of the electricity system in response to an unforeseen event, stopping faults from escalating	Solar inverters are able to provide synthetic inertia. Storage also provides synthetic inertia	Ancillary	Both

Service	Explanation	Applicability	Service Type	Connection
Black Start	A locational service which would help ‘turn back on the lights’ if the national electricity system failed	Solar is unlikely to provide Black Start on a stand-alone basis. Stand-alone storage may be capable of providing limited Black Start support. A co-located asset is likely to be able to be more useful.	Ancillary	Both
Constraint Management	Changing output in response to local energy supply, demand and transmission conditions, to ensure locational adequacy at all timescales	Solar can provide downward constraint management services. Co-locating solar and storage can allow for the provision of upward and downward constraint services	Ancillary	Both
Infrastructure	By connecting generation assets where they are needed and where infrastructure already exists, less new electricity transmission and distribution infrastructure needs to be delivered	RES and storage can help with reducing new infrastructure requirements, and sharing connection points by co-locating assets means that, ultimately, less connection points will be needed	Other	

5.11.56 The fourth column describes whether the service is an Ancillary Service, procured by NGESO for the proper functioning of the electricity system or has other purposes which help 'keep the lights on' but are not those services specifically described by the NIC as those which "*support renewables and maintain the security of the electricity system*" (Ref. 63, p6).

5.11.57 The fifth column describes whether in providing each Ancillary Service (as categorised in the fourth column), a co-located solar + BESS would import, export or both, power from/to the NETS.

5.11.58 BESS are needed to provide these services, because the assets which currently provide these services, being thermal (coal or CCGT plant), are either closing to reduce emissions associated with electricity generation to achieve net zero, or are expected to run less and less in the future as renewable energy grows, and the majority of these services can only be delivered by plant which are already operating.

5.11.59 Under an Ancillary (Balancing) Services contract, thermal plant would provide positive regulation (i.e. are ready to increase their output) by operating at a low level of power which can then be increased in very short order following instruction from National Grid ESO. Thermal assets which are already operating at higher levels of power are able to provide negative regulation (i.e. are ready to decrease their output) in a similar way by turning their output down following instruction from National Grid ESO.

5.11.60 BESS will be able to provide both upward and downward regulation by ensuring that they are entering their contracted period with a 50% State of Charge. This allows the BESS to import energy under instruction and store it until it is full (i.e. SoC reaches 100%), or export energy until it is empty (i.e. SoC reaches 0%).

5.11.61 Table 5-1 shows how the provision of many services requires both an import and an export connection, which allows for the upward and downward regulation as previously described.

5.11.62 Not all grid connections have available import capacity, so it follows that where export and import capacity is available at a particular grid connection point, BESS should be considered and assessed. If those available connections are not used, it is possible that storage will not be able to come forward to the capacity and timings required to support the full integration of low carbon power into the UK electricity system because new connection points will be needed to connect the scale of storage foreseen as necessary by NGESO.

5.11.63 A co-located BESS is foreseen to undertake the following five types of operation during its operational life:

a. Importing from the co-located solar facility when local solar generation is high but national generation is higher than national demand;

b. Exporting to the grid when co-located solar generation is low but national demand is higher than national generation;

c. Importing from the grid when national demand is low but national generation is high;

d. Exporting to the grid when national generation is low but national demand is high; and

e. Importing or exporting from the grid under an Ancillary (Balancing) Service contract instruction from NGESO.

5.11.64 BESS will operate in the electricity market in response to a market need. Market need manifests as a differential in market price at different times, driving the BESS to import or export accordingly. A greater market need will drive a greater price differential. Electricity is bought and sold ahead of time (based on operational forecasts of supply and demand, see following) and also by NGESO much closer to (or at) delivery. Buying or selling ahead of time is called trading and commitments are then delivered through BESS operations, as is illustrated in the following. Any other operation at delivery will be under an Ancillary (Balancing) Services contract arrangement.

5.11.65 Section 6.9 of this Statement shows how a co-located Solar + BESS scheme may operate and how the BESS may support the solar facility as well as fulfil additional functions to support high-RES electricity system operation in the UK energy market.

5.11.66 Section 9.2 of this Statement describes the commercial operation of the UK's electricity market and how changing levels of forecast supply and demand may affect electricity price. In summary, if over some future period of time, the national supply of electricity is expected to be higher than the national demand for electricity, then market price will be low. If national demand is forecast to be higher than supply over a different period of time, then market price will be higher.

5.11.67 A BESS which imports during lower price periods and exports that power during higher price periods will therefore help balance supply and demand in both periods.

5.11.68 Once charged, a lithium ion BESS is able to hold its charge without significant depletion (charge leakage) for a period of at least days, meaning that BESS are able to import energy one day and export it the next.

5.11.69 In practice however, lithium ion BESS are anticipated to provide short term balancing and electricity market operations and the long-term storage of imported energy in the BESS is not currently foreseen as a normal mode of operation for any lithium-ion BESS co-located with a solar facility.

5.11.70 Evidence on possible modes of operation of a co-located solar and BESS scheme are included at Section 6.8 following.

5.12 Conclusions

5.12.1 This Statement of Need aligns with NPS EN-1 and concludes that many low-carbon generating technologies are urgently needed to meet government's energy objectives by:

a. Providing security of supply;

b. Providing an affordable, reliable system (through the deployment of technologies with complementary characteristics); and

c. Ensuring the system is net zero consistent.

5.12.2 This Statement of Need describes progress made in the development of as yet unproven, unconsented or unfunded schemes or schemes with long or as yet unproven development timelines.

5.12.3 Yet, to address the ongoing climate emergency, it is critical that the UK urgently develops a large capacity of low carbon generation.

5.12.4 The evidence shows that there are many significant uncertainties associated with the development of such schemes, particularly in relation to the timeframes in which material contributions to decarbonisation and security of supply must be made. Put plainly, such schemes cannot yet be relied upon to contribute to the delivery of net zero and many simply will not be ready to contribute in a meaningful way to decarbonisation before the 2030s. The importance of achieving meaningful progress in decarbonisation during the 2020s is described in Section 5.3.

5.12.5 The evidence therefore points to the development of proven technologies such as large scale solar as necessary to mitigate against the potential for non-delivery of other technologies. Such schemes should be brought forwards with urgency to make tangible and essential advances in decarbonisation in the near term.

5.12.6 The government's current policy of developing market-led frameworks to support the development of low-carbon generation from diverse sources of energy remains important. Such schemes have the potential to complement the UK's growing renewable generation capacity to bring decarbonisation and security of supply benefits in next decade and beyond.

5.12.7 Solar power generation has global momentum and large-scale schemes are already being developed in GB. Solar is a proven technology. It is already delivering as part of the UK's electricity system and will continue to deliver further critical benefits to consumers through the urgent and continued decarbonisation, security of supply and affordability.

5.12.8 The IPCC has stressed the importance of urgent action to decarbonise electricity generation, and the CCC have reported that the UK needs to commission more low-carbon generation, and more quickly, to meet its net zero obligations.

5.12.9 The prompt development and deployment of proven technologies, such as solar, is a lower-risk pathway for delivering low-carbon generation both now and for the longer term, than waiting for technologies which may not deliver.

5.12.10 This is consistent with the approach described by government in NPS EN-1 which articulates the prudence of planning infrastructure development on a conservative basis, including for scenarios in which the future use of hydrogen is limited. (Ref. 1, Para 3.3.10)

5.12.11 Solar generation is needed in the UK to keep the country on course in its fight against climate change because it is a beneficial, fundable and deliverable technology. The Scheme should therefore be recognised for the critical contribution it will make to the UK's journey to net zero. Consenting the Scheme, such that it will be able to be developed as planned, will bring the UK closer to its required track through the critical 2020s to meet its legally binding carbon emissions reduction targets. The delivery timing associated with current forward nuclear and CCUS projections strengthen this conclusion.

5.12.12 It is vital that the development of low-carbon generation capacity occurs urgently in the near-term and also on an ongoing basis to facilitate wider necessary decarbonisation actions. It is important that schemes with long development timescales continue progressing their plans to achieve or sustain carbon reductions in decades to come.

5.12.13 Developments with the proven ability to achieve carbon savings comfortably within in the next decade are essential to keep the UK on its legally binding carbon reduction path.

5.12.14 An actual, potential or aspirational pipeline for longer term low-carbon generation schemes presents additional opportunity for future decarbonisation. However, the presence of such a pipeline cannot legitimately be used as an argument against the consent and development of a scheme proposing to use proven technology and short development timescales, thereby delivering dependable decarbonisation benefits.

5.12.15 The Scheme is a viable proposal, with a strong likelihood of near-term deliverability. It will achieve significant carbon reduction benefits through the deployment of a proven, low-cost technology from a very suitable grid connection. As such, the Scheme possesses exactly those attributes identified as being required both in the near-term and in the future in order to continue to make material carbon reductions in the UK electricity sector.

6. Technical considerations for the development of solar in the UK

6.1 Chapter summary

6.1.1 This chapter provides an overview of the characteristics of solar power and the delivery of large-scale projects.

6.2 Large-scale and small-scale generators

6.2.1 Generation assets can be ‘centralised’ (connecting to the NETS) or ‘decentralised’ (connecting to the distribution networks or ‘behind the meter’ in consumer premises).

6.2.2 Electricity transmission networks operate at high voltages. High voltage operation reduces transmission losses and makes the bulk flow of energy over longer distances more efficient. Distribution networks operate at a lower voltage than the transmission networks, and are located closer to points of final demand. A lower voltage connection means that Generators which connect to distribution systems must be of a smaller capacity than those which connect to the NETS. Therefore, to connect the same total capacity of generators, more connections would be required at the distribution network level (at a potentially greater overall cost to consumers) than would be required directly into the NETS.

6.2.3 The NETS was designed to allow for the connection of large generating assets, but distribution networks were originally designed to transmit power to consumers. Distribution networks were not designed to connect significant capacities of electricity generation. Connecting generation assets of any meaningful size to distribution systems is becoming more difficult and more expensive (ultimately to the bill-payer). The Connections Action Plan includes an example of how distribution network constraints cause a significant delay to the installation of rooftop solar for an industrial consumer (Ref. 16, p79). It is therefore not the case that the connection of renewable generation to the distribution networks is either quick, or cheap.

6.2.4 By virtue of their role in transferring power from the bulk NETS to businesses, built facilities and houses, many distribution networks are in built up areas, away from areas of large natural resource potential. Geographical and technical constraints may therefore arise as generators continue to be connected to these networks, applying upward pressure to the costs and durations required to grant a connection agreement. This may materialise as significant cost, timing, and complexity considerations both for asset developers as well as for consumers who ultimately pay for the developments and the operation of the complex distribution systems which result.

6.2.5 However, currently 30% of all generation capacity is connected to the distribution networks, and FES pathways project that by 2050, that proportion may reduce as low as 27% (Ref. 20(2023), Figure ES.10). The proportion of generation capacity in 2050 connected to the distribution networks has decreased year-on-year in NGESO's analyses since the government committed to net zero by 2050.

6.2.6 This fact reflects the increased and urgent need for renewable generation capacity to come forwards, but with increasing complexity associated with connecting generation to distribution networks. An ongoing programme of work is seeking to increase the capacity of the NETS in as affordable a way as possible (Ref. 65).

6.2.7 Although the total capacity of generators connected to distribution systems is expected to grow, the total capacity of generators connected to transmission systems is also expected to grow.

6.2.8 FES (2023) pathways which meet net zero in 2050, project that the capacity of generation connected to the transmission network will increase by a factor of approximately 2.9 (2050 vs. 2022 capacity) to a total of 227.7GW. The capacity of generation connected to distribution networks is projected to increase by a factor of approximately 3.3 (2050 vs. 2022 capacity) but to a smaller total of 111.1GW (Ref. 20(2023)).

6.2.9 A wholesale decentralisation of the UK's electricity system is not expected to occur in the next 30+ years, if at all, and even in the most consumer-led scenario, the share of generation capacity connected to distribution networks is anticipated to rise to only 40%.

6.2.10 Decentralisation is not in itself a strategy or a requirement of the energy system but is a trend which will go some way to delivering a flexible, low-carbon and affordable energy system. Distributed generation will contribute to meeting carbon emissions targets and improving energy security, but the Government does not believe they will replace the need for new large-scale electricity infrastructure to meet UK energy objectives (see Section 3.3 previously).

6.2.11 Operating a mainly national electricity system (as current) will likely be more affordable than operating multiple distribution systems, connected by a 'light' transmission system.

6.2.12 By connecting more decentralised assets to distribution networks, less power will flow on the NETS and its unit cost of operation, which must be passed to consumers, will increase.

6.2.13 However, to ensure local as well as national adequacy of supply, the connection of more assets to distribution systems would also require either investment power transfer capability between each separate distribution system and the NETS, or a greater capacity of local low-carbon generation on each distribution system to manage local peak power security of supply.

6.2.14 In contrast, a system with a high proportion of transmission-connected assets would offer *"a number of economic and other benefits, such as more efficient bulk transfer of power and enabling surplus generation capacity in one area to be used to cover shortfalls elsewhere."* (Ref. 1, Para 3.3.12).

6.2.15 Further, to accommodate more decentralised generation capacity, more investment will be required to reinforce distribution networks and provide more connection capacity.

6.2.16 Operating a primarily decentralised electricity system in the UK would also likely be significantly more complex than operating today's primarily centralised system.

6.2.17 Electricity consumers, either directly or indirectly, through their energy bills, pay for all costs related to both transmission and distribution systems, including market inefficiencies, economic decision making, asset investments, balancing actions and transmission and distribution system enhancements. Energy bills will rise if existing assets are underutilised and/or reinforcements are required on other systems.

6.2.18 The NETS remains an important measure to maintain interregional connectedness, support the meeting of national peak demand *"reliably in all areas"* from geographically disparate sources whatever the weather (Ref. 23, p182) and keep power flowing to consumers with the high levels of reliability consumers have come to expect.

6.3 Large-scale, brownfield and rooftop solar

6.3.1 Decentralised solar may be installed on domestic or commercial rooftops or on brownfield land. In relation to brownfield locations, some may be suitable for solar deployment, but many will not.

6.3.2 Many decentralised sites may be unable to source a cost-effective and timely grid connection to support a stand-alone solar site. Distribution networks, which by 2022 were already straining with 32GW of distributed generation (Ref. 20(2023), Table ES.22), do not necessarily have the ability to connect the capacities required, even if connection points are close to potential renewable energy sites.

6.3.3 Many sites may simply not be suitable. They may be in areas of low solar irradiation, have unfavourable topography or be too small to develop in a cost-effective manner. Others may have remediation issues which render sites unattractive for solar development given potential costs or liabilities associated with clean-up prior to installation.

6.3.4 In relation to roof space, larger commercial structures or buildings with shared roof space may have contractual issues relating to ownership, occupation and upkeep which must be resolved prior to any solar development, or may not be resolvable in a timely and efficient way. Any roof space sloping to the north will be unsuitable for solar panels. Smaller buildings, listed buildings or those with period features are also unlikely to be suitable.

6.3.5 Other locations may be suitable from an engineering perspective but may be overshadowed by nearby taller structures or natural features which could significantly impact irradiation and output, and therefore yield and benefit. Shaded homes in built up areas may be a prime example.

6.3.6 Other roof space may need to be reinforced to accommodate the additional loading associated with solar infrastructure, all of which will add to installation costs for homes and businesses.

6.3.7 Section 9.3 provides more information on the economics of solar power, and demonstrates that it is already among the cheapest forms of generation over its lifetime. However, the installation costs of small scale solar are significantly higher than that of large-scale solar on a per unit capacity basis.

6.3.8 Very small installations, such as those on domestic roof spaces, may not be large enough to make solar installation viable once the 'fixed' costs of installation (e.g. design, scaffolding, cabling and commissioning) have been accounted for. This is important because it is for bill payers to pay for the installation of small-scale generation at their properties, and installation costs for small-scale solar have increased both on an absolute scale and in relation to Government estimates for the installation costs of large scale solar.

6.3.9 Figure 6-1 following shows cost information relating to the installation of domestic solar panels from the government's Microgeneration Certification Scheme (MCS) (Ref. 66), benchmarked against the capital cost range for small scale (domestic) solar PV and large-sale solar from the government's Cost of Electricity Generation report (Ref. 67(2023)). Capital cost includes development and construction costs where appropriate.

6.3.10 The data shows that small scale solar (red area) is expected to be two to four times more expensive to install than large scale solar (green area). During the period 2019 to 2021 inclusive, MCS data shows that actual installation costs were comfortably within the government's range estimate, in early 2022 installation costs rose to above the top of that range.

6.3.11 The reported installation cost for small schemes started to reduce again from a high in early 2023, but still remains above Government's range, and significantly higher than Government's range for large-scale solar.

6.3.12 Many home or business owners may not have the capital reserves to pay for the installation of solar panels on their roof areas and others may not want them. Since the wind-down of the Feed in Tariff scheme, which was introduced on 1st April 2010 but closed to new applicants from 1st April 2019, the government has been silent on measures to support domestic and small commercial solar installations, other than the removal of VAT from installation costs.

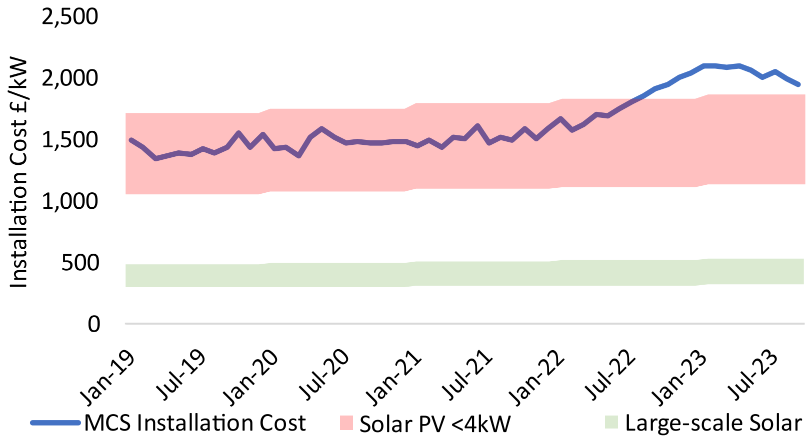

Figure 6-1: Reported and estimated small-scale and large-scale solar capital costs (£/kW) (Ref. 66 & Ref. 67)

6.3.13 The implication of these factors is that the real potential for decentralised solar in the UK is likely to be much lower than any gross potential identified when the suitability, availability, practicality and economics of such developments are taken into account.

6.3.14 Further, the installation of many thousands of separate systems is likely to take longer than the installation of a smaller number of ground-mount systems to achieve the same capacity. This is an important point in relation to the required urgency for solar generation.

6.3.15 Data from the government's MCS scheme shows that small-scale installations rose above 70MW per month in October 2022, from an average installation rate of just 30MW per month in the two years prior (Ref. 66). For the government's target of 70GW of operational solar by 2035 to be achieved by rooftop solar alone, microgeneration scheme installation rates would need to increase more than five-fold versus current already recorded installation rates. This increase would need to start immediately and be maintained throughout the next 11 years. It is the author's view that this is not a credible projection.

6.3.16 Decentralised generation has an important role to play in decarbonisation, however on its own, smaller scale solar, including rooftop solar, is not likely to deliver a sufficient total capacity at the required pace and at an affordable cost to meet the government's targets.

6.3.17 This information shows that smaller scale solar, including rooftop solar, must be considered as additional to, as opposed to instead of, the need for large-scale solar.

6.4 Site selection for large scale solar

6.4.1 Site selection is a critical step in the delivery of projects with aims of meeting the UK national need for sufficient low-carbon, low-cost energy supplies to support legal decarbonisation targets and national energy security requirements. This section sets out, in generic terms, the assessment process for sites for large-scale solar generation in the UK.

6.4.2 Suitable sites will be:

a. Capable of delivering to the required scale (in relation to the need for the scheme)

b. Technically and environmentally feasible within the stated timeframes

c. Commercially attractive to the developer

6.4.3 Site selection utilises a screening approach which considers possible alternative sites, taking into account the three requirements listed above. In addition, the screening approach recognises the required urgency of low-carbon development in the UK and therefore, in an approach which is consistent with guidance contained in NPS EN-1, applies a principle of proportionality to options which are vague or immature, (Ref. 1, Paras 4.2.26-27), especially where those considerations are critical for the viability of the project, on the grounds that they are not important and relevant to the Secretary of State's decision. The screening process will prioritise options which are more likely to be able to meet the intended aims of the project, over options which are less likely to proceed due to technical, commercial or other reasons.

6.4.4 Solar developments require three fundamental attributes, and these therefore drive the initial screening process. These attributes (which are consistent with NPS EN-3 (Ref. 2, Paras 2.10.18-48) are:

a. The existence and availability of sufficient land to deliver to the project to meet the scale set out in the scheme's aims;

b. The availability of a suitably placed point of connection to the NETS and/or local Distribution Network; and

c. Solar irradiation levels which support the potential for the development to produce an energy yield which is both useful and economic.

6.4.5 Other attributes will also apply later into the screening process, for example those environmental attributes described in NPS EN-3 Paras 2.10.27 to 2.10.48 and the potential for environmental impacts as described in NPS EN-3 Paras 2.10.73 to 1.10.126. However, a site which does not possess all three fundamental attributes is less likely to be a suitable location for large-scale solar generation than a site which does possess these attributes.

6.4.6 Further information on site selection for the Scheme can be found in Environmental Statement (ES) **Chapter 4: Alternatives and Design Evolution [EN010142/APP/6.1]**.

6.4.7 The UK's approach to the energy sector provides that *"It is for industry to propose new energy infrastructure projects within the strategic framework set by government"* (Ref. 1, Para 3.2.3). It is important therefore to acknowledge that an individual developer's approach to screening may not be rigid and inflexible but instead may be sensitive to local variability and indeed developer approach. Developers may therefore weigh the importance of one or more criteria in their screening approach differently for different schemes to accommodate and incorporate the needs and benefits of different geographies and local characteristics.

6.4.8 The site selection process also considers other factors which will not be a simple pass/fail for taking forward a site for development, but sites which are environmentally, technically, operationally and commercially suitable will likely score favourably on a majority of important characteristics.

6.4.9 For example, adjoining land parcels may be both suitable and available for development, resulting in an increased density of solar deployment and an environmental footprint over a more focussed area of the countryside. Other proposals may consider separate land parcels which do not border each other but instead combine to an integrated scheme which is more dispersed within a countryside setting.

6.4.10 Further, the connection of separate parcels of suitable land together into a single scheme may, subject to analysis, enable those parcels of land to connect economically to the electricity system, whereas if developed as stand-alone schemes they may not be able to carry the associated costs of connection and therefore may never be developed.

6.4.11 Large-scale solar schemes, precisely because of their scale and the area of land required for their development, are more likely to be sited in more rural areas of the country. In order to enhance the energy delivered from the installed capacity, schemes are also more likely to be sited in areas of higher solar irradiation levels.

6.4.12 Figure 6-2 is a map of PV power potential in the UK. Areas of higher irradiance are identified by colours towards the red end of the spectrum, while areas of lower irradiance are towards the blue end of the colour spectrum.

6.4.13 The government's Digest of UK Energy Statistics (DUKES) (Ref. 19, Table 6.2) shows that the installed capacity of solar generation in the UK rose above 10GW in 2016. Further, the average load factor of UK solar generation since that time has been 10.4% (min 9.9% in 2021, max 11.1% in 2018). A 10.4% load factor is equivalent to 910 kWh/Yr/kW(p), a value which corresponds to the boundary between the yellow to the right of 876kWh/Yr/kWp, and the darker yellow to the left of 949kWh/Yr/kWp on the scale shown in Figure 6-2.

6.4.14 Early experience in panel efficiency, system efficiency, site layout and scale effects may mean that the load factor of existing solar in the UK is not as high as it would be if all existing solar facilities were re-powered with panels of a current specification and technical performance. However, from Figure 6-2 it can be seen that any solar facility developed to the east of a line between Aberdeen to Manchester, and south of Manchester, could be expected to experience a higher load factor than the current UK average.

6.4.15 Large-scale solar schemes are expected to connect to the NETS. The NETS is an existing national infrastructure asset which is designed specifically for the bulk transmission of energy from its point of generation to nationwide consumers.

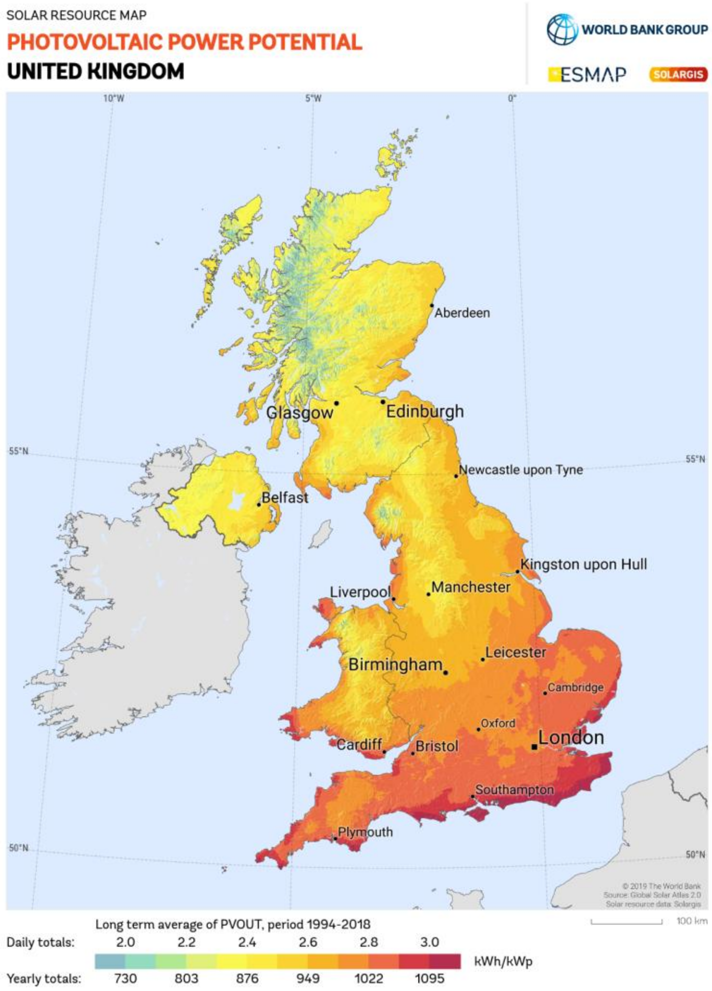

Figure 6-2: United Kingdom solar irradiation (Ref. 68)

6.4.16 NPS EN-3 states that:

"The capacity of the local grid network to accept the likely output from a proposed solar farm is critical to the technical and commercial feasibility of a development proposal." (Ref. 2, Para 2.10.22).

"Larger developments may seek connection to the transmission network if there is available network capacity and/or supportive infrastructure" (Ref. 2, Para 2.10.23).

"To maximise existing grid infrastructure, minimise disruption to existing local community infrastructure or biodiversity and reduce overall costs applicants may choose a site based on nearby available grid export capacity." (Ref. 2, Para 2.10.23)

6.4.17 To enhance the overall benefit of the scheme in terms of environmental impact, efficiency and timeframes for connection, schemes may elect to make use of existing and available points of connection to the NETS insofar as such connection points exist, in preference to building new connections or increasing the available connection capacity at existing locations.

6.4.18 Figure 6-3 following shows data from NGET's online ConnectNow Research assistant (Ref. 69). The tool is a useful but sombre reflection of the challenge faced by the UK to bring new large-scale generation developments online in timelines which will support the urgent need for decarbonisation and energy security in the UK.

6.4.19 Each numbered circle on the map shows the number of connection points in that broad geography, and the colour represents NGET's view (current at the time of download of the map) of when connection might be achieved at those locations. The map shows that connecting any new assets (i.e. those which have not already secured a connection agreement with NGESO) to the National Electricity System before 2030, is not currently possible.

6.4.20 The UK will therefore need largely to look to those projects which already have connection agreements to deliver the low-carbon capacity required to support the delivery of net zero and energy security aims until the mid-2030s.

6.4.21 It is important to recognise therefore, and as evidenced by the data shown in Figure 6-3, that connection to the electricity network, which is an essential element of project development, is currently a constraint to many projects which are coming forwards.

6.4.22 This issue has also been acknowledged by Ofgem who in May 2023 issued an open letter launching a policy review on reforming the electricity connections system (Ref. 70), by NGESO who are now working with the industry to undertake a review of the connections queue (Ref. 71), and by the government which published, in November 2023, a Connections Action Plan which explains these sets of actions and how together they will work towards delivering quicker connections for low-carbon generation assets (Ref. 16).

6.4.23 The importance of utilising an existing and already available connection to meet the urgent need for new large-scale solar generation is starkly clear.

6.4.24 Further, in light of the urgent need to decarbonise the electricity system and the current lack of available connection points for low-carbon generation assets, developers may make use of different ways of maximising the generation potential from available and accessible land resource through any limited yet available grid connection capacity the project has secured.

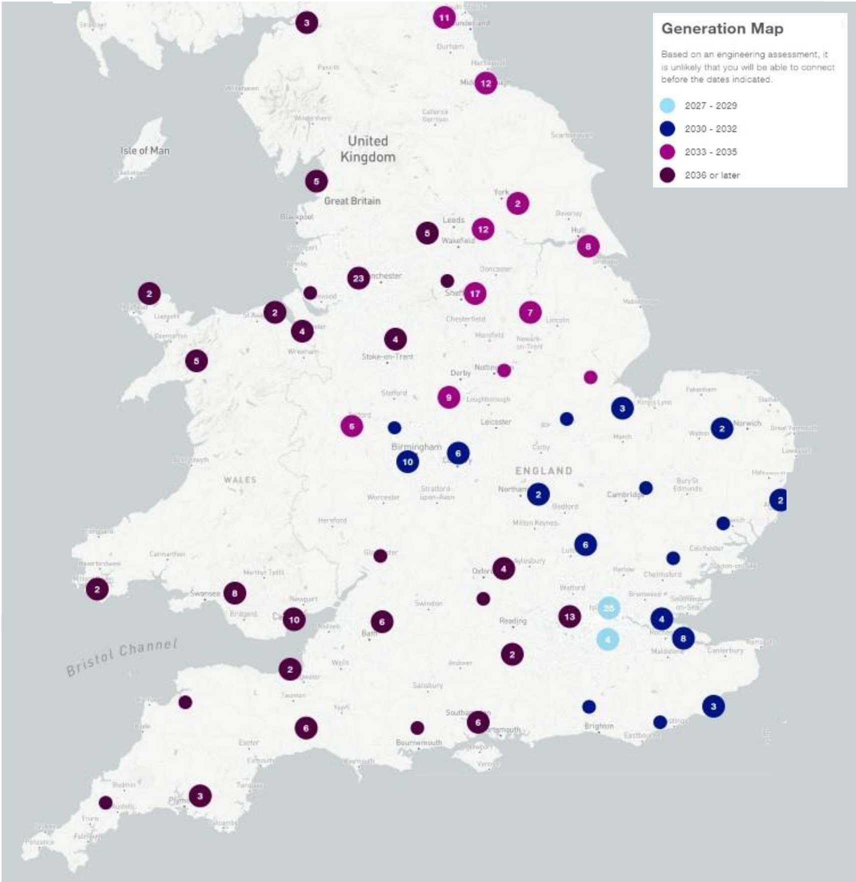

Figure 6-3: Transmission system connection points and potential connection dates (Ref. 69)

6.4.25 Great Britain’s energy transition to date has been characterised by the decommissioning of (primarily) coal fired power stations and the development of new renewable power plants. When power stations decommission, they leave behind the infrastructure used to connect them to the grid.

6.4.26 In light of the grid connection constraints identified above, the re-purposing of existing but unused infrastructure is an incredibly important strategy to help bring renewable power online in the timeframes required to support decarbonisation and security of supply.

6.4.27 Existing substations, and especially those at ex-coal sites, are incredibly important because they provide existing, therefore largely sunk-cost, opportunities to connect proposed projects to the NETS earlier than is currently possible at other types of substations.

6.4.28 Large scale solar schemes must connect to the grid via high voltage electrical cables. Locating solar schemes close to grid connection points will reduce electrical losses (which are proportional to cable length) and may result in a scheme with a lower environmental footprint than a scheme located further away from the point of connection, which would have longer cable routes.

6.4.29 Grid connection capacity is therefore a firm guide for selecting sites for large-scale solar schemes. However, due to the finite number of existing substations – and the smaller number of those substations with available capacity, it is also anticipated that:

a. New grid substations may be needed to connect the anticipated capacity of solar required to meet net zero

b. Sites may be located at greater distances from existing grid substations than previous developments

6.4.30 All proposals, whether to new grid substations or at greater distances from existing substations, will need to be technically feasible and environmentally sound for them to come forwards as viable proposals.

6.4.31 The number of locations in the UK which satisfy all three core site selection requirements (land availability and suitability, feasible irradiation levels and grid connection availability) is limited. For example, high population density and a large extent of designated land limits opportunities for large-scale solar development in the south east of England (where Figure 6-2 shows that irradiation is highest), and the need for proximity to existing and available grid connection capacity limits opportunities in the South West and East Anglia (where Figure 6-2 shows that irradiation is also high).

6.4.32 It should therefore not be expected that large-scale solar is located only where irradiation is highest in GB; nor only where suitable land is available; nor only in close proximity to existing grid substations with available capacity. Developments will be proposed in locations with the blend of characteristics which is assessed as suitable for each scheme, and each scheme may have unique features which are particular to its proposed location.

6.4.33 Further evidence supporting the suitability of the Scheme is included in Chapter 7.

6.5 Technology selection / orientation

6.5.1 NPS EN-3 sates that, along with associated infrastructure, a solar farm requires between 2 to 4 acres for each MW of output (Ref. 2, Para 2.10.17).

6.5.2 There are currently three main configurations of solar panel used in the UK, each has different physical and operational characteristics:

6.5.3 Fixed South Facing (FSF) panels are installed in rows stretching from east to west, with the receiver side of the panel facing south. The panels will be fixed on frames at an angle to the ground (dependent on latitude and ground slope) which will have been optimised prior to installation.

6.5.4 Single Axis Trackers (SAT) are installed in rows stretching from north to south. A single table of panels rotates about the north-south axis so that the panel is perpendicular to the incident irradiation from the sun for as long as possible.

6.5.5 East-West (E-W) panels are installed in rows stretching from north to south, with panels facing both east and west and an apex between them. As with FSF, the panels will be fixed on frames at a set (immovable) angle to the ground.

6.5.6 Panels may be orientated vertically (portrait) or horizontally (landscape) and may be mounted with one or more above (or next to) the first.

6.5.7 Different configurations have different benefits and disbenefits, and some configurations may be better suited to some locations than others.

6.5.8 As the sun tracks in the sky, both throughout each day and throughout the year, the inbound irradiation on the panels will vary and frames, axes and panels will be oriented to best optimise irradiation at that location, for that configuration, across the year.

6.5.9 A characteristic which is common to all three configurations is the potential for there to be a shadowing effect of one panel on another panel from time to time. Site designers will seek to optimise output given the specific location, the available land, and a known grid connection capacity and this will include reducing panel-on-panel shadowing effects where possible.

6.5.10 Latitude will impact on the effects of shadowing and site-specific mitigations at FSF layouts. In higher latitude locations, rows of FSF panels may be spaced further apart to reduce shadowing effects, while at lower latitudes spacing may not be as large. This is because the sun tracks lower in the sky when seen from higher latitude locations, casting longer shadows.

6.5.11 Spacing FSF panels further apart increases the ratio of acres / MW for the installation, but also increases the expected generation from each of the panels and therefore increases the ratio of energy generated over capacity installed (MWh / MW(p)) for the facility.

6.5.12 A similar analysis can be carried out for SAT and E-W configurations, however it should be noted that generally:

a. SAT requires more land per MW(p) but has the potential to generate more MWh/MW(p) than FSF; and

b. FSF requires more land per MW(p) but has the potential to generation more MWh/MW(p) than E-W.

6.5.13 Other local characteristics such as location and land topography may determine which configuration or combination of configurations delivers the greatest benefit in terms of annual MWh generation from a proposed development while considering the land area used, cost of installation and ongoing cost of operation and maintenance of specific developments.

6.5.14 **Chapter 4: Alternatives and Design Evolution** of the Environmental Statement **[EN010142/APP/6.1]** describes that the Applicant is bringing forward a scheme which optimises use of the available grid connection capacity through the installation of SAT technology.

6.6 Overplanting

What is overplanting?

6.7 NPS EN-3 describes 'Overplanting' as

"The situation in which the installed generating capacity or nameplate capacity of the facility is larger than the generator's grid connection" (Ref. 2, Para 2.10.55, Footnote 92).

6.7.1 NPS EN-3 also sets out that reasonable overplanting at a scheme should be considered as acceptable in a planning context as long as it can be justified and its impacts have been assessed through the planning process on the basis of the full extent of the scheme including any overplanting (Ref. 2, Para 2.10.55, Footnote 92).

6.7.2 By selecting sites with the right blend of characteristics, developers will bring to commercial operation, solar projects which deliver decarbonisation, security of supply and affordability benefits.

6.7.3 An important consideration for developers is maximising the utilisation of the available grid connection capacity through the life of the project because projects with greater lifetime outputs deliver greater decarbonisation and security of supply benefits and should also be more affordable. Location-specific commercial and environmental constraints also need to be respected in order for projects to be consentable and financially rational.

6.7.4 Solar panels degrade as they get older, meaning that they produce less energy year-on-year. Degradation is caused by physical processes relating to weather effects including the effects of light on the panels over time. Overplanting provides an opportunity to increase the quantity of valuable low-carbon, zero-marginal cost MWh of electricity transmitted from a solar scheme to the grid over its lifetime.

6.7.5 Overplanting is dependent on sufficient suitable land area to be available to the scheme for installing solar panels. Overplanting is commercially rational on all types of schemes subject to the availability and suitability of land near to the point of connection.

6.7.6 Similarly, locations with sufficient local, available and suitable land but a capped grid connection capacity may seek to use that land by overplanting the scheme, thereby exporting more MWh to the grid over the life of the scheme.

6.7.7 However, there may be legitimate reasons why a particular developer, at a particular location, does not pursue an overplanting strategy.

6.7.8 Further, overplanting is also commercially rational for both stand-alone schemes and schemes which include co-located storage facilities, although the optimum extent of overplanting at each type of scheme (i.e. with or without co-located storage) is likely to be different. Indeed (and further subject to the availability of land and co-located storage technology chosen) different schemes may have different optimum overplanting strategies.

6.7.9 It is possible that, at the application stage, applicants may not be sufficiently informed to deliver an *optimum* overplanting strategy. In these circumstances, at the detailed design phase the developer must judge appropriate trade-offs to make to deliver the optimum deliverable scheme at a specific location. Some constraints may require judgement rather than pure quantitative analysis to resolve in an optimal way.

6.8 The benefits of overplanting

6.8.1 Overplanting increases the generation potential of a scheme through a fixed capacity network connection, especially when the effects of panel degradation are considered, but balance is required. Overplanting implies that when irradiation is high and panels have not yet degraded, sites may be forced to self-curtail because, at those times, they will be generating more power than they are able to export. At these times, inverters will limit the amount of energy exported to the grid, and excess energy is lost. This is sometimes called *clipping*.

6.8.2 Para 6.6.40 of this Statement explains that the co-location of storage facilities with solar generation assets provides an opportunity for clipped generation to be stored and released when generation levels are lower.

6.8.3 However, when irradiation is lower, such that panels are not generating to their maximum potential, it is clear that an overplanted scheme will generate more than a scheme which is not overplanted. This is because at those times output will not be limited by the grid connection capacity. This is illustrated in Figure 6-4 below.

6.8.4 The royal blue line in Figure 6-4 shows output (against the dark blue connection capacity line) of a unitary solar scheme on an average irradiation day (left hand graph) and a high irradiation day (right hand graph). Note that the term ‘unitary’ is here intended to describe any scheme where the total capacity of the panels installed equals the export capacity of the scheme. The grey line on each graph shows the output of a solar scheme which is identical to the representative scheme, except that it has been overplanted (i.e. it has more panels, but no more grid capacity, than the unitary scheme).

6.8.5 On an average irradiation day, more energy is exported from the overplanted scheme than the unitary scheme and no energy is clipped. However, on a high-irradiation day, more energy is exported each hour from the overplanted scheme until the grid capacity limit is reached and the overplanted scheme experiences clipping. At this time, the output from the overplanted scheme ‘flatlines’ until lower incident irradiation causes the overall output of the scheme to reduce below the grid export limit again.

6.8.6 As solar panels degrade, clipped energy volumes will reduce. This is because the peak output from a degraded scheme is lower than the peak output from a scheme which has not yet degraded. Therefore, under the same irradiation conditions, the maximum generation from the degraded scheme would be lower than the maximum generation from the scheme before degradation occurred.

6.8.7 In time, the maximum achievable generation from the scheme may fall below the grid export limit. This case is illustrated by the light blue lines in Figure 6-

4 which show overplanted schemes exporting more energy than unitary schemes and not incurring any clipping.

6.8.8 Developments which are overplanted therefore generate more low-carbon electricity than unitary schemes. Overplanted schemes increase the utilisation of the available grid connection capacity throughout a scheme's operational life. This is a key driver of enabling the transmission of as many MWh of energy onto the grid through the (limited) available grid connection resource as is possible, noting that, nationally, grid connection capacity is currently constrained and is projected to remain constrained over the coming decade.

6.8.9 Degradation of solar panels may mean that panels need to be replaced through the operational life of the scheme. Other than in instances of the premature failure of individual panels (which would likely be replaced under a warranted maintenance arrangement) panel replacement is likely to be guided by data gathered through monitoring panel performance throughout the life of the project. This may be carried out on a rolling or programmed basis subject to any parameters which defined the assessment of the scheme's impacts on the environment.

6.8.10 The opportunity to overplant is driven by scheme-specific characteristics, such as available land area, cable access routes, and grid connection capacity. Overplanting (or the level to which overplanting is proposed) also has commercial drivers and these may differ from scheme to scheme and between developers.

6.8.11 It is therefore expected that solar schemes will overplant where possible while balancing commercial, geographical and environmental considerations.

6.8.12 Developments which seek to make best use of available grid connection capacity will present as highly viable schemes and therefore will help to ensure that the need for large-scale solar generation can be fulfilled. This is an important and relevant factor in the decision-making process.

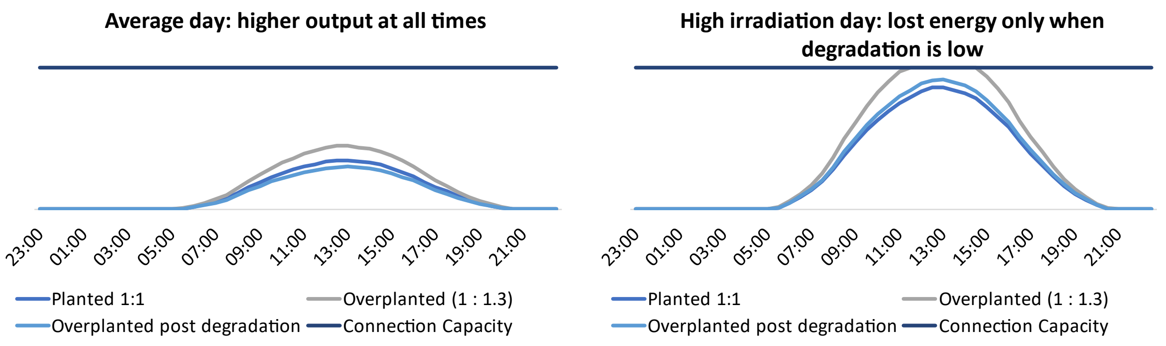

Figure 6-4: Illustrating clipped generation vs. optimised generation on overplanted solar schemes vs. unitary schemes

6.8.13 Given the constrained nature of available connections to the NETS, developers of solar schemes typically look for suitable locations close to existing and available grid connection points.

6.8.14 Further, schemes which maximise the generation and transmission of energy through the available connection will deliver a greater quantum of national climate change and energy security benefit through their operation, than schemes which deliver less energy to the grid.

6.8.15 Developers are therefore likely to aim to make greatest use of the existing and available grid connection at their contracted substation, by which it is meant to design a scheme which will generate the greatest volume of low-carbon energy over the lifetime of the scheme.

6.8.16 Overplanting supports developers in achieving this aim, but there are limits to the benefits of overplanting.

Limits to the net benefits of overplanting

6.8.17 Figure 6-5 and Figure 6-6 below show the results of an analysis of the average annual output of a solar scheme per MW installed (y-axis) as a function of the overplanting ratio (x-axis), for a Fixed South Facing (FSF – orange) scheme and a Single Axis Tracker (SAT – blue) layout.

6.8.18 These figures have been derived from inputs which are appropriate for UK-based solar schemes generally and therefore the conclusions following are also applicable across all schemes, excluding the impacts of location-specific parameters.

6.8.19 As the overplanting ratio of a scheme increases, clipped solar generation at times of high irradiation and early in the scheme's operational life increases. Those losses may be compensated for by greater output in times of lower irradiation and more generally later in operational life, as illustrated previously. The level of overplanting determines the overall balance between clipped generation during times of high irradiation, and incremental generation at times of lower irradiation.

6.8.20 Figure 6-5 below illustrates the average annual output of a scheme in terms of a Grid Utilisation metric (%) over the first 40 years of its operation.

6.8.21 Grid Utilisation is calculated as the total MWh exported through the grid connection during the life of the project, divided by the maximum MWh export possible through the connection during the life of the project, i.e. [grid connection capacity] x [project life].

6.8.22 The points on Figure 6-5 show the lifetime Grid Utilisation for schemes with an overplanting ratio of between 0.8 and 2.2, at regular increments under either an FSF (orange) or a SAT (blue) layout.

6.8.23 The orange and blue lines are straight lines of best fit through each "curve" of points. These are for visual aid only, as they help the reader to identify the gradient of the curve which passes through each point, and where that gradient changes.

6.8.24 As the overplanting ratio increases, so too does Grid Utilisation. However, beyond an overplanting ratio of approximately 1.5 (where the coloured points are furthest above the same colour straight trend lines), the incremental benefit of overplanting on grid utilisation reduces (the points start to return back towards the straight line, and ultimately fall below it).

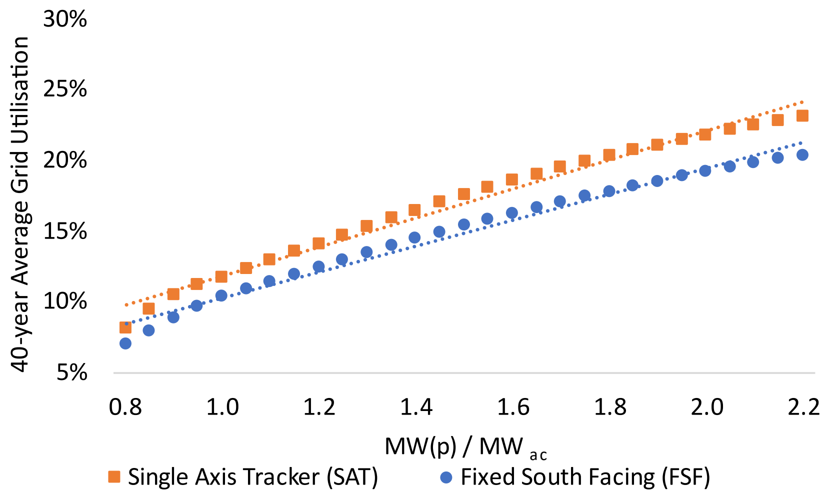

Figure 6-5: Grid Utilisation increases as overplanting increases, but gains are incrementally smaller above a ratio of c.1.5.

6.8.25 Figure 6-6 following shows that the average annual output of a scheme over the first 40 years of its operation on a per MW installed basis decreases only when the overplanting ratio increases above a certain level.

6.8.26 Beyond an overplanting ratio of c.1.3, the curve between the points starts to turn downwards more steeply than it did for a lower overplanting ratio, implying an increasing inefficiency as overplanting ratio increases beyond c.1.3.

6.8.27 This analysis does not seek to establish ‘hard and fast’ rules around overplanting, but together Figure 6-5 and Figure 6-6 do provide quantifiable evidence which suggests that the “optimum” overplanting ratio for a solar scheme, may lie between 1.3 and 1.5, depending on the local characteristics of the site in question, such as topography, archaeology, land and other environmental factors which may reduce the scope for overplanting.

6.8.28 The extent to which a proposed location can be overplanted cannot be determined in isolation, however. There is an intrinsic relationship between orientation, overplanting and land take which must be considered in the design of all developments in relation to optimising the benefits of the scheme while respecting the planning balance.

6.8.29 The output from any illustrative design may be based on different ways in which the site may be laid out within the parameters which define the extent of the scheme, and which make use of an effective overplanting ratio. The final design and layout will reflect the available technology (and overplanting ratio) arranged in accordance with the assessed parameters.

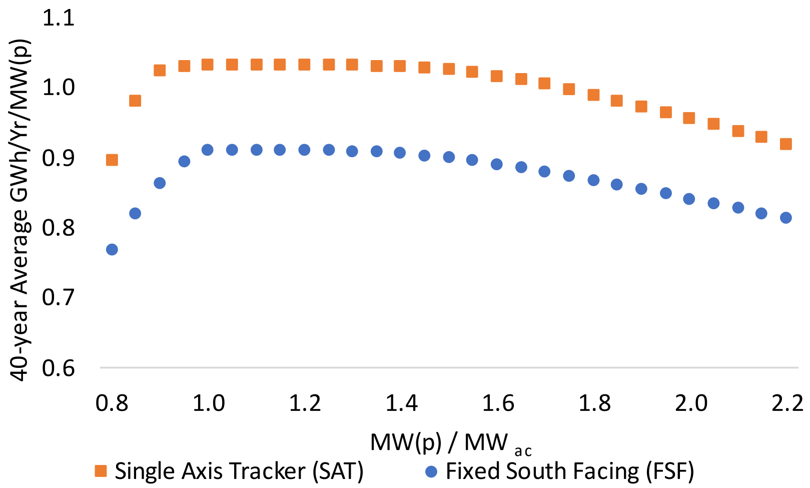

Figure 6-6: GWh/Yr/MW decreases as overplanting increases, and losses are incrementally larger above a ratio of c.1.3.

6.8.30 The co-location of storage facilities with solar generation assets provides an opportunity for clipped generation to be stored and released when generation levels are lower.

6.8.31 Generally, storage facilities may be connected to generators through Alternating Current (AC) or Direct Current (DC) coupling. These different solutions provide different benefits but also can lead to different effects and there is no ‘one size fits all’ approach to optimising co-located facilities.

6.8.32 AC-coupled BESS can be placed in one single location which may be in close proximity to the substation or may have very low LVIA impacts. DC coupled systems are placed in small groups which are dispersed among the solar arrays. Access must be available to all BESS groups and some locations may render this unachievable for operational or commercial reasons. Schemes may therefore be better suited to one technology over the other from an environmental impacts perspective.

6.8.33 Being located close to the grid substation means that line losses associated with power flows between the BESS and the grid are lower for AC-coupled BESS, while line-losses between the panels and the BESS are lower for DC-coupled BESS. These considerations may be significant when assessed over the anticipated operational life of the scheme.

6.8.34 AC-coupled BESS require a greater capacity of inverters to store clipped generation, increasing the cost and embedded carbon associated with the scheme when compared to a DC-coupled system.

6.8.35 AC-coupled systems are more established in the UK market and developer strategies may not include the development of DC-coupled systems at the time an application from DCO is made.

6.8.36 Schemes which provide for the storage of what would otherwise be clipped generation in co-located BESS will not be limited in their overplanting ratios by the analysis presented here. Rather, the power and energy capacity of the co-located BESS facility will be important factors in determining the economically rational limit for overplanting at the Scheme.

6.8.37 Section 6.8 of this Statement provides further detail on the benefits of co-location, including factors which affect a developer's choice of AC or DC coupling. Further information on technical details and considerations for AC and DC-coupled BESS can be found in **Chapter 4: Alternatives and Design Evolution** of the Environmental Statement **[EN010142/APP/6.1]**.

6.9 Land use associated with large-scale solar

6.9.1 As noted above, NPS EN-3 indicates that along with associated infrastructure, a solar farm typically requires between 2 to 4 acres for each MW output (Ref. 2, Para 2.10.17). Different configurations have different performance characteristics in terms of acres/MW(p), but MW(p) is not the only metric for the decarbonisation benefit brought forwards by solar schemes.

6.9.2 Lifetime average annual generation is the key metric which, if maximised for a scheme, provides the maximum decarbonisation and energy security benefit for the scheme. For a given scheme, lifetime average annual generation depends upon the overplanting ratio while taking into account the potential shading effects of panels on each other.

6.9.3 *In extremis*, it is possible for two panels to be located sufficiently far away from each other for neither to ever be in the shade of the other. In contrast, moving one of those panels to be directly in front of the other, would not change the total installed capacity (two panels) but would halve the annual output because the second panel would always be shaded by the first. The *in-extremis* example would however use significantly more land area than the contrasting example.

6.9.4 In reality, optimising lifetime average annual output across a large array of solar panels while respecting a finite land area and a finite grid connection capacity requires iteration and judgement and is a non-trivial task.

6.9.5 It is therefore possible that a scheme which appears to lie out with the NPS EN-3 guidance in terms of the ratio of acres used per MW installed (Ref. 2, Para 2.10.17) may deliver a higher lifetime average annual generation per acre than a scheme which lies within that guidance, and may therefore deliver greater lifetime benefits than a scheme which falls within the range set out in the NPS.

6.9.6 The inclusion of co-located storage as part of a scheme may also change the scheme's land take ratios, particularly as different coupling technologies are laid out in different ways.

6.9.7 Large-scale solar schemes are also efficient in comparison to other technologies in terms of the energy they generate over their lifetime on a per unit area basis.

6.9.8 Solar technology can also generate more energy per hectare than other electricity generation technologies, for example growing crops for energy, and by following good design principles can generate a similar amount of energy per hectare as onshore wind.

6.9.9 For example, a Guardian article (Ref. 72) reported that 450Ha of crop is required to provide fuel for a 1MW biogas plant, implying that a biogas plant may generate 20 MWh per year per hectare of land used.

6.9.10 An academic study published in 2020 (Ref. 73) indicates that the installed capacity density of onshore wind farms in Europe is 19.8 (6.2–46.9) MW/km^2, which is equivalent to 0.2 (0.06-0.47) MW/ha.

6.9.11 Guidance on industry norms for onshore wind farm developments in the UK suggests that turbine towers should be placed between six and ten rotor diameters apart from each other in order to optimise the output of each turbine. This separation is sufficient to ensure that no turbine lies within the 'wind shadow' of any other turbine. It is the Author's experience however that in practice turbine towers on UK wind farms tend to be spaced between three and five rotor diameters apart, consistent with the findings of the academic study (Ref. 73).

6.9.12 NPS EN-3 states that UK solar typically uses between 0.8 (High density) and 1.6Ha (Low density) of land per MW of installed capacity (Ref. 2, Para 3.10.8) which is equivalent to 62.5–125 MW/km^2 and the illustrative design for this Scheme lies within that range.

6.9.13 By assuming an annual load factor of 35% for onshore wind, a conservative 10% for solar and 100% for Biogas (Table 8-1), it is possible to calculate that onshore wind may generate 61 (18–144) GWh/Yr/km^2 while solar may generate 54–108 GWh/Yr/km^2. At the midpoint of EN-3's typical capacity range, large-scale solar may generate 72 GWh/Yr/km^2 which is higher than the average reported in the academic study (Ref. 73).

6.9.14 Biogas will generate just a small percentage of the levels of the two renewable technologies from the same area of land, while for efficient designs, the expected annual generation output per hectare of land for solar and onshore wind will be of a similar magnitude.

6.9.15 This analysis demonstrates that large-scale ground-mount solar schemes, including those that are developed with a configuration which maximises annual output, are likely to produce a greater quantity of low-carbon electricity per acre than the output from an onshore wind or crop-to-biogas application.

6.10 Solar cell efficiency

6.10.1 It is important to differentiate between the efficiency of solar technology (which is a measure of how much of the energy contained in the sunlight incident on the panel is converted into electrical energy) and the load factor, as described previously in Section 6.4. Both influence the output of a scheme.

6.10.2 The load factor of a scheme is influenced by the proposed location, the installed capacity of panels and their orientation and layout. Panel selection, and the physical properties of those panels, combine with the selection of other electrical components which make up a scheme, and the electrical design of that scheme, to influence the efficiency of the facility. In summary, the efficiency of a scheme is intrinsic to its design, whereas the load factor is also dependent on incident sunlight and therefore layout.

6.10.3 Solar panels and electrical infrastructure have become larger and more efficient, as shown in Figure 6-7, meaning that more electricity can now be generated from the same area of land than was previously possible. As a consequence, solar is now, and is expected to remain, a leading low-cost generation technology.

6.10.4 While they do not represent an independently sourced update to Figure 6-7, product specifications can be used to assess the efficiency of currently available solar panels.

6.10.5 Figure 6-7 shows that the efficiency of solar cell technology has increased over the last 40 years and that Crystalline-Si, Multi-Function and Thin-Film technology cell efficiencies have increased broadly linearly.

6.10.6 As of summer 2023, a wide range of solar panels commonly available on the open market were advertised as being between 20.7% and 21.6% efficient and converted incident irradiation at a rate of 210 – 220W/m^2 .

6.10.7 For context only, over the period 2019 to 2022, coal generation in the UK achieved an average efficiency of 31% and the UK's CCGT achieved 48%. Both technologies emit CO_2 as a by-product of electricity generation (Ref. 74).

6.10.8 The existing UK nuclear portfolio achieves an average efficiency of c.36%, Hinkley Point C is expected to achieve 36-37%. Smaller gas-fired reciprocating engines achieve similar levels, but they too emit CO2 when they generate. Wind turbines are 20% - 40% efficient at converting wind into energy.

6.10.9 The efficiency of solar generation is towards the lower end of the scale of efficiencies for technologies commonly used to generate electricity in the UK, but solar cell efficiency continues to improve.

6.10.10 It is important to recognise however that sunlight, the input energy source for solar generation, is abundant, predictable, renewable and free. Wind is similar but can be more difficult to predict. Solar generation produces no marginal carbon emissions and no long-term radioactive waste. Therefore the lower efficiency exhibited by solar technology versus other generation sources should not be considered as a material objection to its future use.

6.10.11 Solar panel output increases as a product of panel size (area) and panel efficiency. Panel size has been and remains the key driver of panel power in newly released products, although efficiency increases have been achieved as a result of ongoing research and development.

6.10.12 Any increase in panel output due to increasing the size of each panel will not materially affect their coverage across a proposed parcel of land because the total area of panels which can be placed in the parcel will be broadly the same.

6.10.13 It is difficult to predict what the future capacity of a PV module will be, but manufacturers are constantly improving the technology. For example, one panel which became available in Q4 2020 was advertised at 21.3% efficiency, while a panel from a different manufacturer, which became available in Q1 2023, was advertised at 23% efficiency.

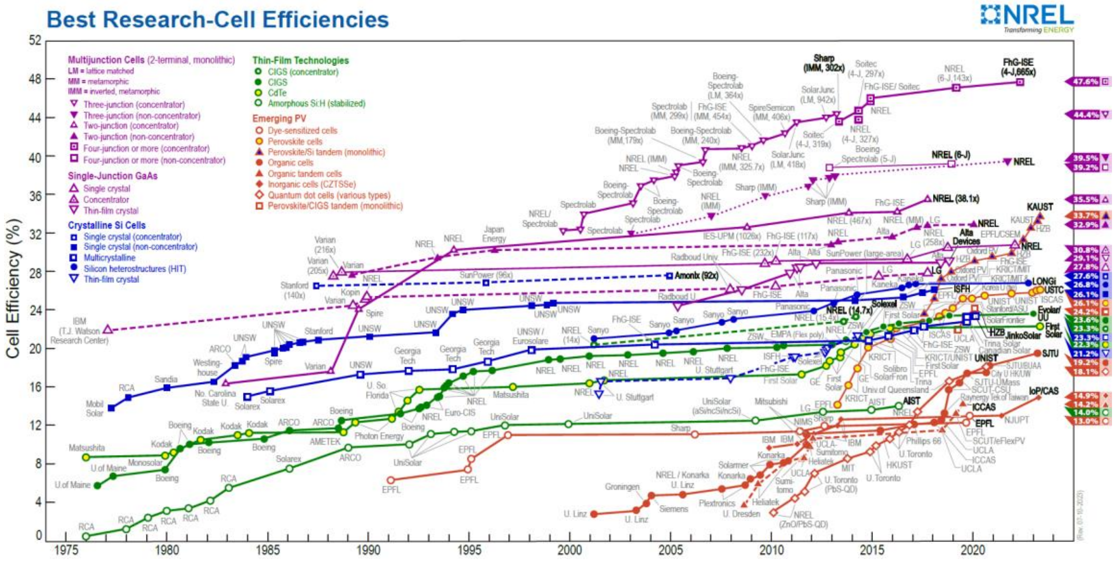

Figure 6-7: Evolution in solar cell efficiency 1975 – 2020 (Ref. 75)

6.10.14 It therefore seems reasonable to anticipate that panel efficiency will continue to increase linearly over the 2020s.

6.10.15 By installing more efficient panels, a facility may install less panels but the total coverage across a site is not expected to change significantly, and it is not a given that the installation of higher efficiency panels will result in reduced land take. Opportunities to enhance the overall efficiency of the scheme may materialise at the detailed design stage, for example by procuring more advanced (efficient) panels and spacing them out more (increasing the pitch) within land parcels to reduce shadowing effects or removing inefficient corners of fields that reduce infrastructure requirements.

6.10.16 Proposed designs can only incorporate products which are already available in the market. Similarly, detailed designs, which will be carried out post consent for a scheme, will only incorporate those panels which are available at the time.

6.10.17 At the detailed design stage, opportunities will be investigated to increase the lifetime generation output of the scheme and the benefits arising from its development, within the envelope of development secured at consent.

6.11 Co-location

6.11.1 NPS EN-3, states that:

“Government is supportive of solar that is co-located with other functions (for example, agriculture, onshore wind generation, or storage) to maximise the efficiency of land use”. (Ref. 2, Para 2.10.10)

6.11.2 Section 5.9 describes the role of BESS within a net zero energy system. BESS provide services which support the operation of renewable energy generation schemes and the efficient and secure operation of the UK's electricity system provided that they are able to both import energy from and export energy to the electricity system.

6.11.3 BESS may be proposed as part of solar projects as a resource to hold energy generated by the solar farm during times of low demand and release it to the national grid through the scheme's grid connection at times of high demand. If a scheme is to connect to the electricity system at a location where the scheme is also able to import electricity from the grid, a co-located BESS could allow energy to be imported from the grid at times of low demand and exported back to the grid at times of high demand.

6.11.4 At some locations, the former can be achieved without upgrades being required to existing grid connection substations, but at other locations, significant upgrades to transmission system infrastructure may be required to allow BESS to contribute fully to the electricity system.

6.11.5 Such upgrades may be time consuming and/or expensive. Waiting for grid upgrades to deliver before developing a project may therefore delay the project's commissioning date, thus delaying the delivery of much needed renewable energy as a critical and urgent contribution to meeting net zero. Delays and increased costs may also increase the commercial risk associated with the project above the level at which investment may be secured, risking the deliverability of the project as a whole.

6.11.6 Developers may propose to install storage at sites which do not have an import connection, however current commercial, technical and system operation considerations would suggest that storage is more beneficial to the electricity system, and more likely therefore to be developed, if it is able to import and export to the NETS.

6.11.7 The following Figures illustrate how co-located solar and BESS may work together under a number of different well-defined and distinct market scenarios. The reality of electricity market operation is that BESS and solar operations are unlikely to be so clearly defined and actual operations may vary significantly on a day to day basis.

6.11.8 For simplicity, Figures 6-8 to 6-11 illustrate a 500MW solar array co-located with a 500MW, 1 hour (therefore 500MWh energy storage capacity) BESS, but the illustrations are applicable to larger arrays and co-located schemes with a different capacity of energy storage.

6.11.9 In each of Figures 6-8 to 6-11, the yellow bell-shape areas in sub-figures (a) and (b) represent solar generation which is transmitted to the grid through the day. The green areas represent energy imports to the BESS, and the red areas represent energy exports from the BESS through the day. In sub-figures (c) the blue area represents the energy stored in the BESS through the day.

6.11.10 The import of energy from the co-located solar facility is illustrated by a green area overlapping a yellow area. The import of energy from the electricity network is illustrated by a green area which does not overlap a yellow area.

6.11.11 For example, in Figures 6-8 to 6-11 following, the BESS is shown moving from 0% to 100% State of Charge and back again on each operation. In reality this may not be the case, and the BESS may instead undertake many more partial, rather than full, import/export operations.

6.11.12 Local solar generation is usually highest in the middle of the day, and national demand is usually highest in the evening (around approximately 17:00 in winters, 19:00 in summers).

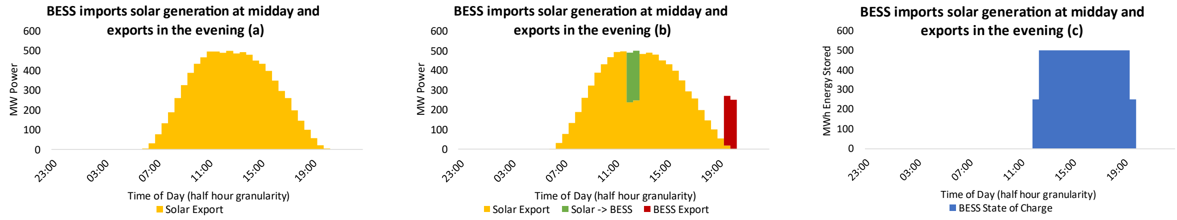

Figure 6-8: BESS imports solar generation at midday and exports in the evening

6.11.13 Figure 6-8(a) represents solar generation at the facility over the course of one sunny day. If the asset operator's forward view was that energy may be in surplus in the middle of the day but would be needed in the evening, the operator could schedule the BESS to import from the solar generation during the middle of the day (Figure 6-8(b), green area) and to export that energy later when it was needed more (Figure 6-8(b), red area). Figure 6-8(c) shows the State of Charge of the BESS on that day.

6.11.14 The BESS may be configured to import and export at a lower rate than its maximum power output, this will allow it to import over a longer period and export as shown in Figure 6-9. Critically, the amount of energy the BESS can store is the same as in Figure 6-8. Operators would determine their rate of import and export according to market needs.

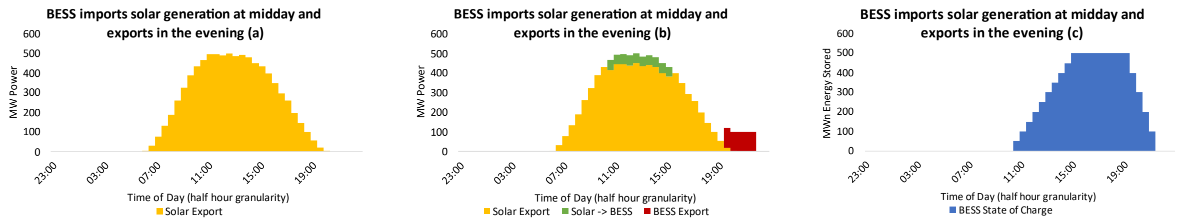

Figure 6-9: BESS imports solar generation at midday and exports in the evening – lower import / export rates

6.11.15 National UK electricity demand varies through the day, and can also be different from day to day for example weekdays versus weekends, or summer versus winter days. Additionally, solar is not the only variable renewable generation on the UK electricity system. This means that at times when the BESS is not supporting the operation of the principal solar site, it may be useful for the BESS to support the national supply and demand balance by importing directly from the grid rather than from the co-located solar, as was shown in Figures 6-8 and 6-9 previously. A good example of when the BESS might import from the grid in response to national supply / demand balance, might be when wind generation is high.

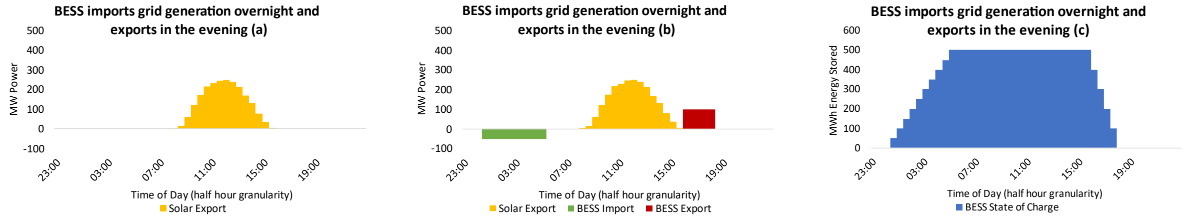

Figure 6-10: BESS imports grid generation overnight and exports in the evening

6.11.16 Figure 6-10 above shows how the BESS may import overnight, store its charge through the day, and export in the evening peak. Figure 6-10 uses a solar output profile which may be more typical of a winter's day, but the type of operation shown is not foreseen to be restricted only to the winter.

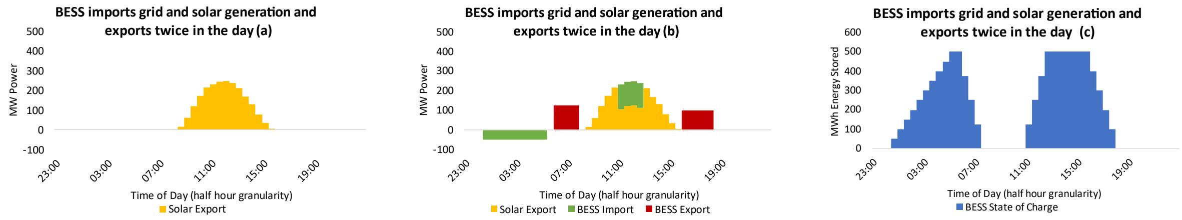

Figure 6-11: BESS imports grid generation and solar generation and exports twice in the day

6.11.17 On some days, operators may foresee the market need for the BESS to operate more than one import/export cycle over a 24-hour period, and Figure 6-11 shows how this might work. In practice, the BESS operational parameters will limit how the BESS is able to respond to market need.

6.11.18 Ancillary (Balancing) Services are contracted at relatively short notice (e.g. contracted 'today' for delivery 'tomorrow') and service time windows tend to be contracted in multiples of 4 hours, commencing 23:00, 03:00, 07:00, 11:00, 15:00 and 19:00 daily.

6.11.19 BESS are also able to store clipped generation and export it to the grid when solar irradiation falls such that generation from the scheme is lower than the grid export capacity. Figure 6-12 shows how this might work in practice.

6.11.20 Figure 6-12 assumes an overplanted scheme (e.g. 600MW) connected to a capped (e.g. 500MW) grid connection. Figure 6-12(a) shows generation on a sunny day might exceed the grid connection cap for multiple hours. A co-located BESS may be able to store this energy, shown by the green area in

Figure 6-12(b), so that it can be exported when grid capacity is available as indicated by the red area in Figure 6-12(b).

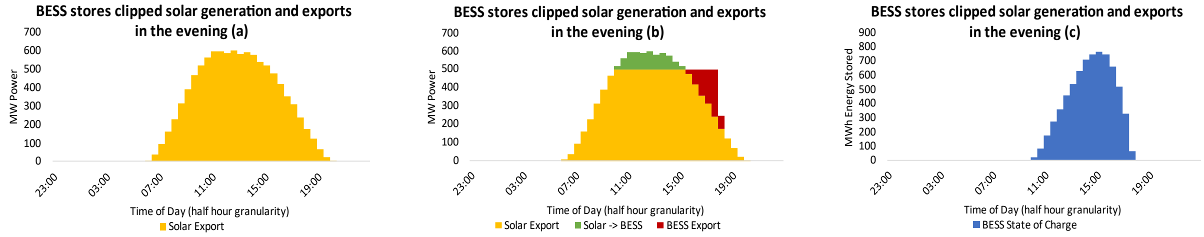

Figure 6-12: BESS stores clipped solar generation and exports in the evening

6.11.21 Abundant generation can be stored in either AC- or DC- coupled energy storage facilities. However, storage facilities which are DC-coupled to solar facilities use less equipment and provide a more efficient solution for storing abundant co-located generation without losing functionality to store energy imported from the grid, as is illustrated in Figure 6-11. However there may be very good reasons why, despite the benefits associated with DC-coupled batteries, some schemes may propose AC-coupled batteries, or as stand-alone solar schemes.

6.11.22 Ancillary (Balancing) Services help to keep the UK electricity system operating safely and securely. Many Ancillary (Balancing) Service contracts require BESS to provide both upward (export) and downward (import) regulation to the national grid, and that to do this BESS would be likely to seek to commence their period of contracted operation with a State of Charge at or close to 50%. This may mean therefore that immediately prior to a contracted period for Ancillary (Balancing) Service provision, a BESS may elect to import or export to achieve a State of Charge of 50% at the start of its contracted window.

6.11.23 The UK's electricity system operates at a nominal frequency of 50Hz and National Grid procure services over very short timescales (sub-second response services) out to minutes or hours for reserve services to keep frequency always at or close to 50Hz.

6.11.24 BESS operation under reserve service contracts will be similar to the BESS operation shown in Figures 6-8 to 6-11 above, i.e. consistent importing or exporting over periods of minutes or hours at pre-agreed levels. BESS operation under response service contracts will however be different.

6.11.25 Response contracts require the immediate import or export of energy to the grid based on whether the instantaneous frequency of the national grid is higher or lower than the statutory 50Hz. Importing energy into the BESS has the effect of reducing grid frequency (so import actions are instructed when frequency is high). Exporting energy from the BESS has the effect of increasing grid frequency (so export actions are instructed when frequency is low).

6.11.26 Under normal operating conditions, the frequency of the national grid varies by small amounts from the statutory 50Hz level. Short duration injections (or exports) of energy to the grid nudge frequency back to the statutory level. Figure 6-12 following shows how grid frequency changed second-by-second over a 30 minute period of operation in July 2023, and how a BESS operating under a Frequency Response contract may respond to those normal changes in grid frequency.

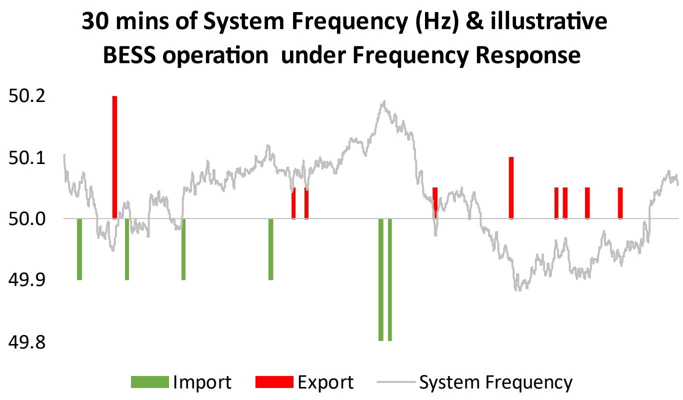

Figure 6-13: Illustrative BESS operation under Frequency Response type operation

6.11.27 Figure 6-12 seeks to illustrate that if frequency is moving away from the nominal 50Hz line, BESS will respond to bring frequency back towards 50Hz. The height of the green (import) and red (export) columns is intended to signify the magnitude of the BESS response, which would be driven by a combination of the rate of change of frequency (quicker changes require a larger response) and the magnitude of the variation of grid frequency from its nominal 50Hz at the time of the instruction.

6.11.28 In reality BESS imports/exports may be much more frequent than those illustrated in Figure 6-12. In normal operational conditions, under Frequency Response, a BESS could be expected to import roughly the same amount of energy as it exports, leaving its State of Charge broadly unchanged over the contracted period. However it is important that the contracted State of Charge is known before the contracted period starts such that in fault conditions, the BESS can be relied upon to deliver the extent of the services it has contracted with NGESO.

6.11.29 Co-located BESS with both an import and export capability will allow the BESS to charge from the co-located solar and from the grid whenever UK system supply was greater than UK system demand. This type of operation provides much needed flexibility to the UK power system and therefore will provide benefits to the UK system and decarbonisation generally.

6.11.30 Being able to regulate power flows both to and from the grid would allow the BESS to provide many kinds of system-wide ancillary services which will support a further reduction in the UK's reliance on fossil fuels, see Table 5-1 for more information.

6.12 Conclusions

6.12.1 Large-scale solar is a highly beneficial technology within the UK's electricity system.

6.12.2 Solar developments require locations to possess three fundamental attributes of sufficient available land, a point of connection to the electricity system and sufficient solar irradiation levels.

6.12.3 Large-scale schemes which connect to the NETS allow for a *"more efficient bulk transfer of power"* for national consumption (Ref. 1, Para 3.3.12) than smaller schemes which connect to distribution systems.

6.12.4 Connections to both transmission and distribution systems in the UK are in short supply. The use of existing and available connections is therefore necessary to support the delivery of low-carbon generation in the next decade to meet the government's aims for a zero-carbon electricity system by 2035.

6.12.5 The development of new points of connection are also foreseen as necessary but are likely to have longer development timeframes than connection points which already exist, therefore the prioritisation of existing and available connections goes towards meeting the urgent need to decarbonise the electricity system.

6.12.6 Solar schemes represent an efficient use of land for energy generation purposes.

6.12.7 The efficiency of solar generation is towards the lower end of the scale of efficiencies for technologies commonly used to generate electricity in the UK, but solar cell efficiency continues to improve. Sunlight, the input energy source is abundant, predictable, renewable and free. Solar's lower efficiency than other generation sources should not therefore be considered as detrimental to its future use.

6.12.8 Overplanting and panel layout optimisation can both increase the likely annual generation of schemes through their grid connection points. This goes towards best meeting the urgent need for solar generation within the context of a constrained grid connection queue.

6.12.9 The connection of thousands of small-scale (including rooftop) systems to the aggregate capacity anticipated as required by National Grid's FES pathways is unlikely to meet the urgent need for solar. The installation cost of small-scale schemes, which would be met by individual households, is much higher than the cost of large-scale schemes on a per unit basis.

6.12.10 The inclusion of a BESS as Associated Development to the main solar scheme will support the operation of the main solar scheme and will be able to store clipped generation and export it to the NETS when it is needed.

7. Suitability of the proposed location for large-scale solar

7.1 Chapter summary

7.1.1 This chapter provides an overview of the evidence provided to support the suitability of the proposed location of the Scheme for large-scale solar plus storage.

7.2 Local Demand / decarbonisation requirements

7.2.1 The Applicant has accepted a Connection Offer from National Grid to connect the Scheme to the NETS at National Grid's 400kV Cottam Substation. Cottam Substation lies on a well-connected and resilient part of the NETS and is located near to the Scheme. Although the Scheme proposes to connect to the NETS, the Scheme is also located in the area covered by the East Midlands distribution network.

7.2.2 Grid substations and Grid Supply Points (GSPs) are where the generators connect to the NETS and/or the NETS connects to local distribution systems. At these points, voltage is reduced from the NETS high-voltage cables to lower voltages for more local transmission via Bulk and Primary substations, then on to consumers.

7.2.3 Other grid substations close to Cottam are located at West Burton then Keadby to the north and High Marnham and then Staythorpe to the south, as well as other grid substations and Grid Supply Points and Bulk substations closer to urban areas within the East Midlands distribution area. These substations ensure that although the energy generated at the Scheme may be transmitted to consumers nationally without constraint, there is a network pathway from the Scheme to the local Bulk substations which service local consumers.

7.2.4 This does not mean that the energy generated at the Scheme will necessarily or solely service either local or national consumption, but it does mean that the connection at Cottam is well suited for energy to flow unconstrained from the Scheme to either local or national consumers, whenever it is needed.

7.2.5 Figure 7-1 shows that the East Midlands has a significant annual energy demand (Ref. 9). In 2021, 19.7TWh of electricity, or around 7.5% of national consumption. Transport needs in the region consumed 37TWh of energy, and a further 56TWh of energy consumption (non-electricity demand) was sourced from other fuels such as coal, gas, oils and biomass.

7.2.6 Total energy demand in the East Midlands reduced by 12% over the period 2005 to 2021 and electricity demand decreased by 18% over the same period.

7.2.7 Non-electricity demand has also decreased, but by 17%. 2022 data is not yet available.

7.2.8 Regional energy demand reduced in aggregate from 2005 to 2021 across both the domestic and non-domestic sectors, however domestic non-electricity demand in 2021 was higher than it has been since 2011 with the exception of during 2020 (domestic demand grew during Covid lockdowns because consumers were at home more). Non-domestic non-electricity demand has not significantly reduced since 2009.

7.2.9 Transport demand decreased by 11% over the period 2005-2021.

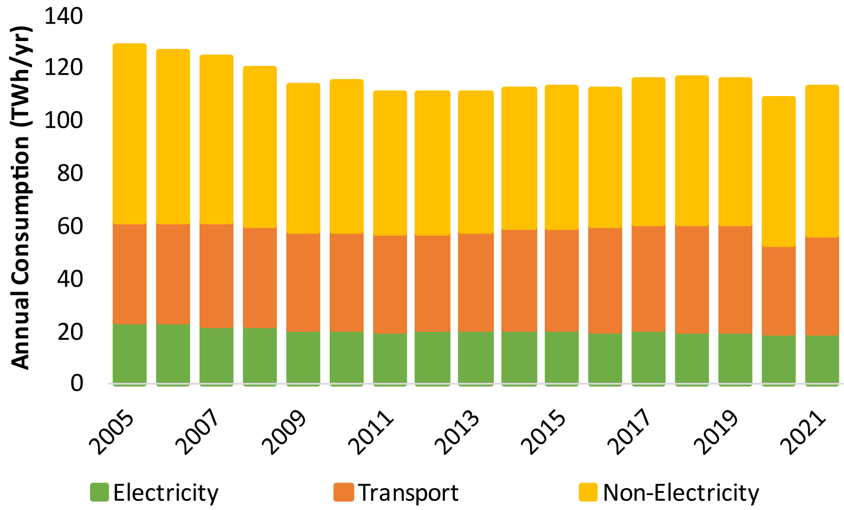

Figure 7-1: Energy consumption in East Midlands (TWh/Yr) (Ref. 9)

7.2.10 The data shows that non-electricity demand in the East Midlands is approximately three times that of electricity demand. A significant increase in electricity demand will be required in the future to meet net zero locally. These trends are broadly consistent with the national trend as described in Chapter 4 of this report.

7.3 Local Supply

7.3.1 As part of its 2022 FES, National Grid published a map of regional generation carbon intensity on two types of day (a higher wind day and a lower wind day) (Ref. 20(2022), p32). The map is reproduced in Figure 7-2.

7.3.2 In 2022, the average national carbon intensity of generation was 183 g/kWh, i.e. at the 'low' end of the 'moderate' range. Emissions in 2023 were expected to out turn in the range 148 – 170 g/kWh (Ref. 20(2023), Table ES1).

7.3.3 The map on the left of Figure 7-2 shows the carbon intensity of generation by region during a higher wind day, and the map on the right shows the same but for a lower wind day. The values indicate the installed wind capacity in each region at the time of publishing the map (therefore current capacities may be higher).

7.3.4 As expected, during windy days, the carbon intensity of generation is on average lower than the annual average figure. On days with lower wind, electricity supply in Scotland and the north of England looks to remain below the annual average, but from Yorkshire and North Wales and further south, the carbon intensity of generation is at best moderate, and may approach double the annual average figure.

7.3.5 Measures must be implemented to reduce the carbon intensity of generation outside of the Scotland and the north of England during low-wind days. Solar generation is well suited to support a such a reduction.

7.3.6 Further, Figure 7-2 suggests that there is carbon emitting plant located in the south of the country which currently generates when wind output is low. This can be inferred because at times of low wind, the carbon intensity of generation in the south of the country is high. During periods of low wind, National Grid's analysis shows that the East Midlands area has the highest carbon intensity of generation of any of the other distribution areas in the country. The Scheme will, if consented, reduce the carbon intensity of generation in the East Midlands area in both low and 'normal' wind conditions. The inclusion of BESS as part of the Scheme means that the Scheme will be able to store low-carbon energy when generation is in abundance and release it when demand for energy is higher.

7.3.7 As Section 5.2 describes, solar generation (and other renewable generation) displaces carbon emitting generation from the grid and therefore has a decarbonising effect on the electricity system. The placement of any solar farms in these areas means that when the sun is shining their generation will be flowing through parts of the transmission system where otherwise there would be energy generated by carbon emitting plant. It is unlikely therefore that the installation of solar facilities in the areas shown would cause any significant network constraints as a result of their operation. Further information on the benefits of a multi-technology energy system can be found in Chapter 8.

7.3.8 Figure 6-2 shows that the Scheme is located in an area with solar irradiation levels above average for the UK, and initial studies suggest that an average annual load factor before degradation at the site could be up to 10% higher than the current national average. The region is well positioned to use its natural resources and existing infrastructure to support the UK's energy needs through the development of the proposed large-scale solar scheme to generate clean electricity to power homes, locally and nationally, cars, offices, shops and factories.

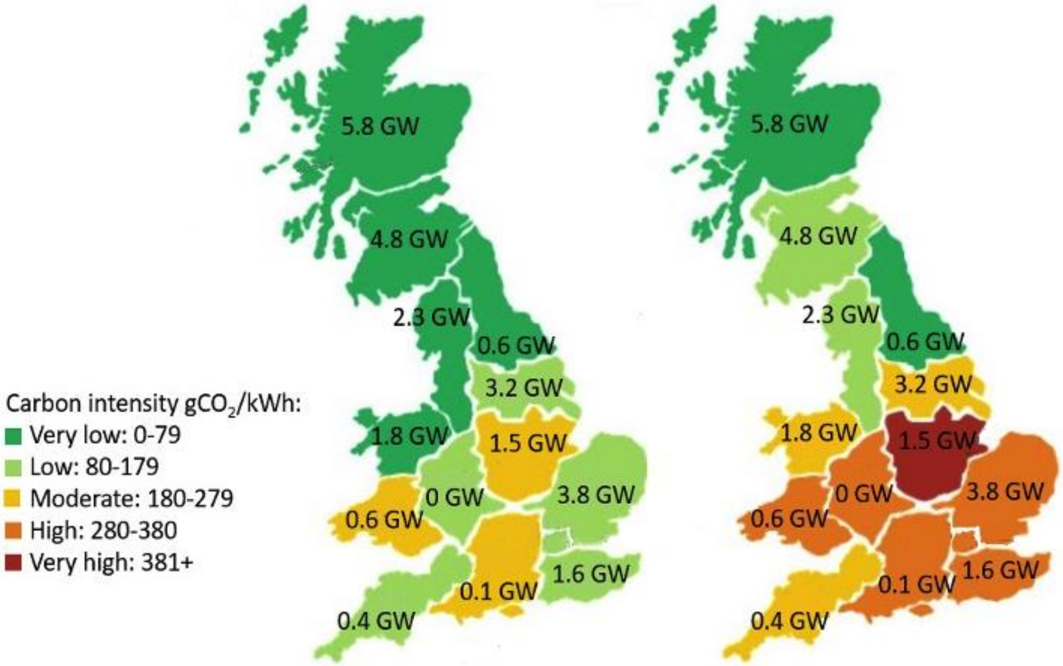

Figure 7-2: NGESO Regional generation carbon intensity analysis (Left: on a higher wind day, Right: on a lower wind day) (Ref. 20)

7.4 Grid suitability

7.4.1 Annually, NGESO perform an analysis of the NETS from a security and quality of supply (SQSS) and power flow capability perspective. Their analysis can be found in the Electricity Ten Year Statement (ETYS) (Ref. 76), and options to improve power flow capability can be found in NGESO's Network Options Assessment (NOA) publications (Ref. 77).

7.4.2 National Grid ESO subdivides its network into operational areas by means of system boundaries. These boundaries are not hard, nor physical, but differentiate areas within which NGESO characterise power flows.

7.4.3 The ETYS looks at whether the current network allows GB national demand to be met through two lenses.

7.4.4 The first is the Security Criteria. This validates that the capability of each boundary is sufficient to allow the expected maximum flow across that boundary required to ensure security of supplies across the network. In other words, the maximum boundary transfer capability must be greater than that required to maintain, under reasonable 'worst case' conditions, security of supply at all locations on one side of the boundary with supplies from the other side.

"The boundary transfer requirements needed to satisfy demand without relying on intermittent generators or imports from interconnectors." (Ref. 76)

7.4.5 The second is the Economy Criteria. This validates that the capability of each boundary is sufficient to allow the expected flow of power across the network such that a national merit order of operation is maintained. In other words, this criteria balances the need for cheap power to flow unconstrained across the network (therefore lowering prices and costs for consumers) against the enabling cost of upgrading the network:

"The boundary transfer requirements when demand is met with high output from intermittent and low carbon generators and imports from interconnectors. This ensures capacity is adequate to transmit power from highly variable generation without any network constraint." (Ref. 76)

7.4.6 The NOA then identifies, assesses, and recommends (where appropriate) specific upgrade projects which meet the future needs as anticipated in the ETYS.

7.4.7 Cottam Substation is located on one of the three major 400kV transmission lines which provide connections between Keadby in the north to demand centres in the south and London. Cottam 400kV substation is also connected directly to the Grid Supply Points (GSP) at West Burton, Staythorpe and Stoke Bardolph. The West Burton, Staythorpe and Stoke Bardolph substations supply primary substations in important centres of demand in Newark and Nottingham as well as provide power further throughout Nottinghamshire and Lincolnshire.

7.4.8 Keadby links to two double circuits heading south which then split into four major double-circuit transmission 'arteries' connecting to the demand centres in the south. All transmission lines connecting Cottam substation to other substations are double lines, providing defence in depth (in the event that one faults power can still flow on the other line) and high-power flow capability (Ref. 76, Appendix A).

7.4.9 The strength and capacity of connections within the East Midland area, including the transmission lines to which the Scheme will connect, contribute to the transfer capacities available across the system boundaries.

7.4.10 Cottam 400kV substation is situated in NGESO's North Midlands and North Wales area; an area which is connected to the surrounding NETS as illustrated in Figure 7-4. It is located just below National Grid's B8 boundary.

7.4.11 The system boundaries which are important to The Scheme are:

a. B8 (North of England to Midlands) which is one of the wider boundaries that intersects the centre of GB, separating the northern generation zones including Scotland, Northern England and North Wales from the Midlands and southern demand centres
b. B9 (Midlands to South of England) which separates the northern generation zones and the southern demand centres
c. NW3 (The North Wales boundary) lies to the west of the North Midlands and North Wales area and is also relevant because future offshore wind and biomass generation connecting in North Wales have the potential to drive increased power flows eastward into the Midlands where power plant closures are set to occur, and demand is set to remain fairly high

7.4.12 Critically, the Scheme lies to the south of boundary B8 and to the north of boundary B9.

7.4.13 Figure 7-3 shows the current and projected level of boundary transfer capacity (thick solid red line) across the B8 (left) and B9 (right) boundaries. The fine solid red line shows the Economy Criteria and the dashed red line shows the Security Criteria for each year to 2042.

7.4.14 Boundary B9 currently has a larger transfer capability than Boundary B8 (by 1.8GW) and both are expected to increase over the coming twenty years. Boundary B8 is expected to increase to 21.5GW by 2033 to accommodate power flows into the area from the north. Boundary B9 is expected to increase to 16.4GW as flows further to the south are anticipated to continue over the study period. Decarbonisation of industry and demand generally located between the boundaries will increase electricity demand in the area, and the development of generation assets further south will also work to meet southern demand. The boundary capacities are both expected to be above the range bounded by the Security Criteria through the study period and boundary capacities are projected to need to increase only from the late 2020s in response to the economy criteria level increasing as more renewable generation connects to the system. Therefore, connecting a large-scale renewable generator between the B8 and B9 boundaries is not likely to cause any incremental constraints under either the economy or security criteria.

7.4.15 The flow of energy from the Scheme will therefore be capable of displacing more expensive and more carbon intensive power generated south of the B8 and B9 boundaries. The displacement of carbon intensive power generation will be to the benefit of electricity system decarbonisation and consumer cost nationally.

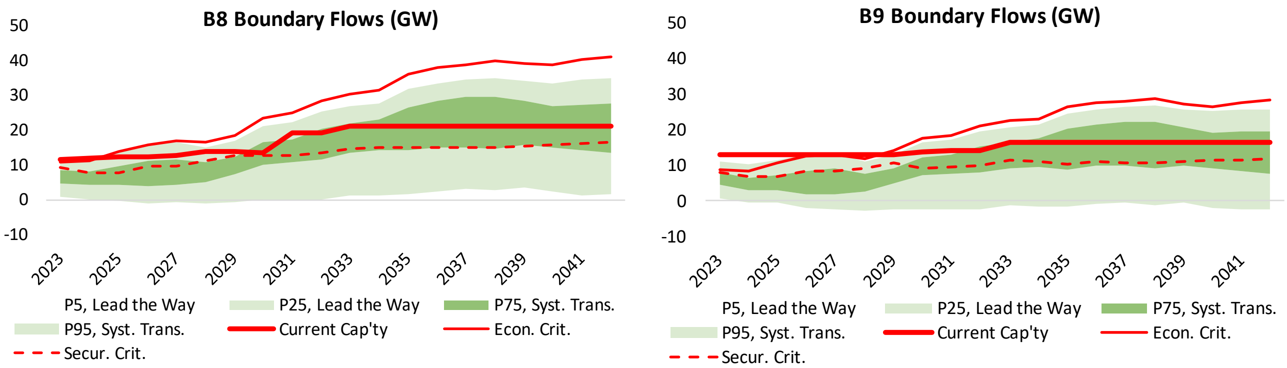

Figure 7-3: B8 and B9 Boundary flows under most extreme scenarios (Ref. 76)

7.4.16 Cross-boundary flows will be highest during periods of high wind. Periods of high wind do not usually coincide with periods of high solar irradiation, highlighting a beneficial natural ‘fit’ between the Scheme (and other large solar facilities in the East Midlands area) with flows of wind-generated electricity from northern wind farms through this area.

7.4.17 The inclusion of BESS as part of the Scheme provides opportunities for NGESO to manage any potential power flow constraints on the NETS in the vicinity of the Scheme over its operational life. This may for example include any constraints which occur as a result of high wind or other causes, and minimising these in a cost effective way would be to the commercial benefit of consumers.

7.5 Connection points / history

7.5.1 Figure 7-4 shows a map of the NETS, with a 50km radius drawn, centred at Cottam 400kV substation. Table 7-1 following provides, by type of connection point for those connection points within 50km of National Grid's Cottam Substation but not including Cottam substation itself, the current proposed connection capacity for all low-carbon generation projects excluding the Scheme, which are currently listed on the TEC register, by connection date range.

7.5.2 Co-located solar and storage schemes are the only type of low-carbon generation schemes which currently hold connection offers with National Grid to connect in this area. The capacity listed in Table 7-1 refers to the connection capacity of those schemes, rather than the installed generation capacity of the solar or storage elements of those schemes. One stand-alone storage project proposing to connect in the area in 2032 has not been included in the analysis.

7.5.3 The data shows, firstly, the importance of the area within 50km of Cottam substation, to the UK's solar pipeline.

7.5.4 Secondly, existing substations at ex-coal sites are critical because they are the only available points of connection currently available for the connection of new generation schemes in this area. This data sample is not unique however and similar conclusions can be drawn from analysis carried out in many other parts of Great Britain.

7.5.5 Specifically, the data shows that all generation capacity which plans to connect to the NETS within 50km of Cottam, has connection offers at former coal station connections. All schemes which are listed on the TEC register in this area propose to include solar and storage facilities as part of their schemes.

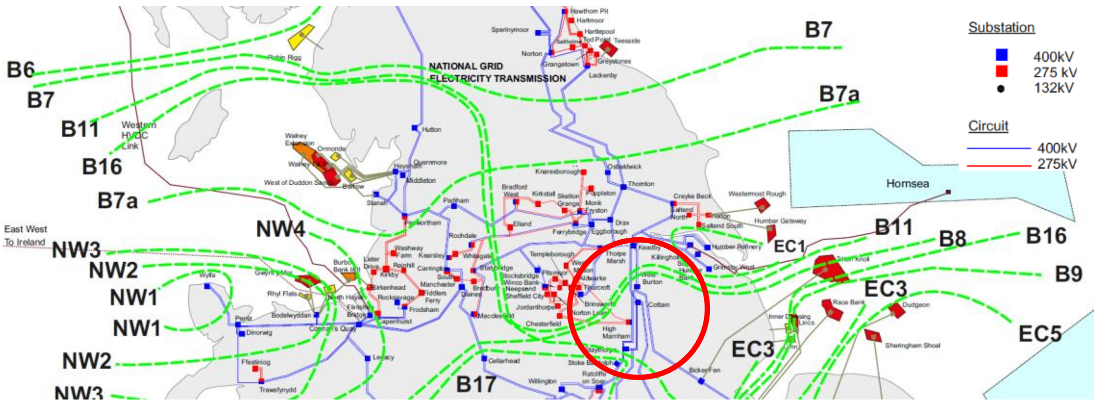

Figure 7-4: Transmission system and potential connection points within 50km of Cottam (Ref. 76)

7.5.6 Clearly if all existing and available grid connection points including former coal sites are not used to connect low-carbon generation at the earliest available opportunity, the deployment of low-carbon generation will be significantly slower and potentially achieve a lower overall level of installed capacity, than in the case that former coal sites are used.

Table 7-1: Transmission system connection points and potential connection dates (Ref. 38)

Substation Type	By end 2028	2029/2030	After 2030	Total
Former Coal (GW)	1.9	1.6	1.1	4.6
Other (GW)	0.0	0.0	0.0	0.0
Total (GW)	**1.9**	**1.6**	**1.1**	**4.6**

7.6 Conclusion

7.6.1 The East Midlands has a history of using its available natural resources to power the UK, firstly through coal and then through natural gas, piped from the UK Continental Shelf for local industrial and power generation use. The analysis shown, when considered in combination with Figure 6-2 and Figure 7-4 shows that the region is well positioned to use its natural resources and existing infrastructure to support the UK's energy needs for a third time, through the development of the proposed large-scale solar and storage scheme to generate, store and release clean electricity to power homes, locally and nationally, as well as cars, offices, shops and factories.

7.6.2 This Statement of Need demonstrates that the proposed connection point is suitable and no adverse operability effects are anticipated as a result of connecting at this location.

7.6.3 The Scheme has a Grid Connection Agreement with National Grid. As part of National Grid's connection reforms, "Energy generators that are not progressing [with project development] and will not meet their connection date will either be able to choose to move backwards or leave the [connection] queue, in order to make way for projects that want to connect and are delivering on their milestones" (Ref. 71).

7.6.4 Subject to obtaining the necessary consents, the Applicant aims to construct the Scheme ready for connection to the NETS in line with the timeframes set out in the Scheme's Grid Connection Agreement.

7.6.5 Therefore, if consented, the Scheme would be able to contribute to the UK's decarbonisation and security of supply efforts prior to 2030.

7.6.6 If the DCO is not granted, then a critical opportunity will be missed to deliver a significant capacity of low-carbon solar generation capacity onto the NETS in the important 2020s. This would increase the risk of non-delivery of the government's legal obligations because:

a. The benefits which would have been brought forward by the project would need to be delivered by as yet undefined, unconsented projects;

b. The criticality and scale of projects required to deliver in later timeframes to make up for those benefits would both increase; and

c. The pace and cost of delivery of such projects would also likely be higher than in the case that the Scheme was consented.

7.6.7 Specifically in relation to the existing and available grid connection at National Grid's Cottam substation, unless a different low-carbon generation scheme came forward and was consented to connect at Cottam, connection capacity would need to be created elsewhere which would likely take more time (increasing carbon emissions in the ensuing period) and increase consumer costs (when compared to utilising an existing and available point of connection).

7.6.8 NPS EN-1 is clear on the point of need:

The Secretary of State should assess all applications for development consent for the types of infrastructure covered by this NPS on the basis that the government has demonstrated that there is a need for those types of infrastructure which is urgent (Ref. 1, Para 3.2.6).

7.6.9 NPS EN-1 further states that "the Secretary of State has determined that substantial weight should be given to this need when considering applications for development consent under the Planning Act 2008" (Ref. 1, Para 3.2.7) and that the "Secretary of State is not required to consider the specific contribution of any individual project to satisfying the need established within the NPS" (Ref. 1, Para 3.2.8).

7.6.10 The need for the Scheme is urgent and substantial weight should be given to that need. The proposed location for is a highly suitable location for large-scale solar because of the attractive combination of grid connection, solar irradiation and suitable land at the site. Further, the development of a large-scale solar development at Cottam will help decarbonise locally generated electricity to the benefit of consumers both locally and nationally.

7.6.11 The Applicant's grid connection at Cottam is suitable and available for the Scheme to commission in the 2020s thereby permitting the Scheme to contribute to the UK's 2030 decarbonisation targets. Connection to the transmission system is of significant importance, enabling an unencumbered and efficient transfer of bulk power across the country, in order to provide electricity wherever it is needed.

7.6.12 The land included in the Scheme's proposals will support an optimisation of the available grid connection at Cottam. The Scheme has been sized to optimise use of the grid connection from a preferred SAT technology with DC-coupled BESS, while being sympathetic to planning issues and respecting identified constraints.

7.6.13 SAT is currently preferred at the Scheme because of its enhanced MWh to MW ratio vs. FSF technology. The illustrative layouts would deliver a commercially rational overplanting ratio on both schemes, and the inclusion of DC-coupled BESS as Associated Development to the Scheme will capture generation which may be clipped if BESS were not to be included as part of the Scheme.

7.6.14 Any optimisation of layout at a detailed design stage would be unlikely to identify any useful areas of land as these are likely to be around the edges of field margins and disconnected from other useful areas and therefore would have no agricultural value.

7.6.15 Lastly, the electricity network local to the Scheme has sufficient capacity to accommodate the anticipated generation from the Scheme without constraint. By connecting below the B8 boundary, the anticipated generation is not expected to exacerbate existing network constraints often associated with periods of high generation in northern wind farms.

8. The contribution of large scale solar to system security

8.1 Chapter summary

8.1.1 This chapter provides an overview of the system security benefits of large-scale solar in the UK.

8.1.2 Decarbonisation is just one of the three pillars of GB energy policy. Low carbon generation of all forms, solar, wind and nuclear included, brings with it new challenges. Current and future energy policy and related actions must ensure that security of supply is maintained, and that electricity is affordable for all. This chapter demonstrates how solar has contributed, and will continue to contribute, to security of supply in Great Britain. As set out in NPS EN-1:

"[The government] need[s] to ensure that there is sufficient electricity to always meet demand; with a margin to accommodate unexpectedly high demand and to mitigate risks such as unexpected plant closures and extreme weather events" (Ref. 1, Para 3.3.1).

"The larger the margin, the more resilient the system will be in dealing with unexpected events, and consequently the lower the risk of a supply interruption" (Ref. 1, Para 3.3.2).

"We need a diverse mix of electricity infrastructure to come forward, so that we can deliver a secure, reliable, affordable and net zero consistent system during the transition to 2050 for a wide range of demand, decarbonisation, and technology sources" (Ref. 1, Para 3.3.19).

"A secure, reliable, affordable, net zero consistent system in 2050 is likely to be composed predominantly of wind and solar" (Ref. 1, Para 3.3.19).

8.1.3 'Security of supply' means, essentially, keeping the lights on in people's homes, and has two main components:

a. Ensuring that there is enough electricity generation capacity available and operational to meet demand (adequacy); and

b. Ensuring that the quality of electricity supplied to customers falls within a narrow "quality" band during all reasonably foreseeable operational circumstances and is resilient during rare excursions from this band.

8.1.4 This definition of adequacy includes not only the capacity of generation assets but also the availability of source fuel to those assets so that they are able to generate electricity.

8.2 Power system stability

8.2.1 Power systems connect supply (sources of power, largely generators) to assets which demand power (industrial, commercial or domestic customers). Power systems are complex; yet they must be designed and operated safely, securely, and economically.

8.2.2 Governments define policy to ensure that adequacy requirements are met, i.e. that there is sufficient generating capacity (i.e. the maximum achievable level of power generation which may be connected to the NETS) available to meet maximum expected demand, with secure and economic supply chains for the fuel they use to generate electricity.

8.2.3 Key power quality characteristics (including frequency, voltage, and power shape) must also be controlled for the electricity system to operate without fault. NGESO define this topic area as system operability, specifically: *“the ability to maintain system stability and all of the asset ratings and operational parameters within pre-defined limits safely, economically and sustainably”* (Ref. 78, p5).

8.2.4 Keeping an electricity system from entering fault conditions during operation or returning an electricity system to normal operational conditions post fault, is also important. All large-scale generators must be capable of maintaining their own synchronicity with the system to a high level of reliability.

8.2.5 NGESO also ensure that power demand, or load, and power supply, always remain balanced. Balancing requires the right generating assets to be connected and disconnected to/from the right power levels, and at the right time. This can sometimes be at short notice, in response to emergent (fault) conditions. NGESO call those services which support NETS stability and operability are called Ancillary Services and examples have been listed previously in Figure 5-8 and Table 5-1.

8.2.6 The National Infrastructure Commission addressed the topic of system stability by stating that it is *"Important that generators are responsible for costs and benefits they impose on the system, such as those related to where they situate"* (Ref. 79, p40).

8.2.7 It is well understood that the activities associated with integrating renewables into the GB electricity system will increase with their penetration. Energy balance must be managed at all times; and as renewable capacity increases, a greater volume and range of Ancillary Services may be required to maintain or regain supply / demand balance and retain system control, particularly when demand is either very high or very low. Balancing actions may also increase.

8.2.8 Technological advances, in particular in the introduction of power electronics into generating assets, is increasing the ancillary services and system stability services available from users of the electricity system, for example, by improving an asset’s response speed and capability to system faults, and their ability to withstand periods of system instability without disconnecting.

8.2.9 The installation of power electronics at low-carbon generation assets is an exciting development which will enable them to provide important system stability services as part of their normal daily operational routine. By reprogramming the digital power inverters attached to solar panels, services required by the ESO can be delivered from solar generation facilities. Some solar farms already operating have incorporated state-of-the-art power electronics into their designs, and are providing important stability services to the ESO.

8.3 Power system adequacy

8.3.1 Solar plays an important role in diversifying renewable generation sources to maintain adequacy and minimise curtailment.

8.3.2 The uncontrollable nature of the weather raises a potential challenge to the ability of solar generation to play a significant role in electricity supply. However, the variability of solar generation can be mitigated by:

a. Developing larger generation capacities (to maximise output during periods of low irradiation, for example through overplanting);

b. Connecting assets to different parts of the NETS; and

c. Developing projects with generation profiles which are complementary to solar (for example wind: see Section 8.8).

8.3.3 'Integration technologies' may also be used to respond to the intermittency of renewable generation, including electricity storage, interconnection, hydrogen and demand side response (Ref. 1, Para 3.3.12). 'Integration technologies' will help balance supply and demand, improving the efficiency of the electricity system as a whole and potentially reducing the installed generation capacity required to meet peak demand.

8.3.4 National Grid state that security of supply *"refers to meeting all electricity demand at any given time"* and that *"Traditionally, risks to meeting electricity security of supply, have been at times of high demand, particularly peak demand. In the future, these risks will also be driven by periods of over-supply and/or supply and demand mismatch"* (Ref. 20(2023), p116).

8.3.5 The Capacity Market, which is one of the UK's primary measures for delivering security of supply, applies a de-rating factor to contracts on a technology-by-technology basis. All technologies attract a de-rating factor, and all de-rating factors are below 1. This highlights that no single technology can be relied upon to deliver security of supply at all times (else it would have a de-rating factor of precisely 1).

8.3.6 Critically, the de-rating factor for solar in the Capacity Market has nearly tripled for projects contracting capacity over the period 2021/22 to 2027/28 (Ref. 80) from 2.34% to 6.35%, demonstrating how quickly the market is moving away from traditional norms of supply risk at winter evening peak times only, and how important a multi-technology mix is to the achievement of security of supply for consumers at all times of the day and year.

8.3.7 Government's Energy White Paper describes that meeting a possible doubling of electricity demand by 2050 *"would require a four-fold increase in clean electricity generation with the decarbonisation of electricity increasingly underpinning the delivery of our Net Zero target"* (Ref. 10, p42).

8.3.8 A significant increase in UK electricity generation capacity is required to meet growing demand and deliver security of supply under different weather conditions. Because the weather is uncontrollable, more capacity is needed to ensure that demand can be met even when renewable output is low. The implication is that when renewable output is high, there is a risk of oversupply. The laws of supply and demand in liquid markets such as electricity, imply that at times of oversupply, the price of the traded commodity – electricity – will decrease.

8.3.9 National Grid ESO state that *"There is day-to-day uncertainty due to weather but in general, solar generation is quite predictable over the course of a year and the position of the sun and its expected radiation levels over the year are well known. This means it can be a great asset for meeting annual demand levels, especially* [and therefore by extension, not exclusively] *when coupled with suitable storage"* (Ref. 20(2023), p132). Figure 5-6 of this Statement provides further information on the growth of storage facilities in Great Britain.

8.3.10 Solar generation, and its potential abundance at foreseeable times of the day and year, will provide regular market signals which support the growth in demand-side flexibility (shifting demand to times of abundant renewable generation) and storage. As well as providing essential support to the security of supply during daylight hours, growth in solar generation will also encourage a shift in demand away from times of traditional peak needs, and/or store abundant energy which can then be dispatched when it is needed.

8.3.11 The inclusion of a storage facility as Associated Development to the main solar scheme allows the scheme to support the transition to net zero by providing flexibility to a fully low-carbon electricity system.

8.4 Curtailment

8.4.1 National Grid's Future Energy Scenarios document also describes and evaluates the potential for curtailment to occur in the UK's future electricity system.

8.4.2 It is important therefore to explain why curtailment currently occurs in the UK electricity system, and the level of the prices currently paid to generators for some curtailment actions.

8.4.3 Currently, the majority of curtailment in the UK occurs on the large-scale wind fleet and mainly due to transmission constraints. Transmission constraints occur when the electricity network linking the point of generation to the major points of consumption, does not have the capacity to transmit all of the generation at certain times, but in particular when generation output is high.

8.4.4 In the 12 months starting 1st October 2022 and ending 30th September 2023, National Grid data records that wind generated 63TWh of energy. Transmission constraints amounted to 3.3TWh (c.5% of net generation) and constraints due simply to there being 'too much wind energy on the system' totalled c.0.6TWh, or less than 1% of net generation.

8.4.5 Curtailment in the UK is therefore currently more to do with where electricity is generated, than how much electricity is generated, and curtailment in the UK is anticipated to be associated more with wind generation than with solar generation.

8.4.6 Curtailment for network constraints currently results in a compensation to the asset operator for the electricity which would have been generated and sold but for the fact that that energy was not accepted onto the transmission system.

8.4.7 An asset located on a transmission network which is well connected to demand centres, is unlikely to be curtailed for the same reasons as the majority of current curtailment in the UK, however the possibility of curtailment for non-locational reasons remains.

8.4.8 In such circumstances, curtailment would occur because more energy was being generated than that which could be consumed or stored at that time. Figure 9-1 of this Statement shows that an excess of supply reduces market price, incentivising price-sensitive demand to increase, or in extremis, incentivising supply to shut down so as to avoid having to pay (rather than be paid) to generate. Critically, neither of these outcomes results in a compensation payment from consumers to the asset operator for the electricity they have not generated.

8.4.9 National Grid's analysis shows that average solar curtailment in the years 2031 – 2040 is anticipated to be 2.4TWh - 2.7TWh (Ref. 20(2023) Tables FL.18, ES1).

8.4.10 Chapter 8 of this Statement describes that the Scheme proposes to connect to a well-connected section of the NETS which has available transmission capacity. As such, transmission constraints are unlikely to cause curtailment at the Scheme and during its operational life, the Scheme is unlikely to receive compensatory payments for curtailments which would ultimately be funded by consumers.

8.4.11 Further, with energy storage assets proposed as Associated Development to the main solar scheme, the scheme will be able to provide its own operational flexibility to the electricity system without relying on flexibility provision from other electricity system users. Such flexibility could include storing solar energy in the co-located batteries during periods of abundant solar supply until it is needed.

8.4.12 More generally, a growth in flexibility (including demand-side response, storage, interconnection and hydrogen) will help to minimise the curtailment of assets in the future UK electricity system arising from the build out of large capacities of renewable generation. But because renewable electricity is variable, the UK may not be able to meet demand at times of low renewable output without the build out of large capacities of renewable generation.

8.4.13 Having insufficient renewable generation capacity operational in the UK may cause:

a. Power cuts (contrary to the government's aim to ensure security of supply);

b. Price spikes (contrary to the government's aim to shield consumers from volatile energy markets); and/or

c. Stand-by fossil fuel assets to generate (contrary to the government's aim to decarbonise the electricity system by 2035).

8.4.14 The alternative approach, which is the government's approach, is the build-out of large capacities of renewable generation. This approach meets the government's aims and provides opportunities for market approaches to manage curtailment through flexibility, by:

a. Using curtailed energy to support security of supply when demand is high;

b. Keeping consumer costs down by capturing and storing energy when it is abundant (therefore cheap) and releasing it when it is needed; and

c. Displacing stand-by fossil assets by using stored energy as a low-carbon "peaking" energy resource, further supporting the government's aim for the electricity system to be operating with net zero carbon emissions from 2035.

8.4.15 One such flexibility measure which has already gained traction in the UK and has been enabled by the introduction of smart meters into domestic homes, is the introduction of 'time of use tariffs' (ToUTs). ToUTs apply different prices to consumption metered at different times of the day or year. ToUTs provide customers with the opportunity to schedule their electricity consumption towards times of low prices and away from times of high prices. Consumers would benefit from their actions through their normal utility bills.

8.4.16 In summary, future curtailment, if/when it occurs, could be interpreted as a 'good' problem for the UK power sector to have when compared to the alternate of under-delivering on the government's decarbonisation and energy security aims. This is because if curtailment occurs, it would be because large capacities of renewable generation have already been built out to deliver low-carbon supplies to meet demand, deliver security of supply, meet carbon reduction targets and reduce wholesale costs of energy.

8.4.17 Further, the market signals associated with curtailment, will drive the development of consumer and/or supply side flexibility to make efficient use of abundant resources and drive further security of supply, decarbonisation and affordability benefits for consumers across the whole energy system.

8.5 The system adequacy of solar generation

8.5.1 System adequacy is primarily managed through the GB Capacity Market. On an asset-by-asset basis, intermittent generation capacity, such as wind or solar, can be variable, which means that individual assets are de-rated in the Capacity Market. However, the output from portfolios of intermittent capacity, especially those that consist of different technologies, can be relied upon more fully and are easier to forecast more accurately. This supports the efficient provision of system adequacy and security of supply.

8.5.2 The following analysis demonstrates this by showing that the average aggregate monthly output per unit installed capacity of a multi-technology portfolio of wind and solar assets is less variable than the average monthly output per unit installed capacity of each of the single technology portions of that portfolio.

8.5.3 The data for Figure 8-1 is sourced from National Grid's Demand Data and Actual Metered Generation data. These are operational data files, available to download from National Grid's data portal, and are updated on a regular basis. These files are large and as such have not been submitted as a reference to this document, but extracts can be provided to the Examining Authority if required or requested.

8.5.4 The Demand Data files include National Grid's estimated output, and capacity, for unmetered wind and unmetered solar generation.

8.5.5 The Actual Generation file includes metered wind generation (but not installed capacity). The workbooks accompanying regular FES publications also include historic installed wind capacity by type (onshore and offshore), connection type (distribution and transmission) and year (Ref. 20(2023)).

8.5.6 Data from 1st January 2021 to 31st December 2022 has been used by the author to derive a series of historical metered wind capacity of onshore and offshore wind.

8.5.7 Using two recent years of data provides a credible representation of national generation and capacity including all micro wind, onshore wind and offshore wind as well as rooftop, commercial and larger scale ground mounted solar to a total combined portfolio of approximately 30GW of wind and 15GW of solar (estimated at year end 2022). The solar and wind generation facilities included in this portfolio are located throughout the UK.

8.5.8 Figure 8-1 displays the resulting output per unit of installed capacity at a monthly level for GB wind (green columns) and solar generation (yellow columns). It shows the seasonality of wind load in GB: low in the summer months but higher in the Autumn through Spring. It also shows the seasonality of solar generation in GB: high in the spring and summer months and lower in autumn and winter. The output associated with an illustrative combined portfolio is shown by the red line.

8.5.9 The red line in Figure 8-1 is the weighted average load factor for the combined national portfolio of wind and solar i.e., (wind generation + solar generation) / (wind capacity + solar capacity). The red line always lies between the extent of the green and yellow columns and is flatter across the timeframe analysed than either of the columns, showing a lower variation from month-to-month through the year.

8.5.10 Taking a multi-technology approach to electricity supply can reduce the effects of weather variability on output. By combining two generation portfolios which are largely independent of each other (meaning, the level of solar generation in the UK at any time is not mathematically dependent on the level of wind generation in the UK at that time, and vice-versa) the variation of the combined portfolio of (solar + wind), when averaged over a period of time, is lower than the variation of each of the portfolios separately.

8.5.11 Clearly, the identification of a general trend does not imply conformance to that trend on all days and at all times. Future 'actuals' will be dependent on prevailing weather conditions as well as levels of installed wind and solar generation capacity at delivery.

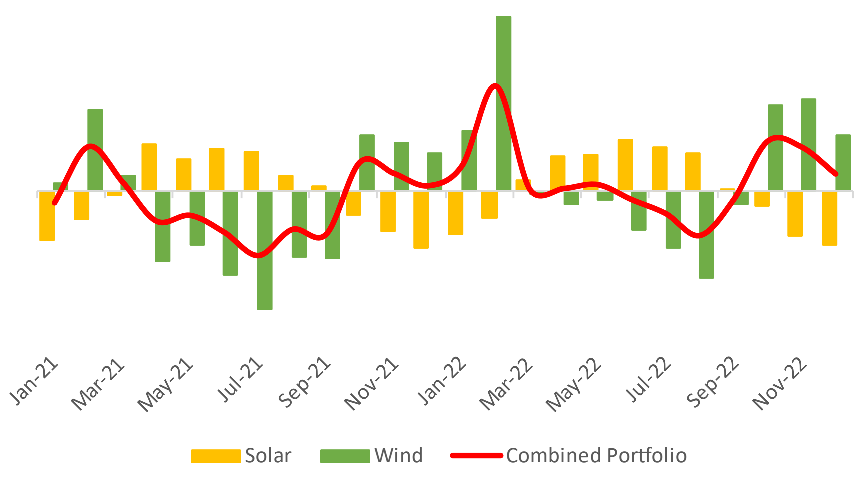

Figure 8-1: Illustrative Generation Dependability for a combined portfolio of solar and wind in GB (Ref. 81)

8.5.12 Running the analysis over different time periods by using a different range of historical data derives similar results. The level of certainty which may be ascribed to the general conclusions of the analysis is therefore high, based on historical information. Insofar as solar and wind capacity both increase in the future in broadly similar proportion to each other as has been experienced historically, then it is reasonable to assume that the conclusions reached will remain valid in the future.

8.5.13 Forecastable and stable generation output per unit of installed capacity is important because it relates to the reliability of, and therefore NGESO's ability to depend on, forward forecasts of generation outturn. At the macro level, a greater reliability of generation outturn allows for a more efficient and targeted asset development program to be developed; and a lower requirement for (currently fossil fuelled) backup plant, without creating an excess of generation capacity.

8.5.14 A growing portfolio of solar generation would therefore complement the existing and growing GB wind portfolio to deliver a combination of low-carbon generation with improved reliability and predictability than associated with the separate technologies.

8.5.15 A second analytical model has been developed to illustrate the collective capability of solar and wind generation in meeting seasonal demand for electricity in the UK.

8.5.16 The model evaluates the contribution made by different types of GB generation to overall GB consumption needs throughout a year on a month average basis but does not take into account the requirement to balance supply and demand on a short-term basis.

8.5.17 The data sets model underlying demand, heat demand, transport demand and different sources of low-carbon supply including solar generation and wind generation and how each of these change through the year.

8.5.18 The analysis is based on the within-year shape of demand averaged over 2015 to 2019.

8.5.19 Each data set therefore comprises a month-to-month shape and a future level. The methodology used to derive the shape for each series is as follows:

a. 2015 – 2019 national demand data is used to derive a month-average demand expressed as a ratio of annual average demand. The data therefore avoids any one-off within-year impacts associated with outlier weather patterns (because the base data covers multiple years) or due to the COVID-19 pandemic (because data including and after 2020 has not been used);

b. The heating demand shape has been derived from the industry rule of thumb that in the UK, gas demand in the winter is up to five times higher than in the summer, and therefore electricity demand for heating (when it displaces gas heating) will follow a similar shape;

c. The transport demand shape has been estimated as flat through the year; and

d. Demand for electrolysis of water to produce hydrogen has been included in monthly demand estimates for completeness but at only small capacities in the 2030 timeframe, in line with National Grid's projections.

8.5.20 Total demand is the sum of underlying demand, heat demand, transport demand and electrolysis demand.

8.5.21 Supply has been modelled with only zero-carbon technology types, consistent with the government's target of achieving a zero-carbon electricity system by 2035 and the results are shown in Figure 8-2. The technology types are: zero carbon baseload (grey), onshore wind (green), offshore wind (blue) and solar (yellow).

8.5.22 The methodology used to derive the shape for each series is set out below.

a. Zero carbon baseload generation represents nuclear energy supplied by Hinkley Point C (assumed to be commissioned by 2030) and Sizewell B (assumed not to be decommissioned before 2030). Only the first CCUS and Hydrogen generation facilities are assumed to be operational in 2030. All assets are assumed to have an Unplanned Capability Loss Factor (breakdown rate) of 10% and planned outages are assumed to take place in summers rather than winters, leading to a summer month availability of 79% and a winter month availability rate of 90%;

b. The average monthly load factor for onshore and offshore wind and solar generation has been derived from National Grid market data for the entire UK operational wind and solar portfolio for the period 2020 and 2021. The data sources are the same as those used to derive Figure 8-1 previously. Historically, both onshore and offshore wind generation in winter months (October through March) has been just below twice the level seen in the low months of the year (June and July), which is almost the inverse solar generation levels; and

c. The data derives a within-year shape (at monthly granularity) which is consistent with National Grid Operational Data for the entire UK operational solar estate over the period 2016 – 2020.

8.5.23 Table 8-1 below shows the load factors assumed in the analysis alongside National Grid assumptions (Ref. 20(2023), Data worksheet ES1) and other relevant sources, such as Department for Energy Security and Net Zero (DESNZ) Regional Renewable Electricity Report (Ref. 9(2022)) and DESNZ Electricity Generation Cost Report (Ref. 67(2023)).

8.5.24 New offshore wind farms have significantly higher load factors than early farms, and the technology is projected to see significant growth between now and 2030 (and beyond). This is predominantly due to:

a. Developments being located in areas with higher average wind resource, and larger more efficient turbines now being available on the market. The model assumption (derived from author analysis) matches the FES 2023 assumption; and

b. New onshore wind farms are likely to be more constrained in location and turbine size than new offshore wind farms and growth in load factor is less certain. The model assumption therefore adopts a lower load factor derived from Author Analysis.

Table 8-1 Comparison of assumed load factors with independent data sources (Ref. 9, Ref. 20 & Ref. 67)

Load Factor (%)	Model Assumption	FES Average	DESNZ Regional Data	DESNZ Cost Assumption
Offshore Wind	47%	47%	38%	65%
Onshore Wind	35%	38%	26%	41%
Solar	10%	10%	10%	11%

8.5.25 The FES (Ref. 20(2023), Table ED1) provides projections for the average levels of demand associated with underlying electricity use, heat, transport and electrolysis capacities of each technology which may be in operation in 2030.

8.5.26 The analysis assumes annual average load levels for underlying demand of 30.1GW, for heat demand of 4.3GW, for transport demand of 4GW and for Electrolysis of 1.5GW.

8.5.27 Assumptions on the future levels of supply capacity have also been included in the model and are listed in Table 8-2, alongside the projections of capacity in FES 2023 (average; minimum and maximum installed capacity in 2030 for each technology in the three net zero compliant scenarios, which are all within +/- 1 GW of FES 2022 figures, which were used for the analysis, and the Author therefore judges that the general conclusions made in the Statement of Need are unchanged).

8.5.28 The model is an illustration based on projections of capacity roll out, electrification of demand and efficiency / load factor. Figure 8-2 shows the output of just one projection of a multitude of possible projections. Other outcomes are therefore possible, including those associated with rapid expansions of other zero-carbon generation technologies, should they materialise.

Table 8-2: Comparison of installed capacity assumptions vs. FES 2023 (Ref. 20)

Assumed Capacity (GW)	Model Assumption	FES 2023 Average	FES 2023 Min	FES 2023 Max
Offshore Wind	50	41	32	48
Onshore Wind	25	25	20	29
Solar	47	29	19	41
Zero-carbon baseload	6.0	6.3	4.6	7.6

8.5.29 However, considering the contribution only of proven low-carbon generation technologies to meeting future demand is a prudent approach because:

a. Section 2.11 of this report describes the urgency for action to reduce carbon emissions from the UK's electricity system in the critical 2020s, and Sections 5.5-5.7 of this report describe that there are as yet no fully funded and consented CCUS, nuclear or hydrogen projects set to deliver in the 2020s beyond the projections already included in the analysis

b. Section 4.3 articulates the government's prudent view that infrastructure development should be planned on a conservative basis, without over-relying on yet-to-be-proven technologies, technologies with long development lead-times, or technologies which have historically experienced funding difficulties

8.5.30 Figure 8-2 should not be inferred to advocate either for a specific renewables mix, nor for a system without adequate backup or flexible generation, both of which may be required to support decarbonisation of the NETS by managing day-to-day swings in both demand and supply.

8.5.31 However, Figure 8-2 does show that a portfolio of low-carbon generation which includes solar, onshore and offshore wind and a low-carbon base, is capable of closely matching a future projection of national electricity demand on a month-average level.

8.5.32 The government's current target of 50GW of offshore wind operational by 2030 (an increase of ~37GW on 2022 levels), when developed alongside projections of onshore wind and baseload low-carbon power, would likely generate sufficient power to meet estimated winter (October to March) demand. The tops of the blue stacked columns (total generation) are near to the red line (total demand) during these months.

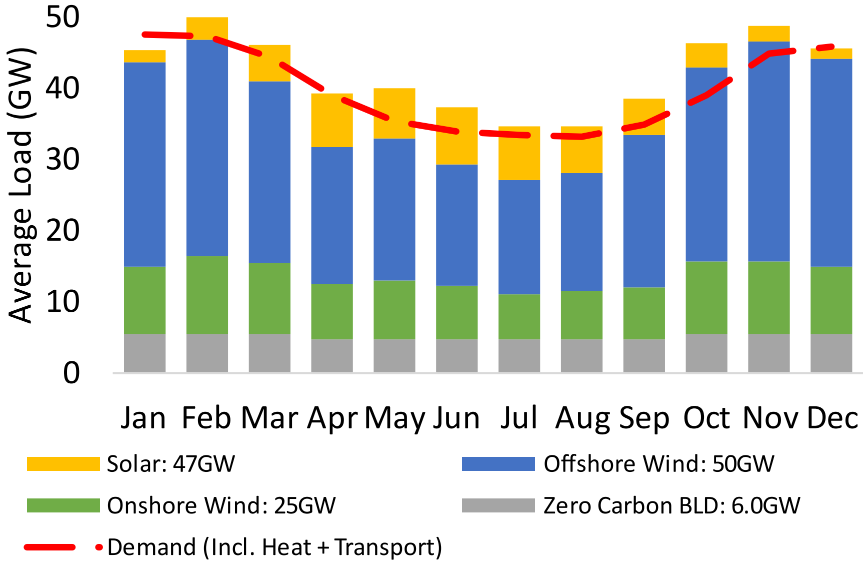

Table 8-3: Deploying 47GW of large-scale solar alongside government offshore wind ambitions (50GW) meets anticipated seasonal demand levels (Ref. 20 & Ref. 81)

8.5.33 However, because of the seasonality of wind generation in UK territory, 50GW of offshore wind would not be sufficient to meet summer (April to September) demand. The top of the blue stacked column is below the red line in these months.

8.5.34 Approximately 47GW of solar (an increase of 32GW on mid-2023 levels and consistent with the government's target of 70GW installed by 2035) would neatly "fill the gap" during summer months without delivering significant over-generation in winter periods, as is shown by the yellow portions of the stacked columns. To meet 2030 summer levels without solar generation, a further 15GW of offshore wind generation (i.e. a total installed capacity of ~65GW), or an additional ~7GW of low-carbon baseload generation (two new Hinkley Point C equivalent power plants), would be required to be built in the next 10 years.

8.5.35 However, by building out either an additional 7GW of low-carbon baseload generation or 15GW of offshore wind generation to meet summer demand levels without solar, there would be significant over-generation of power in the winter periods (of between 12% and 18%). Over-generation may be curtailed (either at a cost to the consumer or by reducing available revenues to asset operators) or stored. If revenues are reduced for asset operators, in some cases assets may not be commercially attractive and therefore may not get built out.

8.5.36 A high degree of certainty may be attached to the model's conclusion, which is that the deployment of large-scale solar alongside offshore wind, onshore wind and low-carbon baseload assets provides the opportunity for a lower capital, lower curtailment (therefore lower cost) energy system through diversity of asset type than that provided by scenarios which do not include solar generation.

8.5.37 As the technical and economic viability of inter-seasonal storage advances, more options will become available for optimising GB's generation mix in relation to balancing capital deployment, development risk, the availability of suitable locations and ongoing system operations (e.g. curtailment). However, based on current assessments, it is clear that the deployment of large-scale solar alongside that of offshore wind, onshore wind and low-carbon baseload assets, provides the opportunity for a lower capital, lower curtailment (therefore lower cost) energy system through diversity of asset type than that provided by scenarios which do not include solar generation.

8.6 Conclusion

8.6.1 This Statement of Need sets out the case for the urgent development of low carbon sources of electricity in the UK. The British Energy Security Strategy provides additional focus on both the scale and the urgency to deliver new low carbon generation capacity, and the Scheme is ideally suited to play an essential role in meeting that urgent need.

8.6.2 Although individual renewable assets are variable generators, aggregated generation output from portfolios which consist of different renewable technologies is more stable. The generation profiles of diverse ranges of low-carbon generators combine to meet seasonal average demand levels without requiring significant and unproductive capital investment, seasonal excess generation, or inefficient network / system operating costs.

8.6.3 Many integration measures are already available, or are already in development, which, over short periods, help balance electricity generation from variable generators to meet demand, and to ensure that the best use is made of low-carbon electricity when it is being generated in oversupply. For example, BESS, pumped hydro or interconnectors (see Sections 5.7 and 5.9)

8.6.4 The contribution made by flexible assets to the short-term balancing of supply and demand are described in Section 6.8 and Chapter 7. However, until inter-seasonal storage is brought forwards at scale and at grid parity costs, the most efficient measures for seasonal balancing of renewable generation include increasing the capacity and geographic diversity of renewable generators, including portfolios of assets with complementary seasonal generation profiles; and managing shorter term intermittency through storage or other measures.

8.6.5 Solar is an asset class which is needed to support a high level of generation adequacy and generation dependability within the GB electricity system.

8.6.6 The Scheme, as a leading large-scale solar scheme in GB, represents c. 2% of the additional solar generation capacity required in the FES projections to 2030, for scenarios compatible with net zero only (Ref. 20(2023)). In this context, the Scheme is therefore an essential stepping stone towards the future of efficient decarbonisation through the deployment of large-scale, technologically and geographically diverse low-carbon generation assets.

8.6.7 Global expertise in the operation of electricity systems with high proportions of RES is growing. Technologies which help the integration of renewable assets to the grid are already in operation in the UK. However, solar assets are increasingly able to provide important system services themselves, and flexible integration assets are being deployed on a stand-alone and co-located basis to do the same, as well as to manage short-term supply / demand volatility.

8.6.8 Growth in solar capacity, alongside other renewable technologies, is expected to improve the dependability of those assets as a combined portfolio, and this is expected to reduce further any integration costs associated with such growth.

8.6.9 The Scheme, if approved, would contribute to an adequate and dependable GB generation mix, through enabling the generation of more low-carbon power from indigenous and renewable resources. Therefore, the approval, construction and operation of the Scheme will make a significant contribution to GB's energy security needs, and the decarbonisation needs of the UK.

9. The contribution of large scale solar to the affordability of electricity

9.1 Chapter summary

9.1.1 This chapter provides an overview of the affordability benefits of large-scale solar in the UK.

"Analysis [commissioned by the National Infrastructure Commission] suggests that there is no material cost impact, either over the short or long term, of deploying renewables faster. Renewables are now the cheapest form of electricity generation due to dramatic cost reductions in recent years. Cost reductions have been greater than was predicted in 2018 when the Commission made its recommendation on what level of renewable generation the government should be targeting" (Ref. 63, p9).

9.2 Pricing in the GB electricity market

9.2.1 In the GB power market, generators schedule themselves to generate in response to whether a market price signal for a specific period is above or below their marginal cost of generation. Marginal cost of generation is defined as the cost of generating an additional 1MWh, usually including variable fuel, emissions and transmission costs.

9.2.2 Each day is subdivided into 48 half-hour Settlement Periods (SPs) and power is traded ahead of delivery for these periods, or continuous groups thereof, from just 90 minutes ahead, up to months or even seasons ahead.

9.2.3 Solar generation has very low or zero marginal costs and therefore solar assets generate as much power as they are able to, when they are available (i.e. whenever there is light) and whenever power prices are positive. Because of the variable, but forecastable, nature of solar irradiation, they also tend to trade on near-term power markets, therefore much of the impact of sunny (or overcast) weather on power price is felt in the few days close to delivery.

9.2.4 Thermal and hydro plants have higher marginal costs, relating to the cost of the fuel they are converting into that additional MWh, and any emissions costs associated with the use of that fuel. Thermal and hydro plants will therefore only generate when the market is providing a higher price signal, i.e. when demand is expected to be higher than the supply of low-marginal cost supplies at the time of dispatch. Thermal and hydro plants may also trade power, fuel and emissions costs into the future to fix their income.

9.2.5 Increases in the cost of source fuels and emissions increase the cost of generation from these assets, therefore when they are required to generate electricity, they will do so at a high cost which increases the price of electricity for all market consumers for that period.

9.2.6 All generators produce active power (MWs), and at all times, the total national active power generated must meet the total national system load. If solar farms are generating electricity during a settlement period, then less electricity is required from plants with more expensive marginal costs, therefore the price of electricity for that settlement period reduces.

9.2.7 Emissions pricing ensures that carbon-emitting generation is more expensive to dispatch than zero-carbon generation. Therefore, by undercutting carbon emitting assets on marginal cost, zero-carbon assets will displace carbon intensive assets, providing both a carbon emission saving and a cost benefit to consumers.

9.2.8 This market mechanism is illustrated in Figure 9-1. The blue line, increasing from left to right along the x-axis, represents the marginal cost of generation in GB at each level of demand. As demand increases, more expensive supply must be scheduled into the market to meet that demand.

9.2.9 The three red vertical lines represent different levels of demand. At a mid-level of demand, the solid vertical red line crosses the blue line (in this illustration: at about £45/MWh) and is the price of electricity for that period.

9.2.10 If demand falls (e.g. to the left-hand dashed vertical red line), less plant is required to run to meet demand, therefore the marginal cost of the most expensive asset required to run to meet demand is lower and the price of electricity for that period would also reduce vs. the previous case.

9.2.11 Conversely, as demand increases, (e.g. to the right-hand dashed vertical red line) assets with higher marginal costs of production are required to run, and it is them which set the price of power.

9.2.12 The blue line in Figure 9-1 will be different for each half hour settlement period because generators may become available or unavailable through the day due to outages or breakdowns. The level of renewable generation will also change through the day. More renewable generation will stretch the blue line within the red ellipse (around a zero marginal cost of power), lowering the price of electricity for that period (the point of intersection between a vertical red line point with any fixed red line) and as a result, the blue line slides to the right for all higher levels of demand.

9.2.13 The marginal cost of production to meet demand over these periods will therefore be lower and as a result, the traded price of power will be lower.

9.2.14 By running this type of analysis over every settlement period over the future trading horizon, it is possible to derive a view of the price of power for the next week, month, quarter or season.

9.2.15 The conclusions are the same, however: increasing the capacity of renewable assets in GB reduces the traded price of power.

9.2.16 The GB power pricing mechanism also provides the explanation as to why the British Energy Security Strategy increases the UK’s ambition for renewable generation to reduce our dependency on volatile international energy markets.

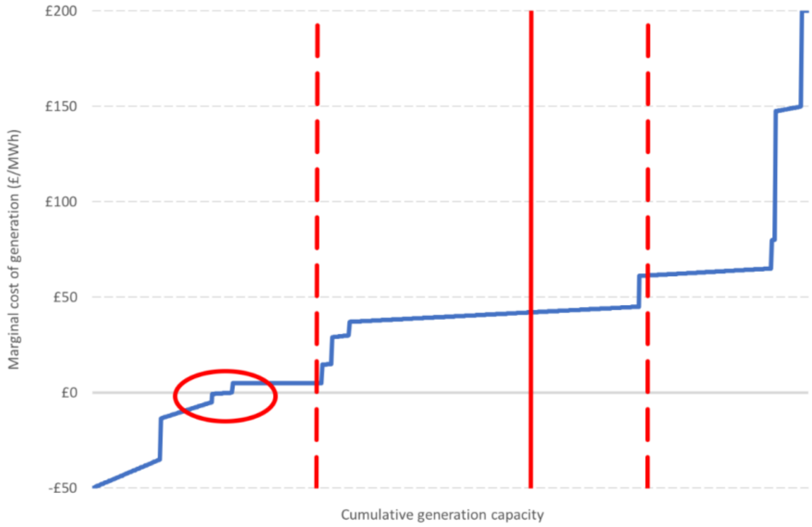

Figure 9-1: Representative marginal cost stack for the GB electricity system

9.3 Levelised cost of solar generation

"The International Renewable Energy Agency (IRENA) found that between 2010 and 2019, the cost of solar PV globally dropped by 82% ... In 2019 alone, the cost of electricity from solar fell by 13% to just over five pence per kilowatt-hour. This means that by … [2020] globally, there will be up to 1,200GW of existing coal capacity that will cost more to operate than it would to install new solar PV capacity". (Ref. 82).

9.3.1 The market mechanisms described in Section 9.1 only reduce the price of power if solar projects come to market, or if developers believe they are able to make reasonable returns on their investments. The cost of solar generation is an important enabler of its development. Solar panels and electrical infrastructure have become larger and more efficient, as described in Section 6.7, meaning that more electricity can be generated from the same area of land as was previously possible. As a consequence, solar is now a leading low-cost generation technology (see Figure 9-2).

9.3.2 Levelised Cost of Energy (LCOE) is an important metric allowing all forms of generation to be compared with each other on a consistent basis. LCOE is calculated using a discounting methodology and is a measure of the lifetime unit cost of generation from an asset, including capital and operating costs. In-life cap capital and operating expenses, for example the re-powering of sites to manage anticipated degradation, are also anticipated.

9.3.3 Figure 9-2 shows the results of an analysis of Government's Electricity Generation Costs report (Ref. 67(2023)) with the range of values representative of different complexities of technical solution.

9.3.4 Figure 9-2 shows a "triple" of columns for each of five generation technologies. Each column within each triple shows the technology's anticipated LCOE for assets commissioning in 2025 (left hand column), 2030 (middle column) and 2035 (right hand column).

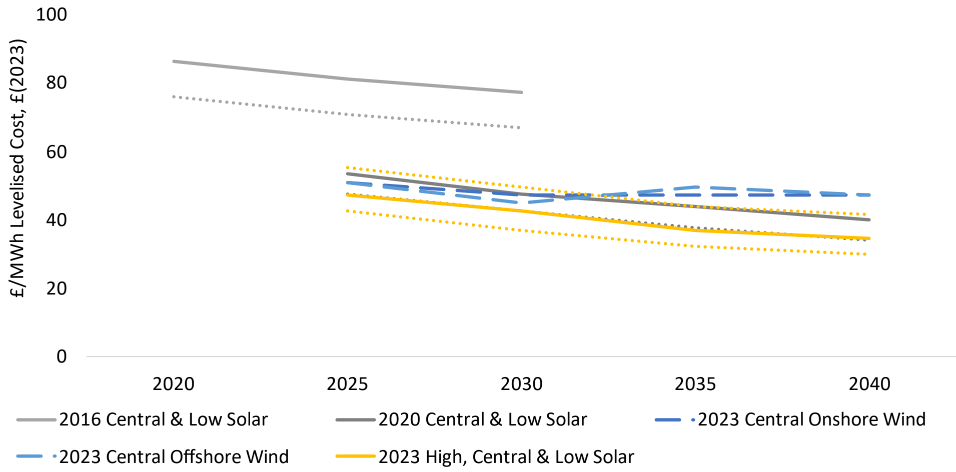

Figure 9-2: Levelised cost of energy comparison (Ref. 67)

9.3.5 Government modelling anticipates different projected operational lifetime, load factors (a measure of the output of the plant per year versus its theoretical maximum if availability is unconstrained), capital and operational costs and development duration to derive a range of cost projections. The blue bars show that range while the red columns represent the LCOE range under different projections for input fuel costs for those technologies which require a non-zero cost input fuel.

9.3.6 The levelised cost ranges of large-scale solar (the government's analysis assumes a capacity of 20MW) are highlighted in yellow. Figure 9-2 shows that renewable generation technologies hold a significant levelised cost benefit when compared to technologies which are reliant on fossil fuels, even when fuel input costs are included at a low level.

9.3.7 The government's analysis concludes that the LCOE of solar delivered in 2025 is lower than the LCOE of offshore wind delivered at a similar timeframe and is comparable to the LCOE of onshore wind. However, predictions are that solar generation delivered in future years is likely to be cheaper than both onshore and offshore wind on an LCOE basis.

9.3.8 A project with a lower LCOE is more likely to be developed because of its greater resilience to low market prices, versus a project with a higher LCOE.

9.3.9 The government's Cost of Electricity Generation report series (Ref. 67) also shows that solar LCOE has reduced significantly in the last decade. Solar, already being highly competitive against current conventional and renewable generation costs, is predicted to retain a cost advantage for the decades ahead.

9.3.10 Solar costs have been driven down through the realisation of efficiencies in capital infrastructure, development and integration costs, and lifetime O&M. This includes working to reduce the effects of degradation of solar panels and inverters. Improvements in lifetime cost are likely to continue to be delivered.

Figure 9-3: Government's Cost of Generation. An evolution of Levelised Cost forecasts (Ref. 67)

9.3.11 Technological advances have also increased the efficiency of solar panels (see Section 6.7 of this Statement) and extended their useable lifetimes. At the same time, economies of scale through the global supply chain have reduced the cost of panels. Development costs have also reduced as efficiencies in the build process have been captured through prior experience.

9.3.12 Figure 9-3 shows the results of the government's previous and current analysis. The mid grey lines show the government's 2016 projections of the LCOE of solar commissioning in 2020, 2025 and 2030. The solid line shows the central case projection, and the dotted line shows the low case projection.

9.3.13 The government's 2013 projections (not shown in Figure 9-3) were approximately 70% higher on a consistent 2023 real price basis. Just four years later, the government's 2020 solar LCOE projection (shown in dark grey) was over 30% lower for sites commissioning in 2025 and 2030.

9.3.14 Their projections made in 2023 are shown by the yellow solid line (central cost) and are bounded by the high and low cases shown by the dotted lines. The government's 2023 solar LCOE estimate is a further 10% lower than the 2020 estimate on a consistent 2023 real price basis.

9.3.15 Industry-sourced data and opinion concurs with the direction of Government's findings. For example, a CCC illustration of data from IRENA analysis (2020) showing cost reductions in and competitiveness of renewable generation technologies against fossil fuel generation (Ref. 8(2020), Figure 2.2).

9.3.16 Figure 9-3 should not however be taken as a justification for delaying the development of renewable projects, in order to capture a lower future installed price. Section 2.2 explains the rationale for urgent action to develop significant capacities of low-carbon generation. Time is a precious commodity.

9.3.17 Further, it is the continuous development of projects which allows learnings to be implemented, technology to advance through practical application, and markets and supply chains to evolve and improve efficiency, to achieve the future cost reductions which have been forecast by the government and others.

9.3.18 Solar was included in the 2021/22 CfD Allocation Round (AR4) to help *"deliver a diverse generation mix at low cost"* and to realise *"the rate and scale of new projects needed in the near-term to support decarbonisation of the power sector and meet the net zero commitment"* while providing other benefits such as diversity of supply through different resource requirements and a geographical separation from other significant renewable energy sources (Ref. 83, pp16, 20).

9.3.19 Many solar projects were successful in CfD AR4 and Allocation Round 5 (AR5) of 2023 had a similar outcome indicating the importance of solar as a technology class within the evolving GB electricity system and the competitive cost of the technology (Ref. 84).

a. In AR4, over 2.2GW of solar capacity across 66 projects (commencing in 2023/24 or 2024/25) secured CfDs at an initial strike price of £45.99 (2012 indexation, estimated to be equivalent to £61.81 in 2023 money); and

b. In AR5, over 1.9GW of solar capacity across 56 projects (commencing between 2025 and 2028) secured CfDs at an initial strike price of £47.00 (2012 indexation, estimated to be equivalent to £63.17 in 2023 money).

9.4 Whole system costs

9.4.1 The NIC's current view is that RES represent a most likely low-cost solution for GB electricity generation, over large-scale conventional investments:

"More renewables do lead to more money being spent to match supply and demand: a system with 90 per cent renewables is estimated to cost up to £4.5 billion more per year to balance. But cheaper capital costs are estimated to offset this within the costs for the overall system" ... (Ref. 79, p39).

9.4.2 Both Figure 8-1 and Figure 8-2 provide evidence that the deployment at scale of more than one renewable generation technology will help reduce the capacity of integration technologies needed to manage generation variability across many timeframes, including potentially the long-term storage of excess generation, although it is unlikely to fully remove the need.

9.4.3 An Imperial College expert economic analysis of whole system costs of renewables agrees; they show that the integration costs of RES fall on an absolute basis, as capacity increases from 10GW up to 50GW (Ref. 85).

9.4.4 The National Infrastructure Commission published the results of a whole system cost analysis in 2020. NIC's analysis complements that of the Imperial College team, suggesting that *"there is no material cost impact, either over the short or long term, of deploying renewables faster. Renewables are now the cheapest form of electricity generation due to dramatic cost reductions in recent years."* (Ref. 63).

9.4.5 The costs of solar are reducing as new projects are being developed, and the technology is now becoming more economically attractive over a growing geography. The factors which have already pushed prices down — such as technological design (greater efficiency over longer lifetimes, i.e. slower degradation), development and construction risk mitigation, efficient grid connection, efficient financing and shorter development timelines — will continue to shape prices in emerging markets. As a consequence, utility-scale project costs are falling more quickly than forecast; the global solar market is growing; and the GB solar market is growing.

9.5 Conclusions

9.5.1 Large-scale solar power decarbonises the electricity system and lowers the market price of electricity by generating power so that expensive and more carbon intensive forms of generation do not need to generate as much.

9.5.2 In doing so, solar power delivers national decarbonisation benefits and supports consumer affordability aims, to the benefit of electricity consumers.

9.5.3 Due to technological advances, solar facilities are already among the cheapest form of electricity generation in the UK and Government forecasts indicate that costs will continue to reduce in the future.

9.5.4 Scale remains important, and maximising the generating capacity of schemes improves their economic efficiency, and so brings electricity generation to the market at the lowest cost possible.

9.5.5 Larger solar schemes deliver more quickly and at a lower unit cost than multiple independent schemes which make up the same total capacity, bringing forward carbon reduction and economic benefits in line with government policy.

9.5.6 The Scheme will be a substantial infrastructure asset, which if consented will deliver large amounts of cheap, secure and low-carbon electricity both during and beyond the critical 2020s timeframe. Maximising the capacity of generation in the resource-rich, well-connected and technically deliverable proposed location for the Scheme represents a significant and commercially rational step forwards in the fight against the global climate emergency.

10. Conclusions

10.1.1 Decarbonisation is a UK legal requirement and is of global significance. It cannot be allowed to fail, and urgent actions are required in the UK and abroad, to keep decarbonisation on track to limit global warming.

10.1.2 The government has concluded that there is a critical national priority for the provision of nationally significant low-carbon infrastructure, which includes large-scale solar farms, because a combination of many or all types of such infrastructure is urgently required for both energy security and Net Zero.

10.1.3 Government expects that *“For projects which qualify as CNP Infrastructure, it is likely that the need case will outweigh the residual effects in all but the most exceptional cases”* (Ref. 1, Para 4.1.7). This Scheme is CNP Infrastructure therefore it follows that the urgent need for the Scheme to achieving the UK’s energy objectives, together with the national security, economic, commercial and net zero benefits, will outweigh any other residual impacts not capable of being addressed by application of the mitigation hierarchy (Ref. 1, Para 3.3.63).

10.1.4 The Scheme is required to ensure that the UK remains on track to meet its legally binding carbon emissions reduction targets, while enhancing national security of supply, and at a cost which, in relation to other electricity generation infrastructure developments, provides value for money for end-use consumers.

10.1.5 This Statement has shown that large-scale solar generation is economically and technically viable in the UK, and that it is an economically and technically preferable source of low-carbon energy for the GB electricity consumer.

10.1.6 The UK has substantial renewable energy resources, including wind and solar, and large areas of the country receive high levels of solar irradiation. These resources must be harnessed to decarbonise our economy.

10.1.7 The government’s view is that a low-cost, net zero consistent system is likely to be composed predominantly of wind and solar (Ref. 10, p43). Flexible assets are also needed to balance supply with demand, and the government is supportive of solar that is co-located with storage to maximise the efficiency of land use.

10.1.8 The Scheme will, if consented, bring forwards large-scale ground-mount solar with co-located DC-coupled storage facilities. The Scheme which is a large-scale solar plus energy storage scheme, therefore goes towards meeting the government’s aims.

10.1.9 Chapter 5 of this report describes the ambitions set out in the government’s aims for many renewable technologies and describes the real risks associated with their delivery. If solar generation does not meet the decarbonisation and energy security contributions ascribed to it, the challenge faced by the UK in meeting its decarbonisation targets from other technologies will be significantly harder.

10.1.10 Conversely, the continued development of proven low-carbon technologies like large-scale solar is important to protect against the possibility that technologies which are currently in 'prototype' stage do not deliver operational capacity at the pace or scale required.

10.1.11 Other conventional low-carbon generation (e.g. nuclear or conventional generation with CCUS) and new low-carbon dispatchable generation (e.g. hydrogen) will be important contributors to achieving the 2050 net zero obligation, but their contributions in the important 2020s will be very low.

10.1.12 The Scheme would generate power ahead of other potential technologies (which may have longer construction timeframes or have potentially not yet been proven at scale) which will support decarbonisation only in future years and only if they are brought forwards.

10.1.13 The need for solar is especially important given the context of the CCC's identification of the need for urgent action to increase the pace of decarbonisation in the GB electricity sector, and the government's adoption of their recommendations for the Sixth Carbon Budget (2033 – 2037).

10.1.14 The Scheme will, if consented, be capable of supporting the achievement of that aim by 2035. Large-scale solar is needed alongside rooftop solar because without increasing capacities of both types of solar generation, the UK will likely fall short of its solar capacity aims and therefore its climate change targets.

10.1.15 Beyond 2035, large-scale solar will remain important not only to reduce power-related carbon emissions, but also to provide a timely next step contribution to a future generation portfolio which will support the electrification and therefore decarbonisation of transport, heat and industrial demand.

10.1.16 As part of a diverse generation mix, solar generation improves the stability of capacity utilisations which in turn improves generation dependability. When developed alongside other renewable technologies, large-scale solar will help smooth out seasonal variations in total GB renewable electricity generation, more closely matching anticipated seasonal average levels of demand.

10.1.17 As Associated Development to the main solar scheme, co-located storage will help the Scheme operate flexibly as an essential part of a zero-carbon electricity and energy system.

10.1.18 The Scheme would connect to an existing and available grid connection point on the NETS, efficiently optimising its utilisation of an already existing national infrastructure asset.

10.1.19 By being connected to the transmission system, large-scale solar generation can and will play an important role in the resilience of the GB electricity system from an adequacy and system operation perspective. This is because the transmission system is able efficiently to transfer bulk power from where it is in abundance to where it is needed. This connection means that it will be required to play its part in helping NGESO manage the national electricity system.

10.1.20 Large-scale solar generation also supports security of supply by helping reduce the national dependency on imported hydrocarbon source fuels. The Scheme will therefore also help reduce the UK's exposure to volatile international energy prices.

10.1.21 The low marginal cost and low marginal carbon emissions energy generated at the Scheme can be confidently forecast and priced into future contracts for power delivery by all market participants, thus allowing all consumers to benefit from the market price reducing effect of solar generation.

10.1.22 The cost of solar generation is already highly competitive against the cost of other forms of conventional and low-carbon generation, both in GB and more widely.

10.1.23 Internationally, and importantly for GB in this regard, there is the ongoing trend of solar generation assets becoming larger and more affordable, each subsequent project providing a real-life demonstration that solar schemes of similar size and scale as the Scheme can and should be developed in GB. The development of such schemes will provide decarbonisation, energy security and commercial benefits to consumers.

10.1.24 If consented, the Scheme, along with other solar schemes, will make a critical contribution towards net zero, with NGESO scenarios predicting the need for 25 – 40GW of operational solar capacity in GB by 2030, or an increase of between 10 and 25GW over the next 6 years.

10.1.25 The meaningful and timely contributions offered by the Scheme to UK decarbonisation and security of supply, while helping lower bills for consumers throughout its operational life, will be critical on the path to net zero.

10.1.26 Without the Scheme, a significant and vital opportunity to develop a large-scale low-carbon generation scheme will have been passed over, increasing materially the risk that future Carbon Budgets and net zero 2050 will not be achieved.

10.1.27 The Scheme is a leading GB large-scale solar plus storage scheme. If consented, it would be an essential component of the UK's plan to deliver a future of efficient decarbonisation through the deployment of large-scale, technologically and geographically diverse low-carbon generation schemes and would also deliver flexibility to the UK electricity market.

10.1.28 The Scheme addresses all important and relevant aspects of existing and emerging government policy.

11. Author's Qualifications and Experience

11.1 Qualifications and experience

11.1.1 This Statement of Need has been authored by Si Gillett, Director at Humbeat Ltd.

11.1.2 Humbeat is an independent electricity consultancy, established in 2016, to support participants in the UK's transition to a low-carbon electricity and energy system. The consultancy supports and advises private individuals and organisations with pre- and post-construction electricity developments by providing commercial and strategic advice in relation to those developments.

11.1.3 Humbeat specialises in assessing, describing, and quantifying the benefits specific technologies and individual developments bring to the overarching and urgent need for decarbonisation in the UK. Humbeat has been commissioned to provide electricity market expertise to over 12,000MW of development-phase renewable generation developments across the UK, including over 3,000MW of ground mount solar, ranging from 10MW sites to large-scale developments.

11.1.4 Specifically, Mr Gillett authored the Statement of Need for Cleve Hill Solar Park (CHSP) and Longfield Solar Farm – both of which are NSIPs. CHSP received its Development Consent Order in May 2020, the first of its kind in the UK, and Longfield Solar Farm received its DCO in June 2023.

11.1.5 Mr Gillett also developed evidence to support IROPI (Imperative Reasons of Overriding Public Interest) justifications for Hornsea 3 and Hornsea 4 Offshore Wind Farms. DCOs were granted in December 2020 and July 2023 respectively.

11.1.6 Humbeat is currently supporting approximately ten other nationally significant electricity generation infrastructure developments by providing electricity market and low-carbon transition expertise to their development teams, as well as multiple engagements on TCPA planning applications for solar and solar + storage developments.

11.1.7 Mr Gillett has 20 years of experience in energy sectors including petroleum and natural gas liquids, and conventional, nuclear, and renewable electricity – on both the generation and sale side. A wide range of energy experience provides a robust basis for a balanced assessment and analysis of the UK energy sector as a whole. This is especially important as the journey to net zero involves more integrated and system-level thinking than has ever previously been required in the electricity sector.

11.1.8 Mr Gillett holds Masters degrees in mathematics and nuclear regulation.

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13. Abbreviations

Abbreviation/Term	Definition
AR4/5/6	Allocation Round 4/5/6 of the Contracts for Difference scheme
BECCS	Bioenergy with Carbon Capture and Storage
BESS	Battery Energy Storage Scheme
BEV	Battery Electric Vehicle
CCC	The Committee on Climate Change
CCGT	Combined Cycle Gas Turbine
CCUS	Carbon Capture Use and Storage
COP21	21st Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC)
DCO	Development Consent Order
DESNZ	Department for Energy Security and Net Zero
DUKES	Government's Digest of UK Energy Statistics
ETYS	National Grid ESO's Electricity Ten Year Statement
EV	Electric Vehicle
E-W	East-West solar panel layout
FES	National Grid ESO's Future Energy Scenarios
FiT	Feed in Tariff
FSF	Fixed South Facing solar panel layout
GBN	Great British Nuclear
GDA	Generic Design Assessment
GHG	Greenhouse Gas
GSP	Grid Supply Point
GWh / GW	Gigawatt hour (energy) / gigawatt (power). 1GW = 1,000 MW
ha	Hectare
HAR	Government's Hydrogen Allocation Round
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
kWh / Kw	Kilowatt hour (energy) / kilowatt (power). 1MW = 1,000 kW
LCOE	Levelised Cost of Energy

LULUCF	Land Use, Land-use Change and Forestry

Abbreviation/Term	**Definition**
MCS	Government's Microgeneration Certification Scheme
$MtCO_2$ / $MtCO_2$(e)	Million tonnes of carbon dioxide / Million tonnes of carbon dioxide equivalent
MWh / MW	Megawatt hour (energy) / megawatt (power)
NDC	Nationally Determined Contributions
NETS	National Electricity Transmission System
NGESO	National Grid Electricity System Operator
NGET	National Grid Electricity Transmission
NIC	National Infrastructure Commission
NOA	National Grid ESO's Network Options Assessment
NPPF	National Planning Policy Framework
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
NZS	Government's Net Zero Strategy
ONR	Office for Nuclear Regulation
PV	Solar Photovoltaics
REPD	Government's Renewable Energy Planning Database
SAT	Single Axis Tracker solar panel layout
SMR	Small Modular (nuclear) Reactor
SP	Settlement Period (of the GB electricity market)
TEC	Transmission Entry Capacity
TWh / TW	Terawatt hour (energy) / terawatt (power). 1TW = 1,000 GW
WMO	World Meteorological Organisation