SUNNICA ENERGY FARM

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7.1 Statement of Need

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Sunnica Energy Farm

Statement of Need

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Executive summary

Sunnica Energy Farm Limited (Sunnica) is seeking a Development Consent Order (DCO) for a large-scale solar and storage development, connecting to the National Electricity Transmission System (NETS) at Burwell Substation, near to the Cambridgeshire / Suffolk border (the Scheme), as described in the introduction to this report.

This Statement of Need for solar generation and storage builds upon the 2011 National Policy Statements (NPSs) and describes how and why the Scheme addresses all relevant aspects of established and emerging government Policy, including the draft National Policy Statements EN-1 and EN-3 as published by Government for consultation, in September 2021 [102, 103].

The case for need is built upon the contribution of the Scheme to the three important national policy aims of decarbonisation

a. Net Zero and the importance of deploying zero-carbon generation assets at scale;

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

c. Affordability.

The case for need specifically includes a section on the effect of the 2020 COVID-19 pandemic on Great Britain's (GB) energy market and infrastructure investment, and the important role of energy infrastructure projects in fiscal recovery plans.

Chapter 1 provides a recap of the Policy framework established by the NPSs, and the arguments set out within them, which support the need for significant new low-carbon electricity generation infrastructure in order to meet the UK's legal decarbonisation targets[1]. A synthesis of the relevant parts of the draft *National Policy Statements EN-1* and *EN-3* is also included this chapter.

Chapter 2 sets out the legal requirement for decarbonisation in the UK and explains how that requirement has developed based on an increased need and urgency for decarbonisation in order to meet the UK's obligations under the Paris Agreement (2015). This chapter summarises the latest expert views on the urgency and depth of low-carbon investment required to deliver the UK's Net Zero legal obligations, including the *National Infrastructure Strategy* [1] and the Committee on Climate Change (CCC) *Sixth Carbon Budget* [2]: any new low-carbon power generation schemes which can be delivered as soon as possible will make essential contributions to meeting this need, and many more schemes than those currently under development will also be required under all potential future scenarios of how to meet Net Zero, hence establishing the need for the development of large-scale solar schemes in the crucial 2020s.

Chapter 3 provides an up-to-date view of how decarbonisation in the UK has been achieved to date, through a substantial reduction in coal-fired generation and the deployment of significant numbers of wind and solar schemes and explains why a number of schemes as foreseen in previous carbon plans (and for which the NPS were largely written) have hitherto lagged behind these in terms of deployment.

Chapter 4 provides an overview of the effect of the COVID-19 pandemic on the UK energy market and provides industry views on demand and price recovery. UK and international

[1] The commitment to decarbonise extends across the United Kingdom of Great Britain and Northern Ireland. Northern Ireland is interconnected with the mainland power system through interconnectors but is operated under a different electricity market framework. Therefore, hereinafter we refer to Great Britain (GB) in relation to electricity generation and transmission, and the UK, to refer to the nation which has legally committed itself to Net Zero carbon emissions by 2050.

governments are discussing the important role green investment would play in global recovery, and UK is signalling its ambition to “lead the way”.

Chapter 5 confirms that future electricity demand will grow significantly through the decarbonisation-through-electrification of other industry sectors (the same reasons as those stated in the NPS), and therefore that significant new low-carbon electricity schemes, and particularly Sunnica, as discussed in **Chapter 6**, are required to meet that demand and deliver decarbonisation.

Chapter 7 explains the contribution of solar generation and storage to security of supply, both from an availability and a system operation perspective, and concludes that the Scheme, if approved, would contribute to an adequate and dependable Great British (GB) generation mix.

Chapter 8 describes characteristics of the part of the NETS to which the Scheme will connect and sets out the very strong reasons for connecting large-scale solar generation and/or storage facilities at the proposed location.

Chapter 9 provides an analysis of the economic viability of large-scale solar generation as a future contributor to a low-carbon GB electricity supply system in comparison to alternate technologies; and an analysis of why the Scheme will be most beneficial to the achievement of government’s aims if it is consented to the scale proposed.

Chapter 10 provides an overview of the role of integration technologies in the future Net Zero energy system, in particular the cross-vector nature of the leading viable pathways to a Net Zero future and the importance of integrating low-carbon generation at scale, with Energy Balancing Infrastructure (EBI) technologies, such as hydrogen and Battery Energy Storage Systems (BESS).

Chapter 11 concludes that significant capacities of low-carbon solar generation is urgently needed in the UK, and that integration technologies will also play an essential part in delivering Net Zero for the UK. Therefore, developing the Scheme as proposed will be an essential near-term step in meeting government objectives of delivering sustainable development to enable decarbonisation and by doing so, addressing the climate change emergency that affects everyone’s lives and the environment, by ensuring our energy supply is secure, low-carbon and low-cost.

Introduction

The Sunnica Energy Farm is a new solar energy farm proposal that would deliver electricity to the national electricity transmission network. Sunnica Limited is proposing to install ground mounted solar photovoltaic (PV) panel arrays to generate electricity energy from the sun and combine these with a Battery Energy Storage System (BESS) which will connect to the Burwell National Grid Substation in Cambridgeshire.

Electricity will be generated at Sunnica East Site A, near Isleham in Cambridgeshire; Sunnica East B, near Worlington and Freckenham in Suffolk; Sunnica West Site A near Chippenham and Kennett in Cambridgeshire; and Sunnica West Site B, near Snailwell in Cambridgeshire. All locations will comprise ground mounted solar PV panel arrays, supporting electrical infrastructure and, with the exception of Sunnica West Site B, a BESS.

Supporting electrical infrastructure will include onsite substations on Sunnica East A and B and Sunnica West A, and on-site cabling between the different electrical elements across the Scheme. The generating equipment of the Scheme will be fenced and be protected via security measures such as Closed Circuit Television and lighting. Inside the fenced areas, in addition to the generating equipment will be, internal access tracks, and drainage. It is not proposed for any area to be continuously lit.

Visual, ecological and archaeological mitigation is proposed which includes proposed grassland planting and new woodland; retention of existing woodland, wetlands and other vegetation; and offsetting areas where there will be no development. The BESSs will consist of a compound and battery array to allow for the importation, storage and exportation of energy to the National Grid. There will also be areas at Sunnica East Site A and Sunnica East Site B for office and storage facilities for use during the Scheme's operation.

The Scheme will be connected to a new substation extension at the existing Burwell National Grid Substation, using 132 kilovolt (kV) cables buried underground. The cables will run between Sunnica East Site A, Sunnica East Site B and Sunnica West Site A (Grid Connection Route A), and then from Sunnica West Site A to Sunnica West B and onwards to the Burwell National Grid Substation (Grid Connection Route B). The Burwell National Grid Substation Extension will convert the 132kV to 400kV. The 400kV cables will be buried and will connect the Scheme to the existing Burwell National Grid Substation to allow distribution to the national transmission network

The Scheme will have two main access points, one north of Elms Road at Sunnica East B and one south of La Hogue Road at Sunnica West Site A. The main access route to Sunnica West Site A will be via the Chippenham junction of the A11, to the north of junction 38 of the A14. Sunnica East Site B will be accessed via the A11 and B1085. A number of secondary access points are proposed to access the individual land parcels through construction, operation and decommissioning activities.

The Scheme qualifies as a Nationally Significant Infrastructure Project (NSIP) and will require a Development Consent Order (DCO) from the Secretary of State for Business, Energy and Industrial Strategy, due to its generating capacity exceeding 50 MW. This Statement of Need supports the DCO application submitted by Sunnica Limited.

The Scheme is in receipt of a Grid Connection Offer from NGESO for 500MW of Transmission Entry Capacity and where reference is made to the Scheme's proposed capacity in this Statement of Need it should be interpreted as an assumption based on the current design and not a proposed cap to installed generation capacity. The application has stipulated, and proposes to secure in the DCO, parameters for the Scheme, the final design of which will fall within these parameters. Sunnica wishes to be able to take advantage of technological improvements between preparing its application for development consent and it starting to commence development. This may mean that the capacity could increase beyond the existing assumptions and this is acceptable provided that the Scheme remains within the parameters which were set at this stage.

Solar generation is not specifically referred to in the *National Policy Statements (NPS) EN-1* [3] and *EN-3* [4], but this statement has been prepared on the basis that the current NPSs are important and relevant to the determination of this application (see **Section 1.1**). The government remains committed to actively considering other ways in which to encourage industry to accelerate progress towards a low carbon economy [3, Para 1.7.9]. For example, solar is included in the 2021 *Contracts for Difference 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 technologies [5, pp16, 20]. The development timescales, location, and scale of the Scheme, provides a near-term decarbonisation opportunity as well as diversifying supply, and should be afforded significant weight when the Secretary of State considers matters which are important and relevant in his decision making process. This Statement of Need for the development of large-scale solar generation, builds upon the arguments made in the NPS documents to demonstrate why the Scheme is urgently needed at the scale proposed; why the proposed location is highly suited 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.

The case for need is built upon the contribution of the Scheme to the three important national policy aims of:

a. Decarbonisation (Net Zero and the importance of developing at-scale zero-carbon generation assets);

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

c. Affordability.

This Statement of Need includes a description of how decarbonisation has so far been achieved in GB, and where further decarbonisation is required to meet the Net Zero legal requirements. The need to decarbonise further underpins the need for at-scale, urgent delivery of consentable and affordable schemes which make best use of GB’s natural low-carbon energy resources. The nuances of the fundamental arguments made in the 2011 NPSs have progressively shifted over recent years, and government, industry and international attention in the area of decarbonisation continues to grow, despite the significant turbulence caused by the 2020 COVID-19 pandemic to near-term GB power markets. Green infrastructure is set to play both a prominent and essential role in government’s COVID-19 pandemic recovery strategies.

This Statement of Need extends the case made in the NPSs for low carbon generation and reflects emerging 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 respected third parties, to support the Scheme’s case. This Scheme is required to ensure that the UK remains on track through the critical 2020s 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 GB end-use consumers.

The conclusion reached is that a significant capacity of low-carbon solar generation is urgently needed in the UK, and that developing the Scheme as proposed will be an essential near-term step in meeting that urgent need and the government objectives of delivering sustainable development to enable decarbonisation. By doing so, the Scheme will contribute to addressing the climate change emergency that affects everyone's lives and the environment, by ensuring our energy supply is secure, low-carbon and low-cost. The Scheme's contribution to addressing the need for new renewable energy should be afforded significant weight when the Secretary of State considers matters which are important and relevant in his decision making process.

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1 The National Policy Statements

1.1 Establishing the basis provided by the existing NPSs

1.1.1 The NPSs were established against obligations made as part of the *Climate Change Act 2008* (CCA2008) – see **Section 2.1**. The overarching *National Policy Statement for Energy (NPS) EN-1* [3] sets out national policy for energy infrastructure in England and Wales. It has effect, in combination with *NPS EN-3 (for renewable energy infrastructure)* [4] and *NPS EN-5 (for electricity networks)* [20], on recommendations made by the appointed Examining Authority (ExA) to the SoS for BEIS on applications for energy developments that fall within the scope of the NPSs [3, Para 1.1.1]. *NPS EN-1*, when combined with the relevant technology-specific energy NPS, provide the primary basis for decisions by the SoS. The NPSs set out a case for the need and urgency for new energy infrastructure [1, Paras 3.3.1 & 3.3.15]. The urgency of the need 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*. Further, the NPSs set out a case for new energy infrastructure to be consented and built with the objective of supporting the government's policies on sustainable development, by:

1.1.1.1 Mitigating and adapting to climate change; and

1.1.1.2 Contributing to a secure, diverse and affordable energy supply. [4, Para 1.3.1]

1.1.2 The NPS for renewable energy infrastructure covers those technologies which, at the time of publication in 2011, were technically viable at generation capacities of over 50MW onshore and 100MW offshore. Critically, solar is not included within the scope of the current NPS as at that time it was not proven at scale. However, government is actively considering other ways in which to encourage industry to accelerate progress towards a low carbon economy [3, Para 1.7.9] and the Scheme should be considered in the light of that encouragement and change to proven ability of solar to deliver and contribute at scale. This document therefore extends the analysis of needs as contained in the NPS documents to large-scale solar technology. It parallels those arguments made for NPS-relevant technology and extends them to demonstrate, firstly, that large-scale solar is now technically and economically feasible, and secondly, that large-scale solar can and will deliver benefits for the UK. These benefits manifest in terms of the technology's contribution to the UK's legal decarbonisation targets; improvement in security of overall electricity supply; and improvement in the affordability of electricity for consumers.

1.1.3 The arguments made in 2011 have shifted as a result of a growing urgency (informed by developing scientific opinion and evidence) to reduce carbon emissions globally and locally; and the progress made by other low-carbon technologies and initiatives which were expected to deliver a low-carbon electricity system but which are currently falling behind in delivering against that expectation.

1.1.4 The government has determined that the NPSs should be reviewed and in its December 2020 Energy White Paper [21], government signalled a review of the existing National Policy Statements, issuing draft versions *of NPS EN-1* and *NPS EN-3* for consultation on 6th September 2021 [102, 103]. While the draft *NPS EN-1* confirms that the "Secretary of State has decided that for any application accepted for examination before designation of the 2021 amendments, the 2011 suite of NPSs should have effect in accordance with the terms of those NPS." [102, Para 1.6.2] the same document also states that "any emerging draft NPSs (or those designated but not having effect) are potentially capable of being important and relevant considerations in the decision-making process" [102, Para 1.6.3]. **Section 1.3** therefore contains a synthesis of the 2021 *Draft National Policy Statements EN-1* and *EN-3* and shows that the demonstration of need for the Scheme as set out in this Statement of Need is consistent with the updated policy contained within the revised NPSs.

1.1.5 This Statement of Need therefore extends the analysis contained in the NPSs to cover low-carbon solar generation against today's climate, security of supply and cost of generation. It parallels those arguments made for NPS-relevant technology and extends them to demonstrate: firstly, that there is now an even greater need for solar technology (as a renewable source) in GB than there was in 2011; secondly, that large-scale solar is now technically and economically feasible; thirdly, that large-scale solar can and will bring benefits for the UK; and fourthly that integration technologies will play an essential role in full decarbonisation of the whole GB energy system, enhancing the benefits brought by low-carbon generation. These benefits 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.

1.1.6 The NPSs set out, for England and Wales, the national case for NSIP energy projects and establish the need for certain types of infrastructure, as well as identifying potential key issues that should be considered by the decision maker. S104 of the *Planning Act (2008)* makes clear that where an NPS exists relating to the development type applied for, the SoS must have regard to it. In this case, the Energy NPSs do not expressly refer to solar generation and so it is considered that the application will be determined under S.105 of the Planning Act 2008 (cases where no national policy statement has effect). While the NPSs do not provide specific policy in relation to solar development, this Statement of Need has been developed on the premise that the policies set out in *NPS EN-1*, *EN-3* and *EN-5* apply and should be considered as 'important and relevant' matters for the decision maker determining the application under the powers set out in S.105 of the *Planning Act (2008).* The urgent national need for energy generating stations set out in both *NPS EN-1* and *EN-3* means that significant weight should be attributed to the Scheme's ability to contribute to meeting that urgent need.

1.1.7 The transitionary provisions in the draft NPSs [102, 103] mean that although they will not directly be applicable to the Scheme, they may remain an important and relevant matter for the SoS to consider under S.105 of the Planning Act 2008.

1.1.8 Policies within NPSs *EN-1 (Energy)*, *EN-3 (Renewable Energy Infrastructure)* and *EN-5 (Electricity Networks)* are important and relevant to this proposal. The policies which are of particular relevance and importance to this examination are set out in **Section 1.2**.

1.2 Synthesis of National Policy Statements EN-1 and EN-3, 2011

1.2.1 At the time the NPSs were published, scientific opinion was that, to avoid the most dangerous impacts of climate change, the increase in average global temperatures must be kept to no more than 2 °C. Global emissions must therefore start falling as a matter of urgency [3, Para 2.2.8].

1.2.2 The energy NPSs were intended to speed up the transition to a low carbon economy and help the UK to realise its climate change commitments sooner than would a continuation under the current planning system [3, Para 11.7.2]. They recognise that moving to a secure, low carbon energy system to enable the UK to meet its legally binding target to cut greenhouse gas emissions by at least 80% by 2050, compared to 1990 levels, is challenging, but achievable.

1.2.3 This would require major investment in new technologies to electrify heating, industry and transport, and cleaner power generation [3, Para 2.2.1]. Under some 2050 pathways, electricity generation would need to be virtually emission-free, because emissions from other sectors were expected still to persist [3, Para 2.2.6]. Consequently, the need to electrify large parts of the industrial and domestic heat and transport sectors, either directly or by using intermediary energy vectors, will significantly increase electricity demand by 2050 [3, Para 2.2.22].

1.2.4 The UK chose to largely decarbonise its power sector by adopting low carbon sources quickly, and invited industry to bring forward many new low carbon developments to meet the twin challenge of energy security and climate change [3, Para 3.3.5].

1.2.5 The NPSs conclude that the UK needs sufficient electricity capacity from a diverse mix of technologies and fuels [3, Para 2.2.20], and therefore the UK also needs all the types of energy infrastructure covered by the NPSs in order to achieve energy security at the same time as dramatically reducing greenhouse gas emissions [3, Para 3.1.1]. **Chapter 3** of this Statement of Need describes the progress made in decarbonisation in the UK to date, and demonstrates that many of the foreseen technologies covered by the NPSs, due either to technological reasons or project development timescales, will not be sufficient to contribute significantly to decarbonisation through the critical 2020s. Thus, applications for development consent for renewable generation infrastructure, whether covered by the energy NPSs or not, should be assessed on the basis that the government has demonstrated that there is a need for such infrastructure and that the scale and urgency of that need is as described within *EN-1* Part 3. Substantial weight may therefore be given to the contribution which projects would make towards satisfying this need when considering applications for development consent under the *Planning Act 2008* [3, Paras 3.1.3, 3.1.4]. The economic feasibility of harvesting sufficient available natural resource at locations well suited to the selected technology, will be an important driver for the proposed locations of renewable energy projects [4, Para 2.6.57].

1.2.6 To hit the target of UK commitments to largely decarbonise the power sector by 2030, 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.

1.2.7 Solar generation is expected to make an important contribution to the UK's renewable energy generating capacity towards 2050, further detail is provided in **Section 6.3**.

1.3 Synthesis of draft National Policy Statements EN-1 and EN-3, 2021

1.3.1 The structure of the NPS suite has not changed in the latest draft documents. Draft *NPS EN-1* sets out the Government's policy for the delivery of major energy infrastructure, and draft *NPS EN-3* covers both onshore and offshore renewable electricity generation. However, given the increasing urgency of action required to combat climate change, the draft NPSs are recognised as being "transformational in enabling England and Wales to transition to a low carbon economy and thus help to realise UK climate change commitments sooner than continuation under the current planning system." [102, Para 1.7.4]

1.3.2 The fundamental need for the large-scale infrastructure, which draft *NPS EN-1* considers, remains the legal commitment to decarbonisation to Net Zero by 2050 in order to hold the increase in global average temperature due to climate change, to well below 2 degrees above pre-industrial levels, as described in **Chapter 2** of this Statement of Need. 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.* [102, Para 2.3.6]

1.3.3 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*. [102, Para 3.3.3]

1.3.4 **Chapter 5** of this Statement of Need comes to the same conclusion, and also recognises that low-carbon generation is already cheaper than fossil fuel generation both in relation to its marginal cost of generation and its Lifetime Cost of Electricity (**Chapter 9**).

1.3.5 Section 3.3 of the draft *NPS EN-1* explains that large capacities of low-carbon generation will be required to:

1.3.5.1 Ensure that there is sufficient electricity to meet increased demand;

1.3.5.2 Replace output from retiring plants;

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

1.3.5.4 Mitigate risks such as unexpected plant closures and extreme weather events.

1.3.6 **Chapters 6 and 7** of this Statement of Need are consistent with the arguments as they have been set out in draft *NPS EN-1*.

1.3.7 Draft *NPS EN-1* articulates the prudence of planning infrastructure development on a conservative basis, including for scenarios in which the future use of hydrogen is limited [102, Para 3.3.11]. **Chapter 3** of this Statement of Need describes the risks associated with the development of nuclear and CCUS technology. Like **Chapter 6** of this Statement of Need, draft *NPS EN-1* concludes that there is an urgent need for new electricity generating capacity to meet our energy objectives. Further, "a secure, reliable, affordable, net zero consistent system in 2050 is likely to be composed predominantly of wind and solar" [102, Para 3.3.31]. **Chapters 6 and 7** of this Statement of Need align with draft *NPS EN-1* and conclude that all low-carbon generating technologies are urgently needed to meet government's energy objectives by:

1.3.7.1 Providing security of supply;

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

1.3.7.3 Ensuring the system is net zero consistent.

1.3.8 In noting the crucial national benefits of increased system robustness through new electricity network infrastructure projects, draft *NPS EN-1* also recognises the particular strategic importance this 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 a target of 40GW of offshore wind by 2030 … and the requirement for sustained growth in the capacity of onshore wind and solar in the next decade.* [102, Para 3.3.21]

1.3.9 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. Draft *NPS EN-1* goes on to provide that:

> *The Secretary of State should consider that the need for a new connection or network reinforcement has been demonstrated if the proposed development represents an efficient and economical means of: connecting a new generating station to the network; reinforcing the network to accommodate such connections; or reinforcing the network to ensure that it is sufficiently resilient and capacious (per any performance standards set by Ofgem) to reliably supply present and/or anticipated future levels of demand*. [102, Para 3.3.55]

1.3.10 **Chapter 8** of this Statement of Need demonstrates that the proposed connection point is suitable and no adverse operability effects are anticipated as a result of connecting (power flows, available transmission connection capacity, proximity to demand centres, etc).

1.3.11 Draft *NPS EN-1* includes that much of the electricity infrastructure to support Net Zero is anticipated to be required to enable the continued development of large-scale capacity which will connect at the transmission level and **Section 7.6** of this Statement of Need aligns on this point. This is “because connection of large-scale, centralised electricity generating facilities via a high voltage transmission system enables the pooling of both generation and demand, which in turn offers 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.” [102, Para 3.3.14]

> *Government does not believe [decentralised and community energy systems] will replace the need for new large-scale electricity infrastructure to meet our energy objectives” although it is recognised that they make an important contribution to meeting national targets on reducing carbon emissions and increasing energy security.* [102, Para 3.3.13]

1.3.12 In relation to integration technologies, draft *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*. [102, Paras 3.3.16&17]

1.3.13 Draft *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. The local and national services which storage assets can provide are also referenced in *EN-1*, being “peak shaving” constraint management and the provision of a range of balancing services [102, Para 3.3.25]. 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 the infrastructure required to generate low-carbon power, and produce, store and transport hydrogen to where it is needed [102, Paras 2.3.5-2.3.7]. **Chapter 10** of this Statement of Need provides additional and consistent arguments for the need for electricity storage and hydrogen and therefore justification for the inclusion of electricity storage technology within the Scheme.

1.3.14 *Draft NPS EN-3* covers nationally significant renewable energy infrastructure which includes solar photovoltaic (PV) at >50 MW in England and >350MW in Wales [103, Para 1.6.1].

1.3.15 *EN-3* re-iterates the contribution that solar generation is expected to make to achieving Net Zero targets:

> *Solar farms are one of the most established renewable electricity technologies in the UK and the cheapest form of electricity generation worldwide. 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 and at little to no extra cost to the consumer. The government 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. [103, Para 2.47.1]

1.3.16 With the further development of large capacities of intermittent low-carbon generation, *EN-3* foresees that:

There will be an increasing need for storage infrastructure to balance electricity supply and demand [103, Para 2.38.2]

1.3.17 BEIS suggest anticipated levels of land efficiency for solar generation, this recognises 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, generally 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, although this can vary significantly depending on the site and is also expected to change over time as the technology continues to evolve to become more efficient. [103, Para 2.47.2]

1.3.18 Draft *NPS EN-3* lists Irradiance and site topography as key inputs to site selection. This Statement of Need aligns with the draft *NPS EN-3* position on these points. The suitability of the location and design of the Scheme, including the scale of the Scheme and critical aspects relating to the selection of the proposed location, is addressed in **Section 6.4** of this Statement of Need.

1.3.19 Grid connection, and in particular the likely proximity of schemes to suitable connection points on the transmission network, is also addressed, and is also consistent with **Section 6.4** of this Statement of Need:

The applicant may choose a site based on nearby available grid export capacity. Locating solar farms at places with grid connection capacity enables the applicant to maximise existing grid infrastructure, minimise disruption to local community infrastructure or biodiversity and reduce overall costs. [103, Para 2.48.12]

1.3.20 The degradation of solar efficiency over time is addressed in draft *NPS EN-3* [103, Paras 2.48.8 and 2.49.9] and is referenced in **Sections 9.2** and **10.4** of this Statement of Need (for solar and for storage respectively):

Solar panels typically have a design life of between 25 and 30 years, although this can sometimes be longer, and can be decommissioned relatively easily and cheaply. Solar panel efficiency deteriorates over time and applicants may elect to replace panels during the lifetime of the site. [103, Para 2.49.9]

2 The United Kingdom has a legal commitment to decarbonise

This chapter sets out the obligations of the *Climate Change Act 2008*, against which the NPSs (2011) were established. It then outlines the UK's 2019 legally binding commitment to achieving Net Zero carbon emissions by 2050, against which the need for future electricity generation developments should be assessed.

2.1 Climate Change Act 2008

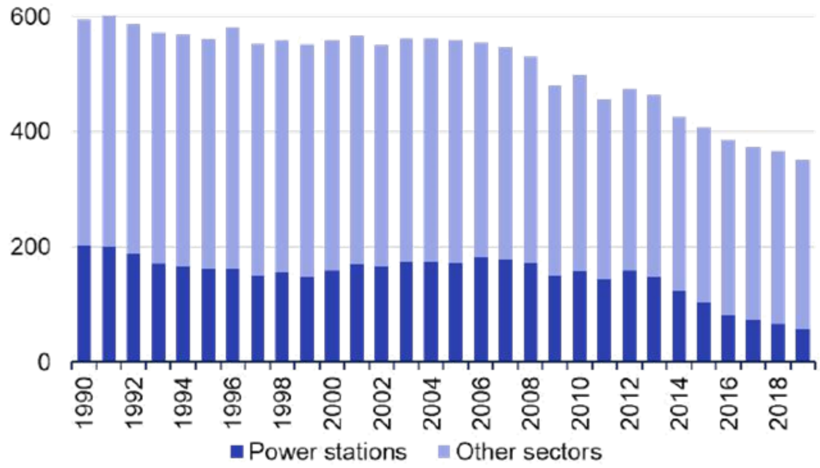

Figure 2-1: UK greenhouse gas emissions, 1990 – 2019 (provisional). [6, p9].

2.1.1 The government, through the *Climate Change Act 2008* (CCA2008), made the United Kingdom[2] the first country in the world to set legally binding carbon budgets, aiming to cut emissions (versus 1990 baselines) by 34% by 2020 and at least 80% by 2050, "through investment in energy efficiency and clean energy technologies such as renewables, nuclear and carbon capture and storage" [18, Five Point Plan].

2.1.2 CCA2008 is underpinned by further legislation and policy measures. Many of these have been consolidated in the *UK Low Carbon Transition Plan* [18], and *UK Clean Growth Strategy (2017)* [22]. A statutory body, the Committee on Climate Change (CCC), was also created by CCA2008, to advise the United Kingdom and devolved governments and Parliaments on tackling and preparing for climate change, and to advise on setting carbon budgets. The CCC reports regularly to the Parliaments and Assemblies on the progress made in reducing greenhouse gas emissions. The UK government has set five-yearly carbon budgets which currently run until 2037, the process for setting the sixth carbon budget having concluded in April 2021. The UK has met its first and second carbon budgets and is currently on track to outperform the third (2018 to 2022) – partly attributable to

[2] The commitment to decarbonise extends across the United Kingdom of Great Britain and Northern Ireland. Northern Ireland is interconnected with the mainland power system through interconnectors but is operated under a different electricity market framework. Therefore, hereinafter we refer to Great Britain (GB) in relation to electricity generation and transmission, and the UK, to refer to the nation which has legally committed itself to Net Zero carbon emissions by 2050.

effective policy, but also attributed to changes in the applicable Emissions Trading Scheme(s) and the impact of COVID-19 on emissions [2, p435].

2.1.3 Up to 2019, the UK has made progress with its carbon reduction obligations, as shown in **Figure 2-1**, through significant reductions in the power, industry, and waste sectors. CCA2008 obligations translate to a total emissions target of ~550 $MtCO_2e$ in 2020, and ~ 165 $MtCO_2e$ in 2050. The main driver of UK carbon reduction to date has been the GB power generation sector. Overall carbon intensity from GB power generation has fallen significantly in recent years, with (virtually) carbon-free generation (wind, solar, hydro, bioenergy, and nuclear) accounting for around 62% of electricity generation in 2020 [104]. CCA2008 committed the UK to sourcing 15% of its total energy (across the sectors of transport, electricity, and heat) from renewable sources by 2020 and new projects were expected to need to continue to come forward urgently to ensure that this target was met. Government projections made in 2011 suggested that by 2020 about 30% or more of GB electricity generation – both centralised and small-scale – could come from renewable sources, compared to 6.7% in 2009 [3, Para. 3.4.1].

2.1.4 All industry sectors have important roles to play in decarbonisation, but so far carbon reductions outside of power, industry and waste have been less significant than those achieved within the power sector, as shown in **Figure 2-1**. Electrification of non-power sectors is therefore an important part of the realisation of overall carbon emission reductions. Indeed:

> *Moving to a secure, low carbon energy system is challenging, but achievable. It requires major investment in new technologies to renovate our buildings, the electrification of much of our heating, industry and transport, prioritisation of sustainable bioenergy and cleaner power generation.* [3, Para 2.2.1].

2.1.5 However, the context for the need for greater capacities of low-carbon generation to come forward in GB with pace, has continued to develop since 2018. 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) 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 1ºC 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 action is required. The ambition against which CCA2008 was established has been extended, and the targets for carbon emissions reduction have tightened.

2.2 Net Zero: UK government's climate change policy enhancement

2.2.1 In response, in May 2019, the CCC published *Net Zero: The UK's contribution to stopping global warming*. [24]. This report recommended that government extend the ambition of CCA2008 past the delivery of net UK greenhouse gas savings by 80% from 1990 levels, by 2050. The CCC recommended that "The UK should set and vigorously pursue an ambitious target to reduce greenhouse gas emissions (GHGs) to Net Zero by 2050, ending the UK's contribution to global warming within 30 years." The CCC believe that this recommendation is "necessary [against the context of international scientific studies], feasible [in that the technology to deliver the recommendation already exists] and cost-effective", reporting that "falling costs for key technologies mean that . . . renewable power (e.g. solar, wind) is now as cheap as or cheaper than fossil fuels". Importantly, the CCC recommendation identifies a need for low-carbon infrastructure development which is consistent with the need case set out in *NPS EN-1*, but points to an increased urgency for action.

2.2.2 In June 2019, the government announced the laying of a statutory instrument in Parliament, which amended CCA2008, in order to implement the CCC's recommendation into law. The UK thus became the first major economy to pass laws to end its contribution to global warming by 2050. In the same month, the CCC also reported to Parliament that "UK action to curb greenhouse gas emissions is lagging behind what is needed to meet legally-binding emissions targets" [25]. Despite having met its first and second carbon budgets and being on track to outperform its third (2018 – 2022), the UK is not on track to meet its fourth (2023 – 2027) or fifth (2028 – 2032) carbon budgets. Recognising the need for progress in decarbonisation to continue, the CCCs recommendations for a sixth carbon budget, running from 2033-2037, which were accepted by government in April 2021 and were enshrined in law in June 2021, included measures which, when delivered, will result in a 78% reduction in UK territorial emissions between 1990 and 2035, in effect, bringing forwards the UK's previous 80% target by nearly 15 years [2, p5, 100].

2.2.3 **Figure 2-1** illustrates the reduction in carbon emissions from GB electricity generation which has been achieved since 1990. Despite this reduction, the CCC's position is that extending the ambition of CCA2008 is not credible unless decarbonisation progresses with far greater urgency than currently exists. The CCC's June 2020 report to government stated that:

> *To reach the UK's new Net Zero target emissions will need to fall, on average, by around 14 MtCO$_2$e every year, equivalent to 3% of emissions in 2019. As the existing carbon budgets were set on a cost-effective path to achieving an 80% reduction in UK greenhouse gas emissions by 2050, a more ambitious long-term target is likely to require outperformance of the carbon budgets legislated to date*. [26, pp52-53].

2.2.4 Consistent with the NPS, the UK's pathway to a successful 2050 carbon budget must involve wider transitions outside of the GB power generation sector: decarbonisation of transport, industry, agriculture and the home, and utilisation of alternate energy vectors to enable the decarbonisation of traditionally hard-to-reach sectors remains required to reduce non-power sector emissions. The CCC agree that decarbonisation progress must occur not only within the electricity generation sector, but also in other sectors which use energy, including low-carbon heating systems in the built environment, and the electrification of transport, with most sectors needing to reduce emissions to close to zero by 2050 for the Net Zero target to be achieved. The CCC anticipate a future of "extensive electrification, particularly of transport and heating, supported by a major expansion of renewable and other low-carbon power generation". Government's *Industrial Decarbonisation Strategy* (March 2021) confirms that decarbonising UK industry is a core part of the ambitious plan for the green industrial revolution, built on the expectation that emissions will need to reduce by at least two-thirds by 2035 and by at least 90% by 2050 [27, p8]. **Chapter 5** includes a more detailed analysis of this topic. Continuing as we are, simply put, is not enough.

The increased electrification of primary energy use will double down on the requirement to reduce carbon emissions from electricity generation even further than that which has already been achieved, for example, government are targeting around 20TWh per year of fossil fuel demand switching to low carbon fuels by 2030 [27, p8]. Therefore, to deliver carbon savings, it is vitally important to ensure that GB can meet an increased demand for electricity in a secure way, with a significantly lower carbon intensity even than current levels. The decarbonisation of GB's electricity generation assets is therefore of vital importance in meeting the UK's legal obligations on carbon emissions.

2.2.5 The Energy Systems Catapult (ESC) was set up to accelerate the transformation of the UK's energy system and ensure UK businesses and consumers capture the opportunities of clean growth. The ESC is an independent, not-for-profit centre of excellence that bridges the gap between industry, government, academia, and research. In March 2020, the ESC's *Innovating to Net Zero* report observed that:

> *Net Zero narrows the set of viable pathways for the future energy system. Where an 80% target allowed considerable variation in relative effort across the economy, with some fossil fuels still permissible in most sectors, Net Zero leaves little slack*. [8, p5]

2.2.6 ESC analysis [8, pp23, 27] anticipates that the decarbonisation of other sectors will require at least double today's electricity demand by 2050, all of which must come from zero-carbon sources. Coupled with NGESO's own forecasts of the requirement for electricity generated from low-carbon sources in GB (see **Section 5.1**) ESC's analysis leads to the conclusion that, for the UK to achieve Net Zero, all available low-carbon resource and infrastructure developments must be brought forward at pace: the power generation sector must both increase in capacity and reduce in carbon intensity on an unprecedented scale.

2.3 UK demonstrating leadership on climate action

2.3.1 Government policy on climate change does not stop at our national borders, indeed since 2010, government has included within its policy actions, "driving ambitious action on climate change at home and abroad" [3, Para 2.2.3]. In this regard, the CCC states:

> *Whether the world achieves the long-term temperature goal of the Paris Agreement will depend on the actions of other countries alongside the UK. A large-scale shift in investment towards low-carbon technologies is needed and emissions need to stop rising and to start reducing rapidly. Falling costs for key technologies mean that the future will be different from the past: renewable power (e.g. solar, wind) is now as cheap as or cheaper than fossil fuels in most parts of the world.* [28, pp83-84]

> *More rapid electrification must be accompanied with greater build rates of low-carbon generation capacity, accompanied by measures to enhance the flexibility of the electricity system to accommodate high proportions of inflexible generation. While key renewable options look increasingly like they can be deployed without subsidy, this does not mean they will reach the*

necessary scale without continued government intervention (e.g. continued auctioning of long-term contracts with subsidy-free reserve prices) [28, p178]

2.3.2 Further, the CCC set out an ambitious course for the UK to lead, internationally, in climate change mitigations and actions:

The UK has the strongest record of emissions reduction in the G20 over the last decade, and over a longer period back to 1990. [26, p13]

UK domestic climate ambition can be the basis for UK international leadership in 2021, in the Presidency of the delayed UN climate summit in Glasgow (COP26) and in the G7 Presidency. [26, p16]

2.3.3 At the end of June 2020, the Prime Minister set out his vision that the UK would lead in markets and technologies. He committed to backing the vision of the UK becoming a global leader in developing batteries and said that the UK would lead in long-term solutions to global warming such as solar, wind, nuclear, hydrogen and carbon capture and storage [29]. The Energy White Paper supports a quadrupling of low-carbon power generation by 2050.

2.3.4 In July 2020, government made commitments to support the transition from natural gas to clean hydrogen power, and to scale up carbon capture and storage, by providing £350M funding for a “green recovery supercharge.” Such an endeavour is necessary for the decarbonisation of heavy industry, construction, space and transport sectors. This funding has been announced in support of meeting the Prime Minister’s goal of leading the most ambitious environmental programme worldwide [30].

2.3.5 In August 2020, government announced funding for several green infrastructure development and innovation projects [31], further evidence of government’s continued backing of the sector and its support for organisations to make decisive contributions to support the UK leading international development in this field.

2.3.6 In August 2020, the National Infrastructure Commission (NIC) issued a report stating that:

The latest analysis for the Commission suggests that 65 per cent of Britain’s electricity could be delivered from renewables by 2030 with no material change in cost when compared to the Commission’s previous recommendation to deliver 50 per cent renewables. [32, p5]

2.3.7 Importantly, the CCC make recommendations for BEIS to “deliver plans to decarbonise the power system to reach an emissions intensity of 50 gCO_2/kWh by 2030, with at least 40GW of offshore wind and a role for onshore wind and large-scale solar power, with a clear timetable of regular [Contract for Difference] auctions” [26, Table 4].

2.3.8 In November 2020, the Prime Minister published his ten-point plan, which to a degree responds to the CCC’s recommendations, including the aim to “create, support and protect hundreds of thousands of green jobs, whilst making strides towards net zero by 2050”. [44] The urgent need for large capacities of low-carbon generation is clear, and momentum is building from varied independent experts, in support of the nation’s drive, capability and capacity to lead the world in decarbonisation. The CCC write:

The signs point to a propitious moment for global climate ambition in Glasgow next year. But our international leadership, in the Presidency of COP26 and of the G7, must begin at home. Our influence in the wider world rests ultimately on strong domestic ambition. [2, p6]

2.3.9 And government agrees with this advice:

The actions we take as a result of this white paper, as part of our wider climate agenda, are intended to show leadership and vision and demonstrate to our partners around the world that now is the time to take the bold steps to tackle climate change. The UK is leading from the front in the transition to clean energy, while ensuring that we leave no one behind as we build back greener. [21, p2]

The UK is the world's first major economy to present a net zero Industrial Decarbonisation Strategy ... The UK was also the first major economy to legislate an ambitious net zero target and we are taking a leading role globally in the fight against climate change. Domestically, this is a pioneering agenda, and this government will continue to seek ambitious targets and collaboration from other countries ... through the UK's presidency of COP26 ... in November 2021. [27, p6].

2.3.10 On announcing the adoption of the CCC's recommendations for the sixth Carbon Budget in April 2021, the UK set the world's most ambitious national climate change target into law. An address by the Prime Minister at the opening session of the US Leaders' Summit on Climate, hosted by US President Joe Biden and held on Earth Day (22nd April 2021) urged countries to raise ambition on tackling climate change and join the UK in setting stretching targets for reducing emissions by 2030 to align with Net Zero.

2.3.11 The Scheme presents a significant opportunity to take a further step forward in the UK's fight against climate change, and in the transition to a diverse supply mix of clean generation. The consent of the UK's first large-scale solar park at Cleve Hill, granted in May 2020, demonstrates that large-scale solar in the UK is consentable due to the significant decarbonisation and supply diversification benefits the technology class brings forward. But, as subsequent chapters of this Statement of Need establish, solar technology is an essential element of the future generation mix, and more large-scale solar parks will be required in GB for the UK to meet its Net Zero obligations. The opportunities for siting and connecting large-scale solar in GB are limited, therefore feasible opportunities for solar development should benefit in the planning balance from the full weight of the benefits they bring to UK and global climate needs, in order to maintain pace and scale with UK legal requirements. The proposed location for the Scheme presents a highly suitable solution for the efficient delivery of solar at scale over timeframe which will provide significant decarbonisation benefits (see **Chapter 8**) and the Scheme is therefore an essential step in the development of the portfolio of solar generation required. The Scheme will make a valuable contribution to adopted UK government policy and the achievement of world-leading decarbonisation commitments.

3 Progress against the Low Carbon Transition Plan

> The *UK needs to wean itself off such a high carbon energy mix: to reduce greenhouse gas emissions.* [3, Para 2.2.6]
>
> *The Overarching National Policy Statement on Energy EN-1 sets out how the energy sector can help deliver the government's climate change objectives by clearly setting out the need for new low carbon energy infrastructure to contribute to climate change mitigation.* [3, Para 2.2.11]
>
> *It is for industry to propose new energy infrastructure projects within the strategic framework set by government.* [3, Para 3.1.2]

In 2011, approximately 75% of GB's electricity came from carbon-based fuels; and contributed over a third of UK greenhouse gas emissions. Since then, carbon emissions from electricity have reduced, but mainly through measures other than those which were anticipated as part of the *Low Carbon Transition Plan*.

3.1 Progress to date in achieving emission reductions in the UK

3.1.1 **Figure 2-1** shows the trend in reductions in carbon emissions in the UK, including from GB power generation, since 1990. Power sector reductions have been achieved through many initiatives and circumstances, including:

3.1.1.1 Electricity volumes generated from coal and gas fired plants has reduced. The Large Combustible Plant Directive (aiming to improve air quality but also having significant carbon reduction benefits) required the clean up or time-limited operation of coal-fired power generation prior to 2016. Between 2012 and 2015, at least 11.5GW of coal plant decommissioned because of the Directive. Further, in late 2017, government announced a commitment to a programme that will phase coal out of all electricity generation by 2025, brought forward following BEIS' December 2020 consultation to 2024 [21, p41]. National carbon pricing ensures that coal assets have unfavourable marginal costs (see **Section 9.1**) and are therefore dispatched only when necessary. In June 2020, GB ended a record run of not generating any electricity from coal for 1,630 consecutive hours – the longest period since the 1880s, and less than 4TWh was generated from coal during 2020, down from 20TWh in 2017 and 75TWh in 2015. In 2019, many asset operators announced the closure of their coal generation assets. Just one coal station (Ratcliffe, 2.0GW) now remains commercially operational with four other units (two at West Burton A and two at Drax, with a combined generation capacity of 2.2GW) responding to system stress events only since October 2021 and until their closure before October 2022 [Author Analysis].

3.1.1.2 GB's second-generation nuclear fleet (9GW) has continued to operate significantly past its original decommissioning dates. Despite recent availability issues at some older stations, nuclear provided 16% of electricity demand in 2020 with low carbon emissions [104], however the decommissioning of existing plants commenced in 2021. Advances in new nuclear plants to replace the existing fleet have been slower than was originally envisioned (see **Section 3.4**).

3.1.1.3 Low carbon variable generation, predominantly wind and solar, has been deployed to GB grid more quickly and more widely than originally projected.

3.1.2 The GB electricity market is complex with long-term price uncertainty. Within it, multiple players are developing assets in response to market signals rather than because of a centrally coordinated asset development program [33, p80], and therefore are favouring technologies which have short development timescales, generate Net Zero consistent carbon-free electricity and have low development and operational costs – such as solar power.

Table 3-1: Historical capacities of renewable generation deployment and sites under scoping / application / construction (GW). Adapted from [15, 16, 17, 101]

<table>
<tr><th>Technology</th><th>January 2011</th><th>October 2021</th><th>Projects under application / construction</th></tr>
<tr><td>Solar</td><td>0.0</td><td>13.3</td><td>4.9[3]</td></tr>
<tr><td>Embedded Wind</td><td>1.7</td><td>6.5</td><td>0.4[4]</td></tr>
<tr><td>Onshore Wind</td><td rowspan="2">3.8</td><td>6.0</td><td>11.1</td></tr>
<tr><td>Offshore Wind</td><td>10.8</td><td>55.8</td></tr>
<tr><td>Total</td><td>5.5</td><td>36.6</td><td>72.2</td></tr>
</table>

3.1.3 Conventional (thermal, dispatchable) plants in GB have closed, but new dispatchable low-carbon plants have not yet opened. By contrast, Renewable Energy Sources (RES, including solar PV, onshore wind and offshore wind) have been deployed because of the subsidy frameworks available to them, and are continuing to be deployed because of their cost-competitiveness in relation to other, more traditional methods of electricity generation.

[3] Includes projects which are listed on each Distribution Network Operator's *Embedded Capacity Registers* [101] but which are not yet commissioned, and NGESO's TEC Register [15].
[4] Includes projects which are listed on the Renewable Energy Planning Database [16], less those which are listed on NGESO's TEC Register [15]

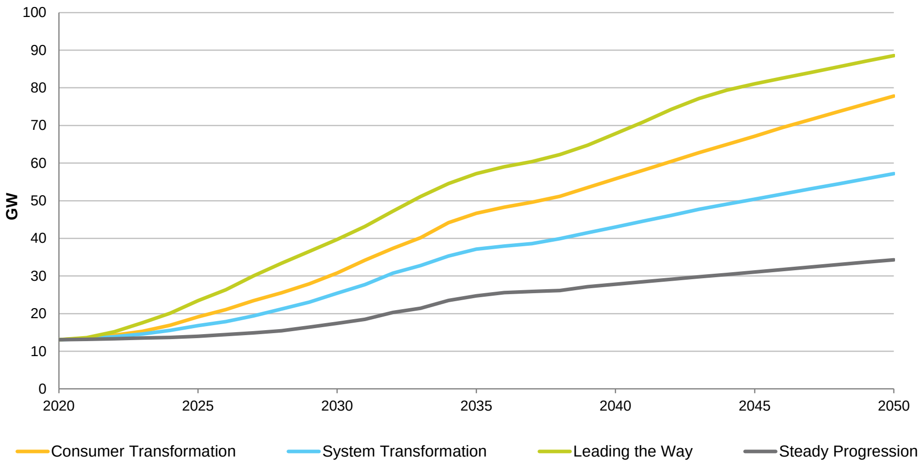

Figure 3-1: FES solar capacity evolution scenarios [104, Figure SV.31]

3.2 Action during the 2020s will be critical to meet the 2050 Net Zero target

3.2.1 In an address to the opening session of the US Leaders' Summit on Climate, hosted by US President Biden on Earth Day (22nd April 2021), the Prime Minister urged countries to follow the UK in raising their ambitions on tackling climate change, and to join the UK in setting stretching targets reducing emissions by 2030 to align with Net Zero. Strong and swift action in the critical 2020s is needed to keep the UK – and other countries – on track to meet the commitments to which they agreed by signing the Paris Agreement. [100]

3.2.2 The timescales for building out new, large-scale generation schemes are generally long. Many schemes being planned today may not generate their first MWh of carbon-free electricity for a further 5 or more years. Solar generation assets sit at the shorter end of this range. Steps taken to re-engineer established industrial processes are also taken over years, not months. However, the need for decarbonisation grows stronger each year because every year during which no action is taken, more carbon is released into the atmosphere and the global warming effect accelerates. Therefore, early action will have a correspondingly more beneficial impact on our ability to meet the 2050 targets than will later action. Furthermore, potential future schemes of any technology which have not yet been confirmed cannot be used as a reason not to consent other schemes – such as this Scheme – which meet the urgent need for action, because the risk of non-delivery of such future schemes would place at significant risk, the UK's ability to decarbonise sufficiently in order to meet those 2050 targets. In June the International Energy Agency (IEA) issued a call to arms on energy innovation, stating that "[The] world won't hit climate goals unless energy innovation is rapidly accelerated ... About three-quarters of the cumulative reductions in carbon emissions to get on [a path which will meet climate goals] will need to come from technologies that have 'not yet reached full maturity.'" [34] DNV GL expressed this observation in a different way: "measures today will have a disproportionately higher impact than those in five to ten years' time" [35].

3.2.3 Recalling from **Chapter 2** that the UK's pathway to a successful 2050 carbon budget must involve wider transitions outside of the power generation sector, implies also that the power generation sector must first decarbonise to enable the successive decarbonisation of transport, industry, agriculture, and the home. NGESO analysis suggests that to meet Net Zero, emissions from the electricity generation sector must be reduced to below zero in the early 2030s, as shown in **Figure 3-2**. The scale and pace of change required within this sector, to meet that target, is immense, and any delays incurred now, make the challenge increasingly more difficult for the years ahead. Because the lead times associated with solar development and construction are generally short, solar is well placed to deliver low-carbon power against timeframes which will be incredibly beneficial to the UK's climate goals.

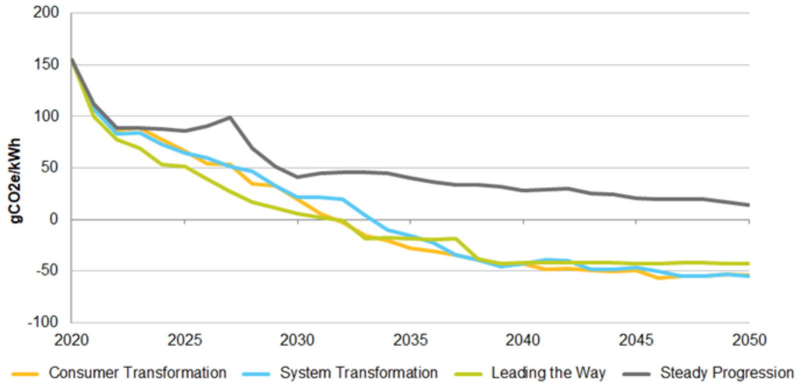

Figure 3-2: Power generation emissions must reduce to negative in the early 2030s to meet 2050 Net Zero targets [104, Figure SV.27]

3.2.4 The *Industrial Decarbonisation Strategy* clearly states the objective for the 2020s, which "will be crucial ... to lay the bedrock for industrial decarbonisation. Over the next decade ... the journey of switching away from fossil fuel combustion to low carbon alternatives such as hydrogen and electrification [will begin, alongside] deploying key technologies such as carbon capture, usage and storage". [27, p6]

3.2.5 In conclusion, to address the ongoing climate emergency, it is critical that the UK develops a large capacity of low carbon generation, and it is critical that this development occurs urgently – in the near-term and not just later – to facilitate wider decarbonisation actions. It is also important for schemes with long development timescales to continue progressing their plans to achieve carbon reduction in decades to come. Schemes with the proven ability to achieve savings in this decade, and even more importantly in the early part of this decade, must be consented. It is these schemes which are most critical to keeping the UK to its required carbon reduction path. An actual, potential or aspirational pipeline for longer term low-carbon generation schemes presents additional opportunity for future decarbonisation, but does not present a valid argument against consenting and developing schemes with proven deliverability, short timescales and dependable decarbonisation benefits. The Scheme is a viable proposal, with a strong likelihood of near-term deliverability, which will achieve significant carbon reduction benefits through the deployment of a proven, low-cost technology in a very suitable location. 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 gains in carbon reduction.

3.3 Many technologies foreseen in the Low Carbon Transition Plan are unlikely to reduce carbon emissions during the critical 2020s

3.3.1 It is important to clarify that this report does not seek to justify or promote the exclusion of any generation technologies other than solar power from the future GB generation mix.

3.3.2 **Table 3-2** shows elements of the government's *Low Carbon Transition Plan* (LCTP) made in 2009, which were expected to make significant contributions to reducing the carbon intensity of electricity generation. A current status on these initiatives is also included. While several of the major initiatives detailed in the LCTP have not yet delivered, the power generation sector is currently on track with its carbon reduction targets. This has provided a major contribution to the UK's current "on track" performance versus its legal decarbonisation obligations and has been delivered predominantly by the closure of the existing coal fleet as well as an increase in renewable generation capacity.

3.3.3 NGESO's *Future Energy Scenarios* (FES) 2020 and 2021 [7, 104] both describe three pathways involving radical change across many industry sectors, which will deliver the required 100% reductions in carbon emissions by 2050. 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. The National Infrastructure Commission (NIC)[5] stated in their first *National Infrastructure Assessment* report in 2018 [36] that:

> *New nuclear power plants and carbon capture and storage infrastructure will not be built by the private sector without some form of government support.* [36, p38]

3.3.4 FES 2012 [37] estimated that between 5GW and 14GW of Carbon Capture Usage & Storage (CCUS) could be operational (across coal, gas, and biomass plant) by 2030. One of the biggest challenges with CCUS at the time of writing the LCTP, was that while each stage – capture, storage, and transport – had already been shown to work, it had never been tried at a commercial scale on a power station and never the complete process from start to finish. As of April 2021, Grid-scale CCUS from power generation has not yet been proven in Europe[6]. CCUS technology has not yet progressed to industrial scale, and no new large-scale carbon generating power stations with CCUS capability have yet been constructed in GB. Government do not foresee that CCUS will make any significant contributions to carbon reductions in GB until the 2030s [41 and 26, p115].

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[5] NIC was established in 2015 to provide independent, impartial advice on the UK's long-term infrastructure needs

[6] Only two large-scale CCUS for power generation are currently operational (Boundary Dam (Canada) and Petra Nova (USA) [38] with only 20 projects in use across all sectors and worldwide [39].

3.3.5 The UK chose to largely decarbonise its power sector by adopting low carbon sources quickly but remained cognisant of the advantages to the UK of maintaining a diverse range of energy sources so avoid dependency on a particular fuel or technology type [3, Para 3.3.5], thus the continuation of support for CCUS through the 2010s. The NIC concluded in their 2018 assessment of national infrastructure [36], that CCUS would only become useful for decarbonisation of the electricity generation sector in the 2040s and beyond, when the decarbonisation and adequacy of electricity generation must already have been largely achieved to support decarbonisation in other sectors. A 2020 update to NIC's analysis [40] proposes CCUS be utilised with bioenergy to generate power at negative emissions or produce hydrogen. Crucially the NIC presented CCUS as an alternative to nuclear generation rather than as a substitute for RES capacity.

3.3.6 The Prime Minister included within his Ten Point Plan, an ambition to develop 'world-leading technology to capture and store harmful emissions away from the atmosphere, with a target to remove 10 million tonnes of carbon dioxide by 2030.' [44]

3.3.7 Until as recently as 2019, government did not foresee that CCUS would make any significant contributions to carbon reductions in the UK until the 2030s [41, 42, p115] however recent progress has been made in the development of industrial CCUS, including plans to capture up to 10m tonnes of CO_2 by the end of this decade [21, p17]. A separate project plans to take industrial European CO_2 and store it (also under the North Sea), locking in 8m tonnes each year (0.2% of Europe's 2017 emissions), again by the mid-2020s [43]. The common thread between these consortia is that they are led by traditional, integrated oil majors, representing significant capital availability, prior asset ownership and technical experience: therefore, a strong credibility in their approach, and, one might argue, a critical need for success. However, in aggregate, these flagship European projects represent less than 1% of Europe's 2017 CO_2 emissions. A significant pipeline of projects, commissioning in incredibly quick order, will be needed for CCUS to become a significant support to decarbonisation efforts in Europe before the mid-2030s. The Prime Minister included UK CCUS projects focussed around industrial clusters predominantly in the north east within his ten-point action plan, setting out an ambition to develop "world-leading technology to capture and store harmful emissions away from the atmosphere, with a target to remove 10 million tonnes of carbon dioxide by 2030" [44]. CCUS is prominent in the *National Infrastructure Strategy* (2020), *Energy White Paper* (2020) and *Industrial Decarbonisation Strategy* (2021). CCUS remains regarded as essential for Net Zero, to decarbonise dispatchable power plants, decarbonise industry, produce low-emissions hydrogen and deliver greenhouse gas removal technologies. However, such benefits will materialise if and only if projects become operational in time. Recognising that 'the technology has not been delivered at scale and significant risks remain' government has committed to:

3.3.7.1 Invest £1 billion to bring forward four CCS clusters by the end of the decade, with two to begin construction by the mid 2020s;

3.3.7.2 Set an ambition to capture 10 megatons of carbon dioxide per year by 2030; and

3.3.7.3 Outline further details on new business models and revenue mechanisms to attract private sector investment. [1, p53]

3.3.8 Wave / Tidal power has been proposed at several locations in the UK, although wave technology development has experienced both cost and operational challenges [45]. Early predictions on future rollout of wave / tidal power showed varying levels of ambition, ranging from 0.5GW to 4.5GW by 2030 [37, p54]. Tidal power remains complicated to consent, and expensive to deliver, a position made clear by governments' rejection of the Swansea Bay Tidal Lagoon in June 2018 [46].

3.3.9 Nuclear power has attracted significant government attention over the last decade, including plans for 16GW of new build capacity by 2030, described in the 2013 *Nuclear Industrial Strategy* [47]. One new nuclear project (Hinkley Point C) is under construction and others either remain in their development phases or have been abandoned. The potential contribution made by new nuclear will be discussed more fully in **Section 3.4**.

3.3.10 In summary, despite recent commitments from government to providing continued support for both technologies, neither nuclear power nor carbon capture and storage are likely to play a significant role in furthering decarbonisation before the 2030s due to the delivery risk and timing constraints associated with both. The significance to the achievement of Net Zero 2050, of decarbonisation during the 2030s is set out in **Section 3.2**.

3.3.11 Solar power generation has global momentum and large-scale schemes are already being developed in GB. With this context, the attractiveness of solar, a proven technology which will deliver significant benefits to consumers through decarbonisation, security of supply and affordability this decade, becomes clear. 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. 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, and this is consistent with the approach described by government in draft *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. [102, Para 3.3.11]

3.3.12 The role that solar has played in decarbonising GB's electricity generation to date is transparent within **Table 3-2**. Solar has undergone significant technological advances in scale and efficiency, and the UK has many areas of high solar irradiation and land which is available for non-agricultural use. 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.

3.3.13 Solar generated 11.7TWh of power in 2019. this increased to over 12.1TWh in 2020 [Author analysis from NGESO market data]: an important contribution to national demand. Solar is well placed to play the role that recent government papers have ascribed to it: [1, p43], and **Chapter 7** and **Chapter 9** of this report expand on the reasons behind this statement. The Scheme should therefore be recognised for the critical contribution it will make to the UK's journey to Net Zero.

Table 3-2: Projections from 2009 for a low carbon power sector, summarised from [18, 11, 68]; and a 2021 status [Author analysis]

Initiative	Projection	Status at October 2021
New Nuclear	2013: construction of new nuclear commences. 2018: first new nuclear operational (of up to 16GW fleet).	2017: Hinkley Point C construction commenced, with a Commercial Operation Date currently estimated during 2026. 2018: Government advised to permit only one more GW+ nuclear project before 2025. [36, pp10,42] 2019/20: Two GW+ scale nuclear projects (Wylfa & Moorside) abandoned by their proposed developers. 2020: Energy White Paper is consistent with NIC advice [21, p16] 2020/21: End of life announced for 4 GW of existing nuclear, in 2021 (1 GW), 2022 (1 GW) and 2024 (2 GW), and one station (1 GW) enters decommissioning.
Wave / Tidal	2014: Larger-scale wage and tidal energy generation (>10MW) to be deployed.	2021: No larger wave or tidal energy generation yet to be deployed. The second Severn Estuary / Swansea proposal was denied public funding in 2018.
CCUS	2020: Up to 4 CCUS demonstration projects operational in the UK.	2021: No CCUS projects yet operational in GB. Business model blueprints published in 2021, two industrial clusters progress with project development. [1, p53]
Renewable Energy Share	2020: Around 30% of electricity is generated from renewable sources.	2020: Wind, solar, hydro, bioenergy accounted for 44% of generation. Nuclear accounted for 16%. 2020: NIC conclude that 65% of GB's electricity could be delivered from RES [36]; the CCC highlight the need for 75 - 90GW of solar capacity in the UK by 2050 [2, Table 3.4.a].

3.4 The potential contribution from nuclear power in the UK to reduce UK carbon emissions in the critical 2020s.

3.4.1 Nuclear currently provides the largest capacity of dispatchable low-carbon power generation and therefore is an incredibly important operational generation technology in the context of decarbonisation. Nuclear has historically met approximately 20% of GB demand. For the time being, nuclear continues to generate approximately a one-fifth share of demand, but existing nuclear is close to the end of its life. At the date of writing this report, Dungeness B (1 GW) has closed and firm closure dates have been set for a 2 GW of nuclear capacity during 2021 (Hunterston) and 2022 (Hinkley Point B). A further 2 GW (Heysham 1 and Hartlepool) will close during 2024. New nuclear projects are ongoing, one under construction and others at various stages of development, but it is clear that new nuclear will not be built out at the appropriate rate and scale so to allow it to continue to contribute a one-fifth share of GB demand through the 2020s and into the 2030s. Further, the scale of nuclear's contribution to decarbonisation beyond the 2030s cannot be relied upon at this time, because of the lack of projects currently confirmed. It is therefore important to set out and assess the projected contribution of nuclear power to the reduction of UK carbon emissions within the context of current policy and project developments.

3.4.2 Any contribution new nuclear power may make to the GB power mix is, except for Hinkley Point C (3.2GW, forecast at the time of writing this Statement of Need to commission in 2026), highly likely not to commence earlier than the mid-2030s. With 4GW of existing nuclear now slated to close in 2024 or earlier, the low carbon electricity generated by nuclear power during the 2020s will reduce year-on-year, as operational capacity reduces from today's levels before new assets come online to replace them.

3.4.3 It is therefore vitally important that other deliverable, fundable, affordable and beneficial technologies are consented as a priority, to keep pushing carbon reductions lower. This directly strengthens the importance of current government policy on market-led developments of low-carbon generation from diverse sources of power, including solar, to meeting the UK's Net Zero legal commitments.

3.4.4 The 2019 BEIS consultation on new nuclear financing [48] includes statements on forecast energy growth and the importance of renewable generation (alongside nuclear) in meeting that demand:

> *Meeting Net Zero will require emissions from the power sector to be reduced to low levels and the deployment of negative emissions technology to offset emissions from those sectors that cannot be completely decarbonised. It is likely that electricity demand will grow significantly by 2050 as other sectors of the economy such as transport and heat are electrified, potentially nearly doubling (or more) from today's levels. To meet this increasing demand, whilst reducing emissions to low levels, there will need to be a substantial increase in low carbon generation – the Committee on Climate Change estimate a four-fold increase may be needed. This is at a time when seven out of eight of our existing nuclear power plants – important contributors to our low carbon generation – are due to come offline by 2030 as they reach the end of their operational lives. As the cost of renewable technologies such as solar and offshore wind continues to fall, it is becoming clear that they are likely to provide most of our low carbon generating capacity in 2050.* [48, p7]

3.4.5 The author concludes that while the door remains open for nuclear to make contributions to low-carbon generation in the 2040s and beyond, the decommissioning in the next four years of much of the existing nuclear fleet creates a gap in low carbon generation which must be closed. The risk associated with achieving financial close on new nuclear developments and the long timeframes associated with these developments, mean that the possibility of new nuclear schemes coming forward should not be relied upon to deliver Net Zero. Fundable and deliverable schemes, which use proven technologies to generate low-carbon electricity at scale, should be brought forwards with urgency to make tangible and essential advances in decarbonisation in the near term. This Scheme is needed in the UK to keep us on course in our fight against climate change precisely because it is fundable and deliverable. Developing the scheme as planned, will ensure that the UK remains on track through the critical 2020s 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 GB end-use consumers. The delivery timing associated with current forward nuclear capacity projections strengthen this conclusion.

Nuclear projects have long development timeframes.

3.4.6 A series of government white papers and consultations through 2007/8 was precursor to an enabling framework for a UK nuclear renaissance. Over the subsequent 5 years, government removed successive barriers to nuclear development. This covered: site selection (the *National Policy Statement for Nuclear Power Generation*); regulatory approval of reactor designs (the *Generic Design Assessment* (GDA) process); and revenue and back-end cost certainty (the *Contract for Difference* (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. These policy instruments clearly signalled that the UK was open to nuclear business and that it was now for commercial entities to bring new nuclear to market. The process which needs to be followed however is neither easy, nor short.

3.4.7 From a regulatory perspective, the GDA of a reactor is a voluntary process undertaken by the ONR taking 4–5 years to complete and may be applied for ahead of an application[7] for a Nuclear Site Licence (NSL). GDA gives a clear indication of whether the design would meet safety, security, and environmental regulatory requirements, and simplifies the necessary NSL and Planning Consent applications. The site-specific NSL is granted by ONR, who may take up to 18 months to assess the capability and resources of the applicant organisation, the site safety case, and other site-specific factors. Planning consent should be quicker having secured GDA approval, assuming appropriate and successful community consultation has taken place.

3.4.8 Aside from achieving these consents, the applicant must confirm its commercial arrangements. There are potentially three main agreements: Shareholder investment agreements (if the applicant is a JV); the CfD or equivalent commercial arrangement which provides increased revenue certainty for the applicant; and the Secretary of State Investor Agreement (providing protection for the applicant and (ultimately) consumers, against significant changes to project economics or market arrangements). Once secured, the real task of digging dirt and pouring concrete can begin. During construction and commissioning, the NSL

[7] ONR may take up to 18 months to assess the capability and resources of the applicant organisation, the site safety case and other site-specific factors.

introduces at least 5 separate hold points. These may only be moved past when consent has been granted by the ONR.

3.4.9 The development timeline for the Hinkley Point C project (currently under construction and currently forecast by its developer to commission in 2026) has been illustrated in **Figure 3-3**.

Figure 3-3: HPC Timeline [Author analysis]

Progress in the development of new nuclear projects

3.4.10 Hinkley Point C (HPC) is currently under construction in the UK by an EDF Energy / China General Nuclear (CGN) partnership: Nuclear New Build Generation Company (NNB). The technology employed will be a UK EPR, designed by EDF and Areva. The GDA process commenced in 2007, and nuclear significant (as opposed to earthworks) construction commenced in late 2018 – a project development timeframe lasting 11 years.

3.4.11 HPC construction has been impacted by the COVID-19 pandemic, but construction milestones for the second reactor were achieved in line with the anticipated schedule (securing schedule gains to progress of 30% to date versus the first reactor [49]). In January 2021, the Commercial Operation Date (COD) was reforecast back by six months to summer 2026 [50, 51, 52].

3.4.12 In 2016, the Low Carbon Contracts Company signed a CfD with NNB for the Hinkley Point C project, guaranteeing power price for a 35-year term. Since signing this agreement, there has been a shrinking appetite for another HPC-style CfD contract in the UK energy market, and a growing view that a different approach is needed.

3.4.13 Government's *Energy White Paper*, published in December 2020, sets the scene for further nuclear development in GB and confirms through their summary of responses received to the 2019 *Regulated Asset Base for nuclear* (RAB) consultation, indicate 'that a RAB model remains credible for funding large-scale nuclear projects' [21, p49].

3.4.14 Sizewell C (SZC), also EDF/CGN, is progressing through its development phase. A project aiming to build the third and fourth UK EPR, SZC may proceed through planning, consenting and construction more rapidly than HPC, once funding mechanisms have been agreed. EDF have formally stated that: "the [SZC] project does not currently have a timeline ... although construction work could overlap with Hinkley Point C", SZC "will take 9-12 years to build"[8]. SZC has unofficially been forecast to come online in the early 2030s [50]. In December 2020 government confirmed that it is to enter negotiations with EDF in relation to the

[8] https://www.edfenergy.com/energy/nuclear-new-build-projects/sizewell-c/about

Sizewell C project as it considers options to enable investment in at least one nuclear power station by the end of the current Parliament (no later than May 2024).

3.4.15 CGN have taken the lead on the Bradwell B project. GDA on their reactor design started in 2017, with conclusion anticipated in 2021 / 2022. No indications of intended project timelines have been published by the developer, however an assessment of the potential earliest commercial operation date for this reactor, based on development durations of other projects, may be in the mid/late 2030s.

3.4.16 Two other large-scale new nuclear projects have folded without securing agreement to proceed. The first to be abandoned was Moorside, Cumbria. Toshiba planned to develop three Westinghouse AP1000 reactors, commissioning from 2026 onwards. In March 2017, the failure in the US of two AP1000 developments which were unable to keep pace with time and cost schedules, came to a head. This directly resulted in Westinghouse (a Toshiba-owned subsidiary) filing for Ch. 11 bankruptcy in 2017. International AP1000 construction experience outside of the US has also been challenging with four AP1000s finally achieving Commercial Operation in China (Sanmen and Haiyang) at the end of 2018 after a construction duration of approximately 9 years for each reactor: more than twice their initial planned durations. A divestment of the UK project was at that time all but inevitable. Unable to find a new owner (both CGN (China) and KEPCO (South Korea) were reportedly interested in the site for their own technologies, but neither signed a deal) Toshiba announced their withdrawal from the project in November 2018. While the AP1000 remains an approved technology (having secured GDA in March 2017) the earliest possible commission date for any large-scale new nuclear at Moorside would be highly unlikely before the mid/late 2030s, if at all.

3.4.17 The second, more recent, abandonment was Wylfa Newydd, Anglesey, Wales. Hitachi, the parent owners of Horizon Nuclear Power, were until recently developing a project to construct and operate two ABWRs[9]. The ABWR is not a new reactor design: four Japanese plants have already commenced operation, and more are under construction internationally. Critically, each of the completed reactors were built in less than 5 years. The ABWR received its GDA in late 2017; secured many of the necessary EA permits through 2018; and commercial discussions started with Government on funding arrangements in June 2018.

3.4.18 Horizon's forecast commissioning date for Wylfa remained at or around 2026 throughout the project development process, however commercial conversations with Government concluded without agreement in January 2019, prompting Hitachi to announce a suspension of the project under grounds of "economic rationality as a private enterprise." [53] Horizon withdrew its application for DCO on 16th January 2021, effectively closing the current chapter of potential nuclear development at Wylfa, citing a lack of "any definitive proposal" to transfer Wylfa to an alternative developer.

3.4.19 Wylfa Newydd was seen by many as the brightest light in world of UK new nuclear. Because Horizon was only trying to do something that has successfully been done before, their progress had been swift and their proposition compelling. Certainly, given momentum and past history, commissioning Wylfa Newydd in the

[9] Advanced Boiling Water Reactor

2020s remained a distinct possibility. Following the DCO withdrawal however, the earliest possible commission date for new nuclear at Wylfa would now be highly unlikely before the mid/late 2030s as any new proposals will effectively be starting afresh. At the time of writing this report, government has been reported as discussing with developers the very early stages of plans to build the Westinghouse AP1000 at Wylfa[10].

3.4.20 Government remains committed to ensuring all technologies have a part to play in the future energy mix, providing that they offer value for money for consumers. Nuclear power can achieve this through either the delivery of larger projects (see **Paras 3.4.31 – 3.4.34**) or Small Modular Reactors (SMRs). SMRs aim for cost improvements through the production of multiples of units rather than an increase in scale. In 2015, the Energy Technologies Institute (ETI) published a report into the enabling framework required to realise such a vision. This included a "manufacturing line" capability to deliver efficiency and accuracy in the modular construction techniques. Their analysis showed (for a more conventional water-based reactor design) a minimum 17-year development timeframe from the initial design concept through to commissioning of the first production unit. ETI do note that some SMR concepts may already have progressed along this timeframe [54, p6].

3.4.21 The earliest delivery of any first of a kind (FOAK) SMR scheme is therefore not likely to be before the mid-2030s, and the roll out of subsequent next of a kind (NOAK) schemes highly contingent on a large number of technical, commercial and environmental factors. Government's *Industrial Decarbonisation Strategy* aspires to have the first SMRs commercially deployed in the UK in the early 2030s, with an operational AMR[11] demonstrator deployed at the same time [27, p73], although ETI consider that the timeframe for delivery may extend by up to 9 years for more evolutionary designs. A global leading design, the American NuScale SMR, plans its first US installation by 2030 [55], three years later than previously planned. NuScale is at the front of the global race to develop and deploy SMR technology.

3.4.22 In July 2020, government announced a £40 million kick start to develop the next generation of nuclear energy technology, supporting three AMR projects, which use less conventional technologies with longer design timeframes than anticipated in the ETI report. Meanwhile, a consortium approach to the development of a conventional SMR is being undertaken. No design has yet been submitted for Generic Design Assessment in the UK, but the GDA process has been readied for the potential of SMR applications and it opened in 2021 [21, p50].

3.4.23 The 2020 *National Infrastructure Strategy* confirms government's continued support for the development of nuclear technologies:

> *The government will provide up to £525 million to bring forward large-scale nuclear and invest in the development of advanced nuclear research and development (R&D), including up to £385 million in an Advanced Nuclear*

[10] https://www.thetimes.co.uk/article/multibillion-pound-plan-to-build-uk-nuclear-power-plant-grkqchkh7, see [109]
[11] Advanced Modular Reactors use novel cooling systems or fuels and may offer new functionalities (such as industrial process heat).

Fund for small modular reactors and advanced modular reactors. This is alongside £220 million for nuclear fusion. [1, p52]

3.4.24 The most recent possible indicator for the potential role of nuclear within a future energy landscape appears in the CCC balanced Net Zero pathway for electricity generation, which states that: "Despite retirements of existing nuclear plants in the 2020s, this scenario sees new nuclear projects restore generation to current levels by 2035. The Balanced Pathway reaches 10GW of total nuclear capacity by 2035, with 8GW of new build capacity" [2, p135], implying that Hinkley Point C, and a combination of at least one other large-scale project and some small modular reactors must be operational before 2035 to meet the levels of decarbonisation recommended for the sixth carbon budget. It is the author's view that this pathway is already at risk, but that low-carbon generation schemes, such as this Scheme, which utilise proven and deliverable technologies and have short construction timeframes, are capable of making real and tangible contributions to closing the generation gap left by retiring nuclear in the timeframes required to maintain the progress required in the 2020s and beyond, towards UK decarbonisation.

3.4.25 The *National Infrastructure Strategy* does not go as far as to indicate a target capacity for future nuclear technology, stating only that "government is pursuing large-scale nuclear projects, subject to clear value for money for both consumers and taxpayers and all relevant approvals". The *Energy White Paper* sets out government's commitment to aim 'To bring at least one largescale nuclear project to the point of Final Investment Decision by the end of this Parliament, subject to clear value for money and all relevant approvals' [21, p16].

Decommissioning GB's existing nuclear power stations

3.4.26 By their initial lifetime expectations, almost all of the UK's existing reactors should by now have closed, however successive lifetime extensions have kept them running for longer than expected. Current operator expectations for plant closure dates for the Advanced Gas-Cooled Reactor (AGR) fleet are displayed in **Figure 3-4**.

3.4.27 In June 2021 EDF energy announced that Dungeness B (1 GW), would move immediately to defueling and decommissioning: the first of the AGR fleet to close. Further life extensions are looking less possible at the AGR, as graphite cracking in the core of the two oldest stations (Hunterston B and Hinkley Point B) has also caused operator EDF Energy to announce the closure of Hunterston B in December 2021 / January 2022 and of Hinkley Point B in June/July 2022. Hartlepool and Heysham 1 will follow by 2024.

3.4.28 Therefore, just two stations will remain operational in the AGR fleet post 2024 (Torness, Heysham 2): a total generation capacity of c. 2.4 GW, until 2030 at the latest.

3.4.29 The UK's only Pressurised Water Reactor, the 1.2GW Sizewell B is currently scheduled to close after 40 years operation, in 2035, but 20-year life extensions to PWRs are globally commonplace.

A synthesis of new nuclear commissioning date projections

3.4.30 The conclusion of the narrative in this section is illustrated in **Figure 3-5**, which shows that capacity from current and committed new nuclear projects (at the time of writing: only HPC) will reduce from now until 2030. Without a significant and immediate drive from government to commit to further nuclear projects, nuclear capacity will most likely remain lower than current levels until the mid 2030s. Therefore, although nuclear will play an important role in the generation of low carbon electricity through the 2020s, the contribution it will make to achieving Net-Zero will be lower in each year from 2023 until at least the mid 2030s than is currently the case. This gap must be made up.

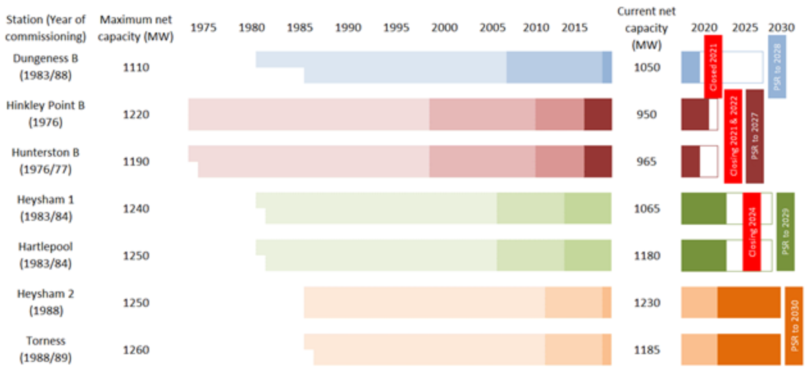


Figure 3-4: Generating capacities and announced closure dates for each AGR station [Author analysis of data sourced from www.edfenergy.com]

3.4.31 The commitment by government to specific nuclear projects which start to deliver some of the growth scenarios illustrated in **Figure 3-5** will, if secured, provide additional confidence to the role that nuclear generation will be able to play in the journey to Net Zero, however these commitments have not yet been made and therefore subsequent nuclear developments remain at risk. The Prime Minister's November 2020 plan for green recovery includes the ambition to "Push nuclear power as a clean energy source and include[s] provision for a [i.e. one] large nuclear plant, as well as for advanced small nuclear reactors" [44]. The CCC sixth carbon budget models nuclear capacity to be between 5GW and 10GW by 2035 and maintained within that range through to 2050 [2, p135 and Table 3.4.a].

3.4.32 Although nuclear will continue to play a role in the generation of low carbon electricity through the 2020s, the contribution it will make to achieving Net Zero will be lower in each year from 2021 until HPC comes online, then continue to drop until such time as any second project which may have secured funding commissions (mid 2030s). Uncertainty remains both with existing nuclear remaining lifetimes, and with development timescales for new projects. When compared to the confirmed projection of nuclear capacity, many forward scenarios look to include very optimistic ranges. Each year that goes by without concrete action to develop new projects reduces the achievability of these scenarios, as well as increases the possibility of availability reductions in the existing fleet. The deficit in low-carbon generation caused by the decommissioning of existing nuclear power without equivalent nuclear projects replacing it is more likely to grow than shrink and must therefore be made up for by other low-carbon generation technologies. Other low carbon generation projects, such as solar and wind, which have short timeframes for consenting, financing and construct, will play a critical role in decarbonisation even if any longer-term nuclear plans come to fruition.

3.4.33 This analysis is relevant to the Scheme, because of the importance of urgently bringing forward significant capacities of deliverable low carbon power with urgency. Draft *NPS EN-1* articulates the government's prudent view that infrastructure development should be planned on a conservative basis [102, Para 3.3.11], without over-relying yet to be proven technologies, technologies with long development lead-times, or technologies which have historically experienced funding difficulties.

3.4.34 Solar generation is needed in the UK to keep us on course in our fight against climate change precisely because it is a fundable and deliverable technology. The Scheme itself is fundable and deliverable and therefore consenting the Scheme such that it will be able to be developed as planned, will be a critical contribution to bringing the UK closer to its required track through the critical 2020s to meet its legally binding carbon emissions reduction targets.

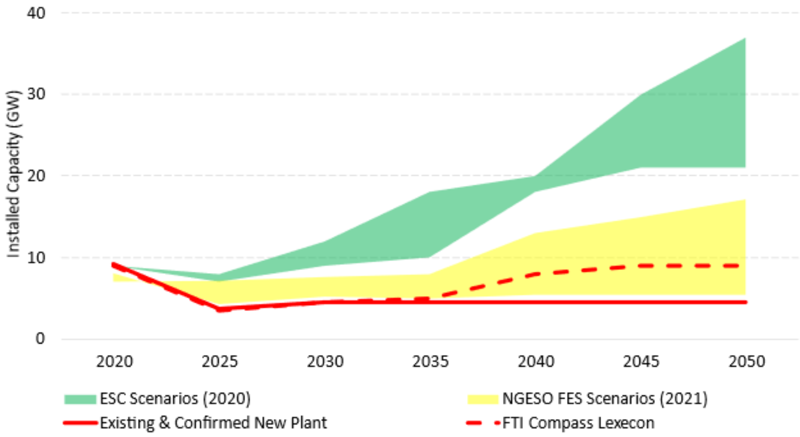


Figure 3-5: Projections of current nuclear capacity as existing stations close. Source: [7, 8, 9, Author Analysis, www.edfenergy.com]

4 Recovery from COVID-19

> *As nations move out of the shadow of coronavirus and confront the challenge of climate change with renewed vigour, markets for new green products and services will spring up round the world.* [21, p4]

Government has consistently shown its commitment through the 2020 COVID-19 pandemic, to build back greener in order to tackle climate change and stimulate economic recovery. During the Summer 2020 COVID-19 lockdown period, power demand and power price were significantly down year-on-year. The threat of significant long-term effects remains present, lockdown impacts potentially feeding through into a weak economy resulting in a high risk of industrial and commercial business closures. However, although the fight against climate change requires urgent action, it also requires sustained action over a long timeframe, and government have begun a strategy of “build back stronger” through “fairer, faster, greener” investment [1]. The near-term impacts of the COVID-19 pandemic are therefore not anticipated to negatively impact the continued development of long-term energy infrastructure assets, rather the national need to make long-sighted investments now which support a green recovery from 2020’s difficult times is anticipated to support energy infrastructure investments. The *Energy White Paper* puts in place a strategy for the wider energy system that:

a. Transforms energy, building a cleaner, greener future for our country, our people and our planet; and

b. Supports a green recovery, growing our economy, supporting thousands of green jobs across the country in new green industries and leveraging new green export opportunities [21, p4].

4.1 GB electricity demand since summer 2020

4.1.1 Electricity demand in GB dropped during lockdown as industry shut down to contain the virus. Headline reports were of major reductions in demand with more severe impacts on year-on-year movements in gas and electricity prices.

4.1.2 **Figure 4-1** shows the raw trends in electricity demand and the major fuel markets by comparing the percentage change in average value by month in 2020 and 2021 with the monthly average value for the same month in 2019. The data shows that at the height of the first UK lockdown, average demand dropped 20% year-on-year; that gas dropped in price by over 60%, power price by nearly 50% and carbon (EUA) price by 20%. As lockdown restrictions gradually lifted through August and September, market levels rose again, and prices since September 2020 were higher than they were in 2019.

4.1.3 Fuels and power prices have responded to global shifts in supply and demand, UK power responding to global gas and coal prices, and the price placed on carbon through the European Emissions Trading Scheme, and since May 2021 the UK Emissions Trading Scheme. At the time of writing this report, all three charted commodities are trading at all-time high levels.

4.1.4 Through a weekly Operational Forum, NGESO estimated that demand has been tracking within 2% of 2019 actuals since November 2020, a trend continued into December despite a second lockdown. Just months after the first lockdown, and arguably during the second, industry found new ways to adapt to lockdown measures, and life has adapted to a ‘new norm’ which is anticipated may be quite different to the ‘old norm’ in many ways. Only our collective actions over the coming months and years will determine exactly how; and forward forecasts are varied with wide differences between ‘high’ and ‘low’ scenarios.

4.1.5 An illustration of the short-term effect of the pandemic on projected UK demand is shown in **Figure 4-2**, which illustrates data published by consultancy EY. Their published analysis (dated March 2021) forecasts a drop in electricity demand during 2021 and 2022 (relative to a pre-pandemic baseline forecast). Beyond 2023 however, EY now expect that electricity demand will increase more rapidly than their pre-pandemic projections, as a result of deeper and more accelerated electrification, particularly across heat and transport, in response to the climate crisis and government’s policy response.

4.1.6 There are two critical points arising from this analysis. Firstly, although as a result of the pandemic, UK electricity demand is currently down in comparison to recent history, the need for and delivery of a green recovery is expected to return electricity demand to sustainable growth levels within the next year and the pandemic has not damaged the long term prospects for electricity demand to increase significantly in the timeframe to 2050. Secondly, in an increasingly global and volatile commodity fuels market, an increase in the capacity of solar generation will help the UK to increase its indigenous generation and therefore help keep a grip on power prices. **Chapter 9** has further details.

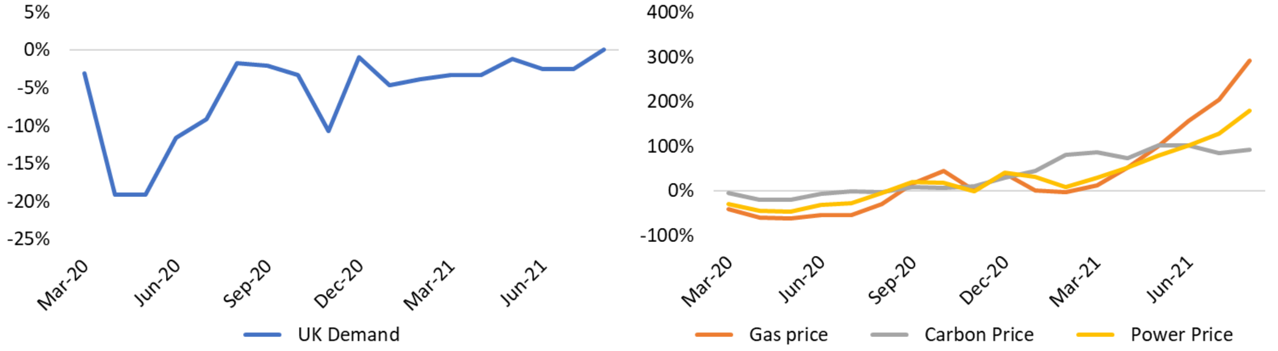


Figure 4-1: Monthly year-on-year change in average absolute levels of demand and gas, carbon and power market levels [Author analysis, from market data]

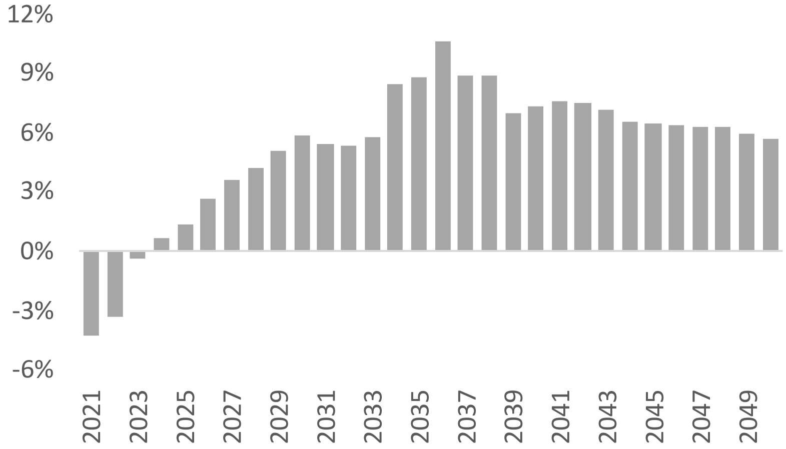


Figure 4-2: EY projections of the potential impact of COVID-19 on future UK Electricity Demand 2021 to 2050 (Change in forecasts dated Mar-21 versus Jan-20) [Author adaption of EY Consulting forecast]

4.2 Environmental health and public health are linked

4.2.1 Researchers have discovered a correlation between air pollution levels and risk of death from COVID-19. High levels of fine particulate pollution (generated largely from fuel combustion from cars, refineries, and power plants) has been linked with risk of death from COVID-19 e.g. [57]. This link having been established, the inter-generational aspect of global warming, used by some to delay making decarbonisation decisions now because of the potential costs of action, which today's economies would have to bear but from which future economies would benefit, would lose its edge. By reducing fine particulate pollution now, almost immediate positive health effects can be brought to today's citizens: a direct cost / benefit relationship which supports the need to decarbonise with urgency.

4.2.2 A study by the Office for National Statistics (ONS) was reported, in August 2020, to have found that "single-unit increase in pollution exposure over long term may increase [COVID-19] death rate by up to 6%" [58]. Along with these findings from the UK and US, Chinese and Dutch studies have also made similar conclusions. Replacing polluting industry with clean air industry, will help keep people alive both now, and in the future.

4.2.3 COVID-19 drove carbon emissions down through a reduction in economic activity and therefore energy requirement. Many environmental indicators were (and remain) up. Skies were clear, pollution haze disappeared, fine particulate pollution reduced. Nature rebounded in many places, and many health indicators also ticked upwards. COVID-19 is an opportunity not to rest on climate ambition, but to reset climate ambition levels higher still. COVID-19, for its many negative and destructive effects, has given an adrenaline shot in the arm to environmental movements.

4.3 Economic and social recovery from COVID-19

4.2.4 In June 2020, the Business, Energy and Industrial Strategy (BEIS) Committee launched an inquiry on *Post-Pandemic Economic Growth*. The inquiry was established to consider all options available to government to secure the UK's economic recovery from the impact of COVID-19, covering investment; industrial strategy; jobs; skills; exports and sustainable growth. The inquiry is likely to examine the measures needed to stimulate economically and environmentally sustainable growth and investigate whether the post-pandemic world presents an opportunity for a resetting of the UK economy and (among other themes) to drive forward progress on broader government priorities including the delivery of green growth and speeding up progress on delivering Net Zero.

4.2.5 In June 2020, the Prime Minister "build better and build greener but also build faster", saying that "the UK would lead in markets and technologies such as net zero planes and long-term solutions to global warming such as solar, wind, nuclear, hydrogen and carbon capture and storage." [29]. By July 2020, government had committed £350m to "supercharging green recovery" [30].

4.2.6 The CCC provided strong direction in both their 2020 and 2021 *Progress Report to Parliament* [26, 105]. They present evidence of how a range of low-carbon and climate adaptation "green stimulus" measures can fulfil both the short-term needs (protecting workers and businesses and rebuilding a greener economy) and long-term needs (investing in key assets to build capacity and enable productive activity in the future) arising from the COVID-19 pandemic [26, p15], and paint the picture of an opportunity to pivot the economy to long-term environmental solutions. A green lung, rather than an iron lung, for the UK.

4.2.7 In November 2020, in anticipation of the publication of government's *Energy White Paper*, Energy Minister Kwasi Kwarteng confirmed that government remained committed to domestic and international efforts to tackle climate change; and explained that government would "Build on [the new energy white paper in 2021] to deliver a stronger greener and more sustainabl[e] economy after the pandemic ... relying on experts ... to drive forward the agenda along our path to net zero" [59]. The Prime Minister's ten-point plan, part of a broader £12bn package of public investment, provides further evidence that government remains focussed on delivering in this important sector [44].

> *Fighting climate change offers huge opportunity for both growth and job creation ... the time is now to seize these opportunities*. [21, p2]

5 Future demand for electricity is growing

> *[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.* [3, 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*. [3, Para 3.3.21]

The annual demand for energy from all sources in GB in 2020 was 1,369TWh, with 19% (258TWh) in the form of electricity [104, Chart CV.1]. While total GB energy demand must reduce significantly by 2050, electricity demand is expected to grow 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. The annual NGESO Future Energy Scenarios (FES) documents provide critical information on these points.

5.1 Expert analysis of the energy sector of the future

5.1.1 The future characteristics of GB's electricity demands are described through a set of possible scenarios developed (through industry consultation) on an annual basis by GB's Electricity System Operator and statutory undertaker, NGESO. This annual publication is called *Future Energy Scenarios* (FES)[12], see [104] for the most recent publication. In completing their work NGESO look at a number of inputs including legislation, policy, technology and commercial drivers. Consumer behaviour is also considered. On their website, NGESO state:

> *All our scenarios consider energy demand and supply on a whole system basis, incorporating gas and electricity across the transmission and distribution networks. We continually develop all aspects of our Future Energy Scenarios process ensuring that the outputs are as rich and robust as possible to provide a sound reference point for a range of modelling activities. This includes extensive stakeholder consultation and detailed network analysis, which enables NGESO to identify strategic gas and electricity network investment requirements for the future.*

5.1.2 FES publications go back to at least 2012 (FES publications specifically referred to in this report have been downloaded for reference). The speed of decarbonisation is a key feature in each edition of the FES since 2018, with three of the four scenarios from both FES 2020 and FES 2021 meeting the 2050 carbon reduction target via distinct pathways, requiring heavy investment in either energy efficiency, or electricity decarbonisation, and/or new or enhanced energy vectors[13] (e.g. hydrogen). In reality these pathways are not mutually exclusive, and government and industry are currently pursuing initiatives which cover both.

[12] National Grid publications specifically referenced in this report have been downloaded for reference
[13] Energy vectors enable energy to be transported or transmitted and then converted back into another form of energy for end (or onward) use

5.1.3 The future scenarios in **Figure 5-1** describe one of the three NGESO 2021 scenarios which meet the 2050 emissions objective (System Transformation), and the one which does not (Steady Progression).

5.1.4 One important development in FES documents since 2019, and as a direct result of the increasing urgency of the requirement to meet Net Zero, is the prominence of a hydrogen economy in those scenarios which meet the 2050 requirement, although hydrogen has for a long time been acknowledged as having potential to facilitate deep and broad decarbonisation by providing “difficult to reach” sectors with access to zero carbon fuels. The relevance of the hydrogen economy, and the potential for hydrogen to play an increasingly important role in the energy ecosystem of the future, is two-fold for the development of the Scheme because the increasing use of hydrogen as a low-carbon energy vector will require an increased production of hydrogen, and an increase in the demand for electricity to produce that hydrogen without carbon emissions.

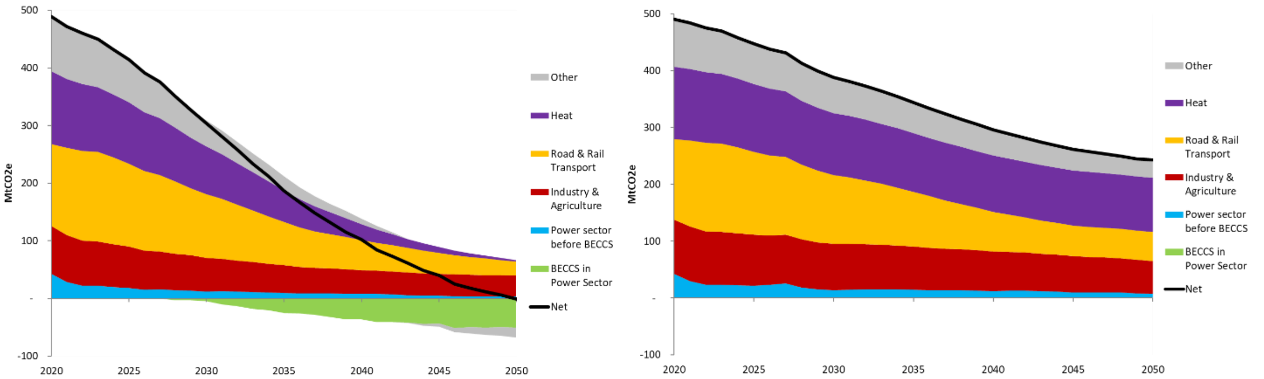
5.1.5 For more information see **Section 10.3**.

5.1.6 The most recent FES [104] brings together future operation of existing generators, and future trends in the demand for energy, to conclude that:

5.1.6.1 Net emissions from the power sector likely must be negative from the early 2030s to achieve Net Zero;

5.1.6.2 Hydrogen and carbon capture and storage are likely to be required to achieve Net Zero, with more than 29TWh of electricity demand required by 2040, and in excess of 95TWh by 2050, for hydrogen production. This is likely to increase the need for low-carbon electricity generation over and above that needed to meet other growth in electrification; and

5.1.6.3 Solar generation is, based on current economics, likely to be one of the cheapest source(s) 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.



System Transformation Steady Progression

Figure 5-1: NGESO scenarios, showing the importance of a whole-society approach to decarbonisation and low carbon electricity generation.
[104, Data sheet, Figures NZ.5]

5.1.7 In March 2020 the Energy System Catapult (ESC) published a report, *Innovating to Net Zero* which summarised the results of an update to their national Energy System Modelling Environment (ESME) [8]. The aim of the analysis was to consider potential pathways to 2050 to support the identification of technologies, products and services which will be most important to achieving the Net Zero target. The ESC's analysis provides a useful independent analysis of the trends described in the FES and therefore provides useful confirmation of some points, while drawing different conclusions on others. The ESC's analysis adds breadth and depth to the consensus of how best to achieve the Net Zero target. Other professional organisations also share their views of future demand and these are discussed in **Section 5.2**.

5.2 Future electricity demand

5.2.1 In the 1990s and early 2000s, GB electricity demand has grown only slowly, but since 2005 has fallen. This trend in underlying demand reduction reflects three drivers:

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

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

5.2.1.3 The introduction of energy efficiency measures, especially more efficient lighting within the last seven years, but also technology development more generally.

5.2.2 Today's view of future GB electricity demand remains uncertain, partly as a result of the COVID-19 pandemic as discussed in **Chapter 4**, but growing, for the same reasons as those stated in the 2011 NPS documents:

5.2.2.1 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;

5.2.2.2 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

5.2.2.3 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.

5.2.3 These observations are consistent with those made by NGESO in their FES 2020 and 2021. Of the four scenarios in these documents, only one (Steady Progression) does not meet Net Zero.

5.2.4 There are many expert projections of GB electricity demand in 2050, and the majority of forecasts are for it to increase (from today's level of circa 300TWh). The amount by which they increase varies according to the level of decarbonisation of non-energy sector demand, and the source for that decarbonisation. For example (see **Section 10.3**) 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 values presented in the following list):

5.2.4.1 The National Policy Statements foresaw a doubling of current demand [3, Para 2.2.22], i.e. to circa 600TWh;

5.2.4.2 NGESO present a range from 388 – 494TWh [104, Chart CV.1];

5.2.4.3 The National Infrastructure Commission forecasts 465 – 595TWh [40, p35];

5.2.4.4 The Energy Systems Catapult forecasts 525 – 700TWh [8, pp23&27];

5.2.4.5 The Q4 2020 EY Power Price Outlook for GB forecasts 485TWh [EY Consulting forecast];

5.2.4.6 The CCC's sixth carbon budget presents a range from 550 – 680TWh [2, Table 3.4.a];

5.2.4.7 The BEIS impact assessment for Carbon Budget 6 (CB6) presents a range from 610 – 900 TWh [106, p29]; and

5.2.4.8 The 2020 Energy White Paper presents a range from 575 – 665TWh [21, p42].

5.2.5 The ESC underpins its scenarios with the premise that "Net Zero requires switching to low carbon technologies wherever we can" including hard-to-treat activities as well as carbon sequestration. Critically the ESC conclude that Net Zero requires society-wide adoption of low-carbon heating and transport technologies as well as continuing to drive "upstream" changes in the electricity mix and reduced energy use in industry [8, p5].

5.2.6 In the ESC scenarios, population growth and societal habits drive underlying demand growth, with either centralised or society-led decarbonisation supporting their demand forecasts. Industrial demand overall is forecast to decrease by between 20% and 30% due to a move away from energy-intensive industry and an adoption of energy efficiency measures wherever possible.

5.2.7 Further similarities between the ESC report and the FES are that a hydrogen economy must be created to decarbonise hitherto "hard to reach" end uses; the production of hydrogen through electrolysis will increase electricity demand; and the transport sector, which also requires fundamental transformation, will need to be a strong adopter of hydrogen (for heavier freight) if emissions are to fall. Other forecasts are closely aligned with these views.

5.2.8 However, it remains 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, including where the use of hydrogen is limited.

5.3 Transport

5.3.1 Surface transport is currently the largest source of UK greenhouse gas emissions (surface transport accounted for 24% of 2019 emissions, [26, p21]) however surface transport emissions fell by 19% [105, p64] year-on-year due predominantly to the COVID pandemic. Emissions are expected to rebound in 2021 as lockdown restrictions have been lifted. A rapid shift to low emission vehicles will give a significant boost to the decarbonisation of our economy.

> *The emissions from passenger cars and light goods vehicles make up over two thirds of all transport emissions, so decarbonising those forms of transport is a priority.* [21, p92]

5.3.2 Growth in the use of electric vehicles (EVs) is expected to create significant new demands on the supply of electricity. The UK government has proposed a ban on the sale of all new petrol and diesel vehicles to be effective from 2030 [44], bringing further forwards a prior indication of 2035. The Prime Minister's November 2020 announcement, confirmed alongside a ban on sales of new hybrid vehicles by 2035 within the *Energy White Paper* [21, p92] brought emerging government policy more into line with the CCC's latest recommendation: that the date for phasing out petrol and diesel cars and vans (including hybrids) should be brought forwards to no later than 2032, with EVs supported by detailed policy arrangements to be able to fill the light transport gap this would create [26, p19]. Innovation is bringing affordable and highly desirable low emission private road vehicles to market, with almost every major brand now sporting a fully electric model, and EV costs are reducing. In September 2020, market frontrunners TESLA unveiled a new EV battery design which "will enable the company to produce a $25,000 electric car in the next three years" [61].

5.3.3 The UK has put leadership of transport revolution at the heart of its *Industrial and Clean Growth* strategies, with investment being directed into electric vehicle manufacturing, battery manufacturing and grid recharging points. In late June 2020, the Prime Minister committed to backing the vision of the UK becoming a global leader in developing batteries for electric vehicles [29]. Specifically, commitments were made to:

5.3.3.1 Make funding available to attract investment in "gigafactories", which mass produce batteries and other electric vehicle components, enabling the UK to lead on the next generation of automotive technologies;

5.3.3.2 Make £10m of funding immediately available for the first wave of innovative R&D projects to scale up manufacturing of the latest technology in batteries, motors, electronics, and fuel cells, and nearly £500m for battery manufacture in the UK; and

5.3.3.3 Provide additional funding to allow the progression of initial site planning and preparation for manufacturing plants and industry clusters, with sites under consideration across the UK, forming part of the government commitment to spend up to £1bn to attract investment in electric vehicle supply chains and R&D to the UK. [62, 63]

5.3.4 These commitments came on top of the over £1bn provided at the Spring Budget 2020 to support the rollout of ultra-low emission vehicles in the UK via support for a super-fast charging network for electric vehicles, and extension of the Plug-In Grant schemes. In late July 2020, the Mayor of London joined with local utilities to announce funding of £1.5bn for infrastructure work, including upgrading utility supply networks and boosting the EV charging infrastructure across the capital [64].

5.3.5 The government regards EVs as a critical new technology, vital in the fight against climate change. The commitments listed above are evidence that there is strong political support for the rapid development and rollout of EVs, and with that will come additional electricity demand. EVs are predicted to play a major part in the future GB electricity mix because of their energy demand requirements (moving from fossil fuels to clean electricity) and potentially also their electricity storage capabilities. Ofgem have announced a plan to “Enable drivers to go electric by supporting an energy network that can power 10 million electric vehicles by 2030” [65, p7] and anticipate that the number of electric vehicles on UK roads may grow from 320,000 at June 2020 [21, p93] to 46 million by 2050 [65, p4]. The FES suggests a more conservative number, due to trends to share cars and increase mileage per car to achieve Net Zero, with scenarios ranging from 20 to 33 million in 2050, but in all increasing annual electricity demand by approximately 100TWh [104, Tables CV.31–35].

5.3.6 Hydrogen is well placed to help decarbonise hard-to-reach sub-sectors of transport (particularly larger, long-haul, road freight vehicles) and is making tangible steps towards mainstream use in this and other transport sub-sectors. In September 2020, the first UK train journey was powered by hydrogen. In the same month, the maiden flight by a hydrogen-powered commercial aeroplane was made [66, 67]. Annual electricity demand from road transport (i.e. incorporating both EVs and vehicles powered by hydrogen) could be 130 – 150TWh in scenarios which meet Net Zero [104, Tables CV.31–33]. This projection is consistent with previous projections from 2019 and 2020 [7, Tables CV.23–26], [60, p77] and [68, p12]. The use of hydrogen in rail and air use will increase these estimates even further.

5.3.7 To support efforts in the decarbonisation of heavy-duty transport, government have pledged to invest £20 million in 2021 in freight trials to pioneer hydrogen and other zero emission truck technologies; and £120 million in 2021/22 to start the delivery of 4,000 zero emission buses. [21, p94]

5.3.8 The ESC scenarios also foresee the decarbonisation of transport as a major influence on future electricity needs, anticipating approximately 35 to 40 million battery EVs on the roads by 2050 and only small numbers of PHEV or hybrid vehicles remaining operational. Hydrogen is anticipated by the ESC to be the major fuel for heavy transport. [8, pp22&25]

5.4 Home and space heating

5.4.1 The UK will need to reduce its dependence on natural gas in order to reduce further its carbon footprint. Gas must be displaced from the built environment to create low- or zero-carbon homes. Heating, cooking and hot water must be decarbonised and commercial properties must follow suit. This will be achieved either indirectly, by using electricity to produce hydrogen for domestic and commercial use, or directly, by electrifying domestic and commercial energy demand. Government's plans for new homes also increase demands on the NETS. For every household that is supplied with electricity, an average additional burden of at least 4MWh per year could be placed on the grid [69, p9]. Projections are that the nation should be building at least 200,000 new homes a year [69, p7], implying a potential additional increase in electricity demand by at least 24TWh per year by 2050 before additional electrification is considered. The Prime Minister announced in November 2020 his intention to bring forwards, to 2023, the date by which new homes will need to be warmed without using gas heating [44]. Even if GB is currently able to meet its current electricity needs and renewable generation targets now, it will be very difficult, if not impossible, to do so into the medium and long term, without the deployment of significant capacities of new low- or zero-carbon generation.

5.4.2 The ESC anticipates a hybrid approach to home and space heating, with electric heat pumps being installed in thermally efficient homes, and hydrogen or electricity providing heating for peak periods and/or cold spells. These measures are also included in the *Energy White Paper*: government aims to increase the rate of installation of electric heat pumps from 30,000 per year to 600,000 per year by 2028; and will consult on whether it is appropriate to end gas grid connections to new homes, to open the market of homes not on the gas grid to heat pumps or other clean energy alternatives, representing some 50,000 to 70,000 installations a year [21, p110].

5.4.3 District heat systems are anticipated to capture process heat from thermal power plants, critically these assets will need to be low carbon themselves, linking back to an increase in electricity demand through carbon capture and/or hydrogen electrolysis: the increasingly critical energy vector. [26, pp21&24].

5.5 Future peak electricity demand

5.5.1 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.

5.5.2 **Figure 5-2** illustrates the potential peak demand for GB power (using NGESO's Average Cold Spell methodology) to 2050. In the four scenarios, peak demand is anticipated to range between 65GW and 69GW by 2030 (for comparison, 2020: 58GW); between 85GW and 96GW in 2040, and between 92GW and 113GW in 2050 [104, Table FL.4]. Despite there being anticipated to be a drop in peak demand until 2025 in most scenarios, all scenarios show an increase in peak demand thereafter, driven by underlying industrial and commercial demand growth as well as the electrification of heating and transport.

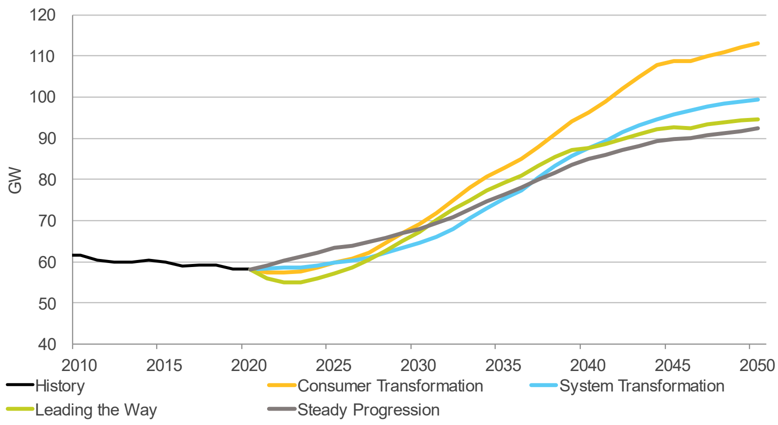


Figure 5-2: Future net peak electricity demand [104, Figure FL.4]

5.5.3 EVs and Hydrogen vehicles require the deployment of significant additional electricity generation capacity and may also act as integration measures for all renewable and baseload generation technologies, capable of shifting load from when demand is high, to periods where supply is high. Until recently, system peak demand has been expected to reduce in the future, with Vehicle-to-Grid (V2G) technologies working alongside enormous national-level batteries, helping keep peak electricity demand down as well as providing income for vehicle owners. More recently, NGESO (in particular) have updated their analyses to incorporate consumer behaviour, noting that many cars will be on the road returning children from school and workers to their homes, during peak periods. V2G is less likely to be a significant contributor to peak demand shaving than previously thought. Tesla's Elon Musk aligns with NGESO's thinking:

> *Vehicle-to-grid sounds good but I think actually has a much lower utility than people think ... Very few people would actually use vehicle-to-grid capabilities ... in part because cars are not plugged in constantly.* [61]

5.5.4 Ofgem announced a new Strategic Innovation Fund in August 2021. The £450M fund will be deployed over five years as part of the regulated price controls for the electricity system operator, and for the network companies which operate GB's energy networks. The fund, and its source, further signals the significant and imminent changes required to continue the journey to Net Zero. Ofgem state that the fund will help GB "find greener ways to travel, and to heat and power Britain at low cost. Britain's energy infrastructure will play a pivotal role in cutting net zero greenhouse gas emissions". Growth in electricity demand through the electrification of heat and transport, and the introduction of versatile energy vectors, such as hydrogen, which will be produced with the help of low-carbon electricity generation capacity, to decarbonise industry and hard-to-reach sectors, is certain. An increase in the complexity of electricity – and energy – system operation is likely, but must be overcome in order to meet Net Zero. The Strategic Innovation Fund, and others like it, will work to ready our energy networks for the growth in low-carbon generation required to meet future estimates of electricity demand.

6 Implications for future electricity supply needs

To enable the Net Zero transition, the power generation sector must both increase in capacity and reduce in carbon intensity on an unprecedented scale.

> *[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.* [21, p42]
>
> *We are not targeting a particular generation mix for 2050 ... The electricity market should determine the best solutions for very low emissions and reliable supply, at a low cost to consumers.* [21, p42]
>
> *New low carbon capacity is needed over the next decade and renewables can deliver this. As the [National Infrastructure] Commission argued in the first Assessment, due to current plant retirements, in the 2020s there will be a gap in electricity generating capacity, that needs to be filled. It must be the case that low carbon generation fills this gap. Given their short lead times, renewables are ideally placed to do this ... It therefore makes sense for government to take action to deploy renewables now*. [40, p10]

6.1 Future electricity supply

6.1.1 Each FES scenario developed by NGESO describes a possible way that the energy system may develop, based on a forecast of demand and the impact of government policy on generation mix. The scenarios do not indicate forecasts of confirmed and consented generation capacities, nor do they seek to imply or impose restrictions on the capacities of generation of particular technologies which may be required or may be delivered. The FES scenarios therefore do not imply a requirement for particular generation technologies, and nor can their datasets sensibly be disaggregated to indicate need for a single generation technology within a future system scenario.

6.1.2 In the context of Net Zero, the FES are a useful suite of documents to indicate whether particular future pathways for electricity generation will be successful against a national policy perspective. 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. While the need for more generation capacity to be built has been a consistent theme since the first FES was published in 2012.

> *It is for industry to propose new energy infrastructure projects within the strategic framework set by government*. [3, Para 3.1.2]

6.1.3 Further, once projects are identified and enter a development phase, their inclusion within the planning system does not also indicate a commitment by or obligation on the Applicant to deliver that project at all, or if it does, at a particular generation capacity[14].

6.1.4 Each year the FES scenarios have described consistently high capacities of solar generation connecting to the national transmission system, based on an objective economic assessment of current and future costs and/or market drivers. The FES scenarios can therefore be regarded as an important point of view, which contributes to an objective assessment of the need for, and scale of, low-carbon solar generation developments under different future scenarios of demand and government policy, particularly within the context of Net Zero.

6.1.5 The 2021 FES foresees one of four scenarios (being a scenario of steady progression rather than rapid low-carbon generation deployment) missing the legally binding national decarbonisation targets in 2050. This is the scenario with the slowest growth in renewable electricity generation capacities. All three of NGESO's 2050-compliant scenarios include the commissioning of large capacities of low-carbon generation, including solar, among other initiatives designed to facilitate emissions reduction in other industrial sectors. Research by the ESC corroborates this view.

6.1.6 From their analysis, NGESO conclude that installed electrical generation capacity in GB needs to increase from today's ~105GW to between 168 and 199GW to meet anticipated demand in 2030, this being a 79 to 110GW increase on existing generation capacity following the decommissioning of all but 1GW of existing nuclear generation and the closure of all remaining coal generation (5GW) before that date.

6.1.7 The most striking insight from the 2021 FES is that by 2030, over 70% of installed generation capacity must be low carbon generation in order to meet Net Zero targets, pointing to a significant growth in low carbon generation in the coming decade. Interconnectors are expected to contribute 10% of capacity and these will rely on our national neighbours to follow similar decarbonisation plans to the UK for their supply to be low-carbon. Only ~20% of capacity will be indigenous GB carbon-intensive generation, down from 41% in 2020.

6.1.8 Further, NGESO forecasts that between 305 and 357GW of generation capacity will be required to meet demand by 2050 (continuing the increasing trend from previous forecasts), with no remaining GB operational carbon-intensive generation [104, Table SV.22], [7, Table SV.23], [60].

6.1.9 The FES scenarios which achieve Net Zero include solar capacities in 2030 of 25 – 40GW, in 2040 of 43 – 68GW, and in 2050 of 57 – 89GW [104, Table SV.31]. 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.

6.1.10 NGESO are not alone in anticipating a significant increase in the capacity of low-carbon generation required to meet Net Zero. The CCC suggest that in order to meet a doubling of electricity demand from 100% low-carbon sources, up to

[14] Analysis of the CfD Register shows that 16 projects with CfDs have registered a reduction to the capacity of the CfD Unit to date. They are: offshore wind: 2 projects, 76MW reduction (11% of initial installed capacity); onshore wind: 10 projects; 66MW (12%); biomass conversion: 1 project, 13MW (3%); solar PV: 2 projects, 4MW (14%); advanced conversion technology: 1 project, 3MW (10%). Further, 6 projects have had their CfD terminated, including 4 advanced conversion technology projects, (52MW), 1 biomass with CHP project (85MW), and one solar PV project (12MW). [70]

60TWh of low-carbon generation, on top of the offshore wind sector deal (30GW by 2030, although government is now targeting 40GW by 2030 [21, p16]) is required by 2030 [26, p155], with solar generation currently an area of strength for the UK [24, p239].

6.1.11 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. [40, p19]

6.1.12 The ESC anticipates broadly similar generation capacities. 165 – 285GW of capacity will be required in 2050, including 18 – 80GW of solar [8, pp23, 27]. The ESC is more bullish on future nuclear capacity than other analyses, anticipating 20 – 38GW of nuclear versus 5 – 16GW (NGESO) and just 5GW (NIC).

6.1.13 Many forms of low-carbon generation will be required to meet the UK Climate objectives. A diverse mix of generation is required to minimise integration costs for those times when variable technologies are not generating electricity, but this does not mean that low-carbon generation developments should be curtailed to promote diversity. Indeed, by increasing the installed capacity of diverse renewable generation technologies across a broad geography, intermittency impacts are lower than they would be from a single-source supply deployed across a tighter geography. **Section 7.7** and **Section 7.8** provide further information.

6.1.14 In 2020, GB sourced 44% of its electricity from renewables, of which approximately 9.3% was from solar [104, Table SV.23]. In both 2019 and 2020, Denmark sourced 50% of its electricity needs from renewable generation, demonstrating that high proportions of renewable generation can be accommodated within national electricity systems [72, 107], and GB can learn how to do this from other nations which are further ahead in this regard.

6.1.15 The 2021 FES was just the second publication since GB adopted Net-Zero legal commitments. FES 2021 analyses three scenarios under which Net-Zero emissions can be achieved by 2050, and one scenario which misses the targets. NGESO align with the Energy Systems Catapult (see **Section 2.2** above) on the view that the 80% decarbonisation target could have been reached through multiple technology pathways, but that achieving Net Zero requires greater action across all solutions, including broader system-wide thinking. FES 2019 concluded that action on electrification, energy efficiency and carbon capture will all be needed at a significantly greater scale than assumed in any core scenarios [60, Page 2], and subsequent FES scenarios have borne out that conclusion. Six important predictions from NGESO's analysis [7] are that, by 2030:

6.1.15.1 While in all scenarios, GB energy demand is expected to be lower in 2050 than 2020 (by between 42 and 57%), in all scenarios GB electricity demand is expected to increase because of electrification of transport & home heating, and replacement of fossil fuels with blended, gas, hydrogen or electricity. By 2050, electricity demand is forecast to increase by between 50 and 91% versus 2020 [104, Table CV.1];

6.1.15.2 Storage and interconnection (flexibility) capacity will need to increase (from 8GW in 2020) to 25 – 38GW in 2030 and 47 – 71GW by 2050 to balance supply and demand both within the GB system and across borders [104, Table SV.22];

6.1.15.3 Due to the electrification of other sectors, peak demand15 is expected to rise (from 2020's level of 58GW) by 63 – 94% by 2050, even with the storage and interconnection capacities anticipated above to support "peak shaving" [104, Table SV.22];

6.1.15.4 Therefore, GB installed generation capacity will need to increase (from 103GW in 2020) to 168 – 199GW by 2030 to meet demand with 69 – 75% of that capacity being low-carbon in 2030 (vs. 55% today), and 100% low-carbon by 2050;

6.1.15.5 Installed generation capacity will need to grow even further (to 305 – 357GW) by 2050 to meet demand, and must be 100% low-carbon to meet Net Zero legal requirements;

6.1.15.6 To meet the Net Zero target, a radical transformation to our national energy ecosystem is required, meaning even more low-carbon, solar and wind generation capacity than even the most ambitious scenarios currently envisage, will be required to meet the UK's legally binding targets.

6.1.16 In summary, experts have concluded, and government has agreed, that decarbonisation in the UK needs to be significantly deeper and broader than it has previously been considered, this is evident through FES 2021 by an increase in all low-carbon metrics versus previous FES editions and in published analyses by other market experts.

6.1.17 A massive move to electrification will be required fundamentally to underpin broad and deep national decarbonisation, and Net Zero requires a "system view" to be taken. This means recognising the importance of whole-system thinking in relation to the decarbonisation of non-energy sectors. Alternative energy vectors, for example hydrogen, will be of fundamental importance in the displacement of fossil fuels from domestic and industrial energy uses, and transport. Electricity generated from low-carbon sources will be the primary means of producing hydrogen.

6.1.18 Therefore, significantly more low-carbon generation than is operational today, from diverse sources, along with energy efficiency and electricity storage is required to meet the anticipated increase in electricity demand.

6.2 Demand Response

6.2.1 Energy demand management, called Demand Side Response (DSR), also could play an important role in the future of the energy balance of the UK. DSR is valuable insofar as it is compatible with end use generation technologies and

[15] FES uses the Average Cold Spell (ACS) definition which is consistent with the treatment of demand in the electricity Capacity Mechanism.

system wide commercial drivers, but DSR on its own will be unlikely to deliver a decarbonised electricity system.

6.2.2 Currently DSR capacity is estimated at 1.3GW nationally [104, Table FL.9]. FES scenarios forecast between 3.3 and 5.5GW may be operational by 2030, rising to 6 – 16GW by 2050. The significance of the scale of growth of DSR as an enabler of a low-carbon energy system must be viewed within the context of a 11GW of coal and nuclear generation coming offline before 2030 (versus the FES 2021 baseline) and additional GB generation required to meet the demand growth as described in **Section 5.2**. Therefore, although DSR may deliver a significant contribution to the delivery of UK decarbonisation before 2030, DSR cannot fully replace the need for new generating capacity to deliver GB's energy objectives, further underpinning the need for low-carbon generation to come to market within this timeframe.

6.3 Wider decarbonisation requires a significant capacity of solar generation

6.3.1 Because electricity can be generated from low-carbon technologies, the demand for electricity in GB will grow as electricity decarbonises other sectors. The need for significant growth in new generation assets is therefore clear, not only to meet this additional demand, but also to offset the closures of many existing generation assets, either because of environmental regulation or technological lifetime limits.

6.3.2 Historically generation assets in GB have been called "conventional": predominantly coal, oil, gas, nuclear or hydro-powered. They have been dispatchable assets, meaning that their output and operational schedules are controllable: electricity on demand. Generally capacity utilisations[16] have been high (>80%).

6.3.3 **Figure 6-1** shows NGESO's analysis of how generation capacity may evolve between 2030 and 2050 to meet a growing electricity demand, and a decreasing carbon budget. Notably, fossil fuel capacity is anticipated to reduce from 42GW in 2020 to between 28 and 37GW by 2030, and on to nil unabated generation by 2050. As GB makes progress towards its legal decarbonisation targets through the installation of more renewable generation capacity, total installed capacity rises in proportion. This is firstly because electricity demand will increase, and secondly because the capacity factor at renewable assets is lower than the capacity factor at conventional assets.

6.3.4 It is important to appreciate that of the very many possible future scenarios for future electricity demand and supply, only a subset of those will achieve Net Zero. Some scenarios may cause cost-to-consumers to increase, while others may provide efficient and effective solutions. Government's position on the wider benefits of renewable generation is clear and consistent:

> *Increasing the amount of energy from renewable and low carbon technologies will help to make sure the UK has a secure energy supply, reduce*

[16] This is usually expressed as a quotient, calculated as {Total energy generated in a year [MWh]} divided by {Maximum power output [MW] x 8760 (hours in the year [h])}

greenhouse gas emissions to slow down climate change and stimulate investment in new jobs and businesses. [73]

The Energy White Paper provides further clarity on the Prime Minister's [Ten Point Plan] measures and puts in place a strategy for the wider energy system that: Transforms Energy ... Supports a green recovery ... [and] creates a fair deal for consumers. [21, p4]

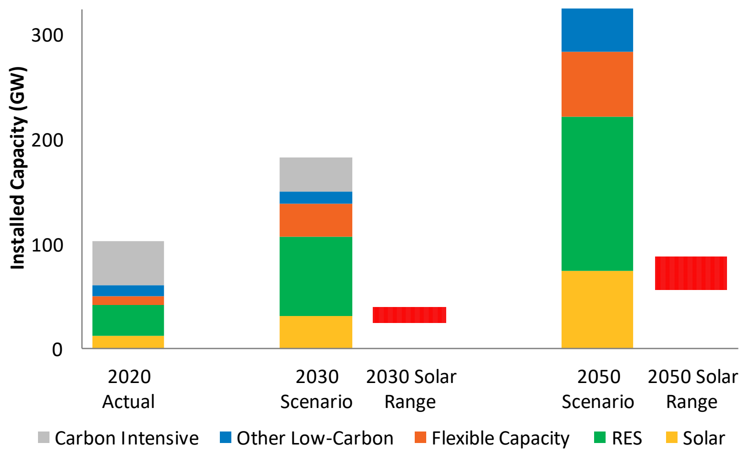


Figure 6-1: Generation capacity by technology type and amount of renewable capacity for 2030 and 2050 [104, Figure SV.22]

6.3.5 NGESO data shows that solar generated 12TWh of electricity during 2020 from 13GW of built capacity, up 2% from 2019 [7, Table ES1]. This makes solar generation an important renewable power generation technology (with third highest output, behind wind and biomass) in GB, with future potential, and need, for further growth. The largest power generation technology, Combined Cycle Gas Turbine (CCGT), is not low-carbon, so continued gas generation without carbon abatement technology is not currently consistent with Net Zero requirements. Either the source fuel must be decarbonised (e.g. a move from natural gas to hydrogen) or the power stations must be integrated with a CCUS network in order to remove net carbon emissions. The changing contribution of the second largest technology (nuclear) to low-carbon generation in the coming decade, is shown in **Figure 3-5**.

6.3.6 **Section 3.3** describes why it is not likely that CCUS (the process to decarbonise carbon-intensive electricity generation) will play a significant role in reducing UK carbon emissions in the decade ahead, and **Section 3.4** describes why nuclear generation will also not make a net positive contribution to carbon reduction over the same period. Yet **Section 3.2** describes the need for urgent progress in decarbonisation. Significant additional renewable generation capacity is therefore required to make progress in decarbonisation, both as dispatchable low-carbon technology developments continue, and on an enduring basis, to meet foreseen electricity demand growth.

6.3.7 **Figure 6-2** shows the cumulative carbon emissions saved by solar generation versus the case that the electricity generated by solar was instead generated by CCGT (at 350 gCO_2/kWh). The red area shows that future additional solar generation will reduce the carbon emissions of the GB electricity system in each of the FES scenarios which contemplate future solar generation. Without the development of additional solar projects, other measures will be required to fill the gap which solar will fill, effectively making it much harder for the UK to achieve Net Zero. While offshore wind makes the largest contribution to decarbonisation in most forward electricity system scenarios, solar complements offshore wind deployment (see **Section 7.8** for further information). The first conclusion is therefore that the bringing forward of solar schemes such as this Scheme should be continued and progressed with determined rigour and drive, to enable their timely delivery. Secondly, that the further identification of solar schemes and other low-carbon initiatives which complement offshore wind generation should be progressed with urgency to ensure the required trajectory in reducing carbon intensity can be achieved or bettered.

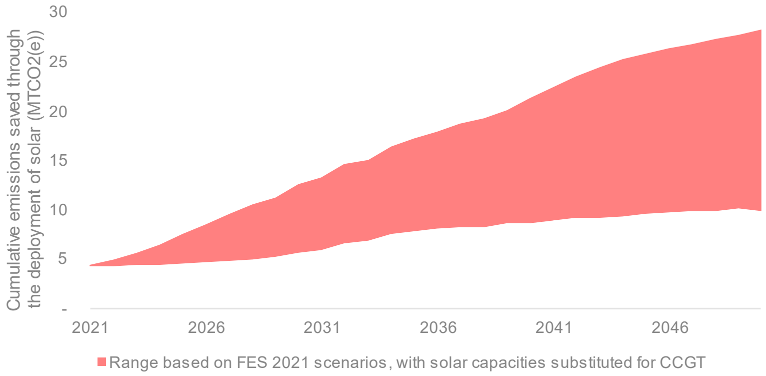


Figure 6-2: Generating power from solar along FES projections will provide cumulative carbon emissions versus if that power was generated from higher carbon sources. Adapted from [104 Table SV.27].

6.3.8 The UK requires swift and continued deep decarbonisation actions in order for it to meet its 2050 climate targets. As one of the leading low-carbon generation technologies in GB, and one which is viable on an unsubsidised basis, it is critical that solar generation is permitted to continue to grow to move the country towards meeting its Net Zero commitments.

6.3.9 **Table 3-1** shows that GB currently has 13.3GW of installed solar generation. Projects totalling a further 4.9GW have also been identified and are listed on industry pipeline databases. **Figure 3-1**Figure 3-1: FES solar capacity evolution scenarios [104, Figure illustrates NGESO's modelling of possible future solar capacity by scenario. Capacity grows due to falling technology costs; installation of larger, standalone, facilities; continued residential and commercial PV installations; and repowering of existing installations, particularly through the mid-2030s.

6.3.10 The inclusion of a project on a "future project pipeline" – for example, a list of projects which have applied for a DCO, or the scoping / consents / construction pipeline included in **Table 3-1** and **Figure 3-1** – does not indicate that the project will go ahead, or if it does, at a particular generation capacity. It is therefore not the case that the forecasts shown in **Table 3-1**, **Figure 3-1** or **Figure 6-2** are sufficiently secure to justify the de-prioritisation of pathways which include the development of alternative and complementary generation technologies. Nor is it the case that the ambitions of the Offshore Wind Sector Deal (40GW of wind generation by 2030), nor of newly adopted government policy, will certainly be met by those projects currently under consideration by developers. Projects right across the wider zero-carbon technology landscape must continue to come forward in order to improve the likelihood of meeting required decarbonisation targets. Without the Scheme[17], it is very possible that solar's contribution to the future generation mix may be artificially limited, risking the success of established government policy and strategy on decarbonisation and reaching Net Zero.

6.3.11 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. The Scheme is a critical step in the development and delivery of large-scale solar capacity in the UK.

6.4 Large-scale solar generation site assessment and selection for the UK

6.4.1 The methodology and rationale for the selection of the proposed location for Sunnica is described in the *Alternatives and Design Evolution* (**Chapter 4** of the *Environmental Statement* **[EN010106/APP/6.1]**) and the *Alternative Sites Assessment* (**Appendix 4A** of the *Environmental Statement* **[EN010106/APP/6.2]**). These documents describe the steps included in the site selection process, which considers (among other aspects) irradiation and topography; availability and location for connection to the electricity system; planning and environmental constraints (including biodiversity, landscape and visual amenity, cultural heritage, flood risk, land use etc); and local considerations, including availability and ownership of land, and access rights to the land through construction and operation. Many of the above characteristics 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.

6.4.2 *Alternatives and Design Evolution* concludes that the location of the scheme:

6.4.2.1 maximises the utilisation of low grade, non-best and most versatile agricultural land;

6.4.2.2 is not located within internationally and nationally designated biodiversity sites and avoids direct impact on locally designated biodiversity sites;

6.4.2.3 is not located within or close to Areas of Outstanding Natural Beauty or designated areas of local landscape value;

6.4.2.4 is not located within designated green belt;

6.4.2.5 avoids direct physical impact on designated heritage assets;

[17] Which holds a Grid Connection Agreement, is listed on the NGESO TEC Register [15], and which could be built out by the mid 2020s

6.4.2.6 is predominantly within Environment Agency flood zone 1 and is therefore at a low risk of flooding;

6.4.2.7 has good transport access for construction, being adjacent to the strategic road network;

6.4.2.8 is of a size and has topography which meets the requirements of the Scheme to generate significant amounts of electricity and store it; and

6.4.2.9 has limited land use conflicts with respect to local development plan allocations and displacement of existing businesses.

6.4.3 Hitherto, this report has built up the evidence base for the need for large-scale solar generation schemes in the UK. **Section 6.1**includes projections of the capacities of new solar generation needed in order to meet Net Zero from NGESO, NIC and ESC. Their projections combine to the need for an additional 44 – 76GW of additional solar capacity by 2050, with approximately one quarter of this extra capacity needed in the next ten years.

6.4.4 Once the evidence base, and the need for solar, has been accepted, suitable locations must be found for solar development. In order to meet the significant capacity growth projections, it will be necessary to develop all sites which have been identified and assessed as suitable. By not developing a suitable location, the UK will risk falling short of its decarbonisation targets. Especially if site selection becomes more difficult once the more suitable locations have been identified and developed, as has occurred with the deployment of other technologies, including smaller-scale solar.

6.4.5 The suitability of the proposed connection at Burwell National Grid Substation, in relation to the services which would be provided by the Scheme and the benefits of exporting generation from the Scheme onto the grid network through that substation, is described in **Section 7.4** and **Chapter 8**. The suitability of the proposed location in respect of the incident irradiation is illustrated in **Figure 7-1**.

6.4.6 Draft *NPS EN-3* [103] includes an anticipated range of acres for each MW of output generally required for a solar farm along with its associated infrastructure. The Scheme as proposed delivers a large-scale solar generation asset which is consistent with this range. This demonstrates that the proposed location is a suitable site and the efficient detailed design provides for an asset which is consistent with government's view of best practice ratios of land take and installed capacity.

6.4.7 Therefore, this Scheme, which scores highly against the above criteria, presents as a highly viable scheme and therefore would help to ensure that the need for large-scale solar generation can be fulfilled which is an important and relevant factor in the decision making process.

7 Decarbonisation can maintain or enhance security of supply

7.1 Setting the scene on security of supply

7.1.1 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 also 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.

> *The government needs to ensure sufficient electricity generating capacity is available to meet maximum peak demand, with a safety margin or spare capacity to accommodate unexpectedly high demand and to mitigate risks such as unexpected plant closures and extreme weather events.* [3, Para 3.3.2]
>
> *The larger the difference between available capacity and demand ... the more resilient the system will be in dealing with unexpected events, and consequently the lower the risk of a supply interruption.* [3, Para 3.3.3]
>
> *A diverse mix of all types of power generation. . . helps to ensure security of supply.* [3, Para 3.3.4]
>
> *A low-cost, net zero consistent system is likely to be composed predominantly of wind and solar.* [21, p43]

7.1.2 “Security of supply” means keeping the lights on and has two main components.

7.1.2.1 Ensuring that there is enough electricity generation capacity available to meet demand (adequacy); and

7.1.2.2 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.

7.1.3 This chapter includes a brief introduction to power systems and aspects of their operation. The challenges associated with integrating renewable generators into existing systems are characterised, and key points on the contribution of solar generation to system adequacy and system operation are presented. Specifically:

7.1.3.1 The Scheme will provide a significant capacity of low-carbon generation to national system adequacy targets;

7.1.3.2 The diversification of GB’s electricity supplies through the commissioning of both solar and wind assets to the NETS, alongside other low-carbon technologies, provides benefits in the functioning of the NETS and ensuring power is available to consumers across the country when it is required, due to its requirement to operate within the stringent operability and control requirements of the Grid Code [74];

7.1.3.3 Technical advances in the field of power electronics and other measures are significantly increasing the utility of power generation assets in the provision of services and protections which support grid operation [75];

7.1.3.4 A program of grid investment and operational development by NGESO, regulated by Ofgem, is aiming for safe and secure operation of the NETS at zero-carbon [60, p1] by 2025; and

7.1.3.5 By including the possibility of Electricity Storage assets within the planned development, the Applicant will be able to bring forward and install battery energy storage systems to aid the integration of high levels of renewable power generation into the electricity market, in response to a developing need.

7.1.4 To provide appropriate context and understanding we set out in brief an introduction to a number of high-level concepts of power system operation.

7.2 An introduction to power system operations

7.2.1 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.

7.2.2 Governments define policy to ensure that there is sufficient generating capacity[18] available to meet maximum expected demand. This is called adequacy.

7.2.3 Key power quality characteristics (including frequency, voltage, and power shape) must be controlled in order to maintain the synchronicity of all assets. 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” [76, p5].

7.2.4 Protecting the synchronicity of a system when an asset operates outside of normal expected parameters is also important, and individual transmission-connected generators, such as this Scheme, must maintain their own synchronicity with the system to a high level of reliability.

7.2.5 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.

7.2.6 The voltage level on the system is dependent on the type and quantity of generator and demand load connected to the system at the time. Over volts occur when power demand is low, and load is too light. Voltage collapse occurs when load (particularly from heavy inductive machinery) is too high. Reactive power

[18] i.e. The maximum achievable level of power generation which may be connected to the NETS.

helps to maintain voltage levels, and its provision by generators is a mandatory service for transmission-connected generators.

7.2.7 System frequency must also be maintained[19]. Unless generation is scheduled to match demand, when system load increases, system frequency dips; and when system load is lightened, frequency increases. Because demand fluctuates continuously through the day, frequency must be continuously managed, and generators must therefore provide frequency response (FR) services. Under FR, generator output is raised on receipt of a signal from the system operator of a falling frequency; and reduced on receipt of a signal from the system operator of a rising frequency. Due to the impact of FR on MW output[20], generators which are able to provide FR will usually determine the price they would accept to provide the service.

7.2.8 If a sudden and unexpected disconnection of either demand or generation occurs, frequency may change rapidly. System inertia, a measure of the kinetic energy stored in rotating machines which are directly connected to the NETS, helps protect the system against rapid frequency changes. A system with high inertia is less likely to experience rapid system changes and will therefore be more stable, reducing the risk of faults escalating into wide ranging effects on generators and customers [76, p43]. An important metric is the Rate of Change of Frequency, (RoCoF) which measures how quickly the electricity system may move from a stable state to an unstable state following a perturbation. A system with low RoCoF is more stable. System inertia is a phenomenon uniquely important to NETS because of its relatively low levels of interconnection to other, larger, electricity systems such as is the case, in particular, across Europe.

7.2.9 This chapter explains how solar power generally, and the Scheme’s proposed ground mounted solar PV panel arrays and battery energy storage system specifically, are ideally suited to support NGESO’s needs in maintaining a safe, secure and economic electricity system.

7.3 Operating high-RES electricity transmission systems

7.3.1 The integration of RES and their likely effect on electricity transmission systems, is not a new topic. In a 1991 paper [77], M.J. Grubb foresaw that capacities of renewable generation will not be limited; and therefore that “proper management” of those capacities (alongside any remaining conventional capacities) must be carried out to maintain a stable electricity system. Over the last 30 years the electricity industry has implemented new processes as technologies have changed, and stable operation of electricity systems is now being achieved with higher shares of renewable generation on an increasingly regular basis. For example, in both 2019 and 2020, Denmark sourced over 50% of its electricity needs from renewable generation [72, 107]. In GB, renewables’ share of electricity generation was 44% during 2020 [104, Table SV.23]. These statistics demonstrate that high proportions of renewable generation can already be operationally accommodated within national electricity systems.

[19] The NETS operates at a nominal 50Hz
[20] Output remains the main source of generator income.

7.3.2 In foreseeing a need for maintaining the quality of electricity supplies, Grubb identified important considerations for system operation[21], and explained how an increase in renewable generation influences each one. He saw the critical issue as being the determination of how important each ancillary service becomes in a future energy system, and how capable the generation assets connected to that system are to provide that service.

7.3.3 The NIC agree, 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” [36, p40]. If they are not, others may do it for them (and potentially at a greater cost to the end consumer).

7.3.4 The activities associated with integrating renewables into the GB electricity system will increase with their penetration [78, p2]. Energy balance must be managed at all times; and as renewable capacity increases, more services will be required to regain supply / demand balance and retain system control, particularly when demand is either very high or very low.

7.3.5 Importantly however, the dynamic behaviour characteristics for a high-RES system are well understood. NGESO’s *System Operability Framework* (SOF) [79, 80] describes these in specific relation to the GB electricity system.

7.3.6 Further, technological advance, 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 fast response to system frequency changes, and their ability to withstand periods of system instability without disconnecting.

7.3.7 System stability services have been provided by fast response batteries as far back as NGESO’s Enhanced Frequency Response service, tendered for in 2016 and recently rebranded as part of NGESO’s new frequency response product suite. More recent advances have been made in the conversion of thermal and pumped storage assets into synchronous inertia providers into the National Grid ESO transmission constraint management market.

7.3.8 The installation of power electronics at low-carbon generation assets is an exciting development which will enable them to provide important system stability services [75] as part of their normal daily operational routine. By reprogramming the digital power inverters attached to solar panels, the behaviour required by the System Operator can be achieved. Solar farms under development are well placed to incorporate state-of-the-art power electronics into their designs, to be able to provide important stability services through their operational lives. This Scheme will be no exception, and **Chapter 8** describes the advantages associated with providing such services at the Burwell National Grid Substation.

7.4 Connecting generators to the power grid

7.4.1 The electricity system in GB operates at two levels: the high-voltage NETS, and the lower-voltage Distribution Networks. The NETS is mainly made up of 400 kV, 275 kV and 132 kV assets connecting separately owned generators,

[21] Rate of change of frequency; system operational control and fault containment; and reserve operation.

interconnectors, large demands, and distribution systems, and currently consists of approximately 4,500 miles of overhead line, 1,000 miles of underground cable and 350 substations.

7.4.2 Grid connection is an important aspect of generation project viability and development timescales. The selection and utilisation of efficient grid connections in beneficial locations allows projects to come forwards at lower cost of generation and ultimately helps reduce overall cost to consumers. By maximising the generation capacity installed behind the grid connection point, grid connection utilisation is increased and over the lifetime of the project, a higher volume of low-carbon electricity is generated for a single episode of construction work.

7.4.3 Applications for connection to the NETS are assessed through the first-come-first-served *Connect and Manage* process.

7.4.4 *Connect and Manage* offers are given to those customers who request a connection date ahead of when any identified wider transmission reinforcement works can be completed. The connection agreements contain the requirement for derogation against the *National Electricity Transmission System Security and Quality of Supply Standards* (SQSS) which, once approved, allows for a connection to be made ahead of those wider transmission reinforcement works.

7.4.5 Wider transmission reinforcement works may be required to ensure that, once connected, electricity can flow from generators to where it is needed without constraint or hindrance. Generation connections close to demand centres (e.g. large cities or industrial areas) provide the opportunity for the bulk transfer of power over short distances, and therefore attract both capital and operational cost benefits when compared to generation connections far away from where the power is needed. However, with an ever-growing share of renewable generation capacity on the NETS, the bulk transfer of power over long distances remains vitally important, in order to keep lights on across the whole country when renewable generation output is high only in one area.

7.4.6 In the *Network Options Assessment 2020/21*, NGESO recommended an investment of £183m in 2020/21 across 25 asset-based projects to maintain the option to deliver projects costing almost £13.9 bn. This would allow them to manage the future capability of the GB transmission network against an uncertain energy landscape over the coming decades [81, p6]. These costs will ultimately be recovered from consumer bills. As such it is in the interests of consumers to maximise the efficiency and effectiveness of existing and new transmission connections and ensure value for money is secured for any wider reinforcement works which may be required as a result of new locations.

7.4.7 However, not all existing locations are necessarily efficient. Connecting new assets to parts of the NETS which are already overloaded, or to parts where the new asset may contribute to existing new seasonal flows of power or network instabilities, may increase either the infrastructure cost of the connection, or the ongoing operating cost of the NETS, both of which ultimately impact consumer bills.

7.4.8 The Scheme proposes to connect to an existing National Grid substation (Burwell) which is located on one of the highly reinforced major radial system connections between Walpole (with connections to the north and east) and

Pelham (with connections to London, the south east and mainland Europe). Burwell National Grid Substation is also a Grid Supply Point (GSP). GSPs supply power from the NETS down to local networks. Burwell services 132/33kV and 132/11kV substations located on the northern and eastern edge of Cambridge, which in turn supply primary substations throughout the county. By connecting at Burwell, the Scheme is making use of an existing connection point and existing transmission infrastructure in a way which does not present the risk of overload or congestion on the NETS during any period of normal operation, and provides a regional source of regionally generated bulk low-carbon supplies of electricity to consumers in Cambridge (a growing city both in terms of residential, industrial and commercial sectors) and the wider Cambridgeshire area [82, p3]. **Section 8.1** discusses this point further and provides additional evidence which underpins Burwell National Grid Substation as an excellent point of connection for Sunnica.

7.5 Centralised and decentralised generation

7.5.1 Generation assets can be centralised (connecting to the NETS) or decentralised (connecting to the distribution networks). Decentralisation of generation is expected to continue in all FES 2021 scenarios, driven by the growth in smaller scale renewable generators. Many small generators do not connect directly to the high voltage national transmission system (NETS), but rather to the medium or low voltage distribution systems [83, p34]. Currently 30% of all generation capacity is connected to the distribution networks, and FES scenarios project that by 2050, the proportion may develop to between 25% and 44% [104, Table ES1]. Distribution networks operate at a lower voltage than the transmission networks, and are located closer to points of final demand, so generators which connect to these systems must have smaller capacities than those which connect to the NETS. As a consequence, in order to connect the same total generation capacity, 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; however, being closer to demand centres, suitable land and acceptable planning proposals may be more difficult to secure.

7.5.2 However distributed generation capacities grow, the replacement and growth of transmission connected assets is also foreseen. Although distributed generation will contribute to meeting carbon emissions targets, increasing energy security and will lead to some reduction in demand on the main generation and transmission system, government does not believe they will replace the need for new large-scale electricity infrastructure to meet UK energy objectives. The recent implicit market preference for decentralised generation connections should be understood in the context of GB's national electricity system, with 72 GW of generation currently connected to the transmission network and 31 GW to the distribution network. FES 2021 scenarios [104] show that capacity connected to the distribution networks is likely to grow at similar or higher levels than capacity connected to the transmission network. In 2050, between 2.7 and 4.5 times 2020's distributed generation capacity may be connected to distribution systems, while the multiplier for transmission-connected assets ranges between 2.5 and 3.2. NGESO scenarios indicate a total of 178 – 233 GW capacity installed at the transmission connected level by 2050.

7.5.3 Distribution networks were originally designed predominantly to transport power to consumers. They were not designed to connect significant capacities of electricity generation. 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. Further:

> *Government does not believe that decentralised and community energy systems are likely to lead to significant replacement of large-scale infrastructure. Interconnection of large-scale, centralised electricity generating facilities via a high voltage transmission system enables the pooling of both generation and demand, which in turn offers several 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.* [3, Para 3.3.29]

7.5.4 NGESO has also made many public statements on their support for the connection of electricity generation technologies which provide a diverse energy mix to ensure that they can continue to manage supply and demand, for example [60, 84].

7.5.5 In conclusion, the need for distribution connected generation is in addition to, not the place of, the need for additional transmission connected generation. The development of distribution connected generation will not do away with the need for further transmission connected capacities, indeed the further development of transmission connected assets is essential in order to connect the scale of new capacity required to meet Net Zero requirements. The Scheme, which will connect to the NETS, will be well placed to support grid adequacy through its proposed transmission network connection. Further, the power it generates will efficiently feed into both the local distribution networks and the NETS, maximising the opportunities to supply low-carbon power in the most efficient way across the widest possible geography.

7.6 Transmission connected generation assets integrate with electricity systems more transparently than distribution connected generation

7.6.1 As described in **Section 7.5**, large generating assets are connected to transmission systems and many smaller generators are linked either to customer connections or distribution networks. Some of the most relevant differences between transmission- and distribution- connected generator characteristics are listed in **Table 7-1**.

Table 7-1: Characteristics of transmission- and distribution-connected generators [Author analysis]

	Transmission	Distribution
Description	Connected to NETS at high voltage	Connected to distribution network at lower voltage (distributed) or into end use consumer systems (micro). Collectively called Distributed Generation
Size	Typically large (100s of MW)	Typically small (<30 MW) to very small (single kW)
Technical Compliance	Required to conform to regulations and standards for critical service provision and response characteristics including reactive power, frequency response and fault ride-through.	Minimum technical thresholds are not as stringent but are increasing as a result of system interconnection requirements. Conformity with required standards may be harder to enforce.
Dispatch	Centrally dispatched by NGESO with known reliability	Generally locally dispatched with unknown reliability; outside of the direct control of NGESO.
Measurements	Metered to a high degree of accuracy, forecast output signalled to NGESO.	Largely unmetered, indications of availability, forecast output not required to be provided to NGESO

7.6.2 Distribution-connected generators also contribute to meeting national demand, but because of the way they are connected, they effectively self-dispatch when they are available and offset national demand, thereby reducing the transmission demand level which transmission-connected assets must meet. The connection level of an asset impacts the benefits it brings to bill payers. Four major considerations are:

7.6.2.1 Transmission connected assets provide visibility of their expected generation to the national energy market and NGESO as part of their licence to operate. This increases transparency in the market and allows sensible economic decisions to be made by all market players, including NGESO, in both planning and operational timescales to ensure that power demand and system security needs are met with the least possible cost;

7.6.2.2 Transmission connected assets are required to be available for instruction by NGESO. They are required to participate in the Balancing Mechanism (BM)[22], making their flexibility available (at a transparent and cost-reflective price) to ensure that supply and demand remain balanced at all times. By contrast, distribution assets are not required to

[22] The BM allows NGESO to access uncommitted asset flexibility, as a market of last (though frequently used) resort. This can be to resolve constraints on the NETS; to provide Balancing Services to support NETS operation; or to balance supply with demand.

do this, although voluntary balancing markets are currently under development for smaller assets at the distribution level;

7.6.2.3 While transmission systems have historically been designed to allow for the connection of large generating assets, distribution systems have not. Connecting generation assets of any meaningful size to distribution systems is becoming more difficult and more expensive (see **Chapter 9** for more detail);

7.6.2.4 The mandatory requirements for a generator to connect to the NETS include minimum requirements for fault protection as well as system ancillary services (e.g. Obligatory Reactive Power Services). Distribution connected assets have different fault protection requirements (which are harder to enforce) however access to system ancillary services is expected to grow into the future. Transmission-connected assets are therefore differentiated in that they are de-facto required to support system operation in many ways as part of their connection agreement.

7.6.3 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.

7.6.4 By connecting more assets at the distribution level, less power flows on the transmission system, and the unit cost of running the GB NETS increases and more investment is required to reinforce distribution systems so that they can accommodate more generation. Electricity consumers, either directly or indirectly, through their energy bills, pick up costs related to both transmission and distribution systems, including market inefficiencies, economic decision making, asset investments, balancing actions and transmission and distribution system enhancements, so energy bills will rise if existing assets are underutilised and/or reinforcements are required on other systems. The NETS remains an important measure to maintain interregional connectedness, support the meeting of national demand from geographically disparate sources [24, p182] and keep power flowing to consumers with the high levels of reliability we have all come to expect.

7.6.5 The interaction of embedded generation with the balancing of the transmission network is complex, which is one reason why it is important to maintain diversity of generation assets across technology choice, scale and connection voltage.

7.6.6 Walpole, at the northern end of the main Walpole-Burwell-Pelham line, is a major route south for the fossil generation located around The Wash, the East Midlands and towards the Humber. Eggborough coal power station, located north of Walpole, closed in 2018. Drax, also located north of Walpole, will close to commercial operation in 2021, as will West Burton A, also located close by. There are ten operational and one mothballed CCGT plant also located above Walpole, their power will flow through Burwell (in addition to other routes) when they generate. In the coming years, as higher capacities of renewable generation squeeze CCGT load factors and carbon emissions limits tighten, output from these assets is likely to reduce, and some may be mothballed or close (e.g. Sutton Bridge, which fell into administration in 2020 as part of the Calon Energy group). Such a shift in generation characteristics provides an additional opportunity for the Scheme to help replace some of that power, thus improving the utilisation of this area of the NETS and increasing the diversity and balance of generation in the area.

7.6.7 By connecting to the NETS at Burwell, the Scheme brings benefits to the NETS by: replacing transmission-connected assets located in the region which are closing; increasing power flows on the NETS, thus lowering unit operating costs for all users; making use of available transmission capacity (therefore not increasing system management or system operating cost) and transparently conforming to Grid Code operability requirements.

7.7 Solar plays an important role in diversifying renewable generation sources to maintain adequacy and minimise curtailment

7.7.1 A long-standing challenge to the ability of solar generation to play a significant role in electricity supply relates to the uncontrollable nature of the weather. The variability of solar generation can be mitigated by developing larger generation capacities (to maximise output during periods of low irradiation); by connecting assets to different parts of the NETS; by developing projects with complementary profiles (for example wind: see below); or by developing integration technologies (for example, battery storage or participation in the hydrogen economy). There are several other technologies which can be used to compensate for the intermittency of renewable generation, such as electricity storage, interconnection and demand side response [3, Para 3.3.12].

7.7.2 Ueckerdt et al [19, p2] describe important considerations for the introduction of RES to power systems. These are described in **Table 7-2**.

7.7.3 Uncertainty may manifest in that the level of the demand or supply of power may be higher, or lower, than was expected. Yet it is a fundamental property of all electricity systems that demand and supply must be balanced at delivery. Improvements in demand and supply forecasting would help minimise balancing effort, and ‘integration measures’ are working as part of, and alongside renewable generators to provide necessary upward and downward regulation.

7.7.4 An example of local specificity is that south east England has better potential for plentiful solar generation than the south west, because of its higher irradiance levels. The south west may be better suited to onshore wind generation because the area is dominated by fresh westerly coastal winds. Variability is best described by the difference between summer and winter power demand, or generation. Generation variability is broadly forecastable. 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 portfolio of interconnected assets from as broad as possible a range of technologies and geography may be beneficial. The Scheme is an important part of the growing solar generation portfolio, whose dependable output is growing (see **Section 7.8**). As shown in **Figure 7-1**, the Scheme is proposed to be located in one of the higher solar irradiation areas of the UK. This increases the benefit it will bring to the UK, in relation to the bulk generation of low-carbon electricity per MW installed.

Table 7-2: Complexities associated with renewable energy source variability in power systems [19, p2]

Complexity	Description	Implication
Uncertainty	Weather forecasts incur an inherent unpredictability bringing uncertainty to both demand and supply sides of the requirement to balance power.	Balancing activities (including injection and withdrawal of power from BESS) will grow as renewable generation capacities increase.
Local specificity	Renewable assets must be built to complement their local environment, in order to maximise their yield.	A localised preference for most suitable technologies will emerge, diversity should be built in where possible.
Variability	While weather forecasts incur uncertainty, the weather itself is also variable.	Over timescales from hours to seasons, generation levels from renewable assets may be very different. A larger portfolio of RES will provide a larger dependable power level than a smaller portfolio.

7.8 The system adequacy of solar generation

7.8.1 System adequacy is primarily managed through the GB Capacity Market. In return for capacity payments, eligible assets agree to generate at or over a minimum commitment (their “derated capacity”) whenever NGESO (subject to a prescribed process) determine that additional generation output is required in GB in order to “keep the lights on.” BEIS have recently included wind and solar technology within the GB capacity market [85] and both onshore wind and solar have been reintroduced to the Contracts for Difference mechanism in time for Allocation Round 4, which opened in 2021. Details on the process required to be followed in the CfD AR4 were published in late 2021. While the Capacity Market is not open to assets which already hold CfD contracts, the inclusion of renewable generation technologies in the Capacity Market underlines the contribution it can make to 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” [86, p114]. It should be noted that renewable assets also already participate in capacity mechanisms in other highly volatile electricity markets, such as Ireland’s Single Electricity Market, and parts of the US.

7.8.2 By measuring the capacity utilisation of a set of generating assets over a month, it is possible to calculate the variation in delivered generation from month-to-month as a proportion of installed capacity. Stable capacity utilisation (here called Generation Dependability) 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 rolled out; and lower requirement for (fossil fuelled) backup plant, without creating an excess of generation capacity.

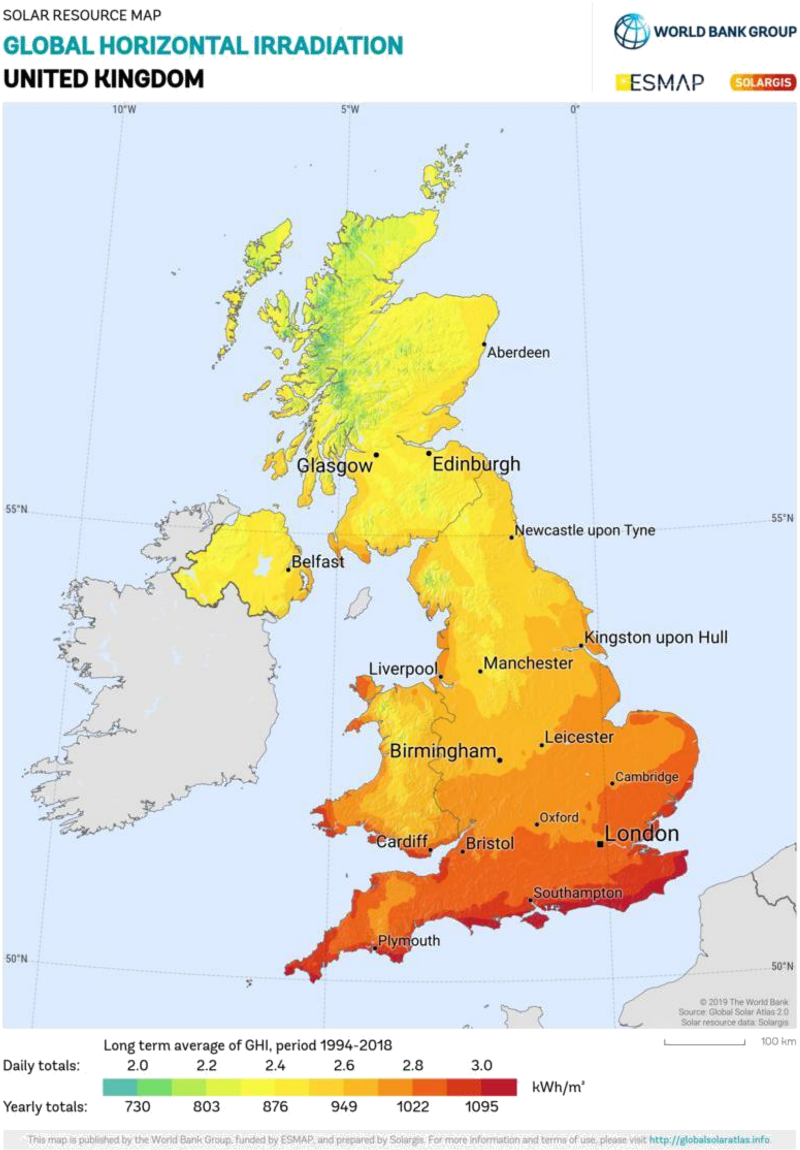


Figure 7-1: United Kingdom solar irradiation, © The World Bank [Source: Global Solar Atlas 2.0, Solar resource data: Solargis]

7.8.3 **Figure 7-2** displays this metric, calculated at a monthly level using 2019 and 2020 actual market data, for GB wind generation (blue line) and solar generation (orange line). 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. It also shows an illustrative combined portfolio (green dashed line), which shows that Generation Dependability is improved when diverse RES technologies are deployed alongside each other in the same electricity system (the green dashed line is always between the blue and orange lines; and the line is by far the flattest of the three). 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 a generation dependability which is improved over that of the separate technologies. This in turn will help reduce (but not fully remove) the need for integration technology capacity to manage generation variability across many timeframes, including long-term storage of excess generation.

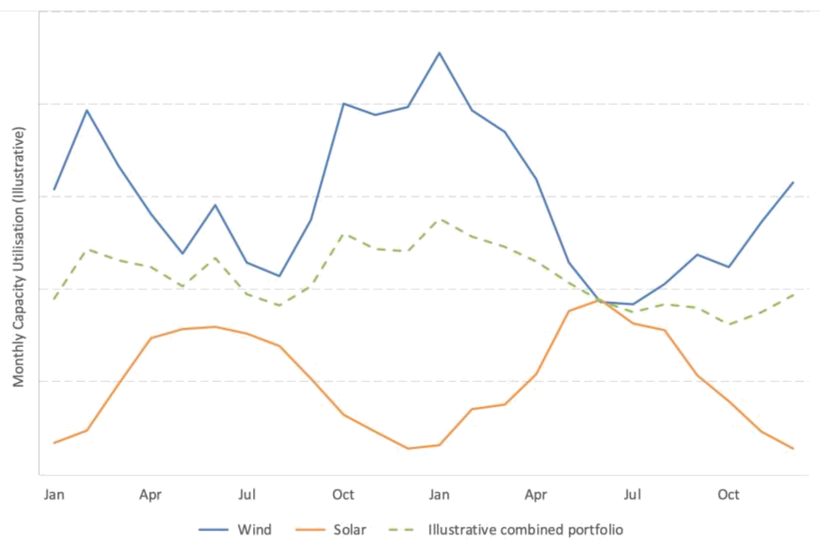


Figure 7-2: Illustrative Generation Dependability for a combined portfolio of solar and wind in GB [Author analysis]

7.8.4 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 [87].

7.8.5 The National Infrastructure Commission also commissioned a whole system cost analysis, the results of which were published in 2020 [32]. NIC's analysis complements that of the Imperial College team, suggesting that: "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."

7.8.6 An analytical model has been developed to illustrate the mutual compatibility of solar and wind generation. The model evaluates the contribution made by different types of GB generation to overall GB consumption needs throughout a year but does not take into account the requirement to balance supply and demand on a short-term basis. The analysis, based on 2015 to 2019 actual data so as to avoid any one-off impacts from either outlier weather or the COVID-19 pandemic, shows that power demand, solar generation and wind generation patterns change through the year, and also takes into account scenarios from the FES [7, Data Workbook] regarding how demand levels and shape are anticipated to evolve into the future. The model results are included in **Figure 7-3**.

7.8.7 Operational metering has been used to determine average load factors by month for each of the generation types listed. By extrapolating load factors onto scenarios of forward capacity, the graph shows that the government's current target of 40GW of offshore wind operational by 2030 (an increase of ~30GW on 2020 levels) would, when developed alongside projections of onshore wind and baseload low-carbon power, generate sufficient power to meet estimated winter (October to March) demand.

7.8.8 However, because of the seasonality of wind generation in UK territory, 40GW of offshore wind would not be sufficient to meet summer (April to September) demand.

7.8.9 Approximately 35GW of solar (an increase of 22GW on 2020 levels) could neatly “fill the gap” without inducing significant over-generation in winter periods. To meet 2030 summer levels without solar generation, a further 15GW of offshore wind generation (i.e. a total installed capacity of 55GW), 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.

7.8.10 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 13% 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.

7.8.11 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.

7.8.12 Therefore, it can be concluded that although individual renewable assets are variable generators, the generation dependability of a portfolio which consists of different renewable technology classes is more stable, and the generation profiles of a diverse range of low-carbon generators would combine to meet seasonal average demand levels without requiring significant and unproductive capital investment or seasonal excess generation, or inefficient network / system operating costs. There are many integration measures already available, or 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.

7.8.13 One prominent integration measure, also included in the Scheme description, is the BESS. BESS, and their suitability for the proposed location of this Scheme, are described more fully in **Section 10.4**. 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 other assets with complementary seasonal generation profiles; and managing shorter term intermittency through storage or other measures.

7.8.14 Solar is an essential asset class which is needed to support a high level of generation adequacy and generation dependability within the GB electricity system without incurring excessive capital spend, nor causing significant system integration costs or inefficiencies.

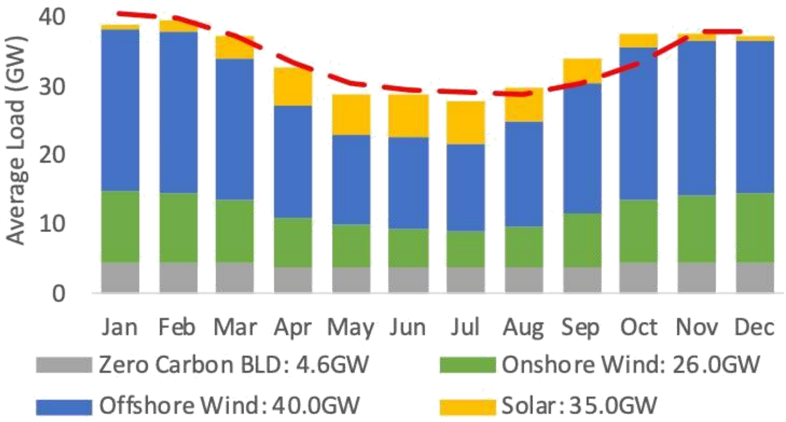


Figure 7-3: Deploying 35GW of large-scale solar alongside government offshore wind ambitions (40GW) meets anticipated seasonal demand levels [7, Market data, Author analysis]

7.8.15 The Scheme, as a leading large-scale solar scheme in GB, is an essential steppingstone towards the future of efficient decarbonisation through the deployment of large-scale, technologically and geographically diverse low-carbon generation assets.

7.9 The Scheme would make a significant contribution to the adequacy and dependability of the GB electricity system

7.9.1 The UK has substantial renewable energy resources, including 40% of Europe's wind resource [3, Para 3.4.3] and areas of developable land which receive high levels of solar irradiation. These resources must be harnessed to decarbonise our economy, and in **Section 6.3** it was demonstrated that without solar generation, the challenge faced by the UK in meeting its decarbonisation targets would be significantly harder. **Section 7.8** showed an analysis of the generation dependability of solar generation within the GB renewable technology class, and the important role solar will play alongside offshore wind in meeting demand through the year without causing significant unproductive costs through the curtailment of generation for system operation purposes. For these reasons, many experts are active supporters of capitalising on the progress made to date in bringing unsubsidised solar forwards in GB.

7.9.2 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 to wherever and whenever it is needed. **Section 7.6** described the measures required of transmission connected solar generation to support system operability due to its connection to the NETS.

7.9.3 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 being developed, are already in operation in the UK. However, solar assets are increasingly able to provide important system services themselves, and integration assets (such as BESS, which are included in the Scheme's proposal, see **Section 10.4**) are being deployed to do the same, as well as to manage short-term supply / demand volatility.

7.9.4 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.

7.9.5 Sunnica, 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.

8 Forward infrastructure plans and operability needs of the NETS near to the Scheme's proposed point of connection

This chapter describes aspects of the NETS in the vicinity of the Scheme. Annually, NGESO perform an analysis of the NETS from both an SQSS and power flow capability perspective. This analysis can be found in the *Electricity Ten Year Statement* (ETYS), and options to improve power flow capability can be found in NGESO's *Network Options Assessment* (NOA) publications. In particular, the ETYS looks at whether the current network allows GB national demand to be met (the "security" criteria), and whether generation is and will remain unconstrained (the "economy" criteria).

8.1 Network togography

8.1.1 The Scheme will connect into the NETS via the existing Burwell substation, on the Cambridgeshire/Suffolk border.

8.1.2 Burwell National Grid Substation, the Scheme's grid connection location, is situated in NGESO's East of England area; an area which is connected by several sets of long 400kV double circuits, as shown in **Figure 8-1**. It is sandwiched between the B9 and the B14 boundaries, these boundaries are not hard, nor physical, but are areas within which NGESO characterise power flows.

8.1.2.1 B9: Midlands to South of England separates the northern generation zones and the southern demand centres;

8.1.2.2 B14: London encloses London and is characterised by high local demand and a small amount of generation. London imports power across the B14 boundary.

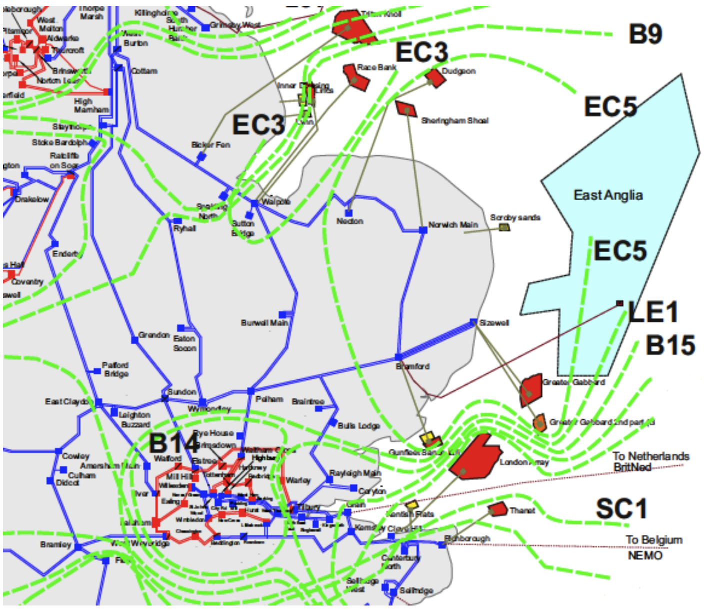


Figure 8-1: The NETS in the vicinity of Burwell Main [10, Appendix A]

8.1.3 Burwell National Grid Substation is a main substation on an important radial “artery” of the NETS, running north-south (from the traditional coal generation areas near and north of the east midlands) through to London and the south east, major areas of demand. The Walpole to Pelham line (to which Burwell Main has access) is one of five lines which transmit power south (shown in **Figure 8-1**, providing resilience through strength in depth to the NETS to enable very high levels of reliability to all users.

8.1.4 The NETS in the East of England is an area of transient power flow, although flows into and out of this area do not currently impose constraints on anticipated future power flows through the nearby NETS, However, being located near to important areas of demand and power flow, very high reliability and deep resilience to potential transient operating states is of vital importance to maintain connection for a significant part of GB’s residents, services and commerce.

8.1.5 By connecting the Scheme to the Burwell National Grid Substation, the Grid Supply Point for Cambridgeshire and much of Cambridge, the Scheme will be providing a local low-carbon source of supply for local residents and businesses, while also playing an important role in the provision of bulk power, capable of transport across the entire NETS and to wherever it is demanded.

8.1.6 Relevant points from the 2020 ETYS [88] which is concerned only with the proper functioning and development of the NETS, rather than local (distribution) networks, include:

8.1.6.1 Current power flows do not significantly challenge the existing transfer capability;

8.1.6.2 Developments in the east coast and East Anglia regions, such as the locations of offshore wind generation connection, potential new nuclear build and network infrastructure requirements, will affect the transfer requirements and boundary capability of boundary B9. The FES highlights that between 7 and 25GW of generation could be expected to connect within this region by 2035;

8.1.6.3 Although currently a power import region, the East of England is anticipated to become a power export region as a consequence of these foreseen low carbon generation connections;

8.1.6.4 However, peak demand in the East of England region is expected to be between five and seven GW by 2040;

8.1.6.5 London, the regional demand centre, is expected to retain low levels of generation and therefore relies heavily on surrounding NETS circuits to draw power in, particularly at times of high winter demand. With an increased reliance on interconnectors, power flows from the north through London to the continent, and vice-versa;

8.1.6.6 During export events (when GB power is flowing to the Continent), London circuits can become overloaded. However, because these events are constrained when they occur, boundary B14 is also unlikely to require any urgent network developments;

8.1.6.7 Due to the forthcoming closure of (particularly) coal stations to the north west of the region (near the Walpole substation), boundary B9 and its major arteries are unlikely to require any urgent network developments;

8.1.6.8 However local network stability may become an additional concern when large generators connect in the future, which will require management.

8.1.7 National Grid will continue regularly to assess their development plans for the future management of flows across the B9 and B14 boundaries, a key input to these plans will be the potential capabilities of any assets planned to connect at Burwell Main (among other locations) in the coming years.

8.1.8 **Figure 8-2** shows the average day ahead daily flow of power into the south east from the north, across the B9 boundary, over 24 months from 1 October 2019 to 30 September 2021. A positive number on the y-axis represents a flow into the region (from the north and north-west), and a negative number represents a net flow out of the region back north and north-west. If, in operational timescales (i.e. close to real time), flows across the boundary are anticipated to exceed transfer limits, NGESO take actions in the real time Balancing Mechanism ('BM') to turn some plant down and others up, at a cost charged to the consumer.

8.1.9 It can be seen from the chart that during this period, the boundary limit was sometimes challenged at the day ahead stage by average import power flows and more often, flows peaked over the boundary limit (yellow area is above the blue line). Peaking flows result from high demand for power to the south and south-east, including for export to the continent through interconnectors with landfall on the south coast.

8.1.10 Therefore, the location of the Scheme's point of connection at Burwell (on the south side of the B9 boundary) could improve the import transfer position across the B9 boundary and ease the transport of power to meet high demand in the south and south east and the Continent, when it occurs, as well as providing an important source of low-carbon power for East Anglian consumption, in East Anglia. These points will help reduce the per-unit cost of transmission system management, which are charged to all users of the NETS, by displacing the need for power to be transported from generators in the north to demand in the south through the NETS when conditions so require that to happen.

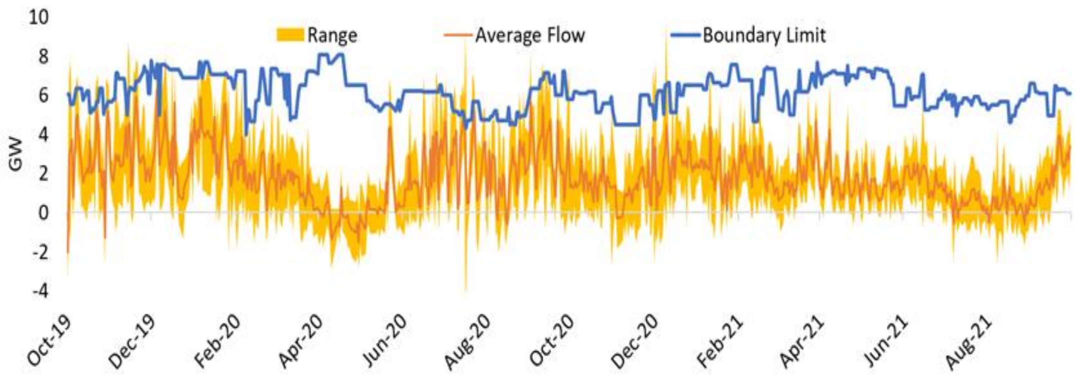


Figure 8-2: Day ahead constraint limit and flow into the south east of England [11, Author Analysis]

8.1.11 The connection of energy balancing infrastructure at Burwell Main, which is one of the characteristics of the Scheme will, if granted, provide additional options to NGESO to manage flows across the boundary in an efficient way, by providing a resource which could be called upon by NGESO to provide services to resolve any additional operational challenges or constraints on this important area of the NETS which may from time to time arise.

8.2 Local network operability considerations

8.2.1 The transmission ecosystem around Burwell Main must remain capable of managing these complications for future system operability. The capabilities of any assets planned to connect in this area are likely to influence National Grid's local system management and investment plans. The complications are:

Circuit overloads

8.2.2 Power flows past Burwell Main are currently circa 2GW, generally in a north-south direction. NGESO have forecast these to remain relatively steady until 2026/27, when the Norway Interconnector and several large offshore wind areas connect, moving average power flows up to circa 3GW [88, Appendix C]. While this level of flow is not anticipated to challenge to the current circuit ratings (See **Table 8-1**) for Burwell Main's direct connections, being part of the East of England area, heavy circuit overloads remain a risk from the late 2020s onwards as more generation connects. Power flows past Burwell Main may need to be managed through NETS-connected flexible generation in the event of a transmission system fault.

Table 8-1: Future forecast power flow capability at Burwell Main substation [10, Appendix B, Data Tables]

Season	Spring	Summer	Autumn	Winter
Rating (MVA)	5845	5003	5450	6137

Voltage Management

8.2.3 The long double-circuit overhead lines in the East of England have potential to cause local voltage management issues, especially following a fault on one of the five major north-south arteries. Such a fault could force power to travel a longer way from its supply points (e.g. wind from northern connected offshore wind farms) to its demand (London) by having to route via the remaining (un-faulted) transmission lines. Voltage control must be applied locally, through local reactive power provision. Dynamic voltage support, as may be provided by the inverters connected to the Scheme's solar panels and therefore connected to the Burwell Main substation, may be of significant use to NGESO in managing voltage in the area.

Stability issues

8.2.4 Stability is a description of the dynamics of a power system under normal or fault disturbances. A stable system is one where faults take time to propagate and are therefore manageable by well-understood measures and within planning timescales. High power flows may make the East of England area prone to instability, particularly at times of high local generation which needs to be exported from the area. NGESO may therefore need to bolster the resilience of their system, in order to be well-prepared to be able to manage any faults which occur. Some measures which support system stability may be provided by locally-connected assets which are fast-acting and/or quick-ramping.

8.2.5 The relationship between the location of new or existing generation assets, the transmission systems around them, and overall system strength remains complex. By their presence, these assets support short circuit levels, therefore the location of those assets, particularly ones which are able to provide system services (see **Table 10.1**) will be important in areas of high NETS power flows. The East of England (among others) has the potential to become a complex part of the GB transmission network. It is an area of interest under both the security and economy assessment criteria, and with significant levels of local power demand and growing levels of power supply.

8.2.6 The commissioning of a large-scale solar scheme which connects to the NETS at Burwell would contribute towards both assessment criteria and reduce the requirement for bulk transmission of power in from other locations. Ancillary service provisions such as those available from solar and / or storage assets, as described in **Table 10.1**, are also likely to become increasingly important in this location into the future to contribute to the proper functioning of the local NETS.

8.3 A conclusion on system security

8.3.1 Innovation in generation must not be allowed to challenge security of supply, but a lack of innovation in generation must not be allowed to risk achieving decarbonisation targets. Few market commentators and participants have faith in the ability of a single new technology to bridge the energy gap. Many commentators however are active proponents for the future of solar power in GB, for example:

> *R&D brings the promise of new and much more efficient renewable-generation vintages. The most exciting of these probably lie with solar*. [86, p66]

8.3.2 Moreover, whilst the promise of a single saviour technology is exciting, the fact is that no suitable standalone technology has yet emerged which will meet all of government's emerging policies. It is therefore far more likely to be the deployment of a range of diverse technologies, critically including solar, other renewables, storage and other low-carbon technologies, which will deliver a sufficiently mature energy mix at the scale required to meet GB's needs of energy security, while meeting carbon reduction targets.

8.3.3 This is in line with current government policy, in that the NPS set out a case for the need and urgency for new energy infrastructure to be consented and built with the objective of supporting the government's policies on sustainable development, in particular by:

8.3.3.1 Mitigating and adapting to climate change, and

8.3.3.2 Contributing to a secure, diverse and affordable energy supply. [4, Para 1.3.1]

8.3.4 In light of these observations, the following conclusions are made.

8.3.4.1 The connection of a large-scale solar scheme connected to Burwell National Grid Substation will contribute to national system adequacy and decarbonisation targets;

8.3.4.2 Connecting a solar scheme at Burwell will enable NGESO to increase the level of dependence they can place on expected renewable generation outturn nationally and would provide a local supply of bulk low-carbon generation to consumers in the local area, especially Cambridge and its surrounding area;

8.3.4.3 The services which (by virtue of its intended scale and direction connection arrangements with the NETS) are mandatory for the Scheme to provide, are likely to be beneficial to NGESO in securing the NETS in the local area;

8.3.4.4 The ancillary services available from a large-scale energy storage asset connected to the NETS, would likely provide significant benefit for NGESO's management of energy balance and system security.

8.3.4.5 Co-locating an energy storage asset with a large solar scheme at the Burwell Main substation would also provide a uniquely beneficial asset which will support the ongoing operation of this busy area of the NETS.

8.3.5 The scheme, which consists of a large-scale solar generation asset, and includes co-located battery storage, supports UK decarbonisation; supports GB electricity supply adequacy, and provides much needed system services in support of GB electricity system operation.

8.3.6 Crucially though, any such asset must meet a third government policy objective: that of economic supply.

9 Solar is economically efficient in GB

The third pillar of GB's energy strategy is economic efficiency.

> *Most renewable energy resources can only be developed where the resource exists and where economically feasible.* [4, Para 2.5.36]
>
> *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.* [32, p9]

This section discusses broad principles of economic efficiency, by explaining how the GB electricity market operates and demonstrating how competitive solar assets have become because of recent gains in experience, technology and scale.

9.1 An introduction to pricing electricity in the GB power market

9.1.1 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[23]. Each day is subdivided into 48 half-hour periods ("Settlement Periods") 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. Typically, solar generation has 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 the sun is shining) and whenever power prices are positive. Because of the variable, but forecastable, nature of solar irradiation, they also tend to trade on the 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. Thermal and hydro plants have higher marginal costs (relating to the cost of the fuel they are converting into that additional MWh), therefore will only generate when the market is providing a higher price signal. They may also trade power, fuel and carbon costs further ahead in order to lock in a gross margin. All generators produce active power (MWs), and to balance the electricity system, the total national active power generated must meet the total national system load at all times. 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.

9.1.2 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. This is represented by the three red lines. At a mid-level of demand, the solid red line crosses the blue line at about £45/MWh. This becomes the price of power. If demand falls (e.g. to the left-hand dashed 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. Therefore, the

[23] The cost of generating an additional 1MWh, usually including variable fuel and transmission costs.

price of power reduces (here, to about £10/MWh). Conversely, as demand increases, (e.g. to the right-hand dashed red line) assets with higher marginal costs of production are required to run; therefore, the price of power increases (in this example, to about £65/MWh).

9.1.3 Critically, the blue line in **Figure 9-1** also varies for each half hour settlement period, as generating assets become available or unavailable due to outages, breakdowns or, critically, more or less wind or sunshine is expected or experienced. Therefore, as more electricity is generated by solar farms, the blue line within the red ellipse (around a zero marginal cost of power) will stretch horizontally, and as a result, the blue line slides to the right for all higher levels of demand. 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. 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. The conclusions are the same though: increasing the capacity of renewable assets in GB reduces the traded price of power. This demonstrates that solar power reduces the market price of electricity in GB, but the effect is not limited to GB. A 2018 paper by Energy Institute of Haas, *Setting with the sun*, describes a quantitative analysis of the impact of deep solar penetration in California, an historically conventional generation market. The paper concludes that renewable investment has had a significant impact on power prices, and appears to be responsible for the majority of price declines over the last five years in California [89, p26].

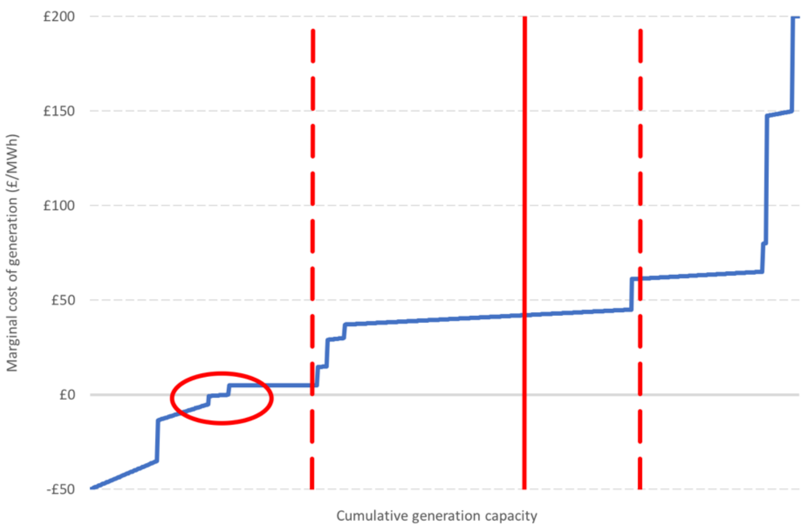


Figure 9-1: GB electricity system representative marginal cost stack [Author analysis]

9.2 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 next year 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. [90, p67]

9.2.1 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 shown in **Figure 9-2**, 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 9-3**).

9.2.2 An important measure of the lifetime cost of solar generation, is its Levelised Cost of Energy (LCOE). 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 as well as anticipated in-life capital and operating expenditure, for example the re-powering of sites to manage anticipated degradation. Critically this allows all forms of generation to be compared with each other on a consistent basis. Lazard [13], albeit historically focussed on the US market, is a recognised source of such comparative analysis. The most recent revision of their analysis, published in October 2020, illustrates that utility scale solar PV is already more economically attractive than almost all other existing forms of generation, and is matched only by wind and the marginal operating cost of fully depreciated gas combined cycle, coal and nuclear facilities.

9.2.3 This comparison is presented in **Figure 9-3**, with the range representative of different complexities of technical solution.

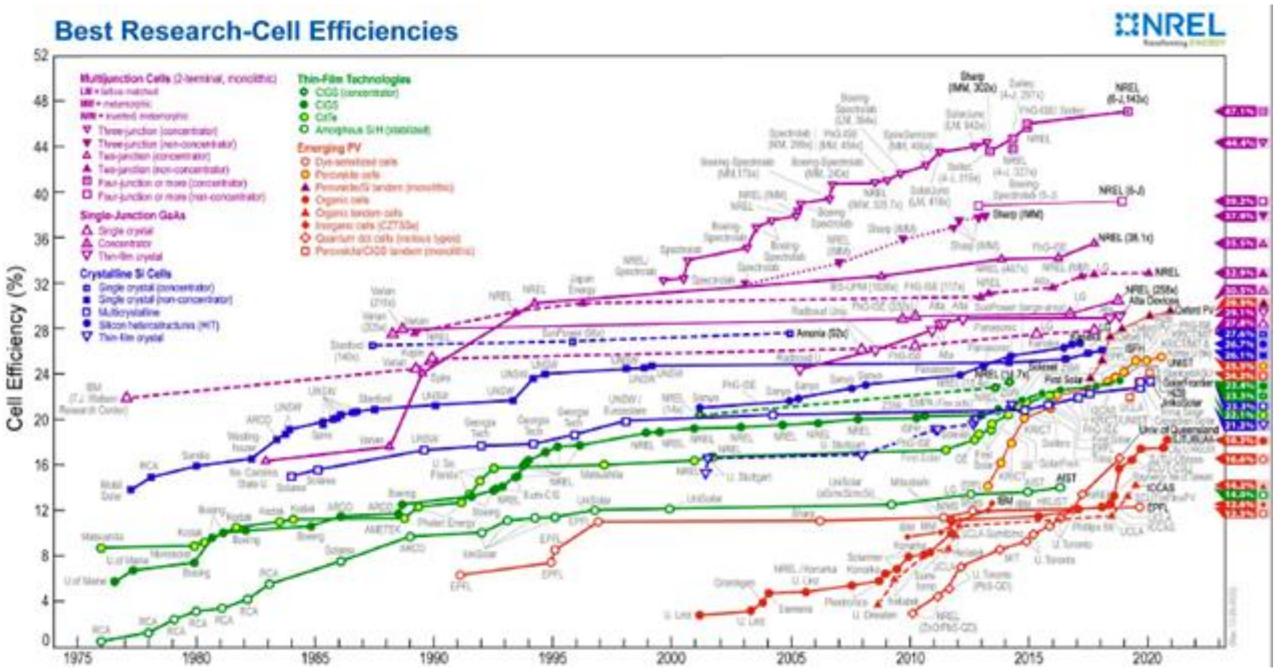


Figure 9-2: The efficiency of solar cell technology has increased significantly year-on-year for decades [12]

9.2.4 Closer to home, 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 ...* [36, p39]

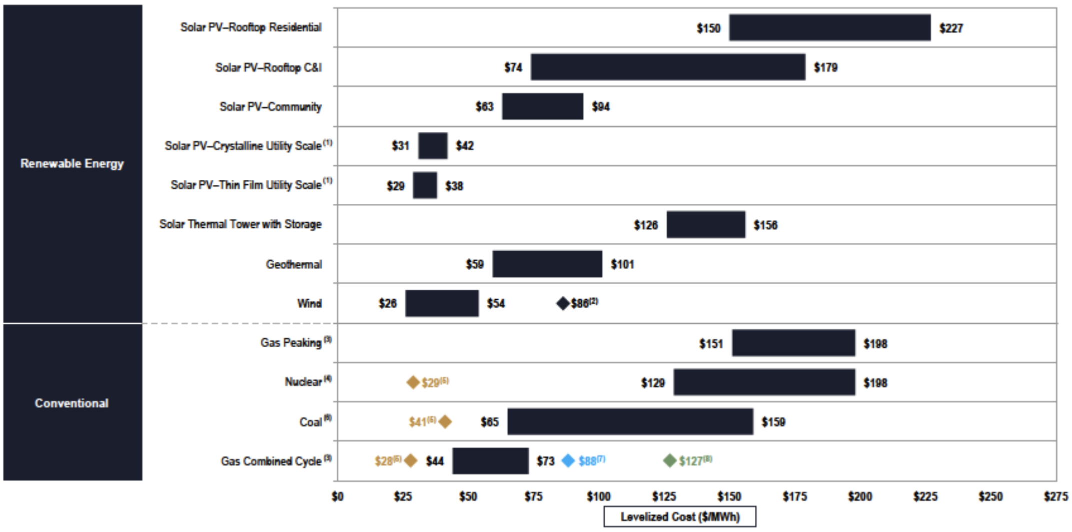


Figure 9-3: Unsubsidised levelised cost of energy comparison [13, p2]

9.2.5 Solar costs are driven by capital infrastructure, development and integration costs, and lifetime O&M including minimising or addressing the anticipated degradation of solar panels and inverters. Technological advances have increased the efficiencies of solar panels, 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. This fact is also demonstrated by Lazard in **Figure 9-4**, corroborating a low-cost present and lower-cost future for electricity generated by solar installations.

9.2.6 Industry-sourced data and opinion concurs with Lazard'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 [26, Figure 2.2].

9.2.7 The BEIS *2020 Cost of Generation* update [14] concurs with the analysis shown, and results are summarised in **Figure 9-5**. The analysis shows that UK-specific estimates of levelised cost of energy from solar have reduced significantly since 2013; that they are predicted to fall further in the decades ahead; and that solar, already being highly competitive against current conventional and renewable generation costs, is predicted to retain a cost advantage for the decades ahead.

9.2.8 **Figure 9-5** 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 3.2** explains the rationale for urgent action to develop significant capacities of low-carbon generation: time is a precious commodity. Further, it is the development of early projects which allow learnings to be implemented, technology to advance through practical application, and markets and supply chains to evolve in more efficient ways, to achieve the future cost reductions which have been forecast by BEIS and others.

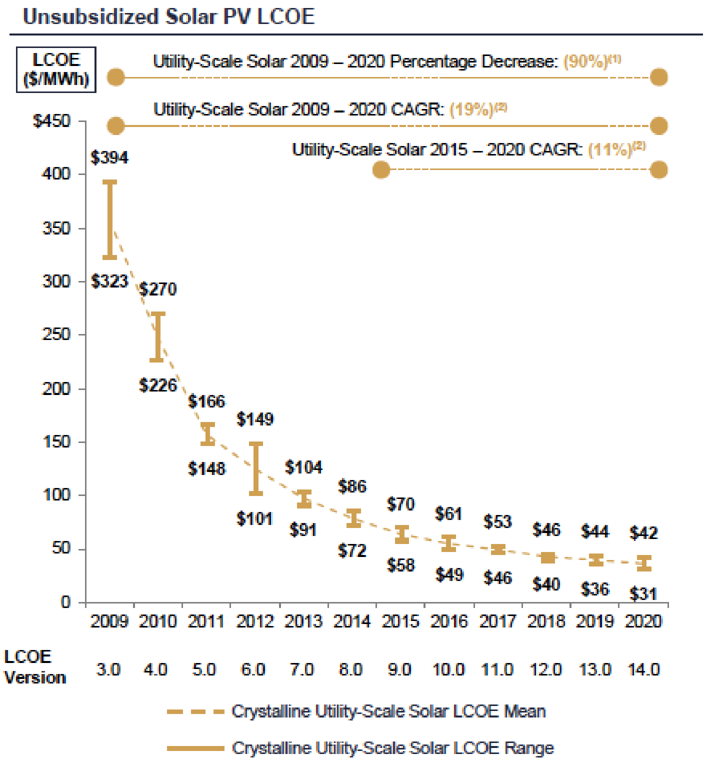


Figure 9-4: Historical reductions in the LCOE of solar generation [13, p9]

9.2.9 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.

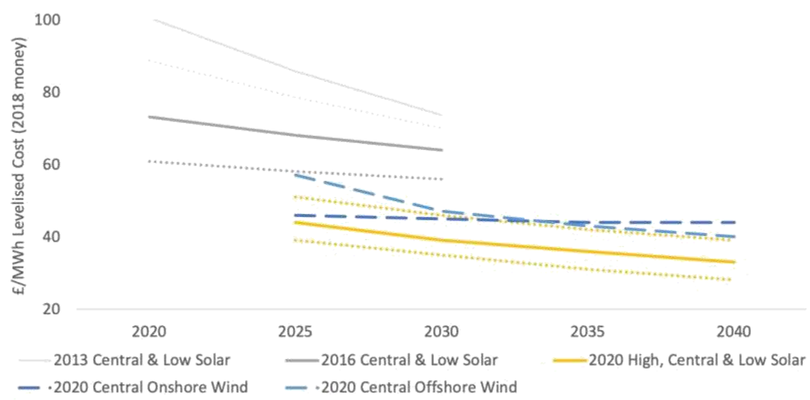


Figure 9-5: BEIS Cost of Generation. An evolution of Levelised Cost forecasts [14, and Author analysis]

9.3 The importance of scale in a solar development

9.3.1 This Statement of Need builds upon the case for need established in the NPSs for the urgent development of low carbon electricity generation, and sets out the need for a rapid increase in low carbon electricity generation capacity in GB to meet decarbonisation obligations, and the critical role that large-scale solar schemes will play in meeting that need. The NPSs [3, 4, 20] do not set any upper limit, target or threshold for electricity generation capacity, and details of future generation capacities are included in **Section 6.1**. Estimates from NGESO, NIC and ESC of the capacities of new solar generation needed in order to meet Net Zero include 44 to 76GW of additional solar capacity by 2050, with approximately one quarter of this needed in the next ten years. In order to meet those projections (noting that, consistent with the NPSs, these capacities are not presented as a target, nor indeed a quota, and therefore could be gone further than) a very high proportion of (if not all) solar projects of any scale which come forward for consent will need to be approved. Falling short on solar development at any stage in the next decades will risk causing the UK falling behind on decarbonisation and will increase the magnitude of the task (and therefore the intolerable risk of failure) of meeting its 2050 legal commitments to achieve Net Zero.

9.3.2 The case has also been made for the socially economic benefits of as-low-as-possible electricity generation costs. Assuming that the need for solar generation in GB has been accepted by the reader, this section illustrates the benefit in reduced carbon emissions pre-2030, and the lifetime economic benefit to the consumer, of optimising the installed generation capacity at the Scheme, versus developing the same total capacity but across multiple locations and over a phased timeframe (necessary, due to the concurrent management of multiple projects through development and consent).

9.3.3 Solar schemes incur fixed costs, for example project development, site infrastructure and grid connection costs. Project development timeframes are also generally fixed, although smaller schemes are assumed to be deliverable (from construction start to commercial operation) in one year, while larger schemes may take two years. Other costs vary according to the amount of capacity installed, including the capital costs of solar panels and balance of plant equipment, land rent, and other aspects. O&M is also variable according to the capacity installed, while individual sites will incur fixed operational overheads, for example security and monitoring, accounting and business management, etc.

9.3.4 **Figure 9-6** shows the results of an analysis which illustrates that development of one large solar scheme brings carbon savings and economic benefits versus developing combinations of smaller independent schemes, each combination matching to the same total installed generation capacity. The analysis assesses the relative costs and construction timeframes associated with the development of different sized independent solar schemes against the total cost and carbon benefit achievable through the development of one large solar scheme such as the scheme proposed at Sunnica.

9.3.5 The base case scenario (against which each of the scenarios illustrated in **Figure 9-6** is compared) models the LCOE and carbon benefit associated with the development of one large solar scheme with characteristics which are consistent with the Scheme.

9.3.6 Four other scenarios, the results of which are shown in **Figure 9-6**, include two, four, eight and ten smaller independent schemes, each developed and grid-connected independently from each other, but each scenario matches the same total installed capacity as the base case scenario. Each independent scheme is assumed to be at or over 50MW installed capacity.

9.3.7 A final scenario models multiple smaller schemes, each under the 50MW capacity threshold, in order to simulate the development of distribution connected schemes which are outside of the NSIP process.

9.3.8 The analysis considers development, capital and operating costs. The financial data inputs been drawn from BEIS's *2020 Electricity Generation Costs* report [14] and have been supplemented as necessary with industry benchmarks from the Author's experience. The analysis considers development timescales and development concurrency. Smaller schemes may have shorter construction durations than larger schemes; but a developer's capacity to handle multiple concurrent schemes is more influenced by the number of schemes applying for consent or undergoing design or construction at one time, than it is by the total capacity of the schemes under development.

9.3.9 The analysis then compares the environmental and economic benefits or disbenefits achieved by each scenario relative to the first single large solar scheme.

9.3.9.1 Development costs, both fixed and variable, are included at the beginning of each scheme within each scenario;

9.3.9.2 Ongoing operational costs, based on industry benchmarks, have been included through life for each scheme within each scenario;

9.3.9.3 Solar irradiation, load factor and annual degradation have been held constant across all schemes and scenarios;

9.3.9.4 Development costs and unit operating costs scale according to the size of each scheme, but unit capital costs (£/MW(p)) are constant across each scheme in each scenario;

9.3.9.5 A cash flow model incorporates these costs and includes an allowance for institutional rates of return on investment over a consistent anticipated project lifetime;

9.3.9.6 The key outputs are an indicative LCOE (£/MWh) for each scenario, as well as the carbon savings (tonnes of CO_2e) each combination delivers in the critical pre-2030 timeframe;

9.3.9.7 In the interests of simplicity and transparency, the analysis excludes tax and capital allowances;

9.3.9.8 The LCOE and carbon emissions savings pre-2030 are then compared between different scenarios.

9.3.10 **Figure 9-6** shows a comparison of the LCOE for each of these solar scenarios with the base case, single solar scheme.

9.3.11 Storage, the benefits of which are described more fully in **Chapter 10**, has not been included in this analysis, although storage does provide additional benefits to the local and wider energy system, and specifically to the Sunnica Scheme.

9.3.12 This analysis shows that the LCOE for each scenario increases (i.e. the scenario costs more) as the number of schemes which deliver each scenario increases (or the average size of each individual scheme decreases). This is because all schemes incur fixed development, construction and operational costs, and these are multiplied up by the number of schemes included in each scenario. Larger schemes also attract some cost efficiencies as a result of their increased scale, for example unit procurement costs, or annual maintenance costs. Such efficiencies of scale are less apparent in smaller schemes.

9.3.13 This analysis also assumes a fixed ratio of installed solar capacity per unit of grid connection capacity. In smaller locations, which can be more footprint constrained than larger locations, it may not be physically possible to lay out sufficient panels to preserve these ratios. The outcome would be lower overall output over the same connection, a corresponding reduction in load factor and a corresponding (further) increase in LCOE, a further disadvantage to multiple smaller schemes when compared to an equivalent capacity single large scheme.

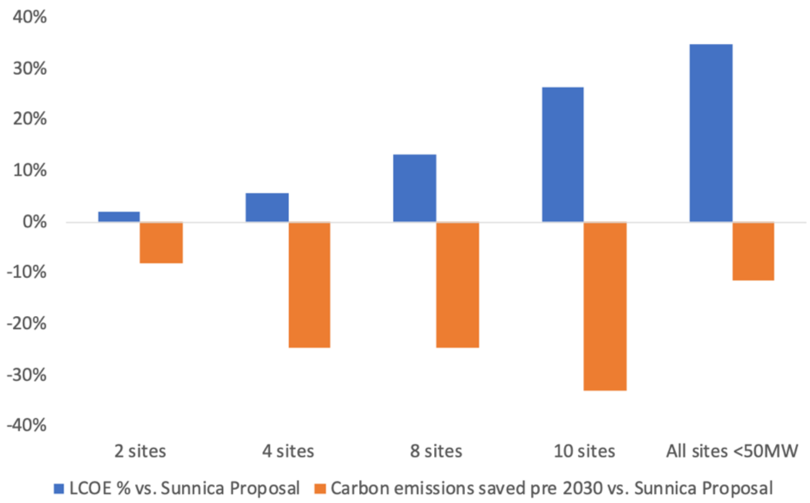


Figure 9-6: LCOE and carbon emissions savings at large-scale single-site solar, versus developing the same total capacity across multiple projects [Author analysis]

9.3.14 The results also show that as the number of schemes within each scenario increases, and that scenario's development timescales also increase, less low-carbon electricity is generated in the critical period before 2030 (see **Section 3.2**). Each multiple-scheme scenario produces between 8% and 33% less low-carbon electricity before 2030 than does the single-scheme base-case scenario. The analysis does not allow for any failures in site identification, selection or consent for scenarios with multiple schemes across multiple locations, and nor does it allow for any potential delays associated with managing multiple schemes through the development process. The analysis therefore presents a "best possible case" for multiple scheme scenarios. It is more likely that in delivery, multi-scheme scenarios would slip back, or under-deliver, against the analysis presented.

9.3.15 It is important to clarify that this analysis should not be taken to imply that smaller solar schemes should not be brought forward or consented for economic or carbon reduction reasons, and reasons may exist which favour the development of individual schemes rather than incorporating them into a larger scheme. However the analysis demonstrates that where the opportunity for the development of larger schemes exists, that opportunity is likely to bring about greater decarbonisation and economic benefits than any combination of smaller independent schemes comprising an equivalent total installed capacity.

9.3.16 The Scheme presents an opportunity to develop and install large-scale solar generation in a highly beneficial location, and this analysis demonstrates that it is consistent with government policy to develop the scheme at the largest scale possible subject to the planning balance and potential techno-economical constraints.

9.4 A conclusion on economic efficiency

9.4.1 The main points in summary of this chapter are that:

9.4.1.1 Solar power reduces the market price of electricity by displacing more expensive forms of generation from the cost stack. This delivers benefits for electricity consumers;

9.4.1.2 Due to technological advances, power generated by solar plants is already at or below grid parity cost in GB;

9.4.1.3 Solar power is economically attractive in GB against many other forms of conventional and renewable generation;

9.4.1.4 Size remains important, and maximising the generating capacity of schemes improves their economic efficiency, so bringing power to market at the lowest cost possible. 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;

9.4.1.5 The Sunnica Scheme proposes a substantial infrastructure asset, which if consented will deliver large amounts of cheap, low-carbon electricity both during and beyond the critical 2020s timeframe. Maximising the capacity of generation in the resource-rich, accessible and technically deliverable proposed location, represents a significant and economically rational step forwards in the fight against the global climate emergency.

10 Flexibility and integration

An important enabler for the further development of the large renewable generation schemes which are leading UK (and international) decarbonisation actions, are flexible technologies which optimise the integration of RES schemes into electricity grids. Significant cost and capability advancements are being made in the development of flexible technologies. New operability regimes are also successfully keeping the lights on and the power consistently flowing as RES share increases.

> *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.* [32, p6]

> *New forms of flexibility could lower future costs for consumers, by minimising expensive network reinforcement or reducing the need for additional generation, especially peaking capacity which needs to be deployed quickly to meet spikes in demand.* [21, p72]

In this chapter, we describe three important classes of integration measure which deliver flexibility: interconnection, electricity storage, and hydrogen. Of these, electricity and hydrogen are most relevant for the Scheme.

10.1 Integration measures support low-carbon electricity system operation

10.1.1 The utility of renewable generation assets is enhanced by the development of flexible integration measures. The technologies which provide these measures will be important to the proper functioning of high-RES electricity systems in terms of both decarbonisation and security of supply. It is anticipated that the beneficial effects of their functions on electricity system operation will increase as the proportion of renewable generation on that system also increases. Flexible integration technologies are capable of:

10.1.1.1 Capturing “free” energy when it is not useful and dispatching it when it has use;

10.1.1.2 Transferring “free” energy from where it is not useful, to a location where it is useful;

10.1.1.3 Transforming “free” energy from a form which is not useful, into a form which is useful; and / or

10.1.1.4 Providing system services which help integrate renewable assets into the GB energy mix.

> *New storage technologies reduce the problem of meeting peaks in demand, and dampen wholesale price volatility, back up solar and wind intermittency, and open up the prospect of the electrification of transport.* [86, p68]

10.1.2 The meaning of flexible integration measures has expanded in recent years as a result of considering ways of achieving Net Zero. Not only must generation and demand assets integrate with each other within the electricity market, but also the integration of the electricity market with other energy markets is now being pursued as a way of driving down carbon emissions across many sectors.

10.1.3 The Energy System Catapult predict that "Beyond bulk energy provision, a significant increase in different types of storage and flexibility is needed", concluding that major innovation and deployment of storage technologies across different timescales (from seconds to seasons) will be needed to renewable generation intermittency without the requirement for unabated fossil fuel back-up systems. Their modelling suggests that day-to-day electricity system flexibility in 2050 will be provided by between 4GW and 8GW of electricity storage and 10GW of interconnectors [8, pp7, 23].

10.1.4 NGESO's most recent FES predicts that storage will be required across hydrogen, heat, carbon and electricity to efficiently manage flexible supply and demand. Their modelling indicates the need to increase storage capacity (from 4GW at the end of 2020) to 9 – 16GW by 2030 and 28 – 43GW by 2050 to balance supply and demand within the GB system [104, Table SV.22]. The NIC predicted 12GW – 19GW of electricity storage in 2050 in their Net Zero power systems with 60%, 80% and 90% renewable scenarios respectively [40, pp19, 21].

10.2 Interconnection

10.2.1 Interconnectors (and network development) are important strategies for managing the intermittency of power generation, and localised flows as a result of weather-dependent generation. Interconnectors allow the sale of green energy to neighbouring international markets when production is in surplus, and provide access to energy from other countries when demand is greater than supply. Importantly, until the power system in any interconnected country becomes fully decarbonised, there is uncertainty around the carbon intensity of foreign imported electricity. The FES predicts the need for 16 – 22GW of interconnection by 2030 (up from 6 GW at the time of writing) and 20 – 28GW by 2050 [104, Table SV.22].. The NIC anticipate the need for 18GW of electricity interconnection to other countries in 2050 in their Net Zero power systems with 60%, 80% and 90% renewable scenarios respectively [40, pp19, 21], a scale which was matched by the CCC in their Sixth Carbon Budget Balanced Pathways scenario [2, p136].

10.2.2 At the time of writing this report, the UK has 6GW of operating interconnector capacity to France, Belgium, Ireland, the Netherlands and Norway. Interconnector projects are large and complex, with long lead times. Danish, Icelandic and other French interconnector projects are currently at various stages of development, all currently advertised as commissioning in the 2020 to 2025 timeframe, however delays can be experienced, for example on France / UK interconnector ElecLink (not yet commissioned) and IFA2 (commissioned January 2021). Current projects in development total approximately 4GW of capacity, with a further 7GW proposed. Interconnection is one contributor, but is not the standalone solution, to low-carbon electricity supply for two reasons.

10.2.3 Firstly, there is no guarantee that power flowing through the interconnector to NETS was generated from low-carbon generation (or is causing carbon-intensive backup plant in Europe to generate in order to supply GB).

10.2.4 Secondly, there is no guarantee that the interconnector will flow in to GB when power is needed. Interconnectors respond to price signals, so a pan-European weather event which may cause demand to increase simultaneously in both connected markets, would cause prices in both markets to chase each other up; and power would ultimately flow to where price outturn was highest. This could transform the anticipated supply from an interconnector into a demand to that interconnector, making the demand for power in the supplying market higher than it otherwise would have been.

10.3 Hydrogen

10.3.1 As described in **Section 5.1**, the prominence of a hydrogen economy has increased in subsequent FES since the 2019 edition. This is a direct result of the requirement to meet Net-Zero, and hydrogen is an important constituent of those scenarios which meet the 2050 carbon emissions reduction target. Although the public prominence of hydrogen has recently grown, it has been forerun by a longer acknowledgement of its potential to enable deep and broad decarbonisation.

10.3.2 The Union of Concerned Scientists describe that hydrogen is an important energy vector which may be able to help decarbonise homes and buildings, and power road transport, however hydrogen needs to be made through large-scale industrial processes, which require significant amounts of energy. Thus, in order for hydrogen to contribute to decarbonisation, the energy source for hydrogen production must itself be low carbon. [91]

10.3.3 Government's 2021 *UK Hydrogen Strategy* explains that hydrogen has "the potential to overcome some of the trickiest decarbonisation challenges facing our economy" [108, p2] especially in enabling the decarbonisation of industry and land transport, and as a potential substitute for current carbon-intensive marine and aviation fuels.

10.3.4 There are many practical ways in which a hydrogen economy can enable decarbonisation. The major potential uses of hydrogen are:

10.3.4.1 A further development on from already existing technologies such as liquefied petroleum gas (LPG) and compressed natural gas (CNG) will enable hydrogen's use in road transport, reducing the carbon intensity of freight haulage and public road transport, enabled by a national supply infrastructure;

10.3.4.2 Hydrogen, when blended with mains gas into the GB National Transmission System (NTS), will reduce the carbon intensity of current gas use (home and commercial heating, home cooking, industrial use). Potentially only minor changes would be required to enable existing appliances to run on a blended fuel, especially one with only low (c. 10%) amounts of hydrogen in the blend;

10.3.4.3 A greater share of hydrogen in a blended natural gas mix will provide greater decarbonisation, leading effectively to a substitution of natural gas by hydrogen in homes and businesses, wherever possible. An upgrade to the NTS would be required but would be cheaper than building a new network;

10.3.4.4 This also opens up the use of hydrogen as a power generation vector: substituting the current CCGT fleet (c. 350 gCO_2/kWh at current efficiencies) and Open Cycle Gas Turbine fleet (c. 450 gCO_2/kWh at current efficiencies) for a zero-carbon dispatchable generation technology, covering both baseload and peaking (flexibility) needs. For example, the Intermountain Power Project (Utah, USA), which is replacing 1.8GW of coal generation with 0.8GW of CCGT plant, capable of burning up to 30% hydrogen, 70% natural gas before 2025, and 100% hydrogen by 2045;

10.3.4.5 Hydrogen is a highly suitable energy vector for inter-seasonal energy storage. By using excess low-carbon electricity generation to produce hydrogen to send to storage, that hydrogen can later be released for other application when needed. Because of the low unit costs of keeping hydrogen in storage, this technology is particularly well suited to long-term use.

10.3.5 At the current time, most hydrogen is produced by methane cracking. Methane cracking emits carbon as a by-product, therefore the ramp up of methane cracking facilities would require CCUS capability to achieve Net Zero carbon, such as the industrial cluster projects described in **Section 3.3** which are hoped to become operational in the second half of the 2020s.

10.3.6 Electrolysis currently accounts for approximately 1% of global hydrogen production, however a growth in electrolysis capability and capacity opens out the prospect of using RES to produce hydrogen, in potentially significant quantities.

> *Electrolytic hydrogen ... through nuclear and renewables, has the lowest carbon emissions over the full life cycle. Hydrogen can play a vital role in decarbonising sectors such as industry and heavy transport where few alternatives exist*. [92, p16]

10.3.7 Hydrogen produced by electrolysis, which uses low-carbon (renewable) electricity, therefore has exciting prospects for replacing natural gas; displacing petroleum products from heavy transport; and providing an energy vector suitable for long-term zero-carbon energy storage.

10.3.8 Actual examples of hydrogen produced by electrolysis from low-carbon generation (predominantly in the US) include solar-to-hydrogen at California’s Stone Edge Farm Estate (where excess solar generation is used to produce green hydrogen for own use), and California’s SunLine Transit Agency, who have been operating a fleet of sixteen hydrogen buses since early 2021 using green hydrogen generated from a 4MW solar array.

10.3.9 In its *UK Hydrogen Strategy* publication, government explains that:

As a result of its geography, geology, infrastructure and capabilities, the UK has an important opportunity to demonstrate global leadership in low carbon hydrogen and to secure competitive advantage … When it comes to production, our 'twin track' approach capitalises on the UK's potential to produce large quantities of both electrolytic 'green' and CCUS enabled 'blue' hydrogen. [93, p10]

10.3.10 Hydrogen is making tangible steps towards mainstream use in the decarbonisation of hard to reach subsectors of transport. In September 2020, the UK's first hydrogen-powered train journey was made. In the same month, a hydrogen-powered commercial aeroplane made its maiden flight in UK airspace [66, 67]. NGESO estimate that annual electricity demand from road transport as a whole (incorporating both EVs and vehicles powered by hydrogen) could be between 133 and 153 TWh [94, Table CV.31], this is consistent with independent analysis carried out by SNC Lavalin (Atkins) which estimated 150 TWh [68, p12]. The potential for use in rail, marine and air travel increase estimates of hydrogen use even further.

10.3.11 NGESO estimate that at between 100 and 325 TWh of electrical energy will be required annually by 2050 to produce hydrogen to meet its many potential end-uses [104, p106], the wide range 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". The ESC also foresees the need for over 600TWh of hydrogen storage, covering strategic and operational reserves to an acceptable level of security [8, pp6, 36].

10.3.12 The National Infrastructure Commission considered the benefits hydrogen could bring in terms of lowering the overall cost of a highly renewable electricity system in their Net zero: opportunities for the power sector publication:

Highly renewable systems are still a low-cost option in a net zero world. The analysis once again finds that electricity system costs are broadly flat across a range of different levels of renewable penetrations. If hydrogen is deployed, providing low-carbon and flexible generation, it could further reduce the costs of highly renewable systems ... The conclusions also hold in a lower demand scenario where heating has been decarbonised using hydrogen. [40, p7]

10.3.13 The hydrogen economy is set to grow in the UK with recent government announcements targeting "Five gigawatts of low carbon hydrogen production capacity by 2030 – for industry, transport, power and homes – and [to] develop the first town heated by the gas by the end of the decade" [44, 107]. To support this ambition, government is providing £240M for the *Net Zero Hydrogen Fund* out to 2024/25 for co-investment in early hydrogen production projects, and up to £60M under the *Low Carbon Hydrogen Supply 2* competition. A *Hydrogen Business Model*, alongside indicative Heads of Terms will be delivered in Q1 2022, which will be published alongside the promised hydrogen production strategy and "twin-track" approach which foresees a significant opportunity for the role of low carbon generation in the production of green hydrogen.

10.3.14 Hydrogen, attracting a subsidy of up to £500m, is foreseen to be produced in the UK, partly by energy from renewable generators.

10.3.15 In order for hydrogen's potential to play an increasingly important role in the energy ecosystem of the future to be realised, hydrogen must be produced by low-carbon methods, those methods increase even further future electricity demand, and therefore increase the need for large quantities of low-carbon electricity generation capacity. As a large-scale solar generation asset, the Scheme is fully aligned with the national drive to develop a hydrogen economy, where hydrogen is produced from low-carbon electricity sources.

10.4 Electricity storage

10.4.1 While the Infrastructure Planning (Electricity Storage Facilities) Order 2020 removed all forms of electricity storage, other than pumped hydroelectric storage, from the definition of nationally significant energy generating stations, it is relevant to describe in this Statement of Need the important role electricity storage is required to play in the development of a low-carbon GB energy system. Whilst the electricity storage element of the Scheme is not an NSIP in itself it is associated development and adds important utility to the operation of the Scheme as a solar generation station.

10.4.2 Significant investment is also being made in the advancement of electricity storage as an integration aid for renewables and other generation and consumption technologies. In September 2020, an International Energy Agency (IEA) / European Patent Office publication, *Innovation in batteries and electricity storage* found that battery innovation is playing a key role in the transition to clean energy technologies, and that the sector is developing rapidly:

> *Between 2005 and 2018, patenting activity in batteries and other electricity storage technologies grew at an average annual rate of 14% worldwide, four times faster than the average of all technology fields ... [and] batteries account for nearly 90% of all patenting activity in the area of electricity storage.* [93]

10.4.3 Other electricity storage technologies are also under development, using for example, momentum (fly wheel), pressure (compressed air energy storage), heat or chemical processes to store energy. Many of these technologies are under development, and each has its own advantages in relation to the costs and benefits of different models of commercial operation. This report focuses on the predominant technology: batteries. Some expert industry forecasts of future electricity storage capacity requirements have been included in **Section 10.1**.

The continuing and growing need for Balancing Services

10.4.4 The activities associated with integrating renewables into the GB electricity system will increase with their penetration [78, p2]. Energy balance must be managed at all times; and as renewable capacity increases, more services will be required to regain supply / demand balance when demand is either very high or very low. Further, when demand is low and renewables provide a significant share of total power generated, the maintenance of power quality and system stability levels may also require more services to achieve. Importantly, NGESO's SOF [79] describes the dynamic behaviour characteristics for a high-RES system. Plant operation may be impacted upon by these characteristics, unless integration measures are employed to limit their impact. In high-RES systems:

10.4.4.1 Voltage and frequency may not evolve linearly in unbalanced or distributed systems and faults may evolve quickly;

10.4.4.2 Generators may find it challenging to remain synchronous to systems following fast-evolving faults, increasing the risk of cascading faults;

10.4.4.3 Fast-moving fault conditions will be more complicated and may not be predictable; and

10.4.4.4 High-renewable systems will be harder to mimic for test, research or safety justification purposes.

10.4.5 The SOF describes two related concepts: system inertia, and system short circuit level.

System inertia and Rate of Change of Frequency (RoCoF)

10.4.6 NGESO foresee a significant decline in GB system inertia as a result of less synchronous plant connecting to the NETS, resulting primarily in the requirement for increased frequency response services. Over the coming years, the requirement for these services at certain times during the year may increase by 30 to 40% [78, Figures 1.2, 1.3]. With the expected closure or reduced running hours of many thermal plants, much system protection must be obtained in the form of synthetic inertia through frequency response services. Crucially, while system inertia is a physical property of a synchronous power plant, solar plants are also able to provide inertia through synthetic means. Synthetic inertia is a clever electronic alternative to physical inertia, but it does not conform to the same rules. Synthetic inertia is provided by reprogramming power inverters attached to wind turbines so that they emulate the behaviour of synchronised spinning masses.

10.4.7 RoCoF is closely related to system inertia in that RoCoF increases as inertia decreases. A high RoCoF means that faults may evolve quickly, therefore response measures will need to be capable of responding quickly in order to avoid large-scale system failures. Providers of synthetic inertia, frequency response and reserve services will provide an effective countermeasure to reducing system inertia and resulting high RoCoF.

Short circuit levels and voltage dips

10.4.8 Short circuit level is a measure of transmission system strength, or its ability to remain within (or return to) normal operational states. Analogous to system inertia, the connection of large synchronous plants to the transmission system maintains high short circuit levels[24], and levels are expected to fall in GB as conventional capacity decreases. When this happens, critical system variables[25]

[24] "High" short circuit levels are more resilient than "low" short circuit levels
[25] Such as voltage or power flow

may enter unstable states more easily, more frequently, and potentially for longer periods in the future [80, Figures 31, 32].

10.4.9 Short circuit level reductions increase the depth and geographical reach of voltage dips. Voltage dips have detrimental effects on generators and may cause disconnections of customer or generator circuits. In a system with a low short circuit level, generators at greater distances from a fault initiation location become more susceptible to those faults, implying an increase in the expectation that GB's transmission connected generating assets experience a fault in future years.

10.4.10 The connection, directly to the NETS, of assets that are capable of delivering voltage support services, provides the opportunity for services to be delivered to NGESO which prevent the dissipation of faults over wide geographies, thus improving the security of electricity supplies in the GB.

Services provided by electricity storage facilities

10.4.11 Critically, electricity storage is increasingly well placed to deliver a number of ancillary services for NGESO, and this is of growing importance in GB. Environmental Regulations and government policy require the closure of all GB's coal generation assets before 2025. Economic pressures, resulting from both shifts in the global gas market and changes to structural pricing in the GB electricity market are also causing the operational profiles of coal and gas assets to shift. These two points leave these traditional providers of ancillary services less available to provide, and/or less competitive in the provision of, such essential services on an ongoing basis.

10.4.12 Some ancillary services must be delivered at specific locations, but others are location-independent. A description of those services which remain important for the proper functioning of the electricity system, and which could be delivered by Energy Balancing Infrastructure incorporated in the Scheme, are listed in **Table 10-1**.

10.4.13 Whilst the electricity storage element of the Scheme is not an NSIP in itself the Applicant considers it is associated development. There is a clear, direct relationship between the solar generation station and the electricity storage which means that there are substantial benefits to their colocation which will result in an improved contribution to low carbon UK electricity supplies when compared to either coming forward independent of the other. Colocation of energy storage within solar generation schemes is not essential for either asset to make a significant contribution to the future operation of the NETS, however **Table 10-1** demonstrates that the colocation of those assets enables additional operational capabilities to be accessed for system benefit, supporting the view of the Applicant that electricity storage is associated development as per the *Guidance on associated development applications for major infrastructure projects*. Colocation is especially beneficial for NGESO where connections are to the transmission, rather than to the distribution network, because the combined asset is required to meet certain planning, notification and service obligations (see **Section 7.5**).

Growth within the electricity storage sector

10.4.14 A 2016 study commissioned by the former Department for Energy and Climate Change (DECC), concluded that energy storage could result in savings of around £2.4 billion per year [from] 2030 for the UK [94, p3]. Through government and industry actions, GB is pursuing number of projects which aim to deliver some of these benefits, although the UK is currently lagging behind the global leaders in battery storage.

10.4.15 The International Energy Agency report the year-end 2019 installed capacity of energy storage projects deployed since 2013 globally at grid-scale to be 5.3GW, with a further 5.4GW “behind the meter” [95]. The IEA report describes that, despite a need for growth in installed capacities to return to and remain at double-digit levels in order to meet the Sustainable Development Scenario pathway[26], growth has been fragile as policy intervention has been required to support or create markets which bring investment to the sector.

10.4.16 This certainly holds true in the UK. A 2015 report of energy storage assets in GB listed just 27 installed energy storage projects, with a total capacity of around 33GWh [96, p16], a large proportion of that capacity was in the form of heritage pumped storage (hydro).

10.4.17 The current status of the larger battery storage assets in GB shows that since the 2015 report, progress has been made in delivering large battery storage projects, and that market participants have ambition to deliver larger projects still, because the need for more energy storage remains clear.

10.4.18 NGESO report that 1.2GW of battery storage was in operation in 2020 [104, Table ES.1], and a government report stated that a further 4GW of storage projects were progressing planning consent [97].

10.4.19 NGESO’s FES 2021 [104] estimates that electricity storage capacity (excluding vehicle-to-grid technologies) will need to *increase* by 6 – 13GW by 2030, by 15 – 24GW by 2040, and by 24 – 39GW by 2050, in order to achieve Net Zero.

10.4.20 NGESO’s *TEC Register* shows a total of 16.5GW of connection capacity requests from developers of either stand-alone or hybrid solar plus storage schemes. These 163 projects range in proposed capacity, currently up to 500MW [15, Accessed 9/9/2021]. A further 19 Energy Storage System projects totalling 0.6 GW and ranging from 1 MW to 50 MW are listed in the NGESO *Embedded Register* [99, Accessed 9/9/2021]. Further projects still are listed on the *Embedded Capacity Registers* [95] although some of these projects may be purely speculative with low probability of coming forward to operation.

10.4.21 The listing of a scheme on the TEC or any grid connection register, or in the planning database, does not guarantee that the scheme will come forwards. A clearer indicator (although by no means providing full certainty) of schemes coming forwards is the Capacity Market register, which shows that not more than

[26] The world is not on track to meet the energy-related components of the Sustainable Development Goals (SDGs). The IEA’s *Sustainable Development Scenario* (SDS) outlines a major transformation of the global energy system, showing how the world can change course to deliver on the three main energy-related SDGs simultaneously.

2.2GW of installed battery storage capacity has secured a Capacity Agreement since 2015. However only one half of this is currently operational.

10.4.22 This implies that although development pipelines for BESS schemes are healthy, only a small proportion of proposed schemes have so far progressed towards financial commitment decisions, and on to commercial operation.

10.4.23 A much higher conversion rate will be required on the remaining pipeline in order to meet the FES view of an additional 6 – 13GW of electricity storage operational by 2030.

10.4.24 The need to convert the pipeline of potential projects into commissioned assets reinforces the case for the colocation of energy storage as part of the Scheme.

10.4.25 Globally, BESS have already achieved significant advances in technological ability and economic performance: batteries are becoming bigger, better (greater power, durability and longer operating lives) and cheaper. Portable applications, such as consumer electronics, drove cost reduction and technological innovation in batteries in the early 2000s. Since 2010, electric mobility has been behind the growth in inventive activity in battery packs, and since then, improvements to battery packs catering for the wide range of all-electric cars and plug-in hybrid cars on the market have had positive spill-over effects on stationary applications, such as grid-scale battery energy storage solutions [93, pp7, 30].

10.4.26 In November 2020, the “UK’s largest battery” commenced commercial operation: a 50MW / 75MWh located in South Yorkshire, which has provided energy balancing and dynamic frequency response services to NGESO since operation [98]. Construction has started on battery storage sites of approximately double the South Yorkshire project size; and larger battery storage projects still, have already been granted planning consent.

10.4.27 The economics of battery storage remain uncertain in GB at present, despite the clear need for further build out of the technology. The Prime Minister’s Ten Point Plan, announced in November 2020, includes “nearly £500m for battery manufacture in the Midlands and north-east England” [44] to help make the vision of the UK becoming a leader in battery manufacturing capability a reality, with further cost reduction through giga-scale manufacturing facilities. An industry-sourced projection of the future procurement costs of Li-Ion battery cells is included in **Figure 10-1**, and as cost reduction targets are met, more storage projects will be commissioned.

10.4.28 Batteries will become well suited to displace other technologies (such as reciprocating gas engines, which are currently performing the role of meeting peak demand but for which no carbon capture solution has yet been identified) from the generation stack. In this regard the forward views of installed capacity included in **Section 10.1** above are unconstrained, subject to industry achieving the cost improvements aspired to in **Figure 10-1**. Additionally, it is anticipated that further ambition in the development of renewable generation assets, such as is set out in the 2020 Energy White Paper [21], would increase the important role of electricity storage within the GB electricity system.

10.4.29 The proposal to include BESS as part of the Scheme is therefore in accordance with emerging government policy on the need for integration measures on the electricity system to support the transition to a fully low-carbon grid. The grant of a consent for BESS at Sunnica, would therefore allow the project to fulfil its ambitions in providing full support to UK action plans to deliver decarbonisation.

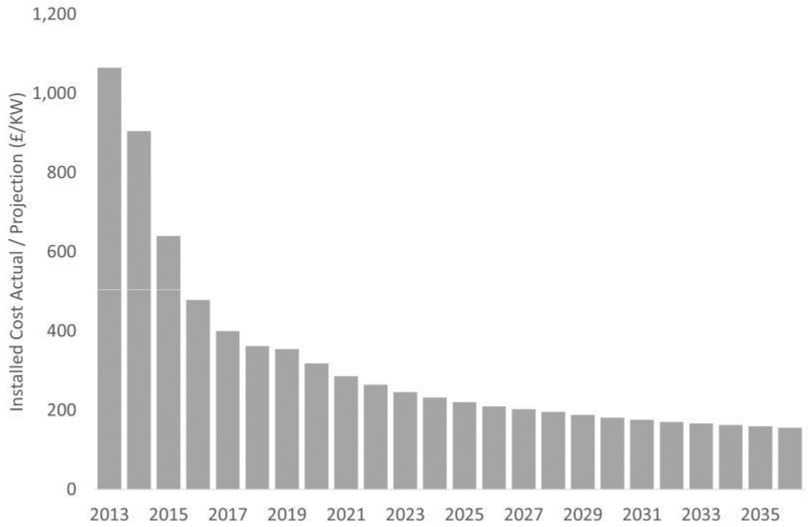


Figure 10-1: A projection of future battery component costs.
[Author analysis of published data]

Table 10-1: The potential contributions of a storage asset within the Scheme to the GB electricity market, including ancillary service provision. [Author analysis]

<table>
<tr><th>Service</th><th>Explanation</th><th>Applicability</th></tr>
<tr><td>Trading</td><td>Selling energy at market prices</td><td>The backbone of renewable generation asset investment cases. Storage reduces energy market risk as output can be directed from lower-price to higher-price periods. This helps reduce curtailment of otherwise useful low-carbon generation, and provides additional revenues to the asset.</td></tr>
<tr><td>Balancing Mechanism</td><td>Being available to NGESO to balance supply and demand at delivery</td><td rowspan="3">Renewable generators can provide downward flexibility, but at the “cost” of carbon-free energy. Renewables plus storage both provide upward and downward flexibility, potentially without ’losing’ any low-carbon energy. This can be dispatched over varying timeframes, from milliseconds to hours, depending on available technology.</td></tr>
<tr><td>Frequency Response</td><td>Changing output minute by minute to help maintain system frequency at the statutory level of 50Hz</td></tr>
<tr><td>Reserve Operation</td><td>Changing output over minutes and hours to rebalance supply and demand following a fault or other unforeseen event on the electricity system</td></tr>
<tr><td>Reactive Power</td><td>Locational service which allows power to “flow” from source to destination</td><td>A mandatory service for all transmission-connected assets, delivered by renewable and/or storage assets as part of the DC to AC conversion.</td></tr>
<tr><td>Inertia</td><td>A service which helps slow the rate of change of the whole electricity system in response to an unforeseen event, stopping critical faults from occurring.</td><td>Inverters installed on solar sites are able to provide synthetic inertia, storage devices are also capable of this provision. Both will be important as the traditional sources of inertia (large fossil fuelled assets) close prior to 2025.</td></tr>
<tr><td>Black Start</td><td>A locational service which would help ‘turn back on the lights’ if an event caused the national electricity system to fail</td><td>Solar alone is not capable of providing Black Start services, but standalone storage is. Co-located renewable generation plus storage may be able to provide a more robust Black Start service than standalone storage.</td></tr>
<tr><td>Constraint Management</td><td>Changing output in response to local energy supply, demand and transport issues, to ensure locational adequacy at all timescales.</td><td>Solar can provide important downward constraint management services, and solar plus storage can provide services in both directions. Because of its proposed connection location, The Scheme will be highly unlikely to cause constraints on the local NETS.</td></tr>
<tr><td>Infrastructure Costs</td><td>By connecting generating assets where they are needed, less electricity transmission and distribution infrastructure needs to be built out, making national savings for electricity users</td><td>Renewable generation and electricity storage can help with reducing new infrastructure requirements, although their benefits may be higher if co-located than if located separately.</td></tr>
</table>

11 In support of this Scheme for solar generation and storage

11.1.1 This report has shown that solar generation is economically and technically viable, and that it is economically and technically preferential, to the GB electricity consumer. The summary points are as follows:

11.1.1.1 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;

11.1.1.2 Solar generation is an important element of the delivery plan for the urgent decarbonisation of the GB electricity sector. This is important not only to reduce power-related emissions, but also to provide a timely next step contribution to a future generation portfolio which is capable of supporting the decarbonisation of transport and heat sectors, through electrification;

11.1.1.3 As part of a diverse generation mix, solar generation contributes to improve the stability of capacity utilisations among renewable generators and when developed alongside other renewable technologies, will help to smooth out seasonal variations in generation in line with anticipated seasonal levels of demand. By being connected at the transmission system level, 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;

11.1.1.4 Internationally, and importantly for GB in this regard, is the ongoing trend of solar generation assets becoming bigger and cheaper, each subsequent project providing a real-life demonstration that size and scale works for solar in GB, and providing decarbonisation benefits and commercial benefits to consumers in the process. Other conventional low-carbon generation (e.g. tidal, nuclear or conventional carbon with CCUS) remain important contributors to achieving the 2050 Net Zero obligation, but their contributions in the important 2020s will be very low;

11.1.1.5 The cost of solar generation is already super-competitive against the cost of other forms of conventional and low-carbon generation, both in GB and more widely;

11.1.1.6 Single large-scale 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

11.1.2 These general benefits of solar generation in GB also apply specifically to the Sunnica Scheme:

11.1.2.1 The Scheme is a substantial infrastructure asset, capable of delivering large amounts of low-carbon electricity. The Scheme, along with other solar schemes, is of critical importance on the path to Net Zero, especially given the context of the CCC's recent identification of the need for urgent action to increase the pace of decarbonisation in the GB electricity sector, and government's adoption of their recommendations for the sixth Carbon Budget (2033 – 2037);

11.1.2.2 The Scheme's NETS connection means that it will be required to play its part in helping NGESO manage the national electricity system. This includes participating in mandatory balancing markets (to help balance supply and demand on a minute-by-minute basis and provide essential ancillary services) as well as providing visibility to the GB power market of its expected generation. This means that the low marginal cost solar power it will produce, can be forecast and priced into future contracts for power delivery by all participants, thus allowing all consumers to benefit from the market price reducing effect of low-marginal cost solar generation;

11.1.2.3 The Scheme provides an efficient opportunity to integrate BESS with large-scale solar generation. BESS are an essential technology for high-RES electricity systems, such as that which the NETS is anticipated to become during the critical 2020s, as the power generation sector seeks to achieve rapid decarbonisation in support of wider decarbonisation on the path to Net-Zero. BESS play essential roles in the provision of those services necessary to keep power flowing to all consumers, as well as integration measures which help balance supply and demand, thereby reducing the need for carbon-intensive back-up generation.

11.1.2.4 Maximising the capacity of generation in the proposed Cambridge/Suffolk border area, is to the benefit of all GB consumers, and the solar industry generally.

11.1.3 The Scheme will deliver large amounts of low-carbon power before many other large-scale solar projects (which are behind the Scheme in the development process, but which are also needed). The Scheme will also deliver 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.

11.1.4 In summary: 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. 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.

11.1.5 This Scheme is a leading GB large-scale solar scheme, and is an essential stepping-stone towards the future of efficient decarbonisation through the deployment of large-scale, technologically and geographically diverse low-carbon generation schemes. This Scheme addresses all important aspects of existing and emerging government policy.

12 About the author

12.1.1 This Statement has been prepared by Si Gillett. Si has European energy sector experience, spanning 20 years of commercial, analytical and consulting roles within Utilities and the Oil & Gas sector, and provides services to UK energy market participants covering:

12.1.1.1 Renewable generation pre-construction feasibility studies and advice for GB assets;

12.1.1.2 GB electricity market commercial operation;

12.1.1.3 Electricity market transformation.

12.1.2 Si specialises in market change readiness and the implementation and performance of energy market regulations and in previous roles he has held responsibility for the commercial operation of electricity generation assets in GB, EU wholesale energy market trading and for the assessment and evaluation of new developments.

12.1.3 He prepared a Statement of Need for Cleve Hill Solar Park (DCO granted May 2020) and provided written and verbal evidence in the Issue Specific Hearings.

12.1.4 He also prepared a Statement of Need to support the IROPI (imperative reasons of overriding public interest) arguments made in response to the Secretary of State for Business, Energy and Industrial Strategy request for further information under Article 6(4) of the Habitats Directive and section 126(7) of the Marine and Coastal Access Act 2009 for Orsted Hornsea Project Three (DCO granted December 2020).

12.1.5 He holds Masters degrees in Mathematics, from Oxford University, and in Nuclear Safety, Security and Safeguards, from the University of Central Lancashire.

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