

# Gate Burton Energy Park Statement of Need

Statement of Need  
Document Reference: EN010131 / APP 2.1  
January 2023

APFP Regulation 5(2)(q)  
Planning Act 2008  
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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# 1 Executive Summary

## 1.1 Background

- 1.1.1 Gate Burton Energy Park Limited (The Applicant) is seeking a Development Consent Order (DCO) for a large-scale solar photovoltaic (PV) and Battery Energy Storage System (BESS) development, connecting to the National Electricity Transmission System (NETS) at National Grid's Cottam 400kV Substation (The Scheme), as described in the introduction.
- 1.1.2 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 Revised National Policy Statements EN-1 and EN-3 as published by Government for consultation, in September 2021 [1, 2].
- 1.1.3 The case for need is built upon the contribution of the Scheme to the three important national policy aims of decarbonisation:
- Net Zero and the importance of deploying zero-carbon generation assets at scale;
  - Security of supply (geographically and technologically diverse supplies); and
  - Affordability.

## 1.2 Overview of this Statement of Need

- 1.2.1 Chapter 3 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. A synthesis of the relevant parts of the draft National Policy Statements EN-1 and EN-3 is also included in this chapter.
- 1.2.2 Chapter 4 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 [3] and the Climate Change Committee (CCC) Sixth Carbon Budget [4] and 2022 Progress Report to Parliament [115]. The CCC conclude that any new low-carbon power generation schemes which can be delivered this decade will make essential contributions to meeting the climate change 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.

- 1.2.3 Chapter 5 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 5 also provides an overview of the important role green investment is being positioned to play in global recovery following the COVID-19 pandemic, and the UK is signalling its ambition to "lead the way".
- 1.2.4 Chapter 6 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 The Scheme, are required to meet that demand and deliver net zero (see Chapter 7).
- 1.2.5 Chapter 8 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.
- 1.2.6 Chapter 9 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.
- 1.2.7 Chapter 10 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.
- 1.2.8 Chapter 11 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 which lead to an increasing requirement for low-carbon electricity generation capacity and how greater capacities of low-carbon generation can and will be integrated into the GB energy system by by deploying integration technologies such as hydrogen and Battery Energy Storage Systems (BESS).
- 1.2.9 Chapter 12 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.

## 2 Introduction

### 2.1 Master Scheme Description

- 2.1.1 Gate Burton Energy Park (The Scheme) is a proposed solar farm with energy storage which will generate and store renewable electricity for export to the National Electricity Transmission System (NETS).
- 2.1.2 The Scheme will comprise the construction, operation, maintenance and decommissioning of a solar photovoltaic (PV) electricity generating facility with a total capacity exceeding 50 megawatts (MW), an energy storage facility and an export/import connection to the NETS. The Scheme will be located within the "Order limits" (as will be described in the DCO Application documents) and is the subject of the Application.
- 2.1.3 The Scheme will be developed on a site which straddles the counties of Lincolnshire and Nottinghamshire. The site consists of agricultural fields interspersed with individual trees, woodlands, hedgerows, linear tree belts, farm access tracks, and local transport roads. The site lies between several rural villages including Gate Burton and Knaith to the west; Marton to the south west; and Willingham by Stow to the east.
- 2.1.4 The Scheme will be connected to the NETS via a Point of Connection (PoC) at Cottam 400kV Substation, which lies on a well-connected and resilient part of the NETS and is located near to the proposed site. The PoC, which formerly was utilised by a 2GW coal fired power station, provides a connection solution for the highly suitable land which minimises the above or below ground transmission infrastructure required to export the power generated to customers in Lincolnshire, Nottinghamshire and nationally.
- 2.1.5 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.

### 2.2 Background

- 2.2.1 Solar generation is not specifically referred to in the National Policy Statements (NPS) EN-1 [5] and EN-3 [6], 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 3.1), pursuant to Section 105 of the Planning Act 2008. The government remains committed to actively considering other ways in which to encourage industry to accelerate progress towards a low carbon economy [5, Para 1.7.9]. For example, solar was included in the 2021/22 Contracts for Difference (CfD) Allocation Round (AR4) to help "deliver a diverse generation mix at low cost" and to realise "the rate and scale of new projects needed in the near-term to support decarbonisation of the power sector and meet the Net Zero commitment" while providing other benefits such as diversity of supply through different resource requirements and a geographical separation from other significant Renewable Energy



Sources (RES) [7, pp16, 20]. As an indicator of the importance of solar as a technology class within the evolving GB electricity system, and an indicator of the competitive cost of the technology, over 2.2GW of solar capacity across 66 projects secured Contracts for Difference in AR4, at an initial strike price of £45.99. All CfDs commence in either 2023/24 or 2024/25.

- 2.2.2 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.
- 2.2.3 The case for need is built upon the contribution of The Scheme to the three important national policy aims of:
- Decarbonisation (Net Zero and the importance of developing at-scale zero-carbon generation assets);
  - Security of supply (geographically and technologically diverse supplies); and
  - Affordability.
- 2.2.4 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. UK-located low-carbon electricity generation infrastructure also provides a benefit to the security of national electricity supplies, which is especially poignant following the impact of international fuel price volatility on UK energy prices since the winter of 2021/22.
- 2.2.5 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.

2.2.6 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.

## 3 The National Policy Statements

### 3.1 Establishing the basis provided by the existing NPSs and their draft Revisions

3.1.1 The NPSs were established against obligations made as part of the Climate Change Act 2008 (CCA2008) – see Section 4.2. The overarching National Policy Statement for Energy (NPS) EN-1 [5] sets out national policy for energy infrastructure in England and Wales. It has effect, in combination with NPS EN-3 (for renewable energy infrastructure) [6] and NPS EN-5 (for electricity networks) [8], 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 [5, 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 for developments that fall within the scope of the NPSs. Where developments do not fall within the scope of those existing NPSs (such as for solar), then they will be an important and relevant consideration pursuant to Section 105 of the Planning Act 2008, as discussed below. The NPSs set out a case for the need and urgency for new energy infrastructure [5, 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:

- Mitigating and adapting to climate change; and
- Contributing to a secure, diverse and affordable energy supply. [6, Para 1.3.1]

3.1.2 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 [6, Para 1.7.9] and the Scheme should be considered in the light of that encouragement and change to the 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.

3.1.3 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.

- 3.1.4 The government used its December 2020 Energy White Paper [9] to signal a review of the existing National Policy Statements, issuing draft revisions of NPS EN-1 and NPS EN-3 for consultation on 6<sup>th</sup> September 2021 [1, 2]. While the draft Revised 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." [1, 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" [1, Para 1.6.3]. Section 3.3 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.
- 3.1.5 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.
- 3.1.6 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.

- 3.1.7 The transitional provisions in the draft NPSs [1, 2] 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.
- 3.1.8 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 3.2.

## 3.2 A synthesis of the 2011 National Policy Statements EN-1 and EN-3

- 3.2.1 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 [5, Para 2.2.8].
- 3.2.2 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 [5, 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.
- 3.2.3 This would require major investment in new technologies to electrify heating, industry and transport, and cleaner power generation [5, 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 [5, 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 [5, Para 2.2.22].
- 3.2.4 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 [5, Para 3.3.5].
- 3.2.5 The NPSs conclude that the UK needs sufficient electricity capacity from a diverse mix of technologies and fuels [5, 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 [5, Para 3.1.1]. Chapter 5 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 [5, 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 [6, Para 2.6.57].

- 3.2.6 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.
- 3.2.7 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 7.4.

### 3.3 A synthesis of the 2021 draft Revised National Policy Statements EN-1 and EN-3

- 3.3.1 The structure of the NPS suite has not changed in the latest draft documents. Draft Revised 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" [1, Para 1.7.4].
- 3.3.2 The fundamental need for the large-scale infrastructure, which draft Revised 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 4 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 [1, Para 2.3.6].*
- 3.3.3 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 [1, Para 3.3.3].*

- 3.3.4 Chapter 6 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 Levelised Cost of Energy (Chapter 10).
- 3.3.5 Section 3.3 of draft Revised NPS EN-1 explains that large capacities of low-carbon generation will be required to:
- Ensure that there is sufficient electricity to meet increased demand;
  - Replace output from retiring plants;
  - Ensure there is sufficient margin in our supply to accommodate unexpectedly high demand; and
  - Mitigate risks such as unexpected plant closures and extreme weather events.
- 3.3.6 Chapter 7 and Chapter 8 of this Statement of Need are consistent with the arguments as they have been set out in draft Revised NPS EN-1.
- 3.3.7 Draft Revised 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 [1, Para 3.3.11]. Chapter 5 of this Statement of Need describes the risks associated with the development of nuclear and CCUS technology. Like Chapter 7 of this Statement of Need, draft Revised 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" [1, Para 3.3.31]. Both Chapter 7 and Chapter 8 of this Statement of Need align with draft Revised NPS EN-1 and concludes that all low-carbon generating technologies are urgently needed to meet government's energy objectives by:
- Providing security of supply;
  - Providing an affordable, reliable system (through the deployment of technologies with complementary characteristics); and
  - Ensuring the system is Net Zero consistent.
- 3.3.8 In noting the crucial national benefits of increased system robustness through new electricity network infrastructure projects, draft Revised 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 [1, Para 3.3.21].*
- 3.3.9 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 Revised 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 [1, Para 3.3.55].*

3.3.10 Chapter 9 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).

3.3.11 Draft Revised 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 8.5 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." [1, 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. [1, Para 3.3.13]*

3.3.12 In relation to integration technologies, Draft Revised 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. [1, Paras 3.3.16 & 17].*

3.3.13 Draft Revised 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 draft Revised NPS EN-1, being "peak shaving," constraint management and the provision of a range of balancing services [1, 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 to produce hydrogen for subsequent storage and/or transport and use [1, Paras 2.3.5 -



2.3.7]. Chapter 11 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.

3.3.14 Draft Revised NPS EN-3 covers nationally significant renewable energy infrastructure which includes solar photovoltaic (PV) at >50 MW in England and >350MW in Wales [2, Para 1.6.1].

3.3.15 This document 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. [2, Para 2.47.1]*

3.3.16 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 [2, Para 2.47.2].*

3.3.17 Draft Revised 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 7.5 of this Statement of Need.

3.3.18 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 7.5 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 [2, Para 2.48.12].*

3.3.19 The degradation of solar efficiency over time is addressed in draft Revised NPS EN-3 [2, Paras 2.48.8 & 2.49.9] and is referenced in Section 10.3 and Section 11.5 of this Statement of Need (for solar and for storage respectively):

*Light induced degradation affects most solar panels and on average panels degrade at a rate of up to 1% each year. Applicants may account for this by overplanting solar panel arrays. [2, Paras 2.48.8].*

*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 ... applicants may elect to replace panels during the lifetime of the site [2, Paras 2.49.9].*

3.3.20 This is considered more fully in Section 7.7.

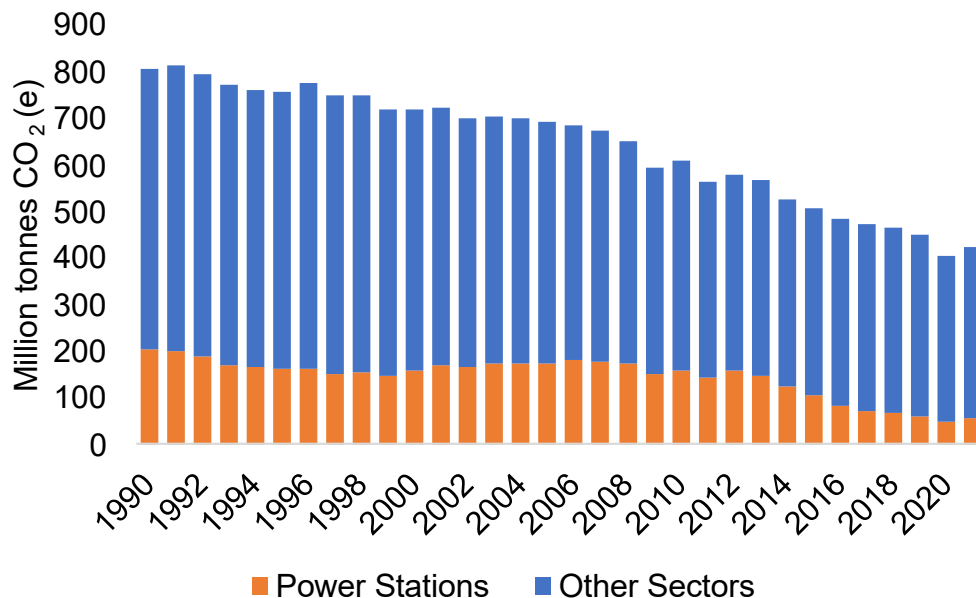
## 4 The United Kingdom has a legal commitment to decarbonise

### 4.1 Setting the scene on Climate Change

4.1.1 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.

### 4.2 Climate Change Act 2008

Figure 4-1: UK greenhouse gas emissions, 1990 - 2021



[10, Table 1.2]

4.2.1 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.

4.2.2 The government, through the Climate Change Act 2008 (CCA2008), made the United Kingdom 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" [11, Five Point Plan].

- 4.2.3 CCA2008 is underpinned by further legislation and policy measures. Many of these have been consolidated in the UK Low Carbon Transition Plan (2009) [11], and UK Clean Growth Strategy (2017) [12]. 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 effective policy, but also attributed to changes in the applicable Emissions Trading Scheme(s) and the impact of COVID-19 on emissions [4, p435]
- 4.2.4 Up to 2020, the UK made progress with its carbon reduction obligations, as shown in Figure 4-1, through significant reductions in the power, industry, and waste sectors. CCA2008 obligations translate to a total emissions target of ~550 MtCO<sub>2</sub>(e) in 2020, and ~ 165 MtCO<sub>2</sub>(e) 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 [13]. 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 [5, Para 3.4.1]
- 4.2.5 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 4-1. 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 [5, Para 2.2.1].*
- 4.2.6 However, information provided by National Grid ESO (ESO Data Portal: Historic Generation Mix & Carbon Intensity - Dataset| National Grid Electricity System Operator [REDACTED]) illustrates that the further decarbonisation of the electricity grid is not a given. Ageing zero-carbon nuclear is being replaced by renewable wind and solar. The net effect is an electricity generation carbon intensity holding position, with no material reductions having been made between 2019 and 2022. Further nuclear

closures in 2024 may mean that further reductions in grid average carbon intensity may not be seen until 2025 or later.

- 4.2.7 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 1°C above pre-industrial levels, and that without a significant and rapid decline in emissions across all sectors, global warming would not be likely to be contained, and therefore more urgent international action is required. The ambition against which CCA2008 was established has been extended, and the targets for carbon emissions reduction have tightened.

## 4.3 Enhancements of existing UK government policy on climate change: Net Zero

- 4.3.1 In response, in May 2019, the CCC published Net Zero: The UK's contribution to stopping global warming [14]. 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.
- 4.3.2 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" [15]. Despite having met its first and second carbon budgets and being on track to outperform its third (2018 – 2022), the UK is not yet 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 forward the UK's previous 80% target by nearly 15 years [4, p5], [16].

- 4.3.3 Figure 4-1 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<sub>2</sub>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. [15, pp52-53].*

- 4.3.4 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 [17, p8]. Chapter 6 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 [17, 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.
- 4.3.5 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.
- 4.3.6 In March 2020 the Energy System Catapult (ESC) published the Innovating to Net Zero report which summarised the results of an update to their national Energy System Modelling Environment (ESME) [18]. 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 and is referenced in the following Chapter 6. Other professional organisations also share their views of future demand and these are discussed in Section 6.3. In Innovating to Net Zero the ESC 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. [18, p5].*

- 4.3.7 ESC analysis [18, p27] 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 6.2) 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.
- 4.3.8 In September 2022, Government announced the commissioning of an independent review of their approach to delivering the Net-Zero target, to ensure that it is pro-business and pro-growth. The Terms of Reference of the review [122] shows that it will consider how the UK's approach to Net Zero can:
- Deliver maximum economic growth and investment, driving opportunities for private investment, jobs, innovation, exports, and growth right across the UK;
  - Support UK energy security and affordability for consumers and business and the need to rapidly increase and strengthen UK energy production and supply; and
  - Minimise costs borne by businesses and consumers, particularly in the short-term.
- 4.3.9 The Skidmore Review is anticipated to produce a report including a set of recommendations which will be submitted to the BEIS Secretary of State by the end of December 2022. In advance of the publication of that report, it is noted that Chapter 8 of this Statement of Need explains the contribution of solar generation to security of supply and Chapter 9 describes the very strong reasons for connecting this Scheme at its proposed location to make effective use of existing infrastructure, supporting both security of supply and affordability. Further, Chapter 10 of this Statement of Need 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.

## 4.4 UK demonstrating leadership on climate action

- 4.4.1 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" [5, 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. [19, 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) [19, p178]*

- 4.4.2 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. [15, 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. [15, p16].*

- 4.4.3 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 [20]. The Energy White Paper supports a quadrupling of low-carbon power generation by 2050.
- 4.4.4 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 [21].
- 4.4.5 In August 2020, government announced funding for several green infrastructure development and innovation projects [22], 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.



- 4.4.6 Also 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. [23, p5].*

- 4.4.7 Importantly, the CCC make recommendations for BEIS to "deliver plans to decarbonise the power system to reach an emissions intensity of 50 gCO<sub>2</sub>/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" [15, Table 4].

- 4.4.8 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". [24]. 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. [4, p6].*

- 4.4.9 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. [9, 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. [17, p6].*

- 4.4.10 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 (22<sup>nd</sup> 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.

- 4.4.11 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, and the second at Little Crow, granted in April 2022, demonstrates that large-scale solar in the UK is consentable due to the significant decarbonisation and supply diversification benefits the technology class brings forward. 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 9) 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.

## 4.5 COP26: Uniting the world to tackle climate change

- 4.5.1 The 26<sup>th</sup> UN Climate Change Conference of the Parties (COP26) was held in Glasgow on 31<sup>st</sup> October to 13<sup>th</sup> November 2021. COP26 brought parties together to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on Climate Change. As the first COP since the first Nationally Determined Contributions (NDCs) had been published since Paris, the run up to COP26 in Glasgow was a critical moment in the world's mission to keep the hope of limiting global temperature rises to 1.5°C alive [25]. International pledges could be reviewed and amalgamated and a view of global commitments made towards limiting carbon emissions and adapting to climate change could be created for the first time.
- 4.5.2 Agreements were reached on many themes at COP26, including: science and urgency; adaption; adaption finance; mitigation; finance, technology transfer and capacity-building for mitigation and adaptation; loss and damage; implementation; collaboration; and confirmation and developments of elements of the Paris rulebook.
- 4.5.3 Of greatest relevance to this Statement of Need, specifically because collective progress to date to reduce emissions has not been sufficient, are the outcomes agreed at COP26 relating to mitigation: setting out the steps and commitments that Parties will take to accelerate efforts to reduce emissions "to keep 1.5 degrees in reach". Key achievements at COP26 under the theme of mitigation include [26]:
- Over 90% of world GDP and around 90% of global emissions are now covered by net zero commitments and 153 countries have put forward new or updated emissions NDCs, which collectively cover around 80% of

the world's greenhouse gas emissions. Net Zero is a global endeavour and the world is getting on board;

- The importance of action now to address the urgency of climate change and drive emissions down before 2030 was cemented in an agreement from all parties to revisit and strengthen their current emissions targets to 2030, in 2022;
- The role of clean electricity in delivering climate action, and the importance of driving down emissions from fossil fuel generators as well as increase capacity of renewable generators, was acknowledged in the negotiated agreement by 190 countries at COP26 to "phase down coal power". Further commitments to cease international coal finance and direct public support of unabated fossil fuel energy, by the end of 2021 and 2022 respectively, will free funds to be redirected for deployment in renewable energy; and
- Accounting for over 10% of global greenhouse gas emissions, and around half the world's consumption of oil, road transport is a critical sector to decarbonise with pace. Agreement was reached by countries, cities, companies, investors and vehicle manufacturers to target all new car and van sales to be zero emission by 2040 globally and 2035 in leading markets, and ultimately to phase out fossil fuelled vehicles. Electrification of transport is inevitable, underway and accelerating. Low carbon electricity supply must keep growing to provide the energy to enable the rapid displacement of oil.

4.5.4 It is appropriate that COP26 was held in the UK, because of the significant leadership and progress shown by the UK through its climate actions and ambitious climate change targets. And as the COP26 Outcomes report reminds its readers: "we must continue the work of COP26 with concerted and immediate global effort to deliver on all pledges" in order to keep alive the hope of limiting the rise in global temperature to 1.5°C [26].

4.5.5 The Scheme presents an opportunity for the UK to underpin its delivery on the COP26 mitigation pledges:

- The UK has published its NDC, which is a reduction in economy-wide greenhouse gas emissions by at least 68% by 2030, compared to 1990 levels and represents a greater reduction in emissions than that required by Carbon Budget 5 (2028 – 2032). This Scheme is a critical measure in support of achieving the UK's NDC, by providing new low-carbon electricity generation facilities to power heat, transport and industrial demand and save emissions;
- The Scheme will generate low-carbon power in the critical 2020s and therefore before the current emissions target date of 2030. Early action to decarbonise is important in the climate fight;
- The Scheme will generate low carbon power for transmission across GB, meaning that less power will need to be generated in GB from fossil fuelled power stations, or imported from other countries, potentially associated with carbon emissions due to the electricity mix of imported power which will at times still include fossil fuel fired power stations; and

- The UK is leading the way globally in electrifying vehicles and the Scheme will be an essential source of low-carbon power to keep GB consumers and businesses moving in new electric vehicles while at the same time, saving carbon emissions.

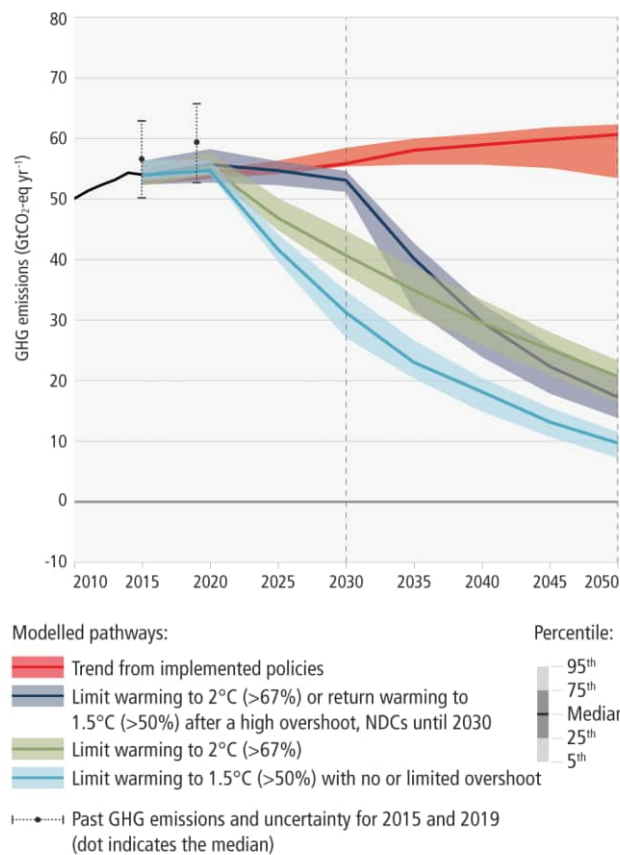
## 4.6 The IPCC's Sixth Assessment Report

- 4.6.1 As part of the IPCC's Sixth Assessment Report, IPCC Working Group III (IPCC WGIII) published their Summary of Climate Change in April 2022 and related summaries [27]. The key outcome of their research was that total anthropogenic GHG emissions continued to rise during the 2010s and average annual GHG emissions during that decade were higher than in any previous decade. The rate of growth between 2010 and 2019 was lower than that between 2000 and 2009. [27, SPM-4].
- 4.6.2 Further, although emissions dropped temporarily in the first half of 2020 due to the COVID-19 pandemic, they had rebounded by the end of the year. [27, SPM-5]. Emissions increases were experienced across all major sectors (transport, heating, power generation, etc). [27, SPM-7].
- 4.6.3 IPCC WG III observed that unit costs of several low-emission technologies have fallen since 2010, and their use has increased, this has so far contributed to the slowing of emissions growth in some countries.
- 4.6.4 For example, from 2010–2019, IPCC WGIII observe that there have been sustained decreases in the unit costs of solar energy (85%), wind energy (55%), and lithium-ion batteries (85%), and large increases in their deployment, e.g., >10x for solar and >100x for electric vehicles (EVs) [27, SPM-12].
- 4.6.5 However, and most alarmingly:

*Global GHG emissions in 2030 associated with the implementation of nationally determined contributions (NDCs) announced prior to COP26 would make it likely that warming will exceed 1.5°C during the 21st century. Likely limiting warming to below 2°C would then rely on a rapid acceleration of mitigation efforts after 2030. Policies implemented by the end of 2020 are projected to result in higher global GHG emissions than those implied by NDCs. [27, SPM-15]*

- 4.6.6 The IPCC WGIII's global greenhouse gas emissions for four modelled scenarios are included in Figure 4-2, which illustrates that:
- Global NDCs are not yet sufficient to meet nor sustain a (likely) successful track towards containing global temperature rise below 1.5C; and
  - Policies implemented to date fall short even of those NDCs. The IPCC report findings therefore imply that mitigation after 2030 can no longer establish a pathway which will likely not exceed 1.5°C global temperature increase vs. 1990, during the 21st century.

**Figure 4-2: Funnelled representation of global GHG emissions of modelled pathways**



[27, Adapted]

- 4.6.7 Only the most dramatic and most urgent actions provide a route which is likely to limit global warming to 1.5°C.
- 4.6.8 Much more action is required globally, and with much more urgency, than has so far been committed to within national policies. Regional disparities in emission reductions to date and opportunities and resources to deliver further reductions exist. This implies that countries which are able to deliver greater emissions reductions than their others, should deliver those greater emission reductions, and with the greatest degree of urgency possible. Such ambition will mitigate potential shortfalls from countries which reduce emissions more slowly, in order to limit the global rise of temperatures and minimise the harmful effects of global warming.

## 4.7 Committee on Climate Change Progress Report 2022

- 4.7.1 In July 2022, the CCC published their report on UK emissions in 2021, and this section provides a summary of that report.

- 4.7.2 The CCC's 2022 report reviews emissions performance of 2021, which "rose 4% in 2021 compared with those in 2020 as the economy began to recover from the COVID-19 pandemic ... but were still 10% below pre-pandemic 2019 levels" [115, p14].
- 4.7.3 Year-on-year emissions increases occurred primarily in the surface transport, electricity generation and manufacturing sectors, highlighting the importance of urgent deployment of low-carbon generation assets to keep generation emissions under control while providing more low-carbon power to decarbonise other sectors.
- 4.7.4 The 2022 report concludes that the UK's emissions targets are compliant with the Paris Agreement and the Net Zero strategy (and supporting strategies) to reach them are credible.
- 4.7.5 However, the CCC report that policies "are not yet in place to drive the large programme of delivery required this decade" – implying that further development (and completion) of associated policy frameworks should be completed with urgency.
- 4.7.6 Further, the CCC echo the findings of the IPCC report [27] in that tangible progress is lagging the policy ambition, again implying that more needs to be done in delivery as well as in policy and strategy. Without a greater emphasis and focus on delivery, the UK's climate ambitions may not be credible.
- 4.7.7 The CCC assess that the take-up of renewable electricity and of electric vehicles is very positive and therefore attract confidence that the necessary progress will be made in deployment, although risks around delivery require active and ongoing management, and the implementation of contingency plans.
- 4.7.8 The development of renewable electricity projects is a critical enabler of decarbonisation and must continue with pace to achieve the policy objectives associated with the Net Zero strategy. The CCC assess that approximately 80% of the carbon reductions to be achieved through plans to decarbonise electricity supply are credible, with significant risks associated with the remaining approximately 20%. [115, Figure 5]. The CCC assess that these risks are associated with timelines for delivery [115, Table 2], adding weight to the benefit associated with the Proposed Development which if consented is currently planned to operate commercially from 2028.
- 4.7.9 The CCC recommend that BEIS should continue to plan for full decarbonisation of electricity supply by 2035; address risks around connecting assets to the grid; and develop contingency plans for the current reliance on unproven carbon removal technologies. [115, p32 & Table 3].
- 4.7.10 The CCC report is relevant to the Scheme because it highlights that government's strategy and policy aims in relation to the decarbonisation of electricity supply are credible and are necessary for achieving Net Zero – although further policy aims are likely to be published later in 2022.

- 4.7.11 However the CCC recognise that delivery against the current generation supply policy aims is not risk-free, specifically in relation to the timing of decarbonisation delivery, reliance on carbon removal technologies and a recommendation to develop further contingency plans.
- 4.7.12 The Scheme, which will use a proven generation technology and is at an advanced stage of development, offers the opportunity, if consented, for GB to deliver a solar farm with grid connection capacity of 500MW by 2030.
- 4.7.13 Connecting generation capacity of proven technologies (such as solar power) reduces the risk associated with delays in development in later years and also reduces the reliance needed to be placed on unproven technologies.
- 4.7.14 Further, connecting proven generation capacity early reduces the scale of contingency plans required to manage later delivery risk, all of which improves the deliverability of policy aims and makes critical steps towards delivering Net Zero.

# 5 Progress against the Low Carbon Transition Plan

## 5.1 Setting the scene on the transition to zero carbon

*The UK needs to wean itself off such a high carbon energy mix: to reduce greenhouse gas emissions. [5, 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. [5, Para 2.2.11]*

*It is for industry to propose new energy infrastructure projects within the strategic framework set by government. [5, Para 3.1.2]*

- 5.1.1 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.

## 5.2 Progress to date in achieving emission reductions in the UK

- 5.2.1 Figure 4-1 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:

- 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 to 2024 following BEIS' December 2020 consultation [9, p41]. National carbon pricing ensures that coal assets have unfavourable marginal costs (see Section 8.2) 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) remained commercially operational beyond September 2021 with operational life at four other units (two at West Burton A and two at Drax, with a combined



generation capacity of 2.2GW) extended to respond to system stress events only since 1<sup>st</sup> October 2021 until their closure (currently scheduled for March 2023) [Author Analysis]. Ratcliffe is currently signalling that it will close all of its units by 2024.

- GB's second-generation nuclear fleet (9GW) operated significantly past its original decommissioning dates. Nuclear provided 16% of electricity demand in 2020 with low carbon emissions [13], however the decommissioning of existing plants commenced in 2021 and as of September 2022, the UK is operating just five nuclear stations (5.9GW). Advances in new nuclear plants to replace the existing fleet have been slower than was originally envisioned (see Section 5.4).
- Low carbon variable generation, predominantly wind and solar, has been deployed to GB grid more quickly and more widely than was originally projected, as illustrated in Table 5-2.

5.2.2 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 [28, 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.

5.2.3 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.

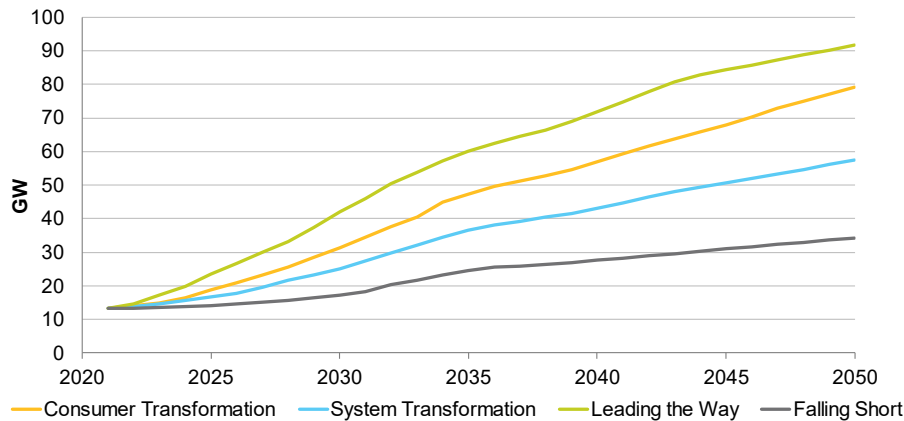
**Table 5-1: Historical capacities of renewable generation deployment and sites approved for construction (GW)**

Technology (GW)	January 2011	July 2022	Projects approved for construction
<b>Solar</b>	0.0	13.8	15.3
<b>Embedded Wind</b>		0.6	17.5
<b>Onshore Wind</b>	5.5	13.1	
<b>Offshore Wind</b>		13.0	67.9
<b>Total</b>	<b>5.5</b>	<b>40.4</b>	<b>100.7</b>

Adapted from [30, 116, 117]

5.2.4 NGENSO's Future Energy Scenarios (FES) 2020, 2021 and 2022 [35, 13, 116] describe three pathways involving radical change across many industry sectors, which will deliver the required 100% reductions in carbon emissions by 2050 and one scenario which will not. 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. Figure 5-1 shows the contribution National Grid's analysis predicts solar will need to make to GB energy supply for each of the four scenarios included in FES 2022. Delivery of these significant capacities of new solar generation will require the consent and delivery of this Scheme, and many more like it.

**Figure 5-1: Illustration of potential solar capacity evolution by FES scenario**



[116, Table ES.E.16]

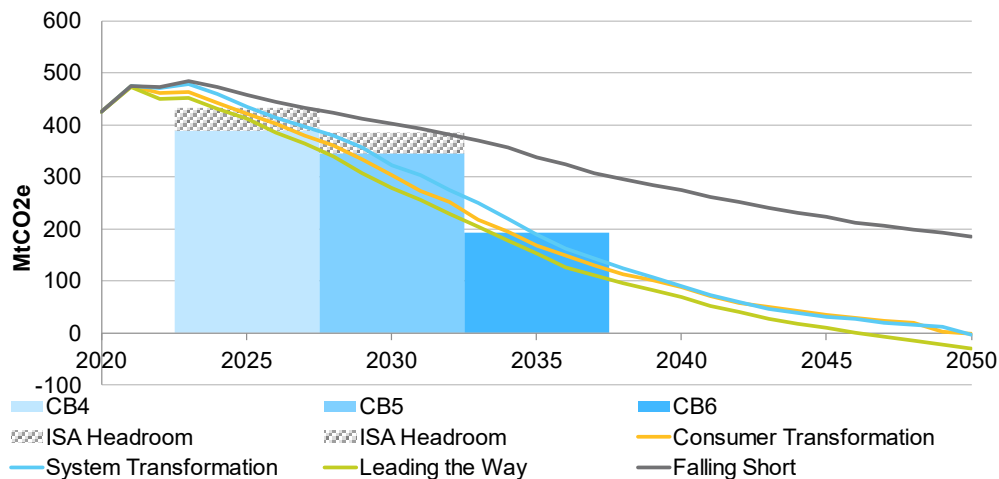
## 5.3 Action during the 2020s will be critical to meet the 2050 Net Zero target

- 5.3.1 In an address to the opening session of the US Leaders' Summit on Climate, hosted by US President Biden on Earth Day (22<sup>nd</sup> 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. [16].
- 5.3.2 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 to 15 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 2021 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." [33, July 2020]. 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" [34].

5.3.3 Recalling from Chapter 4 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 5-2. 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 5-2: Power generation emissions must reduce to negative in the early 2030s to meet the 2050 Net Zero target and interim carbon budgets.**



[116, Figure NZ.08]

5.3.4 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". [17, p6].

5.3.5 However, information provided by National Grid ESO (ESO Data Portal: Historic Generation Mix & Carbon Intensity - Dataset| National Grid Electricity System Operator (nationalgrideso.com)) illustrates that the further decarbonisation of the electricity grid is not a given. Ageing zero-carbon nuclear is being replaced by renewable wind and solar. The net effect is an electricity generation carbon intensity holding position, with no material reductions having been made between 2019 and 2022. Further nuclear closures in 2024 may mean that further reductions in grid average carbon intensity may not be seen until 2025 or later.

5.3.6 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.

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

- 5.4.1 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.
- 5.4.2 Table 5.2 includes 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, the operation of the existing UK nuclear fleet beyond its original lifetime expectations, and a significant increase in renewable generation capacity.
- 5.4.3 The National Infrastructure Commission (NIC) was established in 2015 to provide independent, impartial advice on the UK's long-term infrastructure needs. NIC stated in its first National Infrastructure Assessment report in 2018 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]*

**Table 5-2: Projections from 2009 for a low carbon power sector**

Initiative	Projection	Status, September 2022
<b>New Nuclear</b>	<b>2013:</b> construction of new nuclear commences.	<b>2017:</b> Hinkley Point C construction commenced, with a Commercial Operation date currently estimated during 2026
	<b>2018:</b> first new nuclear operational (of up to 16 GW)	<b>2018:</b> Government advised by NIC to permit only one more GW+ nuclear before 2025
		<b>2019/20:</b> Two GW+ scale nuclear projects abandoned by their proposed developers
		<b>2020:</b> Energy White Paper is consistent with NIC advice
		<b>2021/22:</b> End of life announced for 4 GW of existing nuclear, in 2021 (1.5 GW), 2022 (1.5 GW) and 2024 (2 GW).
	<b>2022:</b> Nuclear Energy (Financing) Act is adopted. British Energy Security Strategy calls for 24GW of nuclear power by 2050. In July 2022, Sizewell C received its Development Consent Order, although at October 2022 a Final Investment Decision had not been taken on the project.	
<b>Wave / Tidal</b>	<b>2014:</b> Larger-scale wave and tidal energy generation (>10 MW) starts to be deployed	<b>2022:</b> No larger-scale wave and tidal energy generation yet to be deployed. The second Severn Estuary / Swansea proposal was denied public funding in 2018.
<b>CCUS</b>	<b>2020:</b> up to 4 CCUS demonstration projects operational in the UK	<b>2022:</b> No CCUS projects yet operational in GB. National Infrastructure Strategy includes business model blueprints in 2021; two industrial clusters progress with project development with a third cluster designated "reserve" status.
<b>Renewable Energy Share</b>	<b>2020:</b> Around 30% of electricity is generated from renewable sources	<b>2019:</b> Wind, solar, hydro, bioenergy accounted for 37% of generation. Nuclear accounted for 17%.
		<b>2020:</b> Renewables made up 43% share of GB power generation in 2020.
		<b>2021:</b> NIC conclude that 65% of GB's electricity could be delivered from RES; the CCC highlight the need for of 90 – 175 GW of offshore wind capacity in the UK by 2050. Low carbon produced c.42% of 2021 generation
		<b>2022:</b> British Energy Security Strategy calls for much deeper and faster deployment of renewables, including 50GW of offshore wind by 2030 and a five-fold increase in solar deployment by 2035.

Summarised from [11, 36, 9, 3, 4]; and a 2022 status [Author Analysis]

## Carbon Capture Usage and Storage

5.4.4 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 May 2022, grid-scale CCUS from power generation has not yet been proven in Europe. 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. According to the Global CCUS Institute's 2022 status report [38], only one commercial scale CCUS project (Boundary Dam, Canada) is currently operational for power generation purposes, operations having been suspended at Petra Nova (USA) during 2021. 27 CCUS projects (36.6Mtpa) are currently operational worldwide [38].

5.4.5 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 [5, Para 3.3.5], thus the continued 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 [42] proposes CCUS be utilised with bioenergy to generate power at negative emissions or produce hydrogen. Crucially the NIC presented CCUS as an option for deployment alongside RES capacity.

5.4.6 The Prime Minister's Ten Point Plan of November 2020 included 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." [24].

5.4.7 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 [12 p126, 40, 41, p115] however recent progress has been made in the development of industrial CCUS, including plans to capture up to 10m tonnes of CO<sub>2</sub> by the end of this decade [9, p17]. A separate project plans to take industrial European CO<sub>2</sub> 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 [40]. 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<sub>2</sub> 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. 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:

- Invest £1 billion to bring forward four CCS clusters by the end of the decade, with two to begin construction by the mid 2020s;
- Set an ambition to capture 10 megatons of carbon dioxide per year by 2030; and
- Outline further details on new business models and revenue mechanisms to attract private sector investment. [3, p53].

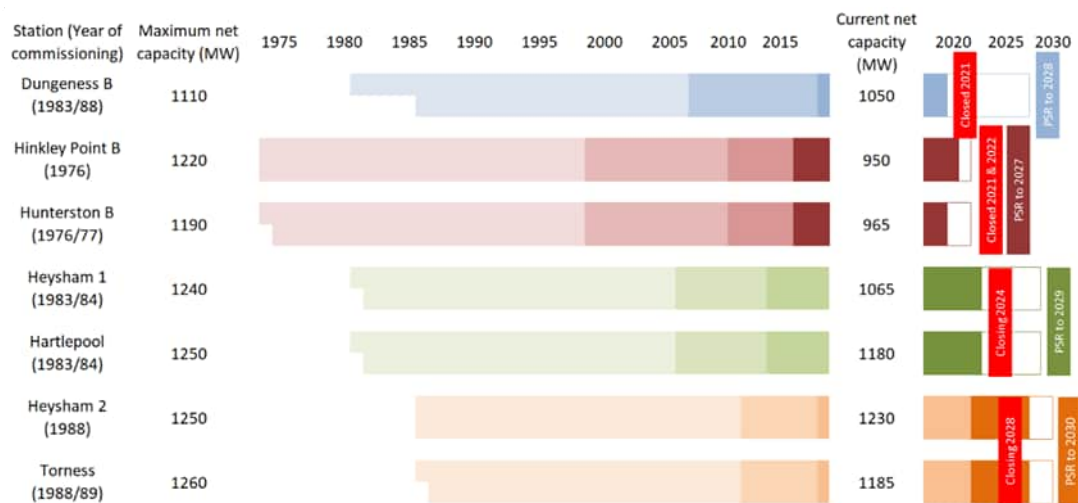
### Wave / Tidal Power

5.4.8 Wave / Tidal power has been proposed at several locations in the UK, although wave technology development has experienced both cost and operational challenges [43]. Early predictions on future rollout of wave / tidal power showed varying levels of ambition, ranging from 0.5GW to 4.5GW by 2030 [36, p54]. Tidal power remains complicated to consent, and expensive to deliver, a position made clear by governments' rejection of public funding for the Swansea Bay Tidal Lagoon in June 2018 [44].

## Nuclear Power

- 5.4.9 Nuclear currently provides the largest capacity of dispatchable low-carbon power generation in GB and therefore is an incredibly important operational generation technology in the context of decarbonisation. Nuclear has historically met approximately 20% of GB demand and because the existing nuclear fleet has been able to continue operating beyond its original closure dates, nuclear has until recently continued to generate approximately a one-fifth share of demand.
- 5.4.10 Existing AGR (Advanced Gas-cooled Reactor) nuclear is close to the end of its life. At the date of writing this report, Dungeness B (1GW) Hunterston B (1GW) and Hinkley Point B (1GW) have closed and firm closure dates have been set for all but 1.2 GW of nuclear capacity (Sizewell B, a Pressurised Water Reactor (PWR) which is not shown in Figure 5-3). Heysham 1 and Hartlepool will close during 2024 (although operators EDF are currently considering a “short” life extension subject to engineering and safety analysis) [EDF energy online] and 2.4GW (Heysham 2 and Torness) will close by 2028. This information is illustrated in Figure 5-3.

**Figure 5-3: Generating capacities and announced closure dates for existing UK AGR stations**

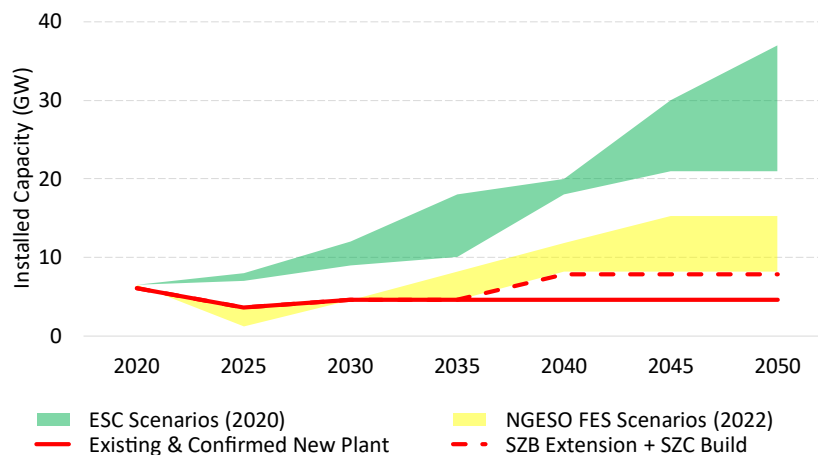


[Author analysis of data sourced from ██████████]

- 5.4.11 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 [45].
- 5.4.12 New nuclear developments are progressing. Hinkley Point C is currently under construction and other projects are 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. The scale of nuclear’s contribution to decarbonisation beyond the 2030s is also currently uncertain, because currently only Hinkley Point C is a confirmed and funded development. Figure 5-4 charts projections of nuclear capacity out to 2050 based on current end of life dates for the existing fleet as well as scenarios of new nuclear build.

- 5.4.13 Figure 5-4 shows that capacity from current and committed new nuclear projects (at the time of writing: only Hinkley Point C) 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 at least 2035, by which time Sizewell C may come online, see following. 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 2024 until at least the mid 2030s than the contribution it currently makes. This gap must be made up and the Scheme is part of the solution to closing that gap.
- 5.4.14 Government have removed many barriers to nuclear development over the last decade, including: 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. Government is currently progressing a Regulated Asset Base funding model for selected nuclear projects and in November 2022 committed to continue to support the development of Sizewell C through development funding and a (currently) 50% stake in the development, subject to final approvals.

**Figure 5-4: Projections of current nuclear capacity as existing stations close.**



[13, 18, 46, Author Analysis, ██████████]

- 5.4.15 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. Nuclear projects have long development and construction lead times, as illustrated in the development timeline for the Hinkley Point C project whose development started in earnest in the late 2000s and is currently under construction and currently forecast by its developer, a joint venture between EDF Energy and China General Nuclear (CGN) to commission in 2027 with the risk of further delay assessed at 15 months [118]) shown in Figure 5-5.
- 5.4.16 Government’s Energy White Paper, published in December 2020, sets the scene for further nuclear development in GB and confirms the identification of



a "RAB (Regulated Asset Base) model [which] remains credible for funding large-scale nuclear projects" [9, p49].

- 5.4.17 Another project, Sizewell C (SZC), also EDF/CGN, is currently progressing through development and received its Development Consent Order in July 2022. A project aiming to build the third and fourth UK EPR, SZC construction may proceed more rapidly than HPC, once funding mechanisms have been agreed. EDF have stated that: "the [SZC] project does not currently have a timeline ... although construction work could overlap with Hinkley Point C", and that SZC "will take 9-12 years to build" [online resource]. In December 2020 government confirmed that it would enter negotiations with EDF in relation to the Sizewell C project as it considered options to meet its Energy White Paper commitment to aim "To bring at least one large scale nuclear project to the point of Final Investment Decision by the end of this Parliament [i.e. no later than May 2024], subject to clear value for money and all relevant approvals." [9, p16]. In November 2022, Government announced that it would take a £700 million stake in Sizewell C and so would become a 50% shareholder in the project's development with EDF. Government and EDF will now work together with the project company to raise capital investment for the project [125].
- 5.4.18 The Nuclear Energy (Financing) Act, which formalises the application of a Regulated Asset Base financing model for new nuclear construction, achieved Royal Assent in 2022 and allows the possibility for Sizewell C and other projects to secure funding support.
- 5.4.19 SZC has previously been predicted to come online in the early 2030s [47] but progress to date and construction performance at Hinkley Point C point to commercial operation from the mid 2030s at the earliest opportunity.
- 5.4.20 CGN have taken the lead on the Bradwell B project. GDA on their reactor design started in 2017, and concluded successfully in early 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 late 2030s subject to any requirements of the National Security and Infrastructure Investment Act 2021.

**Figure 5-5: HPC Timeline**



[Author analysis]

- 5.4.21 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.

- 5.4.22 The second abandonment was Wylfa Newydd, Anglesey, Wales. Hitachi, the parent owners of Horizon Nuclear Power, were developing a project to construct and operate two Advanced Boiling Water Reactors (ABWRs). 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.
- 5.4.23 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." [48] Horizon withdrew its application for DCO on 16<sup>th</sup> 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.
- 5.4.24 At the time of writing this report, government has been reported as discussing with developers the very early stages of plans to build the AP1000 technology at Wylfa. Following the withdrawal of Hitachi's DCO application however, the earliest possible commission date for new nuclear at Wylfa would now be highly unlikely before the late 2030s as any new proposals will effectively be starting afresh.
- 5.4.25 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 could achieve this through either the delivery of larger projects or Small Modular Reactors (SMRs). SMRs aim for cost improvements through the production of multiples of units rather than an increase in scale.
- 5.4.26 Government's Industrial Decarbonisation Strategy aspires to have the first SMRs commercially deployed in the UK in the early 2030s, with an operational Advanced Modular Reactor (AMR) demonstrator deployed at the same time [17, p73]. AMRs use novel cooling systems or fuels and may offer new functionalities (such as industrial process heat). The roll out of subsequent next of a kind (NOAK) schemes would be highly contingent on a large number of technical, commercial and environmental factors. American company NuScale is at the front of the global race to develop and deploy SMR technology. NuScale plans its first US SMR installation by 2030 [49], three years later than previously planned. BEIS requested the ONR and the environmental regulators for England and Wales to begin a GDA for the first SMR design (from Rolls Royce SMR Limited) in March 2022. The GDA process has been open for the potential of SMR applications since 2021 [9, p50].
- 5.4.27 The 2020 National Infrastructure Strategy confirms government's continued support for the development of nuclear technologies through the provision of funding to bring forward large scale and small modular reactors [3, p50], but the 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".

- 5.4.28 Nuclear holds a prominent position in Government's British Energy Security Strategy [50], published in 2022, and which is discussed in Section 8.9.

## 5.5 Summary

- 5.5.1 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 their development. The important bearing that decarbonisation during the 2030s has on the achievement of Net Zero 2050 is set out in Section 5.3.

- 5.5.2 The 2019 BEIS consultation on new nuclear financing [51] 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. [51, p7]*

- 5.5.3 Government's current policy for market-led developments of low-carbon generation from diverse sources of power, including solar, to meeting the UK's Net Zero legal commitments, is critical for success.
- 5.5.4 While the door remains open for nuclear power to make significant contributions to low-carbon generation in the mid/late 2030s and beyond, the gap created by the closure of the existing nuclear fleet must be filled (as discussed in Section 5.3). Additionally, the risks associated with achieving financial close on new nuclear developments and the long timeframes associated with these developments, mean that new nuclear cannot currently be relied upon to deliver Net Zero.
- 5.5.5 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.

- 5.5.6 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. This is consistent with the approach described by government in draft Revised 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. [1, Para 3.3.11]
- 5.5.7 The role that solar has played in decarbonising GB's electricity generation to date is clear from Table 5-2. Solar has undergone significant technological advances in scale and efficiency, and the UK has many areas of high solar irradiation. It is therefore for GB to make best use of this natural, renewable energy resource in order to meet its legal carbon emission reduction obligations.
- 5.5.8 Solar generated 11.7TWh of power in 2019. This increased to over 12.1TWh in 2020 and 2021 generation was 11.2TWh [Author analysis from NGESO market data]: an important and reliable annual contribution to national demand. Solar is well placed to play the role that recent government papers have ascribed to it: [3, p43], and Chapters 8 and 10 of this report expand on the reasons behind this statement.
- 5.5.9 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 Revised NPS EN-1 articulates the government's prudent view that infrastructure development should be planned on a conservative basis [1, Para 3.3.11], without over-relying on technologies which are yet to be proven, have long development lead-times, or which have historically experienced funding difficulties.
- 5.5.10 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 should therefore be recognised for the critical contribution it will make to the UK's journey to Net Zero and consenting the Scheme such that it will be able to be developed as planned, will bring the UK closer to its required track through the critical 2020s to meet its legally binding carbon emissions reduction targets. The delivery timing associated with current forward nuclear and CCUS projections strengthen this conclusion.

## 5.6 Building a green recovery

*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. [9, p4].*

5.6.1 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. 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 [3]. Long-term energy infrastructure assets are well placed as a focus for the long-sighted investments which will support a green recovery from the difficult early 2020's. The Energy White Paper puts in place a strategy for the wider energy system that:

- Transforms energy, building a cleaner, greener future for our country, our people and our planet; and
- 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 [9, p4].

## 5.7 Environmental health and public health are linked

5.7.1 Research has uncovered a correlation between air pollution levels and risk of death. For example, 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. [52]. 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 through providing the electricity generation to decarbonise the industrial and transportations sectors, 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. The Environment Act 2021 establishes a legally binding duty on government to bring forward at least two new air quality targets in secondary legislation by 31 October 2022.

5.7.2 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%" [53]. Findings from the UK and US, Chinese and Dutch studies have also reached similar conclusions. Replacing polluting industry with clean air industry, will help keep people alive both now, and in the future.

5.7.3 COVID-19 drove carbon emissions down through a reduction in economic activity and therefore energy requirement. Many environmental indicators improved during the lockdown period. The restart of economic activity,

however challenged, leads to a requirement for more positive action to hold ground and sustain environmental performance. The development of green infrastructure, like solar generation assets which produce low-carbon power and enable biodiversity opportunities, presents an excellent opportunity to deliver economic and environmental benefits both as part of the same project.

## 5.8 Economic and social recovery for the 2020s

- 5.8.1 In June 2020, the Prime Minister tasked the UK to "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." [20]. By July 2020, government had committed £350m to "supercharging green recovery" [21].
- 5.8.2 The CCC provided strong direction in both their 2020 and 2021 Progress Report to Parliament [15, 54]. 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 [15, 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.
- 5.8.3 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 sustainable economy after the pandemic ... relying on experts ... to drive forward the agenda along our path to Net Zero" [55]. 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 [56].

*Fighting climate change offers huge opportunity for both growth and job creation ... the time is now to seize these opportunities. [9, p2]*

## 6 Future demand for electricity is growing

### 6.1 Setting the scene on future electricity demand growth

*[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. [5, 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. [5, Para 3.3.21].*

- 6.1.1 The annual demand for energy from all sources in GB in 2020 was 1,355TWh, with 20% (272TWh) in the form of electricity [116, Figure EC.02]. 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.

### 6.2 Expert analysis of the energy sector of the future

- 6.2.1 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), see [116] 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.*

- 6.2.2 FES publications go back to at least 2012 ( [REDACTED] )  
[REDACTED] The speed of decarbonisation is a key feature in

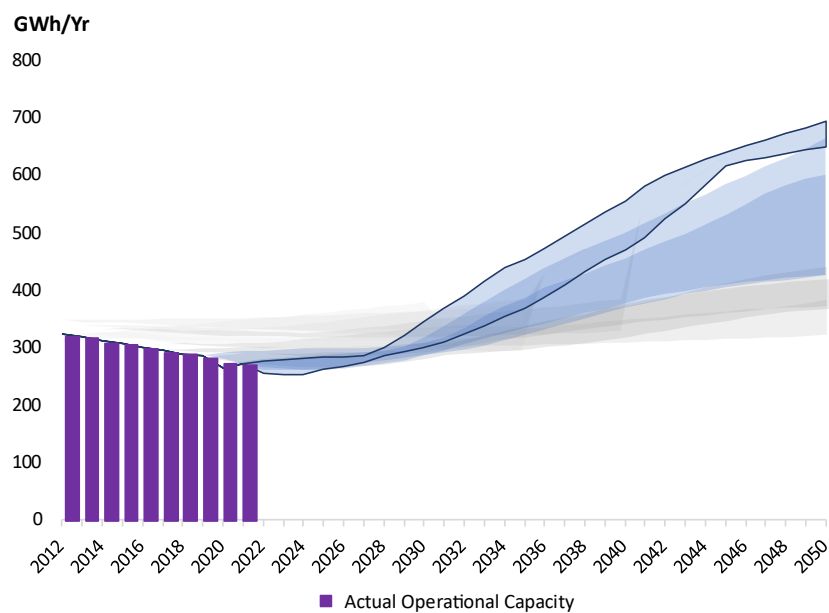
each edition of the FES since 2018, with three of the four scenarios from both FES 2020, FES 2021 and FES 2022 meeting the 2050 carbon reduction target via distinct pathways, requiring heavy investment in either energy efficiency, or electricity decarbonisation, and/or new or enhanced energy vectors. Energy vectors enable energy to be transported or transmitted and then converted back into another form of energy for end (or onward) use (e.g. hydrogen). In reality these pathways are not mutually exclusive, and government and industry are currently pursuing initiatives which cover both.

- 6.2.3 FES 2022 [116] recommends strategic whole system thinking. This means a consideration of all aspects of energy demand and supply as an interconnected system, rather than thinking about electricity, transport or heat separately. Strategic coordination and whole system thinking, especially between the electricity and hydrogen sectors, is required to achieve decarbonisation targets and deliver more effective initiatives to fight climate change while maximising affordability.
- 6.2.4 FES 2022 addresses delivery of the British Energy Security Strategy and concludes that it requires urgent anticipatory investment to ensure that the energy system is not a blocker to Net Zero. Whole system thinking, especially across the electricity and hydrogen sectors, is required to achieve decarbonisation targets and avoid unmanageable network constraints and potential curtailment of valuable low-carbon generation.
- 6.2.5 This, coupled with a further increase in the urgency of action against Climate Change, manifests in FES 2022 through a greater emphasis on interim milestones such as carbon-free operation of the National Electricity Transmission System by 2035 and a deeper insight into how the whole energy system works together.
- 6.2.6 FES 2022 includes four modelled scenarios. Two of the four (Consumer Transformation and System Transformation) meet the Net Zero target in 2050. A third, Leading The Way, meets Net Zero in 2047. The fourth scenario has been renamed from Steady Progression (in FES 2021) to Falling Short (in FES 2022), and only achieves emissions levels of 80% of 1990 levels by 2050 – the original objective of the Climate Change Act 2008, but not sufficient to secure Net Zero 2050.
- 6.2.7 The key observation drawn from FES 2022, is that in all lower-carbon futures, the electricity sector will not operate in isolation from other energy sectors. Rapid decarbonisation is required across all areas of demand – including residential, transport, industrial and commercial. Deep electrification of all of those areas is required in order to meet Net Zero, and NGENSO conclude in 2022 that the need for urgent electrification has increased year-on-year.
- 6.2.8 FES 2022 reiterates that electricity demand will need to increase if Net Zero is to be achieved, but crucially by more than previously has been considered. Consequentially low-carbon electricity supply will need to increase further to meet both that demand and anticipated demand for green hydrogen, which could be produced using renewable electricity to electrolyse water with no carbon emissions.



- 6.2.9 2035 is a critical timeframe for electricity supply to achieve Net Zero, providing a low-carbon source of power for the substitution of hydrocarbon fuels in other sectors
- 6.2.10 Figure 6-1 shows a superposition of UK electricity demand forecasts from FES 2012 to 2022, each forecast represented as a shaded area ranging from the lowest forecast demand scenario to the highest scenario in each year. Historical demand is shown as purple columns. As electricity demand reduced year-on-year, so too did future demand forecasts prior to the UK's 2019 commitment to Net Zero. UK electricity demand in 2050 broadly converged to a forecast range of 350 to 400TWh. Since the Net Zero commitment, forecasts for future electricity demand have increased significantly. To highlight this the FES forecasts since 2020 have been shown in blue, with the 2022 forecast bordered in dark blue. Increased electrification of transport, heat and industrial demand is essential for the achievement of Net Zero, and is a key driver for the increase in future electricity demand.

**Figure 6-1: Evolution of UK electricity demand forecasts 2012 – 2022**



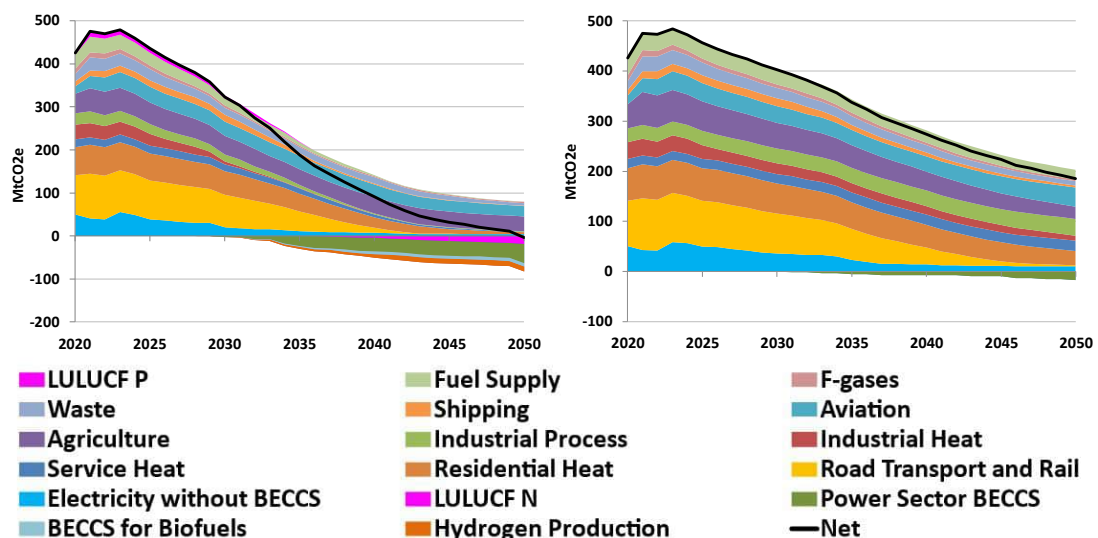
[116, and previous publications, 2012 - 2021]

- 6.2.11 Figure 6-2 illustrates two of NGENSO's 2022 Future Energy Scenarios [116]. One of these meets the 2050 emissions objective (System Transformation); two other scenarios (not shown) also meet the objective, and the other charted scenario (Falling Short) does not.
- 6.2.12 An 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 wide range of future electricity demand forecast shown in Figure 6-1 is explained by the extent to which hydrogen is adopted as a low-carbon energy vector in the UK.

6.2.13 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 therefore 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. In reality the need for low carbon electricity generation capacity is, based on currently known and deliverable technologies, independent of the scale of adoption of hydrogen in the UK.

6.2.14 For more information see Section 11.4.

**Figure 6-2: NGESO scenarios, showing the importance of a whole-society approach to decarbonisation and low carbon electricity generation.**



[116, Figures NZ.09]

6.2.15 The most recent FES [116] brings together future operation of existing generators, and future trends in the demand for energy, to conclude that:

- Net emissions from the power sector likely must be negative from the early 2030s to achieve Net Zero;
- Hydrogen and carbon capture and storage are likely to be required to achieve Net Zero, with more than 30TWh of electricity demand required by 2040, and in excess of 112TWh by 2050, for hydrogen production [116, Table WS1]. This is likely significantly to increase the need for low-carbon electricity generation over and above that needed to meet other growth in electrification; and
- 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.

6.2.16 In March 2020 the Energy System Catapult (ESC) published the Innovating to Net Zero report which summarised the results of an update to their national Energy System Modelling Environment (ESME) [18]. 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 6.3.

## 6.3 Future electricity demand

6.3.1 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:

- A decline in economic growth rate (particularly with the recession of 2009);
- A reduction in the level of electricity intensity as the economy has shifted to less energy-intensive activities; and
- The introduction of energy efficiency measures, especially more efficient lighting within the last seven years, but also technology development more generally.

6.3.2 Today's view of future GB electricity demand remains uncertain, partly as a result of the COVID-19 pandemic and ongoing economic challenges, but in the future electricity demand is forecast to grow, for the same reasons as those stated in the 2011 NPS documents:

- 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, however ongoing improvements on the efficiency of household electrical appliances is anticipated to act in the other direction.
- 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
- 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.

6.3.3 These observations are consistent with those made by NGENSO in their 2020 – 2022 FES. Of the four scenarios in these documents, only one, previously named "Steady Progression" does not meet Net Zero. It is now named "Falling Short".

6.3.4 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 of that decarbonisation. For example (see Section 11.4) 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):

- The National Policy Statements foresaw a doubling of current demand [5, Para 2.2.22], i.e. to circa 600TWh;
- NGENSO present a range from 565 – 716TWh [116, Table ED1];
- The National Infrastructure Commission forecasts 465 – 595TWh [42, p35];
- The Energy Systems Catapult forecasts 525 – 700TWh [18, pp23 & 27];
- The Q4 2020 EY Power Price Outlook for GB forecasts 485TWh [EY Consulting forecast];
- The CCC's sixth carbon budget presents a range from 550 – 680TWh [4, Table 3.4.a];
- The BEIS impact assessment for Carbon Budget 6 (CB6) presents a range from 610 – 900TWh [57, p29]; and
- The 2020 Energy White Paper presents a range from 575 – 665TWh [9, p42].

6.3.5 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 [18, p5].

6.3.6 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.

6.3.7 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.

6.3.8 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.

## 6.4 Transport

- 6.4.1 Surface transport is currently the largest source of UK greenhouse gas emissions (surface transport accounted for 22.6% of 2020 emissions, [115, Executive Summary Data Tables]). Emissions rebounded by 10% in 2021 as lockdown restrictions lifted. A rapid shift to low emission vehicles will give a significant boost to the decarbonisation of our economy.
- 6.4.2 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 [56], 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 [9, 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 [15, 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" [58].
- 6.4.3 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 [20]. Specifically, commitments were made to:
- Make funding available in 2020 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;
  - 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
  - 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. [59, 60]
- 6.4.4 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 [61].

- 6.4.5 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" [62, p7] and anticipate that the number of electric vehicles on UK roads may grow from 320,000 at June 2020 [9, p93] to 46 million by 2050 [62, 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 [13, Tables CV.31–35].
- 6.4.6 The Society of Motor Manufacturers and Traders reported a 49% increase in Battery Electric Vehicle (BEV) registrations in the UK in the year-to-date (end August 22) versus the same period the previous year, and over 14% of all new vehicle purchases in the UK in year-to-date August 2022 were BEVs. Ongoing grants (available until at least March-23) and cheaper running costs are anticipated to continue to push EV market share over the coming years. [Society of Motor Manufacturers BEV Sales August 2022].
- 6.4.7 Government is facilitating the adoption of electricity into transport through its Electric Vehicle Infrastructure Strategy (March 22) [64] which sets out the expectation, by 2030, of there being around 300,000 public chargepoints as a minimum in the UK [up from just 30,000 in the first quarter of 2022], but there potentially being more than double that number, delivering "Effortless on and off-street charging for private and commercial drivers" [64, pp4&5].
- 6.4.8 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 [65, 66]. Direct annual electricity demand in 2050 for road transport (i.e. incorporating only EV demand) could be 90 – 123TWh in scenarios which meet Net Zero [13, Tables CV.31–33]. This projection is consistent with previous projections from 2019, 2020 and 2021 [35, Tables CV.23–26], [67, p77], [68, p12] and [13, Tables CV.31-33]. The use of hydrogen in rail and air transport (with the consequential electricity needs to provide that hydrogen\_ will increase these estimates even further.
- 6.4.9 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. [9, p94].
- 6.4.10 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. [18, pp22 & 25].

## 6.5 Home and space heating

- 6.5.1 Reducing dependency on natural gas and thereby reducing carbon footprint further, requires gas to be substituted from home and industrial / commercial heating, cooking and water heating.
- 6.5.2 The long-term need to diversify to low-or zero-carbon home and industrial / commercial heating, cooking and hot water will increase demands for electricity on the NETS. Gas will be either directly substituted through electrification, or indirectly using electricity to produce hydrogen or by other renewable technologies.
- 6.5.3 Coupled with governmental plans for new homes in England, Wales and Scotland, electrification of home and space heating will increase GB's demand for electricity. For every household that is supplied with electricity, an average additional burden of approximately 3.8MWh per year could be placed on the grid [69] and more as gas use in homes is substituted for electricity as suggested. In 2019, research by Homes for Scotland revealed that a further 25,000 homes are needed each year to keep up with housing demand and recognised a backlog of 80,000 homes created by a shortfall in the supply of housing since 2008 [70]. The need for new homes in Wales has been estimated at 7,300 new homes per year to 2024, reducing to 4,500 per year to 2039 [71]. Estimates have put the number of new homes needed in England at up to 345,000 per year, accounting for new household formation and a backlog of existing need for suitable housing [72]. Projections therefore imply a potential additional increase in electricity demand in Great Britain of at least 41TWh per year by 2050.
- 6.5.4 The Prime Minister announced in November 2020 his intention to bring forwards, to 2025, the date by which new homes will need to be warmed without using gas heating [24]. 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.
- 6.5.5 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 [9, p110]. The British Energy Security Strategy aims to ensure that by 2050 all UK buildings will have low-carbon heating, and reconfirms Government's intent to phase out the sale of new and replacement gas boilers by 2035. [50, p12].

6.5.6 Whilst district heat systems are anticipated to capture process heat from thermal power plants, in the context set out in this report, critically these heat producing 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 [15, pp21 & 24].

## 6.6 Future peak electricity demand

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

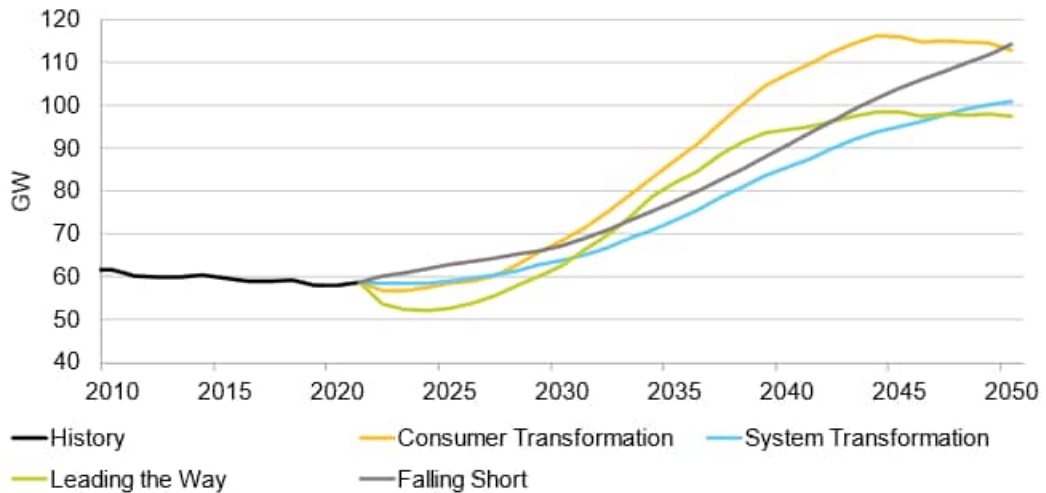
6.6.2 Figure 6-3 illustrates the potential peak demand for GB power (using NGESO's Average Cold Spell methodology) to 2050. In the four scenarios, peak demand is anticipated to range between 62.7GW and 68.4GW by 2030 (for comparison, 2020: 58.8GW); between 85.5GW and 107.1GW in 2040, and between 97.5GW and 114.3GW in 2050 [116, Table FL.04]. 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 and the electrification of heating and transport.

6.6.3 EVs and hydrogen vehicles require the deployment of additional electricity generation capacity and may also act as integration measures for renewable and baseload generation, capable of shifting load from when demand is high, to periods where supply is higher. Initially, system peak demand was 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. [58].*



**Figure 6-3: Future net peak electricity demand**



[116, Figure FL.04]

6.6.4 Ofgem announced a new Strategic Innovation Fund in August 2021. The £450M fund is being 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 have stated 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.

# 7 Implications for future electricity supply needs

## 7.1 Setting the scene on future electricity supply

- 7.1.1 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. [9, 42]*

*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. [9, 42]*

*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. [42, p10].*

## 7.2 Future electricity supply

- 7.2.1 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.

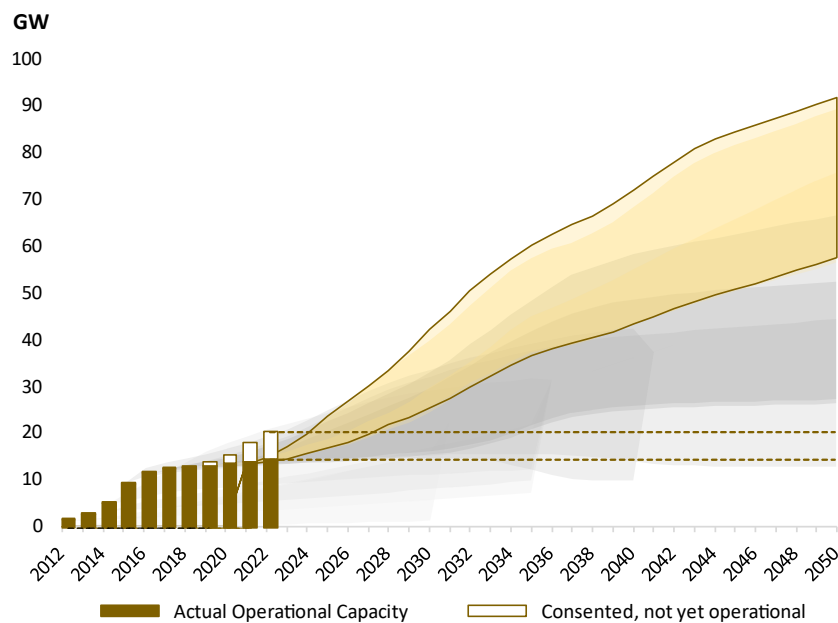
- 7.2.2 In the context of Net Zero, the FES are a useful suite of documents to indicate whether particular future pathways for electricity generation will be successful against a national policy perspective. Trends in the data help identify which pathways are more likely to be successful than others 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. [5, Para 3.1.2].*

- 7.2.3 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.
- 7.2.4 Analysis of the CfD Register [73] shows that 34 projects with CfDs have registered a reduction to the capacity of the CfD Unit or have had their CfD terminated. They are:
- Offshore wind: 10 projects, 99MW reduction (1% of total technology initial anticipated installed capacity under CfD);
  - Onshore wind: 12 projects; 69MW (9%);
  - Biomass / Waste / CHP projects: 4 projects, 150MW (10%, of which 3 projects (135MW) were terminated);
  - Solar PV: 3 projects, 16MW (41%, 1 project (12MW) terminated);
  - Advanced conversion technology: 7 projects, 96MW (63%, all terminated).
- 7.2.5 Each year, based on an objective economic assessment of current and future costs and/or market drivers, FES scenarios have described consistently high capacities of solar generation connecting in the future to the national electricity transmission system. The FES scenarios are 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.
- 7.2.6 The 2022 FES foresees one of four scenarios (“Falling Short” and characterised as 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 NGENSO’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.
- 7.2.7 From their analysis, NGENSO conclude that installed electrical generation capacity in GB needs to increase from today’s 107GW to between 156 and 209GW to meet anticipated demand in 2030, this being a 55 to 109GW increase on existing generation capacity following the decommissioning of all but 1.2GW of existing nuclear generation and the closure of all remaining coal generation (5GW) before that date.
- 7.2.8 The most striking insight from the 2022 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 7% – 9% 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 9% – 17% of GB operational capacity in 2030 will be carbon-intensive generation, down from 38% in 2021.

- 7.2.9 Further, NGEN forecasts that between 310 and 365GW of generation capacity will be required to meet demand and Net-Zero by 2050 (continuing the increasing trend in required capacity from previous FES editions), and 100% of operational generation must by 2050 be zero-carbon. [116, Table ES.E.01], [13, Table SV.22], [35, Table SV.23] and [67].
- 7.2.10 The FES scenarios which are predicted to achieve Net Zero include solar capacities in 2030 of 25 – 42GW, in 2040 of 43 – 68GW, and in 2050 of 57 – 92GW [116, Table ES.E.01]. In every scenario, a pathway to Net Zero includes a significant future increase in solar capacity beyond that which is installed or in development today, as shown in Figure 7-1.
- 7.2.11 Figure 7-1 shows a superposition of UK solar capacity forecasts from FES 2012 to 2022, each forecast represented as a shaded area ranging from the lowest forecast capacity scenario to the highest scenario in each year. Historical installed capacity is shown as brown columns, and the Author’s view of a risked future capacity forecast based on capacity registers and likelihood of achieving project completion based on scale, technology and location at the time of writing ([29, 74, 32]) is shown as white columns. Since the Net Zero commitment, forecasts for future solar capacity have increased significantly. To highlight this the FES forecasts from 2020, 2021 and 2022 have been shown in yellow, with the 2022 forecast bordered in brown.

**Figure 7-1: Evolution of future solar capacity forecasts in the UK, 2012 - 2022**



[11, and previous publications, 2012 – 2021 and Author Analysis]

- 7.2.12 The following observations can be made from Figure 7-1:
- Future UK solar capacity forecasts have increased year on year since 2012. Year-on-year solar cost reductions have made the technology progressively attractive (and now preferential) to other forms of electricity generation, promoting the commercial rationality for the UK to prioritise

the development of solar capacity in order to address energy affordability challenges (see Chapter 10);

- The UK's Net Zero commitment has, since 2020, coincided with a further increase in solar capacity, shown by the yellow ranges (the 2022 forecast shows the greatest installed capacity and is bordered in brown and is consistent with the forecast published in 2021); and
- The range of installed capacity may be explained by the extent to which other low carbon technologies including onshore and offshore wind, nuclear and BECCS (Bioenergy with Carbon Capture and Storage) are deployed in the UK. Delays or shortfalls in the deployment of any technologies will require a compensatory acceleration or expansion in the deployment of others in order for the UK to remain on track to achieve Net Zero. With a relatively short development timeframes, the solar sector may be well placed to respond to any difficulties or delays in the deployment of other technologies.

7.2.13 NGESO are not alone in anticipating a significant increase in the capacity of low-carbon generation required to meet Net Zero. The CCC suggested that, on top of delivery of the offshore wind sector deal (which was 30GW by 2030 at the time), in order to meet a doubling of electricity demand from 100% low-carbon sources, up to 60TWh of low-carbon generation would be required by 2030 [15, p155], with solar generation currently an area of strength for the UK [14, p239]. Government targeted 40GW of offshore wind to be operational by 2030 [9, p16] and has expressed its ambition for the delivery of up to 50GW of offshore wind by 2030 and a five-fold increase in solar deployment by 2035 [50].

7.2.14 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. [42, p19].

7.2.15 The ESC anticipates broadly similar generation capacities. 165 – 285GW of capacity will be required in 2050, including 18 – 80GW of solar [18, 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).

7.2.16 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 8.7 and Section 8.8 provide further information.

7.2.17 In 2021, GB sourced 42% of its electricity from renewables, of which approximately 9.4% was from solar [Author Analysis of National Grid data, 116]. 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 [75, 76], and GB can learn how to do this from other nations which are further ahead in this regard.

7.2.18 2022 saw the third edition of the FES since GB adopted Net Zero legal commitments. FES 2022 analyses three scenarios under which Net Zero emissions can be achieved by 2050, and one scenario which misses the targets. NGENSO align with the Energy Systems Catapult (see Section 4.3 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 [67, p2], and subsequent FES scenarios have borne out that conclusion. Six important predictions from NGENSO's recent analysis [116] are that, by 2030:

- While in all scenarios, GB energy demand is expected to be lower in 2050 than 2021 (by between 40 and 56%), 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 62 and 100% versus 2021 [116, Table EC.02];
- Storage and interconnection (flexibility) capacity will need to increase (from 10GW in 2021) to 19 – 33GW in 2030 and 48 – 79GW by 2050 to balance supply and demand both within the GB system and across borders [116, Table ES.E.01];
- Due to the electrification of other sectors, peak demand (FES uses the Average Cold Spell (ACS) definition which is consistent with the treatment of demand in the electricity Capacity Mechanism) is expected to rise (from 2021's level of 58.8GW) by 66% – 92% by 2050, even with the storage and interconnection capacities anticipated above to support "peak shaving" [116, Table FL.04];
- Therefore, GB installed generation capacity will need to increase (from 107GW in 2021) to 171 – 209GW 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;
- Installed generation capacity will need to grow even further (to 310 – 365GW) by 2050 to meet demand, and must be 100% low-carbon to meet Net Zero legal requirements;
- 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.

7.2.19 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 2022 by an

increase in all low-carbon metrics versus previous FES editions and in published analyses by other market experts.

- 7.2.20 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.
- 7.2.21 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.

## 7.3 Demand response

- 7.3.1 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 system wide commercial drivers, but DSR on its own will be unlikely to deliver a decarbonised electricity system.
- 7.3.2 Currently DSR capacity is estimated at 6.5GW nationally [116, Table FL.03]. FES scenarios forecast between 13 and 24GW may be operational by 2035, rising to 16 – 27GW by 2050. The significance of the scale of growth of DSR is a reflection on the scale and urgency of decarbonisation actions required between now and 2030. DSR must grow alongside the development of solar and other renewable generation technologies of all scales, in order to stay on a path to achieve Net-Zero..
- 7.3.3 Therefore DSR may deliver an important contribution to the delivery of UK decarbonisation before 2030, but it DSR cannot replace nor reduce 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.

## 7.4 Wider decarbonisation requires a significant capacity of solar generation

- 7.4.1 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.
- 7.4.2 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.
- 7.4.3 Capacity utilisation 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])}. Historical capacity utilisations have been high (>80%).
- 7.4.4 Figure 7-2 shows NGENSO'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 41GW in 2021 to between 19 and 33GW 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.
- 7.4.5 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 greenhouse gas emissions to slow down climate change and stimulate investment in new jobs and businesses. [77]*

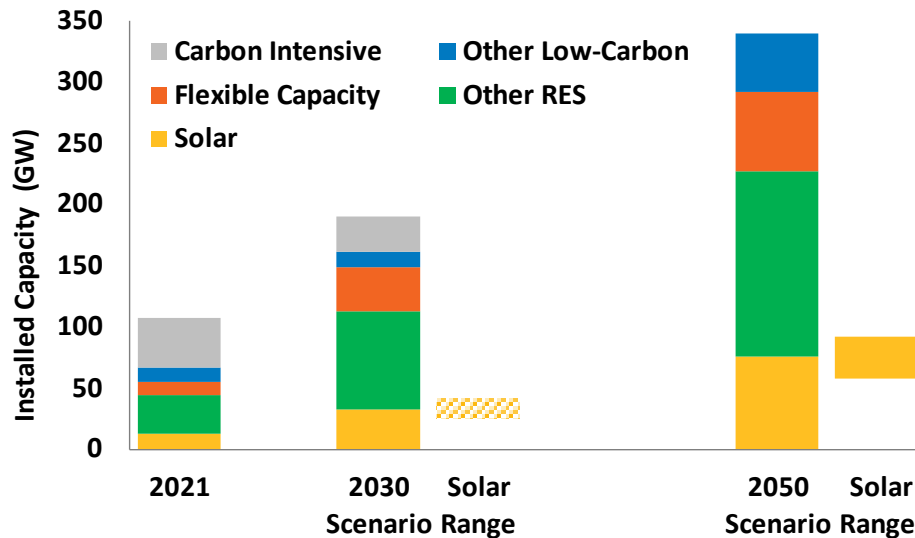
*The Energy White Paper provides further clarity on the Prime Minister's [Ten Point Plan] measures and puts in place a strategy for the wider energy system that: Transforms Energy ... Supports a green recovery ... [and] creates a fair deal for consumers. [9, p4]*

- 7.4.6 NGENSO data shows that solar generated 11.4TWh of electricity during 2019, 12TWh in 2020 and 11.2TWh in 2021, each from ~13GW of built capacity, [35, Table ES1, Author Analysis]. This makes solar generation an important renewable power generation technology in GB, with future potential, and need, for further growth. Solar has the third highest output by renewable technology in GB, behind wind and biomass. 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 5-4.

**Figure 7-2: Generation capacity by technology type and amount of renewable capacity for 2030 and 2050**



[116, Table ES.E.01]

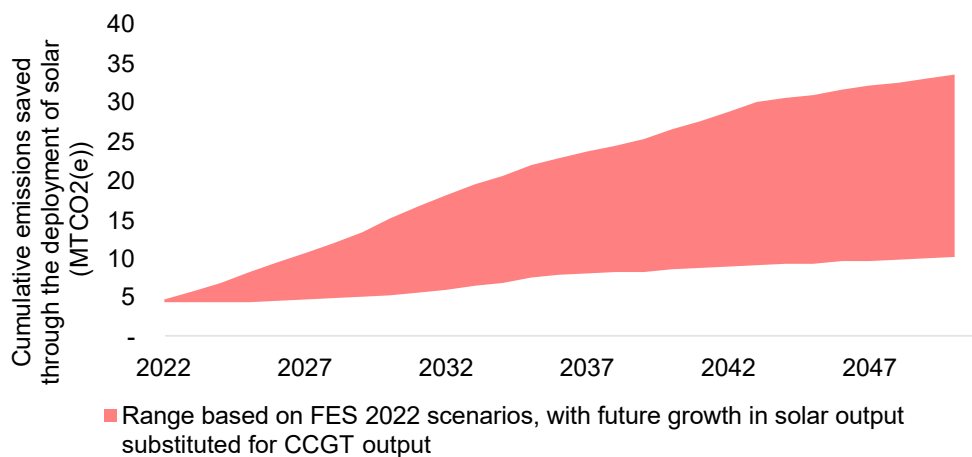
7.4.7 Section 5.4 describes why it is not likely that CCUS (the process to decarbonise carbon-intensive electricity generation) will play a significant role in reducing UK carbon emissions in the decade ahead, and also describes why nuclear generation will also not make a net positive contribution to carbon reduction over the same period. Yet Section 5.3 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.

7.4.8 Figure 7-3 shows the cumulative carbon emissions saved by solar generation versus the case that the electricity generated by solar was instead generated by CCGT (at 394 gCO<sub>2</sub>/kWh [119]). 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, especially with low-carbon generation, 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 8.8 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.

- 7.4.9 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.

**Figure 7-3: Generating power from solar along FES projections will provide cumulative carbon emissions versus if that power was generated from higher carbon sources.**



Adapted from [116, Table ES.E.10, 119 and Author Analysis ]

- 7.4.10 Table 5-1 shows that GB currently has 13.8GW of installed solar generation. Projects totalling a further 4.9GW have also been identified and are listed on industry pipeline databases. Figure 5-1 illustrates NGENSO's most recent modelling of possible future solar capacity by scenario; and Figure 8-1 shows that FES projections for solar capacity have grown year-on-year as the need for a zero-carbon electricity system has become more urgent. Capacity is anticipated to grow due to improving technology costs; installation of larger, standalone, facilities; continued residential and commercial PV installations; and repowering of existing installations, particularly through the mid-2030s.

- 7.4.11 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 Figure 5-1 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 projections shown in Figure 5-1, Table 5-1 or Figure 7-1 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 expressed government ambition, 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 which holds a Grid

Connection Agreement, is listed on the NGENO TEC Register [29], and which could be built out in the important 2020s, it is very possible that the contribution which solar may make to the future generation mix may be artificially limited, risking the success of established government policy and strategy on decarbonisation and reaching Net Zero.

- 7.4.12 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 NGENO 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.

## 7.5 Assessing and selecting suitable locations for large-scale solar generation in the UK

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

- 7.5.2 Suitable sites will be:

- Capable of delivering to the required scale (in relation to the need for the scheme);
- Technically and environmentally feasible within the stated timeframes; and
- Commercially attractive to investors.

- 7.5.3 Site selection utilises a screening approach which considers possible alternative sites, taking into account the three requirements listed above. In addition, the screening approach recognises the required urgency of low-carbon development in the UK and therefore, in an approach which is consistent with guidance contained in the 2021 Draft Revised National Policy Statement EN-1, applies a principle of proportionality to options which have vague or inchoate development considerations [1, p51], especially where those considerations are critical for the viability of the project. The screening process will prioritise options which are more likely to be able to meet the intended aims of the project, above options which are less likely to proceed due to technical, commercial or other reasons.

- 7.5.4 Local factors (the anticipated output of the site is strongly related to the site's layout and location) are also important in the site selection process.

- 7.5.5 Solar developments require three fundamental attributes and these therefore drive the initial screening process. These attributes (which are consistent with Section 2.48 of Draft Revised NPS EN-3 [2]) are:

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

- The availability of a suitably placed point of connection to the National Electricity Transmission System (NETS) and/or local Distribution Network; and
  - Solar irradiation levels which support the potential for the development to produce an energy yield which is both useful and economic.
- 7.5.6 Other attributes will also apply later into the screening process. However a site which does not possess all three fundamental attributes is less likely to be a suitable location for large-scale solar generation than a site which does possess these attributes.
- 7.5.7 The UK's approach to the energy sector provides that "It is for industry to propose new energy infrastructure projects within the strategic framework set by government" [National Policy Statement EN-1, Para 3.1.2]. It is important therefore to acknowledge that an individual developer's approach to screening will not be rigid and inflexible but instead will be sensitive to local variability and indeed developer approach. Developers may therefore weigh the importance of one or more criteria in their screening approach differently for different schemes to accommodate and incorporate the needs and benefits of different geographies and local characteristics.
- 7.5.8 The site selection process also considers the topography of land; planning and environmental constraints (including biodiversity, landscape and visual amenity, cultural heritage, flood risk, Agricultural Land Classification, land use and other factors); and local considerations, including availability and ownership of land, and access rights to the land through construction and operation.
- 7.5.9 Many non-fundamental 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.
- 7.5.10 For example, the number of landowners involved in a scheme, and their willingness to participate, may affect the attractiveness and feasibility of a particular proposal.
- 7.5.11 For example, adjoining land parcels may be both suitable and available for development, resulting in an increased density of solar deployment and an environmental footprint over a more focussed area of the countryside. Other proposals may consider separate land parcels which do not border each other but instead combine to an integrated scheme which is more dispersed within a countryside setting.
- 7.5.12 Further, the connection of separate parcels of suitable land together into a single scheme may, subject to analysis, enable those parcels of land to connect economically to the electricity system, whereas if developed as standalone scheme they may not be able to carry the associated costs of connection and therefore may never be developed.
- 7.5.13 In order to meet the urgent need for large capacities of solar generation in the UK's fight against climate change, ways of bringing forward all suitable parcels of land to the point of connection are likely in time to be considered and

investigated. If they are not, the risk of falling short on climate change targets becomes very much more heightened.

7.5.14 The site selection process seeks to identify locations which meet or come close to meeting the majority of the following criteria (subject to detailed and local review):

- Delivers similar levels of generation infrastructure capacity in similar timescales as described in the project aims;
- Has a reasonable prospect of being commercially and technically viable;
- Is not located within internationally and nationally designated biodiversity sites and avoids direct impact on locally designated biodiversity sites;
- Avoids the use of large areas of best and most versatile (BMV) agricultural land;
- Is not located within or close to National Parks and Areas of Outstanding Natural Beauty or designated areas of local landscape value;
- Is not located within designated green belt;
- Is of a size and has topography which meets the requirements of the Scheme to generate significant amounts of electricity (including irradiation) and store it;
- Prioritises suitable and available previously developed land, if such land is available and can practically be included as part of the Scheme;
- Avoids direct substantial harm on designated heritage assets;
- Is predominantly within Environment Agency Flood Zone 1 and is therefore at a low risk of flooding;
- Has good transport access for construction, being adjacent, or with close connection, to the strategic road network;
- Is not likely to be constrained by features which would result in shading;
- The grid connection route is unlikely to encounter constraints; and
- Has limited land use conflicts with respect to local development plan allocations and displacement of existing businesses.

7.5.15 Large-scale solar schemes, precisely because of their scale and the area of land required for their development, are therefore more likely to be sited in more rural areas of the country.

7.5.16 In order to enhance the energy delivered from the installed capacity, schemes are also more likely to be sited in areas of higher solar irradiation levels.

7.5.17 The number of locations in the UK which are ideal in respect of all three of the requirements of land availability and suitability; higher irradiation and grid connection availability, is low. For example, high population density and high-quality agricultural land limits opportunities for large-scale solar development in the South East of England (where Figure 7-4 shows that irradiation is highest), and proximity to existing and available grid connection capacity limits opportunities in the South West and East Anglia where Figure 7-4 shows that irradiation is also high. It should therefore not be expected that large-scale

solar is located only where irradiation is highest in GB; or only where suitable land is available; or only in close proximity to existing grid substations with available capacity, but schemes will be proposed in locations with the blend of characteristics which is assessed as suitable for the scheme. Figure 7-4 shows that the Scheme's proposed location is in a band of higher solar irradiation in the UK.

7.5.18 In order to beneficially and efficiently transmit the energy generated by the scheme to consumers, large-scale solar schemes are expected to connect to the National Electricity Transmission System (NETS) – an existing national infrastructure asset which is designed specifically for the bulk transmission of energy from its point of generation to nationwide consumers.

7.5.19 Draft National Policy Statement EN-3 (2021) states that:

*The connection of the proposed solar farm into the relevant electricity network will be an important consideration for applicants of solar [2, Para 2.48.10];*

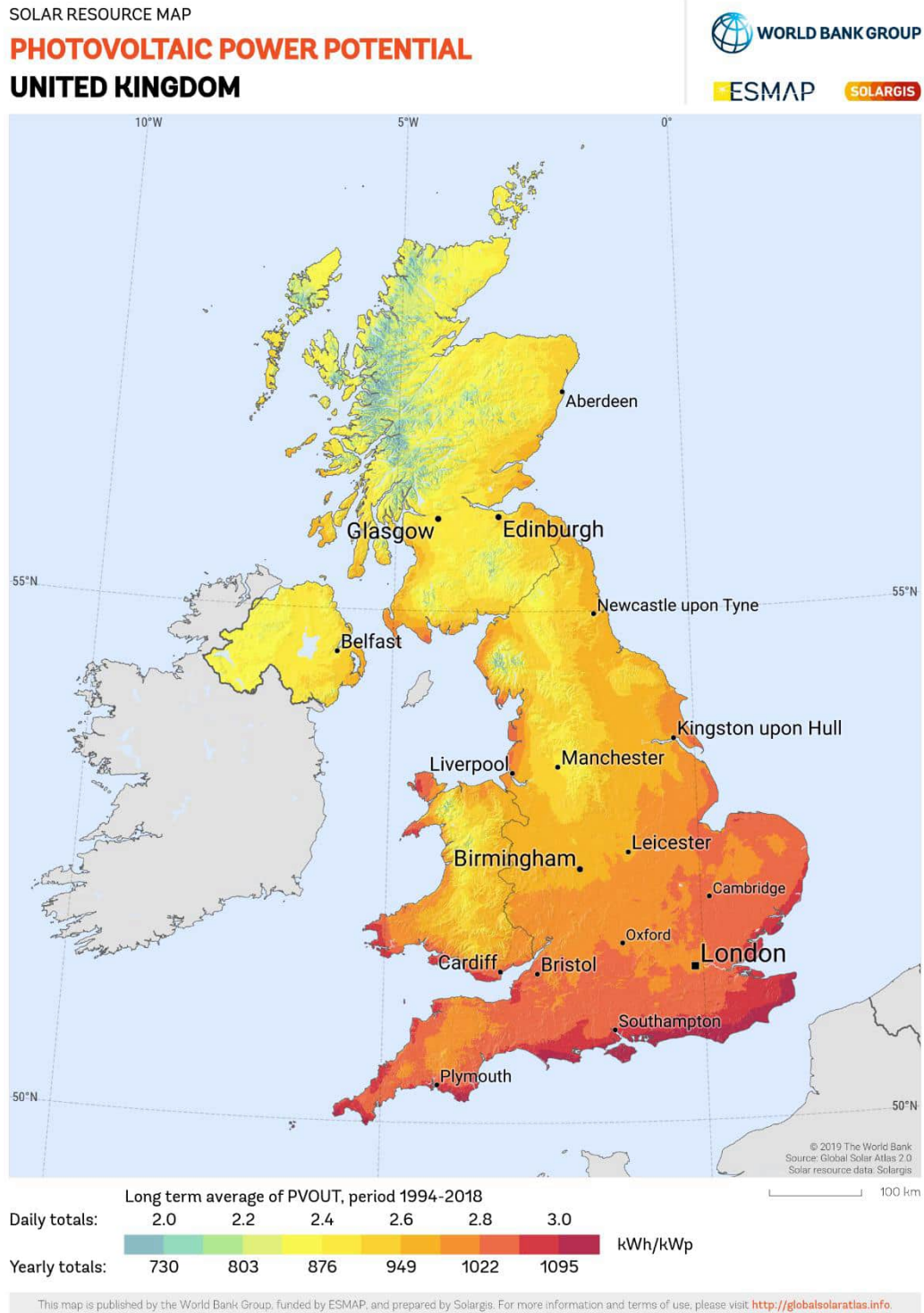
*Larger developments may seek connection to the transmission network if there is available network capacity and/or supportive infrastructure [2, Para 2.48.11]; and*

*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. [2, Para 2.48.12].*

7.5.20 In order to enhance the overall benefit of the scheme, in terms of cost, environmental impact and timeframes for connection, schemes may elect to make use of points of connection to the NETS which already exist and have available capacity insofar as those points of connection are available (such as with the Scheme), in preference to building new connections or increasing the available connection capacity at existing locations. Grid connection capacity is anticipated to guide site selection for early large-scale solar schemes, but due to the finite number of existing substations – and the smaller number of those substations with available capacity, it is also anticipated that in the future new grid substations may be needed to connect the anticipated capacity of solar capacity required to meet Net Zero.

7.5.21 The proposed location for this Scheme is therefore a highly suitable location for large-scale solar because it possesses an attractive combination of each of the three critical points listed above.

**Figure 7-4: United Kingdom solar irradiation**



[© The World Bank: Global Solar Atlas 2.0, Solar resource data: Solargis]

## 7.6 Large-scale solar is the most efficient use of land for energy purposes

- 7.6.1 Large-scale solar farms are more likely to be sited in more rural, rather than more developed, areas - simply because of where land is more likely to be available. National Grid's FES (2022) [116] anticipates between 57 and 92GW of UK solar deployment by 2050. Draft NPS EN-3 [2] includes an anticipated range of 2 to 4 acres for each MW of output generally required for a solar farm along with its associated infrastructure. Using the most conservative value from the range, and assuming that all future solar capacity deployment is large-scale rather than micro-scale (another conservative assumption) implies that a further 167,000 to 300,000 acres of land (approximately 70,000 to 120,000 hectares) would need to be set aside for solar capacity by 2050 in order to meet the FES scenarios. This represents at a maximum, 0.5% of total UK land area, or between 0.5% and 0.9% of the total pastures and non-irrigated arable land in the UK [78, 116, Author analysis].
- 7.6.2 Anticipated solar generation land requirements would also represent between 34.3% and 61.3% of land used by industrial or commercial units.
- 7.6.3 The suitability of the location (in terms of irradiation, grid connection and aspect) has not been taken into account in deriving these proportions, it is therefore likely that the land area currently used by industrial or commercial units on which solar generation would even be possible, will be significantly smaller than the total area of the units themselves. Solar developments made on "brownfield" locations may therefore not be a significant portion of the total developments needed to meet Net Zero. However due to the total area of land within each classification, it is more likely that favourable locations can be identified within UK pasture and non-irrigated arable land than within land used by industrial or commercial units, and both continue to be explored for different scale developments.
- 7.6.4 Solar technology can also produce more energy per hectare than other electricity generation technologies, for example growing crops for energy. According to a Guardian article [80], 450Ha of crop is required to provide fuel for a 1MW biogas plant. The renewable energy hub [REDACTED] indicates that 10 (High generation density) – 16Ha (Low generation density) of land is required per turbine (each with a capacity of 6MW) for onshore wind; while UK solar uses between 0.8 (High density) and 1.6Ha (Low density) of land per MW of installed capacity. Table 7-1 shows a comparison of annual energy yield per hectare for different technologies, including for solar and onshore wind the range from high to low generation density per technology.



**Table 7-1: Annual electricity generation per hectare for different generation technologies**

Technology	MW	Ha	Assumed Load Factor	Annual Output GWh/Yr/Ha
<b>Onshore Wind - High</b>	6	10	30%	1577
<b>Onshore Wind - Low</b>	6	16	30%	986
<b>Solar - High</b>	1	0.8	11%	1205
<b>Solar - Low</b>	1	1.6	11%	602
<b>Biogas</b>	1	450	100%	19

[Author Analysis]

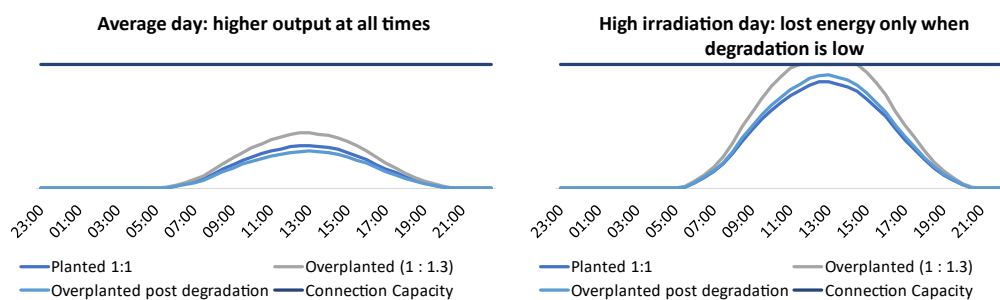
- 7.6.5 Hitherto, this report has built up the evidence base for the need for large-scale solar generation schemes in the UK. Section 7.2 includes projections of the capacities of new solar generation needed in order to meet Net Zero from NGEN, NIC and ESC. These projections combine to the need for an additional 44 – 78GW of additional solar capacity by 2050 in order to meet Net Zero [116, Figure ES.E.01], with approximately one third of this extra capacity needed in the next ten years.
- 7.6.6 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.
- 7.6.7 The suitability of the proposed connection at Cottam 400kV 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 8.4 and Chapter 9. The suitability of the proposed location in respect of the incident irradiation is illustrated in Figure 7-4.
- 7.6.8 Draft NPS EN-3 [2] includes an anticipated range of 2 to 4 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, as is described in EN010131/APP/2.2. This demonstrates that the proposed location is a suitable site and which will provide for an asset which is consistent with government’s view of best practice ratios of land take and installed capacity.

## 7.7 Designing solar schemes to maximise benefits through project life

- 7.7.1 By selecting sites with the right blend of characteristics, developers will bring to commercial operation solar projects which deliver decarbonisation, security of supply and affordability benefits. A further consideration for developers is maximising the utilisation of the available grid connection capacity through the life of the project given that solar panels degrade as they get older, while respecting commercial and environmental constraints. Degradation is managed by overplanting installed capacity at construction. Overplanting means installing more generation capacity than is available for export and is therefore dependent on sufficient suitable land area to be available to the scheme for installing solar panels.
- 7.7.2 Overplanting implies that on occasion when irradiation is high and panels have not yet degraded, sites may be forced to self-curtail: they may be unable to export all of the power they generate at certain times.
- 7.7.3 However schemes which are overplanted will instead generate more low-carbon power at times of lower irradiation (compared to a site which is not overplanted) and at those times output will not be limited by the grid connection capacity. This is illustrated in Figure 7-5.
- 7.7.4 The royal blue line shows normalised output (against the dark blue connection capacity line) of a representative solar scheme on an average irradiation day (left hand chart) and a high irradiation day (right hand chart).
- 7.7.5 The grey line on each chart shows the output of a solar scheme which is identical to the representative scheme, except that it has been overplanted to a ratio of 1.3 (without changing the grid capacity). More energy is exported on an average day (than the representative scheme) and no energy is lost. However on the high-irradiation day, more energy is exported until the grid capacity limit is reached and the scheme self-curtails.
- 7.7.6 Critically, as solar panels age and degrade, losses due to curtailment will reduce peak output during times of high solar irradiation, and the light blue lines show that future years overplanted schemes will export more energy and will not incur any curtailment.
- 7.7.7 Schemes which are overplanted therefore generate more low-carbon electricity than schemes which are not; and increase utilisation of the available grid connection capacity through the scheme's operational life – a key driver of the scheme's cost, and a key benefit in terms of making best use of grid connection capacity which is currently and is projected to remain constrained over the coming decade.
- 7.7.8 Degradation of solar panels occurs roughly linearly, so all solar panels will degrade at approximately the same rate. This means that, other than instances of failure of individual panels (which would likely be replaced under a warranted maintenance arrangement) the rolling replacement of panels through a scheme's operational life would result in the disposal of panels before their useful commercial lives have expired.

- 7.7.9 Not only does overplanting (or the level to which overplanting is proposed) have commercial drivers which may differ from scheme to scheme and developer to developer, but the opportunity to overplant is driven by scheme-specific characteristics, such as available land area, cable access routes, and of course grid connection capacity.
- 7.7.10 It is therefore expected that solar schemes will overplant where possible while balancing commercial, geographical and environmental considerations.

**Figure 7-5: Illustrating lost energy during periods of high irradiation but greater low-carbon energy at all other times on overplanted solar schemes vs. 1:1 schemes**



[Author Analysis]

- 7.7.11 This Scheme contemplates overplanting on the land parcels identified for development within connectable proximity to the Point of Connection, which allows the Scheme to maximise the utilisation of the existing grid connection capacity at National Grid’s Cottam substation throughout its operational life.
- 7.7.12 Therefore, this Scheme, which scores highly against the above site selection criteria, and seeks to make best use of the grid connection capacity which has been made available to it, presents as a highly viable scheme and therefore would help to ensure that the need for large-scale solar generation can be fulfilled. This is an important and relevant factor in the decision making process.

## 8 Decarbonisation can maintain or enhance security of supply

### 8.1 Setting the scene on security of supply

8.1.1 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. [5, 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. [5, Para 3.3.3].*

*A diverse mix of all types of power generation. . . helps to ensure security of supply. [5, Para 3.3.4].*

*A low-cost, Net Zero consistent system is likely to be composed predominantly of wind and solar. [9, p43].*

8.1.2 "Security of supply" means keeping the lights on and has two main components.

- Ensuring that there is enough electricity generation capacity available and operational to meet demand (adequacy); and
- Ensuring that the quality of electricity supplied to customers falls within a narrow "quality" band during all reasonably foreseeable operational circumstances and is resilient during rare excursions from this band.

8.1.3 This definition of adequacy includes not only the capacity of generation assets but also the availability of source fuel to those assets in order for them to generate electricity.

8.1.4 This chapter includes a brief introduction to power systems and aspects of their operation, including fuel supply. 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:

- The Scheme will provide a significant capacity of low-carbon generation to national system adequacy targets;
- The Scheme will make a significant contribution to reducing the UK's dependency on foreign hydrocarbons as a source fuel;

- 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 [81];
- 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 [82];
- 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 by 2025 [67, p1] and for full decarbonisation of the electricity system by 2035 [83]; and
- 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.

8.1.5 To provide appropriate context and understanding, Section 8.2 sets out in brief an introduction to a number of high-level concepts of power system operation and Section 8.9 describes the UK's current direct and indirect dependency on hydrocarbon imports.

## 8.2 An introduction to power system operations

- 8.2.1 Power systems connect supply (sources of power, largely generators) to assets which demand power (industrial, commercial or domestic customers). Power systems are complex; yet they must be designed and operated safely, securely, and economically.
- 8.2.2 Governments define policy to ensure that there is sufficient generating capacity (i.e. the maximum achievable level of power generation which may be connected to the NETS) available to meet maximum expected demand, with secure and economic supply chains for the fuel they use to generate electricity. This is called adequacy.
- 8.2.3 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" [84, p5].
- 8.2.4 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.

- 8.2.5 NGESO also ensure that power demand, or load, and power supply, always remain balanced. Balancing requires the right generating assets to be connected and disconnected to/from the right power levels, and at the right time. This can sometimes be at short notice, in response to emergent (fault) conditions. NGESO call those services which support NETS stability and operability are called Ancillary Services.
- 8.2.6 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 helps to maintain voltage levels, and its provision by generators is a mandatory service for transmission-connected generators.
- 8.2.7 System frequency must also be maintained: the NETS operates at a nominal 50Hz. 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, generators which are able to provide FR will usually determine the price they would accept to provide the service – output remains the main source of income for generators.
- 8.2.8 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 [84, 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.
- 8.2.9 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.

## 8.3 The operation of high-RES electricity transmission systems

- 8.3.1 The integration of RES and their likely effect on electricity transmission systems, is not a new topic. In a 1991 paper [85], 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, Denmark has consistently sourced approximately 50% of its electricity needs from renewable generation [75, 76, 86, 120]. In GB, renewables’ share of electricity generation was 44% during 2020 [13, Table SV.23] and 43% during 2021 [116, Table ES.E.07]. High proportions of renewable generation can already be operationally accommodated within national electricity systems.
- 8.3.2 In foreseeing a need for maintaining the quality of electricity supplies, Grubb identified important considerations for system operation, including rate of change of frequency; system operational control and fault containment; and reserve operation. He explained how an increase in renewable generation influences each one and saw a 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 critical services.
- 8.3.3 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).
- 8.3.4 The activities associated with integrating renewables into the GB electricity system will increase with their penetration [87, 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.
- 8.3.5 Importantly however, the dynamic behaviour characteristics for a high-RES system are well understood. NGESO’s System Operability Framework (SOF) [88, 89] describes these in specific relation to the GB electricity system.
- 8.3.6 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.
- 8.3.7 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 in response to NGENSO's transmission constraint management initiative.

- 8.3.8 The installation of power electronics at low-carbon generation assets is an exciting development which will enable them to provide important system stability services [82] as part of their normal daily operational routine. By reprogramming the digital power inverters attached to solar panels, services required by the Electricity System Operator can be delivered. 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 10 describes the advantages associated with providing such services at the Cottam 400kV Substation to which The Scheme is proposed to connect.

## 8.4 Connecting generators to the power grid

- 8.4.1 The electricity system in GB operates at two levels: the high-voltage NETS, and the lower-voltage Distribution Networks. The NETS mainly consists of 400kV, 275kV and 132kV assets connecting separately owned generators, 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.
- 8.4.2 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.
- 8.4.3 Applications for connection to the NETS are assessed through the first-come-first-served Connect and Manage process.
- 8.4.4 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.
- 8.4.5 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.

- 8.4.6 NGENSO's Network Options Assessment 2021/22 (July 2022 refresh) [121] included recommendations for investment of £215m in 2022 across 94 asset-based projects to maintain the option to deliver projects costing £21.7bn – a significant increase in the previous NOA's 25 asset-based projects costing an estimated £13.9bn [90]. Investments in 2022 would support National Grid in managing the future capability of the GB transmission network against an energy landscape of significant decarbonisation over the coming decades [91, p6]. Investments are required to expand the transmission network to ensure that GB has a power system capable of delivering on its 2030 renewables ambitions and the UK's broader Net-Zero target and energy security aims. 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.
- 8.4.7 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.
- 8.4.8 The Scheme proposes to connect to an existing National Grid substation (Cottam 400kV) which is located on one of the major connections between Keadby in the north and three major 400kV transmission lines which provide connections to demand centres in the south and London. Cottam 400kV substation is also connected directly to the Grid Supply Points (GSP) at West Burton, Staythorpe and Stoke Bardolph. GSPs supply power from the NETS down to local networks. The West Burton, Staythorpe and Stoke Bardolph substations supply primary substations in important centres of demand in Newark and Nottingham as well as provide power further throughout Nottinghamshire and Lincolnshire.
- 8.4.9 Figure 9-1 shows a schematic of the local NETS. By proposing this Point of Connection, 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 foreseen operation, and provides a regional source of locally generated bulk low carbon supplies of electricity to consumers both local to The Scheme and more widely across the country. Section 10.2 discusses this point further and provides additional evidence which supports this highly suitable Point of Connection for The Scheme.

## 8.5 Centralised and decentralised generation

- 8.5.1 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 [92, p34].
- 8.5.2 Currently 31% 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 39% [116, Table ES1]. The proportion of generation capacity in 2050 connected to the distribution networks has decreased year-on-year in NGENSO's analyses, reflecting the increased complexity associated with connecting generation to distribution networks; and enabling works identified in the NOA (see Section 8.4) which will increase the capacity of the NETS in as affordable a way as possible [121].
- 8.5.3 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.
- 8.5.4 However distributed generation capacities grow, the 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 (see quotation following).
- 8.5.5 The recent implicit market preference for decentralised generation connections should be understood in the context of GB's national electricity system, with 74GW of generation currently connected to the transmission network and 34GW to the distribution network. [116, Table ES.1]
- 8.5.6 FES 2022 scenarios [116] 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 4.3 times 2021's distributed generation capacity may be connected to distribution systems, while the multiplier for transmission-connected assets ranges between 3 and 3.2. NGENSO scenarios indicate a total of 202 – 239GW capacity installed at the transmission connected level by 2050 for Net-Zero compliant projections.
- 8.5.7 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. [5, Para 3.3.29].*

- 8.5.8 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 [67, 93].
- 8.5.9 In reviewing the information available, it is the Applicant's view that large-scale solar must be considered as additional to, as opposed to instead of, the need for continued development in distribution connected, smaller scale solar, and this includes the development of rooftop solar.
- 8.5.10 In conclusion, the need for distribution connected generation, including smaller scale and micro-scale solar, 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.

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

8.6.1 As described in Section 8.5, 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 8-1.

**Table 8-1: Characteristics of transmission- and distribution-connected generators**

	Transmission	Distribution
<b>Description</b>	Connected to NETS at high voltage.	Connected to distribution network at lower voltage (distributed) or into end use customer systems (micro). Collectively called Distributed Generation.
<b>Size</b>	Typically large (100s of MW).	Typically small (<30 MW) to very small (single kW).
<b>Technical Compliance</b>	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.
<b>Dispatch</b>	Centrally dispatched by NGENSO with known reliability.	Generally locally dispatched with unknown reliability; outside of the direct control of NGENSO.
<b>Measurements</b>	Metered to a high degree of accuracy, forecast output signalled to NGENSO.	Largely unmetered, indications of availability, forecast output not required to be provided to NGENSO.

[Author analysis]

8.6.2 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:

- Transmission connected assets provide visibility of their expected generation to the national energy market and NGENSO 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 NGENSO, in both planning and operational timescales to ensure that power demand and system security needs are met with the least possible cost;
- Transmission connected assets are required to be available for instruction by NGENSO. They are required to participate in the Balancing Mechanism (BM) making their flexibility available (at a transparent and cost-reflective price) to ensure that supply and demand remain balanced at all times. The BM allows NGENSO 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. By contrast, distribution assets are not required to do this, although voluntary balancing markets are currently under development for smaller assets at the distribution level. By having

more assets operating in the BM, the BM becomes more competitive and the options available to NGENSO to use for system balancing expands. These two points drive to a more affordable and more secure electricity system.;

- 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 (ultimately to the bill-payer); and
- 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 currently have different fault protection requirements (which are also harder to enforce) although 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.

8.6.3 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.

8.6.4 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. Operation of a primarily distributed national electricity system would also likely be significantly more complex than the operation of one with a majority core of transmission connected assets, thereby incurring additional costs for consumers. The connection of more assets to the distribution system would also require investment in either additional power transfer capability to and from the NETS or additional local low-carbon generation to manage local peak power security of supply, adding addition cost and complexity versus a system with a high proportion of transmission-connected assets.

8.6.5 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.

8.6.6 The NETS remains an important measure to maintain interregional connectedness, support the meeting of national demand from geographically disparate sources [14, p182] and keep power flowing to consumers with the high levels of reliability consumers have come to expect.

8.6.7 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.

- 8.6.8 By connecting to the NETS at the proposed Point of Connection, the Scheme brings benefits to the NETS by:
- Replacing transmission-connected assets 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.

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

- 8.7.1 The uncontrollable nature of the weather raises a potential challenge to the ability of solar generation to play a significant role in electricity supply relates to the uncontrollable nature of the weather. However the variability of solar generation can be mitigated by:
- Developing larger generation capacities (to maximise output during periods of low irradiation);
  - Connecting assets to different parts of the NETS;
  - Developing projects with generation profiles which are complementary to solar (for example wind: see Section 8.8); or
  - Developing integration technologies (for example, battery storage or participation in the hydrogen economy).
- 8.7.2 There are several other technologies which can also be used to compensate for the intermittency of renewable generation, such as electricity storage, interconnection and demand side response [5, Para 3.3.12].
- 8.7.3 Ueckerdt et al [94, p2] describe important considerations for the introduction of RES to power systems. These are described in Table 8-2.
- 8.7.4 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.
- 8.7.5 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.

- 8.7.6 The Scheme is an important part of the growing solar generation portfolio, whose dependable output is growing (see Section 8.8). As shown in Figure 7-4, 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 8-2: Complexities associated with renewable energy source variability in power systems**

Complexity	Description	Implication
<b>Uncertainty</b>	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.
<b>Local Specificity</b>	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.
<b>Variability</b>	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.

[94, p2]

## 8.8 The system adequacy of solar generation

- 8.8.1 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 NGENSO (subject to a prescribed process) determine that additional generation output is required in GB in order to "keep the lights on." BEIS included wind and solar technology within the GB capacity market in 2019 [95] and both onshore wind and solar were reintroduced to the Contracts for Difference mechanism in time for Allocation Round 4, which concluded in summer 2022 with 2.2GW of solar capacity across 66 projects securing contracts to deliver in 2023/24 or 2024/25.

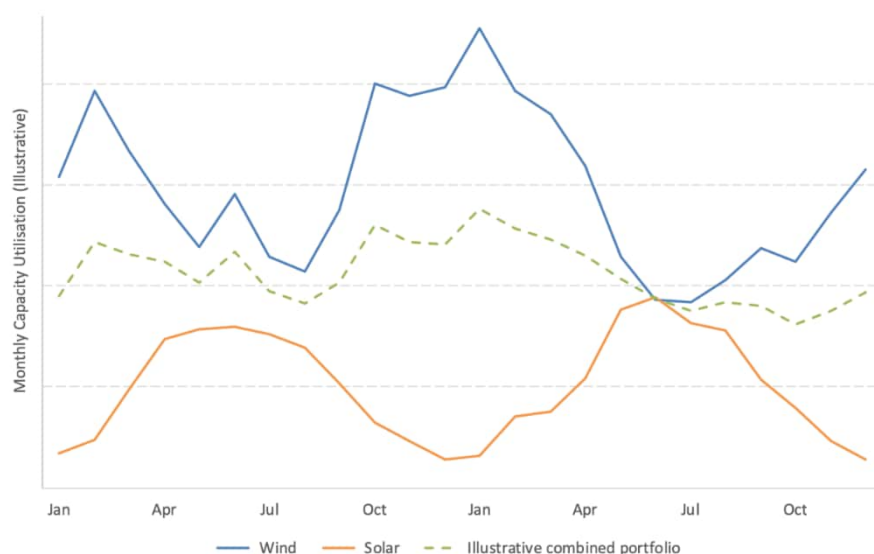
- 8.8.2 While the Capacity Market is not open to assets which already hold CfD contracts, the inclusion of renewable generation technologies in the Capacity Market underlines the contribution it can make to system security:

*The system is typically better off with intermittent capacity than without it – wind farms, for example, can contribute to overall security of supply.*  
[96, p114].

- 8.8.3 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.

- 8.8.4 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 NGENSO’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.
- 8.8.5 Figure 8-1 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. The output associated with an illustrative combined portfolio is shown by the green dashed line.
- 8.8.6 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 is flatter than the other two lines, showing a lower variation from month-to-month through the year.
- 8.8.7 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 8-1: Illustrative Generation Dependability for a combined portfolio of solar and wind in GB**



[Author analysis]

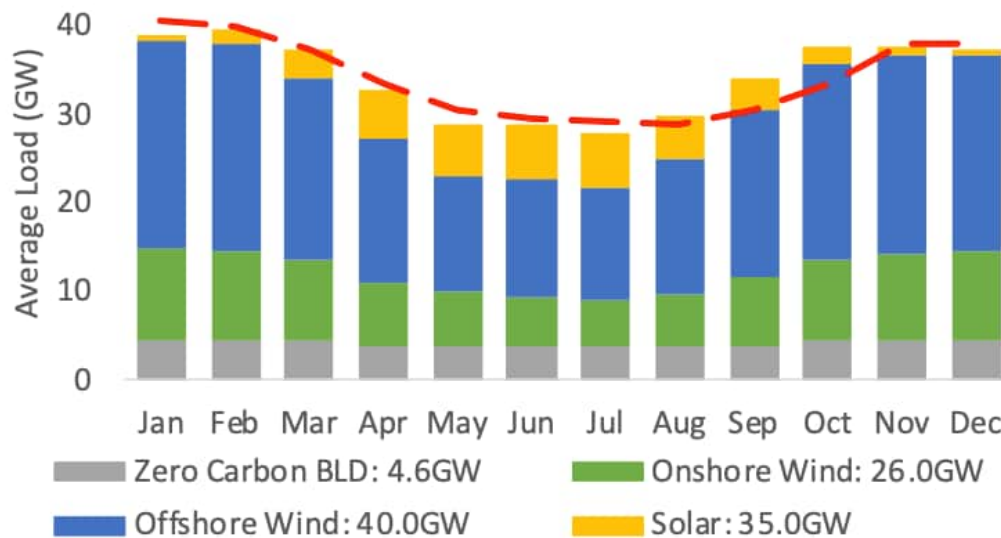


- 8.8.8 An Imperial College expert economic analysis of whole system costs of renewables agrees: they show that the integration costs of RES fall on an absolute basis, as capacity increases from 10GW up to 50GW [97].
- 8.8.9 The National Infrastructure Commission also commissioned a whole system cost analysis, the results of which were published in 2020 [23]. 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."
- 8.8.10 An analytical model has been developed by the Author 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.
- 8.8.11 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 [116, Data Workbook] regarding how demand levels and shape (including electricity demand predictions for heat, transport and hydrogen production) are anticipated to evolve into the future. The model results are shown in Figure 8-2.
- 8.8.12 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 ~27GW on 2022 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.
- 8.8.13 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.
- 8.8.14 Approximately 35GW of solar (an increase of 21GW on early 2022 levels) would neatly "fill the gap" during summer months without delivering 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, 5GW higher than government's current capacity ambition for offshore wind [50]), or an additional ~7GW of low-carbon baseload generation (two new Hinkley Point C equivalent power plants), would be required to be built in the next 10 years.
- 8.8.15 However, by building out either an additional 7GW of low-carbon baseload generation or 15GW of offshore wind generation to meet summer demand levels without solar, there would be significant over-generation of power in the winter periods (of between 12% and 16%). Over-generation may be curtailed (either at a cost to the consumer or by reducing available revenues to asset operators) or stored. If revenues are reduced for asset operators, in some

cases assets may not be commercially attractive and therefore may not get built out.

- 8.8.16 As the technical and economic viability of inter-seasonal storage advances, more options will become available for optimising GB's generation mix in relation to balancing capital deployment, development risk, the availability of suitable locations and ongoing system operations (e.g. curtailment). However, based on current assessments, it is clear that the deployment of large-scale solar alongside that of offshore wind, onshore wind and low-carbon baseload assets, provides the opportunity for a lower capital, lower curtailment (therefore lower cost) energy system through diversity of asset type than that provided by scenarios which do not include solar generation.
- 8.8.17 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. For example, Battery Energy Storage Systems (BESS), Pumped Hydro or Interconnectors.
- 8.8.18 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 11.5 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.
- 8.8.19 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.
- 8.8.20 The Scheme, as a leading large-scale solar scheme in GB, represents c. 2% of the additional solar generation capacity projected to 2030 in National Grid's Future Energy Scenarios (scenarios compatible with Net-Zero only). In this context, the Scheme is therefore an essential stepping stone towards the future of efficient decarbonisation through the deployment of large-scale, technologically and geographically diverse low-carbon generation assets.

**Figure 8-2: Deploying 35GW of large-scale solar alongside government offshore wind ambitions (40GW) meets anticipated seasonal demand levels**



[116, Market data, Author analysis]

## 8.9 Reducing reliance on fossil fuels

- 8.9.1 Energy leaders from around the world gathered in Paris for the 2022 International Energy Agency (IEA) Ministerial Meeting in late March 2022, and from that meeting sent a strong message of unity on the need to strengthen energy security, reduce market volatility and accelerate clean energy transitions worldwide.
- 8.9.2 With increasingly interconnected markets – in electricity as well as source fuels, shocks in one geography can be felt through neighbouring markets and more broadly. Oil and coal, historically international markets, drive global prices through supply chains which connect source and need, and the myriad of markets and exchanges which allow swaps and trades to be transacted across the world. Although gas has historically been supplied through pipeline (i.e. fixed) infrastructure, Liquefied Natural Gas (LNG) has become increasingly prominent in connecting gas supplies with markets and gas is now much more of a global market than once it was.
- 8.9.3 In 2021, BEIS unveiled plans to decarbonise UK power system by 2035. The plans focus on building a secure, home-grown energy sector that reduces reliance on fossil fuels and exposure to volatile global wholesale energy prices [83].
- 8.9.4 The first quarter of 2022 demonstrated how the UK is exposed to volatile energy prices through international energy markets in coal gas and oil. Price rises in 2022 have and will continue to filter through to consumer bills. While the UK once was energy independent, it now is dependent on imports of coal and gas in winter months, which increases our exposure to volatile international prices. Exposure is especially high when either demand is high

in other markets (e.g. a deep cold period in South East Asia in late 2020) or supply is risked through the weaponization of energy supplies, as was threatened in early 2022.

- 8.9.5 In April 2022, HM Government published the British Energy Security Strategy [50]. In it, the Prime Minister wrote that:

*If we're going to get prices down and keep them there for the long term, we need a flow of energy that is affordable, clean and above all, secure. We need a power supply that's made in Britain, for Britain.* [50, p3]

- 8.9.6 The British Energy Security Strategy sets out the immediate need to manage the financial implications of soaring commodity prices in the near term, on households and businesses which are already feeling economic pain as the post-Covid cost of living has risen: "The first step is to improve energy efficiency, reducing the amount of energy that households and businesses need." [50, p5].
- 8.9.7 However the strategy also sets out the long-term goal of "address[ing] our underlying vulnerability to international oil and gas prices by reducing our dependence on imported oil and gas." [50, p6].
- 8.9.8 In the near-term, the strategy sets out a high-level action plan to upgrade the energy efficiency of at least 700,000 homes in the UK by 2025, and to ensure that by 2050 all UK buildings will be energy efficient with low-carbon heating. Further, the strategy sets out an intent to phase out the sale of new and replacement gas boilers by 2035. [50, p12].
- 8.9.9 The strategy also notes the improved cost competitiveness of electrically powered heat pumps which can displace natural gas from use in homes and buildings. Government is targeting 600,000 heat pump installations per year by 2028 and aims to expand heat networks and designated heat network zones to further the electrification of home and commercial heating. A "Rebalancing" of the costs placed on energy bills away from electricity is also intended to incentivise electrification across the economy and accelerate consumers and industry's shift away from volatile global commodity markets over the 2020s. [50, p12].
- 8.9.10 Carbon Capture Usage and Storage (CCUS) retains its important potential role in a decarbonised economy. Government aims to deliver on their £1 billion commitment to four CCUS clusters by 2030, with the first two sites selected in the North East and North West currently proceeding through Track 1, with the Scottish Cluster in reserve. [50, p15].
- 8.9.11 The British Energy Security Strategy also recognises the critical role of renewables in accelerating the transition away from fossil fuels, and notes that renewable capacity in the UK is currently set to increase by a further 15% by the end of 2023. However further and faster actions are required to increase our national energy security and reduce our dependency on fossil fuels, and the exposure consumers currently have to their volatile prices.

### 8.9.12 The Strategy aims to:

- Cut planning consent process time by over half through, among other measures, strengthening the Renewable National Policy Statements (EN-3) to reflect the importance of energy security and net zero;
- Increase the pace of deployment of Offshore Wind by 25% to deliver up to 50GW by 2030, including up to 5GW of innovative floating wind. Wind will contribute over half the UK's renewable generation capacity by 2030. [50, p16];
- Consider all options including Onshore Wind through the improvement of national electricity network infrastructure and support of a number of new English projects with strong local backing, so prioritising "putting local communities in control" of local onshore solutions. Repowering of existing onshore wind sites is also under consideration. [50, p18];
- Support a 5-fold increase in deployment of solar technology by 2035, recognising the abundant source of solar energy in the UK and an 85% reduction in cost over the last ten years, of solar power. For ground-mounted solar, the strategy indicates a future consultation on planning rules to strengthen policy in favour of development on non-protected land, while ensuring communities continue to have a say and environmental protections remain in place. [50, p19];
- Increase UK plans for deployment of civil nuclear to up to 24GW by 2050 – three times more than operational capacity in 2022, and representing up to 25% of our projected electricity demand. This includes the intention to take one project (Sizewell C) to FID during the current Parliament, and two projects to FID in the next Parliament, including Small Modular Reactors, subject to value for money and relevant approvals. [50, p21]. The selection process for further UK projects is anticipated to be initiated in 2023 [50, p22]; and
- Double the UK ambition for hydrogen production to up to 10GW by 2030, with at least half of this from electrolytic hydrogen [50, p22], facilitated by bringing forwards up to 1GW of electrolytic hydrogen into construction or operational status by 2025.

8.9.13 Accelerating the domestic supply of clean and affordable electricity also requires accelerating the connecting network infrastructure to support it, and the British Energy Security Strategy also includes measures designed to increase the pace of improvements and enhancements to the National Electricity Transmission System to enable the connection of the required level of renewable generation capacity both within the 2030 timeframe and beyond.

8.9.14 Work has already commenced in this regard with the formation of a Future System Operator (a national organisation taking over the role of Electricity System Operator, currently carried out by National Grid) and programs of action such as the annual NOA and (ongoing at the time of writing) Holistic Network Design, part of the Offshore Transmission Network Review, which aims to develop a strategy to coordinate interconnectors and offshore networks for wind farms and their connections to the onshore network and bring forward any legislation necessary to enable coordination.

- 8.9.15 Critically the British Energy Security Strategy includes actions which have already been described and discussed elsewhere in this Statement of Need. Bringing forward electricity into home heating (as described previously), and supporting the rollout of electric vehicles as part of Government's electric vehicle infrastructure strategy, will increase demand for electricity in future years, from potentially as early as 2023.
- The Society of Motor Manufacturers and Traders reported a 100% increase in Battery Electric Vehicle (BEV) sales in the UK in the year-to-date (end March-22) versus the same period last year, and over 16% of all new vehicle purchases in the UK in March-22 were BEV. Ongoing grants (available until at least March-23) and cheaper running costs are anticipated to continue to push EV market share over the coming years. [63]; and
  - Government is facilitating the adoption of electricity into transport through its Electric Vehicle Infrastructure Strategy (March 22) [64] which sets out the expectation, by 2030, of there being around 300,000 public chargepoints as a minimum in the UK [up from just 30,000 in the first quarter of 2022], but there potentially being more than double that number, delivering "Effortless on and off-street charging for private and commercial drivers" [64, pp4&5].
- 8.9.16 The rollout of a significantly higher capacity of renewable generation is therefore required to meet decarbonisation as well as energy security aims and the urgency for delivery as increased.
- 8.9.17 Nuclear is poised for its second UK renaissance, but would only deliver its first megawatthours from the middle of the 2030s. Remembering that the UK's nuclear renaissance of the 2000s resulted in the construction (currently ongoing) of just one nuclear power station.
- 8.9.18 Although the British Energy Security Strategy aims to achieve FID at one more nuclear power station by the end of the current parliament, it is important to recognise the significant political, financial and delivery risk associated with nuclear development. There is a long road ahead before any megawatthours of clean energy generated from nuclear technologies can be "banked" in the fight against climate change.
- 8.9.19 CCUS retains its important place within the British Energy Security Strategy, but as an enabler of eliminating carbon emissions from fossil fuel use, rather than eliminating the fossil fuel use itself, has not attracted a more prominent role relating to energy security, than that with which it has already been tasked in the Energy White Paper and the Prime Minister's Ten Point Plan.
- 8.9.20 The increase in ambition for hydrogen generation (for uses as described in Section 11.4) as set out in the British Energy Security Strategy further supports the development of greater capacities of renewable generation and with greater urgency.
- 8.9.21 The path to national control of nationally generated electricity and reduction of exposure to the volatile prices associated with international supplies of fossil fuels, and the path to a low-carbon energy system of the future, which

minimises potentially catastrophic changes to the global climate, are the same path.

- 8.9.22 This Statement of Need sets out the case for the urgent development of low carbon sources of electricity in the UK. The British Energy Security Strategy provides an even sharper focus on both the scale and the urgency to deliver new low carbon generation capacity, and The Scheme is ideally suited to play an essential role in meeting that urgent need.

## **8.10 The Scheme would make a significant contribution to the security, adequacy and dependability of the GB electricity system**

- 8.10.1 The UK has been naturally gifted with substantial renewable energy resources, including 40% of Europe's wind resource [5, Para 3.4.3] and large areas of developable land which receive high levels of solar irradiation. These resources must be harnessed to decarbonise our economy, and in Section 7.4 it was demonstrated that without solar generation, the challenge faced by the UK in meeting its decarbonisation targets would be significantly harder.
- 8.10.2 Section 8.8 described 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 the Author believes that capitalising on the progress made to date in bringing unsubsidised solar forwards in GB should be actively supported.
- 8.10.3 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 8.6 described the measures required of transmission connected solar generation to support system operability due to its connection to the NETS.
- 8.10.4 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 11.5) are being deployed to do the same, as well as to manage short-term supply / demand volatility.
- 8.10.5 Growth in the capacity of solar and other renewable technologies is expected to improve the dependability of the resulting combined portfolio. This is expected to reduce further any integration costs associated with such growth.
- 8.10.6 The Scheme, if approved, would contribute to an adequate and dependable GB generation mix, through enabling the generation of more low-carbon power from indigenous and renewable resources. Therefore, the approval, construction and operation of the Scheme will make a significant contribution to GB's energy security needs, and the decarbonisation needs of the UK.

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

### 9.1 Understanding the transmission network close to the proposed point of connection

9.1.1 This chapter describes aspects of the NETS in the vicinity of the Scheme. Annually, NGENSO 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 NGENSO's 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). The NOA then identifies, assesses and recommends (where appropriate) specific upgrade projects which meet the future needs as anticipated in the ETYS.

### 9.2 Network topography

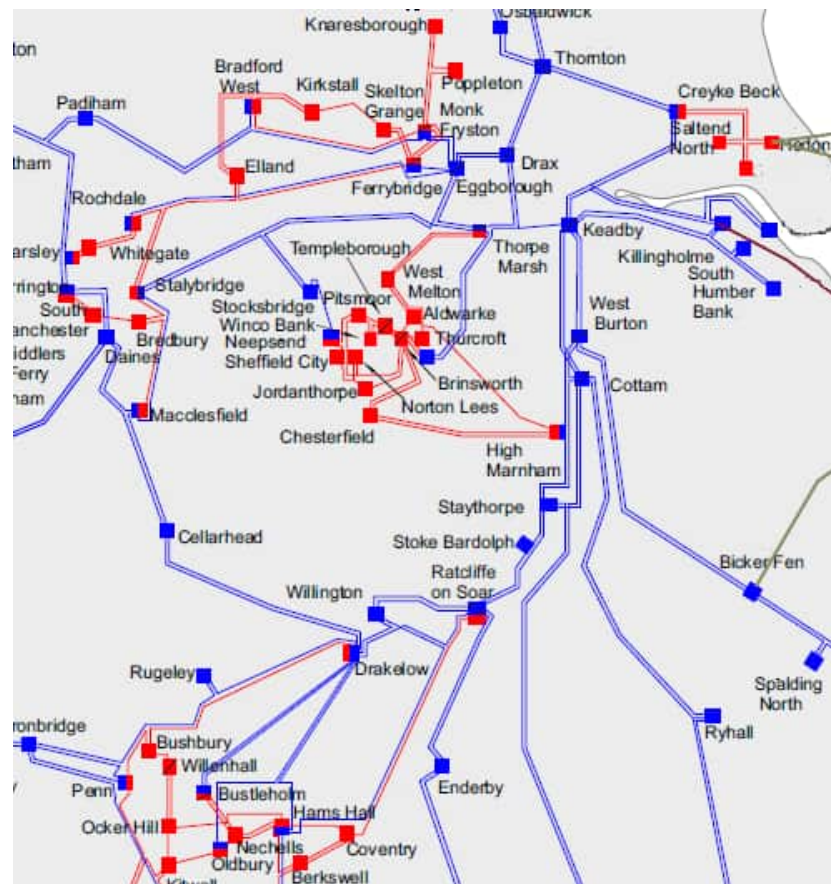
9.2.1 The Scheme will connect into the NETS at Cottam 400kV Substation, an existing National Grid substation near Retford in Nottinghamshire.

9.2.2 The substation is situated in NGENSO's North Midlands and North Wales area; an area which is connected to the surrounding NETS as illustrated in Figure 9-1. It is located just below the B8 boundary. This boundary is not hard, nor physical, but divides areas within which NGENSO characterise power flows. The strength and capacity of connections within the North Midlands and North Wales area, including the lines to which the Scheme will connect, contribute to the transfer capacities available across the system boundaries. The system boundaries which are important to The Scheme are:

- B8 North of England to Midlands which is one of the wider boundaries that intersects the centre of GB, separating the northern generation zones including Scotland, Northern England and North Wales from the Midlands and southern demand centres.
- B9 Midlands to South of England which separates the northern generation zones and the southern demand centres.
- The North Wales boundary NW3 lies to the west of the North Midlands and North Wales area and is also relevant because future offshore wind and biomass generation connecting in North Wales have the potential to drive increased power flows eastward into the Midlands where power plant closures are set to occur, and demand is set to remain fairly high.



Figure 9-1: The NETS in the vicinity of the Point of Connection



[98, Appendix A]

- 9.2.3 Cottam 400kV is a main substation on an important part of the NETS, located between the demand centres of the Midlands and the south and the northern generation zones (shown in Figure 9-1), providing resilience through strength in depth to the NETS to enable very high levels of reliability to all users.
- 9.2.4 The North Midlands and North Wales NETS area is an area of historically strong coal fired generation and is growing in importance because of the enduring CCGT generation located in the area, as well as high demand and power flow from current and planned renewable generation. Being located near to important areas of demand, supply and power flow, very high reliability and deep resilience of the NETS to potential transient operating states is of vital importance to maintain connection for a significant part of GB's residents, services and commerce.
- 9.2.5 By connecting to the existing Cottam 400kV substation the Scheme will be playing an important role in the continued provision of bulk power within the NETS area, which is then able to be transported across the entire NETS and to wherever it is demanded. The NETS links to the local distribution networks through Grid Supply Points (GSPs) at West Burton, Staythorpe and Stoke Bardolph. This means that low carbon power generated at the Scheme will be transmittable for use by local residents and businesses without significant transmission losses, as well as being transmittable more widely across the NETS and to wherever electricity is demanded.

9.2.6 The 2021 ETYS [98] which addresses the proper functioning and development of the NETS, rather than local (distribution) networks, includes the following relevant points:

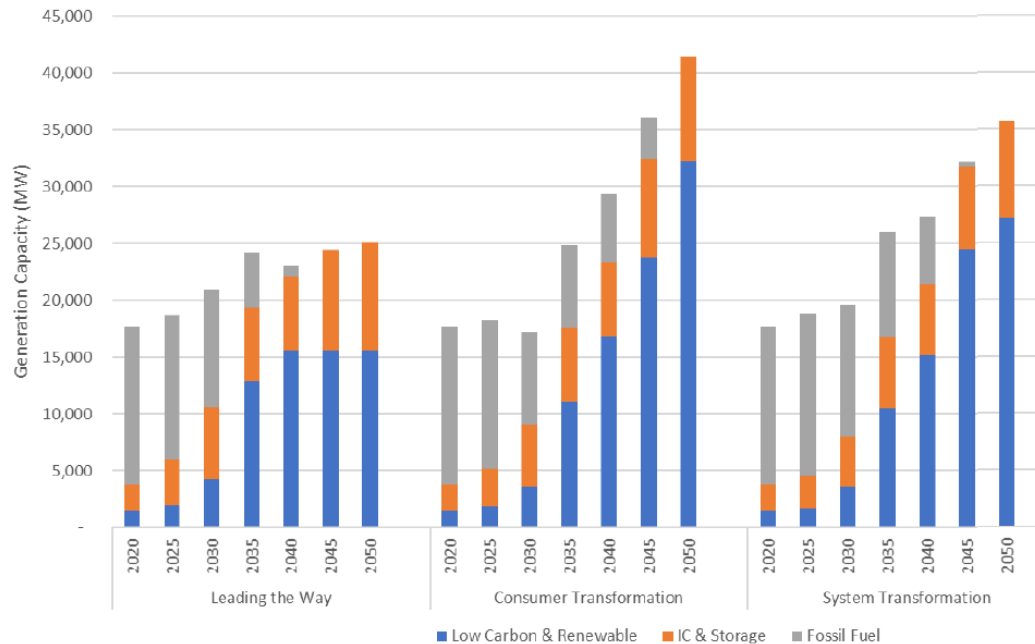
- Future offshore wind and biomass generation connecting in North Wales have the potential to drive increased power flows eastward into the Midlands where power plant closures are set to occur, and demand is set to remain fairly high;
- In a highly decentralised scenario like Leading the Way, local generation capacity connected at the distribution level in this western region could reach 23GW by 2030;
- Across all FES scenarios, North Midlands and North Wales maintains a relative balance between its growth in gross demand and transmission connected generation capacity. North Midlands and North Wales is not and is not expected to become a heavily exporting or importing region before 2050;
- By 2030, the scenarios suggest a total amount of transmission connected generation capacity of between 17GW to 21GW, a modest increase from the current 17GW;
- At present, this region has significant levels of fossil fuel (about 14GW) and all Future Energy Scenarios show a decline in fossil fuel. For all Net-Zero compliant scenarios, fossil fuel generation is not present in the region by 2050;
- A significant growth in low carbon technologies is anticipated in this region.

9.2.7 National Grid will continue regularly to assess their development plans for the future management of flows across boundaries in the vicinity of the Scheme's proposed location, a key input to these plans will be the potential capabilities of any assets planned to connect in the area in the coming years, including the Scheme.

9.2.8 Figure 9-2 shows the future anticipated generation capacity in the North Midlands and North Wales transmission zone. The chart shows that in those scenarios which are expected to enable the UK to meet its net Zero commitments, the amount of low-carbon & renewable generation expected to connect before 2050 will grow from its current level of circa 1GW to between 15 and 32GW.

9.2.9 The need for network reinforcement in this region – as with all regions – are kept under constant review in NGENSO's annual NOAs, most recently published in July 2022 [121], relevant points from which are discussed in the following Section.

**Figure 9-2: Future anticipated generation capacity by technology type in the vicinity of the Scheme for Net-Zero compliant scenarios**



[98, p35]

9.2.10 The connection of integration technologies at the proposed Point of Connection, which is one of the characteristics of the Scheme will, if granted, provide additional options to NGENSO to manage flows across the boundary in an efficient way, by providing a resource which could be called upon by NGENSO 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.

### 9.3 Local network operability considerations

9.3.1 Power flows past Cottam substation are currently circa 1-2GW, in a north-south direction. NGENSO have forecast these to double in the 2030/31 timeframe, when several large offshore wind areas to the north of the country connect, moving average power flows up to circa 3GW [98, Appendix C].

9.3.2 Current circuit ratings (See Table 9-1) indicate 2-3GW of transfer capacity from Cottam substation to other substations to the north and south. Through the NOA process, National Grid continue to evaluate the need for network reinforcement to address any future potential capability, capacity and resilience issues arising as a result of low carbon renewable developments nationally and in specific areas of the country.

9.3.3 Identified projects include a thermal circuit uprate between Keadby and West Burton in 2024, a reconductoring of the Cottam to Keadby circuit in 2025 and upgrades to other major “arteries” which transfer power from the north,

through the Lincolnshire area, to southern circuits. These have been identified principally to facilitate future anticipated offshore wind projects.

**Table 9-1: Future forecast power flow capability at Cottam**

To Substation	Spring (MVA)	Summer (MVA)	Autumn (MVA)	Winter (MVA)
<b>Grendon</b>	2009	1911	1746	1911
<b>Keadby</b>	2212	2125	1979	2125
<b>Ryhall</b>	2779	2569	2217	2569
<b>Staythorpe</b>	2212	2125	1979	2052
<b>West Burton</b>	3326	3160	2971	3160

[98, Appendix B, Data Tables]

### Voltage Management

- 9.3.4 No specific issues have been identified in relation to Voltage Management at the proposed point of connection.
- 9.3.5 Long double-circuit overhead lines have potential to cause local voltage management issues, especially following a fault on major arteries connected to those lines. Such a fault, although highly infrequent, could force power to travel a longer way from its supply points (e.g. wind from northern connected offshore wind farms) to its demand (areas of denser population and industry) by having to route via the remaining (unfaulted) transmission lines. Voltage control must applied locally, through local reactive power provision. Dynamic voltage support, as could be provided by the inverters connected to the Scheme’s solar panels and therefore connected to the Point of Connection, may be of significant use to NGENSO in managing voltage in the area.

### Stability issues

- 9.3.6 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. Any area of the NETS with high power flows may be prone to instability, particularly at times of high local generation which needs to be exported from the area. NGENSO 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.
- 9.3.7 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, generation assets support short circuit levels, therefore the location of those assets, particularly ones which are able to provide system services (see Table 11-1) will be important in areas of high NETS power flows.

- 9.3.8 No specific issues have been identified in relation to stability issues at the proposed point of connection.
- 9.3.9 National Grid assess boundary planning requirements in the NETS in relation to two assessment criteria:
- Security, which relates to the boundary transfer requirements need to satisfy demand without relying on intermittent generators or imports from interconnectors; and
  - Economy, which relates to the boundary transfer requirements when demand is met with high output from intermittent and low carbon generators and imports from interconnectors.
- 9.3.10 Together these criteria ensure that boundary transfer capacity is adequate to transmit power across boundaries from source to demand to an adequate degree of reliability while ensuring that value for money is secured for the consumer from network investments.
- 9.3.11 The commissioning of a large-scale solar scheme which connects to the NETS at the proposed Point of Connection would contribute towards both of the above 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 11-1, are also likely to become increasingly important in many locations into the future to contribute to the proper functioning of the local NETS.
- 9.3.12 We therefore conclude that the connection of the Scheme to the NETS will not cause any additional specific local or regional operability concerns either now or into the future.

## 9.4 A conclusion on system security

- 9.4.1 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 but the current and important future role of solar power in GB is increasingly recognised. In particular in relation to technical developments in the solar sector in recent years. 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. [96, p66].*

- 9.4.2 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.

9.4.3 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:

- Mitigating and adapting to climate change, and
- Contributing to a secure, diverse and affordable energy supply. [6, Para 1.3.1].

9.4.4 In light of these observations, the following conclusions are made:

- The connection of a large-scale solar scheme connected to the NETS at the proposed Point of Connection will contribute to national system adequacy and decarbonisation targets;
- Connecting a large-scale solar scheme at the proposed Point of Connection will also enable NGESO to increase the level of dependence they can place on expected renewable generation outturn nationally and would provide a supply of bulk low-carbon generation to consumers both in the area local to the Point of Connection and also nationally
- 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;
- The local NETS appears to have sufficient transfer capacity to be able to incorporate the Scheme without requirement for upgrades specifically to enable its connection; and
- The ancillary services available from a large-scale solar and energy storage asset connected to the NETS may provide significant system security benefits and will support the ongoing operation of this area of the NETS.

9.4.5 The Scheme, which consists of a large-scale solar generation asset and includes collocated battery storage, supports UK decarbonisation; supports GB electricity supply adequacy, and provides much needed system services in support of GB electricity system operation. In summary, the observations listed above will all help to keep in check the per-unit cost of transmission system management, a cost which is charged to all users of the NETS, as well as contribute to upholding the security of the NETS in the area local to the Scheme. Crucially though, any such asset must meet a third government policy objective: that of economic supply.

# 10 Solar is economically efficient in GB

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

- 10.1.1 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.

*Most renewable energy resources can only be developed where the resource exists and where economically feasible. [6, 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. [23, p9].*

## 10.2 An introduction to pricing electricity in the GB power market

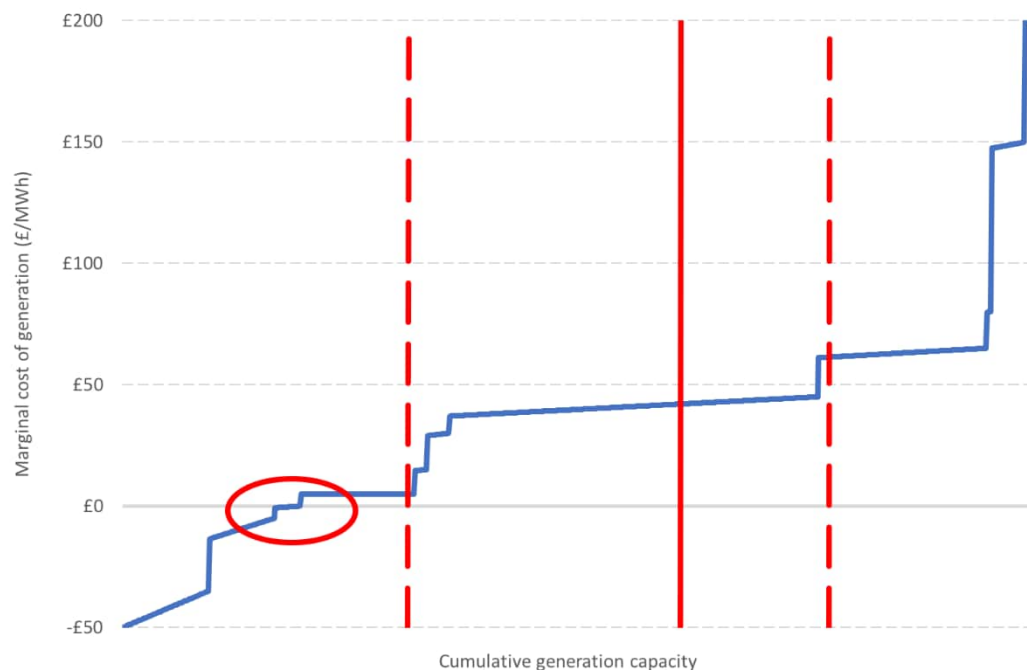
- 10.2.1 In the GB power market, generators schedule themselves to generate in response to whether a market price signal for a specific period is above or below their marginal cost of generation. Marginal cost of generation is defined as: the cost of generating an additional 1MWh, usually including variable fuel and transmission costs. Each day is subdivided into 48 half-hour Settlement Periods (SPs) and power is traded ahead of delivery for these periods, or continuous groups thereof, from just 90 minutes ahead, up to months or even seasons ahead.
- 10.2.2 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 it is light) 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.
- 10.2.3 Thermal and hydro plants have higher marginal costs (relating to the cost of the fuel they are converting into that additional MWh), therefore they 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. Increases in the cost of source fuels increase the cost of generation from these assets, therefore when they are required to generate electricity,

they will do so but at a higher cost and this increases the price of electricity for all market consumers.

- 10.2.4 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.
- 10.2.5 This market mechanism is illustrated in Figure 10-1. 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 (in this illustration: at about £45/MWh). This level therefore becomes the price of power.
- 10.2.6 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 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).
- 10.2.7 The blue line in Figure 10-1 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.
- 10.2.8 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.
- 10.2.9 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.
- 10.2.10 The conclusions are the same though: increasing the capacity of renewable assets in GB reduces the traded price of power, 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 [100, p26].



**Figure 10-1: Representative marginal cost stack for the GB electricity system**



[Author analysis]

## 10.3 Levelised cost of solar generation

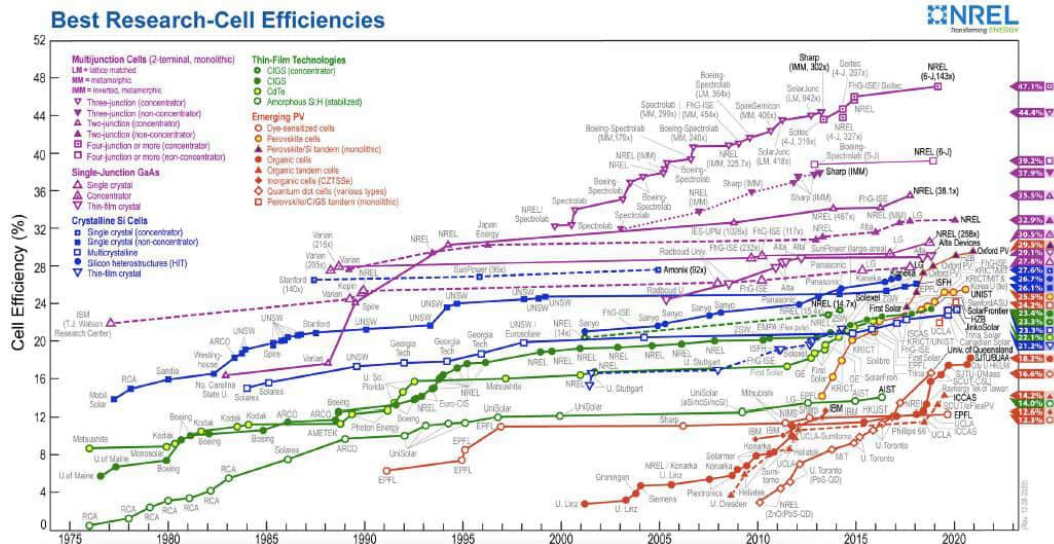
*The International Renewable Energy Agency (IRENA) found that between 2010 and 2019, the cost of solar PV globally dropped by 82% ... In 2019 alone, the cost of electricity from solar fell by 13% to just over five pence per kilowatt-hour. This means that by [2020] globally, there will be up to 1,200GW of existing coal capacity that will cost more to operate than it would to install new solar PV capacity. [101, p67].*

10.3.1 The market mechanisms described in Section 10.2 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 10-2, 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 10-3).

10.3.2 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 [102], 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 2021, 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.

**Figure 10-2: The efficiency of solar cell technology has increased year-on-year for decades**



[104]

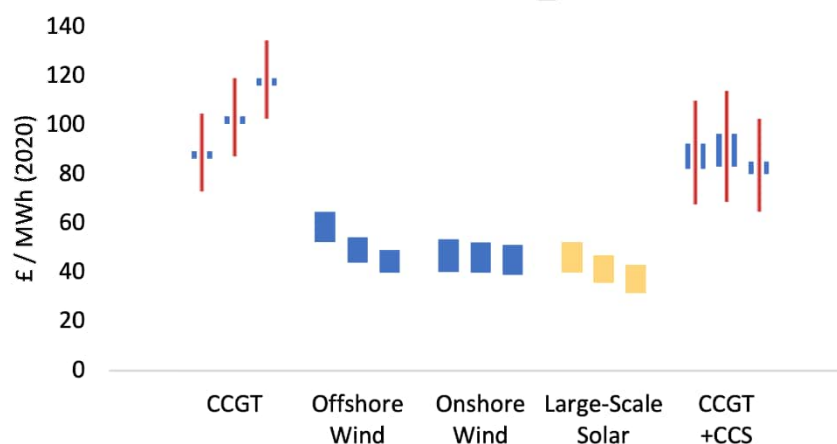
- 10.3.3 Figure 10-3 shows a UK-specific analysis based on data sourced from BEIS' Electricity Generation Costs report, 2020 [103] with the range of values representative of different complexities of technical solution. This analysis is consistent in its conclusions, with that of Lazard.
- 10.3.4 Figure 10-3 illustrates a "triple" of columns for each of five generation technologies, each column within the triple representing the LCOE for the technology calculated by the analysis undertaken in 2020 for assets commissioning in 2025 (left hand column), 2030 (middle column) and 2035 (right hand column).
- 10.3.5 The blue bars represent the range of LCOE given different input assumptions of projected operational lifetime, load factor (a measure of the output of the plant per year versus its theoretical maximum if availability is unconstrained), capital cost, operational cost and development duration. The red columns represent the LCOE range under different projections for input fuel costs (where appropriate).
- 10.3.6 The levelised cost ranges of large-scale solar (defined in the BEIS reports as installations over 5MW in capacity) are highlighted in yellow. Figure 10-3 shows that renewable generation technologies hold a significant levelised cost benefit when compared to technologies which are reliant on fossil fuels.
- 10.3.7 Further, Figure 10-3 shows that the LCOE of solar delivered in 2025 is comparable to the LCOE of onshore wind, however it is anticipated that solar generation delivered in future years is likely to be cheaper than both onshore and offshore wind on an LCOE basis.

- 10.3.8 A project with a lower LCOE is more likely to be developed because of its greater resilience to low market prices, versus a project with a higher LCOE.
- 10.3.9 This is important because renewable power has a very low marginal cost of generation, reflecting the fact that there are no input fuel costs for renewable assets. Therefore, because the GB electricity market dispatches generators on a marginal cost basis, the cost of electricity when renewable generation is high, will be lower (all other inputs being equal) than the cost of electricity when renewable generation is low.
- 10.3.10 The market mechanism described above also provides the explanation as to why the British Energy Security Strategy increases the UK's ambition for renewable generation to reduce our dependency on volatile international energy markets.
- 10.3.11 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].*

10.3.12 Solar costs have been driven by capital infrastructure, development and integration costs, and lifetime O&M including minimising or addressing the anticipated degradation of solar panels and inverters and this is likely to continue. 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, corroborating a low-cost present and lower-cost future for electricity generated by solar installations.

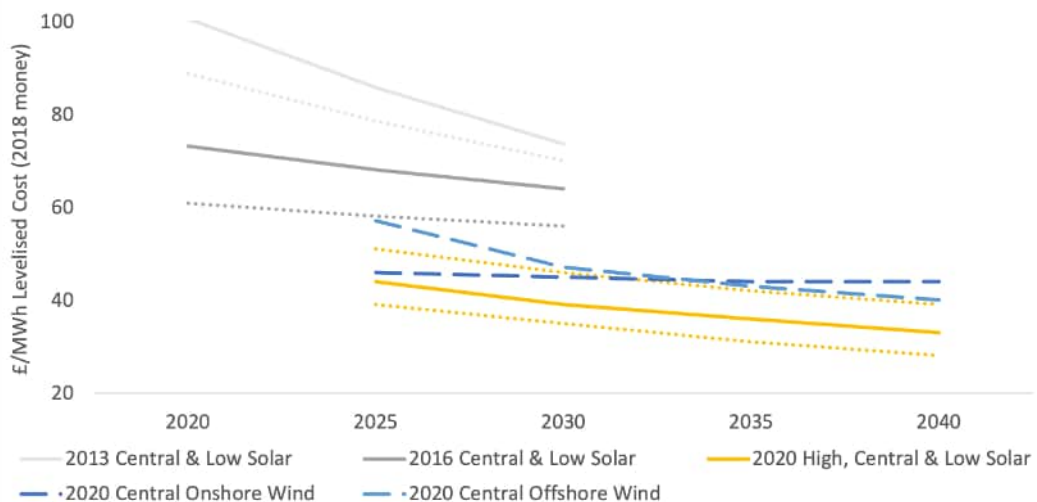
**Figure 10-3: Levelised cost of energy comparison**



[103]

- 10.3.13 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 [15, Figure 2.2].
- 10.3.14 The BEIS 2020 Cost of Generation update [103] concurs with the analysis shown, and results are summarised in Figure 10-4. The analysis shows that UK-specific estimates of LCOE 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.
- 10.3.15 Figure 10-4 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 5.3 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.
- 10.3.16 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 10-4: BEIS Cost of Generation. An evolution of Levelised Cost forecasts**



[103, and Author analysis]

## 10.4 The importance of scale in solar generation

- 10.4.1 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 [5, 6, 8] do not set any upper limit, target or threshold for electricity generation capacity, and details of future possible generation capacities are included in Section 7.2. Estimates from NGENSO, NIC and ESC of the capacities of new solar generation needed in order to meet Net Zero include 44 to 78GW of additional solar capacity by 2050, with approximately one third of this needed in the next ten years.
- 10.4.2 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.
- 10.4.3 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).
- 10.4.4 Solar schemes incur fixed costs, for example project development, site infrastructure and grid connection costs. Project development timeframes are also generally fixed, although in the following analysis it is assumed that smaller schemes are 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.
- 10.4.5 Figure 10-5 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 proposed Scheme.

- 10.4.6 The base case scenario (against which each of the scenarios illustrated in Figure 10-5 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.
- 10.4.7 Four other scenarios, the results of which are shown in Figure 10-5, 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.
- 10.4.8 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.
- 10.4.9 The analysis considers development, capital and operating costs. The financial data inputs have been drawn from BEIS's 2020 Electricity Generation Costs report [103] 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.
- 10.4.10 Development timings influence the environmental and economic benefits or disbenefits achieved by each scenario relative to the first single large solar scheme.
- 10.4.11 Key assumptions incorporated into the analysis include:
- Development costs, both fixed and variable, are included at the beginning of each scheme within each scenario;
  - Ongoing operational costs, based on industry benchmarks, have been included through life for each scheme within each scenario;
  - Solar irradiation, load factor and annual degradation have been held constant across all schemes and scenarios;
  - 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;
  - A cash flow model incorporates these costs and includes an allowance for institutional rates of return on investment (excluding inflationary aspects, which would apply over all scenarios) over a consistent anticipated project lifetime;
  - The key outputs are an indicative LCOE (£/MWh) for each scenario, as well as the carbon savings (tonnes of CO<sub>2</sub>(e)) each combination delivers in the critical pre-2030 timeframe;
  - In the interests of simplicity and transparency, the analysis excludes tax and capital allowances; and

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

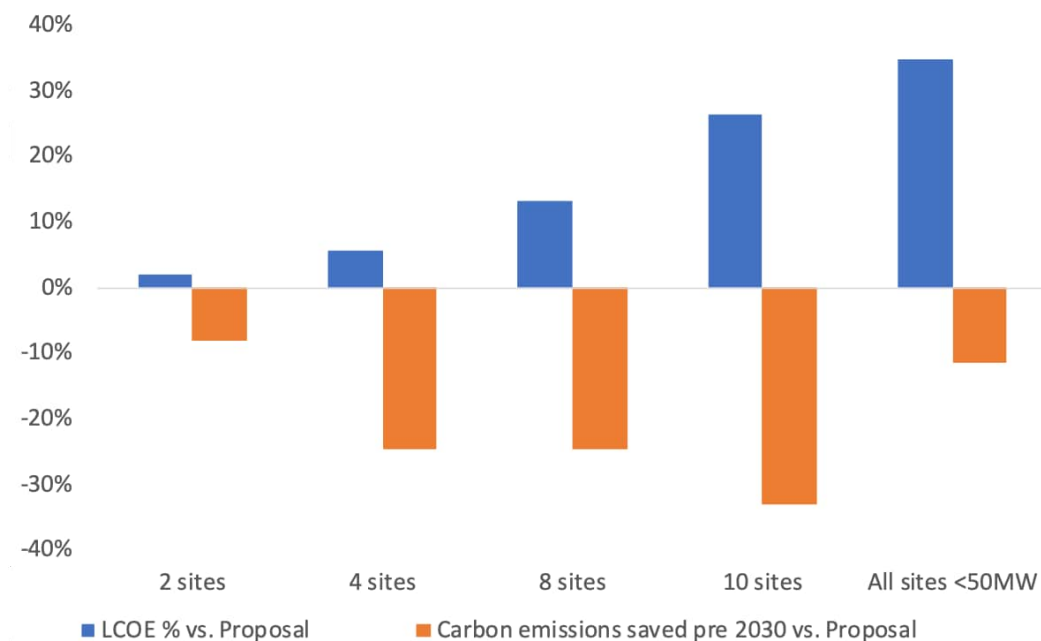
10.4.12 Figure 10-5 shows a comparison of the LCOE for each of these solar scenarios with the base case, single solar scheme.

10.4.13 Storage, the benefits of which are described more fully in Chapter 11, has not been included in this analysis, although storage does provide additional benefits to the local and wider energy system, and specifically to the Scheme.

10.4.14 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.

10.4.15 This analysis also assumes a fixed ratio of installed solar capacity per unit of grid connection capacity. In smaller separate 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 and accommodate the transformer and switchgear necessary to service the location's own point of connection. 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 10-5: LCOE and carbon emissions savings at large-scale single-site solar, versus developing the same total capacity across multiple projects**



[Author analysis]

- 10.4.16 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 5.3). 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.
- 10.4.17 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, carbon reduction or security of supply reasons, and there may be reasons why the development of individual schemes rather than a single larger scheme, is proposed for other projects. However the analysis demonstrates that where the opportunity for the development of larger schemes exists, that opportunity is likely to bring about greater decarbonisation, economic and security of supply benefits than any combination of smaller independent schemes comprising an equivalent total installed capacity.
- 10.4.18 The Scheme presents an opportunity to deliver 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.

## 10.5 A conclusion on economic efficiency

- 10.5.1 Solar power lowers the market price of electricity by displacing more expensive forms of generation and delivers benefits for electricity consumers.
- 10.5.2 Due to technological advances, power generated by solar plants is already at or below grid parity cost in GB.
- 10.5.3 Solar power is economically attractive in GB against many other forms of conventional and renewable generation.
- 10.5.4 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.
- 10.5.5 The 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.



# 11 Flexibility and integration

## 11.1 The need for flexibility

11.1.1 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. [23, 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. [9, p72].*

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

## 11.2 Integration measures play an important flexibility role in the operation of low-carbon electricity systems

11.2.1 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:

- Capturing "free" energy when it is not useful and dispatching it when it has use;
- Transferring "free" energy from where it is not useful, to a location where it is useful;
- Transforming "free" energy from a form which is not useful, into a form which is useful; and / or
- 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. [96, p68].*

- 11.2.2 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 – for example, through the use of electricity either directly or via the production of hydrogen, to decarbonise home heating and transport.
- 11.2.3 Flexible measures will operate over different timeframes, as described in [123]:
- Short Duration: Durations of 4 hours or lower, suited to addressing short duration balancing needs with very fast flexibility;
  - Medium Duration: Durations of over 4 hours, up to 12 hours, suited to addressing within day balancing; and
  - Long Duration: Durations of over 12 hours, required for multi-day and seasonal balancing needs. The category also includes long duration hydrogen storage.
- 11.2.4 Overplanting of solar farms, as described in Section 7.7 above, is a strategy which reduces the requirement for Short and Medium duration measures by increasing solar output from the scheme outside of the middle of the day without also increasing solar output from the scheme in the middle of the day.
- 11.2.5 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 [18, pp7 & 23].
- 11.2.6 NGENSO'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 15 – 28GW by 2030 and 32 – 51GW by 2050 to balance supply and demand within the GB system [116, Table ES.E.01]. In 2020, the NIC predicted 12GW – 19GW of electricity storage in 2050 in their Net Zero power systems with 60%, 80% and 90% renewable scenarios respectively [42, pp19 & 21].

## 11.3 Interconnection

- 11.3.1 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 13 – 19GW of interconnection by 2030 (up from 6 GW at the time of writing) and 16 – 27GW by 2050 [116, Table ES.E.01]. 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 [42, pp19&21], a scale which was matched by the CCC in their Sixth Carbon Budget Balanced Pathways scenario [4, p136].
- 11.3.2 At the time of writing this report, the UK has 7GW of commissioned 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 currently advertised as commissioning in the 2020 to 2025 timeframe are at various stages of development, however delays can be experienced, for example on France / UK interconnector Eleclink which was due to reach its Final Investment Decision in 2015 but only became operational in May 2022. 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.
- 11.3.3 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).
- 11.3.4 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.

## 11.4 Hydrogen

- 11.4.1 As described in Section 6.2, the prominence of a hydrogen economy has increased in each annual edition FES since 2019. 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.
- 11.4.2 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.
- 11.4.3 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. [105]
- 11.4.4 Government's 2021 UK Hydrogen Strategy explains that hydrogen has "the potential to overcome some of the trickiest decarbonisation challenges facing our economy" [106, p2] especially in enabling the decarbonisation of industry and land transport, and as a potential substitute for current carbon-intensive marine and aviation fuels.
- 11.4.5 There are many practical ways in which a hydrogen economy can enable decarbonisation. The major potential uses of hydrogen are:
- 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;
  - 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 although engineering aspects of such a change are still under review;
  - A greater share of hydrogen in a blended natural gas mix would 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 could be cheaper than building a new network;
  - This also opens up the use of hydrogen as a power generation vector: substituting the current CCGT fleet (c. 394gCO<sub>2</sub>/kWh at current efficiencies) and Open Cycle Gas Turbine fleet (c. 651gCO<sub>2</sub>/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;

- 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.

11.4.6 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 5.4 which are hoped to become operational in the second half of the 2020s.

11.4.7 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. [107, p16]*

11.4.8 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.

11.4.9 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.

11.4.10 In the UK Hydrogen Strategy, 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. [106, p10].*

11.4.11 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 [65, 66].

11.4.12 NGESO estimate that annual electricity demand from road transport as a whole (incorporating both EVs and vehicles powered by hydrogen) could be between 90 and 123TWh [116, Table ED1], this is lower than the forecast derived from independent analysis carried out by SNC Lavalin (Atkins) which

estimated 150TWh [68, p12]. The potential for use in rail, marine and air travel increase estimates of hydrogen use even further.

11.4.13 NGESO estimate that at between 126 and 240TWh of electrical energy will be required annually by 2050 to produce hydrogen to meet its many potential end-uses [116, Table ED1], 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 [18, pp6 & 36].

11.4.14 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. [42, p7].*

11.4.15 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" [24, 106]. To support this ambition, government made available £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 was delivered in Q2 2022. The business model was published alongside the hydrogen production strategy which included government's "twin-track" approach which foresees a significant opportunity for the role of low carbon electricity generation in the production of green hydrogen.

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

11.4.17 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.

11.4.18 As a large-scale solar generation asset, the Scheme is fully aligned with the national ambition for the development of a hydrogen economy, where hydrogen production has a zero carbon footprint.

## 11.5 Electricity storage

- 11.5.1 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 if deployed.
- 11.5.2 Electricity storage will play an important role in the development of a low-carbon GB energy system. Electricity storage may be connected as a standalone asset or collocated with a renewable generation scheme. Because the Scheme's grid connection agreement provides both import and export capacity it enables the Scheme to contribute to meeting the national need for electricity storage by including, as Associated Development, an electricity storage asset which supports the operation of the principal solar development and provides the ability to balance the electricity produced by the solar scheme, with demand on the NETS.
- 11.5.3 Collocation of solar and storage assets provides efficiencies in relation to land use and the maximum use of available grid connection capability (if available) because on-site infrastructure can be shared between the two technologies. However standalone solar schemes provide essential low-carbon electricity to the grid and not including storage capability at the site does not detract from their core contribution to decarbonising the electricity network:
- Not all grid connections have both import and export capability, and the import capability may not be cost effective to provide, however export capability, where it is available, should be used to connect renewable generation to the NETS; and
  - Storage facilities have a direct relationship with the renewable generation schemes with which they are often collocated and add important utility to the operation of solar generation schemes. However services which support the efficient flow of renewable power onto the UK electricity system can and also are expected to be provided by other assets which are located and operated separately to renewable generation assets, as is demonstrated by entries in various connection and planning registers including [29, 30, 32].
- 11.5.4 Therefore where available grid connections enable collocation of renewable generation and storage, a scheme which includes both will make sense to develop. This will – among other reasons – ensure that the greatest use can be made of the existing grid connection infrastructure. However locations with an export connection only which therefore may be brought forwards as standalone generation schemes, still play an essential role in contributing to the three pillars of energy policy: decarbonisation, security of supply and affordability.
- 11.5.5 Significant investment is 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. [108].*

- 11.5.6 Other electricity storage technologies are also under development, using for example, momentum (e.g. fly-wheel), pressure (e.g. 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 11.2.

### The continuing and growing need for Balancing Services

- 11.5.7 The activities associated with integrating renewables into the GB electricity system will increase with their penetration [87, 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, NGENSO's SOF [88] 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:

- Voltage and frequency may not evolve linearly in unbalanced or distributed systems and faults may evolve quickly;
- Generators may find it challenging to remain synchronous to systems following fast-evolving faults, increasing the risk of cascading faults;
- Fast-moving fault conditions will be more complicated and may not be predictable; and
- High-renewable systems will be harder to mimic for test, research or safety justification purposes.

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

### System inertia and Rate of Change of Frequency (RoCoF)

- 11.5.9 NGENSO 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% [87, Figures 1.2 & 1.3]. With the expected closure or reduced running hours of many thermal plants, the system protection services they provided must be obtained from other assets and most likely 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 able to provide inertia through synthetic means. Synthetic inertia is an electronic alternative to physical inertia, but it does not conform to the same rules. Synthetic inertia is provided by reprogramming the solar park's power inverters so that they emulate the behaviour of synchronised spinning masses.

- 11.5.10 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

- 11.5.11 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 ("High" short circuit levels are more resilient than "low" short circuit levels), and levels are expected to fall in GB as conventional capacity decreases. When this happens, critical system variables (such as voltage or power flow) may enter unstable states more easily, more frequently, and potentially for longer periods in the future [109, Figures 31 & 32].
- 11.5.12 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.
- 11.5.13 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

- 11.5.14 Critically, electricity storage is increasingly well placed to deliver many ancillary services to 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 shifts in the global gas market and changes to structural pricing in the GB electricity market are also causing the operational profiles of traditional fossil

fuel assets to change. 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.

11.5.15 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 integration technologies incorporated in the Scheme, are listed in Table 11-1.

11.5.16 Whilst the electricity storage element of the Scheme is not an NSIP in itself the Applicant considers it is associated development, as will be explained in the Application Planning Statement. There is a clear, direct relationship between the solar generation station and the collocated electricity storage. The relationship brings substantial benefits which will result in the Scheme making an improved contribution to low carbon UK electricity supplies when compared to the Scheme coming forward independent of the storage., Table 11-1 demonstrates that the collocation 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. Collocation is especially beneficial for NGENO where connections are to the transmission, rather than to the distribution network, because the combined asset is required to meet certain energy market operational planning, notification and service obligations (see Section 8.5).

### Growth within the electricity storage sector

11.5.17 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 [110, 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.

11.5.18 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" [111].

11.5.19 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.

11.5.20 The IEA's report [111] 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, growth has been fragile as policy intervention has been required to support or create markets which bring investment to the sector.

11.5.21 This certainly holds true in the UK. 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 [2, Para 2.38.2]*

11.5.22 A 2015 report of energy storage assets in GB listed just 27 installed energy storage projects, with a total capacity of around 33GWh [112, p16], a large proportion of that capacity was in the form of heritage pumped storage (hydro).

11.5.23 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.

11.5.24 NGESO report that 1.8GW of battery storage was in operation in 2022 [116, Table ES1]. A government report stated that 4GW of storage projects were progressing planning consent [113].

11.5.25 NGESO's FES 2022 [116] estimates that electricity storage capacity (excluding vehicle-to-grid technologies) will need to increase by 13 – 27GW by 2030, by 22 – 43GW by 2040, and by 30 – 50GW by 2050, in order to achieve Net Zero.

11.5.26 NGESO's TEC Register shows a total of 20.6GW of connection capacity requests from developers of stand-alone storage schemes although storage schemes are also coming forwards with collocated storage where grid connection availability allows. These 150 projects range in proposed capacity, currently up to 1400MW [29]. Further Energy Storage System projects are listed on NGESO's Embedded Register [74] and the Embedded Capacity Registers [32] although some of these projects may be purely speculative with low probability of coming forward to operation.

11.5.27 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 4.9GW of installed battery storage capacity has secured a Capacity Agreement since 2015. However not all of this is currently operational. [124]

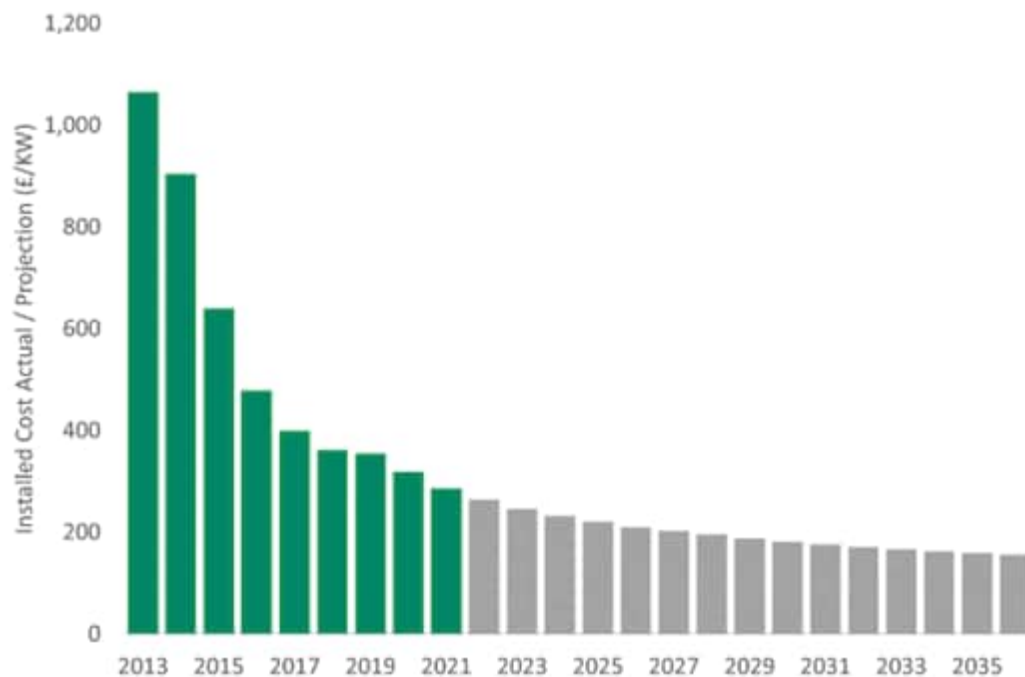
11.5.28 This implies that although development pipelines for BESS schemes are healthy, only a small proportion of proposed schemes have so far progressed towards financial commitment decisions, and on to commercial operation.

11.5.29 A much higher conversion rate will be required on the remaining pipeline in order to meet the FES view of an additional 13 – 27GW of electricity storage operational by 2030.

11.5.30 The storage pipeline – as an enabler of other higher levels of RES capacity in the UK electricity system – is growing in capacity and projects which deliver will be able to support large-scale solar integrate further to the grid as soon as they are delivered. However the need to convert the pipeline of potential projects into commissioned assets reinforces the case for the collocation of energy storage as part of the Scheme.

- 11.5.31 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 [108, pp7 & 30].
- 11.5.32 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" [24] 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 12-1, and as cost reduction targets are met, more storage projects will be commissioned.
- 11.5.33 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 11.2 above are unconstrained, subject to industry achieving the cost improvements aspired to in Figure 11-1. 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 [9], would increase the important role of electricity storage within the GB electricity system.

Figure 11-1: A projection of future battery component costs



[Author analysis of published data]

11.5.34 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 as part of The Scheme, would therefore allow the project to fulfil its ambitions in providing full support to UK action plans to deliver decarbonisation.

**Table 11-1: The potential contributions of a storage asset within the Scheme to the GB electricity market, including ancillary service provision**

Service	Explanation	Applicability
<b>Trading</b>	Selling energy at market prices	The backbone of solar benefit cases.  Storage helps increase the benefits of all RES generation by directing energy from when it is produced to when it is needed. This helps reduce curtailment of low-carbon electricity. Storage assets can be collocated with solar assets or independently. They can also act independently to RES assets to provide services which support electricity system operation.
<b>Balancing Mechanism</b>	Being available to NGENSO to balance supply and demand at delivery.	Solar will provide downward flexibility, but at the "cost" of carbon-free energy.
<b>Frequency Response</b>	Changing output minute by minute to help maintain system frequency at the statutory level of 50Hz.	Collocated RES & Storage can provide both upward and downward flexibility, potentially without 'losing' any low-carbon energy. Stored energy can be dispatched over milliseconds to hours, depending on technology and need.
<b>Reserve Operation</b>	Changing output over minutes and hours to rebalance supply and demand following a fault or other unforeseen event on the electricity system.	A mandatory service for all transmission-connected assets, delivered by Solar, other RES and Storage assets.
<b>Reactive Power</b>	Locational service which allows power to "flow" from source to destination.	Solar inverters are able to provide synthetic inertia. Storage also provides synthetic inertia.
<b>Inertia</b>	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.	Solar is not capable of providing Black Start services when developed on a stand-alone basis. Standalone storage may be capable of providing limited support to a Black Start Event, but a collocated asset is likely to be more versatile.
<b>Black Start</b>	A locational service which would help 'turn back on the lights' if an event caused the national electricity system to fail.	Solar can provide important downward constraint management services. Collocated Solar and Storage can provide upward and downward constraint management services. Because of its proposed connection location, the Scheme will be highly unlikely to cause constraints on the local NETS.
<b>Constraint Management</b>	Changing output in response to local energy supply, demand and transport issues, to ensure locational adequacy at all timescales.	RES and Storage can help with reducing new infrastructure requirements, although benefits may be higher if collocated than if located separately.
<b>Infrastructure</b>	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.	

[Author analysis]

## 12 In summary and in support of this solar and storage scheme

- 12.1.1 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.
- 12.1.2 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.
- 12.1.3 The summary points which support the need for large-scale solar developments are as follows:
- Large-scale solar generation is essential to support the urgent decarbonisation of the GB electricity sector. Large-scale solar is important not only to reduce power-related carbon emissions, but also to provide a timely next step contribution to a future generation portfolio which is capable of supporting the electrification and therefore decarbonisation of transport, heat and industrial demand.
  - As part of a diverse generation mix, solar generation contributes to improve the stability of capacity utilisations among renewable generators. When developed alongside other renewable technologies, large-scale solar will smooth out seasonal variations in total GB renewable generation, more closely matching anticipated seasonal levels of demand.
  - 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.
  - 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.
  - Large-scale solar generation also supports security of supply by helping reduce the national dependency on imported hydrocarbon source fuels.
  - 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.
  - Internationally, and importantly for GB in this regard, is the ongoing trend of solar generation assets becoming larger and more affordable, each subsequent project providing a real-life demonstration that solar schemes of similar size and scale as the Scheme can be developed in GB. The development of such schemes will provide decarbonisation and commercial benefits to consumers.
  - 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 reductions and more affordable electricity, in line with government policy.

12.1.4 These general benefits of solar generation in GB also apply specifically to the Gate Burton Energy Park Scheme:

- The Scheme is a substantial infrastructure asset, capable of delivering large amounts of low-carbon electricity to local and national networks. The Scheme, along with other solar schemes, is of critical importance on the path to Net Zero, with NGESO scenarios predicting the need for 25 – 40GW of operational solar capacity in GB by 2030. The need for solar is especially important 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);
- 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 market participants, thus allowing all consumers to benefit from the market price reducing effect of solar generation;
- 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; and
- Maximising the capacity of generation in the proposed area, is to the benefit of all GB consumers, and the solar industry generally.

12.1.5 The Scheme will 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.

12.1.6 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.

12.1.7 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.



## 13 About the author

- 13.1.1 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:
- Renewable generation pre-construction feasibility studies and advice for GB assets;
  - GB electricity market commercial operation; and
  - Electricity market transformation.
- 13.1.2 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.
- 13.1.3 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.
- 13.1.4 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).
- 13.1.5 He is also supporting c.6GW (offshore wind) and c.5GW (solar) of schemes through their applicable planning processes.
- 13.1.6 He holds Masters degrees in Mathematics, from Oxford University, and in Nuclear Safety, Security and Safeguards, from the University of Central Lancashire

## 14 References

- [1] BEIS. Draft Revised Overarching National Policy Statement for Energy (EN-1). 2021.
- [2] BEIS. Draft Revised National Policy Statement for Renewable Energy Infrastructure (EN-3). 2021.
- [3] HM Treasury. National Infrastructure Strategy. Fairer, faster, greener. 2020.
- [4] Climate Change Committee. The Sixth Carbon Budget: The UK's path to Net Zero. 2020.
- [5] Department of Energy & Climate Change. Overarching National Policy Statement for Energy (EN-1). TSO, 2011.
- [6] Department of Energy & Climate Change. National Policy Statement for Renewable Energy Infrastructure (EN-3). TSO, 2011.
- [7] BEIS. Contracts for Difference for Low Carbon Electricity Generation - Consultation on proposed amendments to the scheme. 2020.
- [8] Department of Energy & Climate Change. National Policy Statement for Electricity Networks Infrastructure (EN-5). TSO, 2011.
- [9] HM Government. Energy White Paper: Powering our Net Zero Future. 2020.
- [10] BEIS. Final UK greenhouse gas emissions national statistics. 2021.
- [11] HM Government. The UK Low Carbon Transition Plan. HMSO, 2009.
- [12] BEIS. The Clean Growth Strategy. HMG, 2017 (Corrected 2018).
- [13] National Grid. Future Energy Scenarios. National Grid, 2021.
- [14] Climate Change Committee. Net Zero – The UK's contribution to stopping global warming. 2019.
- [15] Climate Change Committee. Reducing UK emissions – Progress Report to Parliament. HMSO, 2020.
- [16] BEIS. UK enshrines new target in law to slash emissions by 78%. [www.gov.uk](http://www.gov.uk), 2021.
- [17] BEIS. Industrial decarbonisation strategy. 2021.
- [18] Energy Systems Catapult. Innovating to Net Zero. 2020.
- [19] Climate Change Committee. Net Zero Technical Report. 2019.
- [20] Energy Live News. Boris Johnson promises to “Build build build” to help UK recover from coronavirus crisis. Energy Live News (online), 2020.
- [21] Energy Live News. Government commits £350m to supercharging green recovery. Energy Live News (online), 2020.
- [22] UK Government. Projects to heat homes through disused mines and faster offshore wind farm construction win government backing. UK Government News, 2020.
- [23] National Infrastructure Commission. Renewables, recovery, and reaching Net Zero. [REDACTED]

- [24] Boris Johnson. Now is the time to plan our green recovery. Financial Times, 2020.
- [25] UN Climate Change Conference. COP26 Negotiations Explained. 2021.
- [26] UN Climate Change Conference COP26. COP26: The Glasgow Climate Pact. 2021.
- [27] Intergovernmental Panel on Climate Change Working Group III. Climate Change 2022, Mitigation of Climate Change, Summary for Policymakers. 2022.
- [28] Muench, S., Thuss, S., Guenther, E. What hampers energy systems? The case of smart grids. Energy Policy, 73:80 – 92, 2014.
- [29] National Grid. TEC Register, July 2022.
- [30] UK Government. Renewable Energy Planning Database. July 2022.
- [31] UK Government. Digest of UK Energy Statistics. 2021.
- [32] Distribution Network Operators. Embedded Capacity Registers are published under the OpenData initiative by each of the six GB Distribution Network Operator companies. Online, 2022.
- [33] IEA. Reaching international energy goals. IEA News, 2020.
- [34] DNV GL. Energy Transition Outlook Power Supply & Use. 2020.
- [35] National Grid. Future Energy Scenarios. National Grid, 2020.
- [36] National Infrastructure Commission. National Infrastructure Assessment Chapter 2: Low Cost, Low Carbon. 2018.
- [37] National Grid. Future Energy Scenarios. National Grid, 2012.
- [38] Global CCS Institute. Global Status of CCS 2021. Global CCS Institute, 2022.
- [39] Jillian Ambrose. BP leads energy companies preparing two major UK carbon capture projects. The Guardian, 2020.
- [40] Ambrose Evans-Pritchard. Why fossil fuel dinosaurs may still have life in them yet. Daily Telegraph, 2020.
- [41] BEIS. Business models for carbon capture usage and storage. HMSO, 2019.
- [42] National Infrastructure Commission. Net-zero: Opportunities for the power sector. [REDACTED]
- [43] ETI. ETI sets out priorities for marine energy if it is to compete with other low carbon sources. ETI News, 2017.
- [44] Adam Vaughan and Steven Morris. Government rejects plan for £1.3bn tidal lagoon in Swansea. The Guardian, 25 June 2018.
- [45] Department for Business, Innovation and Skills. The UK's Nuclear Future. HMSO, 2013.
- [46] FTI Compass-Lexecon. Reducing the cost of transition to net zero for GB energy consumers. 2020.
- [47] Nina Chestney. EDF sees UK Hinkley C nuclear plant online by end of 2025. Reuters, 17 January 2019.
- [48] Unattributed. Hitachi and horizon halt £20bn Wylfa project. The Construction Index, 2019.

- [49] Adrian Cho. Smaller, cheaper reactor aims to revive nuclear industry, but design problems raise safety concerns. Science Mag, 2020.
- [50] HM Government. British Energy Security Strategy. 2022.
- [51] BEIS. RAB model for nuclear. HMSO, 2019.
- [52] Harvard T.H. Chan School of Public Health. Air pollution linked with higher covid-19 death rates. 2020.
- [53] Damian Carrington. Exposure to air pollution may increase risk of Covid death, major study says. The Guardian, 2020.
- [54] CCC. Progress in reducing emissions. 2021 Report to Parliament. 2021.
- [55] Rt. Hon. Kwasi Kwarteng, Minister for Energy. Energy live news XPO. 2020.
- [56] HM Government. The Ten Point Plan for a Green Industrial Revolution. 2020.
- [57] BEIS. Impact Assessment for the sixth carbon budget. 2020.
- [58] Robert Walton. Tesla unveils new EV battery design, but Musk downplays vehicle-to-grid application. Utility Dive, 2020.
- [59] Prime Minister's Office. A New Deal for Britain, 30 June 2020.
- [60] Roger Harrabin. Ban on new petrol and diesel cars in UK from 2030 under PM's green plan. BBC News, 2020.
- [61] Energy Live News. Mayor and London's utilities join forces for £1.5bn worth of infrastructure work. Energy Live News (online), 2020.
- [62] Ofgem. Decarbonisation Action Plan. Ofgem, 2020.
- [63] Alice Grundy. More battery electric vehicles sold in March than entirety of 2019. Current Plus, 2022.
- [64] HM Gov. Taking charge: the electric vehicle infrastructure strategy. 2022.
- [65] The Engineer. UK's first hydrogen train makes mainline debut. The Engineer [online], 2020.
- [66] The Engineer. World's first hydrogen powered commercial plane. The Engineer [online], 2020.
- [67] National Grid. Future Energy Scenarios. National Grid, 2019.
- [68] Atkins. Engineering Net Zero Technical Report. SNC Lavalin (Atkins), 2019.
- [69] BEIS. Sub-national electricity sales and numbers of customers 2005 – 2019.
- [70] PBC Today. Scotland needs 25,000 new homes a year to meet demand. 2019.
- [71] Welsh Government. Estimates of Additional Housing Need in Wales (2019-based). 2020.
- [72] Wendy Wilson and Cassie Barton. Tackling the under-supply of housing in England. House of Commons Library, 2021.
- [73] Low Carbon Contracts Company. CfD Register. 2022.
- [74] National Grid. Embedded Register.

- [75] Kate Ng. Denmark sets record by sourcing nearly half its power from wind energy. The Independent, 2020.
- [76] Jacob Gronholt-Pedersen. Denmark sources record, Reuters, 2020.
- [77] Ministry of Housing, Communities & Local Government. Renewable and low carbon energy. 2015.
- [78] Alasdair Rae. A Land Cover Atlas of the United Kingdom. 2017.
- [79] Henry Dimbleby. National Food Strategy Independent Review. 2021.
- [80] George Monbiot. There are solutions to the food crisis. But ploughing up Britain isn't one of them. The Guardian, 2021.
- [81] National Grid plc. Grid Code, National Grid Electricity Transmission plc. National Grid plc [online resource], 2014.
- [82] Alice Grundy. Lightsource BP delivers night time reactive power using solar in 'UK first'. Solar Power Portal, 2019.
- [83] BEIS. Plans unveiled to decarbonise UK power system by 2035 (online). 2021.
- [84] National Grid. System Operability Framework. National Grid, 2014.
- [REDACTED]
- [85] Grubb, M. J. The integration of renewable electricity sources. Energy Policy, 19(7):670 – 688, 1991.
- [86] State of Green. A record year: Wind and solar supplied more than half of Denmark's electricity in 2020. 2021.
- [87] National Grid. System needs and product strategy. National Grid, 2017.
- [REDACTED]
- [88] National Grid. System Operability Framework. National Grid, 2016.
- [REDACTED]
- [89] National Grid. System Operability Framework. National Grid, 2015.
- [REDACTED]
- [90] National Grid ESO. Network Options Assessment. 2021.
- [91] National Grid. Network Options Assessment. National Grid, 2020.
- [92] National Grid. Future Energy Scenarios. National Grid, 2018.
- [93] Edie.net. UK summer "wind drought" puts green revolution into reverse.
- [REDACTED]
- [REDACTED]
- [94] Ueckerdt, F., Brecha, R., Luderer, G. Analyzing major challenges of wind and solar variability in power systems. Renewable Energy, 81:1 – 10, 2015.
- [95] National Grid. De-rating Factor Methodology for Renewables Participation in the Capacity Market. National Grid, 2019.
- [96] Helm, D. Cost of energy review. BEIS, 2017.
- [97] Strbac, G., Aunedi, M. Whole-system cost of variable renewables in future GB electricity system. Imperial College, 2016.
- [98] National Grid ESO. Electricity Ten Year Statement. 2021.

[99] National Grid ESO. Day-ahead constraint flows and limits. National Grid Data Portal, December 2020.

[100] Bushnell, J., and Novan, K. Setting With The Sun: The Impacts Of Renewable Energy On Wholesale Power Markets. Energy Institute at Haas, 2018.

[101] Solar Power Portal. Solar PV costs fall, Solar Power Portal, 2020.

[102] Lazard. Levelized cost of energy analysis – Version 15.0. Lazard, 2021.

[103] BEIS. Electricity generation costs. 2020.

[104] Bell Research. Best Research – Cell Efficiency Chart. National Renewable Energy Laboratory, 2020.

[105] Union of Concerned Scientists. Fulfilling the potential of fuel cell electric vehicles. Union of Concerned Scientists, 2015.

[106] HM Government. UK Hydrogen Strategy. 2021.

[107] EDF Energy. Our Plan for a green recovery. 2020.

[108] International Energy Agency and European Patent Office. Innovation in batteries and electricity storage. 2020.

[109] National Grid. Future Energy Scenarios. National Grid, 2015.

[110] Garton Grimwood, G. and Ares, E. Energy storage in the UK. House of Commons Library Briefing Paper Number 07621, 21 July 2016.

[111] International Energy Agency. Annual energy storage deployment, 2013-2019.

[112] Renewable Energy Association. Energy storage in the UK - An overview. Renewable Energy Association, 2015.

[113] BEIS. Battery storage boost to power greener electricity grid. gov.uk, 2020.

[114] Tim McManan-Smith. UK's largest battery ready to balance the grid. The Energyst, 2020.

[115] Committee on Climate Change. Progress in reducing emissions. 2022 Report to Parliament, CCC. 2022.

[116] National Grid ESO, Future Energy Scenarios 2022, National Grid. 2022

[117] The Crown Estate, Offshore Wind Project Listing, Crown Estate, July 2022

[118] World Nuclear News, EDF revises Hinkley Point C schedule and costs, 2022

[119] National Grid ESO, Carbon Intensity Forecast Methodology, National Grid ESO, 2021

[120] RE News.biz, Danes blame historically bad conditions for wind dip, RE News.biz, 2021

[121] National Grid ESO. Network Options Assessment. July 2022.

[122] BEIS, Net zero review: terms of reference, BEIS, September 2022

[123] BEIS, Benefits of Long Duration Electricity Storage, BEIS, 2022

[124] National Grid ESO – EMR Delivery Body, Capacity Market Registers, 2022

[125] BEIS, UK government takes major steps forward to secure Britain's energy independence, BEIS November 2022