CLEVE HILL SOLAR PARK

STATEMENT OF NEED

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CLEVE HILL
SOLAR PARK

Summary

Cleve Hill Solar Park Ltd, a joint venture between Hive Energy Ltd, and Wirsol Energy Ltd, proposes to make an application for a development consent order (“DCO”) under the Planning Act 2008 for a solar and energy storage generating station project, connecting to the National Electricity Transmission System (“NETS”) at Cleve Hill Substation in Kent. This Statement of Need has been prepared in support of that DCO application and should be read in conjunction with the other documents submitted with that application.

The Cleve Hill Solar Park (“CHSP”) project will deliver large-scale, zero-subsidy, solar and energy storage generation assets, with each expecting to have a generating capacity in the region of 300 - 400 MW. These assets will help the UK meet its legally binding carbon emissions targets, and it has the potential to support operation and balance of the NETS through the delivery of an integrated electricity storage capability.

This Statement has been prepared by Simon Gillett, M.A.(Oxon), M.Sc.(Dist) of New Stream Renewables[1] (“NSR”) and sets out the case for why solar is an important generation technology to include within the future GB generation mix; why it makes sense to operate batteries alongside solar assets; and provides an economic evaluation of different sizes of solar generation asset at Cleve Hill.

This Statement concludes that circa 300 - 400 MW of unsubsidised low-carbon solar generation is needed in the UK, and that the Cleve Hill location is uniquely suited to the co-location of 300 - 400 MW of electricity storage alongside the solar generation asset. Developing the asset as planned, thereby utilising the grid connection availability at Cleve Hill substation, will meet Government objectives of delivering sustainable development, ensuring our energy supply is secure and providing benefits to GB consumers.

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[1] Further credentials are provided in Chapter 8

Contents

CHAPTER 1: THE NATIONAL POLICY STATEMENTS

1.1 The Overarching National Policy Statement for Energy (NPS EN-1) [10] sets out national policy for energy infrastructure in Great Britain. It has effect, in combination with NPS EN-3 (for renewable energy infrastructure) [11] and NPS EN-5 (for electricity networks) [12], on the decisions by the Secretary of State on applications for energy developments that fall within the scope of the NPSs [10, Para 1.1.1]. These NPS, when combined with the relevant technology-specific energy NPS, provide the primary basis for decisions by the SECRETARY OF STATE. 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. [11, Para 1.3.1].

1.2 Critically, the NPS for renewable energy infrastructure includes only those technologies which, at the time of publication, were technically viable over 50 MW [capacity] onshore at the time of publication in 2011. Critically, solar is not currently included within the scope of these documents, however, Government is actively considering other ways in which to encourage industry to accelerate progress towards a low carbon economy [10, Para 1.7.9] and the Cleve Hill project should be considered in the light of that encouragement. The NPS are therefore foreseen to be revised when other renewables technologies appear to be economically and technically viable over 50 MW [11, Para 1.8.2]. 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 Great Britain. These benefits manifest in terms of the technology's contribution to legal de-carbonisation targets; improvement in security of supply; and improvement in the affordability of electricity for GB consumers.

1.3 Chapter 2 of this Statement sets out the legal requirement for decarbonisation in the UK. Chapter 3 provides an up-to-date view of how decarbonisation has been achieved to date, through the deployment of significant numbers of small-scale wind and solar installations, and explains why large-scale assets as foreseen in previous carbon plans (and for which the NPS were largely written) have hitherto lagged smaller-scale assets in deployment.

1.4 Chapter 4 confirms that today's view of future demand remains uncertain, but growing, for the same reasons as those stated in the NPS. Chapter 5 explains the contribution of large-scale solar to security of supply, both from an availability and a system operation perspective. The system operation complexities of a low-carbon energy system have only really been discovered due to the increased penetration of low-carbon generation into the electricity system since the mid 2010s. Electricity storage, which has been cast as deliverer of many benefits and services in this area, is discussed as a stand-alongside proposition to large-scale renewable energy assets.

1.5 Chapter 6 provides an analysis of the economic viability of large-scale solar, both as a stand-alone renewable proposition, and in relation to the incremental benefits it delivers when compared to smaller solar assets.

1.6 Lastly, Chapter 7 contains a summary and the critical conclusions from this report.

CHAPTER 2: THE UNITED KINGDOM HAS A LEGAL COMMITMENT TO DECARBONISE

2.1 The Government, through the Climate Change Act 2008, made the United Kingdom[2] the first country in the world to set legally binding carbon budgets, aiming to cut emissions 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" [7, Five Point Plan].

2.2 The Climate Change Act is underpinned by further legislation and policy measures. Many of these have been consolidated in the UK Low Carbon Transition Plan, and UK Clean Growth Strategy. So far, the UK is on track with its carbon reduction obligations, as shown in Figure 2.1. The main deliverer of UK carbon reduction to date has been the power generation sector. Overall carbon intensity from power generation has fallen significantly in recent years, with (virtually) carbon-free generation (wind, solar, hydro, bioenergy, and nuclear) accounting for around 50 per cent of electricity generation in 2017.

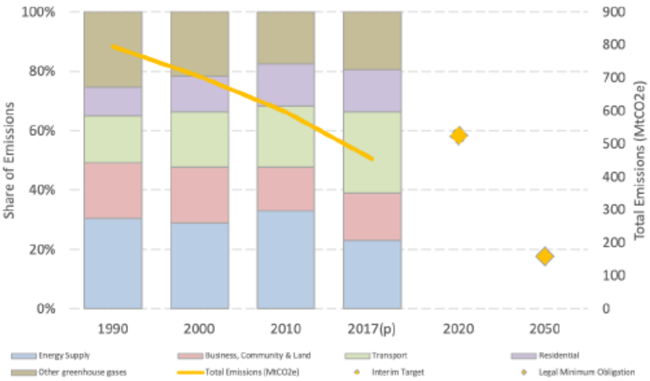

Figure 2.1: UK greenhouse gas emissions by source sector, 1990 - 2017. Adapted from [1].

2.3 All industry sectors have important roles to play in decarbonisation, and electrification of non-power sectors is an important part of the realisation of overall carbon emission reductions. As stated in the Overarching National Policy Statement for Energy,

> *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.* [10, Para 2.1.1].

2.4 Decarbonisation of transport will be supported by removing internal combustion engines from roads, potentially by introducing electric vehicles (in

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[2] The commitment to decarbonisation extends across the United Kingdom of Great Britain and Northern Ireland. Northern Ireland is interconnected with the mainland power system through two interconnectors, but is operated under a different electricity 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 is legally committed to carbon reduction.

private, public and commercial vehicles - see Chapter 4), and/or by improving electrified rail services as an efficient substitute to road freight. Residential savings in carbon emissions are currently being pursued through research into the substitution of gas (currently used in homes for space and water heating and cooking) for electricity (or hydrogen). In order to facilitate those savings, it is vitally important to ensure that GB is capable of meeting an increased demand for electricity in a secure way, with a significantly lower carbon intensity even than current levels.

2.5 The future characteristics of GB's electricity demands are described through a set of four possible scenarios developed (through industry consultation) on an annual basis by GB's Electricity System Operator and statutory undertaker, National Grid ("NGrid"). This annual publication is called Future Energy Scenarios ("FES") (see [2]). In completing their work NGrid look at a number of drivers including legislation, policy, technology and commercial aspects. Consumer behaviour is also considered. The speed of decarbonisation is a key feature in the 2018 publication of FES, with two of the four scenarios meeting the 2050 carbon reduction target via distinct pathways: requiring heavy investment in either energy efficiency, or electricity decarbonation. In reality, these pathways are not mutually exclusive, and Government and industry are currently pursuing initiatives which cover both.

2.6 Both the future scenarios in Figure 2.2 show that, consistent with the NPS, the UK's pathway to a successful 2050 carbon budget must still involve wider transitions outside of the power generation sector: decarbonisation of transport, industry, agriculture and the home, remains required to reduce non-power sector emissions. To enable these transitions, it is clear that the power generation sector must increase in capacity and reduce in carbon intensity on an unprecedented scale. This has been a consistent theme since the first FES was published in 2012. Importantly, both successful scenarios shown in Figure 2.2 include the commissioning of large capacities of low-carbon (solar and/or nuclear) power generation, among other initiatives to facilitate emissions reduction in other industrial sectors.

2.7 The decarbonisation of GB's electricity generation assets is therefore of vital importance in meeting the UK's legal obligations on carbon intensity.

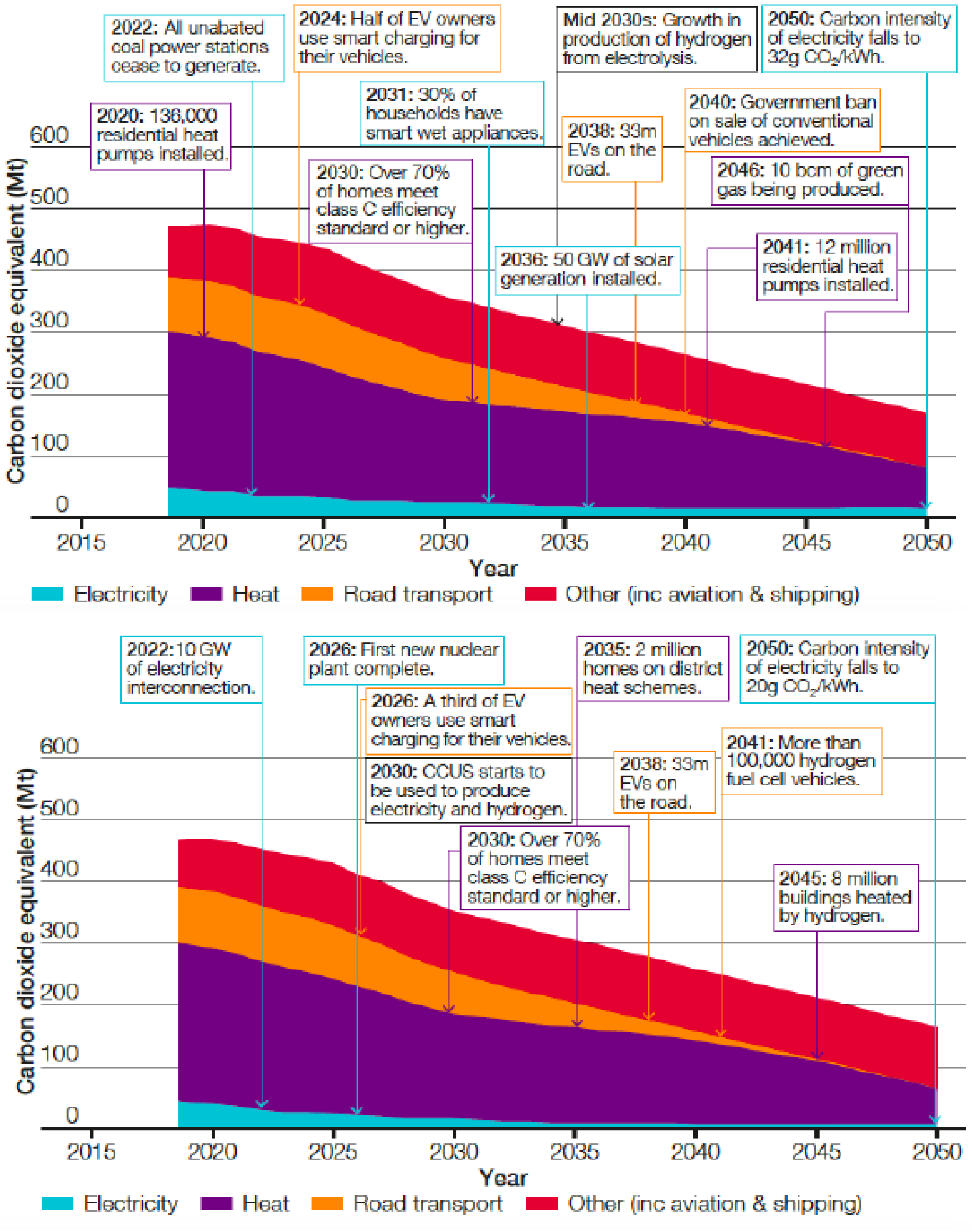

Figure 2.2: Successful pathways to 2050 commitments, showing the importance of a whole-society approach to decarbonisation and low carbon electricity generation [2, Figures 3.1, 3.2].

CHAPTER 3: CARBON REDUCTIONS TO DATE HAVE BEEN DELIVERED BY A DIFFERENT ROUTE THAN THAT ORIGINALLY ENVISAGED

> *The UK needs to wean itself off such a high carbon energy mix: to reduce greenhouse gas emissions, and to improve the security, availability and affordability of energy through diversification* [10, 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* [10, Para 2.2.11].
>
> *It is for industry to propose new energy infrastructure projects within the strategic framework set by Government* [10, Para 3.1.2].

3.1 In 2011, approximately 75% of electricity came from carbon-heavy fuels; and contributed over one third of UK greenhouse gas emissions. Since then, carbon emissions from electricity have fallen. Figure 3.1 shows how much carbon emissions from power generation in GB have fallen since 2013.

3.2 Table 3.1 shows elements of the Government's Low Carbon Transition Plan, 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. It is evident that, while none of the major initiatives detailed in the 2009 Low Carbon Transition Plan have yet delivered, carbon reduction targets for power generation are being met and this has provided a major contribution to the UK's current "on-track" performance versus its legal obligations.

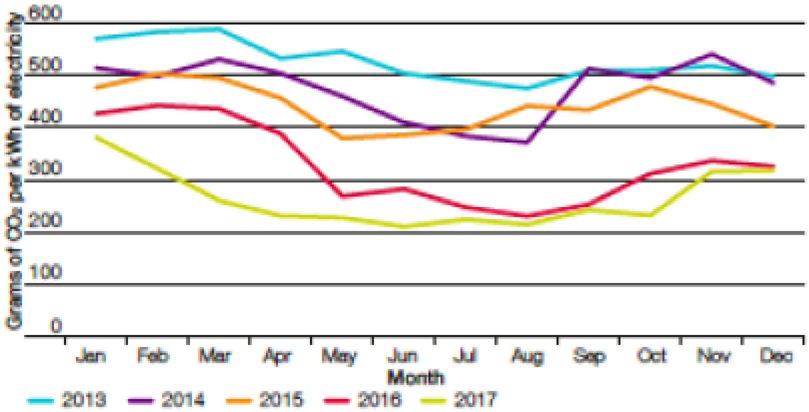

Figure 3.1: Carbon intensity of GB electricity generation 2013–2017 [2, Figure 3.3]

Initiative	Projection	Status
New Nuclear	2013: construction of new nuclear commences. 2018: first new nuclear operational	2017: HPC construction commenced, with a Commercial Operation date currently not before 2025. 2018: Government advised to permit only one more GW+ nuclear before 2025 [13, pp10, 42]. Moorside NPP construction project shelved and development company wound up. Existing nuclear stations edging closer to decommissioning.
Wave / Tidal	2014: Larger-scale wave and tidal energy generation (>10MW) starts to be deployed	2018: No larger-scale wave and tidal energy generation yet to be deployed. The second Severn Estuary / Swansea proposal was denied public funding this year
Carbon Capture & Storage	2020: up to 4 carbon capture and storage demonstration projects operational in the UK	2018: no CCS projects yet operational in GB. CCS at industrial scale remains technologically and economically uncertain
Renewable Energy Share	2020: Around 30% of electricity is generated from renewable sources	2018: Wind, solar, hydro, bioenergy accounted for 30.1% of generation for (Jan to Mar 2018). Nuclear accounted for 17.9%.

Table 3.1: Projections from 2009 for a low carbon power sector; and a 2018 status, Summarised from [7]

3.3 This has been achieved through many initiatives and circumstances, including:

1. Electricity volumes generated from coal and gas fired plants have 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 generation prior to 2016. Between 2012 and 2015, at least 11.5 GW of coal plant decommissioned as a result of the Directive. Further, in late 2017, GB announced a commitment to a programme that will phase coal out of all electricity generation by 2025. National carbon pricing ensures that coal assets have unfavourable marginal costs (see Chapter 6, Section i)) and are therefore dispatched only when absolutely necessary. In April 2018, Britain did not generate any electricity

from coal for more than three consecutive days - the longest period since the 1880s.

2. The GB's second generation nuclear fleet (9 GW) has so far continued to operate past its original decommissioning dates. Nuclear continues to provide approximately 20% of electricity demand with zero carbon emissions. But the existing plants will not go on forever; and advances in new nuclear plants to replace those existing, have been slow, uncertain and expensive. Hinkley Point C (EDF Energy / China General Nuclear Power Group), once famously predicted by developers to be operational before Christmas 2017, is now not expected to commence commercial operation until the mid 2020s. In November 2018, Toshiba, announced that "the economically rational decision [for them to make] is to withdraw from the UK nuclear power plant construction project [at Moorside], and [that they ha[ve] resolved to take steps to wind up [their UK subsidiary development company,] NuGen", year-long talks on a sale of the project having failed with both Asian nuclear giants CGN and KEPCO.

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

3.4 These three points are not surprising. Muench et al [14, p80] list the characteristics of "volatility" and "many-players" to be two significant contributors to modern energy system complexity, and consider them to hamper energy system transformations. The highly politicised nature of the power sector is such that the long-term regulatory stability required to build confidence for investors in large, long-life power plants cannot be relied upon:

> *Important regulations in the energy industry ... have not been consistent in the past. This contrasts with the rather long term planning in this industry, where capital equipment usually last 20 years or even longer.* [14, p84]

3.5 The National Infrastructure Commission (established in 2015 to provide independent, impartial advice on the UK's long term infrastructure needs) in their first National Infrastructure Assessment report [13] share their view on the major challenges in today's electricity market for large-scale non-renewable generation projects….

> *New nuclear power plants and carbon capture and storage infrastructure will not be built by the private sector without some form of government support* [13, p38]

... but go on to conclude that it is not clear what form of support is most appropriate to balance risk and between public and private sectors. While on balance sheet nuclear construction in the UK has been a mixed experience, there is limited experience of using the regulated asset base model for anything as complex and risky as nuclear. Indeed, the NIC go so far as to recommend that the Government should "*Not agree support for more than one nuclear power station beyond Hinkley Point C, before 2025*." The result: commercial procrastination leading to technological and project development delays. Neither nuclear power nor carbon capture and storage are therefore likely to play a significant role in decarbonisation before the 2030s. The consequence of our volatile multi-player market, is that, as conventional plant in GB closes, very few new conventional plants open. By the 2030s, Renewable Energy Sources ("RES") may have taken up the gap, thereby potentially rendering conventional technology redundant. The implications of this change are only now becoming clear, and will be discussed later in this report.

3.6 The role that solar has played in decarbonising electricity generation to date is transparent within Table 3.2. Solar power generation has global momentum and technical promise, especially when fully integrated.

Technology	**Jan 2011**	**July 2018**	**Projects under application**
Solar	0.0	13.7	0.0[3]
Embedded Wind	1.7	5.9	0.1[4]
Onshore Wind	3.8	5.5	7.3
Offshore Wind		7.1	25.5
Total	6.5	32.2	52.0

Table 3.2: Historical capacities of renewable generation deployment and sites under application (GW). Adapted from [8]

3.7 Solar has been an important part of UK decarbonisation to date. As such, and coupled with technological advances in scale and efficiency, solar power is well placed to continue to play an important role in decarbonisation into the future, provided suitable locations for its future deployment can be secured. CHSP is therefore an important pioneer of this stage of GB's low-carbon journey.

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[3] Includes only those projects which have made applications under the FiT programme or have received Grid Connection Agreements from NGrid (a total pipeline of less than 50MW at the time this Statement)

[4] As Footnote 3

CHAPTER 4: FUTURE DEMAND FOR ELECTRICITY IS UNCERTAIN BUT GROWING

> *It is not possible to make an accurate prediction of the size and shape of demand for electricity in the future* [10, 3.3.18].
>
> *[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* [10, 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* [10, Para 3.3.21].

4.1 The current annual demand for energy from gas and electricity in GB is approximately 1,100 TWh, with 27% in the form of electricity [2, p48]. While our total energy demand will have reduced by 2050, electricity demand is expected to grow steadily from the 2030s onwards. 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. Growth in the use of electric vehicles ("EVs") is also likely to create significant new demands on our supply of electricity.

4.2 The UK government has announced a ban on the sale of all new petrol and diesel vehicles from 2040. Innovation is bringing affordable and highly desirable low-emission vehicles to market. The UK has put leadership of transport revolution at the heart of its Industrial and Clean Growth strategies, with investment being directed into both vehicle manufacturing and grid recharging points. Transport is now the largest source of UK greenhouse gas emissions and a rapid shift to low emission vehicles will give a significant boost to the decarbonisation of our economy. Therefore, growth in the number of EVs on our roads is certain, but the trajectory of that growth is less clear. EVs are however predicted to play a major part in the future GB energy mix as a result of their energy demand requirements and potential energy storage capabilities.

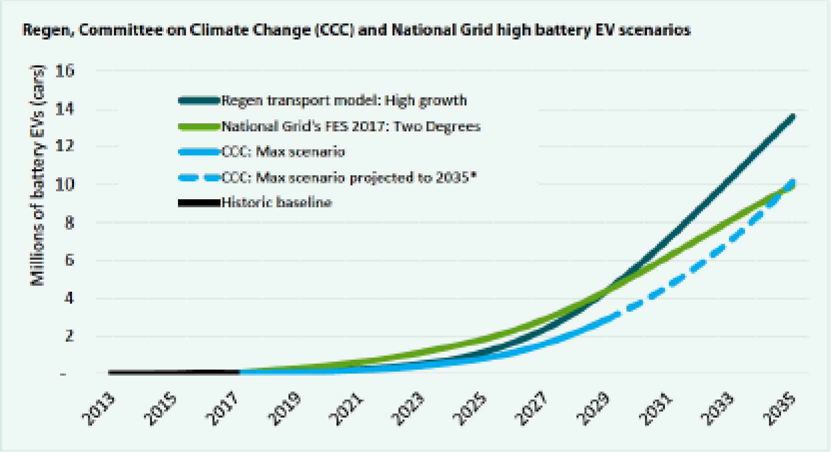

Figure 4.1: Potential growth in EVs in GB to 2035 [3, p9]

4.3 Annual electricity demand from EVs could be as much at 90 TWh [2, p76] but the daily profile of demand is much less easy to forecast. NGrid foresee the importance of Vehicle-to-Grid (V2G) charging technologies, meaning that EV owners will be able to use their vehicles to support grid balancing as well as optimise charging according to the real-time price of power. EVs therefore not only require the deployment of significant additional electricity generation capacity, but also act potentially as an integration measure for intermittent technologies, such as solar.

4.4 Finally, in order to reduce the UK's dependence on natural gas, and thereby reduce further our carbon footprint, the long-term need to diversify to low-or zero-carbon home and industrial / commercial heating, potentially through electrification, would also increase demands on the NETS. This, coupled with meeting the Government's plans for new homes (some projections are that we should be building at least 200,000 new homes a year [15, p7]) is likely to require yet more electricity generation. For every household that is supplied with electricity, an average additional burden of approximately 4MWh per year could be placed on the grid [15, p9]. Even if GB is currently able to meet its current electricity needs and share of 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.

4.5 But decarbonisation is just one of the three pillars of GB energy policy. Low carbon generation of all forms - nuclear, wind and solar included - brings with it new challenges. Our current and future energy policy and related actions must also ensure that security of supply is maintained, and that electricity is affordable for all. The next section demonstrates how solar has contributed, and will continue to contribute, to security of supply in Great Britain.

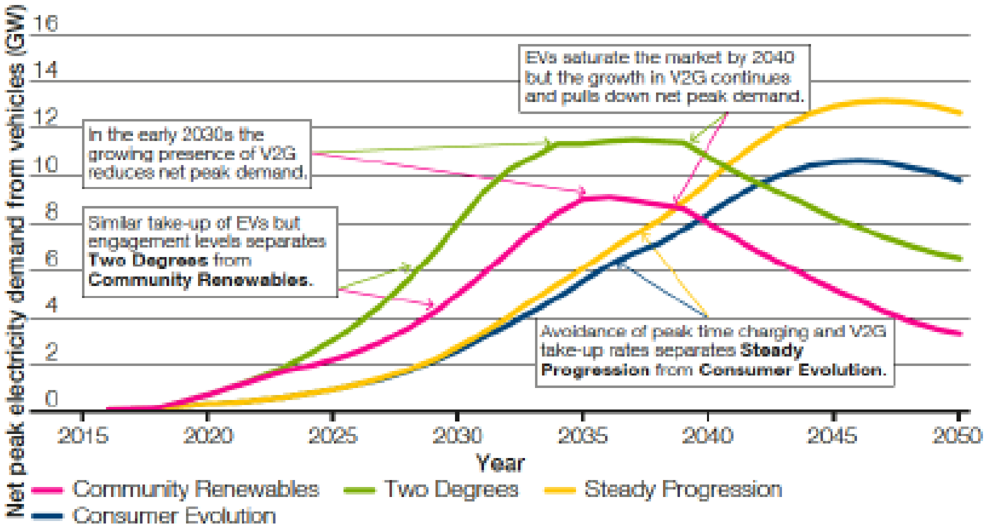

Figure 4.2: Future net peak electricity demand from vehicles [2, Figure 4.22].

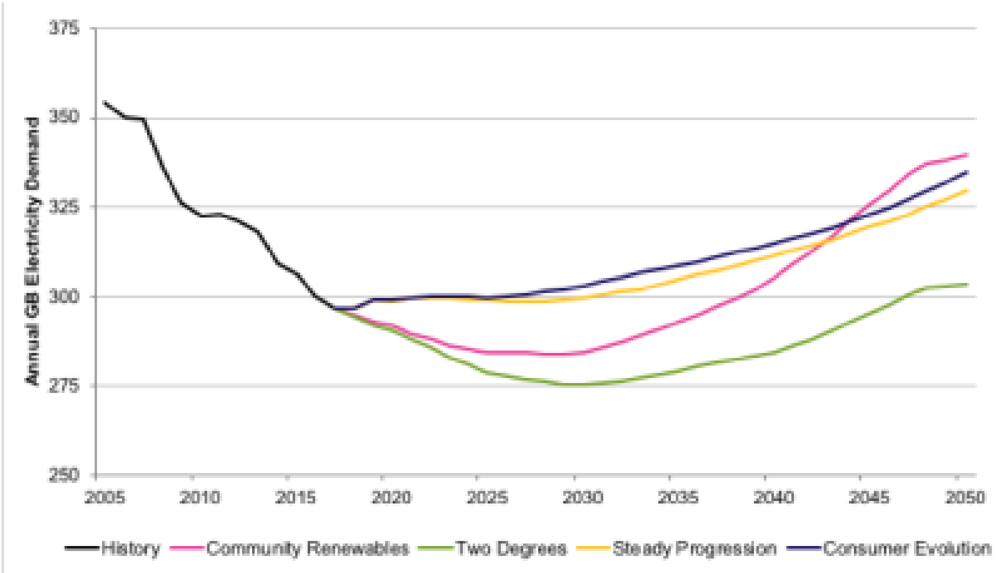

Figure 4.3: Annual GB electricity demand scenarios Adapted from [2, Tables 4.4, 4.6 and 4.16]

CHAPTER 5: DECARBONISATION CAN MAINTAIN OR ENHANCE SECURITY OF SUPPLY

> *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.* [10, 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.* [10, Para 3.3.3]
>
> *A diverse mix of all types of power generation... helps to ensure security of supply.* [10, Para 3.3.4]

5.1 'Security of supply' means keeping the lights on and has two main components.

1. Ensuring that there is enough electricity generation capacity available to meet demand; and

2. Ensuring that the quality of electricity supplied to customers falls within a narrow 'quality' band during all reasonably foreseeable operational circumstances, and is resilient during rare excursions from this band.

5.2 In this section, power systems and aspects of their operation will be briefly introduced. Challenges associated with integrating renewable generators into existing systems will be characterised, and key points on Cleve Hill's planned contribution to system adequacy and system operation are presented. Specifically:

- Through the planned installation of circa 300 - 400 MW of solar generation at Cleve Hill, CHSP will contribute to national system adequacy and decarbonisation targets;

- The diversification of GB's electricity supplies through the commissioning of a large solar asset such as that planned for Cleve Hill, provides benefits in the functioning of the NETS;

- The additional ancillary services provided by circa 300 - 400 MW of electricity storage would also be beneficial in the functioning of the NETS;

- The operability benefits of a large electricity storage asset at the Cleve Hill location are likely to be significant due to the complex network around it.

5.3 To provide appropriate context and understanding we set out in brief an introduction to a number of high-level concepts without setting out full and detailed technical descriptions.

i) An introduction to power system operation

5.4 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.

5.5 Governments define policy to ensure that there is sufficient generating capacity[5] available to meet maximum expected demand. This is called adequacy.

5.6 Key power quality characteristics (including frequency, voltage and power shape) must be controlled in order to maintain the synchronicity of all assets (customers and generators) which are connected to the NETS. NGrid 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" [16, p5]. 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 is planned at CHSP, must maintain their own synchronicity with the system.

5.7 In essence, power demand, or load, and power supply, must be balanced. This requires the right generating assets to be connected and disconnected at/from the right power levels, and at the right time. This can sometimes be at short notice, in response to emergent (fault) conditions.

5.8 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.

5.9 System frequency must also be maintained[6]. 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[7], generators which are able to provide FR will usually determine the price they would accept to provide the service.

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

[6] The NETS operates at a nominal 50 Hz

[7] Output remains the main source of generator income

5.10 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 [16, p43]. An important metric is the rate of change of frequency, ("RoCoF"). System inertia is a phenomenon uniquely important to the NETS because of its relatively low levels of interconnection to other, larger, electricity systems such as is the case, in particular, across Europe. Ancillary services are all those services which support NETS stability and operability.

ii) Connecting generators to the power grid

5.11 The electricity system in Great Britain operates at two levels: the high-voltage NETS, and the lower-voltage distribution networks. The NETS is mainly made up of 400 kV, 275 kV and 132 kV assets connecting separately owned generators, interconnectors, large demands and distribution systems. Itcurrently consists of approximately 4,500 miles of overhead line, 1,000 miles of underground cable and 350 substations. Applications for connection to the NETS are assessed through the first-come-first-served 'Connect and Manage' process.

5.12 Connect and Manage offers are given to those customers who request a connection date ahead of when the 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 which once approved allows for a connection to be made ahead of those wider transmission reinforcement works.

5.13 In the period October 2017 to March 2018, 109 connection offers were issued, of which 82 were under Connect and Manage. These 82 offers allowed generators to connect on average nearly 9 years earlier than would otherwise have been possible [17, p5].

5.14 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) require the bulk transfer of power over shorter distances and therefore may attract either capital and operational cost benefits, or both, when compared to generation connections far away from where the power is needed.

5.15 A recent view from NGrid is that £83 million should be allocated this year for NETS development projects that have a total value of £3.8 billion over their lifetime [5, p9]. These costs will ultimately be recovered from consumer bills. As such it is in the interests of consumers to maximise the use of existing transmission connections, which by virtue of their prior development are less likely to require significant wider reinforcement works than may be required by connections in new locations.

5.16 Decentralisation in electricity generation has been driven by the growth in smaller scale renewable generators, such as solar and wind farms. These do not connect directly to the high voltage transmission system, but rather to the medium or low voltage distribution systems [2, p34]. Currently nearly 30% of all generation capacity is connected to the distribution networks, and this number is foreseen to grow to between 35% and 65% by 2050 [2, Figure 3.6]. Because distribution networks operate at a lower voltage, generators which connect to these system 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 than would be required directly into the NETS.

5.17 Distribution networks were not originally designed to incorporate plentiful electricity generation connections. By virtue of their role in transferring power from the bulk NETS to businesses, built facilities and houses, many are located in built up areas, or at least 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 can have 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 larger-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 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.* [10, Para 3.3.29]

5.18 Grid connection is an important aspect of generation project timescales and costs. The selection and utilisation of efficient grid connections in beneficial locations allows projects to come forwards at lower cost of generation and lower overall cost to consumers.

iii) Transmission connected generation assets integrate to electricity systems more transparently than distribution connected generation

5.19 Generating assets are not only connected to transmission systems. Many smaller generators are linked either to customer connections or distribution networks; these are called distribution-connected generators. Some of the most relevant differences between transmission and distribution generator characteristics are listed in Table 5.1.

	Transmission	**Distribution**
Description	Connected to NETS at high voltage.	Connected to distribution network at lower voltage (distributed) or into end-use customer systems (micro). Collectively, these are named distributed generators
Size	Typically large (100's of MW)	Typically small (<30 MW) to very small (single KW)
Technical compliance	Required to conform to regulations and standards for critical service provision and response characteristics	Minimum technical thresholds are more relaxed but increasing as a result of system interconnection requirements
Dispatch	Centrally dispatched with known reliability by the Electricity System Operator	Locally dispatched with unknown reliability outside of the control of the ESO
Measurement	Metered to a high degree of accuracy	Largely unmetered

Table 5.1: Characteristics of transmission- and distribution-connected generators

5.20 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 system demand level which transmission-connected assets must meet. The connection level of an asset impacts the benefits it brings to bill payers. Three major considerations are:

1. Transmission connected assets provide visibility of their expected generation to the national energy market and Electricity System Operator, NGrid, 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 NGrid, in both planning and operational timescales to ensure that power demand and system security needs are met with the least possible cost.

2. Transmission connected assets are required to be available for instruction by NGrid. They are required to participate in NGrid's Balancing Market, making their flexibility available (at a transparent and cost-reflective price) to ensure that supply and demand remain balanced at all times. By contrast, distribution assets are not required to do this, although voluntary balancing markets are currently under development for smaller assets at the distribution level.

3. While transmission systems have historically been designed to allow for the connection of large generating assets, distribution systems have not. Connecting generation assets of any meaningful size to distribution systems is becoming more difficult and more expensive (see Chapter 6 for more detail).

5.21 Electricity consumers, either directly or indirectly through their energy bills, pick up all of those costs related to market inefficiencies, economic decision making, asset investments, balancing actions and transmission and distribution system enhancements.

iv) Solar supports system adequacy and is necessary to meet decarbonisation targets

5.22 Historically generation assets in GB have been predominantly coal, oil, gas, nuclear or hydro-powered. They have been dispatchable assets, meaning that their output and operational schedules are controllable: electricity on demand. Generally therefore capacity utilisations[8] have been high, and electricity demand has been met by a lower total installed generation capacity. Figure 5.1 shows a scenario from NGrid on how generation capacity may evolve between 2030 and 2050 to meet a growing electricity demand, and a decreasing carbon budget. Clearly, as GB closes in on its legal decarbonisation targets through the installation of more renewable generation capacity, total installed capacity rises in proportion.

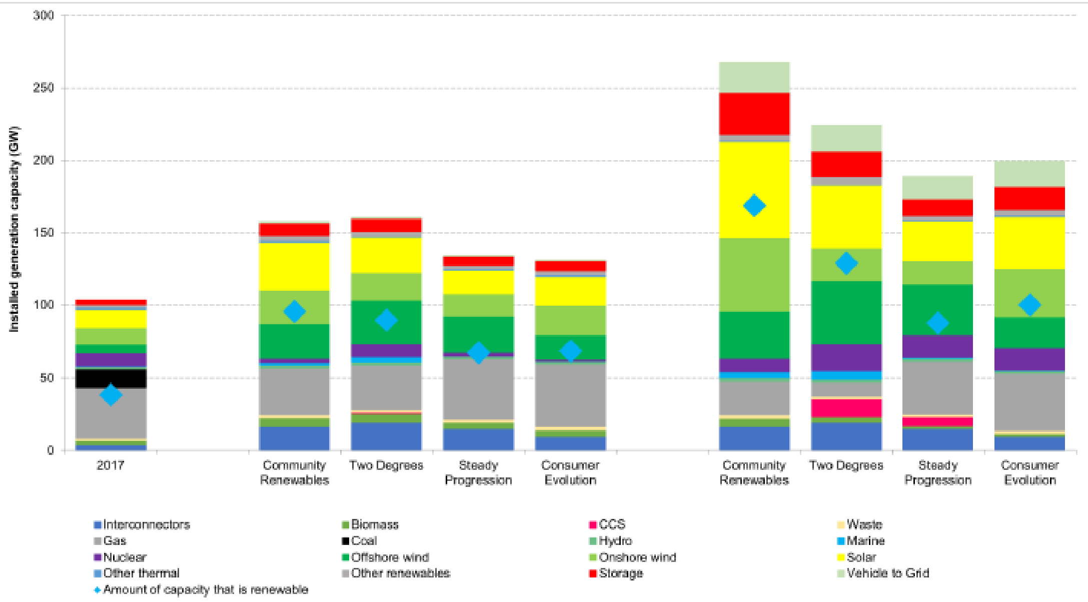

Figure 5.1: Generation capacity by technology type and amount of renewable capacity for 2030 and 2050 [2, Figure 5.1]

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

5.23 It is important to understand there are many future scenarios; some meet the carbon budget, some miss it. Some incur increased costs for consumers, others provide efficient and effective solutions. However there are two consistent themes.

5.24 Firstly, that

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. [18]

5.25 And secondly, that decarbonisation reduces capacity utilisation; and therefore available grid connection capacity grows in strategic importance as decarbonisation advances. The effect of decarbonisation on capacity utilisation (showing actual values from 2011 through to 2018, and a forecast range for 2050) is shown in Figure 5.2.

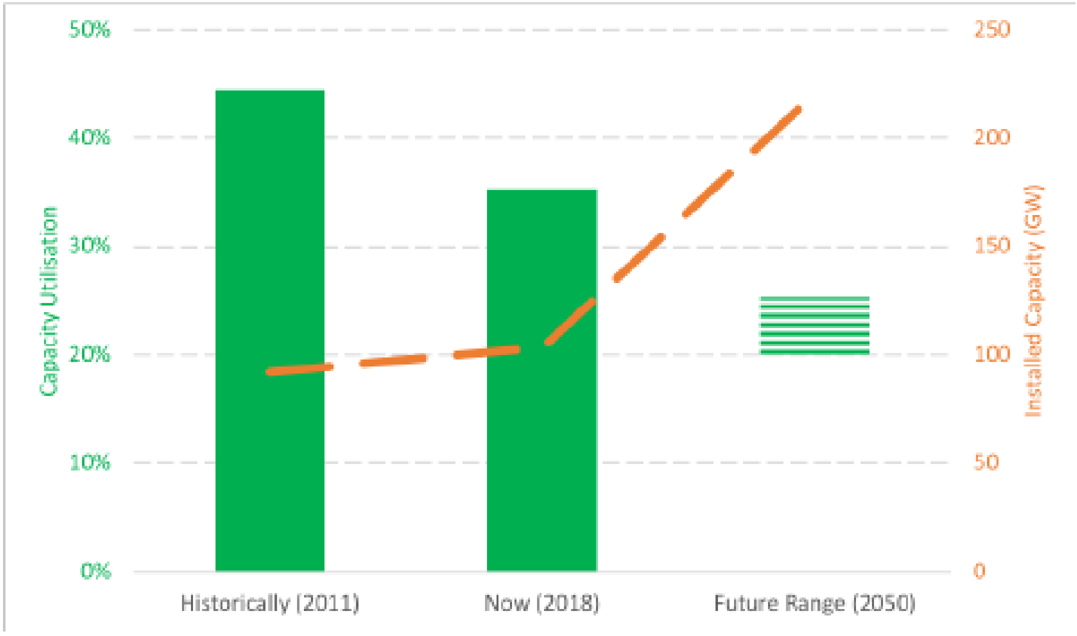

Figure 5.2: Installed generation and Capacity Utilisation for 2011, 2018 and 2050, Adapted from data in [2]

5.26 NGrid's analysis shows that scenarios which meet legal decarbonisation targets lie at the lower end of the capacity utilisation range, i.e. in order to meet decarbonisation and adequacy requirements, a greater installed generation capacity in GB will be required. While the total requirement for capacity build-out could decrease by reverting renewable generation back to fossil fuel generation, (thereby decreasing the total requirement for capacity build-out), legal decarbonisation targets would become more difficult, if not impossible, to meet. Figure 5.3 shows overall GB electricity generation carbon intensity under a NGrid scenario which meets the 2050 legal requirements, and also by substituting a future projection of solar generation capacity over and above 2018 actuals (at 0 gCO2/kWh), for additional gas capacity (at 300 gCO2/kWh).

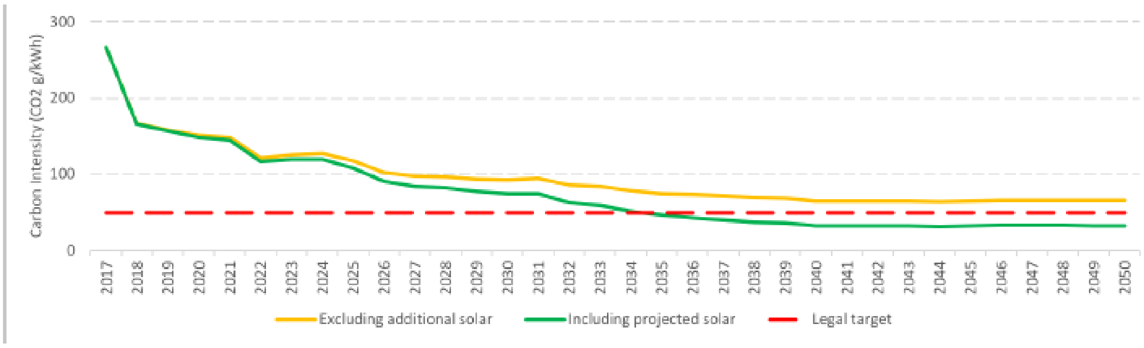

Figure 5.3: The effect on carbon intensity, of removing additional solar generation from the future GB solar mix (adapted from [2])

5.27 The conclusion is clear: if total installed capacity in GB is artificially limited, then legal decarbonisation targets are unlikely to be met without other high-density low-carbon generation (for example coal or gas with Carbon Capture and Storage ("CCS"), or nuclear power) being brought to market. However, the NIC conclude from their analysis that CCS will only become useful for de-carbonisation of the electricity generation sector in the 2040s and beyond, when decarbonisation and adequacy challenges should already be largely on track. Therefore CCS will be too little, too late, and as such "it does not make sense for electricity consumers to subsidise the development of carbon capture and storage, since it will not benefit them in [the] future" [13, p43]. GB's nuclear future may follow a similar, though potentially less severe, theme.

5.28 Currently adequacy is managed through the Capacity Market. In return for capacity payments, eligible assets agree to generate at or over a minimum commitment (their "de-rated capacity") whenever NGrid (subject to a prescribed process) determine additional generation output is required in GB in order to "keep the lights on." As an independent affirmation of the contribution the proposed combined solar plus storage asset at Cleve Hill would make to system adequacy, it should be noted that:

– Batteries are already recognised for their contribution, and are eligible to participate in the Capacity Market;

– Solar already participates in other highly volatile electricity markets with capacity mechanisms (e.g. Ireland, and parts of the US);

– The decision has been made by Government to consider the inclusion of solar power into the Capacity Market [19].

5.29 Critically therefore, low carbon generation is significantly important to the UK's decarbonisation efforts, and as a consequence, available network connection capacity must be utilised in GB as fully as possible in order to reduce the risk to meeting legal decarbonisation targets with the minimum incremental cost and footprint impact to consumers.

5.30 Low carbon generation exists in many forms though, and it is now important to demonstrate the role solar power will play in ensuring adequacy of supply as part of a diverse portfolio of generation capacity in GB.

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

5.31 As described in Table 5.2, a long-standing challenge to the ability of renewable generation to play a significant role in electricity supply relates to the uncontrollable nature of the weather. There will be times when the wind won't blow, and there will be times when the sun won't shine. There may be times when neither the wind blows nor the sun shines, but these are fewer and further in-between. By measuring the capacity utilisation of a set of generating assets over a month, as shown in Figure 5.4, it can be shown that a diverse supply mix, of both wind and solar, has a more stable capacity utilisation over the course of a year, than a portfolio of either wind or solar alone. Solar stands on its own, and stands stronger when deployed with wind power as part of a generation mix. Indeed, "Solar costs are similar in structure to wind ... There are also system costs from its intermittency, but the predictability of supply is much higher and roughly coincides with the daytime demand peaks ... [solar's] intermittency has considerable predictability" [20, p193]

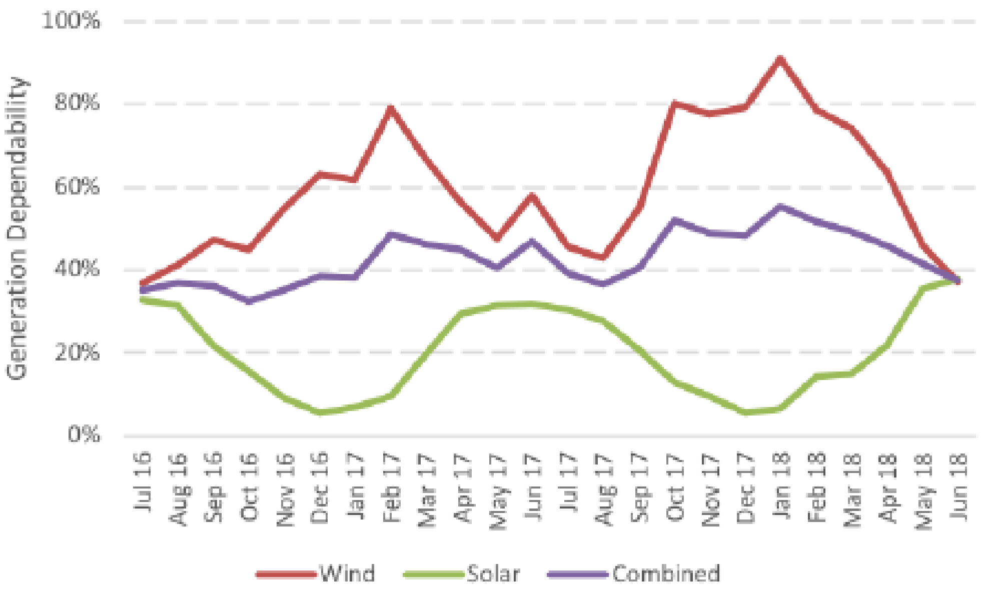

Figure 5.4: Generation dependability for GB's wind, solar and combined portfolios

5.32 Stable capacity utilisation is important, because it relates to the reliability, and therefore ability to depend on, forward forecasts of generation outturn.

5.33 At the macro level, greater reliability of generation outturn allows for a lower requirement for (fossil-fuelled) backup plant (the “troughs” in Figure 5.4 are less pronounced), without creating excess generation. Excess generation may require curtailment and economic inefficiency (the “peaks” in Figure 5.4 are also less pronounced).

5.34 During the summer of 2018, a weather-induced “wind drought” turned a 10% year-on-year increase in wind generation capacity into a near 20% reduction in output. Thankfully, a “record breaking” solar output helped fill the supply gap without forcing dirty coal stations to generate. Experts said that the way solar highs coincided with wind lows showed that both technologies were needed in the switch to green energy: Environmental measurement firm Vaisala, said: “Often wind and solar technologies are played against each other, but the reality is that a diverse portfolio ... will be the solution to long-term variability of this nature.” [21]

5.35 Therefore, it can be concluded that the inclusion of solar into a more diverse Renewable Energy Source (“RES”) mix will reach a required level of generation adequacy with a lower total installed capacity, than one which relies on just one RES technology. Clearly, this also has economic and carbon reduction benefits for GB.

5.36 However intra-day and half-hour to half-hour changes in generation output require a different integration measure, electricity storage, to help meet decarbonisation and security of supply requirements. Here electricity storage - especially in the form of the battery storage assets included in the plan for CHSP - demonstrate their potential importance.

vi) The benefits of renewable generation are further enhanced by integration measures

5.37 Muench et al conclude in their work that due to the rise of renewable generation, the “stability of energy transportation systems [is] at risk” [14, p80]. Further, that politicised incentives for industry-led low-carbon investments may go some way to meeting the aim of decarbonisation, yet may also introduce a risk to system co-ordination and function. Ueckerdt et al [9, p2] describe from an analytical basis the complexities that wind and solar variability may bring to power systems. These complexities can be categorised as described in Table 5.2.

Complexity	**Description**	**Implication**
Uncertainty	Weather forecasts incur an inherent unpredictability bringing uncertainty to both demand and supply sides of the power balance equation.	Power cannot be stored; therefore more near-term actions will be required to balance the power system as renewable generation capacities increase.
Local Specificity	Renewable assets must be built to complement the local environment, in order	A localised preference for most suitable technologies will emerge, introducing local issues

	to maximise yield.	to national transmission systems; an additional management complexity
Variability	While weather forecasts incur uncertainty, the weather itself is also variable.	Over timescales of hours, days, weeks or seasons, generation from renewable assets may be very different yet demand and supply must be balanced, with implications for reserve and conventional plant

Table 5.2: Complexities associated with wind and solar variability in power systems [9, p2]

5.38 Uncertainty may manifest in that the level of the demand or supply of power may be much higher, or much lower, than was expected at any point in time. 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, however both upward and downward regulation must also be considered in order to protect the system against emergent imbalances. This implies the need for "integration measures"' to work alongside renewable generators.

5.39 An example of local specificity is that South East Britain has better potential for plentiful solar generation because of its high irradiance levels than the West Coast of Scotland, which may be better suited to wind generation. Darwin showed that for biological systems, variation and diversity provides strength. The same is true for energy systems, in that a system consisting of diverse intrinsic asset risk profiles is less susceptible to extreme conditions than a system with homogeneous intrinsic asset risk profiles. This is demonstrated in Chapter 5, Section v). The local specificity of power generation technologies may therefore introduce a degree of weakness into local power systems, implying the need for greater interconnection of that system with other areas, or greater local ancillary service provision to maintain wider system strength.

5.40 Variability is best described by the difference between summer and winter power demand. Some variability may therefore be broadly forecastable. However, the traverse of a weather system, through an area with significant renewable generation installed, may introduce very localised and time-bound variations in generation from solar PV or wind assets. In order to match demand with supply in all but the most inconceivable situations, flexibility such as that provided by storage assets will become increasingly important.

5.41 Grubb discusses the integration of RES and their likely effect on electricity transmission systems in his 1991 paper [22]. He foresaw that capacities of renewable generation[9] will not be limited; and therefore that "proper management" of those capacities (alongside any remaining conventional capacities) must be carried out in order to maintain a stable electricity system.

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[9] Especially wind and solar generation

5.42 In foreseeing a need for maintaining the quality of electricity supplies, Grubb identifies important considerations for system operation[10], and explains how an increase in renewable generation influences each one. Ueckerdt et al conclude that “all integration challenges [of RES into existing power systems] increase with [their] penetration” [9, p9]. Identifying and mitigating system ancillary services shortfalls, are two important considerations for future system operability, made more complex by a lack of planning [14, p87]. Grubb sees the critical issue as being the determination of how important each ancillary service becomes in a future energy system, and how capable the generation assets connected to that system are to provide that service. In other words:

– Policy makers should seek advice on whether future energy systems are capable of maintaining their own stability through the provision of sufficiently available and reliable ancillary services; and

– Investors in renewable energy assets may consider correlated investments in assets which “clean up after themselves” in relation to smoothing the integration of their assets into wider electricity systems.

5.43 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” [13, p40]. If they are not, others may do it for them (and potentially at a greater cost to the end consumer).

5.44 It is clear that electricity from the sun is only generated when the sun shines; and from the wind, when the wind blows. Consumer demand is not solely driven by sunny or windy weather, therefore energy generated from these sources needs to be stored when it is being generated, and released when it is required, in order to be of maximum benefit to consumers, and to maximise decarbonisation and security of supply performance. High RES electricity systems benefit from integration measures which help mitigate the challenge of having power available for use when it is needed, not when it is generated, therefore dealing with the three complexities described in Table 5.2. For every additional megawatt-hour (“MWh”) of renewable energy which can be stored and released when needed, a corresponding MWh of (predominantly) fossil fuelled energy will be displaced from the grid[11].

> *There are a number of other technologies which can be used to compensate for the intermittency of renewable generation [i.e. integration measures], such as electricity storage, interconnection and demand-side response, without building additional generation capacity. Although Government believes these technologies will play important roles in a low carbon electricity system, the development and deployment of these technologies at the necessary scale has yet to be achieved. The Government does not therefore consider it prudent to solely rely on these technologies to meet demand without the additional back-up capacity.* [10, Para 3.3.12]

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[10] rate of change of frequency; system operational control and fault containment; and reserve operation

[11] An explanation of why the displaced power is predominantly fossil fuelled is included in Chapter 6, Section i)

5.45 The activities associated with integrating renewables into the GB electricity system will increase with their penetration [23, 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, NGrid's System Operability Framework [24] describes the dynamic behaviour characteristics for a high-RES network. Plant operation may be impacted upon by these characteristics, unless integration measures are employed to limit their impact. In high-RES networks:

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

5.46 Some system integration and operability needs are national, e.g. frequency, or flexibility services. Others are local, e.g. voltage or reactive power. The System Operability Framework also describes two related concepts: system inertia, and system short circuit level.

a) System inertia and rate of change of frequency ("RoCoF")

5.47 NGrid foresee a significant decline in GB system inertia, 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 30-40% [23, Figures 1.2, 1.3]. With the expected closure or reduced running hours of many thermal plants, much system protection must be obtained in the form of synthetic inertia through frequency response services. Crucially, while system inertia is a physical property of a synchronous power plant which, once synchronised, is independent of its generation output, power electronics assets such as solar plants are not able to provide inertia. Synthetic inertia is a clever electronic alternative to natural inertia, but synthetic inertia does not conform to the same physical rules as inertia. Synthetic inertia is provided by the immediate and significant discharge of power to prevent an extreme frequency dip. Therefore in the future, as renewable generation grows and the provision of inertia from fossil plant reduces, more synthetic inertia will be required to maintain security of supply. Batteries are fully capable of providing synthetic inertia services. If operated alongside a solar generation asset, as is proposed at Cleve Hill, the combined portfolio has the potential operational capability to be able to make up for inertia services which a thermal generating plant would otherwise have provided.

5.48 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. Batteries will be well placed to provide synthetic inertia, frequency response and reserve services, thereby providing an effective countermeasure to high RoCoF.

5.49 Cleve Hill's location is unique, sandwiched between interconnectors to and from Europe, and the high demand of London and the South East. Growth in interconnection to mainland Europe would sustain the area's already significant power flows, and require management of bi-directional power flows (potentially with quick directional changes). Inertia and frequency management services provided by the planned on-site battery storage assets will be highly beneficial to GB network stability, especially where they have the opportunity to be recharged with solar-generated electricity.

b) Short circuit levels and voltage dips

5.50 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[12], and levels are expected to fall in GB as renewable capacity increases. Critical system variables[13] may therefore enter emergency or unstable states more easily, more frequently, and potentially for longer periods in the future [25, Figures 31, 32].

5.51 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 may experience a wide system fault in future years.

vii) The growing benefits of electricity storage as an integration measure for renewable generation

5.52 Thankfully, and importantly for the development of large solar generation such as that planned at Cleve Hill, integration measures are making significant technology and cost and capability advancements. New operability regimes are also successfully keeping the lights on and the power consistently flowing as RES share increases. Also, significant investment is being made in the advancement of electricity storage technology as an integration aid for renewables and other generation and consumption technologies, and costs are approaching competitive levels at the utility scale.

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[12] "High" short circuit levels are more resilient than "low" short circuit levels

[13] Such as voltage or power flow

> *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* [20, p68]

5.53 Globally, electricity storage, particularly batteries, has already achieved significant advances in technological ability and economic performance. Batteries are becoming bigger, better and cheaper. As this happens, the utopian view of a wholly-renewable electricity system comes perhaps closer. An industry-sourced projection of future battery costs is included in Figure 5.5, and global experience in the installation of large-scale batteries, facilitated by technological advance as well as cost reductions seen to date, is included in Table 5.3.

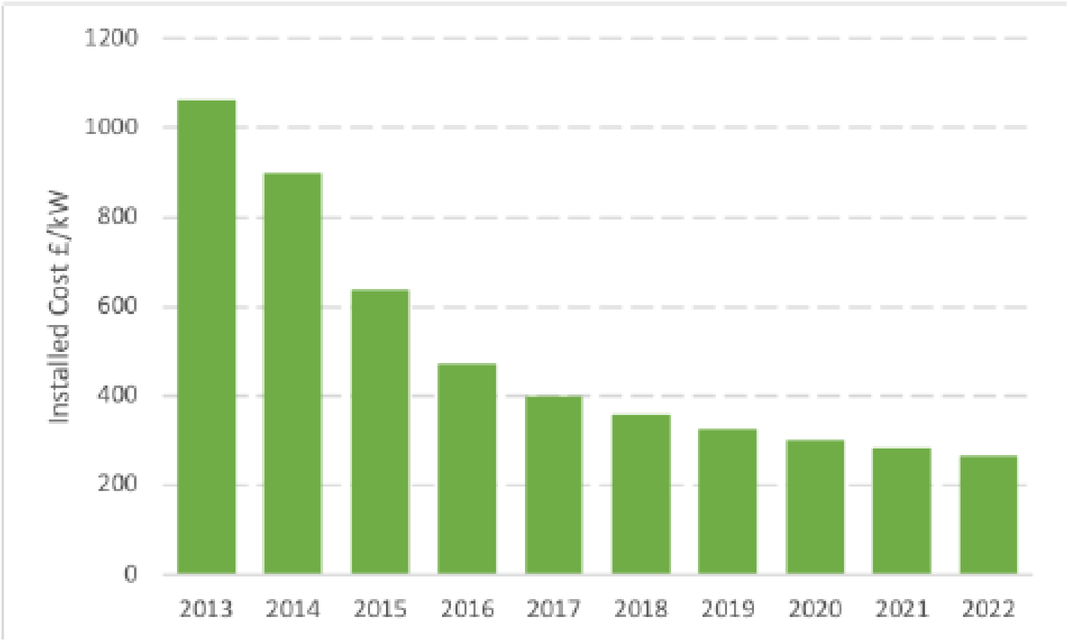

Figure 5.5: A projection of future battery costs, adapted from [4]

Power (MW)	**Energy (MWh)**	**Manufacturer**	**Year**	**Location**	**Status**
40	5	ABB	2003	USA	Delivered
40	20	Toshiba	2015	Japan	Delivered
100	129	Tesla	2017	Australia	Delivered
100	400	AES Corp	2022	USA	Planned

Table 5.3: A selection of global experience in large battery storage installations [NSR analysis]

5.54 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 [26, p3]. Through Government and industry actions, GB is pursuing a number of projects which aim to deliver some of these benefits, although it is currently lagging behind the global leaders in battery storage. A 2015 report of energy storage assets in GB lists 27 installed energy storage projects, with a total capacity of around 33GWh [27, p16], a large proportion of this capacity is delivered by pumped storage (hydro). A current status of the larger battery storage assets in GB demonstrates firstly that since the 2015 report, progress has been made in delivering large battery storage projects, and secondly that market participants have ambition to deliver larger projects still. A list of notable projects and their current status, has been included in Table 5.4.

Lead party	**Capacity**	**Location**	**Status**
Ørsted	20	Liverpool	Expected late 2018
RWE	100	Tilbury	Pre-planning
Statera	50	Pelham	Operational Dec 2017
EDF Energy	49	West Burton	Operational June 2018
Centrica	49	Swindon	Expected late 2018
Drax	200	North Yorkshire	Pre-planning

Table 5.4: The status of other notable battery energy storage projects in the UK [NSR analysis]

5.55 Critically, batteries are also increasingly well placed to deliver a number of ancillary services for NGrid, and this is of growing importance in GB. Environmental Regulations and Government policy require the closure of all GB's coal generation assets before 2025. Economic pressures, resulting from both shifts in the global gas market and changes to structural pricing in the GB electricity market[14] are also causing the operational profiles of coal and gas assets to shift. These two points leave these traditional providers of ancillary services less available to provide, and/or less competitive in the provision of, such essential services on an ongoing basis.

5.56 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 a solar plus storage asset at Cleve Hill, are listed in Table 5.5.

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[14] See Chapter 6, Section i) for a further explanation.

Service	**Explanation**	**Applicability**
Trading	Selling energy at market prices	The backbone of solar investment cases. Storage reduces energy market risk as output can be directed from lower-price to higher-price periods. This helps projects come to market
Balancing Mechanism	Being available to NGrid to balance supply and demand at delivery	Solar can provide downward flexibility, but at the 'cost' of carbon-free energy. Solar plus storage provides both upward and downward flexibility, potentially without 'losing' any low-carbon energy. This can be dispatched over varying timeframes, from milli-seconds to hours, depending on available technology
Frequency Response	Changing output minute-by-minute to help maintain system frequency at the statutory level of 500 Hz	
Reserve Operation	Changing output over minutes and hours to rebalance supply and demand following a fault or other unforeseen event on the electricity system	
Reactive Power	Locational service which allows power to 'flow' from source to destination	A mandatory service for all transmission-connected assets, delivered by solar and/or storage assets as part of the DC to AC conversion
Inertia	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 able to provide inertia, but storage devices are capable of providing 'synthetic inertia' which will be important as the traditional sources of inertia - large fossil fuelled assets - close before 2025
Black Start	A locational service which would help 'turn back on the lights' if an event caused the national electricity system to fail	Solar alone is not capable of providing Black Start; standalone storage is. Co-located solar plus storage may be able to provide a more robust Black Start service than standalone storage
Constraint Management	Changing output in response to local energy supply, demand and transport issues, to ensure locational adequacy at all timescales	Solar can provide important downward constraint management services, but solar plus storage can provide services in both directions. Because Cleve Hill is located close to GB's points of interconnection to mainland Europe, bi-directional constraint management may be an important service in the future
Infrastructure Costs	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	Both solar generation and electricity storage can help with reducing new infrastructure requirements, although their benefits may be higher if co-located than if located separately.

Table 5.5: Solar-plus-storage system contributions to the GB electricity market including ancillary service provision

5.57 Battery energy storage assets provide significant benefits in both decarbonisation and security of supply, and these benefits increase when they are operated as part of a portfolio of renewable generators. Batteries are capable of:

- Capturing "free" energy when it is not needed and dispatching it when it is needed;

- Helping renewable generators capture attractive market prices thereby reducing energy market risk associated with renewable generation projects; and

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

5.58 While the co-location of solar generation assets with energy storage assets is not essential for either asset to make a significant contribution to the future operation of the NETS, Table 5.5 demonstrates that the co-location of those assets enables additional beneficial operational capabilities to be accessed for system benefit. Co-location is especially beneficial where connections are to the transmission, rather than to the distribution network, because the combined solar-plus-storage asset is required to meet certain planning, notification and service obligations (see Chapter 5, Section iii)).

5.59 Other benefits of co-locating storage with solar include shared connection and EPC costs; shared operating and maintenance resources; increased capacity utilisation; and reduced energy losses, all of which reduce the overall cost of generation to the consumer.

viii) Forward infrastructure plans and operability needs of the NETS in the Cleve Hill vicinity

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

5.61 CHSP will connect into the NETS via the existing Cleve Hill substation, located in the South East of England. Figure 5.6 shows the location of the substation and the surrounding NETS. CHSP will share Cleve Hill substation with Phase I of the London Array offshore wind project (630 MW). Phase II of London Array has been cancelled, leaving circa 300 - 400 MW of transmission system entry capacity available and currently unused.

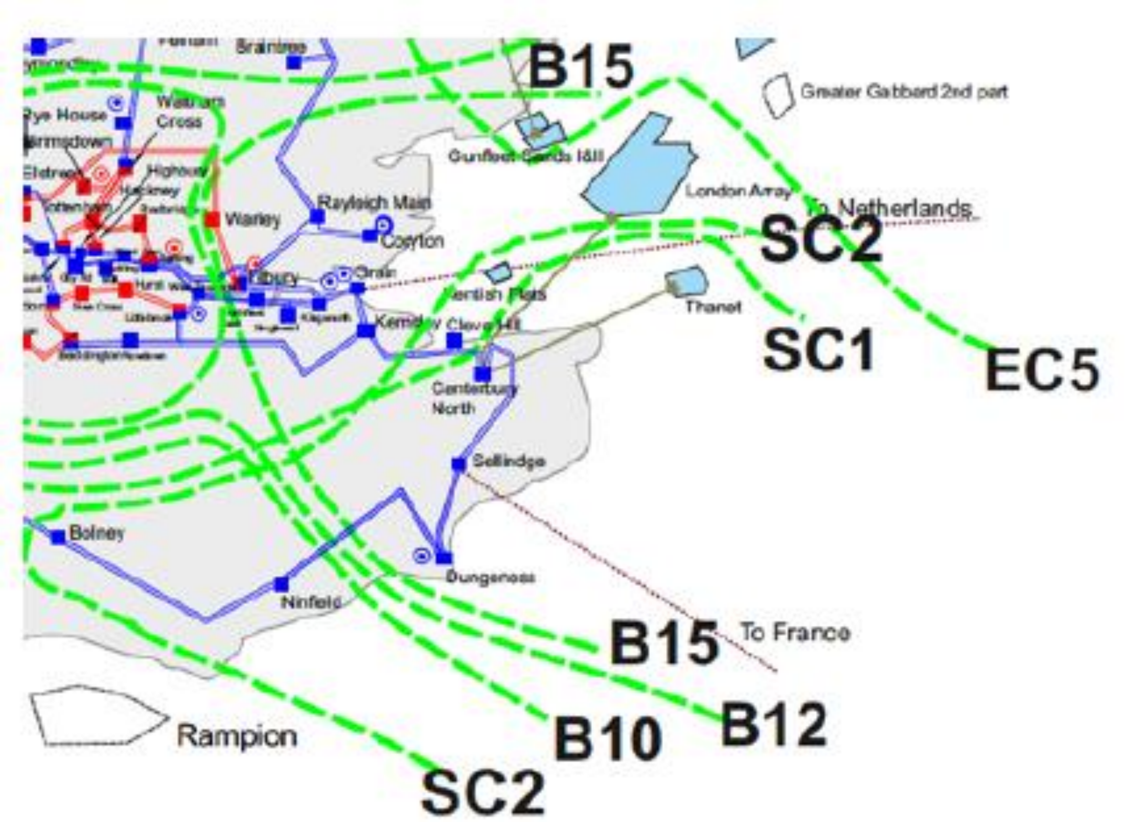

Figure 5.6: The NETS in the vicinity of Cleve Hill [5, Appendix A]

5.62 Cleve Hill sits near three NETS operational boundaries: B15; SC1 and SC2. These boundaries are not hard, nor physical, but are areas within which NGrid characterise power flows.

– B15 encompasses southern Essex, Eastern Kent and elements of Greater London;

– SC1 covers the South Coast, therefore is sandwiched between interconnectors to/from Europe, and the high demand of London and the South East;

– SC2 covers Kent and East Sussex, and is strongly characterised by the presence of existing (and future) interconnectors, a long, coastal transmission line loop and a corridor of generation along the Thames estuary.

a) Network topography

5.63 The South of England is an area of transient power flow, bordered by three other areas with important possible implications for future power flow and operability factors.

– East England (East Anglia), with between 5.0 and 16.5 GW of new nuclear and wind connections possible over the next decade but flat demand, will become a significant power exporter. Unchecked, this could cause heavy circuit loading, voltage depressions and stability issues in the nearby areas through which the excess power would flow;

– The continent is currently connected with a combined 3.2 GW of HVDC to France and Holland. Interconnections to Europe are set to increase significantly over the next 10 years, including 4.9 GW to Belgium, France and Germany connecting within the SC2 boundary area, and a further 2.4 GW within the SC1 area, all before 2022. Growth in interconnection would sustain the area's already significant power flows, and require management of bi-directional power flows (potentially with quick directional changes). Power flows are, at present, predominantly uni-directional (from the continent);

– London, the regional demand centre, is expected to retain low levels of generation and therefore relies heavily on surrounding NETS circuits to draw power in, particularly at times of high winter demand. With an increased reliance on interconnectors, power flows from the North through London to the continent, and vice-versa, compound constraint management in and around the London area, particularly on the Kemsley to Canterbury transmission wires, i.e. past the Cleve Hill substation.

5.64 NGrid are developing plans for the future management of each of these three regional outlooks, a key input to these plans will be the potential capabilities of any assets planned to connect into this area in the coming years.

5.65 Within the local geography, there are four Grid Supply Points ("GSPs") at Bolney, Sellindge, Ninfield and Canterbury. GSPs connect the NETS to the local distribution network (operated by UK Power Networks, ("UKPN"), within which significant additional capacities of distributed and renewable generation are expected to connect in coming years. Both UKPN and NGrid, through their "Power Potential" project (formerly called "TDI 2.0"), are seeking innovative solutions to increase import / export capacity of the South East networks from the rest of the transmission system and overcoming the significant challenge of maintaining a constant balance between local supply and demand by making best use of embedded flexibility and services to strengthen and support the NETS.

b) Local network operability considerations

5.66 The transmission system around Cleve Hill must remain capable of managing three complications for system operability. The capabilities of any assets planned to connect in this area are likely to influence NGrid's local system management and investment plans. The complications are:

- **Circuit overloads**

5.67 Power flows past Cleve Hill are currently of order magnitude 1.0 GW. NGrid have forecast these to grow to 3.5 GW by 2023/24 (due to interconnectors).

This level of flow may become challenging to the current circuit ratings (See Table 5.6). Upgrades / re-conductoring may be required to minimise curtailment actions on connected generators and / or interconnectors. Being part of the South East transmission loop, power flows past Cleve Hill may need to be managed at times of normal operation, and in the event of a transmission system fault. Planning for upgrades to the lines and substations to the North and West of Cleve Hill has already commenced, and additional generation contracted for connection below the SC2 boundary may place additional burden on the region.

Season	**Spring**	**Summer**	**Autumn**	**Winter**
Rating (MVA)	2868	2475	2868	3100

Table 5.6: Future forecast power flows past Cleve Hill substation [5, Appendix B, Data Tables]

- **Voltage management**

5.68 The long overhead lines in the South East have potential to cause local voltage management issues, especially following a fault on the Kemsley to Canterbury stretch. Such a fault could force power to travel a long way from its supply points (e.g. interconnectors on the coast) to its demand (London) by having to route via the Southampton / Portsmouth area. Voltage control is applied locally, through local reactive power provision. Dynamic voltage support measures are already being taken around the South East loop for post-fault reactive stability. However, voltage management during normal operation is also of growing importance in the Kent area, particularly at times when demand is low and generation is high: sunny weekend afternoons, for example.

- **Stability issues**

5.69 Stability is a description of the dynamics of a power system under normal or fault disturbances. A stable system is one where faults take time to propagate and are therefore manageable by well-understood measures and within planning timescales. High power flows, with possible changing directions and a likely scarcity of conventional generation, may make the SC2 boundary area prone to instability, particularly at times of low local generation but high transient power flows. NGrid 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.

5.70 The relationship between the location of new or existing generation assets, the transmission systems around them, and overall system strength remains complex. By their presence, these assets support short circuit levels, therefore the location of those assets, particularly ones which are able to provide system services (see Table 5.5) will be important in areas of high NETS power flows. The South East of England (among others) is fast becoming a complex part of the GB transmission network. It is an area of interest under both the security and economy assessment criteria, and with significant levels of local power demand. The commissioning at Cleve Hill of a circa 300 - 400 MW solar generation asset would contribute towards both assessment criteria and reduce the requirement for bulk transmission of power in from other locations. Ancillary service provisions such as those available from solar and / or storage assets, as described in Table 5.5) are also likely to become increasingly important in this location into the future to contribute to the proper functioning of the local NETS.

ix) A conclusion on system security

5.71 Innovation in generation must not be allowed to challenge security of supply, but a lack of innovation in generation must not be allowed to risk achieving decarbonisation targets. Few market commentators and participants have faith in the ability of a single new technology to bridge the energy gap. Many commentators however are active proponents of solar's future, 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.* [20, p66]

5.72 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.

5.73 In light of that observation, the following conclusions are made.

- 300 - 400 MW of solar generation at Cleve Hill will contribute to national system adequacy and decarbonisation targets;
- Solar generation at Cleve Hill would enable NGrid to increase the level of dependence they can place on expected renewable generation outturn both nationally and in the area local to Cleve Hill;
- The services which (by virtue of its intended scale and direct connection arrangements with the NETS) are mandatory for CHSP to provide, are likely to be beneficial to NGrid in securing the NETS in the area local to Cleve Hill;
- The ancillary services available from an energy storage asset connected to the NETS of circa 300 - 400 MW, would likely be significantly beneficial to NGrid for managing energy balance and system security

- – Co-locating an energy storage asset with a large solar generation asset at the Cleve Hill substation would also provide a uniquely beneficial asset which will support the ongoing operation of this busy area of the NETS.

5.74 A solar generation asset, operated with co-located battery storage, supports decarbonisation; supports adequacy, and provides much needed system services in support of system operation. Crucially though, any such asset must meet a third Government policy objective: that of economic supply.

CHAPTER 6: LARGE SOLAR GENERATION ASSETS ARE ECONOMICALLY EFFICIENT IN GB

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

> *Most renewable energy resources can only be developed where the resource exists and where economically feasible.* [11, Para 2.5.36]
>
> *The [Secretary of State] should accept that ... operators may not know the precise details of all elements of the proposed development until some time after any consent has been granted* [11, Para 2.5.30]

6.2 This section discusses broad principles of economic efficiency, by explaining how the GB electricity market operates and demonstrating how competitive solar assets are because of recent gains in experience, technology and scale. By using a simple financial model, it is also demonstrated how scale impacts the cost of electricity from solar generation assets, and therefore provides a logical argument as to why it is in the interests of the GB consumer for the CHSP planning application to be consented at the maximum potential generating capacity.

i) An introduction to pricing electricity in the GB power market

6.3 In the liberalised GB energy 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[15]. Each day is broken down into 48 half-hour periods ("Settlement Periods") and power is traded over these periods, or multiples thereof (up to months or seasons ahead). Typically, solar power plants have low or zero marginal costs and therefore generate as much as they are able to, when they are available, (i.e. whenever the sun is shining). Because of their intermittent nature, they also tend to trade on the near-term power markets, therefore much of their impact on power price is felt in the few days close to delivery. Thermal and hydro plants have higher marginal costs (related to the cost of the fuel they are converting into that additional MWh of power), therefore they require higher market price signals in order to generate. They may also trade power and fuel further ahead in order to hedge their income. All generators produce active power (MWs), and to balance the electricity system, the active power generated must meet the system load at all times. If solar plants 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.

6.4 This market mechanism is illustrated in Figure 6.1. The blue line, increasing from left to right along the x-axis, represents the marginal cost of generation in GB at each level of demand. As demand increases, more expensive supply must be scheduled into the market. This is represented by the three red lines. At a mid-level of demand, the solid red line crosses the blue line at about £45/MWh. This becomes the price of power. If demand falls (e.g. to the left-hand dashed red line), less plant is required to run to meet demand, therefore the marginal cost of the most expensive asset required to run to meet demand is

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

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 (here, to about £65/MWh).

ii) Solar power reduces the market price of electricity

6.5 Critically, the blue line in Figure 6.1 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 solar assets are brought to market, the blue line within the red ellipse (around a zero marginal cost of power) will stretch horizontally, and as a result, the blue line lowers for all higher levels of demand. The marginal cost of production to meet demand over these periods will therefore be lower and as a result, the traded price of power will be lower. By running this type of analysis over every settlement period over the future trading horizon, it is possible to derive a view of the price of power for the next week, month, quarter or season. The conclusions are the same though: increasing the capacity of solar assets in GB reduces the price of power. This fact has been empirically corroborated by Energy Institute of Haas in their 2018 paper, “Setting with the sun” - a quantitative analysis of the impact of deep solar penetration in California, an historically conventional, but now strongly RES, generation market. They conclude 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 half-decade in California [28, p26]. Given that GB (along other countries) is following California in their up-take of renewable generation, including solar, it seems reasonable to conclude that the same is already, or about to, happen here.

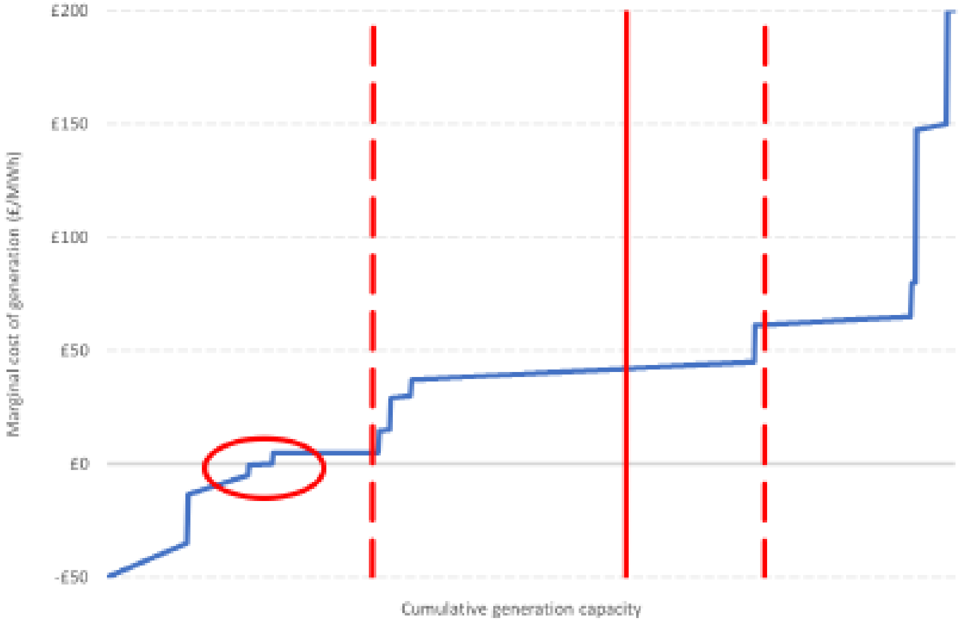

Figure 6.1: Representative marginal cost stack for a future GB electricity system

6.6 Balancing the system is a commercial service in GB, meaning that (although Balancing Mechanism participation is compulsory for transmission-connected assets like CHSP) it is for the generator to decide whether, or how, to respond to a near-real-time instruction to raise or lower power output. Such requests are particularly suitable (i.e. operationally practical and economic) for fast-response plants (e.g. batteries), and plants which have a low marginal cost, or opportunity cost, of generation (e.g. solar generation assets).

6.7 When generated power is higher than system load, generators must be scheduled off. Generally this happens commercially through market signals. In extreme cases, price taking generators[16] may be curtailed, meaning they are required to provide downward flexibility to achieve system balance, possibly (in extremis) disconnecting from the system. Downward flexibility which is ready to be called upon is called foot room. “At the same time, there must be sufficient generation part loaded, ready to pick up for a generation loss; known as headroom” [29, p184]. Assets which receive subsidies are expensive to curtail in balancing markets, while unsubsidised assets may be significantly cheaper. This has knock-on effects on consumers and the mechanism is described below.

6.8 Assets built with subsidies generally receive those subsidies as an additional income per unit of output. If an asset is instructed to reduce its output as part of a balancing action, although its energy market revenues are protected under GB Balancing rules, it foregoes its (sometimes significant) subsidies. Subsidies available for RES are currently decreasing, historically they have been realised at a high level in particular for wind generation. Therefore, a subsidised asset offering downward flexibility to NGrid must (through commercial prudence) recover these missed subsidies if it is required to reduce its output. This is done by offering its downward flexibility to NGrid at a price which compensates it for that subsidy. NGrid end up paying the asset to reduce its output, and that cost is passed back (ultimately) to consumers.

6.9 Further, a renewable asset, operated with an electricity storage facility, may also be able to discharge and provide an upwards flexibility, or store the unrequired energy, rather than export to grid, when ‘turning down’ generation, and dispatching it later into the market when it is needed. This will have the effect of reducing the cost of power for a subsequent settlement period. The relative predictability of solar generation assets makes them particularly suitable for this type of market optimisation.

6.10 Because Cleve Hill is planned to be a transmission connected, unsubsidised solar-plus-storage asset, it will participate in the GB Balancing Mechanism, and will be able to offer its flexibility at prices which are attractive for consumers.

iii) Levelised cost of solar generation

6.11 The market mechanisms described in Chapter 6, Section ii) only work of course, if solar projects come to market. This only happens if developers

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[16] i.e. Those that are generally generating whenever they are available, such as solar

believe they are able to make reasonable returns for their investors. 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. Critically this allows all forms of generation to be compared with each other on a consistent basis. Lazard [6], albeit focussed mainly on the US market, is a globally recognised source of such comparative analysis. The most recent revision of their analysis, published in November 2017, illustrates two important points.

1. Large-scale solar PV generation is cheaper than small-scale solar PV generation; and

2. Large-scale solar PV generation is now super-competitive against other conventional and renewable energy sources

6.12 This comparison is presented in Figure 6.2, with the range representative of different complexities of technical solution. The higher values, coloured tan in the Figure, represent illustrative "... plus storage" costs.

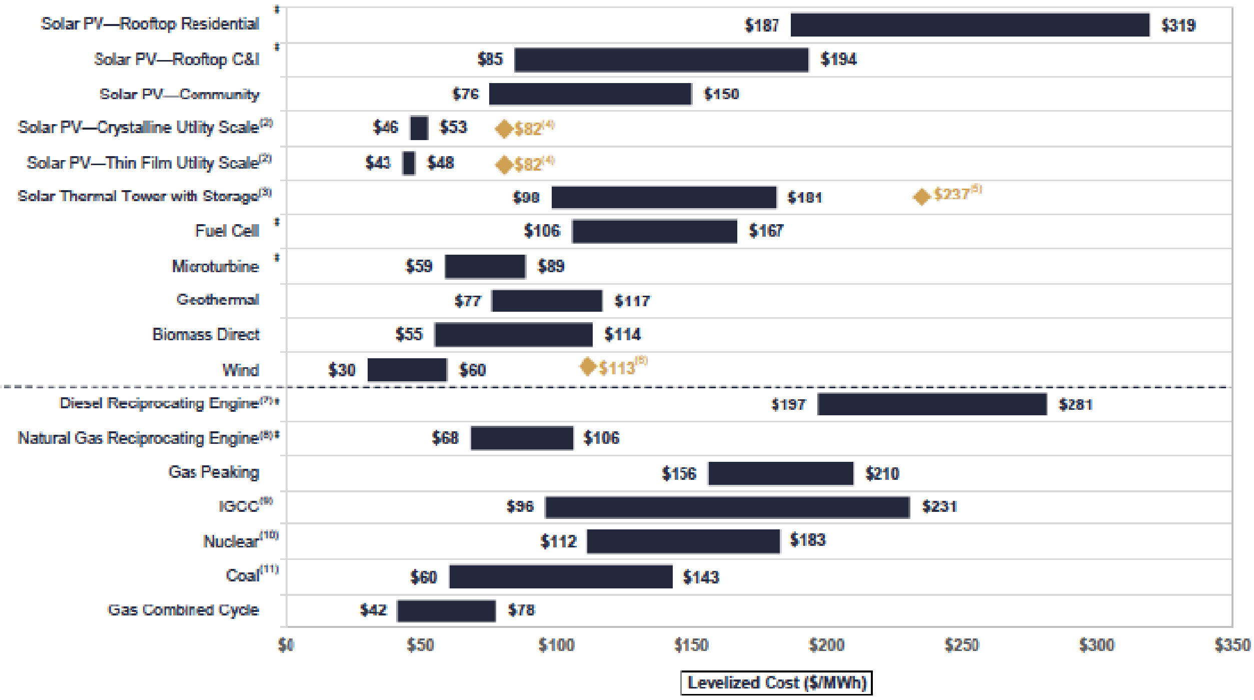

Figure 6.2: Unsubsidised levelised cost of energy comparison [6, p2]

6.13 International trends are aligned. Solar is getting cheaper, and bigger. 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 ... Extra flexibility, which includes technologies such as storage, interconnection and demand side response, is a low regrets investment which reduces estimated total energy system costs by between £1-7 billion per year on average between 2030 and 2050.* [13, p39]

6.14 This view is corroborated by Aurora Energy Research, who completed an analysis of renewable generation and integration costs, and presented a strong case for the further build-out of renewable capacity. Their analysis [30, p18] showed that substantial further solar penetration is possible and affordable: security of supply can be maintained, with up to 40GW of solar by 2030. Intermittency costs at this level do not provide a strong argument against the further build out of renewable generation, especially when set against the substantial year-on-year cost decreases being exhibited by both wind and solar and the benefits of a renewable low carbon power source versus fossil fuel alternatives. Furthermore, should battery costs fall to £100/kWh (Tesla, a major battery manufacturer, claim to be within grasp of this level already), intermittency costs could be significantly lower.

6.15 Solar costs are driven by capital infrastructure, development and integration costs, and lifetime O&M. Economies of scale and technological advances have reduced the costs of solar panels, increased their efficiencies and extended their useable lifetimes. Development costs have also reduced as efficiencies in the build process have been captured through prior experience. This fact is demonstrated by Lazard in Figure 6.3.

Figure 6.3: Historical reductions in the LCOE of PV solar generation [6, p10]

6.16 Industry-sourced data confirms Lazard's findings. The factors which have already pushed global prices down - such as risk mitigation, cheap land, efficient financing, shorter development timelines and a general commitment to tenders from national governments - will continue to shape prices in emerging markets. This data confirms the view that solar costs are falling such that the technology is now economically viable without subsidy in a growing number of markets. As a consequence, the global solar market is growing, and utility-scale project costs (inferred through industry reports on the values of their long-term export contracts) are falling in line with expectations.

6.17 The number of national markets with a tendering or auction scheme has nearly doubled since the second half of 2016: there are 61 currently, compared to 32 just 2 years ago. Solar is pushing out its geographic boundaries as yields increase and costs decrease. The number of markets considering solar schemes has more than doubled, from 14 to 36 in the second half of 2016 and has continued to grow since then. Maturing markets including Saudi Arabia, the United Arab Emirates, and, most recently, Mexico have also recognised utility scale solar as an important part of their future energy mix.

6.18 In January 2018, in the US, a median bid price of $36/MWh (£28/MWh) was achieved for power from solar-plus-storage projects. That improved upon the previous price of $45/MWh (£35/MWh) for a solar-plus-storage project in 2017 in a PPA between Tucson Electric Power and NextEra Energy.

6.19 In March 2018, the U.S. Energy Information Administration said costs to install utility-scale solar systems declined 10% to 15% annually from 2010 through to 2016. GTM Research reported in August 2018 [31] that "highly competitive tenders will see cost compression, and there is still room for costs to fall further" ... that unsubsidised solar auction prices have dropped an average of 74 percent since 2009 and have fallen consistently in the last 2 years ... and that "prices could reach a low of $14.70 per megawatt-hour in a 2022 scenario with optimal financing and technology costs".

6.20 In GB, recent activity has seen solar PPAs being signed at close-to market rates but with a firm floor over 25 years, of £26/MWh.

6.21 GTM Research also projects that global average power-purchase agreements for tendered solar will reach $40/MWh by 2022 or sooner, from the current level of $60/MWh. Combined with the independent analysis from Lazard, this suggests that solar is already the cheapest power in the world, even without a direct subsidy.

6.22 The relevance of a PPA price tag is that developers need to cover cost and make adequate returns at contracted revenues; therefore a fall in PPA value, must be underpinned by a reduction in project (technology and financing) costs. Integration costs, including grid connection costs, however remain a significant input into solar project costs. Lazard takes no account for the potential lack of grid connection capacity or network connection costs for installations. Meaning, just because a technology looks cheap, does not mean that enough can be built to solve all energy problems. But if opportunities exist to optimise project economics, where LCOE, grid connection and land availability align to create attractive propositions, then more solar projects can be built out, and all market participants (including consumers) gain more from lower costs of electricity.

6.23 Also in GB, the country's first unsubsidised solar generation asset, at 15 MW, will be built in Buckinghamshire by Spring 2019, providing private wire power to industrial customers. As part of a private wire offering, the asset will not be required to compete for revenues on the wholesale market with other forms of generation. Instead it will make its returns by offering its customers power at a price which shares the benefits of their avoidance of the additional costs charged to customers for taking power from the NETS. Cleve Hill, by connecting to the NETS, will be required to export its power into the GB wholesale power market and be as competitive as it can be against other forms of generation throughout its operational life, by delivering power at the lowest possible cost. The next section describes how this will happen at Cleve Hill.

iv) Size is important for utility-scale projects in GB

6.24 This report makes the case for growth in electricity generation capacity in GB to meet decarbonisation obligations, and the important role of large-scale solar generation within that growth. 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 economic benefit to the consumer of utilising all of the available grid connection capacity at Cleve Hill substation, versus using part of that capacity and making up the shortfall in other locations.

a)Solar project economics

6.25 Solar projects incur fixed costs: project development costs, site infrastructure and grid connection costs, to name a few. Other costs vary according to the amount of capacity installed. These include 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. The modelling approach which has been adopted for the purpose of illustrating the relative costs of different solar assets, and thereby evaluating the potential benefits or dis-benefits associated with utilising different amounts of the available grid connection capacity at Cleve Hill, is described below.

- Development costs, both fixed and variable, are included at the beginning of a project cash flow, for different capacities of solar generation;

- Revenue streams are included for the life of the project, based on a levelised price of power and expected generation output;

- Ongoing operational costs, based on industry benchmarks, have been included for the life of the project;

- A project cash flow model has been created, which allows the price of power to be set in order to deliver a 5% return on capital - an "institutional"-type return;

- In the interests of simplicity and transparency, tax and capital allowances have been excluded from this model;

- The implied price of power is then used as the measure of comparison between different scenarios.

6.26 This is a simple measure of the unit cost of power generated by the solar asset, similar to LCOE. Different scenarios can be modelled, for different size assets, and a comparison made of the illustrative unit costs of generation for those different scenarios. The storage element, although it is desirable and provides added benefits to the project, has not been included in this analysis. The financial data inputs have been sourced from CHSP's project plans and industry experience of mature, smaller-scale projects. It has been validated as far as possible with known industry benchmarks and industry experience.

6.27 The scenarios are described as follows:

1. 350 MW at Cleve Hill
2. 245 MW at Cleve Hill + 3 x 35 MW elsewhere (four locations)
3. 140 MW at Cleve Hill + 6 x 35 MW elsewhere (seven locations)
4. 10 x 35 MW elsewhere (ten locations)

6.28 These scenarios have been chosen to illustrate the benefit GB consumers will receive from a generation asset which maximises available capacity at Cleve Hill, versus alternative development options which deliver the same installed capacity over different configurations of installations.

b)Cost assumptions

6.29 Development costs of projects of NETS connection size (the smallest scenario modelled in support of this Statement is 140 MW) have been assumed to be similar. This modelling considers the Cleve Hill site specifically, therefore development and fixed costs of construction remain the same for the larger asset across all 4 scenarios listed above. Development costs include legal and planning costs; site surveys and preliminary works (including access and services); grid connection costs; project management and the procurement of items associated with these activities.

6.30 Projects smaller than 50 MW, which are more likely to connect to the Distribution network, will require the same activities to be carried out, although projects which fall below the consenting limit may require less legal and planning support, and being significantly smaller in footprint, will require smaller preliminary works.

6.31 Grid connection costs vary from location to location, especially as smaller assets are more likely to connect to the 33 kV distribution network than the 400 kV NETS.

6.32 Larger projects also take longer to construct, meaning that capital is spent potentially years before first revenues are received. Shorter development and construction timeframes incur less interest and/or time-value-of-money costs.

6.33 Construction costs also have fixed and variable elements. Project management, worker amenities and security costs have been assumed to be fixed for large and small assets. Variable costs include civils and generation equipment (panels, mounts, wiring and transformers). Opex costs also scale with the size of the asset.

6.34 Smaller assets have been assumed to conform to the same cost basis, but incur a 5% procurement inefficiency cost for equipment and services to the build. Fixed cost elements for the 35 MW[17] assets have been costed separately, but no assessment has been made of the likelihood of a suitable site (with comparable irradiance as Cleve Hill) being available or suitable for development. The data

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[17] GB currently has 37 solar installations of over 25 MW in capacity. The average capacity of these sites is close to 35 MW

used for modelling is based on NSR's recent market experience, and has been included in Table 6.1.

Parameter	> > 50 MW	< < 50 MW
Development Costs	£64k/MW	£67k/MW
Grid Connection	£3.0M	£1.5M
Fixed Site Capital Costs	£4.0M	£250k
Variable Capital Costs	£560/MW	£588/MW
Operating Costs	£12.5k/MW/Yr	£13.1k/MW/Yr
Development & Construction Period	5 years	1 year

Table 6.1: Development and construction cost assumptions for large and small solar installations

c)Larger consolidated solar assets can be delivered at lower costs for developers, and consumers

6.35 The analysis allows direct comparisons to be made of the lifetime unit costs of generation at the sites. The results are shown in Table 6.2. Each scenario models the same installed capacity, and has assumed the same annual output. The conclusions are clear. As the total capacity is split over more installations, the capital spend increases; the LCOE increases; and the IRR (a measure of project attractiveness for investors) reduces.

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Installed Capacity (MW)	350	350	350	350
Annual Output (TWh)	0.31	0.31	0.31	0.31
Number of installations	1	4	7	10
Total Capital Spend (£M)	233	248	263	247

Lifetime Unit Cost of Generation (£/MWh)	62.67	67.55	72.45	70.92

Table 6.2: Weighted average lifetime unit cost of generation for 350 MW solar in 4 different configurations

6.36 For so long as electricity generation is a liberal and commercial market, larger single installations are likely to receive investment in preference to opportunities comprising of multiple smaller assets. The potential additional costs associated with inefficient installation configurations can be calculated. Scenario 4 would cost over £8/MWh more than Scenario 1 for the same capacity and output[18]. This additional annual incremental cost, totalling £2.6M/Year, would need to be recovered from the electricity market, costing consumers £90 M over the life of the project[19]. The margins for unsubsidised solar power investors are thin, and will be likely to remain that way. As more solar is built out, it will cannibalise its own revenues, requiring further decreases in capital costs to make subsequent projects economically viable. A study by the Energy Institute at Haas demonstrated this fact in their August 2018 paper, "Setting with the Sun":

> *Compared to the 2,000th MW of solar capacity installed in the market, the 10,000th MW of solar capacity earns 52% less revenue* [28, p23]

6.37 Further, as developers have no mandatory minimum capacity targets, reducing project risk and/or maximising project returns, are important strategies for their future success.

The benefits of economies of scale are more transparent when the economics of standalone assets at Cleve Hill are analysed without "make up" installations in other locations. These are shown in Table 6.3. Critically, while a larger installation at Cleve Hill would generate more low-carbon electricity over its lifetime than a smaller installation at	**Scenario 1**	**Scenario 2**	**Scenario 3**

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[18] Based on the difference in Lifetime Unit Cost of Generation between Scenario 4 and Scenario 1.

[19] Calculation: £70.92 - £62.67 = £8.25 / MWh. Multiply this by 0.31 TWh (or 310,000 MWh) each year for an assumed 35 year project life to derive £90 M.

the same location, this analysis shows that it does so also at a lower total cost of generation.**Parameter**			
Installed Capacity (MW)	350	245	140
Annual Output (TWh)	0.31	0.22	0.12
Number of installations	1	1	1
Total Capital Spend (£M)	233	174	115
Lifetime Unit Cost of Generation (£/MWh)	62.67	66.11	74.74

6.38

*Table 6.3: Weighted average lifetime unit cost of generation for different capacities of solar at Cleve Hill.*A further interesting conclusion from this analysis, is that the incremental costs of increasing the capacity of an existing asset, are lower than the costs of installing the same capacity at a new location. Critically, the underlying delta cash flow between a 245 MW and 350 MW installation, has a higher IRR than the IRR of the cash flow for each option individually[20]. Therefore it appears it would always be more attractive for investors (and be of greater benefit to GB consumers) to increase the installed capacity at Cleve Hill (this can be generalised to all solar installations) rather than to build out the same capacity at a new but different location. As described in Chapter 6, Section ii), ultimately GB consumers would pay the price of inefficient solar investment, therefore it is beneficial for GB to encourage the development of large solar assets, which maximise use of available grid connection capacities, in order to deliver lowest cost solar for our commercial market.

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[20] Calculation: Two cash flows are modelled, for a single 350 MW asset, and for a single 245 MW asset. The delta cash flow between them represents the additional capital costs, revenues and operational costs associated with building out an additional 105 MW at the 245 MW site, critically without any additional grid connection costs. It can then be shown that the LCOE of the incremental asset is lower than the LCOE of either larger stand-alone asset, by approximately £8/MWh.

> *The [Secretary of State] should consider that the need for any given proposed new connection or reinforcement has been demonstrated if it represents an efficient and economical means of connecting a new generating station to the transmission or distribution network.* [10, Para 3.7.10]

6.39 Therefore it is important to demonstrate that (at least in the case of Cleve Hill) the further utilisation of an existing grid connection with spare capacity, is more efficient and economical than the development of a new connection. Reassuringly, Ofgem, the regulator for gas and electricity markets in GB, are aligned in their thinking. As they recently stated, making the best possible use of the available grid connection capacity is important for our own, and future, generations:

> *As the energy landscape transforms, our energy grids have got to adapt with it. In the past if new generators wanted connections or demand grew, the solution was simply to build more infrastructure. We will still need some new grid capacity in future, but we must make better use of what we have got already. If we don't then the costs to consumers of managing these changes will go up and there will continue to be delays in getting renewables and other technologies such as storage connected to the grids.* [32]

v) A conclusion on economic efficiency

6.40 The main points in summary of this chapter of the statement are as follows:

- Solar power reduces the market price of electricity by displacing more expensive forms of generation from the cost stack;
- Unsubsidised assets, if coupled with electricity storage assets, are able to offer economically efficient balancing services to NGrid, benefiting consumers by displacing more expensive, subsidised assets;
- Due to technological advances, solar power is now economically viable in GB without subsidy;
- Solar power is economically attractive against many other forms of conventional and renewable generation;
- Size remains important, and maximising generating capacity across available grid connections increases the likelihood of funding being secured for projects, as well as delivers enhanced benefits to consumers through bringing power to market at the lowest cost possible.

CHAPTER 7: IN SUMMARY AND IN SUPPORT OF THE CASE FOR SOLAR AND ENERGY STORAGE GENERATION ASSETS WHICH UTILISE GRID CONNECTION AVAILABILITY AT CLEVE HILL SUBSTATION

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

1. Solar offers a cost-effective contribution to decarbonising the GB electricity sector. This is important to reduce power-related emissions, but also to provide a future generation portfolio which is capable of supporting the decarbonisation of transport and heat sectors, through electrification;

2. As part of a diverse generation mix, solar contributes to improving the stability of capacity utilisations among renewable generators. Further, when connected at the transmission system level, solar can and will play an important role in the forward planning and real-time balancing of electricity supply and demand in GB;

3. Solar, when coupled with electricity storage, can offer many important ancillary services to the System Operator, supporting the integration of its renewable profile into the GB energy system;

4. Internationally, solar generation assets are getting bigger and cheaper, providing a real-life demonstration that size and scale works for new solar, and providing benefits to consumers in the process. Other conventional low-carbon generation (e.g. tidal, nuclear or CCS coal) are struggling to gain traction in this highly competitive market, raising questions as to whether they will be able to make any meaningful future contribution to the GB energy mix at all. Decarbonisation, a UK legal requirement, cannot be allowed to fail;

5. Maintaining adequacy through the deployment of renewable assets requires relatively more capacity than a fossil fuel equivalent, therefore the effective utilisation of available grid entry capacity is crucially important both now and into the future. Grid connections are becoming more scarce, and more expensive, in GB. Maximising installed generation at each connection location progresses decarbonisation, improves the attractiveness of projects for developers and supports consumers by delivering power at lowest possible cost.

7.2 These five general benefits of solar generation in GB also apply specifically to the Cleve Hill project:

1. The CHSP development proposes a substantial infrastructure asset, capable of delivering large amounts of low-carbon electricity - enough to power over 90,000 homes each year - alongside many important system services;

2. Cleve Hill’s proposed grid connection is at a unique position in the NETS, being close to London (a centre of heavy demand), near the many interconnectors to mainland Europe, and near other large transmission connected wind generators. Its contribution to local system adequacy and stability may be vitally important into the future;

3. CHSP’s connection to the NETS means that it will be required to play its part in supporting NGrid manage the national electricity system. This includes participating in mandatory balancing markets as well as providing visibility to the GB power market of its expected generation. This means that the zero-input cost solar power it will produce, can be forecasted and priced into future contracts for power delivery by all participants, thus allowing all consumers to benefit from the market-price reducing effect of low-marginal cost solar generation;

4. Diversity in supply is also important to meet demand; and this large unsubsidised asset, proposed to connect to the NETS at Cleve Hill, is valuable because of its contribution to both system adequacy and power quality;

5. Integration measures have been designed into project proposals. A large solar farm, such as that planned at Cleve Hill, is capable of capturing massive amounts of zero-input cost, low-carbon energy from the sun. With an array of batteries installed as part of the same generation asset, this energy can be stored and dispatched to the grid whenever and however it will be needed most by consumers. The batteries will also be capable of providing important locational and system-wide system services, made more useful because they will be backed by a non-grid source of electricity;

6. Maximising the installed capacity at Cleve Hill is to the benefit of all GB consumers, and the solar industry generally. A larger project delivers power at a cheaper price, and makes the project more attractive for investors - so improving its chances of coming to market, and providing confidence to subsequent developments. Further, making full use of the available connection capacity maximises the scale of ancillary services available to NGrid from the asset to increase, thereby making its contribution to operability challenges in the area both more efficient and more effective.

7.3 In summary: CHSP is an investible project. It is the right technology in the right place and at the right scale, with the right investment, to make meaningful and timely contributions to GB decarbonisation and security of supply, while helping lower bills for consumers throughout its operational life, thereby addressing all important aspects of emerging Government policy.

CHAPTER 8: NEW STREAM RENEWABLES

8.1 New Stream Renewables (“NSR”), established in 2008, are a specialist consulting and support services group operating in both renewable and traditional energy markets. NSR deliver in-depth market knowledge, to high quality and in response to client needs. NSR have built a unique track record of consistent performance across a wide range of renewable and traditional energy mandates. NSR offers a wide range of pre-commissioning and operational services, including:

- Feasibility studies for prospective assets
- Due diligence reporting for project investors
- Market analyses, insight and commentary
- Active asset management (trading, PPAs and related contracts, including low-carbon benefits schemes and non-energy costs / benefits)
- Power and ancillary services contracting (including Capacity Market, FFR and National Grid bilateral contracts)

8.2 A selection of relevant projects which highlight our experience and competence in this area include

- 2016, a study into the potential future implications of renewable generation growth within GB on secure base-load power operation, for a large GB base-load power generator. Technical and operational risk mitigations were identified and plans established to inculcate resilience into future operating plans and procedures for these strategically significant assets.
- 2017, a commercial feasibility study for a potential pumped storage (hydro) facility in Scotland on behalf of a large infrastructure fund. Project specific characteristics and constraints, relevant electricity and related markets and grid connection aspects were reviewed. An evaluation tool was developed, and credible commercial scenarios (i.e. flexing costs, capabilities and revenues) investigated to provide a rounded view of project suitability.
- 2018, a due diligence report for a potential multi-million pound electricity storage investment. A thorough review of the project economics, locational and grid connection aspects was carried out, and constructive challenge provided on levels of revenue capture and cost across many different aspects of potential operation.

8.3 This Statement has been authored by Simon Gillett, Head of Analysis at NSR. Simon has European energy sector experience, spanning 20 years of commercial, analytical and consulting roles within Utilities and the Oil & Gas sector. In previous roles, Simon has held responsibility for the commercial operation of electricity generation assets in GB, EU wholesale energy market trading and GB Balancing Mechanism participation. Simon specialises in market change readiness and the implementation and performance of energy market regulations. His current focus is forecasting and optimising asset commercial value across many “stacked” revenue streams, within the GB’s rapidly transforming electricity system. He holds a Masters degree in Mathematics, from Oxford University, and in Nuclear Safety, Security and Safeguards, from the University of Central Lancashire.

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