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**From:** Lut Stewart <[REDACTED]>

**Sent:** 16 July 2019 06:47

**To:** Jones, Hefin <[REDACTED]>

**Subject:** Statement of Need --- Submission GREAT

Dear Hefin,

As previously discussed the developers did not agree to provide funds, so GREAT needed to fund raise before an expert could be brought in to comment in detail regarding the Statement of Need. This was completed yesterday and please find enclosed our report in response to the Statement of Need,

Best wishes,

Lut Stewart  
Vice Chair GREAT

# **EXPERT REPORT**

Dr Ralitsa Hiteva

July 2019

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## AUTHOR STATEMENT

I am an energy and infrastructure expert with 11 years of experience working on low carbon infrastructure and energy transition in an UK and international context. During this time I have contributed to numerous consultations of UK institutions including Ofgem, the National Infrastructure Commission and various Parliamentary Groups on Energy and Climate Change. My PhD examined the integration of solar and wind power into the transmission and distribution networks in the UK and the EU. My research in the last 5 years have been dedicated to the governance and regulation of energy transitions and innovation for decarbonising the energy sector, including innovative business models, system change and new digital services. I lead the research group on Infrastructure at the Science Policy Research Unit at the University of Sussex, and have been an active member of the Sussex Energy Group since 2013. From the start of my career I have been a supporter of renewable energy and sustainability.

This report was commissioned by the Graveney Rural Environment Action Team (GREAT) in May 2019 to provide an independent point of view on the wider socio-technical context within which the application for Cleve Hill Solar Park should be considered. In preparation of the report I have made myself familiar with the Statement of Need prepared by the Applicant and its response from June 2019 (RESPONSE TO ADDITIONAL SUBMISSION BY GREAT DATED 16 APRIL 2019 (ANSWERING THE STATEMENT OF NEED FOR CLEVE HILL SOLAR PARK) (AS-012)).

The report draws on my experience and knowledge and on available recent policy and technical literature, including reports, statements, and on peer reviewed state of the art academic publications, as evidence.

The Report challenges some of the claims made in the Statement of Need and in the Developer's response to points raised by GREAT. Furthermore, it points to a number of social and technical issues of the proposed project which undermine the applicant's argument and challenge the suitability of the application at this point of time and in this location.

## EXECUTIVE SUMMARY

This report presents the socio-technical context of the proposed large scale Cleve Hill Solar Park including the regulatory, policy, market and technical barriers which challenge a number of key assumption presented in the Statement of Need and in the Developer's response to points raised by GREAT and undermine the application. In summary, the report argues that:

- Although a mature technology, large scale solar power does not effortlessly plug into the current and future energy mix of the UK. In fact, a large scale solar PV park, such as the proposed Cleve Hill Solar Park has a number of key limitations in the context of an energy system in transition. These limitations are significant enough to overcome the proposition that there is a “need” for the proposed development.
- Despite delays in new nuclear capacity coming online, there is no urgency in bringing more large scale solar PV online to bridge a gap in the UK energy mix left by delays in the development of large energy projects (such as Hinckley C). In fact, there is a stable pipeline of energy infrastructure projects in the UK until 2021, some of which are the largest in size so far for specific technologies (i.e. Hornsea Wind Farm), and policy support and plans for many more energy infrastructure project beyond 2021.
- Solar PV is significantly outperformed by offshore wind in terms of installed capacity, contribution to renewable generation and load factor, making it a suitable alternative to large scale solar despite still benefitting from government support. In fact, the recently announced Offshore Wind Sector Deal sets out to deliver 30GW of wind capacity by 2030. It signals continued stability for the offshore wind sector and a stable future pipeline for offshore wind projects. This is in contrast with the high levels of regulatory and market uncertainty for large scale solar PV in the UK.
- Despite popular rhetoric in industry and mass media of ever growing energy demand, energy demand has been decreasing the UK since the 1970s and is projected to continue to do so, even with the electrification of other infrastructure sectors, such as transport. This undermines the argument made in the Statement of Need that to meet decarbonisation targets power generation capacity needs to be increased at an unprecedented scale.
- The efficiency of a large scale solar PV farm like the one proposed here depends on a number of geographical and technological determinants, such as the type of batteries, inverters and solar panels used. For example, the efficiency between different types of panels can vary from 4% till 19%. The lack of other essential technical information (such as the types of batteries and inverters) which could imply similar variations in efficiency undermines the argument about efficiency in the Statement of Need.
- Coupled with the low load factor of solar PV (10.8% -12%), in comparison with alternative energy technologies like offshore wind (38.6%-47.3%), materially undermines the argument that a large scale solar PV is an efficient way of producing renewable energy or using existing capacity in the grid.

- The range of economic, social and technical benefits from co-locating battery storage with large scale solar PV outlined in the Statement of Need are not achievable under the current regulatory and market structures. In fact, several regulatory, industry and market barriers need to be overcome to enable them. However, the required changes are unlikely to take place before the project comes online. Similar changes in offshore wind have taken over 6 years.
- Furthermore, essential information about the storage aspect of the project is missing, indicating that the storage element of the project has not been considered sufficiently, and may be treated as non-integral to the application.
- Given grid restrictions in the area of the proposed project the application for a large scale solar PV is unfeasible without a strong case for how battery storage could aid integration with the grid. However, until key regulatory and market barriers are removed no strong case for such projects can be made.
- Levelised cost of energy (LCOE) excludes important costs, such as grid integration; system costs; technology types; externalities and the daily variation in demand and supply. In the context of the Cleve Hill Solar Park the exclusion of transmission and distribution costs undermines the assessment offered by the Statement of Need given the large scale of the project and its direct connection to the transmission grid.
- Awareness of LCOE's limitation as a metric is important in delivering an accurate analysis and performing due diligence when making decisions that have widespread economic, social, and environmental impacts in the long run. Given the nature of the proposed project I suggest the use of levelised cost of storage (LCOS) as a metric, to get a more nuanced picture of the economic efficiency of a project over the longer run and in its entirety (including the storage element).
- Another significantly limiting element of the analysis in the Statement of Need is the exclusion of an assessment of the storage element of the project. Given the large scale of the generation capacity, the battery storage is an integral part of its feasibility and shouldn't be treated as separate. This omission materially undermines both aspects of the application.
- The high levels of uncertainty associated with projects co-locating large scale solar PV and battery storage make it difficult to predict the extent to which such projects will be able to meet policy goals about decarbonisation, greater grid flexibility and reducing costs to consumers, and the timeframe within which they could do so.
- Large scale solar power plays a more significant role only in one of the 4 National Grid "Future Energy Scenarios": Community Renewables. However, the modelling suggests that this is an intermediary step. There is strong system preference for diversified domestic solar and micro storage systems, and distribution-connected capacities (rather than large scale solar PV connected to the transmission network).
- The South East electricity system is one of the most complex areas of network in Europe, with several interconnections to continental Europe, a nuclear power station and a significant volume of renewable energy resources. The local DNO UK Power

Networks is experiencing constraints on the transmission network which affect their ability to connect new large intermittent capacities to the energy grid.

- The problems with assessing the efficiency of the storage service, lack of clarity on how exactly it would fit with the provision of large scale solar PV and high levels of uncertainty undermine the proposed project as an optimal choice for providing renewable energy and allocation of grid capacity at this point in time.
- Direct input from UKPN should be sought in assessing the application. Evidence of such is missing from the documents made available by the applicant so far. Connection offer by the DNO is not equivalent to endorsing the application.

## CHAPTER 1

# POSITIONING SOLAR PV WITHIN THE SOCIO-TECHNICAL CONTEXT OF THE UK

*Although a mature technology, large scale solar power does not effortlessly plug into the current and future energy mix of the UK. The number of large scale stand-alone solar PV farms in the UK has been growing for the past 5 years, with some having Contracts for Difference arrangements. This implies tougher competition and economic conditions for new large scale solar PV, without any subsidies. Drops in nuclear generation have been offset by increased capacities in solar PV and onshore and offshore wind. Offshore wind generation capacity is double that of solar PV in the last year. Overall, demand for energy is falling, creating even tougher competition conditions for large scale solar PV against other types of renewables.*

The proposed Cleve Hill Solar Park project needs to be assessed within the socio-technical context of energy in the UK. This requires unpacking the social, policy and economic reasons for promoting solar projects in the UK. The proposed large-scale solar PV park with battery storage is taking place within a changing energy landscape, including a transition towards decarbonisation, a more decentralised and digitalised ways of energy supply and demand. These transitions are changing the nature of the electricity system rapidly, introducing new criteria against which energy projects need to be considered.

There are still high levels of uncertainty with regards to the expected benefits and costs of solar power and battery storage, and how they would fit with other energy sources (such as wind and gas) to meet UK energy demand.

The policy landscape for solar in the UK has changed significantly over the last decade. Initially the UK government and energy sector were keen to get as many solar projects as possible off the ground and learn from the experience to scale them up. Now business models for different types and size of solar are established and more stable, with steady retraction of government subsidies and support in many parts of the solar sector. The policy focus in the UK has shifted away from support and scaling up towards a whole system approach to energy projects. This has several implications of relevance here.

The multi-faceted energy transition (described above) underway in the UK has altered the meaning of the term *energy security*, along with the criteria the UK energy industry and government use to assess it. For example, the energy grid is now considered secure when operating with less capacity margins in reserve. The key energy actors: Ofgem, the National Grid and District Network Operators (DNOs) are looking at longer term models of performance of energy assets.

Accordingly, solar projects should be evaluated not only in terms of cost, meeting energy demand and on providing low carbon energy but also on presenting an option of *no regret* for the energy system. This implies making decisions which will help enable the ability of the

energy system to reduce the levels of carbon while improving the resilience of the energy grid in the longer term. A *no-regret* renewable energy pathway here would simultaneously deliver low impact on the UK energy system, low levels of carbon emissions and enables higher levels of decentralisation.

Furthermore, not all solar technologies are equal and some are more suited for specific contexts. Some, such as domestic solar PV and solar thermal are still strongly supported by the government, while large (utility) scale solar PV projects receive no subsidies. There may be competing types of solar projects that can bring a distinct set of benefits to customers and the energy system.

A large proportion of solar generation in the UK is already coming from large grid-scale solar farms, which were developed in the context of subsidies such as the Feed-In-Tariff (FiT) and the Renewable Obligation (RO) paid on power generated. They were not developed in the context of a specific demand profile. Operating large scale solar PV exist as a result of specific policies and support mechanisms that have now ended. This has shifted the rationale for the economic case of such projects.

Although a mature technology, large scale solar power does not effortlessly plug into the current and future energy mix of the UK. A large scale solar PV park, such as the proposed Cleve Hill Solar Park has a number of limitations in the context of an energy system in transition, which will be discussed in turn in the chapters that follow.

A whole system approach to decarbonising the energy system necessitates placing a far greater importance than before on what would be the impact of any new planned generating capacity on the UK energy system in the shorter, medium and longer term (UKERC, 2013). This should be considered on a par with the environmental impact of the proposed solar project and the cost of the solar power.

The National Grid recognises the need for a whole system approach in connecting any new renewable capacities (National Grid, 2019). A whole system approach does not mean curtailment of investment in new solar capacities but making sure that it is at the right scale and type of solar, to enable, rather than congest the grid and lead to more costly upgrades sooner than needed. This thinking was captured in a Ministerial Speech to the Large Scale Solar Conference in 2013 “*we want to see a lot, lot more [large solar projects]. But not at any cost ... not in any place.*” (Gregory Barker, 2013).

The UK Solar PV Roadmap introduced in 2013 sets out the importance of the relationship between solar power and the wider socio-technical context through its four guiding principles, which have been replicated in subsequent policy documents. These play a key role in assessing the suitability of proposed new solar capacities.

Principle I argues for the selection of solar PV projects which *make a cost-effective contribution to UK carbon emission objectives in the context of overall energy goals of delivering carbon reductions, energy security and affordability for consumers.* Principle II states that support for solar PV should deliver genuine carbon reductions that help meet the UK’s renewable energy targets and *enable the decarbonisation of the economy in the longer term.* Principle III highlights the importance of ensuring that proposals are appropriately sited, give proper weight to environmental considerations such as landscape and visual impact, heritage and local amenity, and provide opportunities for local communities to influence



decisions that affect them. Of particular pertinence to large scale solar projects in general and Cleve Hill Solar Park in particular is Principle IV. It states that grid systems balancing and connectivity are key considerations in the deployment of high volumes of solar PV (DECC, 2013).

Demand for solar in Europe, UK and globally has significantly slowed down over the past 2 years. Unlike in the previous two years, with 30-50% annual growth rates, solar demand rose in the single-digit range in 2018 (Solar Power Europe, 2019). Key reasons for this slow down, among others, are the restructuring of large energy markets, leading to the stripping of subsidies for solar, and the competition with better performing renewable energy sources.

Electricity generation in the UK in 2018 fell by 1.4 per cent (to 334 TWh) with falls in generation from coal, gas and nuclear offset by an increase from renewables. This included a 14 per cent increase in wind and solar generation and a 12 per cent increase in bioenergy generation. The low carbon electricity's share of generation increased from 50.1 per cent in 2017 to 52.8 per cent in 2018. During this period, low carbon generation (nuclear and renewables) accounted for a record high of 52.8 per cent, again due to large increases in renewable generation.

Renewable generation in 2018 made up 33.3 per cent of electricity generated, achieving a record 111.1 TWh in 2018, an increase of 11.8 per cent on a year earlier because of increased capacity. Onshore and offshore wind generation rose by 4.6 per cent and 28 per cent respectively, with increased capacity. Generation from solar PV increased by 12 per cent, to a record 12.9 TWh, largely due to increased sunlight hours. Generation from bioenergy increased, while hydro generation fell (BEIS, 2019b). Offshore wind's share of annual UK generation increased from 0.8 per cent in 2010 to 6.2 per cent in 2017, and is expected to reach around 10 per cent by 2020 (BEIS, 2019c).

At the end of 2018 renewable electricity capacity was 44.4 GW, a 9.7 per cent increase (3.9 GW) on a year earlier. Due to rises in output from oil, bioenergy and waste, wind and solar, total energy production was 3.7 per cent higher than in 2017. Total primary energy consumption and final energy consumption both fell in 2018 (BEIS, 2019a).

At the end of May 2019 there is a total of 13,247.6 MW installed UK solar capacity across 1,004,798 installations. This is an increase of 1.9 per cent (244.9 MW) since May 2018. During May 2019, there have been 2,345 installations confirmed with an installed capacity of 5.8 MW. This is 21 per cent fewer installations than last year due to the closure of the FiT scheme at the end of March 2019. 91 per cent of these were sub-4kW installations, the installed capacity for the month has only increased by 5.8 MW, which is significantly lower than the capacity increase seen in May 2018 (BEIS, 2019b).

As illustrated in Figure 1 below, the most significant growth in the installed solar capacity over the last 5 years was at the micro-scale (up to 4kW), 50kW to 5MW, and between 5 and 25 MW.

To date, 44.7 per cent (5927.0 MW) of total installed solar PV capacity comes from the 457 large scale installations (greater than 5 MW). Whilst 93 per cent of all installations are sub-4kW, these only amount to 20.1% (2,664.9 MW) of total installed solar PV capacity in the UK.

At the end of March 2019, 58 per cent of capacity (7,716.8 MW) came from ground-mounted or standalone solar installations. This includes the two operational solar farms to be accredited for Contracts for Differences (Charity and Triangle solar farms) (BEIS, 2019b).

## UK Solar Deployment: By Capacity (updated monthly)

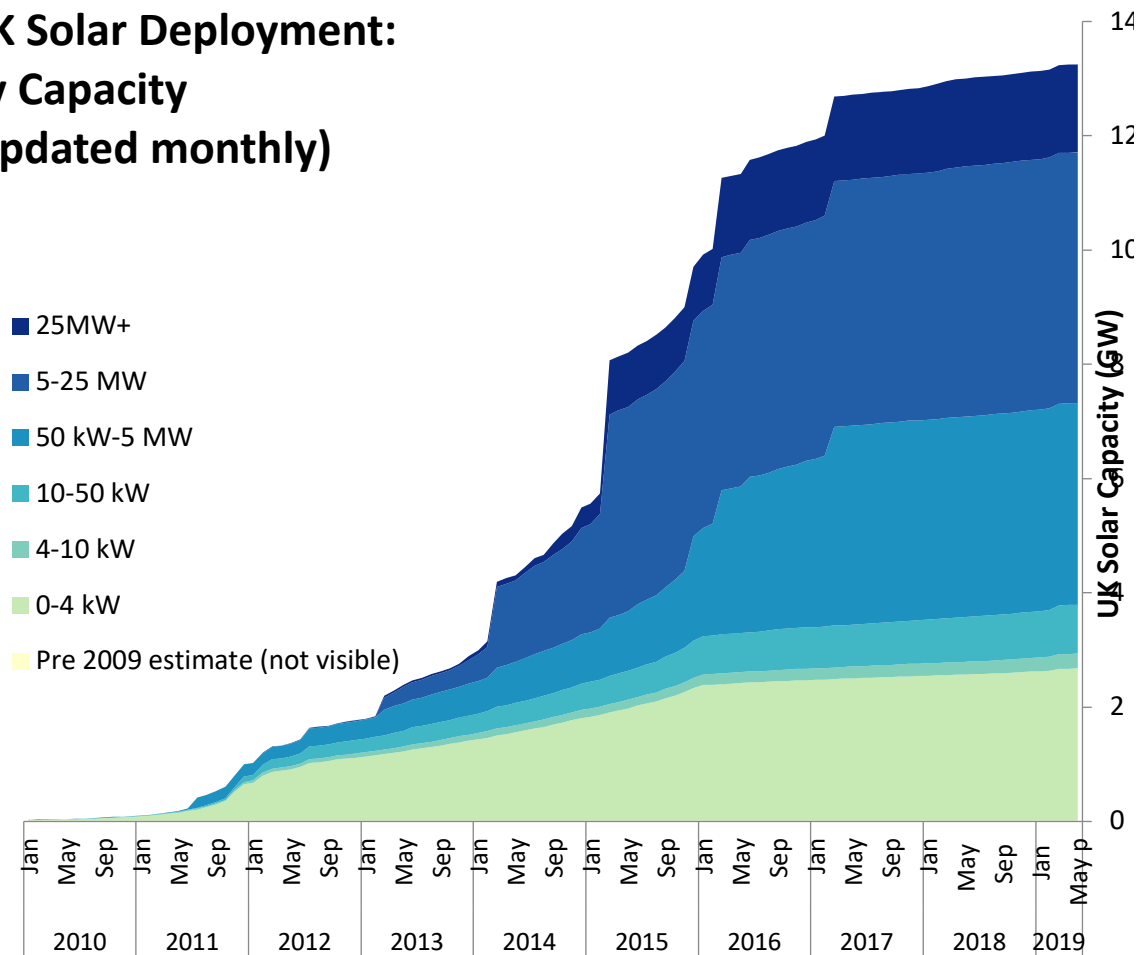


Figure 1. UK solar deployment by capacity in the UK, 2010-2019 (BEIS, 2019b)

Apart from the national energy system undergoing a series of transitions, with the introduction of higher levels of intermittent renewables and digitalisation of energy services, grid balancing and connectivity of solar are core considerations because a large proportion of solar generation in the UK is coming from large scale solar PV farms. A smaller proportion of solar generation comes from roof top mounted panels of domestic customers.

The number of large scale stand-alone solar PV farms in the UK has been growing for the past 5 years, with two solar PV plants guaranteed payments under Contracts for Difference arrangements. This implies tougher competition conditions for new large scale solar PV, without any subsidies. Drops in nuclear generation have been offset by increased capacities in solar PV and onshore and offshore wind. Offshore wind generation capacity is double that of

solar PV in the last year. Overall, demand for energy is falling, creating even though competition conditions with other types of renewables.

## CHAPTER 2

### Energy Infrastructure Pipelines: meeting energy demand

*Growing offshore wind capacities and their contributions to generated energy with larger load factors; as well as continuous reduction of energy demand through demand side response, undermine the claim of the application that Cleve Hill Solar PV Park is needed to meet growing energy demand in the context of delayed nuclear capacity.*

In its report on the state of the energy market Ofgem reported that the UK continued to benefit from secure energy supplies in 2017/18, with no periods of unmet gas or electricity demand. Key mechanisms: the Capacity Market, the Wholesale market and the Electricity Margins are considered stable and improved since last year.

The Capacity Market was designed to deliver supply or reduce demand in times of stress on the system to ensure security of supply. In its first year of full operation Ofgem reported healthy electricity margins with no capacity market warnings. For 2017/18, the National Grid had a target to procure 53.6 GW of capacity but procured 54.4 GW of capacity at a lower-than-expected cost to consumers of £6.95 per KW per year (in comparison with £19.40 per KW per year, projected four years earlier).

The higher procured capacity is to a large extent due to auction prices being significantly lower than anticipated. The capacity market helped maintain healthy electricity margins over 2017/18 with an average winter margin of 24.4 GW, compared 20.5 GW in 2016/17.

Capacity prices for next year also appear to be lower than initially expected (Ofgem, 2018b). Furthermore, over 90% of the capacity market agreements have been secured by existing generators, with limited new capacity entering the market (FIM, 2018).

There is a stable pipeline of energy infrastructure projects in the UK until 2021. In 2018 the energy infrastructure pipeline came to £189 billion, three-quarters of which will be spent on electricity generation, out of which around £21 billion is for nuclear decommissioning and £27 billion on oil and gas projects (including decommissioning).

Renewable energy capacity was 42.2 GW at the end of 2018, 10 per cent higher than the previous year, including a 38 per cent increase in offshore wind capacity. Several large renewable energy projects have been completed in the last 12 months. The scale of capacities coming online can be illustrated by two projects: the Walney Extension and the Hornsea Wind Farm in the North Sea.

The Walney Extension is a 659 megawatt (MW) offshore wind farm situated next to the existing 367 MW Walney project in the Irish Sea off the coast off Cumbria. It was completed in September 2018, making the offshore array the world's largest operational offshore wind farm, which can generate enough electricity to power 600,000 homes. The project was supported through a Contract for Difference awarded in 2014.

Contracts for Difference have been very successful in promoting investment in offshore wind in the UK by providing price certainty and stability to electricity generating companies. Construction has also started on Phase 1 of the Hornsea Wind Farm in the North Sea, which

once completed will generate enough electricity to power over one million homes (Infrastructure and Projects Authority, 2018). The higher portion of wind compared to solar is considered enabling for greater renewable generation (Ofgem, 2018b).

However, achieving the energy transition will continue to require substantial investment in low-carbon energy technologies. Although UK low carbon energy investment (in cash terms) is at its lowest level since 2008 there haven't been substantial reductions in the absolute addition of renewables capacity. Declining costs of renewable technology enable the generation capacity associated with an investment made in 2017 to be higher than in previous years (Ofgem, 2018b).

However, Ofgem and the Committee on Climate Change's assessment at the end of last year was that the UK is not on track to meet its legally binding decarbonisation commitments from 2023 onwards, with risks to delivery of existing policy commitments, and lack of guidance on how the ambitions of the Clean Growth Strategy will be met (Ofgem, 2018b).

The UK Government and Industry responded with the announcement of an Offshore wind sector deal in March 2019 which will drive the transformation of offshore wind generation, making it an integral part of a low-cost, low-carbon, flexible grid system.

The Offshore wind sector deal is expected to drive costs of offshore wind down further, delivering 30GW of generating capacity by 2030, delivering 1-2GW of new offshore wind per year, in a sustainable and timely way. This will address strategic deployment issues including aviation and radar, onshore and offshore transmission, cumulative environmental impacts (both in the marine and onshore areas) and impacts on other users of the sea space, such as navigation and fishing. In addition, the Crown Estate will undertake new seabed leasing in 2019, ensuring a sustainable pipeline of new projects for the late 2020s and early 2030s (BEIS, 2019c).

Government support for offshore wind has been going on since 2010 and it is due to several factors, including UK's natural disposition for offshore wind (i.e. suitable wind speeds), the contribution of the offshore wind supply chain to UK economic growth and the high load factor of the technology. Unlike solar, windy periods can occur during both day and night, and throughout any season. While in the case of solar, periods of lowest generation tend to take place during times of high demand (i.e. the winter months) and periods of high generation (i.e. summer time) have lower energy demand profile, creating balancing problems for the energy grid.

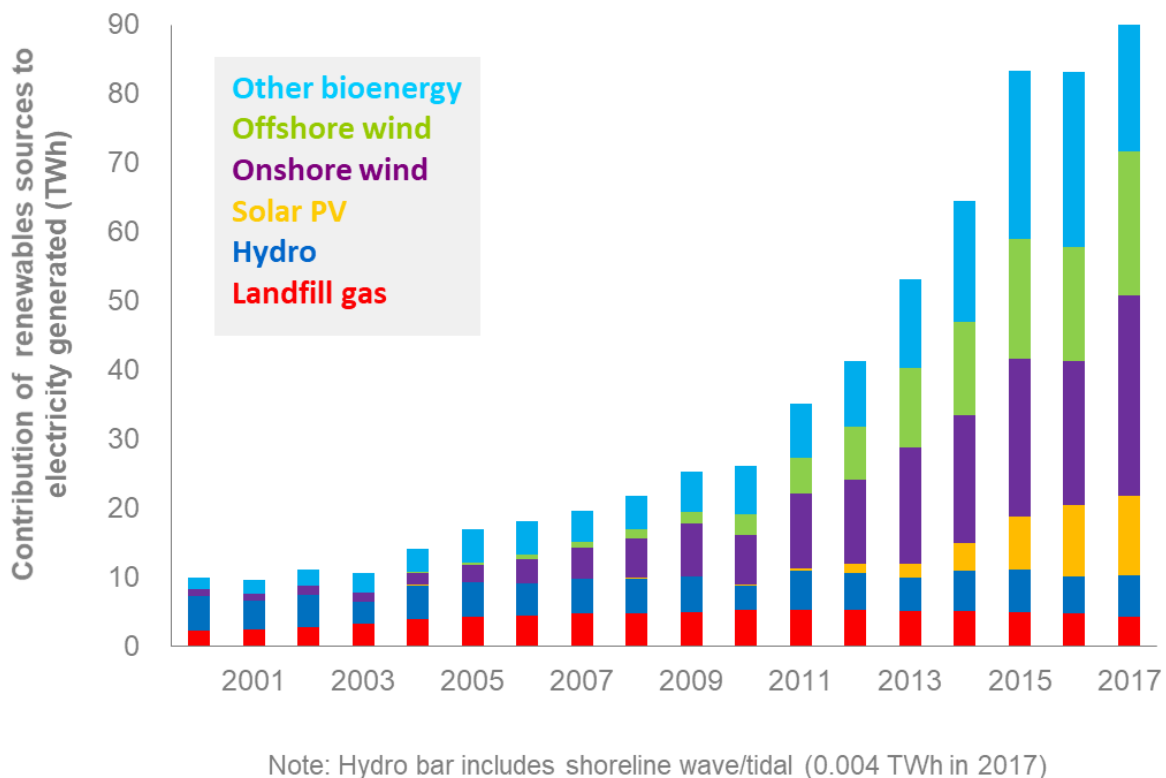
In its most recent load factor report, BEIS (2018a) reported that on average installed onshore wind capacity in the UK was 26.94 per cent, while the load factor of existing offshore wind arrays is 38.6 per cent and 47.3 per cent for new builds. "All wind" (onshore + offshore) is considered to have a load factor of 30.9 per cent. In comparison the load factor for existing solar PV is 10.8 per cent and 12.0 per cent for new builds (one of the lowest in the UK) (BEIS, 2018a).

Further support for low carbon generation is provided through the next round of allocations for Contracts for Difference, scheduled for May 2019, and then every two years thereafter. Up to £557 million of government support is available for these auctions (Infrastructure and Projects Authority, 2018). Offshore wind is performing very well in the Contract for Difference allocations.

This is in stark contrast with the cut to subsidies to solar PV and the ambiguity of government support (Kabir et al, 2018). Solar PV’s principal subsidy, the ROC, closed to all new generating capacity from 31 March 2017 and solar PV is expected to continue to be excluded from future Contracts for Difference auctions (Colville, 2019).

Data from the solar industry puts large-scale ground-mount post-subsidy UK solar pipeline at the start of 2019 as consisting of 197 projects with a combined capacity of 3.343GW. Of these, 72 are at the pre-application stage, totalling 1.858GW. This leaves a total of 125 projects (1.485GW) that are in the planning portal system as full planning applications or amended/phased versions of earlier submissions. Of these 125 projects, 17 (86MW) are pending approval, 12 (197MW) are left over from RO/NIROC activity and will likely be put on hold. Out of the 125 projects, 55 projects (a total of 573MW) are approved/planning-active and should be considered as the real pipeline for large-scale ground-mount post-subsidy UK solar. Five projects are above 50MW in the whole pipeline, 10 come in at the 49.99MW point, 20 fall in the 30-49MW band (746MW), and 60 in the 10-30MW (1.144GW) (Colville, 2019).

Figure 2. Electricity generation from renewable sources since 2000 (BEIS, 2018b).



As illustrated by Figure 2 above, although the contribution of solar PV to generated electricity has grown since 2011 its share of renewable generation is much smaller than onshore and offshore wind, and bioenergy (three other renewable resources). Thus, the contribution of solar needs to be understood in the context of other renewable sources, mainly wind whose profile is better suited to UK energy demand.

Transitions have always been associated with major shifts in energy-using activities and therefore with wider patterns of economic development and social change. The low carbon transition will not simply be a shift from fossil fuels to renewables, but also a change in how, when and where those fuels are used. Demand-side reduction is another key way of meeting UK's energy demand, which should be considered on a par with energy supply solutions such as offshore wind.

Recent report reviewing all existing evidence concluded that energy demand can support all key goals of energy policy – security, affordability and sustainability – with more synergies and fewer trade-offs than supply-side solutions. The International Energy Agency (IEA) and the European Union already treat demand reduction as ‘the first fuel’. Demand-side solutions also form a key part of implementing zero carbon sustainable supply, through using zero carbon fuels and enabling greater use of variable renewables (Eyre and Killip, 2019).

The UK Government's most recent statement on the energy transition, the Clean Growth Strategy (BEIS, 2017) states that decarbonisation and decentralisation of energy system will take place through major improvements in energy productivity in businesses, transport and homes to reduce total energy demand, as well as widespread deployment of clean energy sources.

In the UK the decoupling of energy use and economic activity has been reflected in absolute reductions in energy demand. Primary energy demand in the UK has fallen by 20 per cent since 2003. This reduction has confounded official projections made at the beginning of this period, which projected slow but steady energy demand growth (McDowall et al, 2014).

These changes in energy demand have been driven by a combination of factors, including economic restructuring (away from energy intensive manufacturing and towards services); technical energy efficiency improvements, and a slowing in the growth of demand for many of the services provided by energy. They have contributed more to carbon emissions reduction than the combined effects of the UK's programmes in nuclear, renewable and gas-fired power generation. However, despite the evidence, many people still think that energy demand is inexorably rising and references to ‘increasing energy demand’ remain common in the mass media and in parts of the energy sector (Eyre and Killip, 2019).

Demand flexibility will play a key role in decarbonising the electricity system in the UK and integrating increasing levels of variable renewable energy. The Clean Growth Strategy focuses largely on opportunities based on energy storage and is opening up to alternative solutions across industrial processes, freight transport and space heating (which are difficult to electrify) such as hydrogen.

The recent analysis of the Committee on Climate Change (CCC) shows that changing technology alone is insufficient for most of the carbon emissions reduction required to reach a net-zero target (CCC, 2019). Furthermore, the multiple aims in the energy transition – efficiency, reduction, flexibility and a switch to sustainable fuels – cannot effectively be analysed separately.

When considered in the context of growing offshore wind capacities and contributions to generated energy with larger load factors; and continuous reduction of energy demand through demand side response, the claim of the application of the Cleve Hill Solar PV Park as needed

to meet growing energy demand in the context of delayed nuclear capacities is found to be unsubstantiated.



## CHAPTER 3

### Solar PV Technology Efficiency

*The efficiency of large scale solar PV farm like the one proposed here depends on a number of geographical and technological determinants, such as the type of solar panels used, as efficiency can vary from 4% to 19%. The efficiency of the solar PV technology planned to be used in the proposed project is impossible to assess because of missing important technical information, such as the type of solar panels, batteries and inverters, and undermines claims about efficiency made in the application.*

#### *Geographical determinants*

The efficiency of solar PV technology in the UK depends on a number of factors: latitude, diurnal variation, climate, geographic variation and elevation are largely responsible for determining the intensity of the solar influx that passes through Earth's atmosphere. Solar energy can only be harnessed during the day and works most efficiently when it is sunny. Thus, solar energy is likely not the most reliable source of energy in regions with unsustainable weather or climate conditions.

The UK sees an average annual solar radiation of about 900-950 kWh/m<sup>2</sup>. Solar radiation varies with the time of day and year. As such, the output from a solar PV system is likely to be at its greatest during the summer months and at midday. The average energy output from a 1kWp solar cell in the UK is between 700 and 850 kWh/year. Palmer et al. (2017) warn that when estimating the potential efficiency of large scale solar PV farms can depend to a large extent on local weather because of distinct local weather patterns of the UK.

Air pollution levels at the installation area can also influence the effectiveness of the solar cells. Exposure to exhaust fumes and aerosols reduce the current of silicon solar cells by 10% and 7%, respectively (Kabir, 2019). Exposure to dust, and algal growth can also greatly lower the performance of the system.

#### *Technological determinants*

The performance of the solar panels can vary greatly, leading to difference in overall efficiency. Furthermore, of importance in dictating the overall efficiency of the technology in specific project is the performance limitations of key components such as batteries and inverters. However, specific details about these have not be presented so far. Possibility of cracks within the PV module and water intrusion can greatly lower the performance of the system.

In the context of large scale solar PV generation, the rule of thumb is that a 1 MW solar power plant with crystalline panels (about 18% efficiency) would require about 4 acres (16,187 m<sup>2</sup>) of land area, while thin film technologies (12% efficiency) would require ca. 6 acres (24,281 m<sup>2</sup>).

First-generation PV systems use the wafer-based crystalline silicon technology, either single crystalline or multi-crystalline. Second-generation PV systems (early market deployment) are

based on thin-film PV technologies and generally include three main families: 1) amorphous and micromorph silicon; 2) Cadmium-Telluride; and 3) Copper-Indium-Selenide and Copper-Indium-Gallium-Diselenide (IRENA, 2012).

It is important to be aware of the hierarchy of efficiency in PV, as a number of efficiencies can be quoted. The highest efficiency for a PV material is usually the “laboratory” efficiency, where optimum designs are tested. PV cell efficiencies are less than this, because compromises are often required to make affordable cells. Module efficiency is somewhat lower than cell efficiency, given the losses involved in the PV module system.

The International Renewable Energy Agency (IRENA) estimates that the efficiency of crystalline silicon modules ranges from 14% to 19%. Amorphous silicon PV module efficiencies are in the range 4% to 8%. Very small cells at laboratory level may reach efficiencies of 12.2% (Mehta, 2010). The main disadvantage of amorphous silicon solar cells is that they suffer from a significant reduction in power output over time (15% to 35%), as the sun degrades their performance. The multi-junction thin-film silicon is a variant of amorphous silicon solar cells, which consists of a-Si cell with additional layers and micro-crystalline silicon applied onto the substrate. The advantage of the micro-crystalline silicon layer is that it absorbs more light from the red and near infrared part of the light spectrum, thus increasing the efficiency by up to 10% (IRENA, 2012).

Cadmium Telluride thin-film PV solar cells have lower production costs and higher cell efficiencies (up to 16.7%) than other thin-film technologies. Copper-Indium-Selenide and Copper-Indium- Gallium-Diselenide PV cells offer the highest efficiencies of all thin-film PV technologies. Current module efficiencies are in the range of 7% to 16% (IRENA, 2012).

Frankl et al. (1997) evaluated the benefits of building-integrated PV systems, comparing them to conventional PV power plants through the aspects of a life cycle analysis, maximizing energy efficiency and CO2 reduction potential. The results show favorable effects for building-integrated PV systems in terms of the energy production and reduction in CO2 emissions. They estimated CO2 yields of 2.6 and 5.4 for conventional PV power plants and building-integrated systems, respectively. Although the performance of each technology has since increased the ration between the two has remained, with building integrated solar PV systems having a larger CO2 yield.

### *Capacity factor*

The capacity factor of a PV power plant is usually expressed as a percentage and represents the ratio of the actual output over a period of a year to theoretical output if the plant had operated at nominal power for the entire year. In the case of solar PV it will take into account local solar irradiance and day length. In very sunny countries, such as Australia, solar panel load factors can reach 30% or more. BEIS calculates an average capacity factor for solar PV in Britain of 10.8% for 2018.

<b>Technology</b>	<b>Load factor (existing)</b>	<b>Load factor (new build)</b>
Advanced Conversion Technologies	82.4%	83.2%
Biomass CHP	64.0%	80.3%
Dedicated Biomass	47.2%	67.4%
Sewage Gas	42.1%	-

Hydro	40.2%	29.5%
<b>Offshore Wind</b>	<b>38.6%</b>	<b>47.3%</b>
Landfill Gas	38.2%	-
Onshore Wind	24.2% - 31.1%	30.9% - 35.2%
Anaerobic Digestion	28.1%	79.1%
Energy from Waste with CHP	22.8%	81.5%
<b>Solar PV</b>	<b>10.8%</b>	<b>12.0%</b>
Tidal	9.0%	-
Wave	2.9%	-

Table 1. Load factors for energy technologies, in a diminishing order of load factor (adapted from BEIS, 2018a).

Depending on the type of solar panels used the efficiency of the application can vary from 4% till 19%. This variation gap, along with lack of other essential technical information makes the argument about efficiency in the Statement of Need less convincing. Coupled with the low load factor of solar PV (in comparison with the rest of the energy technologies in Table 1) the argument that a large scale solar PV is an efficient way of producing renewable energy or using existing energy infrastructure, such as the transmission grid, is unsubstantiated. Especially, if a large solar PV capacity blocks access to the grid of more efficient renewable technologies such as onshore and offshore wind.

## CHAPTER 4

### Benefits and barriers in co-locating solar PV and battery storage

*The range of economic, social and technical benefits from co-locating battery storage with large scale solar PV outlined in the Statement of Need are not achievable under the current regulatory and market structures. Several regulatory, industry and market barriers need to be overcome to enable them. However, the required changes are unlikely to take place before the project comes online.*

*Furthermore, essential information about the storage aspect of the project is missing, indicating that the battery storage element of the project has not been considered sufficiently, and may be treated as non-integral to the application. Given grid restrictions in the area of the proposed project the application for a large scale solar PV is unfeasible without a strong case for how battery storage could aid integration with the grid.*

*The business model for large scale solar PV and battery storage is still under development and in the midst of regulatory and policy change, which could be a lengthy and gradual process. With limited participation in key market mechanisms such as the Capacity Market, the Short Term Operating Reserve and the National Grid Enhanced Frequency Response, and lower than expected prices across the board, there are high levels of uncertainty for such solutions in the UK. Until key regulatory and market barriers are removed no strong case for such projects can be made.*

This section discusses the regulatory and market context within which the proposed co-location of large scale solar PV and battery storage would operate. The Statement of Need argues that the co-location of subsidy free large scale solar PV farms, such as Cleve Hill could bring a range of benefits to the solar PV generator (smoothing integration into the grid, additional revenue stream), the DNO (by aiding grid balancing at the local level and avoiding costly upgrades), including energy consumers (by cheaper energy prices). However, these economic, social and technical benefits are not a given at this point in time. In fact, they are unachievable under the current regulatory and market structures. Several regulatory, industry and market barriers need to be overcome to enable them. However, the required changes are unlikely to take place before the project comes online.

Furthermore, essential information about the storage aspect of the project is missing. For example, calculations about the transmission and distribution costs have not been provided (the issue is discussed in more detail in Chapter 5), making any calculation of potential benefits of co-location unrealistic. This is a particular weakness considering the large scale of the project and its direct integration to the transmission grid. This omission indicates that the battery storage elements of the project has not been considered sufficiently at this point of the project development, and may be treated as non-integral to the application by the Developer. Given grid restrictions in the area of the proposed project (the issue is discussed in detail in Chapter 7) the application for a large scale solar PV is unfeasible without a strong case for how battery storage could aid integration with the grid.

Strong cases for battery storage are still hard to make, especially by generators. As Ofgem (2018c) highlights, the energy transition is a step process and the benefits of co-locating solar

PV and battery storage are limited because of direct barriers and still high levels of uncertainty about what exactly the business model of such project will look like. In fact, energy storage for use in electricity systems has had limited applications so far worldwide, as costs are high and the industry is immature (Reid and Wynn, 2015). Despite falling prices of battery storage, storage solutions available today are still expensive. Electricity must be converted into another form of energy and then converted back into electrical energy. Lithium-ion batteries are a popular battery storage technology which costs around £320/kWh currently.

Ofgem and the Government are in the process of identifying and removing barriers to co-locating large scale solar PV and battery storage, however this process takes time. The scope of the barriers that need to be identified and removed to create the right regulatory, market and industry conditions for reaping benefits from battery storage are comparable with those in the establishment of the Offshore Transmission Operators (OFTO) regime in the UK. In the case of the OFTO regime this process took over 6 years. It may be argued that the timeframe for flexibility services (produced by battery storage) could be even longer for battery storage as the OFTO regime faced fewer regulatory barriers.

For example, storage is still not defined within the legislation underpinning the RO or the FIT schemes. This means that the co-location of electricity storage facilities with accredited generating stations or installations, or those applying for accreditation, is neither expressly prohibited nor expressly provided for under the schemes. As a result, larger scale storage systems are complex and risky. They are associated with a large number of small and often short-term revenue streams, which is providing a barrier to this market and is harder to finance (Solar Trade Association, 2016).

Energy storage providers will need to obtain revenue from a number of sources to remain viable, including arbitrage, balancing and ancillary services, and providing services to network operators. Not all of these options are equally developed within the current energy regime (National Grid, 2018).

Although industry and the regulator are working on enabling such business models, so far these are DNO-led and focussing on primarily avoiding network upgrade costs, rather than business models geared towards improving a solar developer-led model.

The National Grid Enhanced Frequency Response (EFR) tenders will be critical for the large-scale deployment of storage systems over the coming years, however these have also been at lower pricing than expected, raising concerns about whether the winning tenders reflect true costs (Solar Trade Association, 2016). At present, demand for frequency services does not support the case for development of storage batteries.

The degree of policy and regulatory uncertainty in the sector and the increased number of battery projects available to provide frequency response services has led to much lower prices in the Capacity Market than anticipated. Energy storage is underrepresented in the Capacity Market and Short Term Operating Reserve (STOR). This is also partly due to cost and systemic problems such as the lack of a definition and resulting regulatory framework for storage.

Ofgem is focused on removing the key policy and regulatory barriers to such services and is looking to change the treatment of storage in legislation and for licensing, the planning regime, the network charging and connections regime, how policy costs are recovered, how it can co-locate with renewables. Once these changes are made the certainty over the treatment of storage

would improve. For example, Ofgem has consulted on a modified generation licence, which clarifies storage as a subset of generation and its treatment in the applicable industry codes for storage. Holding the licence will also enable electricity storage facilities to avoid the overpayment of final consumption levies, which should only be paid by final consumers.

The Government is also expected to define electricity storage as a distinct subset of generation (and not as end consumers of energy) in the Electricity Act 1989, when Parliamentary time allows. This will clarify the treatment of storage across the energy system and reform the current system of double charging for storage. Ofgem reported that the preparatory work for this has been completed at the end of 2018 (Ofgem, 2018c).

Some changes are being left to industry. For example, to address disproportionate network charges faced by storage, Ofgem, in its Targeted Charging Review, noted that changes to the residual network charges for storage could be progressed more quickly by industry to avoid the longer Significant Code Review process. Industry is negotiating reforms to transmission, distribution and balancing charges for storage, such as charging code modifications (Ofgem, 2018c).

Even today, utility scale storage can be economical in certain grid applications, however at present storage at such scale make economic sense for DNOs and the National Grid only, as it is cheaper to employ storage rather than network reinforcement solutions. One example is the 2.5MW Li-ion system installed by Northern Powergrid in Darlington, which is justified as investment deferral. However, such projects are still the exception rather than the rule (National Grid, 2018).

The Capacity Market - a key mechanism for delivering low carbon energy and reliable energy supply - is at present an ineffective instrument for providing flexibility. The Capacity Market aims to “provide a regular retainer payment to reliable forms of capacity (both demand and supply side), in return for such capacity being available when the system is tight” (DECC, 2013). Although it specifically includes DSR, it has been criticised for restricting participation, arbitrarily limiting contract lengths and offering only uncertainty about storage capacity during transitional arrangements.

The Capacity Market only offers one-year storage contracts compared with the up to 15-year terms available for fossil fuel generator contracts. The problem with supporting flexibility through the Capacity Market is that the latter was originally intended for security of supply and, where auctions award long-term contracts, to help de-risk power station construction. This reflects the deeply embedded bias of the energy system and the energy actors (such as the Transmission System Operator) towards capacity adequacy (i.e. enough power generating capacity to meet demand) rather than flexibility (i.e. the system’s responsiveness to changing conditions), which is needed for energy systems with higher renewables penetration.

Following the ruling by the European Court of Justice, the Capacity Market is currently in a ‘standstill period’ and in desperate need for adjustment (in terms of size, duration and notice periods). The last auction for delivery in winter 2019 cleared at £6 per kW. This very low price reflects the high level of capacity, 10.7 GW, bidding for a target of 4.9 GW, although around 5.8 GW was awarded. This makes potential revenues from flexibility payments for the battery storage unlikely.

Electricity wholesale markets in Germany and the UK have, on several recent occasions, moved into negative prices. At such occasions (often sunny and windy Sundays in which demand is low and renewable generation is high) buyers are paid to use power by sellers (Eyre and Killip, 2019).

In addition, expectation of what would be the scale of potential savings to consumers are highly speculative. So far, cost reductions in transmission and distribution struggle to reach consumers. There is nothing distinct about the service provided by battery storage co-located with large scale solar PV that points to a new, more direct mechanism of passing savings to consumers than reductions in the cost of other renewable technologies such as wind. There are trials underway in London with small scale battery storage offering behind-the-meter savings to residents aided by blockchain-enabled peer-to-peer trading. However, no such trials are underway for large scale solar PV.

The high levels of uncertainty associated with projects co-locating large scale solar PV and battery storage make it difficult to predict the extent to which such projects will be able to meet policy goals about decarbonisation, greater grid flexibility and reducing costs to consumers, and the timeframe within which they could do so. Until key regulatory and market barriers are removed no strong case for such projects can be made.

## CHAPTER 5

### Solar PV Cost and Price

*Levelised cost of energy (LCOE) excludes important costs, such as grid integration; system costs; technology types; externalities and the daily variation in demand and supply. In the context of the Cleve Hill Solar Park the exclusion of transmission and distribution costs is a particular weakness provided the large scale of the project and its direct integration to the transmission grid. In fact, network costs (transmission and distribution) can be as much as 40 per cent of total electricity costs, adding a significant burden to the network operators. Given the large scale of the generation capacity the battery storage is an integral part of its feasibility and shouldn't be treated as separate. The cost of the energy delivered by storage needs to take into account the solar panels for producing the surplus energy. This calls for using additional metrics and methodologies, such as LCOS, to get a more nuanced picture of the economic efficiency of a project over the longer run.*

Levelised cost of energy (LCOE) has been used to prove the economic efficiency of large scale solar PV in the UK. LCOE is a commonly used measure of the cost of generating solar power, which divides the lifetime cost of a solar installation by lifetime power generation, measured in pence per kilowatt hour (kWh). This section discusses the extent to which LCOE is suitable way to measure the economic efficiency of Cleve Hill Solar Park.

Awareness of LCOE's limitation as a metric is important in delivering an accurate analysis and performing due diligence when making decisions that have widespread economic, social, and environmental impacts in the long run. The nature of the proposed project (large scale solar PV, co-located with battery storage) and connected to the transmission grid calls for using additional metrics and methodologies to get a more nuanced picture of the economic efficiency of the project over the longer run.

LCOE excludes important costs, such as grid integration; system costs; technology types; externalities (such as waste disposal and pollution) (Reid and Wynn, 2015) and the daily variation in demand and supply, which are the real value of energy. Instead it uses an average of the costs and energy profiles over time (Sklar-Chik et al., 2016). In the context of the Cleve Hill Solar Park the exclusion of transmission and distribution costs is a particular weakness given the large scale of the project and its direct integration to the transmission grid.

Roth and Lambs (2004) calculated the impact of externalities in monetary terms, and concluded that they have a significant effect on the viability of the different generating technologies. They argued that "when externalities are considered, renewable electricity generation is comparable in cost to fossil fuel generation", and externality costs associated with fossil fuel technologies are generally greater than their renewable energy technology counterparts (Sklar-Chik et al., 2016). Embedded carbon and pollution are important factors in achieving policy goals towards decarbonisation, while transmission and distribution costs are key in achieving energy security.



The argument made in this report is for assessing the Cleve Hill Solar Park in a whole system context. A system perspective will include a technology portfolio (all power stations in the grid) as the level of analysis, not merely one type of technology (single power station). Only a system perspective can highlight how technologies impact on the costs of the overall system. However, these system costs are not included in the LCOE metric. Their omission can lead to a misleading assessment of cost. System costs are important, as many projects have an impact on the greater system and electricity grid, and thus need to be considered in greater detail (Sklar-Chik et al., 2016). Because of its size, battery storage and direct integration into the transmission grid Cleve Hill Solar Park is such a project.

Sklar-Chik et al. (2016) suggest that network costs (transmission and distribution) can be as much as 40 per cent of total electricity costs, adding a significant burden to the network operators that must then be recovered through tariffs or by applying a network cost as part of the generation project. The latter however, increases the actual cost when compared with the standard LCOE values (Sklar-Chik et al., 2016).

Difficulties and discrepancies in using LCOE arise when comparing dispatchable (e.g., fossil fuel and CSP) and non-dispatchable (e.g., solar PV and onshore) technologies. LCOE merely accounts for average electricity produced, and does not take into account the production profiles and the market value of energy produced by the different technologies.

Furthermore, power (the rate at which energy is produced) and the actual energy provided are two different yet interrelated terms, and the LCOE does not differentiate between them. Comparing a solar PV farm of 100 MW with a 100 MW pulverised fuel plant purely on a cost basis gives a skewed and incomplete representation of the actual system (Sklar-Chik et al., 2016).

Another significantly limiting element of the analysis in the Statement of Need is the exclusion of an assessment of the storage element of the project. It is dismissed with the statement that: “Although [the storage element] is desirable and provides added benefits to the project” is has not been included in the LCOE analysis in the Statement of Need. However, given the large scale of the generation capacity the battery storage is an integral part of its feasibility and shouldn’t be treated as separate. Metrics for its measurement do exist and are discussed below. The cost of the energy delivered by storage needs to take into account the solar panels for producing the surplus energy (Lai and McCulloch, 2016).

Lai and McCulloch (2016) argue that although the capital cost of storage is an important and frequently reported method of evaluating battery cost, the most important metric is the levelized cost of electricity and the value that should be minimized, rather than minimizing capital cost. Intermittent renewables face two main challenges in the context of the Levelised Cost of Storage (LCOS) metric: storage levelized cost estimations are arbitrary, since the application case can vary widely; and storage levelised cost estimations are incomplete, since they do not cover the required business models and its characteristics for storage.

Furthermore, LCOS usually involves an optimistic estimation and in practice, the storage system will not be used to 100% of its capacity. In the case of PV integration, the energy stored in the storage system depends on the PV system output and this is highly arbitrary as it depends on the nature of solar irradiance. Therefore, the LCOS will be different in real-life situation and expected to be higher. The values provided by Lazard can be used as a comparison for

different storage technologies and applications, but are not useful for system resource planning and decision making (Lai and McCulloch, 2016).

Lai and McCulloch (2016) offer an alternative, more accurate calculation of LCOS known as the LCOD, which includes main parameters such as efficiency, lifetime and discount rate. This method could also be used to assess different storage technologies such as VRB and lithium-ion battery cases. Since energy storage has many applications for power systems such as grid balancing and frequency regulation, the LCOS and LCOD will be significantly different due to the operating conditions of the ESS (Lai and McCulloch, 2016).

Large scale solar PV is expected to reach grid parity<sup>1</sup> within less than 5 years. However, with low prices of the Capacity Market and high levels of regulatory barriers large solar systems whose revenue stream is reliant on selling directly to the market (and are unable to secure a favourable power purchase agreement) will reach parity later than expected.

Reaching grid parity depends on the continued reduction of the cost of solar PV. However, full solar system costs may not maintain the same pace of reductions as seen in the past five years. That is because the swiftest reductions have come from solar modules, which now account for a smaller share of the total. The remaining, so-called balance of system costs, include inverters<sup>2</sup>, installation and financing. Although they are continuing to fall, as the supply chain matures, these reductions may be more gradual from the cost reductions so far (Reid and Wynn, 2015).

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<sup>1</sup> Achieving a stage of development of the PV technology, at which it is competitive with conventional electricity sources.

<sup>2</sup> Inverters convert direct current electricity generated by solar modules into alternating current required by many machines and household appliances.

## CHAPTER 6

### Relevance of the National Grid's "Future energy scenarios"

*Large scale solar power plays a more significant role only in one of the 4 National Grid's Future Energy Scenarios: Community Renewables, which explores achieving the 2050 decarbonisation target through a more decentralised energy landscape. It envisions electricity supply being fulfilled mostly by a combination of onshore wind and solar, co-located with storage. While flexibility is provided by small scale storage, small gas-fired plants, some interconnection, and hydrogen production by electrolysis.*

*The scenario anticipates that by the early to mid 2020s, the lowest demand on the transmission network will regularly coincide with periods of high solar output. Across the 4 scenarios there is a trend towards distribution-connected capacities (i.e. on the DNO network), while large scale solar connected at the transmission network seems to be an intermediary step in the energy transition, which can continue to cause issues with the grid as well as address demand for capacities.*

The National Grid's "Future Energy scenarios" (FES) offers 4 scenarios which provide 4 distinct futures in terms of the means and speed of meeting (or not) important policy goals, such as decarbonisation and decentralisation. The FES are very useful in illustrating the implications of different socio, economic and technical contexts for energy use. The FES are purposely speculative, as they aim to show what and how could be achieved if certain changes were made.

This could also mean that certain types of technologies and solutions are over emphasised in some of the scenarios. This doesn't necessarily mean that they are ready for scaling up. The FES is highly responsive to rapid technological changes and can vary significantly from year to year. All scenarios look 30 years ahead and adopt a whole system approach to balancing energy demand and supply. The four scenarios can be interpreted in multiple ways.

Of importance here is what conclusions we can make about the expected impact of large scale solar and storage plants on achieving decarbonisation and decentralisation. Large scale solar power plays a more significant role only in one of the 4 scenarios: *Community Renewables*. This scenario projects rapid decarbonisation of electricity in the 2020s, due to rapid growth in wind and solar. The falling cost of solar technology and co-location with storage leads to significant solar growth in all scenarios. Even *Steady Progression* has more than double today's solar capacity by 2050.

Growth in solar capacity is most pronounced in *Community Renewables*, however this is due to strong take-up of domestic solar and micro storage systems. By 2030, 33GW of solar is forecast to have been installed. Around half of this is micro solar, such as rooftop installations on homes and industrial buildings. The *Community Renewables* scenario, explores how the 2050 decarbonisation target can be achieved through a more decentralised energy landscape. It envisions electricity supply being fulfilled mostly by a combination of onshore wind and solar, co-located with storage. Flexibility is provided by small scale storage, small gas-fired plant, some interconnection, and hydrogen production by electrolysis. Falling costs, facilitative

government policy and consumer desire to manage their own electricity supply play an important part in enabling this scenario.

With the growth in solar capacity, it will be challenging to manage the grid at times of peak output in summer. During these months, some areas with high solar generation will see electricity supply exceed local demand. This will lead to power being exported back from the distribution network onto the transmission network for use elsewhere in GB. This conversion in turn occurs further losses in the system, while the connection of a large scale solar PV capacity will make harder the connection of a larger number of more distributed capacities including smaller scale generators, domestic solar PV and energy community projects, which create and capture local benefits from energy generation (for more details see Chapter 7).

The National Grid anticipates that by the early to mid 2020s, the lowest demand on the transmission network will regularly coincide with periods of high solar output. This will typically be around 2pm on summer afternoons. Between 2030 and 2050, total output from renewables, including solar, could exceed total demand in GB at certain times in 2050 compliant scenarios. This excess supply explains the growing importance of storage co-location at microscale (individual households and building) across all scenarios because it offers flexibility closest to source).

The *Two Degrees* scenario explores how the decarbonisation target can be achieved using larger and more centralised technologies. Growth in solar capacity is lower than *Community Renewables*, but still substantial. There is greater development of larger scale solar farms connected to the transmission network. In this scenario electricity supply relies on offshore wind and nuclear, and is based more on the transmission network. Flexibility is provided by interconnectors, larger scale storage and later, some large scale gas-fired plants fitted with Carbon Capture Use and Storage (CCUS) technology.

The *Steady Progression* scenario is more centralised and makes progress towards, but does not meet, the 2050 decarbonisation target. There is greater emphasis on large scale, rather than local generation, with generation dominated by nuclear power and offshore wind. Gas plays an important role in providing flexibility and gas-fired generation fitted with CCUS develops through the 2040s.

The *Consumer Evolution* scenario is more decentralised and although it makes progress towards the decarbonisation target it fails to achieve the 80 per cent reduction by 2050. There is a moderate rollout of smart charging of EVs. There are some improvements in energy efficiency with homes, businesses and communities focused and incentivised towards local generation, notably roof top solar, and local energy management. Electricity supply is focused on smaller scale renewables, with gas and batteries providing most of the system flexibility. Some new large scale nuclear power stations are built but there are also a number of small modular reactors. Greater emphasis on domestic and national energy solutions leads to lower levels of electricity interconnection.

Across the 4 scenarios diversifying storage and energy production (heat, gas, thermal) is a least regret option, especially at smaller scale, microgeneration, behind the meter and when linked to other services such as EV charging and solar thermal at that scale. This suggest a trend across towards distribution-connected capacities (i.e. on the DNO network), while large scale solar connected at the transmission network seems to be an intermediary step in the energy transition, which can continue to cause issues with the grid as well as address demand for capacities.

The more decentralised a system is, the more its supply and demand assets are linked to local networks and processes. The electricity supply side, has undertaken a dramatic growth in smaller scale generators, such as solar, wind turbines and small peaking plant, which are not connected to the transmission network. 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 (like the proposed project at Cleve Hill), but rather to the medium voltage distribution system or the low voltage system (for generators connected directly to the consumer).

## CHAPTER 7

### Issues connecting to the transmission network

*The South East electricity system is one of the most complex areas of network in Europe, with several interconnections to continental Europe, a nuclear power station and a significant volume of renewable energy resources. UKPN is experiencing constraints on transmission networks which affect their ability to offer connections on the distribution system. There are several trials underway in different parts of the UKPN network experimenting how these measures could work. However, until these become business as usual for the DNO in balancing the grid and connecting large solar PV capacities with storage, the system can manage incorporating a greater proportion of smaller scale embedded generation connected to the distribution network, rather than large scale solar connected to the transmission network.*

*Direct input from UKPN should be sought in assessing the application. Evidence of such is missing from the documents made available by the applicant so far. Making a connection offer is not the same as an endorsement of the proposed project and the latter should not proceed simply because a grid connection offer has been made and accepted.*

The proposed large scale solar PV plant will be connected to the transmission network, which is one of the biggest weaknesses of the proposal. The co-location of battery storage provides a potential way forward for the project but also adds substantial level of uncertainty and complexity to it. A critical evaluation of the full scope of issues connecting to the transmission grid is lacking in the Statement of Need and in its subsequent response. The issue of connection to the grid is discussed in mostly positive terms, obscuring the complexity of the connection requirements.

The larger the plant the more complex the connection requirements (DECC, 2013). As the network becomes more decentralised, so power flows become more complex and potentially more volatile. As more or larger PV and other distributed generation technologies are connected, it means that DNOs would sooner than later have to enhance the availability of new connections in certain parts of the network in order to accommodate the power available.

Where larger ground-mounted solar PV (like Cleve Hill) is to be connected, connection in the specific area of the grid might not be technically possible due to e.g. the lack of capacity on the lines, low transformer rating ranges, or even lack of substations. Moreover, if connected it will block a chunk of export capacity of the network with one of the least efficient technologies in terms of load factor (see Table 1 for a comparison), preventing connection of renewable technologies with much higher load factors.

Given the local grid constraints, a simple and efficient way of maximizing the contribution of new renewable capacity toward the decarbonisation goals of the UK energy system is to connect a more efficient load such as onshore or offshore wind, and/or connect a higher number of smaller distributed generators such as domestic solar PV, commercial and public solar PV. The connection of large scale solar PV will also preclude the development of local energy community projects, involving solar PV, wind or bioenergy, who are facing even higher barriers to entry since the removal of FiTs earlier in the year. Local smaller scale generators and community energy groups create more social, economic and environmental value from energy generation and help retain it in the local area, through providing free energy directly to

fuel poor customers and building capacity for self-generation, an explicit ambition in the region. Furthermore, the creation and retention of value locally for “prosperous communities” is a specific priority of the UK’s Industrial Strategy (HM Government, 2017).

As experience in other countries has shown, grid connection constraints are among the most significant non-economic barriers for large scale deployment of PV. The National Grid and DNOs are recognising that already network capacity is starting to impede PV connections in certain parts of England. This is contributing to a rising trend for grid connection costs, especially for larger ground-mounted projects. With the very quick lead time for PV projects DNOs need to be responsive to demands to execute large numbers of grid connection applications.

When connection capacity is scarce (both in terms of DNO ability to serve all applications and investment needs in the network) and projects that have been granted connection don’t complete for several months, this may add additional delay and uncertainty to a supply chain in transition, already operating with high levels of uncertainty. By the time of the next RIIO (Ofgem’s performance based framework for assessing revenue, incentive and innovation), the National Grid expects that the UK may host in excess of 15GW of solar, illustrating the scale of change that would need to take place over a 8 year period.

Distributed PV represents a particular type of intermittent energy resource, with three characteristics that set PV generators apart from conventional generators. *First*, the installed capacity is spread over numerous devices scattered across a large geographic area. *Second*, their power output is variable because of the solar cycle and clouds. *Third*, their power output is uncertain because, although the amount of sunlight reaching the PV array follows a regular pattern on average, chaotic atmospheric changes account for large deviations that are difficult to predict precisely.

A whole system planning framework requires a more joined up approach to assessing the costs and risks (and associated benefits) across transmission and distribution. The Solar Industry argued in 2018 that the UK electricity grid faces debilitating congestion and that capacity constraints are delaying and driving up costs for unsubsidised renewables, making “high cost and non-availability of network connections” the most significant barrier to new development. Connection queues are emerging in some parts of the network, slowing the rate of connection for some DERs<sup>3</sup>. Managing these queues is a challenge for the DSO<sup>4</sup>.

There are four key system challenges for connecting solar PV to the grid:

- *First*, there is limited spare connection capacity, with most capacity at suitable sites already assigned to developers, whether or not projects have progressed.
- *Secondly*, solar can lead to voltage level increases, when generation is high and demand is low, and this could result in network assets tripping and damage to

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<sup>3</sup> A distributed energy resource (DER) is a small-scale unit of power generation that operates locally and is connected to a larger power grid at the distribution level. DERs include solar panels, small natural gas-fueled generators, electric vehicles and controllable loads, such as HVAC systems and electric water heaters. An important distinction of a DER is that the energy it produces is often consumed close to the source.

<sup>4</sup> A Distribution System Operator (DSO) securely operates and develops an active distribution system comprising networks, demand, generation and other flexible distributed energy resources (DER).

electrical equipment.

- *Thirdly*, PV does not provide inertia, a property which affects the frequency control capability of the system. Low carbon generation replaces conventional fossil fuelled generation and the overall system inertia reduces because conventional plant has rotating mass which provides inertia to the system, whilst solar PV does not. As a result there is a greater impact in the balancing of supply and demand, requiring additional measures. This can have local effects as well as system-wide ones.
- *Fourthly*, uncontrolled renewable generation can exceed minimum demand and it is not currently possible to turn off most solar PV (DECC, 2014).

Currently, there is 103 GW of generation capacity on the system, 73 per cent of which is transmission connected, 23 per cent distribution connected and 5 per cent microgeneration. As the generation mix evolves, the transmission system needs to be kept balanced, including keeping voltage and frequency stable.

*The local DNO: UKPN is experiencing constraints on transmission networks which affect their ability to offer connections on the distribution system.* They are looking for a better, more sophisticated approach to funding and allocating capacity from a whole system perspective, and aiming to determine what the output measures are that represent whole system efficiency. These include measures such as whole system capacity and balancing services and flexibility capacity.

Network constraints are also due to an outdated connection application system offering a first-come-first-served allocation of existing capacity to developers. This creates a right (and possibly an expectation) on the part of developers that they can connect the project, when assessment for connection should be based on multiple criteria, including no/least regret options for the energy system and consumers. Put simply, the project should not proceed simply because a grid connection offer has been made and accepted.

*The South East electricity system is one of the most complex areas of network in Europe, with several interconnections to continental Europe, a nuclear power station and a significant volume of renewable energy resources.* The network supplies electricity over an area of approximately 8,200km<sup>2</sup>, incorporating all of Kent, East Sussex, and much of West Sussex and Surrey.

The continuing evolution to a decentralised generation landscape and incentives to deliver clean energy onto the system have strained an already heavily loaded part of the system. Just in this area over 1.8GW of embedded generation and 3.6GW of transmission connected generation exists (2GW of HVDC interconnector contracted and coming online in the next 3-4 years).

The principles underpinning the vision for demand flexibility in the UK are set out in the 2017 Smart Systems and Flexibility Plan (BEIS and Ofgem, 2017), which in turn is based on a report that shows a system using demand side response (DSR) and distributed storage to provide flexibility would be between £17billion and £40billion cheaper over the period to 2050 compared to a system that relies on enhancing flexibility through interconnectors and pumped hydro storage (Carbon Trust & Imperial College, 2016). So flexibility, through interconnectors, when they do come online, will be a more expensive option compared with no regret options



involving DSR and distributed storage (unlike the kind of storage proposed at Cleve Hill Solar Park).

The capacity strain on the network is forcing both National Grid and UKPN to adopt a whole system approach to manage and optimise network capacity. *However, this will also be a gradual process with a lot of uncertainty, and innovations required, such as new models for granularity of data exchanges between the two.*

UKPN is collaborating with National Grid to realise additional generation capacity in the highly utilised South East network, where Cleve Hill Solar Park is to be located. The Power Potential project which started in January 2017 aims to help UKPN to make the best use of existing and new DER (including wind and solar) resources in its network, while aiding the manage the operational challenges of the intermittent generation of renewables. The programme will create a reactive power market in the South East, which could deliver over 3.7GW of additional generation capacity in the area by 2050, 30 years from now (UKPN, 2017).

*It has been noted by UKPN and the National Grid that investment in distribution assets rather than transmission assets makes more sense in the interim.* For example, a lower cost option such as a distribution network asset or battery storage could be used in place of a transmission asset in the long term, or to manage costs while the need for a transmission line becomes more certain.

More active management of distribution networks may also be an efficient way to manage local issues. Increase of ‘embedded’ generation can have advantages for both the transmission and distribution networks. It can increase distribution network load factors and reduce overall system losses. It could also enable implementation of several innovations in network management, e.g. Active Voltage Control, Intelligent Network Switching, Phase shift transformers, Advanced Fault Current limiters.

There are several trials underway in different parts of the UKPN network experimenting how these measures could work. *However, until these become business as usual for the DNO in balancing the grid and connecting large solar PV capacities with storage, the system can manage incorporating a greater proportion of smaller scale embedded generation connected to the distribution network* (Ofgem, 2018a). This approach is in line with Ofgem’s priorities of 1) Making best use of existing networks; 2) Minimising costs of network expansion; 3) Facilitating effective energy markets to deliver for consumers; and 4) Achieving whole system efficiencies across energy sectors and vectors (Ofgem, 2019).

In order to assess if, when and how UKPN can connect the proposed capacity at Cleve Hill direct input from UKPN needs to be provided. Although the applicant stated that the DNO was in favour of the application there are specifics about the connection missing which will make it clearer what the associated costs and benefits might be.

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