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ONSHORE WIND AND SOLAR PV COSTS REVIEW

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1 INTRODUCTION

1.1 BACKGROUND

WSP UK Ltd (WSP) has been appointed by the Department for Business, Energy and Industrial Strategy (BEIS) to carry out a review of BEIS' cost assumptions for onshore wind and solar PV projects in the UK.

This report provides the results of that review. WSP has also updated the cost spreadsheets provided by BEIS reflect these results.

1.2 SCOPE

The scope of WSP's review was:

- Internal data gathering and analysis to form a UK-centric view of the wind and solar market, in parallel to discussion with BEIS on the initial dataset provided.
- Undertaking a benchmarking process that compared BEIS' assumptions and analysis against WSP's internal benchmarks and relevant public sources. This also included an examination of BEIS' modelling approach and suggestion of any improvements deemed beneficial.
- An assessment of trends and near-future costs which are to be considered, either in respect to the analysis or in its comprehension moving forwards.
- A review of longer-term trends that may influence future UK costs and progress of solar PV and wind projects.

1.3 APPROACH

WSP's approach to this review has been to explore the model provided and question the assumptions and data presented, using industry benchmarks and knowledge, combined with WSP's own experience, to validate the outputs formed and suggest alterations to BEIS' model where appropriate.

1.4 REPORT STRUCTURE

This report is divided into 3 sections:

- Section 1 – Introduction
- Section 2 – Onshore Wind Review
- Section 3 – Solar PV Review

2 ONSHORE WIND

This Onshore Wind section details WSP's recommendations on the assumptions and values currently listed within BEIS' 'Onshore Methodology' model. The items listed divide into two sub-sections; current cost and performance parameters, and future cost trends. Commentary provided supports the recommended position and is formed from WSP's assessment of project experience and internal data, with appropriate third-party corroborating evidence.

2.1 CURRENT COST AND PERFORMANCE PARAMETERS

Table 2-1 presents WSP's response to the parameters and associated values used by BEIS.

Table 2-1 – Current cost and performance parameters

Parameter	Recommendation	Commentary
Wind farm capacity	No change.	WSP think the value provided is suitable, considering the long timespan which the model is forecasting (to 2050) and WSP's insight into the market trends. The methodology to arrive at the value provided is also deemed suitable. Note that if the model were to look at a near-future timeframe, WSP believes a lower value such as 42MW, which aligns with the REPD, would be more appropriate. Source; Renewable Energy Planning Database (REPD) June 2020.
Availability	No change.	WSP agree with using an availability of 97%, this benchmark remains the industry standard which we are seeing. Typically turbine O&M contracts include a 97% availability warranty, with modern turbines this level is usually exceeded. Taking into account additional balance of plant downtime means that 97% is a reasonable assumption, and the value WSP typically see for financing wind farms.
Load Factor	No change.	The load factor for onshore wind is detailed as 34.8%, as an average, this is what WSP would expect to see. Over the last decade this has significantly increased due to the increased rotor diameter of turbines, which has increased disproportionally to the turbine's rated capacity. This has been especially relevant to lower windspeed sites. As well as rotor diameter, a significant driver of the increased load factor in the UK has been that only higher windspeed sites have been financially viable without subsidies. Moving forward in the UK we would expect the higher wind speed sites to be prioritised before more marginal sites which would come later, this would suggest this trend in increasing load

Parameter	Recommendation	Commentary
		factors would not continue at the same rate and is likely to plateau. In addition, the continuation of this would rely upon the continued increase in rotor diameter for sites which may not be possible in the UK due to planning restrictions and high loading on the turbines in the typical onshore sites WSP see in the UK, especially Scotland. The comment regarding 90% of new projects being in Scotland, and 10% in England and Wales is also a fair characterisation of the market if ignoring Northern Ireland, especially when focussing on future higher capacity and windspeed projects. The Welsh market could be developed further but requires significant investment regarding grid infrastructure.
Timings		
Timings – pre-development period	No change.	The current pre-development period is listed as 4 years. WSP suggests that this pre-development value remains. Such a period allows for; one year of feasibility and land studies, one year for planning and ecological assessments, and then two years of planning and contract negotiations, which is reasonable in our experience.
Timings – construction period	No change.	The current construction period is listed as 2 years. WSP suggests that this construction period value remains based on our experience of this scale of site.
Timings – plant operating period	No change.	The current plant operating period is listed as 25 years. Historically, based on the IEC design standards (IEC64100-1), wind farms have a plant operating period of 20 years however WSP suggests that this 25 year value remains as it reflects our recent project experience. Note that the global market is starting to introduce 30 year lifetimes at present the UK is unlikely to have such projects commissioned, this is due to the higher wind speed and turbulence wind turbines have to endure, therefore limiting their potential operating period compared to other regions. We also note that at present there is a reticence in planning to allow onshore wind farms to extend their operational period significantly.
Costs		
Capital cost – pre-licensing technical and design	No change.	The pre-licensing cost presented of 64 £/kW appears to be within the range WSP would expect and therefore does not require amending. Larger turbines being brought to market and installed in the UK should keep this figure relatively constant.

Parameter	Recommendation	Commentary
Capital cost – regulatory and licensing	No change.	The regulatory and licensing cost presented of 45.9 £/kW appears to be within the range WSP would expect.
Capital cost - construction	No change.	WSP would suggest keeping the current assumption used in the model, it appears to be within the range WSP would expect and reflects what WSP is observing in current projects and from third party sources.
Capital cost - infrastructure	No change.	The infrastructure medium cost present is assumed constant, at £3,322,000. WSP considers this to be a reasonable value and method as onshore wind farm sites with larger turbines will still require similar electrical and civil infrastructure. Significant variation in these costs is expected, especially for sites with expensive grid connection and/or difficult ground conditions such as peat, or topography issues.
Operating costs - fixed	No change.	The fixed OPEX presented is assumed constant, at 22,000 £/MW. This value is considered to be a reasonable value for the market over the near-future.
Operating costs - variable	No change.	The variable OPEX presented is assumed constant, at 5.22 £/MWh. From WSP's experience this appears to be a reasonable assumption.
Operating costs - insurance	No change.	The insurance associated with the OPEX of an onshore wind farm is presented as constant, at 1,441 £/MW/year. WSP considers this to be a reasonable value based on our experience in the market.
Operating costs – connection & UoS	No change.	The connection and UoS charges of an onshore wind farm is presented as being constant, at 3,109 £/MW/year. WSP considers this to be a suitable approach and value for the period in question.

2.2 FUTURE COST TRENDS

This section and Table 2-2 presents WSP's assessment of the model used in regard to longer-term cost trends and the assumptions used.

Table 2-2 – Future cost trends

Parameter	Recommendation	Commentary
Basis for future cost trends	Keep the new CAPEX learning Change the Capex_Learning costs reductions by turbine size. The change is to the Power / MW presented for the *Commissioning Year.* WSP suggest making the changes to the MW associated with each year as shown below; 4 MW 5 MW 5.5 MW 6 MW 7 MW	BEIS' use of a new method of CAPEX forecasting, transitioning from a learning-rate to a turbine size approach, is supported by WSP and is considered the better option of the two. The trend of CAPEX decreasing per kilowatt is likely as the market progresses and larger turbines for onshore use develop and learn from offshore advances. WSP consider the new power values provided as a more likely progression of onshore turbines in the UK market. The trend used in which the CAPEX reduction factor decreases in rate is reasonable, although the wind turbine relative radius used may require additional study as we foresee there to be planning obstacles with such large turbines being installed on the UK mainland. WSP have used an example of a 110m rotor diameter turbine for the 3MW 2017 reference turbine; subsequently using the scaled increase within the model, the resulting rotor diameter reaches 200m in 2035. Although this may be the case in certain geographies, such as rural deserts and plains, WSP believe that if such turbines exist, they will unlikely be implemented in the UK due to both planning and technical obstacles. From WSP's knowledge of the industry and technical advances being made, such large onshore turbines may encounter issues relating to technical feasibility, arising from the turbulence prevalent in the UK onshore wind resource. Turbulence and wind shear challenges increase the physical hurdles the turbine has to overcome to operate effectively over the expected lifespans (equivalent offshore sites do not experience the same loading scenarios). Turbine designs of such a large rotor for the onshore market are yet to materialise, and if they do, at present their UK implementation appears unlikely, both from a survival perspective, and from the difficulties linked with transportation and installation. Transporting blades for onshore turbines like the example mentioned earlier already faces difficulties, therefore longer blades would require significant upgrades to routes and cause considerable disruption. There is an option for modular blades that are assembled on the project site, but these options are relatively limited in the market. In addition to technical constraints, WSP believes such large turbines will struggle to be granted planning permission; this is due to the larger size of the turbines generating a greater number of objections related to their scale within the landscape. Landscape scale can dictate the ability of an area to accommodate wind farm development, a landscape has a scale in which wind turbines are relative to, both vertically and horizontally. The comparison of the turbine to nearby features will raise concerns, therefore the site would require a somewhat featureless surrounding terrain to prevent the turbines dominating the landscape.

Parameter	Recommendation	Commentary
		WSP has therefore recommended a reduction in the increase of turbine capacity by 2035 (compared to the 10MW value currently assumed by BEIS) to reflect the above constraints. Source: Siting and Designing Wind Farms in the Landscape - Version 3 - 2017
Capital cost split	No change.	The capital cost split is reasonable, although these values are more vulnerable to fluctuation due to the inherent variability between onshore projects. The foundation cost is slightly greater when compared to reporting from NREL, although for UK purposes the difference is very low and still within an expected range therefore not warranting a change. Installed cost per megawatt can vary considerably depending on plant size, particularly once going beyond the 20 MW scale. This difference is due to economies of scale and will therefore alter the capital cost split. The range presented in the model facilitates this scenario. Source: NREL Technologies Market Report, 2018
Cost trend - turbines	No change.	Turbine cost per kilowatt has been steadily declining in the global market in the last decade. This trend will likely continue and WSP agree that the CAPEX reduction factor will decrease in rate. A key factor of the reduction in price decline-rate is due to the increasing difficulty turbine manufacturers are having to sell at a sustainable margin. The change from FiT systems to auction systems across Europe forced prices down at a faster than expected rate, as this drop has now occurred the rate of change is expected to reduce. This transition limits the opportunity for further price reductions to some extent.
Cost trend - foundations	No change.	The BEIS model assumes constant cost percentage of CAPEX for the foundations of the wind farm. As the CAPEX of the wind farm decreases, the project foundation cost decreases. As turbines increase in size their foundation cost is likely to rise on a per turbine basis. However on a site basis, as the number of turbines installed for the plant will decrease, the overall foundation cost is not expected to increase. Due to technical innovations the overall foundation cost of the project is also likely to decline. Therefore, WSP deems the model's approach to be a fair reflection of the trend of foundation cost.
Cost trends - infrastructure	No change.	The current model shows no change over time. WSP suggest keeping the current methodology which has infrastructure costs as constant. This is a reasonable assumption as onshore wind plants shall use fewer yet higher capacity turbines, the increase in cost will likely compensate for the slight

Parameter	Recommendation	Commentary
		reduction in costs associated with roads and cabling, although these are likely to remain relatively constant as the area of the projects will reflect the requirements of the turbines used.
Cost trend – grid connection	No change.	Grid connection costs, despite being project specific, are on average considered likely to remain constant. WSP does not suggest any changes to the BEIS model regarding grid connection.
Future OPEX costs	No change.	BEIS' model presents OPEX as a constant value per megawatt over the modelled period. WSP finds this approach reasonable and support the decrease in cost actioned in the last update. WSP does not suggest changing this value for this update. WSP's position on OPEX being a constant value per megawatt stems from insight with manufacturers and developers, in addition to the relatively stable cost of labour and time associated with OPEX. Due to the current constant value regarding OPEX, the primary driver of cost reduction is increased competition. The industry has traditionally found cost savings in CAPEX reduction, although as the industry has developed fewer new savings can be found. This decelerating trend of reduction is expected to continue and forces the market to be competitive elsewhere, potentially increasing the focus on OPEX reduction. However, the UK market is yet to experience a significant change in OPEX values because of this transition, and the timing of any such change is uncertain.

3 SOLAR PV

The Solar PV section details WSP's recommendations to the assumptions and values currently listed within BEIS' 'Solar Methodology 2020' model. Similarly to the previous section, the items listed divide into two sub-sections; current cost and performance parameters, and future cost trends. Commentary provided supports the recommended position and is formed from WSP's assessment of industrial experience and internal data, with appropriate third-party corroboratory evidence.

3.1 CURRENT COST AND PERFORMANCE PARAMETERS

Table 3-1 presents WSP's response to the parameters and associated values used by BEIS.

Table 3-1 – Current cost and performance parameters

Parameter	Recommendation	Commentary
Plant capacity	Change. From 16.4 MW to ~20 MW.	WSP would suggest increasing the size of the medium scenario plant capacity. This suggestion to increase the capacity is due to the likelihood of continued granting of planning applications of large plants, as seen in the REPD, WSP is also witnessing an increase in the scale of UK solar plants. A factor which is aiding this trend includes the increasing capacity of modules and decreasing module price per kW, such advances are expected to continue.
Availability	No change.	The availability profile of 99% is the standard in the UK and most of the world, WSP would expect this benchmark to remain.
Load Factor	No change.	WSP does not think the Load Factor value of 10.88% needs altering as the average of yearly averages between 2012 and 2019, which has been relatively consistent, is 10.925%. The range presented with a high of 11.92%, and a low of 9.69%, is a reasonable evaluation of the UK market.
Timings		
Timings – pre-development period	No change.	The medium value of 0.8 years is provided by BEIS and WSP consider that this value and associated range is appropriate and aligns with the current range of project schedules observed by WSP.

Parameter	Recommendation	Commentary
Timings – construction period	Change. 0.25 to 0.5 years	For the 20 MW plant WSP suggest, the medium value should be altered to reflect this, to an approximate value of 0.5 years. This value still provides an appropriate approach to the breadth of time associated with solar PV construction for the high and low values.
Timings – plant operating period	No change.	The value of 35 years given by BEIS is suitable for projects coming online in the near future with current technologies. It is generally difficult to forecast how future technology advancements will alter operating periods. Operating periods could even decline due to higher capacity and efficiency modules possibly having shorter lifespans yet being cost effective with favourable rates of returns.
Costs		
Capital cost – overall	Change. £ 730 to £ 615 /kW	WSP would suggest reducing the capital cost of £ 730 /kW to a value of £ 615 /kW. This is based on the pricing WSP are observing in the market at present, for plants being commissioned in 2021. The current lower price suggested is partially as a result of 30 GW of unused manufacturing capacity in the market, combined with developers and traders forming inventories to take advantage of the lower prices (IEA, RE Market Update 2020). The impact of COVID-19 is likely to maintain this situation for the near-future, by which point the price is likely to remain low, if not lower as technological evolution continues to take place during this period of over-supply and lessened demand. An example of the evolving industry is that within the last two years, WSP have seen solar plants go from installing 275-300W modules, to modules of 500-550W. Other technological advances that are being seen in the market are mentioned in Section 3.2.
Capital cost – pre-licencing technical and design	Change. £ 37 to £ 31 /kW	The large range presented is considered an appropriate approach to this category. The medium value presented by BEIS was £ 37 /kW, but with WSP's new overall CAPEX value, it has changed to £ 31 /kW. This value is derived from the current breakdown of costs used, which assigns 5% of the overall CAPEX to pre-licencing technical and design, this aligns with WSP's experience. However if the breakdown of costs is updated to IRENA's Renewable Power Generation Costs in 2019, as opposed to the current 2016 version, the distribution would increase 9% of overall costs, using BEIS' previous classification structure. This may be the case as the CAPEX per kilowatt continues to fall, the share of the cost for pre-development phases could increase. WSP considers the large range provided by BEIS in the model to sufficiently encapsulate this variation over the near-future.

Parameter	Recommendation	Commentary
Capital cost – regulatory and licensing	Change. £ 12 to 10 /kW	The methodology's value is listed as £ 12 /kW, the value derived from WSP's new overall CAPEX is £ 10 /kW. This value within the range provided in the model should present a better representation of the current market. The share of 2% of the total cost aligns with WSP's experience of ongoing projects, in addition to being aligned with IRENA's 2019 distribution of 3% (using BEIS' classification). The wide range presented is considered reasonable given the project-specific nature of these costs.
Capital cost - construction	Change. £ 621 to 523 /kW	The CAPEX associated directly to construction is at present, £ 621 /kW. Using WSP's new overall CAPEX input, the medium value for construction costs is £ 523 /kW, this aligns with the data WSP is seeing at present.
Capital cost - infrastructure	Change. £ 73.7 to £ 62.1 /kW	The infrastructure cost which is listed in BEIS' model, of £ 73.7 /kW, is greater than what WSP would expect to see. Using BEIS' classifications, the model produces a value of £ 62.1 /kW. This results in an infrastructure cost value of £ 1,241,000 for the 20 MW plant assumption.
Operating costs - breakdown	No change.	The breakdown of the operating costs generally aligns with a distribution that WSP is observing in the UK market; WSP does not foresee such a breakdown changing considerably in the near future.
Operating costs - fixed	No change.	The fixed operating pricing presented aligns with the trend and values that WSP are witnessing. The UK is yet to experience significant consolidation of O&M contractors, although this may change in the future and is discussed further in Section 3.2.
Operating costs - variable	Reduce to zero.	The BEIS model data currently includes a variable cost element in the "high" case. WSP typically sees solar PV operating costs reported on a fixed basis, and so suggests that all costs are included in the fixed price category.
Operating costs - insurance	No change.	The insurance costs presented, with a medium value of £2,342 MW/year, appear to be an appropriate range that WSP would expect to see.
Operating costs – connection & UoS	No change.	WSP believe the charges associated with the connection and UoS of the solar plant are reasonable and have an appropriate range for the current market.

3.2 FUTURE COST TRENDS

This section and Table 2-2 presents WSP's assessment of the model used in regard to longer-term cost trends and the assumptions used.

Table 3-2 – Future cost trends

Parameter	Recommendation	Commentary
Basis for future CAPEX trends	No change.	There are numerous reasons as to why CAPEX prices are decreasing. Modules are increasing in capacity, and therefore require fewer mounting structures, less cabling, and a reduced required land area when compared to an equal sized plant installed even one year prior. Furthermore, module lifespans are increasing, in addition to the mounting structures they are installed on. This trend continues to the inverters used and their longevity, with string inverters nearly tripling in capacity compared to the same type two years prior. Technological advances with increasing maturity, efficiency and competition, has meant that owners are receiving better value products in general, which reduces their overall plant per megawatt cost. How future technological innovations will influence the UK market is difficult to determine but the general trends of improved value are consistent. New technologies are becoming more prevalent in the international market, such as bifacial modules, half-cell modules, and trackers. This is the result of increasing research and development and the global adoption of the technology expected to cause a six-fold increase in global capacity by 2030. Enabling technologies such as battery energy storage systems (BESS) and new business models are also aiding the increase in solar PV uptake, both globally and in the UK. Source: Future of Solar PV, IRENA, 2019.
Capital cost split	No change.	The solar methodology currently used is an IRENA breakdown of capital costs from 2016; although WSP agrees with this distribution of costs at present, and it has been utilised for all of the previous updates, WSP foresee adjustments being necessary in the future as module and inverter prices continue to decrease per kilowatt, therefore reducing the share of which construction costs constitute of the overall cost. IRENA's 2019 report of Power Generation Costs had been explored by WSP and appears to generally be suitable in its distribution of costs, but when combined with BEIS's classifications, it becomes overly skewed to module costs, which isn't the current trend. Going forwards, as new technical innovations come to market, the distribution of costs used may require updating, but at present the distribution used is appropriate for the UK.

Parameter	Recommendation	Commentary
Capacity forecasts	No change.	The data provided regarding capacity forecasts aligns with WSP's expectation.
Learning rate - modules	No change.	The learning rate presented in the model is 28%, WSP consider this to be appropriate and aligning with both third party data, and WSP's experience.
Learning rate – balance of system	No change.	The learning rate presented is in line with WSP's experience and third party information.
OPEX cost trends	No change.	As mentioned previously, the operating cost trend presented is within the range expected. WSP believes that O&M will have an increasingly important role in solar PV plants in the UK. Previously O&M had been underappreciated by owners, consequently many plants are struggling with unforeseen issues. The scale of monitoring required has grown, but with it so has the technological tools available, such as drones and artificial intelligence forecasting and management. The demand for continuous O&M support services will increase as more plants are installed and a greater level of monitoring is desired. As this occurs, it is possible that the UK will follow many other European nations and have an O&M market which begins to consolidate into a smaller number of larger providers. This aim of future proofing sites to prevent faults arising via continuous monitoring is an increasing trend which will mature in the near-future, this may require a future update in the model as new prices are revealed under increasing demand.
BESS co-location	N/A	Although this is not a current issue or included in the BEIS model, WSP are beginning to see a trend in which more solar PV plants are exploring the possibility of BESS colocation. Using BESS facilities to support the grid and optimise the use of their solar PV plant. The UK energy storage industry is still maturing and becoming increasingly competitive, subsequently a greater number of solar PV plants with colocation is likely. As this trend develops, such a scenario may require the model to be amended to incorporate these new systems.

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