Independent Review of the 2019 BEIS Updating Methodology for the Cost of Generating Electricity from Wind and Solar Technologies

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1. **Terms of Reference, Scope and Declaration**

   This review provides a commentary on the methodological approach taken by BEIS for updating the BEIS Generation Costs (2018)[1] to new estimates for the onshore wind, offshore wind and solar technologies. The review is an assessment of the overall methodology with comments on whether the assumptions developed appear to be of the correct order, are sufficiently robust, and are suitable for use in BEIS modelling. I had previously provided a peer review on BEIS 2018, and in that respect, this peer review is an update of my previous peer review from a year ago.

   Assumptions out of scope include Hurdle Rates, GDP deflators, Exchange rates, and other factors exogenous to the development, construction and operating costs of these three renewable technologies.

   In undertaking this review, I have done so in my personal capacity as a consultant. All opinions are my own and do not reflect those of the various organisations with which I am affiliated. I have no business associations with any particular generation technologies and no conflicts of interest in undertaking this report as an independent advisor.

2. **Summary Opinion**

   As a basis for moving forward from BEIS 2018, I believe the methodology, as presented to me, is fit for purpose. I have examined the spreadsheet models and consider them to be well constructed with adequate explanations of the assumptions and their sources. However, the auction results for offshore wind in AR3 became available during the period of this peer review, and this raises questions for further analysis by BEIS. My understanding is that the LCOE for offshore wind may be adjusted accordingly. I recommend that to be considered, and if an adjustment is justified, then I suggest that there may be a spillover adjustment needed to the onshore and possibly solar technologies, once the reasons for the auction results are clarified.

3. **Sources of Information**

   Following an invitation to tender by BEIS in August 2019, I was requested to perform this review in September 2019. It is an assessment of work-in-progress by BEIS, the approach and the main assumptions that have been made. I have assessed the process as it is being undertaken. It is not a critique of a final report. For this purpose, therefore, I have been provided

[1] At the time of this review, BEIS Generation Costs 2018 had not been published and it had been a selective update of BEIS Generations Costs 2016, previously published as: https://www.gov.uk/govemment/publications/beis-electricitv-generation-costs-november-2016

with the internal BEIS spreadsheet models and notes, with references, for the key assumptions. I was also provided with a summary powerpoint presentation on 'Generation Costs Summer Updates 2019'. There was no time available for interviews or wider background research.

4. Expertise

My qualifications for undertaking this review are briefly summarised as follows. I am a Professor at London Business School, with over 35 years experience in research and advisory work for the electricity sector. I have been Editor of *Journal of Forecasting* since 1984, formerly Editor of *Energy Economics,* and founding Editor of the *Journal of Energy Markets.* I currently serve as an independent member of the Balancing and Settlement Code Panel and I chair the BEIS Panel of Technical Experts which advises on the parameters for the capacity auctions. I have been a special advisor to the House of Commons Select Committee on Energy and Climate Change, consultant to the UK Competition Commission on Electricity Market Abuse, Expert Advisor to the National Audit Office in their review of the electricity industry reforms, peer reviewer for modeling work by DECC and Ofgem, and Expert Witness in several litigation cases before the High Court in London and at international arbitration. Most relevant to this review, in 2016, I undertook an independent peer review for BEIS of the hurdle rate updates for generation technologies[2], and in 2018 I undertook the peer review of the BEIS Generation Costs update.

5. Updated Assumptions

The main objective of the various assumptions is to provide the inputs for levelised cost of electricity (LCOE) estimates, which are essentially the annuitised lifetime costs of electricity production from each technology. Whilst, it is out of scope for me to assess the principles of levelised cost calculations and their appropriateness in this report, I would, nevertheless, like to comment that in the BEIS Electricity Generation Costs 2018 there is a clear awareness of the issues and sensitivities in the parameters and it is my opinion that in the context of using levelised costs, BEIS have been pursuing best practice.

From this basis I look at the updating assumptions for the designated technologies.

5.1 Offshore Wind

On 20 September 2019 BEIS published[3] the results of the Contracts for Difference Allocation Round 3, in which offshore and remote island wind cleared the auction at £39.650/MWh for 2023/24 and £41.611/MWh for 2024/25. Note these are in 2012 prices. This compares with a central estimate LCOE of £59/MWh in BEIS 2018 and £56/MWh in the Updates[4], both in 2017 prices, the latter giving £52/MWh in 2012 prices. I understand BEIS will consider this difference

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[2] https://www.gov.uk/govemment/publications/bunn-2016-peer-review-of-nera

[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/832924/Contracts_for_Difference_CfD_Allocation_Round_3_Results.pdf

[4] The Updates provided ranges, the lower band for 2025 being £51/MWh in 2017 prices, or £47/MWh in 2012 prices, which is also above the auction outturn.

and make revisions accordingly. Evidently the reductions from BEIS 2018 will now have to be more substantial and further stakeholder discussions, ideally with the winners of the CfDs, would be particularly informative in identifying which cost elements were most substantial in driving the reductions. Obviously the competitive elements in the auctions, this round and the previous one, have been instrumental, as they have in other European offshore auctions, but there will be elements of the cost fundamentals that contribute as well. It is out of scope for me to review the hurdle rates, but is likely that hurdle rates may be coming down as lenders and equity providers become more comfortable with the project risk element. I observe that the hurdle rate was reduced from 8.9% in 2015 to 6.4% in 2017 and updated to 6.3% in 2018 . Although LCOE is very sensitive to hurdle rates and a further reduction may reduce LCOE substantially, it is unlikely that stakeholder consultations would indicate much reduction on 6.3%.

In the Updates, BEIS only focused upon three cost fundamentals: (1) updating the length of life from 25 to 30 years, (2) longer term learning and turbine sizes changing capex per kW and (3) opex. The capex fall after 2030 with extended learning is a new update, based upon a number of sources and appears to be a credible projection. The Opex projection is based upon considerations by Arup and BNEF projections of UK cumulative capacity

Not updated from BEIS 2018 were Pre-development costs, Construction costs, Infrastructure, Fixed and Variable O&M, Insurance, Connection costs, Availability, Load factor, Pre-development and construction periods, and Decommissioning costs. Whilst there may be little information over the past year to justify changes, several of the BEIS 2018 cost elements were not updated from BEIS 2016, which in turn were strongly influenced by Arup 2015. Evidently there are several items here where cost reductions may appear. I mention some that may be of some significance:

> *Pre-development costs* should start to manifest economies of scale as the capacity of the sites gets larger.
>
> *Infrastructure* costs may decline further with inter-array cabling and offshore substations cost reducing on a per MW basis as capacity increases with fewer but larger turbines.
>
> With *load factors,* there has been a steady upward trend which may continue, with improved operational software and the larger turbines.

I have examined the BEIS Excel spreadsheet model which is sound in its formulation and transparent in its assumptions. There are no obvious inconsistencies in its working. The documentation is clear in reporting stakeholder engagement, desk compilation of third party reports including some from elsewhere in Europe as well as reference to estimates by Arup BNEF, Baringa and others. I think this demonstrates a careful approach to the synthesis of evidence.

5.2 Onshore Wind

New information between 2018 and 2019 on the drivers of cost reductions for offshore is not likely to impact onshore to the same extent. This is the BEIS view and as a consequence very

minor changes (LOCE reduction of £2/MWh) are introduced in the Updates compared to BEIS2018. This is consistent with the widespread conventional view of onshore being closer to maturity as a generating technology, more standardized in development and less complicated by site specificities. Furthermore, the competitive effect of an auction for price revelation has not been evident for onshore.

However, the history of the three rounds of CfD auctions has in each case revealed clearing prices substantially below the prior LOCE estimates for all technologies. Thus, as a thought experiment, do we believe the market to be already sufficiently competitive that an auction for onshore would offer very little new in terms of price revelation? Whilst the common value for onshore may be better understood at large, looking at the recent offshore results, it is tempting to speculate that an onshore auction would have pushed prices more than £2/MWh below BEIS 2018.

But in this context, the most pertinent observation is that the central estimates for onshore in the Update are around £44/MWh for 2025, in 2017 prices, compared to the clearing price in AR3 for offshore of £41.611/MWh for 2024/25, in 2012 prices. Adjusting both to 2012 prices makes them almost equivalent. However, currently offshore LCOE is reasonably considered to be more expensive than onshore (£52/MWh to £44/MWH in 2017 prices in BEIS Update for 2025) and so to the extent that offshore will be adjusted by BEIS to reflect AR3 clearing prices, onshore will have to move down pro rata to maintain a credible differential[5]. Much will depend upon the forensic analysis by BEIS on the reasons for the low AR3 clearing price compared to the prior LCOE estimate, and the extent to which these reasons will also apply to onshore.

Despite this rather important caveat, in their 2019 update, BEIS have taken a carefully reasoned analysis of moderate changes, which appear to be credible and defensible. However, only capacity and global projections were updated. These mainly affect the learning rates, and appear to be the main reason for the slight drop in LCOE from BEIS2018. As with Offshore, many of the other fundamental cost elements go back to Arup 2015[6] and so some updating may be needed.

Looking again at the main cost elements in turn:

CAPEX construction assumptions were updated in BEIS2018 consistent with other sources such as BNEF[7], Baringa[8] and Aurora[9]. Most projections are showing a flatter cost reduction

[5] Looking further ahead, it may well be the case that offshore LCOE becomes comparable or even lower cost than onshore as turbine sizes and load factors improve offshore.

[6] https://www.gov.uk/government/publications/arup-2016-review-of-renewable-electricitv-generation-cost-and- technical-assumptions

[7] BNEF https://about.bnef.com/new-energy-outlook/

[8] https://www.baringa.com/getmedia/99d7aa0f-5333-47ef-b7a8-1ca3b3c10644/Baringa Scottish-Renewables UK-Pot-1-CfD-scenario April-2017 Report FINA/

[9] *Aurora, 2017* Cutting the cord: long-term Prospects for GB wind and solar. www.auroraer.com

based upon revised learning rates and as the major supply chain efficiencies already introduced become more stable going forward.

Fixed Opex could be reduced more based upon more competitive contracting. This is broadly in line with industry commentaries for the renewable services sector in general.

Variable Opex, insurance and connection costs are assumed to be unchanged, as with offshore. The connection and use of system charges depend upon location but on average are not expected to increase substantially

With *load factors*, they were updated in BEIS 2018 to 34.8% and have not been updated further by BEIS. They are also projected out to 2050 at this level. To the extent that this is consistent with other analysts, being roughly central within the range of five other sources, it is credible. One might expect more efficient turbine to be coming in, even if the best onshore locations may have already been take. Evidently, much depends upon the presumed locations and I note that 90% of new projects are expected to be in Scotland. Curtailment risk is apparently not taken into account in the load factors. I am informed that in BEIS, these market and system effects are taken into account when looking at the generation mix under a range of scenarios.

However, such market and system effects are more pronounced for onshore wind as the cannibalisation effect is becoming more recognized as a future business problem. With high wind conditions, increased penetration and local distribution constraints for embedded generation, this may become more significant. If new connection agreements are cheaper in return for no curtailment compensation, reduced load factors will affect revenues and will need to be factored into the investment calculation. In the Orkney Islands, for example, SSE have operated active network management (ANM) to curtail wind generation on a last-in-first-out basis[10].

I observe in the spreadsheet that *Lifetime* was increased in BEIS 2018 to 25 years to match offshore at the time, but this has not been further increased to 30yrs to match offshore in the 2019 Update

I note *decommissioning costs* are assumed by BEIS to be at net zero, balancing scrap values. The option value of the site for repowering should provide a positive counter to these costs, however.

5.3 Solar

The solar updates appear to be particularly thorough and are more detailed in several respects than the onshore wind, eg with respect to network charges, use of system and balancing costs as well as a finer breakdown of cost elements. The solar spreadsheets are thorough and very

[10] https://www.ninessmartgrid.co.uk/our-trials/active-network-management/what-is-active-network-management/

commendable.

Generation costs from solar have been decreasing substantially and are expected to do so. Thus, the so-called "learning rate" (which captures more reasons for cost reduction than "learning") is crucial to forward estimates. The methodology presented in the BEIS modelling spreadsheet is a thorough compilation of data and presents a detailed analysis. The evidence base that BEIS draws upon is a good one, from reputable organisations, mostly BNEF, without any obvious sector biases.

Capex is the main element and there are now more substantial databases available to estimate current costs than previously. I note that broad evidence has been compiled for the current capital costs, including international data from 11 countries. Final estimates have been made with some averaging across sources, after adjusting for different commissioning dates.

I observe that this update has increased the *lifetime* to 35 years, which is appropriate.

The analysis of small scale solar proceeds in a similar way to the large scale solar. A very detailed analysis of small scale in categories <4kw, 4-10kw,10-50kw has been undertaken using various data sources available to BEIS. Opex and Learning rates have again been based on various sources. As with the larger scale solar, I think the quality of this analysis is sound and the assumptions are credible.

Overall, I think the methodology is sound and the assumptions reasonable. One question that is emerging is about load factors and the way in which these could increase substantially with the increasing use of batteries, both fixed and via electric vehicles, alongside PV generation. I think this leads to a new category of hybrid generation and I am sure BEIS are considering further work on this and its imminent inclusion.

6. **Fit-for-Purpose**

This is a selective and careful updating of generation costs by BEIS. The spreadsheet models produced for onshore wind, offshore wind, and solar appear to be thorough, transparent and well-documented with respect to assumptions and sources of evidence. I think their quality is good and overall the assumptions are sound.

Regarding the major focus of this updating to wind and solar, the progressive reductions in capex are driving the main changes for both technologies. For offshore wind it is the scale effect of larger turbines and whilst the forecasts of 20MW units by 2030 may be exciting developers, much will depend upon the financial strength and competition amongst turbine manufacturers to continue with successively more ambitious product innovations. For solar it is the global market for panels/modules and this continues to show signs of strong price competition. Offshore wind and solar costs in GB are clearly therefore influenced by market fundamentals of worldwide scope, and in that respect the reliance that BEIS places upon major international information providers is defensible and in my opinion a reasonable evidence basis for policy.

In this Update, projections from 2030 to 2050 have been included. They are generally evidence based, relying upon sources such as BNEF and other consultants, or default extrapolations of 2030 values. In the absence of in-house long-term cost models, the evidential sources are a credible basis for extrapolation. The history of technological forecasting of cost reduction in the new renewable technologies, particularly solar PV and onshore wind, has revealed that over the past 20 years, forecasts have been conservative, and have underestimated cost reductions. On the basis of past performance therefore, it is more likely that those forecasts based upon learning rates will overestimate rather than underestimate future cost levels. Nevertheless, the projections are central estimates based upon the best information provided by stakeholders and experts at this time. Such uncertainty going forward would be better represented in asymmetric ranges around the central projections, than in a historical de-bias of the central estimates.

In general, whilst LCOE ranges were produced for wind and solar, I think the Update could have made more use of ranges at the input stages. The spreadsheets were coded to allow ranges for most variables, but often ranges for some inputs were not specified. So the final LCOE ranges reflect only some of the uncertainties. Looking at the ranges forecast for 2020-2050 for onshore, offshore and solar>5MW, we see parallel High, Low and Central bands in all three cases. Forecasters generally expect to see confidence intervals getting wider as uncertainty increases further into the future. The range of uncertainty for 2050 should be much wider than for 2020, for example, but this is not the case in these Update projections. Evidently this must reflect the selective nature of input uncertainties in the BEIS modelling of ranges. Going forward, it would be useful for BEIS to think more about ranges, what they mean, how they should be communicated and how they can be considered to be evidence–based.

The crucial consideration for this Update should, however, be a detailed forensic analysis of cost drivers for offshore wind following the results of AR3. This will have a spillover to onshore. If offshore LCOEs are reduced substantially, a credible differential with onshore will need to be maintained. The spillover to solar may be much less, depending upon the forensic analysis.