Independent Review of the BEIS Updating Methodology for the Cost of Generating Electricity from Different 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 (2016)[1] to new estimates for the onshore wind, offshore wind and solar technologies, as well as a high-level review of some new CCUS assumptions. The review comments on whether the assumptions developed are of the correct order, are sufficiently robust, and are suitable for use in BEIS modelling.

   Assumptions out of scope include GDP deflators, Exchange rates, Carbon price trajectories, Fossil fuel assumptions, Gate fees for waste treatment and Investment hurdle rates.

   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 (2016), I believe the methodology, as presented to me, is fit for purpose, and the new assumptions for the selected technologies to be credible and appropriate for policy.

3. **Sources of Information**

   Following an invitation to tender by BEIS in May 2018, I was requested to perform this review in June 2018. 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 with the internal BEIS spreadsheet models and notes, with references, for the key assumptions. 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 am a member of 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

[1] https://www.gov.uk/govemment/publications/beis-electricitv-generation-costs-november-2016

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].

5. New Assumptions

The starting point for this analysis is the previous BEIS Electricity Generation Costs (2016) publication[3], since the scope of the review is to comment upon the methodology and assumptions being undertaken by BEIS to update these to 2018. Although a substantial objective of these cost estimates is to provide levelised costs, which are essentially the annuitised lifetime costs of electricity production from each technology, it is the elements of these calculations, such as CAPEX, OPEX and load factors that are often used by BEIS in their modelling, and it is upon these elemental assumptions that I comment. It is out of scope for me to assess the principles of levelised cost calculations and their appropriateness in this report. But, I would, nevertheless, like to comment that in the BEIS Electricity Generation Costs (2016) there is a clear awareness of the issues and sensitivities in the parameters and that 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

Some of the assumptions from the 2015 review undertaken by Arup[4] are being retained, but various analysts (eg Bernstein[5], Citi Research[6], Aurora[7]) comment that most cost elements in these technologies are declining, partly due to learning but mainly due to the larger turbine sizes and scale of the new installations. Looking therefore at the main cost elements assumptions in the BEIS spreadsheet model:

Pre-development costs are assumed by BEIS to be unchanged from Arup 2015 and this seems, on balance, to be reasonable. In 2016, Arup noted that these had increased by 16% from DECC2013[8] due to increasingly stringent Environmental Impact Assessments and geotechnical surveys, but, going forward there should be economies of scale as the capacity of the sites gets larger, and these should balance out.

CAPEX construction reduction of 27% for 2020 compared to previous estimates (2015 Arup) and declining further through to 2025 is consistent with many recent reports and the latest auction evidence. Wide ranges are available in various publications, but there is no obvious

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

[3] https://www.gov.uk/govemment/publications/beis-electricitv-generation-costs-november-2016

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

[5] Bernstein, 2017, *Offshore wind: Zero subsidy bids - What do you need to believe in for value creation?* www.bernstein.com

[6] Citi, 2017, *Survival of the fittest: De-mystifying Global Offshore Wind Returns* www.citivelocitv.com

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

[8] DECC, December 2013, Electricity Generation Costs 2013

reason at the moment to suggest that as central estimates these new BEIS assumptions in the short term are out of line. But a 50% reduction based upon 20MW units may be on the high side for 2030, however, as turbine manufacturers may seek to consolidate and retain longer production runs for current and planned models.

Infrastructure costs are assumed by BEIS to be constant from Arup 2015. But, it is possible that inter-array cabling and offshore substations cost may reduce on a per MW basis as capacity increases with fewer but larger turbines.

Fixed Opex is assumed by BEIS to go down from DECC 2013 by 15% for 2020, 40% for 2025 and 50% for 2030, largely factoring in economics of size from fewer but larger turbines per farm, and the larger sizes of the farms. This is broadly in line with industry commentaries.

Variable Opex, insurance and connection costs are assumed to be constant. The trend to more efficient servicing and increases in insurance noted previously in Arup may now have stabilised. The connection and use of system charges depend upon location but on average are not expected to increase substantially

Elsewhere, *25yr lifetime* assumptions retained by BEIS may be a little low as 30yrs is being increasingly mentioned.

With *load factors,* although they are assumed constant by BEIS, there has been a steady upward trend, as the larger turbines come in. I would therefore have expected to see a slight trend in this data.

I note work on *decommissioning costs* is in progress. The option value of the site for repowering should provide a positive counter to these costs.

5.2 Onshore Wind

The scale driver of cost reductions for offshore is not likely to be as significant onshore since turbine sizes are unlikely to increase substantially. Looking again at the main cost elements in turn:

Pre-development costs are assumed by BEIS to be unchanged from Arup 2015 and this seems, on balance, to be reasonable. In 2016, Arup noted that these had increased by 2% from DECC2013 based upon planning timescales.

CAPEX construction reduction from £1252 to £993 for 2020 and then £970 for 2025 and £945 for 230 is consistent with other sources such as BNEF[9], Baringa[10] and Aurora[11]. Most projections are showing a flatter cost reduction based upon revised learning rates and as the

[9] BNEF https://about.bnef.com/new-energy-outlook/
[10] https://www.baringa.com/getmedia/99d7aa0f-5333-47ef-b7a8-1ca3b3c10644/Baringa Scottish-Renewables UK-Pot-1-CfD-scenario April-2017 Report FINA/
[11] *Aurora, 2017* Cutting the cord: long-term Prospects for GB wind and solar. www.auroraer.com

major supply chain efficiencies already introduced become more stable going forward.

Infrastructure costs are assumed by BEIS to be constant from Arup 2015, and it surprises me that these are exactly the same for offshore. They are not a major element however.

Fixed Opex assumptions are down slightly 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 constant, as with offshore. The connection and use of system charges depend upon location but on average are not expected to increase substantially

Elsewhere, *25yr lifetimes* assumed by BEIS may be a little low as 30yrs is being increasingly mentioned.

With *load factors*, although they are assumed constant by BEIS, there has been a steady upward trend, as more efficient turbines come in. 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. With increased penetration and local distribution constraints for embedded generation, this may become more significant. In the Orkney Islands, for example, SSE operate active network management (ANM) to curtail wind generation on a last-in-first-out basis[12].

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 Large Scale Solar

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, without any obvious sector biases.

Capex is the main element and there are now more substantial databases available to estimate current costs than previously in Arup 2015. I note that broad evidence has been compiled for the current capital costs, after adjusting for different commissioning dates. If further substantial evidence becomes available for 2018, given general press reports of falling panel prices (which comprise about half of capital costs), then these estimates should be revised downwards. The value taken, £705, compares with £900 in Arup 2015 and for 2020 the value taken, £585, compares with £728 as projected in Arup 2015. These changes are substantial but credible based

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

on the evidence.

As for future reductions, BEIS estimates of learning rates are credible given other sources of evidence, as are the Fixed Opex costs

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 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.

5.4 Small Scale Solar

This analysis 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, as well as reference to parts of the previous Arup report.

Capex, 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.

5.5 CCUS

The final spreadsheet model that I was requested to review is for CCGT+ Post Combustion CCS. This provides parameters suitable for use in the BEIS Dynamic Dispatch Model. It was out of scope for me to assess the parameters against alternative current reports on CCUS, other than against the assessments in Arup 2015. The model is evidence-based in its specification with extensive references to the assessments. It appears credible.

My comments on the BEIS spreadsheet parameters, are as follows:

> Comparing FOAK and NOAK, it is interesting to see very little difference in plant output *efficiency* and quite narrow confidence bands between the high and low estimates in each case. That could suggest a good scientific basis for performance. On the other hand, *availabilities* range from 84%-90% for FOAK to 91-93% for NOAK which appear rather optimistic. For comparison, new-build conventional CCGT have a derating of 90%, based upon availabilities, as assessed by National Grid[13] for the capacity auctions. I note also that 88% was assumed in BEIS (2016).
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> On *predevelopment costs*, the BEIS spreadsheet shows no difference in FOAK and NOAK, which is surprising, but this element is minor.
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> *Capex construction* costs show a wide range from £1,260 to £1,702 for FOAK, and much narrower, £1025 to £1385 for NOAK. With an average FOAK of £1481, it compares with

13 www.emrdelivervbodv.com/lists/latest%20news/attachments/47/electricitv%20capacitv%20report%202016 final 080716.pdf

£2,100 in BEIS (2016). Since the CCGT unit in the analysis has the same construction cost as unabated CCGT in BEIS(2016), ie £500, it is an open question why the construction cost estimate has reduced by about a third.

On *infrastructure,* there is a wide range, but no difference between FOAK and NOAK, and so this presumably reflects locational complications.

The reductions in *OPEX and CO2 transport/storage* from FOAK to NOAK are plausible.

6. **Fit-for-Purpose**

I note that this is a selective internal updating of generation costs being undertaken at BEIS. It is pragmatic and sensible that the focus has been upon an internal synthesis of evidence on wind and solar, with an updated review on CCUS. The spreadsheet models produced for onshore wind, offshore wind, solar and CCUS 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.

I note that some minor assumption changes are being made to AD and ADCHP digestate disposal costs, tidal stream load factors and the efficiency of CCGT H class. I have not seen the evidence for these changes but they appear to reflect new information which would be relevant.

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 pragmatic, defensible and in my opinion a reasonable evidence basis for policy.