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Cost trajectories of low carbon electricity generation technologies in the UK: A study of cost uncertainty

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HIGHLIGHTS

- Recent UK Government (DECC) levelised cost estimates are compiled and scrutinised.
- Out-turn, past and present generation costs provide an analytical context.
- Uncertainty stemming from the variability in estimation is quantified.
- Strangely, estimate variability decreases as the forecast horizon increases.
- Imminent (forecasted) cost reductions suggest the timing of deployment is not straightforward.

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ABSTRACT

Cost uncertainty has latterly come to be presented in the UK's Department of Energy and Climate Change (DECC) Levelised Cost of Electricity (LCOE) estimates using sensitivities; 'high' and 'low' figures are presented alongside 'central' estimates. This presentation of uncertainty is limited in its provision of context, and as an overall picture of how costs and uncertainty vary over time. This study aims to address these two shortcomings. Two analyses are performed using reported DECC LCOE estimates for three important electricity generation technologies for the UK; nuclear, offshore wind and coal with carbon capture and storage. The first analysis composes LCOE estimate trajectories from previous years' DECC estimates and presents them alongside contextual data, including some out-turn costs. The second quantifies the variability presented in the LCOE estimate trajectories for commissioning dates in the decade 2020–2030. Nuclear costs are presented as both the most consistent and lowest in magnitude. An imminently forecast steep fall in the LCOE of offshore wind raises questions about the timing of investment and deployment. In most cases estimate variability decreases over the estimation horizon, strangely suggesting greater levels of certainty for further flung commissioning dates. Further observations and implications for policy stemming from the analyses are discussed.

1. Introduction

As the *energy trilemma* – the need for decarbonisation, security of supply and affordability – looms, policy-makers scramble to identify an energy supply mix that makes sense. The electricity sector is at the heart of this effort, as it is hoped a growing proportion of low carbon supply can be delivered via this energy carrier in the future. Uncertainty is a key factor in determining electricity generation costs. In advance of investing in a new installation, one can be relatively sure about the degree to which GHG emissions will be abated, or the extent to which it will enhance or diminish energy security. The cost apex of the trilemma on the other hand, remains perennially accompanied by uncertainty. Cost estimation, particularly aspects concerning methodologies, is a topic that is frequently discussed (e.g. Gross et al., 2013). This study differs in its focus, by concentrating on the uncertainty *as it is presented* in the variability of electricity generation cost estimates.

Cost uncertainty has latterly come to be presented in the UK's Department of Energy and Climate Change (DECC) Levelised Cost of Electricity (LCOE) estimates using sensitivities; with 'high' and 'low' figures presented alongside 'central' estimates. This allows a range of cost estimates for a given technology to be compared to

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Table 1
Summary of technology groups and sub-groups.

Technology groups	Technology sub-groups
Nuclear	PWR/EPR
Offshore wind	Round 2 (R2) Round 3 (R3)
CCS	Advanced Super Critical (ASC) coal with CCS Integrated Gasification Combined Cycle (IGCC) coal with CCS

that of another, on a 'levelised' cost per unit (£/MWh) basis (DECC, 2013a, pp. 4–11, 2013b, pp. 6–7; Mott MacDonald, 2010, pp. 2–22). The LCOE methodology itself is not disputed in this study. However, we assert that the elected presentation of uncertainty is limited in its provision of context, and as an overall picture of how costs and uncertainty vary over time. Without numeric context, the relevance and usefulness of cost estimates is reduced. Without tracking the degree to which estimates vary over time, only a partial picture of uncertainty can be gleaned. The purpose of this study is to address these two shortcomings and discuss the implications resulting from the picture of uncertainty that is presented by DECC.

The first component of the work composes *contextual cost landscapes* which present the DECC LCOE estimates as estimate trajectories, in the context of historic and future estimates, and actual (out-turn) costs. The second component is a numerical analysis of the estimate trajectories alone, which aims to quantify the variability in previous estimation. In other words, it is intended that the analysis captures the degree of variability (or consistency) of the DECC LCOE estimates over time. This is premised on the notion that the temporal consistency of an estimate's magnitude is one indication of the overall levels of certainty embodied in it. This quantified measure of variability in estimates over time is hereafter termed *temporal estimate uncertainty*.

Three technology groups – nuclear, offshore wind and coal with Carbon Capture and Storage (CCS) – have been selected for analysis (see Table 1). Contemporary nuclear generation, as represented by Pressurised Water Reactors (PWRs) is a well-established technology. European Pressurised Reactors (EPRs), based on the same fundamental power generation design as PWRs but with enhanced safety features, look to be the chosen design for future deployment in the UK. Though in its infancy, offshore wind generation is a technology that is gaining momentum, with the UK now the world leader in terms of installed capacity (GWEC, 2012, p. 64). Finally, coal with CCS will be a truly First-of-a-Kind (FOAK) technology in the UK, with initial commercial-scale installations planned for the mid-2020s.

The reasons for prioritising these three technology groups are twofold: Firstly, in the context of the UK they represent a diverse range of scalable, low carbon options for electricity generation. Onshore wind, solar photovoltaic (PV) and hydro-power generation for example, may well be scalable elsewhere, but currently look to be less likely options (at least at the time of the DECC scenarios we focus on) for large portions of additional UK capacity. Secondly, a consistently compiled set of LCOE estimates, with good coverage over a fixed timeframe are needed to undertake the analysis. Numerous other sources of cost estimates are available. However, in order to assess temporal estimate uncertainty from estimation variability, the variability being measured must be that of the estimate values, not the methodologies used to compose them. Furthermore, DECC estimates will be a key source of cost information for many industry professionals, investors and academics, so they comprise an appropriate and relevant set of data with which to conduct the analysis.

The UK has ambitious legally binding targets for the decarbonisation of its economy. These involve a 34% reduction of CO_2 emissions by 2020 on 1990 levels extending to almost 50% by 2025 and on to 80% by 2050. The electricity sector is scheduled for approximately 90% decarbonisation by 2030 if these wider targets are to be met. 2020–2030 is therefore a crucial decade for low carbon electricity installations: this is the period when Hinkley Point C and possibly Sizewell C nuclear power stations, several major R2 and R3 offshore wind installations and the first commercially viable coal with CCS plant[1] are forecast to be commissioned.

In Section 2 we discuss the methodology we use to examine reported costs in the rest of our study. Section 3 presents the resulting analysis of reported costs, while Sections 4 and 5 discuss the conclusions and policy implications of the reported cost analysis for each of the three technologies in turn.

2. Methods

2.1. Review of relevant literature

In a comprehensive review of cost estimation methodologies for the electricity sector, a UKERC study broadly characterises the approaches adopted as either 'engineering assessment' methods (bottom-up parametric cost modelling and estimates informed by expert insight) or top-down 'experience curve' (learning) based methods (Gross et al., 2013, p. 22). In highlighting the capabilities and deficiencies of each, across a wide-ranging set of case studies, they conclude that the approaches are complementary, but that decision makers must be aware of the various layers of uncertainty comprised in each.[2]

Variability and trends in out-turn costs can be observed for specific technologies when comparable data are available. This can lead to insights on the cost trend over time on a unit capacity (£/MW) or levelised (£/MWh) basis, such as those gleaned in studies of nuclear (Du and Parsons, 2009; Harris et al., 2013), and offshore wind (Heptonstall et al., 2012; Van der Zwaan et al., 2012) generation. The aim is to capture the rate of learning undergone during a technology's development, thereby gaining an insight into future costs. Jamasb (2007) explores to what extent learning can be attributed to research (R&D) or doing (deployment) for a range of energy technologies.

In the absence of out-turn costs or learning curves, or when it is thought that future cost trends may not mirror those of the past, expert elicitations can be sought. The insights gained are used to characterise explicitly uncertainty around costs in a probabilistic manner. Difficulties arise when comparing elicitations gathered via differing methods from various sources. Verdolini et al. (2015) present results from a study that standardises a range of expert elicitations on the costs of solar PV. The authors find differing levels of confidence (range of estimates) and optimism (level of estimates) across the elicitation studies surveyed.

The Bank of England's (BofE) Monetary Policy Committee (MPC) incorporates a probabilistic dimension of uncertainty in its projections (for inflation, GDP etc.) by using Fan Charts (see example in Fig. 1) (Elder et al., 2005). The single most likely forecast

[1] The *White Rose Carbon Capture and Storage Project* is currently in the examination phase of the planning process. If granted permission the plant should begin generating electricity in early 2020 (Capture Power, 2014).

[2] The authors also specifically address variability in estimation, by categorising its various manifestations in the technologies they explore in their case studies, but do not quantify it.