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Winds of change: How high wind penetrations will affect investment incentives in the GB electricity sector

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ABSTRACT

Wind power is widely expected to expand rapidly in Britain over the next decade. Large amounts of variable wind power on the system will increase market risks, with prices more volatile and load factors for conventional thermal plant lower and more uncertain. This extra market risk may discourage investment in generation capacity. Financial viability for thermal plant will be increasingly dependent on price spikes during periods of low wind. Increased price risk will also make investment in other forms of low-carbon generation (e.g. nuclear power) more challenging.

A number of policies can reduce the extent to which generators are exposed to market risks and encourage investment. However, market risks play a fundamental role in shaping efficient investment and dispatch patterns in a liberalised market. Therefore, measures to improve price signals and market functioning (such as a stronger carbon price and developing more responsive demand) are desirable. However, the scale of the investment challenge and increased risk mean targeted measures to reduce (although not eliminate) risk exposure, such as capacity mechanisms and fixed price schemes, may have increasing merit. The challenge for policy is to strike the right balance between market and planned approaches.

1. Introduction

The electricity generation mix in Britain is set to undergo profound change as the sector decarbonises. In particular, the EU's renewable energy target may require up to 40% of UK electricity demand to be met from renewables by 2020 (DECC, 2009a). As the most cost-effective and scalable renewable technology in British conditions, wind is expected to provide the majority of this (DECC, 2009a). However, due to its variability, this rapid expansion in wind will still need to be complemented by large amounts of flexible thermal capacity, to ensure demand can still be met reliably. The issues discussed in this paper are particularly relevant to Britain, which has a unique combination of a largely islanded system, an energy-only electricity market and high hopes for wind power. However, the issues discussed here have relevance to a wide range of countries, systems and regulatory approaches.

Britain's market (The British Electricity Transmission and Trading Arrangements, BETTA) is designed to maximise direct trading of electricity between suppliers and generators, with the National Grid Plc, the Transmission System Operator (TSO) only contracting for balancing services and taking actions through a balancing mechanism to maintain supply/demand balance close to real time. BETTA is an energy-only market that does not offer any form of capacity payment. Whilst the TSO monitors expected system margin (the margin of overall system capacity above expected peak demand) over a range of timescales it is not responsible for directly commissioning capacity. A large penetration of wind will change the market conditions that conventional plants face. Since the overall capacity of the system will need to be higher to maintain reliability, *on average* there will be more spare capacity available and conventional plants will therefore be used less. For periods when wind output is high, wholesale power prices will be very low, and occasionally negative. Moreover, the variability and unpredictability of wind output will increase uncertainty over conventional plant usage patterns and the prices they will receive (Poyry, 2009; Redpoint, 2009).

For all these reasons, there are some concerns over the British market's ability to manage the risks associated with high penetrations of wind and whether investment in flexible capacity will be sufficient to provide an acceptable level of reliability. In recent years, policy-makers and regulators have increasingly recognised the profound effect that high penetrations of inflexible plant (particularly wind and nuclear) are likely to have on the electricity market (DECC, 2009a, 2009b, 2009c, 2010; Ofgem, 2010). At the same time, a number of commentators have argued that the required pace of low carbon investment other than

[1] Views do not reflect those of SSE.

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renewables (nuclear and CCS in particular) will be difficult to achieve under the current market framework, given the risks currently associated with deploying capital intensive low carbon technologies. This has led some to postulate that a fundamental reworking of the electricity market framework may be needed (CCC, 2009; DECC, 2010; Gross et al., 2009; Ofgem, 2010).

The remainder of this paper provides a literature review and analysis of how high penetrations of wind power will affect incentives to invest in different types of electricity generation capacity and the implications of this for market design. It focuses in particular on capacity adequacy (to maintain reliability) and the *nature* of capacity (e.g. technology type) likely to be built under current market and regulatory conditions as wind penetration increases. Section 2 briefly reviews the main categories of market failure that may result in insufficient or inappropriate investment in electricity markets. Sections 3 and 4 then illustrate how higher wind penetrations will affect the dynamics resulting from these market failures. Section 3 analyses how wind will change the electricity market, in particular the effect on wholesale prices, through a review of the empirical and theoretical literature. Section 4 considers the implications of these impacts for investment decisions for all types of capacity (conventional and low carbon) through a combination of literature review and numerical analysis, Finally, Section 5 discusses the implications of the prior analysis for electricity market design and the policy options available to encourage both capacity adequacy and low carbon investment.

2. Investment under the current market framework

In an idealised electricity market, when supply conditions are tight, price should rise until demand has been rationed off to meet supply.[2] At the same time, the anticipation of tight supply conditions in the future (and consequent high prices) provides incentives for new capacity investment, as well as to extend the life of existing plants and bring old plant out of 'mothballs' (Collins et al., 2008). 'Scarcity rents' earned from the occasional high spot market and balancing market prices allow generating plants to pay their fixed costs within a financially viable timeframe (Adib et al., 2008). Risks around these investments can be managed through forward contracts as well as through vertical integration between generation and supply functions (Moran and Skinner, 2008). For all these reasons, in aggregate, generation firms can be expected to deliver sufficient capacity to meet peak demands with high probability. Indeed, since it was privatised in the 1990s, the British electricity system has been successful in promoting new capacity investment and maintaining reliability, with capacity consistently at least 20% above expected peak demand – the figure often used as a proxy for capacity adequacy (Gross et al., 2006). However, there are a number of reasons why the electricity market may not always deliver the optimal level and type of investments to efficiently meet society's demands for both reliability and carbon emissions reductions:

- *Reliability as a public good*: A number of studies (Awerbuch et al., 1999; Helm, 2008; Lemming, 2003) argue that reliability has public good characteristics and that therefore it will be undersupplied by the market. In particular, reliability is 'non-exclusive' in nature: as one unit of capacity is added to the system, all consumers benefit from the increased reliability that the extra unit provides. This arises because (at present) suppliers lack the technology to disconnect many consumers individually in the case of inadequate supply (Lemming, 2003; Joskow, 2008). A complete market for reliability where consumers could pay for the level of reliability they desire cannot arise. A related issue is that the vast majority of electricity consumers are not exposed to prices in real time. Real-time pricing would encourage consumers to respond to high prices at times of scarcity by reducing consumption, helping to match supply and demand with reduced need for peaking capacity (DECC, 2009a).
- *Market risk and cycles*: Investing in electricity generation capacity is risky for number of reasons. Prices are volatile due to the homogenous nature of electricity, its lack of storability, inelastic demand and the steepness of the supply curve as electricity production nears system capacity (Roques et al., 2005; White, 2006). This price risk increases uncertainty over project revenues, increasing the cost of capital, and discouraging investment. The 'lumpy' nature of investment in capacity (where a new plant can represent a significant and sudden jump in capacity) can also result in 'capacity oscillations' (Collins et al., 2008; Green, 2008). If a shortage of capacity begins to emerge, long lead times limit how quickly the market can respond (Redpoint, 2006). Moreover, during a period where capacity is becoming tight, and prices are rising, a number of companies may simultaneously decide to build new capacity. This may result in overcapacity when these plants come online years later, with consequent price falls.
- *Carbon externality*: A key market failure arises in the electricity sector if generators are not required to pay a price for the carbon they emit that is equivalent to the value society places on emissions reductions (Stern, 2005). At present the EU Emissions Trading Scheme (ETS) carbon price is both uncertain and significantly below this level which, all other things being equal, will lead to underinvestment in low carbon technologies (Newbery, 2009).
- *Learning externalities and technology 'lock-in'*: Investment in immature technologies can generate significant learning externalities meaning that without intervention the market will under-invest in these technologies. Furthermore, new technologies may not become cost competitive until significant deployment of the technology has taken place. In the absence of perfectly functioning capital markets and foresight, new technologies may never achieve the market accumulation needed to be cost competitive without subsidies. This lock-in problem is particularly acute in the electricity sector as the homogenous nature of the product means that there are few niche markets where the technology can be developed with some shelter from established competition (Stern, 2005).

In addition to the reasons described above, changes in policy which cannot be predicted also result in significant regulatory risk for investment. The overall effect is that investment in generation capacity entails significant risks which may be difficult to manage (in the absence of adequate financial instruments) whilst there are important market failures associated with this investment. Both these may lead to underinvestment in capacity and low carbon technologies without significant intervention. It is questionable whether the current market framework sufficiently 'corrects' for this.

The key question for this paper is whether increased penetrations of wind will accentuate and modify these factors. Low carbon technologies (e.g. wind and nuclear) have different characteristics to conventional generation. In particular, they are characterised by high capital costs and very low marginal costs whilst wind is also variable. This raises questions as to (i) how the market will operate with high penetrations of these technologies; and (ii) how well suited the current market framework is for supporting investment in these technologies.

[2] And in the case where demand remains higher than supply (lost load), the market price rises to the value of lost load (Osina, 2006).