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Delivering a secure electricity supply on a low carbon pathway

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ABSTRACT

The energy system can only be considered sustainable in the long term if it is low carbon, affordable and secure. These three create a complex trilemma for all stakeholders in the energy business who have to strike a careful balance without neglecting any one aspect. This discussion paper examines the issues surrounding security of supply of the power system which has received less attention than the other aspects. It looks at how threats and mitigation measures can be classified in terms of where they act on the supply chain and the timescale over which they act. Only by considering the full range of timescales from seconds to decades can the full picture emerge of the effects of new technologies on security of supply. An examination of blackouts over the past 40 years sheds light on the causes of failure to supply and the most vulnerable aspects of the supply chain.

1. Trilemma

When composing pathways towards a future energy system there is a danger of focussing on decarbonisation alone. This is undoubtedly the strongest driver for change at the moment with overwhelming evidence for man-made climate change caused mainly through the release of CO_2. However, if models and scenario authors are given just one constraint of meeting a carbon reduction target the problem is ill defined with a large degenerate solution space. For example one solution for a decarbonised 2050 would be to get all our energy from PV arrays in space, beaming down energy to collectors which retransmit the energy in an all electric world. Other solutions could include an all nuclear future, or all gas with carbon capture etc. The most obvious parameter missing is cost and in fact the objective function of most models is to minimise the cost of meeting the energy demand subject to the carbon constraint. Scenario developers will also often compare technologies based on a cost parameter, recognising that capital and willingness of consumers to pay are both limited.

However there is a third element to developing models and scenario pathways that is often neglected, and that is energy security. If security of supply is not taken into account then it is not unusual for the model solution or scenario proposed to represent a system that would in reality be inoperable, or would fail to deliver when subject to relatively minor shocks, or perhaps be insufficient to meet peak demand.

Balancing the demands of the three elements, carbon, cost and security, is what E.ON first described as the energy trilemma in 2008 (E.ON, 2008). Fig. 1 illustrates this as a triangle with the elements in the corners.

Designing an energy system that balances two is not difficult – the UK electricity system has delivered a high standard of security at relatively low cost for more than 30 years, but it has been dominated by high carbon generation. It is also not difficult to imagine a system supplied entirely by the cheapest low carbon technology, but this would vulnerable to continued supply of that one energy source and would be very unlikely to deliver a supply that was always there. Finally one could also imagine a system where money was no object that delivered low carbon energy with gold plated security standards. However none of these three examples are sustainable. Pumping CO_2 into the atmosphere at current rates will lead to irreversible climate change that will be hugely damaging to all economies (Stern, 2006). An electricity supply that failed to deliver energy to the expected security standard would lead to insistent calls from industry and the public for "something to be done" to stop the lights going out. Gold plated security standards would push consumer bills (or taxpayer subsidy) to a level where public outcry and the migration of industry would cause a re-think. In short ignoring any one element of the trilemma is unsustainable.

Many scenarios towards a low carbon future have been proposed (E.ON holds a database of 147 publicly available scenarios from 30+ organisations), and much attention given to the individual technologies that might feature in these future worlds. Estimates have been made of the cost to the consumer and figures such as the £200 Billion from Ofgem's Project Discovery (Ofgem, 2010) have grabbed the headlines. However less is made of the security aspects of future transitions so this paper attempts to raise the profile of the third corner of the Trilemma, and presents some of its complexities.

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2. Security of supply

Ensuring that an energy system delivers a continuous supply of energy to a given quality level is a multifaceted problem. It is first worth considering how energy security issues should be categorised. Second we look at the threats to security and their mitigation, and finally a comparison with historic blackouts helps calibrate our model. No attempt is made here to measure energy security and the discussion is mainly qualitative but Winzer (2011) has recently opened a welcome debate in this area. He suggests eight dimensions to usefully categorise security threats and evaluates eight measures used to quantify security of supply.

3. Classification

A useful way to categorise threats to security and their mitigation measures is to classify them in terms of position in the system (upstream, midstream and downstream) and the timescales over which they operate. Those that threaten security in the long term can be considered stresses to the system, short timescale events are shocks. Threats on a medium timescale of a few days could be in either camp, depending on the comparators. So an anticyclone event (cold and windless) is a blip on the decade timescale, but a gradually increasing stress to the minute by minute operation of the system.

Understanding the timescales is most important because it is not unusual for very different conclusions to be drawn about the benefits of a particular technology at different timescales. Wind is a case in point – at long timescales (years to decades) it can be considered as enhancing security by reducing dependence on imported fossil fuels. However at medium timescales (hours to days) its unpredictable nature makes the system less stable requiring greater mitigation. At the shortest timescales (less than a second) older wind turbines with their low inertia reduce stability, but modern control systems can more than compensate for this thus enhancing stability.

The following sections classify threats as described above and the mitigation measures that are, or could be, used.

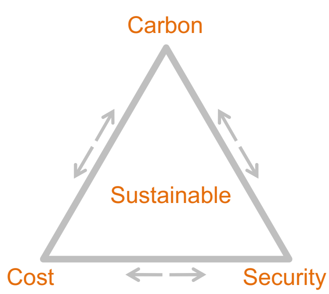

Fig. 1. The trilemma and definition of a sustainable energy system.

4. Threats

It is important to note that this division into timescales is not a precise science, and in some cases threats to security can operate over a range, or number of distinct timescales. For example a poor maintenance regime may lead to tree growth (over the timescale of months and years) which when combined with a hot afternoon (hours) eventually leads to line faults with consequential circuit trips and cascade failure over the timescale of seconds and minutes. Another example is climate change which is happening over decades, but changes weather events which happen over days, or the likelihood of extreme events causing loss of generation or network assets over minutes Fig. 2.

It can be seen from the diagram that threats operate over a continuum of timescales so classification into discrete boxes is not always clear, but for the sake of the narrative below a division into three is used. Long timescale events are those that generally operate over years, short events are those which are less than an hour and are therefore within gate closure of many markets, and medium events occur in the domain of traded markets. Hammond and Waldron (2008) used an online survey amongst a wide range of stakeholders to identify and rank risks according to likelihood and consequence and many of their high scoring risks appear as long to medium term threats in this analysis, or as their underlying causes.

5. Long timescale threats

For generation these are threats which reduce the capacity available to generate, either through lack of new build or restrictions to fuel. Occasionally poor legislation or management can

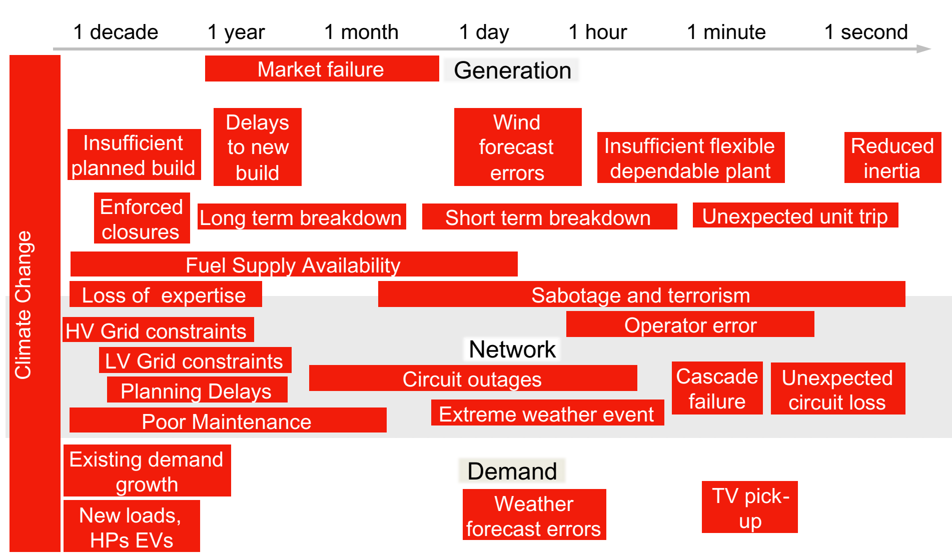

Fig. 2. Timescales of threats to system security.