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THE ROLE OF ENERGY NETWORKS TOWARDS THE 2035 EMISSIONS TARGET

POLICY PAPER SERIES

# Driving Increased Utilisation of Variable Renewable Energy with Targeted Market Reform

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# Policy Brief: Driving Increased Utilisation of Variable Renewable Energy with Targeted Market Reform

Supergen Energy Networks Hub

## Overview

- The utilisation of offshore renewable generation could be increased by providing appropriate financial incentives to low-carbon technologies such as electric vehicles, aligning their operation with the growing renewable generation.
- The ideal market design will encourage new entrants, incentivise the utilisation of variable renewables, whilst avoiding exacerbating fuel poverty.
- Without targeted reinforcement, distribution network capacity could prove to be a barrier to accessing the full flexibility potential of low-carbon technologies.
- Increasing distribution network visibility is likely to be a low-regrets option for ensuring cost- effective and timely reinforcement and could enable location-specific pricing.

The energy sector is undergoing an unprecedented and transformative change, with the goal of delivering on the government's target of reaching Net Zero by 2050. Investments in variable renewable energy generation (such as offshore wind) and in low-carbon technologies (such as Electric Vehicles (EVs) and Heat Pumps (HPs)) are driving this evolution of the whole energy system. These low-carbon technologies are typically installed at the lowest levels of the electrical distribution network, far from the new offshore renewable capacity that is being deployed at pace.

Presently there are no substantial incentives for low-carbon technologies to align their operation with the growing renewable generation sector. Suitable changes to device schedules on the GB system could reduce renewable curtailment, which currently costs consumers hundreds of millions of pounds every year. On the other hand, to ensure that low carbon technologies can drive an efficient utilisation of these variable renewable generation technologies, critical bottlenecks in energy networks will have to be identified and addressed so that energy can be transferred to where it is needed. Without suitable incentives for network operators, there are risks of stranded assets – the lifetime of energy infrastructure can be 30 years or even longer, and so most of the investments made today should be expected to operate in the Net-Zero world of 2050.

The Supergen Energy Networks Hub recently held a Markets and Regulations panel workshop as part of its preparations for COP26. The workshop focussed on the question as to how low carbon technologies can be suitably incentivised to provide the flexibility needed to integrate high levels of new variable renewable energy technologies, explicitly considering how constraints of network infrastructure might influence the whole system approach. This policy brief summarises the main themes of that workshop, representing the personal views of the diverse range of panellists who spoke at the event[1].

## 1. Background – the Road to Net Zero for the GB Energy System

Aligned with the UK government's commitment towards net zero emission, huge investments are committed to the deployment of renewable and low carbon technologies. By 2030, the power sector is expected to connect and operate 40 GW offshore wind generation[2], 11 million EVs[3], and install 600,000 HPs per year by 2028[2]. If there is a lossless electricity network with unlimited network capacity and fully flexible demand, 40 GW of offshore wind capacity would be sufficient for a GB transport fleet of 40 million EVs [Appendix A].

There are therefore two interrelated challenges that need to be addressed to ensure that the incentives needed to ensure new, variable renewables can be integrated efficiently as a part of the whole energy system. Firstly, there is a need for increased spatial and temporal price granularity, so that low carbon technologies have appropriate incentives to driver high utilisation of new renewables. On the other hand, these price signals will necessarily lead to peak flows in energy networks becoming increasingly coincident, as flexible technologies act to meet the bulk of their energy demand when there are favourable meteorological conditions. There will therefore be a need for targeted investments in infrastructure, so that the flexibility afforded by these low-carbon devices can be fully realised.

## 2. Market Designs to enable Gigawatt Supply-Kilowatt Demand Interactions

The present market and regulatory arrangements were developed to reflect the realities of centralised generation, with supply provided via large Megawatt-scale generators, connected to the transmission network, with no significant exposure of small, Kilowatt-scale energy consumers to system-level prices. Current market arrangements have effectively served their purpose for nearly 30 years, and it is not credible to assume that there is likely to be a complete market collapse in the near term due to changes in the technologies used on either the supply- or demand-side.

Nevertheless, the current market design is not set up to be able to efficiently deliver Gigawatt-scale flexibility from these Kilowatt-scale demands. This sort of whole-system demand-side response, requiring the co-ordination of millions of devices to follow variable renewables. A careful augmentation of existing market design could provide sufficient incentives to empower prosumers to interact with the energy system in a positive, complementary way, enabling a cost-effective transition to Net Zero.

One of the clear challenges of such a market is to ensure that there is an appropriate balance of price reflectivity, transparency and simplicity whilst maintaining a high level of social equity. It will not be enough for the benefits of increased system utilisation to be reaped only by the affluent, nor for people experiencing fuel poverty to be unduly penalised for not having the technologies required for automated responses to a dynamic energy market. On the other hand, incentives must be structured appropriately to ameliorate the risk of incumbent players crowding out new entrants to the market.

Whilst there is a clear need for reform to enable this vision to become reality, the trade-offs between these often-competing objectives means that several possible future visions were described by panellists at the workshop.

- **The Flexibility-by-Default model.** Flexible low-carbon technologies could be assigned a default time of use (TOU) profile each day to access cheap, clean energy, based on renewable generation forecasts. Unconstrained use would be attainable by customers who have upgraded to a premium tariff, in a way that is analogous to mobile phone plans. There would be no need for customers to actively participate in day-to-day trading.
- **The Device-level Dynamic Pricing model.** In this model, there would be a highly granular price signal, dependent on a rolling demand forecast using the most up-to-date energy price information, rather than on day-ahead forecasts only. Additionally, local network constraints would be incorporated into prices. Such an approach could be well-suited to EV charging, for example, which can physically carry energy to different locations.
- **The Good Citizenship model.** In this approach, consumers would become much more aware of their impacts on the energy system, and would change their behaviour from day-to-day depending on the weather and time of year. In this vision, incentives would be complemented with a sense of climate citizenship – there would be an understanding that society should be aiming to live alongside a weather-driven energy system, rather than fighting against the uncertainties such a system inherently brings.
- **The Wait-and-See model**. There are still significant uncertainties in the future architecture of the whole energy system. GB network and system operators are in the final stages of developing their plans for the RIIO2 regulatory period, an exercise which is bringing these uncertainties of the future system even five years into the future into stark relief. The government could hold-off and wait to enact reforms, although this approach risks costly retrofits if policy changes in future years.

Each of these four approaches have varying levels of uncertainty, price reflectivity and general political risk associated with them. The four-box model of Figure 1 illustrates these high-level differences between the approaches, illustrating how the level of prosumer participation and market signal strength varies. Increasing either end-user participation or the market signal strength would both require societal change. The Device-level Dynamic Pricing model is therefore the most politically challenging of the four approaches, whilst the Wait-and-See model might lead to the lowest political risk but could fail to capture the full capabilities of the new low-carbon technologies.

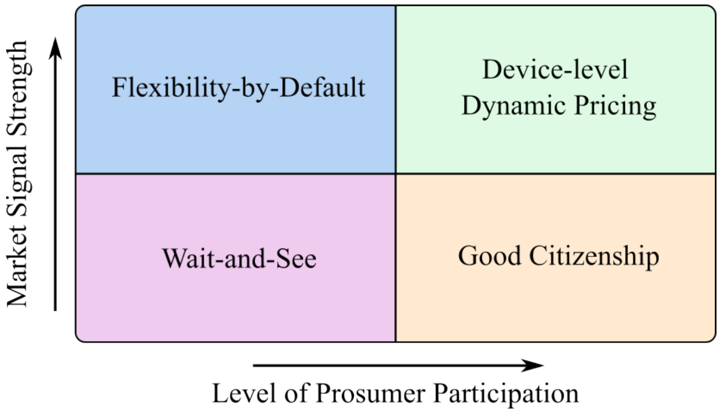

Figure 1: Four approaches to market design to enable high utilisation of new variable renewables. Whilst all of the models will require both additional participation from end-users and an expansion of the market compared to existing arrangements, the level of this additional participation and strength of the price signal from new market design will vary.

Generally, the panellists favoured simpler and more transparent approaches (for example the Flexibility-by-Default model) over more complex cases, although this may not necessarily lead to the highest utilisation of the low-carbon technologies. Some panellists noted that new technologies should generally be working to improve the human condition, rather than adding further complexity in a society which is increasingly attention-driven.

## 3. Enabling High System Utilisation by Incentivising Efficient Infrastructure Investments

The increase in Kilowatt-Scale low carbon technologies is also expected to result an increase in the total level of demand on electrical distribution networks, as the new devices will often result in demand being transferred from carbon-intensive energy vectors to the electrical network (e.g., HPs might replace gas-fired boilers). Furthermore, if the operation of Kilowatt-scale flexible loads is driven by Gigawatt-scale renewables, there will be a significant increase in temporal coincidence of power flows on low voltage networks on a wide geographic scale. As a result, the legacy ‘after diversity- maximum demand’ approach to network design will become redundant for those demand classes, as the operation of those devices will align in a much stronger sense than traditional distribution system demands.

As a result, even with GB electrical demand being much lower today than it has been historically, modest increases in low-carbon technologies could result in a requirement for substantial distribution network upgrades, as these devices interface with electrical networks at the Low Voltage level (the part of the electrical network that is least well-suited to dealing with new demand). It can therefore be forecast that there will likely need to be some level of distribution network investment even if these low carbon technologies are managed using smart controls.

There is, however, huge uncertainty as to the location and timing of new supply and demand will be connected, making it hard to plan and build additional network capacity ahead of when it is required. These challenges are compounded by the difficulties in the prioritisation of energy cost, security of supply, and facilitation of market competition.

Unfortunately, lingering network constraints lead to challenges in both the install of new low-carbon technologies and subsequently in their demand-side capabilities thereafter. Targeted investment in infrastructure will therefore need to be incentivised appropriately to ensure an efficient whole-system outcome. Different approaches discussed at the workshop are captured in the following strategies.

- **The Flexibility-First approach.** This approach provides a location-based premium for users who are willing to provide flexibility services to fully utilise distribution networks. Such an approach is attractive from the point of view of avoiding having to unnecessarily reinforce networks, but it is likely that network constraints might regularly align with times when devices have all been scheduled to utilise high levels of variable renewable generation. This therefore also diminishes the effectiveness of this approach for increasing renewable utilisation.
- **The Proactive Investment approach.** To ensure both a fast uptake of devices and unhindered flexibility, networks are upgraded before constraints become active. This therefore leads to the fastest rate of increase in flexible low-carbon technologies, but risks stranded assets if load growth does not materialise.
- **The Virtual Network - Smart DSO approach.** In this approach, distribution system operators (DSOs) invest heavily in data and digital infrastructure to monitor the distribution network. Network constraints are managed with the broadcast of dynamic and locational pricing, promoting greater utilisation of the network via demand flexibility. This approach is akin to a Smart DSO creating a ‘virtual network’ through digitalisation, data analytics and flexibility, so that EV and heat pump demand can be met with minimal additional infrastructure investment. Such an approach may be cost-effective, but there are limitations to the information available to a DSO about demand growth, and so this approach risks reducing the quality of service to consumers (for example, if the likelihood and severity of outages increases due to less conservative network operation).
- **The Wait-and-See approach.** In this approach, investment follow from key policy decisions, with network investment otherwise following a business-as-usual approach. This likely leads to a low-cost solution as network reinforcement is deferred, but risks slowing down the transition to a highly utilised renewable generation fleet.

These approaches are not mutually exclusive – indeed, a holistic approach that combines the components from each of these strategies would be most likely to enable low-carbon technologies to realise their full potential in an optimal way. For example, it is likely that investments in digitalisation could be a low-regrets option, as this increases visibility of the network, enabling improved decision making by providing actionable information for the DSO.

## 4. Summary: Targeted Market Reforms can enable an Efficient and Equitable Whole Energy System

The combination of the ambition to reach Net Zero and increasingly cost-effective low-carbon

technologies mean that energy regulators have a once-in-a-generation opportunity to provide a framework to transform traditional passive energy consumers into active prosumers. These prosumers can store, convert, generate, and even transport energy, and in doing so they would have the agency to interact with the energy system via **smart technologies that interact with augmented wholesale markets** to increase the utilisation of new, variable renewables. To ensure that these opportunities are not unnecessarily restrained, network operators will need to develop strategies so that **network investments act in consort with increasing penetrations of flexible technologies** in a sensible way.

Current market arrangements are showing a glimpse of the potential pitfalls a future system could have without reform – curtailment leads to increased costs, in terms of both wholesale energy and operating costs. Low-carbon technologies should be harnessed to ensure that new renewable assets can be fully utilised, avoiding costly curtailment of wind and minimising the carbon intensity of the energy system.

This policy paper is written by Dr **Matthew Deakin**, Newcastle University and Dr **Yuankai Bian**, the University of Bath.

# Appendix A[4]

**1GW offshore wind could power 1 million EVs or 1 million heat pumps.**

**1GW offshore wind farm could theoretically power 1 million EVs in an ideal system with full demand flexibility and a lossless network with infinite capacity.**

- i) EV annual energy demand: 2.9 MWh
    - a. the average mileage of 9,435 miles per electric vehicle each year
    - b. the average EV energy consumption of 310 Wh/Mile
    - c. an EV energy consumption per year = 9,435 x 310 ≈ 2.9 MWh
- ii) 1GW offshore wind farm annual production: 3,404 GWh/yr
    - a. the average load factor for offshore wind is 39%,
    - b. the energy 1GW wind farm can produce = 1 GW x 39% x 8,760 hours energy per year = 3,404 GWh/yr
- iii) The number of EVs could be powered by 1 GW offshore wind capacity per year = 3,404 GWh/2.9 MWh = **1.16 million EVs ≈ 1 million EVs**

**1 GW offshore wind could power 1.5 million EVs if we all drive Tesla Model 3 Standard Range Plus**
**1 GW offshore wind farm can power approximate 1 million heat pumps.**

- iv) HP annual energy demand: 3 MWh
    - a. Average annual heating demand for most homes in the UK = 12 MWh (approx)
    - b. Average CoP of a heat pump = 4 (approx)
    - c. Average electrical energy consumed by heat pump = 12 MWh / 4 = 3 MWh per year

## References:

[1] The workshop was chaired by **Professor Furong Li** of University of Bath and had 5 panellists: **Marcia Poletti**, Deputy Director of Strategy and Decarbonisation, Ofgem**. Iliana Portugues**, Head of Innovation UK, National Grid Partners. **Michael Pollitt**, Energy Lead for Policy, Economics and Risk, University of Cambridge. **Chris Harris**, Former Regulatory Director of Npower and Honorary Senior Industrial Fellow of University of Bath. **Andrew Wright**, Cognitive Energy, a Professor in Practice with Durham University.

[2] HM Government, The Ten Point Plan for a Green Industrial Revolution. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf.

[3] UK Parliament, Electric vehicles and infrastructure. https://researchbriefings.files.parliament.uk/documents/CBP-7480/C BP-7480.pdf.

[4] By Isaac Flower, The Institute for Advanced Automotive Propulsion Systems, the University of Bath.