2035: Key Challenges

Introduction and Context

The ESO has a central role today in GB's energy market design. This role has the potential to expand further as BEIS, Ofgem and industry consider roles of the future system operator. The ESO has established the Markets Advisory Council (MAC) to inform our approach to strategic market design and delivery. This paper is intended to provide MAC members with introductory context on the major challenges ESO must address to meet net zero, activities ESO is currently undertaking to meet these challenges, and how the Markets function interacts with other ESO responsibilities such as network planning, digitalisation and reliability.

The UK government has committed to decarbonising the UK electricity system by 2035. The urgent need to facilitate efficient markets for net zero power without compromising reliability and at lowest cost drives all ESO operational and transformational activities. We also recognise that the context in which we are considering market reforms is changing quickly and will continue to change in the future. Ensuring GB electricity markets can adapt and respond to these changes effectively will be of critical importance.

What will the supply and demand landscape of 2035 look like?

Energy use will be transformed, with a significant increase in overall electricity demand

By 2035, according to our Future Energy Scenarios (FES) 'Leading the Way' scenario (note: all figures in this paper refer to this scenario), total electricity demand will have increased from ~300TWh to ~450TWh. Approx. 15m homes (i.e. almost half of all homes) will have heat pumps installed. This will more than double electricity demand for home heating, from 25TWh to 57TWh. The development of local hydrogen networks will also lead to an increase in hydrogen boilers, as the sale of natural gas boilers is banned by 2035.

The number of battery electric vehicles will grow from less than 0.5m today to 27m by 2035, with electricity demand for road transport increasing to 84TWh, from ~1TWh today. Hydrogen demand for transport will have increased gradually, but will still be at a low level, with some limited uptake of hydrogen HGVs.

In the industrial & commercial sector, high electricity prices and strong carbon pricing incentivises significant energy efficiency investments in industry from the mid-2020s. Fuel switching away from fossil fuels occurs from 2025, with more industrial consumers switching to electricity rather than hydrogen.

Electricity supply must increase to meet demand, but must be zero carbon and flexible

Total electricity generation capacity will increase from 104GW today to 248GW in 2035, with offshore wind representing almost half of this increase in capacity. Generation output more than doubles to 568TWh, with over 110TWh (net) exported across interconnectors. The proportion of supply from wind and solar increases from 37% to 85%, with the carbon intensity of generation falling to 16 gCO_2/kWh from over ten times that today, or -18 gCO_2/kWh incl. negative emissions from bioenergy with carbon capture and storage (BECCS).

Flexible sources of electricity supply, including biomass, hydrogen, interconnectors and storage increase from 54GW today to 71GW in 2035, with a reduction in gas and coal more than offset by new technologies such as storage and interconnection. BECCS and hydrogen generation combined make up 10GW of generation, representing new forms of dispatchable thermal generation that provide zero or negative carbon emissions.

What are the challenges in getting to 2035?

Ensuring the right markets: delivering the right investment and operational signals

Investment: between now and 2035, on average, GB will need to see investment in ~15GW of new generation and flexibility capacity each year, including many emerging and first of a kind technologies, such as hydrogen

electrolysers and BECCS, which will need support to reach commercial scale. This investment needs to take place in a world of decreasing average wholesale power prices, driven by low marginal cost renewables. Wholesale prices, as well as revenues from balancing and ancillary services, will also be volatile and unpredictable, creating additional investor risk and driving up the cost of capital.

Flexibility: by 2035, the amount of supply vs demand will be significantly dependent on how windy it is. The proportion of hours with excess generation will increase to ~60% of hours. Conversely, the proportion of hours with residual demand (above renewables, baseload and interconnector flows) will become less frequent but more extreme, with residual demand reaching 45GW at times. We will need lots of firm and flexible zero carbon technologies to make sure we can meet demand at all times, and to avoid significant amounts of curtailment of renewable energy. We will rely heavily on flexibility, including large-scale, long-duration storage and hydrogen technologies, which are yet to be proven at scale. The challenges are both one of investment, but also of ensuring that markets send the right real-time whole-system dispatch signals.

Location: by 2035, substantial additional generation will have connected at the periphery of the network to exploit the locations with the greatest renewable resources. This will already have caused far greater levels of network congestion and triggered more investment in onshore and offshore transmission infrastructure. Under current market arrangements, generators have no incentive to dispatch in a more locationally efficient way. Reform of market design to introduce efficient locational investment and dispatch signals, for both generation and demand, has the potential to greatly reduce whole system costs. Locational granularity could be introduced into wholesale markets via either zonal or nodal pricing. However, this would require a dramatic shift away from the status quo of a national, self-dispatching wholesale market.

Operability: as the GB power system decarbonises, there will be a number of engineering challenges that need to be solved, like low inertia and short circuit levels. The ESO ambition to operate a zero carbon transmission network in 2025 will solve these challenges for short periods. As the system further decarbonises there will be a need for more of these services. Co-ordinated system operator activities and flexibility markets will be used as standard to manage distribution issues as well as transmission issues.

The current combination of markets and policies that signal investment, as well as signals for flexibility, location and operability, will not be fit for purpose to deliver the 2035 outcome we need. ESO's **Net Zero Market Reform (NZMR) project** is looking to address these challenges and recommend a way forward that is optimal for the whole energy system. We are future-proofing operability through **Pathfinders** and innovation projects like **Distributed Restart** and **Power Potential** that will enable us to procure operability requirements from distributed energy resources, instead of the dwindling fleet of large, thermal generators.

Ensuring the right networks: pace and coordination is critical

The scale of investment in transmission infrastructure will be unprecedented: last year's **Networks Options Assessment (NOA)** recommended >£16bn investment in new onshore transmission assets over the next 10 years, and this will only increase due to further increases in renewable generation forecast by FES 2021. Without these network investments, greater power flows driven by more generation and interconnection will contribute significantly to constraints experienced across the entire GB transmission system. By 2035, we will be thinking less about discrete transmission and distribution electricity networks, and instead taking holistic regional views of electricity requirements.

Connecting an additional 66GW of offshore wind and 22GW of interconnectors by 2035 could have an enormous cost impact, as well as broader societal impacts on coastal communities and the environment. We are leading and progressing work as part of the **BEIS-led Offshore Transmission Network Review (OTNR)** to deliver a more coordinated network in the short-, medium- and long-term. This work will have dual focus: one on delivering speed and certainty to the process for the 2030 target of 40GW of offshore wind to be reached; and a longer-term, enduring strategic regime to ensure the onshore and offshore transmission network facilitates the rollout of much higher levels of offshore wind out to 2050. Any reforms to electricity market design, such as reforms to locational pricing, must consider how markets signals will coordinate with centralised transmission planning initiatives.

GB's ability to connect new generation currently exceeds the pace at which the industry can approve, consent and deliver major infrastructure projects. The time taken from approval to delivery of subsea HVDC projects is evidenced at ~8 – 10 years, while new onshore overhead lines would be a few years longer. This means that, under the current frameworks and planning regimes, we need to develop options to meet 2035 challenges immediately. ESO's ongoing **onshore and offshore network planning reviews** are looking at how we collaborate to identify strategic investments - both to ensure transmission network capability is there ahead of need and to identify potential whole energy system optimisations that deliver value.

Ensuring the right resources: capacity adequacy will become a different challenge

The fully decarbonised electricity generation mix in 2035, combined with the significant increase in demand, will present new challenges in ensuring system adequacy. We will be hugely reliant on a much higher penetration of weather-dependent generation (wind and solar), and many of the flexible technologies that we will depend on to balance the system may also be impacted by weather (e.g. storage, interconnectors).

Historically, the main challenges on adequacy have focussed on being able to meet peak demand. In 2035, adequacy challenges could occur away from winter peak demand, manifesting at times when demand is high and/or output from renewables is low (e.g. how do we meet demand during a prolonged period of low wind?).

We are in the process of undertaking a **capacity adequacy study covering the period 2025 – 2040**. This will help us better understand the risks on adequacy. It could also help to inform how the current Reliability Standard may need to change for a decarbonised power system, and whether there is an 'optimal' capacity mix within this standard that provides greater resilience.

Ensuring consumers are at the heart of a just transition

The contribution of consumers to net zero – in terms of their behaviour and lifestyle choices – is fundamental. The scale of change impacting them over the next three decades will be far-reaching, so we need to ensure that the transition is a fair one. We will need significantly more flexibility from consumers:

- Electric heating, which we see shifting peak demand by as much as 11.5GW in 2035; and
- Electric vehicles, which could shift peak demand by 13GW in 2035 from smart charging alone. The addition of Vehicle to Grid (V2G) could see an additional shift of 14GW of peak demand into off-peak periods.

We are transforming the way we think about consumers at the ESO. Our **Crowdflex innovation project** with Octopus Energy is investigating how much consumer flexibility can be unlocked, which will feed our **NZMR** analysis on how to unlock it in a fair and efficient manner, as well as our **Virtual Energy System innovation project** on how to model the impact of consumer behaviour in the wider system.

Ensuring a smart, flexible system through digitalisation and data

The sheer complexity of the whole energy system in 2035, with smart appliances in homes responding to price signals, millions of EVs and heat pumps, and thousands of decentralised assets taking part in wholesale and balancing markets, means that the digitalisation of processes and systems is vital. Increased data sharing will be needed to provide digital systems with the information needed to optimise markets and control room decision making. A major digital transformation is required, not just for ESO but for the industry as a whole, and it must be coordinated across different voltage levels, vectors and sectors. **Increased visibility of distributed generation and demand** will be crucial.

We published our updated **ESO Digitalisation Strategy & Action Plan** in June 2021, aligned with the recommendations of the Energy Data Taskforce. Transforming our data capabilities is foundational to delivering on our digital objectives, and to the wider digital transformation of the UK's energy sector. Our data transformation involves strengthening our data and information culture, upskilling our people, building new capabilities and ways of working with data, and delivery of our strategic **Data and Analytics Platform**.

Conclusion

The challenges to achieving the GB energy future set out in this paper are significant and wide-ranging. We look forward to receiving Markets Advisory Council members' feedback, insight and advice on how we can better support the GB energy system in this period of transition.