Written evidence submitted by ORE Catapult (CGE0081)

1 Introduction

The Offshore Renewable Energy (ORE) Catapult has begun to explore scenarios for achieving high penetration of offshore wind in the energy sector, as a major plank in the UK's decarbonisation strategy. We are sharing some of our preliminary thinking below.

1.1 Offshore wind may be able to affordably supply the majority of the UK's energy needs

Decarbonisation will require replacement of natural gas for heating, and oil for vehicles, with zero-carbon alternatives. If there is an affordable source of zero-carbon electricity, a majority of heating and personal transport is likely to be electrified. Even with robust efficiency improvements, UK electricity end-use demand may double, from ~300TWh today, to 500-600TWh by 2050.

UK offshore wind is the only renewable energy resource capable of supplying the bulk of this electricity demand. It is a natural resource vast enough to have plenty to spare for energy exports to Europe.

The Science and Technology Facilities Council (STFC) (Cavazzi, 2016), used GIS data including data layers from The Crown Estate, to identify the total UK offshore wind resource, and estimated LCOE based on cost estimates and projections available at the time. ORE Catapult has taken the original resource analysis and made high-level adjustments to the resulting cost tables, based on up to date understanding of current and future costs, including taking into account the strike prices achieved in the 2017 CFD auction, to estimate:

308GW of offshore wind for LCOE < £66/MWh, plus
367GW of offshore wind for LCOE of £66 - £72/MWh

based on 2012 prices and assuming a 2023 commissioning date. However, these costs will continue to fall as global deployment of offshore wind accelerates.

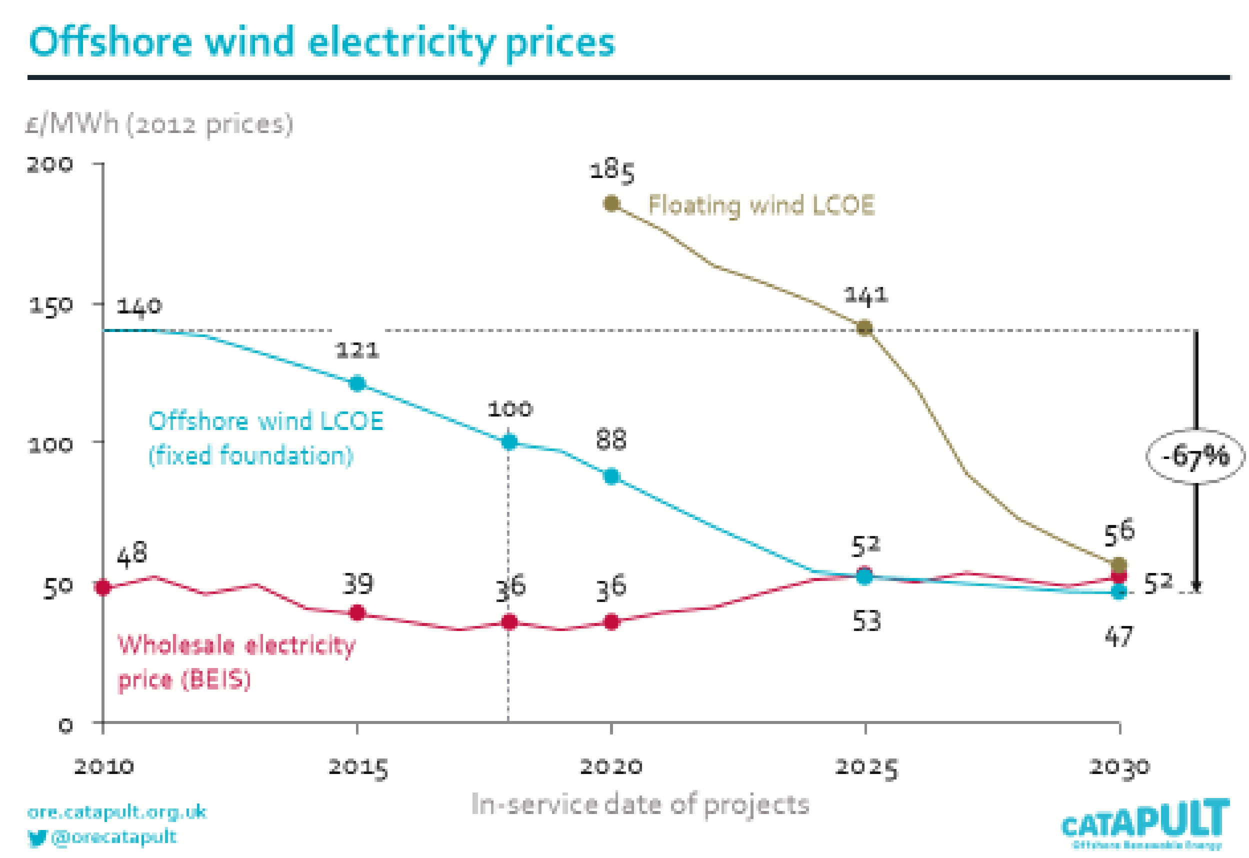
The vast majority of the 675GW highlighted from the STFC study is situated off the East and South coasts of England and in the Irish Sea. In addition to the shallower-water resources of the southern North Sea and Irish Sea, the UK (particularly Scotland and the South West) has an abundance of consistent, high-speed wind resource in deep-water sites, both close to and further from shore. Exploiting these areas can provide an additional layer of energy security and stability through exposure to different weather systems and the cost of accessing this valuable resource will reduce with increasing deployment of deep-water offshore wind.

Each GW of offshore wind provides around 5TWh of electricity per year, so at first sight offshore wind can provide many times our total energy requirement – 1,000s of terawatt-hours. But for offshore wind to become the backbone of the UK energy sector, it must overcome the variable nature of its output. Offshore wind has much lower intermittency than onshore wind or solar energy. It is therefore intrinsically much more straightforward, and cheaper, to provide the short term and seasonal balancing required for an energy sector dominated by offshore wind, rather than onshore wind or solar.

This favourable combination of technology characteristics, and large and consistent wind resource over the sea, makes offshore wind by far the best prospect for attaining a high percentage of renewables in the UK energy mix.

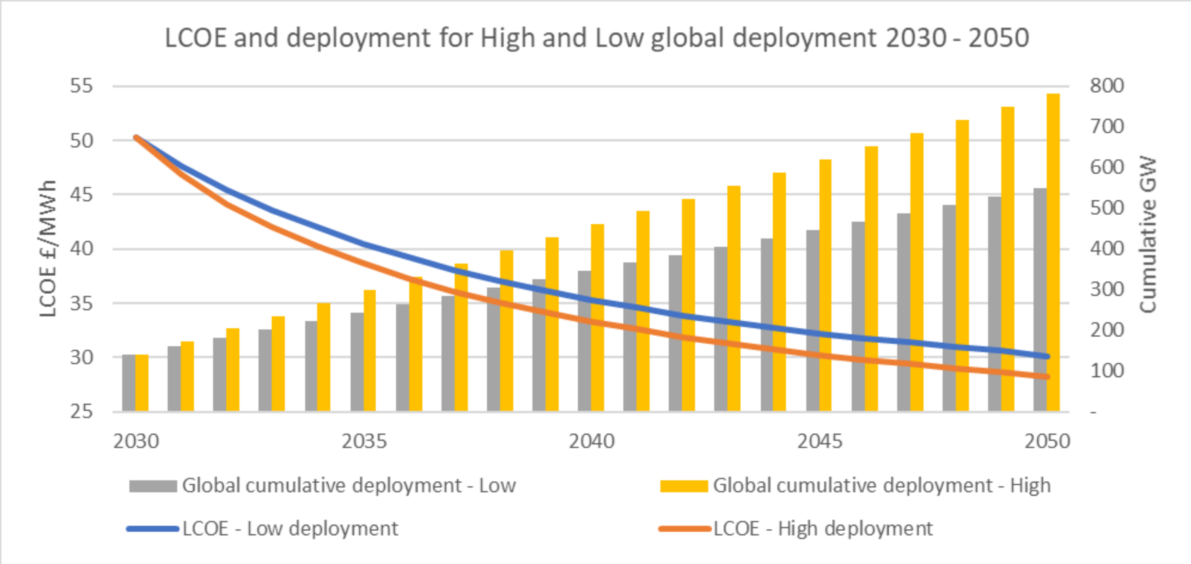
1.2 Ensuring the cost of offshore wind continues to fall

The rapid cost reduction of recent years is set to continue, driven by increasing deployment, which drives economies of scale and provides OEMs and the rest of the supply chain with increased capital for innovation.



The learning rate (or *experience curve*) underlying this cost reduction is approximately a 12% cost reduction for each doubling of global installed capacity. By 2050, global deployment may have doubled around five times, from 20GW today to over 500GW.

There are significant unknowns around how much of the offshore wind learning rate is piggybacking on the onshore wind industry (with 600GW installed globally to date), and whether different cost elements such as turbines, foundations and O&M have independent learning rates. However, the forecast scale of deployment to 2050 indicates that by 2050 offshore wind LCOE should be £30/MWh or less.



Source: ORE Catapult analysis

These cost reductions can only be achieved through continuous innovation throughout the supply chain. This is an industry which, as it scales up, is following the trajectory of aerospace manufacturing – becoming highly concentrated, with deeply integrated supply chains crossing multiple countries. Developing a new turbine model costs in the order of $500m and, as with aerospace, defence or nuclear technologies, OEMs are increasingly dependent on deep partnerships with governments to share the risks and financial burden of R&D and commercialisation.

1.3 Expanding the offshore wind resource for job creation and energy exports

The UK can become a major supplier of clean energy to a decarbonised Europe - by 2050 offshore wind can be the UK's most valuable natural resource, supporting 180,000 jobs in our high-deployment scenario for 2050.

A key objective will be to exploit deep water and sites far from shore, through development and commercialisation of floating wind technologies. The UK is currently the global leader in floating wind and the UK supply chain is well-placed to capitalise on this market opportunity. There is significant opportunity to export existing UK strengths in development, design, engineering and maintenance, but investment in key ports and fabrication facilities is required in order to unlock the full potential value in terms of jobs and Gross Value Add (GVA). A healthy domestic market would be required to underpin UK exports of up to £11bn annually, by 2050.

Electrical infrastructure will need to evolve towards a *mesh network* or *supergrid*, to avoid the inefficiencies of every offshore windfarm requiring its own land-based grid connection point. An energy hub, combining substations and hydrogen infrastructure in one offshore facility is one possible pathway. (A consortium of Dutch, Danish and German utilities and developers led by TenneT is developing energy hub designs based on 20-30GW of electricity supply and hydrogen production from a single offshore hub.)

Innovations in wind turbine characteristics, installation methods and O&M will also expand the exploitable resource by lowering the costs of operating in deeper water, further from shore and in higher wind speeds.

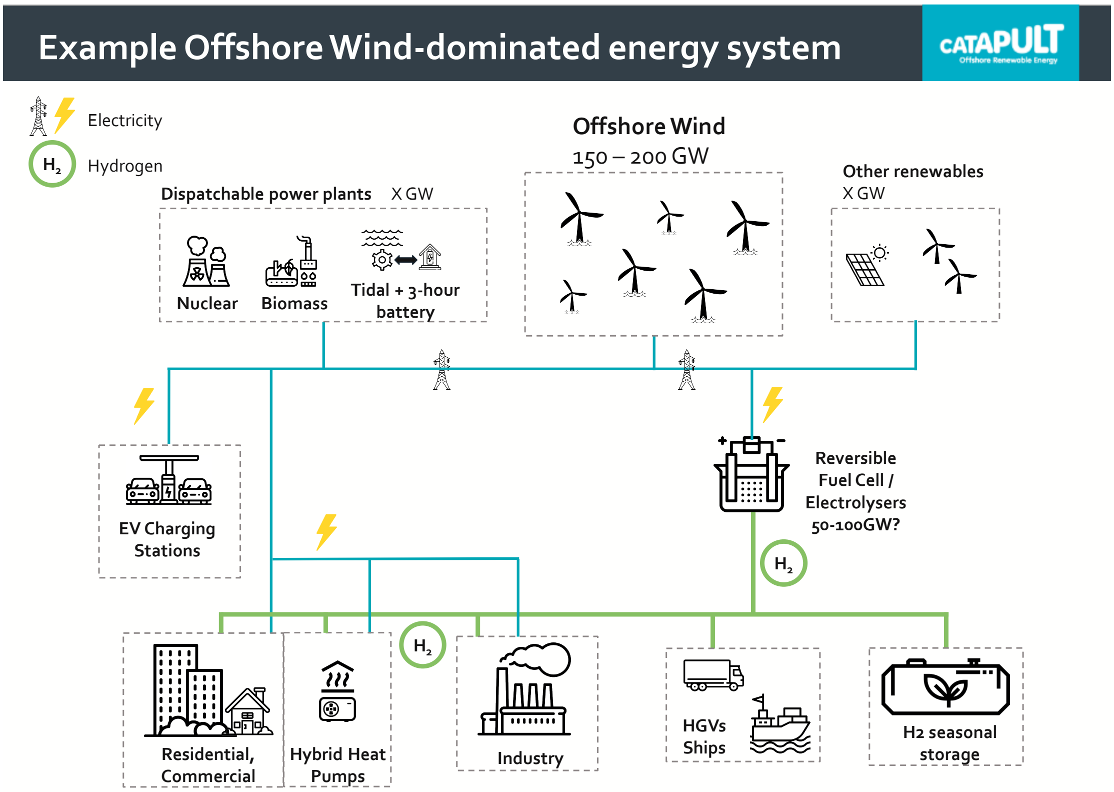
1.4 Increasing the value of offshore wind in the whole energy system

Over the next five years, we need to rapidly advance our understanding of the best pathways for offshore wind to become the primary energy source for an integrated electricity, heat and transport energy system. To do this we must better understand how to increase the *system value* of offshore wind. It will be important to integrate the work of disparate groups, and identify critical innovations for enabling an offshore-wind dominated energy sector.

The *Capacity Factor* is the most important technology characteristic affecting the system value of intermittent renewables such as wind or solar. The closer that a renewable technology can approach the capacity factor of a "dispatchable" power plant (e.g. 90% capacity factor for nuclear or biomass plants) the lower the cost will be to compensate for periods of unavailability. The next generation of offshore wind arrays are expected to achieve 60% capacity factor. Onshore windfarms have typically achieved less than 40% capacity factor, and solar farms around 10%.

The system value captures the cost of measures to offset or compensate for periods when there is a mismatch between offshore wind generation and electricity demand. In general, increased electricity system flexibility can provide low cost balancing, by measures such as shorter trading windows, debottlenecking transmission to allow geographical balancing of supply and demand (including with neighbouring countries), and trading of demand reduction measures. Energy storage, e.g. in batteries, can provide a range of valuable grid services and also cover dips in generation.

Beyond low-cost flexibility measures, an offshore wind-dominant electricity supply will require some level of alternative generation when winds are low. Only a whole energy system view of electricity, heat and transport, that includes integration with the energy systems of neighbouring countries, can provide reliable insights on this balancing requirement. ORE Catapult is developing scenarios to help identify key innovations and policy and regulatory requirements. A high-level schematic of one possible configuration of an offshore-wind dominated energy system is presented below:



In this possible energy future, hybrid heat pumps provide much of the UK's space heating wthout any need to massively expand the country's entire electricity distribution network. When it is very cold, the electric heat pump is inefficient and hydrogen gas supplied via the existing low-pressure gas network takes over the heating duty. Electrolysers produce hydrogen in bulk, and so provide balancing of seasonal mismatches between energy supply and demand. In fuel cell mode, the same electrolyser/fuel cell units provide electricity. (Hydrogen-fired turbines can also perform this function, if reversible electrolyser/fuel cell technology does not progress well.) In winter low-wind and low-temp events, the system would operate as below:

System flexibility for winter heating & power

Dominant operational mode of electrolysers/fuel cells and of hybrid heat pumps

Meteo. event	Very cold COP < 2	Average cold COP > 3
Low OSW	Fuel cell operation; Heating with H2	Heating with Heat Pump
High OSW	Electrolyser operation; Heating with H2	Electrolyser operation; Heating with Heat Pump

Meteo. event – dominant meteorological conditions across UK

COP = coefficient of performance of hybrid heat pump in electric mode; in extreme cold, electric energy to run the Heat Pump exceeds the heat produced for the home (i.e. COP < 1)

Low OSW – offshore wind generation below average

High OSW – offshore wind generation average, or better

Price signals from the electricity & heat markets will determine the operating modes of electrolyser/fuel cell facilities, and hybrid heat pumps

The energy system described above could provide a transition path from primary heating with natural gas, to backup peak-shaving with hydrogen, without any need to build new pipelines for consumers or for bulk transmission. And it has additional advantages, particularly in comparison with decarbonisation pathways that rely on transitional, low-carbon technologies, such as steam methane reforming of hydrogen (SMR):

- Few unproven technologies
- Eliminates need for additional infrastructure systems – e.g. with no H2 from methane reforming, Carbon Capture and Storage infrastructure is no longer required in the energy system
- Reduces fossil fuel price risk, and security of supply risk,
- Avoids the risk of the window for a cost-effective transition via SMR being squeezed out by delays to SMR-CO2 capture technology, and acceleration of decarbonisation targets
- Reduces system vulnerabilities inherent in high-nuclear scenarios (forced outage/shutdown of large plants)
- May avoid splitting the H2 market and infrastructure into Fuel Cell H2, and Combustion H2 (SMR is unlikely to produce high-purity H2 required for fuel cells, e.g. for vehicles), reducing asset duplication, commercial risks, and costs
- Higher certainty around achieving zero-CO2 in 2050, with low overall cost increase and high energy security

Our possible pathway may be a "no-regrets" financial and political choice for the near-to-medium term in two very important regards:

Infrastructure-light - it avoids the need for new, house-by-house, consumer network infrastructure (by contrast, electric-only heat pumps and home EV charging would require digging up every street and re-cabling to every home); it avoids building entirely new energy network infrastructures, such as CCS would require;

Familiarity – drivers can continue to "fill up" EVs or fuel cell vehicles at garages, as they do now; homes still use gas for cooking (H_2 with colorants); home-owners do not have to adapt to low room temperatures in cold snaps (a drawback of non-hybrid, electric-only, heat pumps), or to be persuaded to switch from radiators to indoor units that blow hot air (hydrogen top-up enables low cost, air-source heat pumps to provide the majority of the heat for traditional "wet" central heating systems).

We believe the UK could benefit from enhanced energy sector scenario development and planning, in close cooperation with other efforts. Key objectives for the next few years will be to develop detailed assessments, and recommendations on:

- how and when market rules and regulations should be coordinated with achieving innovation milestones in critical technologies,
- the mutual dependencies of critical technologies, and
- the least-regrets, near-term choices for energy market rule-making, infrastructure investment and innovation funding, to enable an Offshore Wind-dominant energy sector

An example of a question we should aim to answer is,

What are the system level advantages of an electric vehicle rollout based on charging stations at the existing network of around 10,000 UK petrol stations, instead of home and on-street charging? How critical is rapid battery-swap technology for consumers to accept this EV market model? How must transport policy, electricity and gas market regulation, standards-setting, land planning, and innovation priorities and timing be coordinated to move the EV market in this direction? And, how is the scale of deployment and affordability of offshore wind in 2050 affected by this alternative EV market model?

2 Conclusions and Recommendations

With its abundant and affordable offshore wind, the UK is in the enviable position of having a renewable resource capable of supplying most of the energy required for electricity, heating and transport, without competing for land and landscape amenities.

In the near term, to secure this option, the UK government would need to:

- support a major, cross-disciplinary programme to understand the system integration pathways for offshore wind and develop an integrated roadmap for policy, regulation and innovation priorities

- restore funding for offshore wind innovation to at least its former levels (see appendix note on Innovation Funding)

The UK government can continue to make a contribution to cost reduction of offshore wind by:

- providing a large, steady market for new projects and
- supporting innovation throughout the supply chain, including O&M and decommissioning

Flexibility across electricity, heat and transport will be key to affordably integrating a high proportion of offshore wind into the UK energy system. Based on our preliminary internal scenarios, ORE Catapult suggests that the UK may be able to simplify its choice of decarbonisation pathways by applying some guiding principles:

- Use or re-purpose existing infrastructure as much as possible (e.g. use as much of the gas pipeline network as possible for 100% hydrogen)
- Avoid widespread new or expanded consumer networks, such as doubling or tripling the capacity of the wires to homes and businesses - since the peak winter heating load is around 300 gigawatts, this rules out shifting to electric heat, except for heat pumps with hydrogen/biogas backup.
- Connect and integrate networks at the greatest scale possible, e.g. Europe-wide for electricity.
- Integrate networks across energy vectors (gas, electricity), and with short timescale trading. Implement this with natural gas/biogas/hydrogen blends, in preparation for a full transition to hydrogen.
- Avoid large investments in "low-carbon" technologies that are inevitably only a transitional step to zero-carbon. If their commercial deployment is delayed, or decarbonisation deadlines are brought forward, their window of opportunity will disappear. The combination of transitional technology, and new network infrastructure requirements, is particularly risky.

2.1 Responses to specific questions raised

Q: How achievable is the Sector Deal 30GW target? What are the main risks to achieving it?

A: Overall, very achievable, with much of the 30GW in the pipeline in one form or another. There are no major risks to achieving 30GW, and mitigations are available.

Q: Are there any key aspects missing from the sector deal or that you think deserve more prominence?

A: We are happy with the balance struck in the Sector Deal. There is now an opportunity to address the need to restore public budgets for offshore wind innovation, to help support initiatives in the Sector Deal.

Q: Early days obviously, but do Government and industry seem to be acting upon steps proposed in the sector deal with sufficient urgency?

A: Yes, progress so far is on track.

Q: The Committee on Climate Change has flagged floating offshore wind as a key technology to develop, but it seems to receive little specific focus in the sector deal – do you agree with the prominent potential of floating offshore wind in particular, and do you think the sector deal offers enough for this technology?

A: The timeframe of the Sector Deal is only to 2030. We anticipate that, with adequate incentives and demonstration opportunities, floating wind costs will converge with fixed-foundation costs around the end of that period. The innovation related elements of the sector deal encompass floating wind.

Q: How important will the development of floating turbines be for domestic deployment and export markets?

A: Floating wind is essential for UK offshore wind to reach its full potential of supplying a majority of the UK's energy needs, and becoming an energy export commodity. This implies a UK offshore wind fleet well in excess of 100 gigawatts. Fixed-foundation windfarms may provide 30-50GW, depending on relative costs of floating wind, our ability to plan infrastructure development, and other factors. Our success with exports will be strongly related to the size of our domestic industry. The more offshore wind we deploy over coming decades, the more investment we will be able to attract into high-value components and services, and the greater our export potential will be. With floating offshore wind there is a window of opportunity to apply UK expertise from Oil & Gas, and to coordinate innovation funding and demonstration opportunities, in order to establish a dominant template for floating offshore wind, and so capture a large share of global markets. More details are in our report – **Macroeconomic benefits of floating offshore wind in the UK**

Q: I'm aware that ORE Catapult covers other marine tech too – to what extent could other marine technologies contribute to the UK's low-carbon power generation needs over the 4th and 5th carbon budgets, and what support might they need to be able to do so?

A: Tidal stream can be made dispatchable when complemented with 3-hour energy storage, and it does not vary seasonally. It therefore has potential to take a limited but highly valuable role within the UK's decarbonised energy system. Do any of them have particular export potential? ORE Catapult estimated export GVA potential of £129m pa by 2030. Although wave technology is at an earlier stage of technology maturity, the global resource, and hence market potential, is much greater than for tidal stream. With successful commercialisation of UK wave technology, we estimate UK export GVA potential of £486m pa, by 2040. Our recommendations on support for wave and tidal are laid out in detail in our report - **Tidal stream and wave energy cost reduction and industrial benefit**

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