18 May 2020

Dear Committee,

RE: EAC inquiry on Technological Innovations and Climate Change: Offshore Wind inquiry, written evidence submitted by the Geoscience & The Energy Transition and Resource Recovery from Waste teams

Executive summary

The Resource Recovery from Waste programme has explored the circularity of low-carbon infrastructure and in particular of offshore wind (OSW) since 2017. The Geoscience & The Energy Transition team at the University of Leeds started to develop decarbonisation solutions that maximize the opportunities offered by the UK subsurface within the wider energy system.

The OSW sector in the UK has entered a period of steep growth from 8.5GW operational capacity in 2018 to 30/40 GW by 2030 and 175GW by 2050. We share an overview of challenges and opportunities for sustainable OSW developed and highlight the following:

To realise the full potential of the sector it is imperative to solve key barriers: 1) Ensure integration of OSW into a low-cost, low-carbon, flexible energy grid system; 2) Given the intermittency of OSW, establish substantial energy storage capacity which could be developed with the use of existing natural and industrial legacy geoassets; 3) Secure access to resources such as precious and rare earth elements necessary for continued deployment of OSW, within the context of resource demands for other low-carbon infrastructure and technologies and by optimising resource management throughout OSW farm lifecycles including end-of-use management.

We present new evidence on empirically quantified resource use in OSW in the UK. We discuss capabilities to recover materials at end-of-use and conclude that solutions are underdeveloped, while demand for "decommissioning" and waste management will rise within the next 5-7 years. The immature status of resource recovery solutions for blades and rare earth materials is of particular concern given the environmental impacts and resource security concerns respectively.

Applying circular economy approaches to OSW revealed important gaps in the whole life-cycle management, in particular regarding "decommissioning" which includes steps that can be taken throughout the lifecycle of OSW infrastructure, from design for circularity to extending the lifetime with better operations and maintenance, repair, reuse, remanufacturing, replanting, repowering, recycling, energy recovery, and controlled storage. Industry and government are not doing enough to optimise economic, social, technical and environmental values throughout the lifecycle of OSW farms and urgent action is required.

Analysis of OSW decommissioning plans concludes that these are at best formulaic and at worst perfunctory. None of the plans gave reassurances that critical materials would be recovered. Waste management pathways were underdeveloped or completely unavailable. Costs for decommissioning have been underestimated by at least a factor of 4. Taking up lessons from the few OSW decommissioning operations to date, as well as cross-sectoral learning, appears challenging as plans showed little change or improvements in consecutive iterations. The poor quality of decommissioning plans is a reflection of inadequate Government guidance.

The environmental, social and economic sustainability potential of OSW has to be strengthened through the development of whole system scenarios involving a broader range of stakeholders.

We recommend specific actions for Government to take in order to: [a] Adopt a whole systems

We would be grateful if you could consider the evidence provided herein from the Resource Recovery from Waste programme (RRfW) and the Geoscience & The Energy Transitions teams:

RRfW was a £7M strategic investment by the Natural Environment Research Council, the Economic and Social Research Council and the Department for Environment, Food and Rural Affairs, convened by the University of Leeds[1]. The programme aimed to drive radical change in resource and waste management in the transition towards a circular economy. The programme has made significant contributions to progress in academic research, particularly on the recovery of (near) critical materials for green technologies, innovation and business development, and government strategy[2]. Since 2017 we have explored the circularity of low-carbon infrastructure and in particular of offshore wind[3,4].

The recently established Geoscience & The Energy Transition initiative based at the School of Earth and Environment, University of Leeds, aims to address the current gap in understanding of potential geoenergy opportunities, their social acceptance and potential technological and policy barriers necessary to overcome for the energy transition that the UK has committed to. We apply a sustainable, whole system approach to energy underpinned by integrating Leeds' breadth of international research excellence in geoscience, engineering, social science, energy policy, climate science and economics, applied at local, regional, national, and international scale[5]. We are developing decarbonisation solutions that maximize the opportunities offered by the UK subsurface centring on naturally occurring and industrial legacy geoassets. Given the intermittency of most sources of renewable energy, current work focusses on subsurface energy storage, dispatchable via existing gas and electricity networks. The Leeds team sets a novel standard of how to approach sustainable geoscience based solutions, working collaboratively across disciplines and governmental and industrial stakeholders to produce innovative, realistic and low cost short, medium and long-term solutions.

With this letter we would like to offer our initial findings to this inquiry to support the questioning of witnesses and as a basis for recommendations to government directly.

1. How effective has the Government's offshore wind Sector Deal been in moving the sector towards becoming an integral part of a low-cost, low-carbon, flexible grid system and boosting the productivity and competitiveness of the UK supply chain?

1.1 Current capacity: With ca. 8.5GW operational capacity in the UK and ca. 23GW global capacity in 2018, the UK is the global leader in deployment of offshore wind (OSW). New OSW farms are being constructed and this will increase capacity to 13GW by 2022[6].

1.2 Growth ambitions: In the Offshore Wind Sector Deal government and industry made a shared commitment to install 30GW by 2030[7]. In the 2019 UK election that ambition was raised to 40GW. Widely varying targets have been expressed for 2050, ranging from 75GW to 175GW. With this fast growth the OSW sector is highly dynamic and it can be challenging for industry to integrate continuous improvements from project to project[8].

1.3 Increasing scale: The size of OSW infrastructure components is increasing: between 2003-2013 the average turbine was 3.6MW with average blade length 52.5m and by 2018 this had increased to 5.6MW and 68.9m respectively; between 2019 and 2022 this will increase to 7.7MW with blades measuring at least 77.7m in length; and increase in the next decade to at least 8-10MW generators and employ >80m blades[9].

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[1] RRfW website https://rrfw.org.uk/ and https://nerc.ukri.org/research/funded/programmes/waste/

[2] Purnell et al (2019) https://resourcerecoveryfromwaste.files.wordpress.com/2019/05/rrfw_programme_brochure_web_spreads.pdf.

[3] Purnell et al (2018) https://rrfw.org.uk/2018/03/05/low-carbon-infrastructure-decommissioning-workshop/

[4] Jensen et al (Submitted) Low Carbon Infrastructure Decommissioning: Highlighting the Need to Embed Circular Economy in End-of-Life Planning Using the Example of Offshore Wind

[5] The School of Earth and Environment at Leeds is globally leading with top scores for research excellence and impact (REF 2014); and top rankings in national and international league tables.

[6] Ibid 4

[7] BEIS (2019) https://www.gov.uk/government/publications/offshore-wind-sector-deal

[8] Velenturf et al (In preparation) Sustainability challenges and opportunities for offshore wind development.

While an increase in scale enables lower system costs, it also raises new challenges of which a number will be introduced herein. Our research is at an early stage and we do not proclaim our information to be exhaustive and anticipate further complementary evidence to be provided or to be made available from other sources.

1.4 Grid integration and energy storage: The increase in growth of distributed energy will also require an upgrade in grid capacity and its 'smart' integration[10]; OSW cannot stand-alone as a dispatchable energy reservoir. For example, Yorkshire/Humber demanded 22,754 GWh in 2018[11], which according to our preliminary analysis[12] would require 12% energy storage if supplied exclusively by wind and solar energy if we assume an order of magnitude increase in the renewable energy sector characterized by intermittent supply. Without alternative energy storage allowing fast energy dispatchment, gas-fired heaters and electric power peakers will still be needed. Hence, **integration of OSW into a low-cost, low-carbon, flexible energy grid system is imperative and requires substantial development of energy storage**. UK OSW developers posit that 40GW will saturate onshore grids unless consensus and governance manages interconnection landfalls, and market mechanisms have to be put in place to incentivise storage.

Cost-effective energy storage could be developed with the use of existing natural and industrial geoassets close to consumers and wind generation. For example, the UK has billions of m^3 disused mines that technically could offer low cost, dispatchable energy storage directly supporting OSW energy production; including in-shaft gravity hoisting[13] and compressed air or hydrogen storage in subsurface cavities[14]. As an example, Yorkshire has ca. $5km^3$ of voidage in disused mines that could be used for storage. Existing deep mine shafts can be repurposed to provide rapidly dispatchable storage of 1,885MWh using in-shaft gravity hoisting[15], with promising over 75% energy efficiency. Eight deep hydrogeologically encased mine shafts south of York are close to potential high density wind farm areas (e.g. Dogger bank), could store 38MWh of rapidly dispatchable electric power at GW-scale rate. Such a scenario needs to be supported by reducing demand on existing energy networks by shifting load to ground source heat pumps and heat networks and aquifer energy storage[16]. Strategic research assessing the feasibility of compressed air and hydrogen storage in legacy cavities (mines, and former oil and gas fields), naturally occurring spaces (caves) or cheaply excavated cavities (e.g. salt horizons) must therefore play an important role in the growth of the wind sector. This could provide pump-priming to explore suitable matches of other energy storage technologies crossed with various subsurface geoassets. Such research should take a whole system approach integrating technological solutions with appropriate regulatory and policy frameworks, economic viability and public perceptions.

2. What level of output can the sector deliver in the UK, and what Government support would be needed to achieve this?

2.1 Resource security: Our research outcomes suggest that resource availability of e.g. precious and rare earth elements is a risk for continued deployment of OSW, especially in the context of resource demands for other low-carbon infrastructure and technologies[17]. Moreover, solutions for end-of-use management are underdeveloped and resource recovery rates are low. A joined up long-term approach that takes a whole lifecycle perspective from material extraction through to manufacturing, usage and recovery across technologies is still missing in the UK[18]. This causes economic, social and environmental risks at various points in the lifecycle of OSW.

2.2 Current use: Current quantities of rare earth elements, economically valuable metals and composites were assessed based on an interrogation of the UK National Infrastructure Planning

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[9] Ibid 4
[10] Ibid 4, 8
[11] BEIS aggregated electric metering data
[12] Based on National Grid ESO demand data 2018
[13] Morstyn et al (2019) https://doi.org/10.1016/j.apenergy.2019.01.226
[14] Parkes et al (2018) https://doi.org/10.1016/j.est.2018.04.019
[15] Our analysis of Coal Authority datasets: Underground Workings and Mine Entries
[16] Rees (2016) http://eprints.whiterose.ac.uk/127489/
[17] Ibid 3, 4, 8
[18] Ibid 4

portal and the RenewableUK Project Intelligence database, in addition to a review of Crown Estate and OSW farm operator websites (e.g., Ørsted, Vatenfall, SSE, ENGIE, E.ON, Innogy). These included assessment of all currently operational OSW and those currently undertaking offshore construction activities, excludes Blyth wind farm, decommissioned in 2019, or those that were under construction but had not commenced offshore installation activities (i.e. the 857MW Triton Knoll wind farm, which has started construction since our review)[19].

We found that the 13,403GW of wind farms in UK waters that are installed and currently under offshore construction equated to ca. 2,555 OSW turbines. The subsea export and array cables will total to 3,113km and 3,123km respectively. OSW farms using Cu cabling will have ca. 22.8kt Cu in array cables and 23kt in export cables, with additional mass consisting of polyethylene insulation material and metallic armour (e.g., lead). This figure excludes the material present within the Hornsea One and Two OSW farms due to not being able to confirm whether aluminium of Cu cables would be used at the time of analysis, but if they would use Cu cabling then the total volume of this precious metal in OSW would double before 2022. A total of 7,655 blades will be(come) in use with a total length of 476.6km and mass over 151kt of which more than 85% is composite material. Close to 550kt of nacelle is/ being installed housing ca. 12.7kt Copper (Cu), and1.0-1.3kt of neodymium (Nd) and 300kg of dysprosium (Dy) within the magnets. We can share further details regarding estimates of future material demands with the EAC in confidence until the results of our analysis have been academically published.

2.3 Rare Earth Elements: Estimates of resource availability of rare earth elements have been attempted but are not necessarily reliable due, in part, to the disparate nature of data collection and methods for reporting of reserves[20]. Calls have been made for more robust techniques for estimating current and future availability of these economically critical materials.

The Undermining Infrastructure project at University of Leeds developed a new model enabling dynamic analysis of disruption in critical materials supply chains and assessment whether this could impede strategic infrastructure transitions set out to maintain energy security and net-zero carbon targets. The model was piloted on the wind sector. While supply disruption risk was forecasted to reduce up to 2050, this was far outweighed by a significant increase in criticality due to steeply rising demand for neodymium for use in permanent magnet direct drive wind turbines. The study concluded that the **strongly increasing criticality over a short period of time is more challenging for industry and policy makers to respond to than static, high levels of criticality**[21].

With access to rare earth elements uncertain, a more cautious approach should be taken to the resources that we already have in use within the UK. **Greater clarity is required regarding the known quantities, location and form of those critical materials deployed within OSW and other low carbon infrastructure and technologies.** Recovery rates are still very low and it is clear that the logistical and technical challenges involved in recovering these materials require further investigation.

2.4 Copper: There are strong markets for recovered copper. There are also well-established recycling methods in place in most regions to recover copper from within nacelles, but this is not the case for cables. Cables are commonly planned to be left in situ at end-of-use. While this could have environmental benefits for biodiversity in the marine environment around the UK, it reduces copper available for new developments and increases demand for copper extraction elsewhere in the world potentially to the detriment of people and environment outside the UK.

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[19] Ibid 4

[20] Lusty and Gunn (2015) https://sp.lyellcollection.org/content/393/1/265.short

[21] Roelich et al (2014) https://www.sciencedirect.com/science/article/pii/S0306261914000816

Text box: Challenges and opportunities for OSW deployment[22]: A structured review was carried out for academic publications on offshore wind, sustainability and challenges (April 2020). Thematic analysis revealed challenges and opportunities for OSW around the world, which in part may apply to the UK context (Fig 1). A selection of challenges and opportunities include:

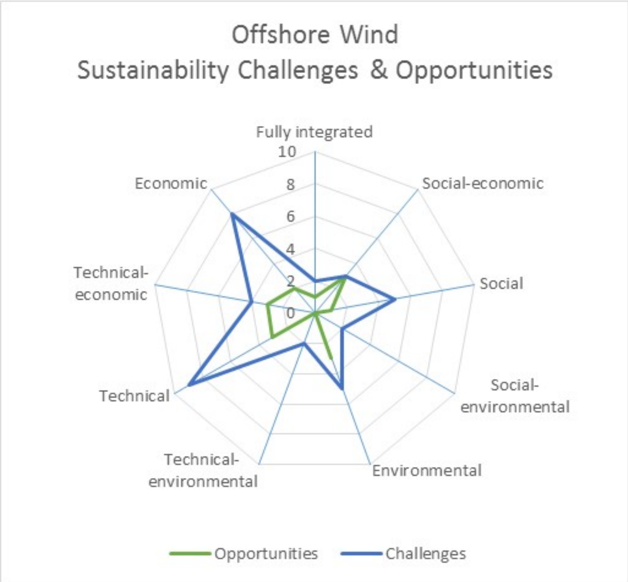

Figure 1: Number of offshore sustainability challenges and opportunities identified in different categories (Author generated, April 2020).

- **Fully integrated** challenge of capability for whole-system assessments, and opportunity to design multi-functional platforms around OSW to address multiple challenges;
- **Social** challenges on stakeholder engagement, uncertain and inadequate regulation, and learning from experience (also across sectors);
- **Social-economic** challenges to balance competition with collaboration for learning, and access to skilled staff, with opportunities to improve energy security;
- **Social-environ-mental** challenges on marine spatial planning, and end-of-use management;
- **Environmental challenges** on impacts on biophysical environment, increasing resource use and long-term impacts of climate change on wind resource, with opportunities including climate change mitigation, nature conservation and reduced pressure on space on land;
- **Technical-environmental** challenges on understanding site particularities and working in the marine environment;
- **Technical** challenges on intermittency, energy recovery, system efficiency, complexity of construction and decommissioning, lifetime extension, scour research and better data systems, and opportunities for design for decommissioning and floating wind;
- **Technical-economic** challenges on managing the distance from shore, vessel availability, fault detection, and grid capacity, connectivity and integration, and opportunities for multi-functional infrastructure and battery technology;
- **Economic** challenges regarding stability of wider market conditions, funding and finance access, international trade relations, cost uncertainty, and supply chain complexity, and opportunities to reduce LCOE and achieve higher economies of scale.

We will survey OSW stakeholders in June 2020 and could then report more detailed outcomes to the EAC.

3. How might the UK take advantage of further technological advances in offshore wind technology, particularly in relation to floating arrays?

3.1 Opportunities[23]: Detailing results from the text box, but bearing in mind that these results are preliminary, there is opportunity to **design multi-functional systems**. For example, combining wave and OSW power can lower development costs and reduce costs and risk during operation by sharing components, infrastructure and maintenance. Combining offshore renewable energy with desalination systems can reduce energy expenditure and cost of fresh water supply, and with recurring drought problems this may be worthwhile investigating for parts of the UK as well. Multi-functional platforms can also help in the management of intermittency challenges.

With **digital technologies** advancing rapidly, opportunities are emerging to design and use better data systems. Better information systems can optimise (increasingly remote) operations and

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[22] Ibid 8

[23] Ibid 3, 8

maintenance and reduce financial risk particularly in conjunction with better fault detection and control systems which could significantly reduce shutdown time when unexpected malfunctions occur. Better data systems can also trace the economic, social and environmental values as well as technical performance of OSW components and materials – increasing the potential for whole system optimisation of resource use. **Robotics** for remote operations and maintenance, **advanced materials**, offshore power **connection to onshore infrastructure** and **energy storage** were also identified as future areas of technological development.

Geoassets offer beneficial geological characteristics for energy storage including long-term stability, high storage capacity, high energy efficiency, potentially low cost implementation aided by legacy infrastructure. However, such solutions must be co-developed with relevant stakeholders (e.g. local residents, government, companies) and this was identified as a challenge in OSW development, operation and maintenance.

3.2 Challenges[24]: To be able to make the most of the opportunity to grow OSW, a number of persistent challenges have to be solved. These pertain to infrastructure such as **grid capacity**, availability of **onshore connection**, and tools to manage **integration of intermittent supply**. As an alternative, OSW power could be **converted into hydrogen** and stored as such but concerns persist regarding the **energy efficiency** of such solutions. While moving power generation offshore reduced competition for space on land, there are growing challenges around other marine uses and a **demand for marine spatial planning** for the UK Continental Shelf. **Floating OSW** is seen as an opportunity to move outside of areas of the sea that already have a competing use, but opens new challenges in terms of managing the greater distance from shore (transport, O&M).

While floating OSW is emerging, it is expected that the market for fixed turbines will be exploited first[25]. With increasing turbine sizes there are more challenges regarding the durability of foundations and stability due to scour depending on the site specific conditions. Research on scour is particularly challenging and this constrains development of anti-scour measures. The durability of OSW foundations can be further improved by detailed mapping of the subsurface in sync with the evolution of foundation technology, particularly in geological complex settings such as the North Sea[26].

There are a number of interlinking economic challenges. Access to affordable **funding and finance** is still challenging, although from the review it was unclear whether this was still the case for the UK. **Unstable markets** pose a risk and, especially given the current dynamic times with CV19 and the UK's departure from the EU, Government could take action for stable market conditions that will enable development. At the side of industry, costs throughout the lifecycle of OSW – from manufacturing to deployment, operation, maintenance and decommissioning – are still too high in some markets and subject to **cost inefficiencies and uncertainties**. Lack of design for **decommissioning** can unexpectedly increase costs[27] (covered in Question 5). To reduce the lifecycle cost of energy, a balance must be struck between **growing competition** and **enabling collaboration** for continuous improvement and learning.

4. What support does the sector require to keep pace with the most cutting-edge innovations, such as in blade technology?

4.1 Blade management at end-of-use: Here we focus on the end-of-use stage of blade management, which must feedback on blade design[28]:

- Blades pose decommissioning challenges in terms of logistics and waste management due to their strength, physical bulk and design to be resistant to degradation within harsh environments and made of multiple, intimately joined materials with low specific cash value.

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[24] Ibid 8

[25] Verbally shared insights at KTN/ Innovate UK webinar "Offshore Wind in the UK, China, USA, Japan and South Korea: Synergies, Opportunities and the Future" on 14 May 2020.

[26] Emery et al. (2019) https://www.frontiersin.org/articles/10.3389/feart.2019.00234/full

[27] Topham and McMillan (2017) https://www.sciencedirect.com/science/article/pii/S0960148116309430

[28] Ibid 4

- While decommissioning of onshore wind has generated thousands of tonnes of blade waste, little progress has been made in the development and uptake of environmentally responsible management methods that could be used for OSW and other composites.
- The main waste management method primarily involves shredding prior to incineration, dumping in landfills, or use as a fuel and raw material in cement making.
- Current solutions available are environmentally suboptimal and there is little evidence of innovation or uptake of sustainable blade recycling at industrial scale.
- Innovations that are being explored[29] (e.g. pyrolysis and solvolysis) have so far not proven to be economically viable or produce suitably reusable fibres[30].
- Claims that solutions will become economically viable with increasing scale may not be realistic based on the fact that composites wastes are already pervasive in society and solutions have still not managed to reach economic viability.
- Research and innovation is required to proactively develop more sustainable materials for use in blade production rather than dealing with waste management issues as an afterthought[31].

5. What is the UK industry doing to promote the sustainability of offshore wind arrays throughout their entire life-cycle from development through to decommissioning, and to improve maintenance and end-of-life repair?

Here we share a brief overview from our results so far on the application of circular economy to OSW and in particular regarding the decommissioning stage. **Industry and government are not doing enough to optimise economic, social, technical and environmental values throughout the lifecycle of OSW farms and urgent action is required.**

5.1 Circular economy perspective: Clean growth and circular economy are two sides of the same coin, given that circular economy prioritises renewable energy, that renewables are subject to resource security concerns (see answer to question 2), and that greater resource efficiency has high potential to reduce carbon emissions. However, applying circular economy approaches to OSW reveals important gaps in the whole life-cycle management, in particular regarding "decommissioning". In our view, decommissioning includes steps that can be taken throughout the lifecycle of OSW infrastructure, from design for circularity to extending the lifetime with better operations and maintenance, repair, reuse, remanufacturing, replanting, repowering, recycling, energy recovery, and controlled storage. **While the wind sector is aware of the basics of CE, focus is firmly on recycling, energy-from-waste and landfill, and design with the full spectrum of circular economy approaches to maximize value is generally not on the agenda yet.**

5.2 Identifying challenges[32]: In January 2018 Resource Recovery from Waste, University of Leeds and Innovate UK hosted a workshop to identify the scale and scope of challenges in end-of-use management of OSW and other low-carbon infrastructures, attracting 34 expert participants (half from academia, half from other organisations), plus a further 18 contributing asynchronously. Eight challenge areas were identified: (1) Value and critical materials; (2) Resource recovery infrastructure; (3) Inventory; (4) Durability; (5) Whole-system analysis; (6) Skills and expertise; (7) Policy, regulation and legislation; and (8) Economics and business models.

5.3 Decommissioning programmes[33]: The decommissioning programmes (DP) for 20 UK OSW farms were reviewed regarding end-of-use plans, where possible alongside each OSW farm's Environmental Impact Assessment. A full list of DPs reviewed can be provided to the EAC.

We conclude that **DPs are at best formulaic and at worst perfunctory** and provide no value to a growing movement toward a circular economy. This conclusion is in line with others who similarly

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[29] see, e.g. Jensen & Skelton (2018) https://www.sciencedirect.com/science/article/abs/pii/S1364032118306233

[30] Leahy (2019) https://static1.squarespace.com/static/5b324c409772ae52fecb6698/t/5dab2848c20b461ef175cdcb/1571498056954/Leahy_SDEWES_Paper2019_v2.pdf

[31] Ibid 29

[32] Ibid 3

[33] Ibid 4

concluded that OSW DPs lack critical detail[34]. Millions of tonnes of materials are being extracted, processed and deployed in OSW with nothing in place that suggests that these materials can be sustainably recovered, managed and returned to productive use at the potential scales required to meet accelerating OSW deployment. Academic and industry literature suggests that this statement is largely reflected within all types of LCI and not just within the deployment of OSW in the UK.

Technically, all DPs met the content demands as required by government guidance. All DPs commit to removing infrastructure but almost all introduce a caveat to fulfil the commitment where it is economically viable and not environmentally punitive (based on "BPEO" – Best Practicable Environmental Option). **The reviewed DPs commit operators to meeting their legal and technical obligations regards decommissioning of OSW infrastructure. However, that is all they do.** Below, we will share results from analysing government decommissioning guidance.

None of the DPs gave reassurances that critical materials, despite their role in the ongoing development of OSW and other emerging low-carbon infrastructure, would be recovered for sustainable reuse. This was also the case for EIAs that accompanied DPs. This does not seem to fit with the sustainable technology narrative of OSW. The presence of rare earth elements was not acknowledged and plans for export and array cables (containing several thousand tonnes of precious metal) are to be left in-situ. While there are environmental arguments against disturbing the seabed with attempted extractions of cables, there would likely be effects elsewhere due to continued extraction to produce cables anew. Moreover, such a blanket stance to abandon materials is contrary to the permitting regime that demands that all structures will be removed in principle. This brings much of the value and purpose of DPs into question.

Waste management pathways were underdeveloped or completely unavailable in respect of handling OSW waste; while available pathways such as energy from waste and landfilling will be expensive and/or not available due to capacity gaps. There is no reference to circular economy within any DP, but the waste hierarchy is referenced throughout. However, it noticeable that there is a distinct focus on the lower inferior reaches of the hierarchy, which is unlikely to deliver on government ambitions regarding sustainability. For recovery and recycling solutions that were covered in DPs, operators make numerous assumptions in respect of the management capacity and reuse of materials at eventual repowering and/or decommissioning that ignore the fact that, for example, composite recycling solutions do not exist in any meaningful manner in the UK, or globally (as discussed in Question 4). Blanket recommendations to reassess DP commitments to abandoning precious materials (i.e. Cu) and committing resources to "*sustainable incineration*", or pushing sub-standard or failing components overseas is questionable from a wider systems management and resource conservation perspective. Blade incineration may only be able to be facilitated by ignoring supposed restrictions on the export of wastes, thus potentially creating another international waste merry-go-round akin to that seen for WEEE and plastics, or ignoring arguments relating to the undesirable technology lock-in effects of incineration as a preferred waste management tool.

We acknowledge that it is difficult to foresee how exactly a given DP will take place ca. 20 years after commissioning an OSW farm. However, we note that OSW developers have access to e.g. LCA reports that discuss the role of decommissioning, recovery and recycling in reducing the lifecycle environmental impacts of OSW farms. Provided there is confidence in these documents and claims regards recycling and reuse of materials, it is reasonable to assume that manufacturers and operators are aware of the waste management capacity limitations and have plans in place to deal with OSW infrastructure that could be incorporated into DPs.

5.4 Underestimating costs: The lack of detail in DPs has in part been the basis for arguments that OSW decommissioning has been undercosted significantly[35]. Our review found that cost estimates appeared to exclude any realistic consideration of waste management costs, regarding logistics, storage, disassembly, and repurposing or disposal[36]. Moreover, our workshop results suggest that **decommissioning costs are underestimated by a factor 4-5**, undermining the

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[34] Freeman (2015) https://thinkrcg.com/wp-content/uploads/2015/10/RCG-Insight-2015-10-09-Decommissioning-offshore-wind.pdf

[35] Ibid 3, 27, 34

[36] Ibid 4

efforts of the Government to avoid a repeat of burdening the tax payer with decommissioning costs such as in the case for nuclear- and oil & gas sectors[37]. Notably, following these publications, the arguments they make were augmented and largely confirmed by a duly commissioned UK Government (re)appraisal of OSW decommissioning, finding that undercosting could potentially run into the £billions and was partly due to the impact of changing legislation, uncertainty over the availability of specialist and expensive vessels[38]. We add that this is also partly due to distinct vagaries around waste management in respect of many statements on what is and is not recovered and how. This feeds into existing narratives of decommissioning being "*poorly understood*" and recent growing concerns over a significant undercosting of OSW decommissioning.

5.5 Learning from experiences: DPs show little change or improvement in terms of specifics of material recovery or management from one iteration to the next[39]. **Learning lessons from one project to the next, and indeed across sectors, was highlighted as a challenge in OSW**[40]. While several relatively near shore farms have, to date, been decommissioned in the UK, Netherlands, Germany, Sweden and Denmark, any in-depth lessons from decommissioning these wind farms is not freely available and does not seem to have been incorporated into any recently produced DPs[41].

Lessons could also be learned from other sectors such as North Sea oil & gas. Oil & gas infrastructure was developed and deployed in a manner where the tax payer has been left to manage substantial parts of the financial and environmental impacts of their decommissioning and clean-up. **OSW should learn from that experience and take a more proactive approach, designing infrastructure with end-of-use in mind in order to optimise value, in all of its forms, throughout the lifecycle of an OSW farm. This will require changes in decommissioning guidance provided by Government.**

5.6 Decommissioning guidance[42]: We reviewed proposed decommissioning guidance for Scotland, which strived to stay close to guidance for the whole of the UK, and refer the EAC to our submission to the Marine Scotland consultation on offshore renewables decommissioning guidance in March 2020 and only summarise a few key points here:

- Guidance for offshore renewables was based on North Sea oil & gas, but guidance should not be transposed directly. Many OSW farms are likely to extend their lifetime rather than being fully decommissioned like North Sea oil & gas. Reuse in North Sea oil & gas is dramatically low for various reasons, and for a sustainable industry like OSW we can and should strive for better.
- **Guidance on waste management is insufficiently challenging companies to aim for sustainable end-of-use solutions and, due the unavailability of waste management solutions for a part of the components, companies do not have to provide costings. This creates financial risks for industry and Government.** Government is currently accepting this risk, contrary to the demands of decommissioning guidance: "*The Government's approach is to seek decommissioning solutions which are consistent with relevant international obligations, as well as UK legislation, and which have a proper regard for safety, the environment, other legitimate uses of the sea and economic considerations including protection of the taxpayer from liabilities relating to decommissioning. The Government will act in line with the principles of sustainable development*" (BEIS, 2019c: 7).
- Government should edit guidance to oblige industry to acknowledge the current scarcity of infrastructure (including recovery vessels) required to undertake decommissioning, the current capacity and limitations of the 'waste' management technologies they are expecting

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[37] Ibid 3

[38] BEIS (2018) https://www.gov.uk/government/publications/decommissioning-offshore-wind-installations-cost-estimation

[39] Ibid 4

[40] Ibid 8

[41] Ibid 4

[42] Velenturf et al (2020) https://consult.gov.scot/marine-scotland/offshore-renewables-decommissioning-guidance/consultation/view_respondent?uuId=899194153

to adopt, the impact of these current limitations, and their own efforts, or awareness of others' efforts, to address these limitations.
- A whole system approach should be adopted in order to access the benefits of a circular economy as aspired to by Government (e.g. under the Industrial and Resources and Waste Strategy). This will require expanding the minimum stakeholders that need to be involved in consultations in the preparation of decommissioning programmes, including organisations with knowledge of decommissioning logistics, project management, and waste management solutions and costs. This will better safeguard the quality of decommissioning plans and realistic cost estimates.
- The guidance is based within marine navigation and energy legislation, but lacks a grounding in resources and sustainability. **Decommissioning programmes should include evidence on how the offshore renewable energy infrastructure has been designed to optimise the economic, social, technical and environmental values at every stage of the infrastructure's lifecycle including the end-of-use.** This will require a feedback to the design of the offshore renewable energy infrastructure itself, and not just to the DP, and the timing of DP preparation has to be adapted to accommodate for this.
- Enabling the optimisation of design of OSW farms throughout whole lifecycles requires better data systems covering multi-dimensional – environmental, social, technical and economic –values.

In sum, we proposed alterations to the DP template based on analysis of differences between the North Sea oil & gas and offshore renewable energy infrastructure, the necessity to integrate the full extent of the waste hierarchy, the importance of developing best practice and new techniques given the limited decommissioning experience in the sector, the importance to broaden stakeholder involvement as part of a whole system approach to optimise multi-dimensional values, and holistic assessment of environmental costs and benefits.

5.7 Solving decommissioning challenges requires collaborative action: The DPs that we reviewed implied that companies are effectively waiting for others to lead on OSW end-of-use management efforts, and to adopt the Best Practicable Environmental Option available at a future time. However, the development of a circular economy in OSW requires pro-activity and forward thinking at the point of project development, not at its point of removal. Weaknesses in DPs produced by industry have been revealed and, similarly, shortcomings in Government guidance can be identified. Both should take action to reduce cost and risk, and to improve whole lifecycle performance of OSW farms. Helping the UK, currently the largest OSW market in the world, to lead on OSW decommissioning will open new business opportunities in the UK and abroad in an area where demand for solutions will steeply grow but solutions are currently few and far between.

6. How well is the UK industry managing the environmental and social impacts of offshore wind installations, particularly on coastal communities with transmission-cable landing sites?

6.1 Stakeholder engagement[43]: The identification and engagement of stakeholders is generally perceived as a challenge for OSW. Multiple stakeholders could be involved at different lifecycle stages of an OSW farm, there is often overlap between stakeholders across lifecycle stages, stakeholders may have profoundly different perceptions, values and attitudes with diverse expectations and abilities to influence, and this may vary between sites. This makes stakeholder engagement complex. However, proactive stakeholder engagement has benefits in terms of making use of local knowledge and managing public concerns.

6.2 Learning from fracking: We should also be prepared to learn from sectors which have been less successful in obtaining public acceptance for onshore development. One example is unconventional oil and gas sector in England which has been effectively stalled for eight years as local campaign groups have launched extensive legal challenges to development through the land use planning process. The decentralisation and consequent increased spatial impact of the energy system which onshore unconventional hydrogen development entails are equally applicable to

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[43] Ibid 8

renewable energy generation projects. The onshore wind sector is likely to bring new communities into proximity with energy production with consequent possibility for social conflict[44].

The failure of the unconventional hydrocarbon industry to obtain public acceptance therefore provides important insights to onshore wind and wind-related developments. Public concern about onshore unconventional hydrocarbons related not only to the impacts of development but also the processes by which decision-making on development were made. Extensive social science research has shown Government remained unresponsive to these concerns[45]. As a result, perceptions of poor governance became the driving force behind the opposition campaign[46], and once such perceptions of poor governance have been established they cannot easily be addressed.

Therefore public consultation exercises should be carried out early, in the spirit of inquiry and should be responsive to public concerns. Framing public opposition as a matter of lack of understanding is likely to entrench social conflict. The public can and will look to other sources of information than those provided by government and developers to inform themselves about the impacts of development.

6.4 Scenario development: To identify future research and government support priorities for the sector, a participatory scenario planning exercise would be useful. The identification and analysis of potential scenarios for OSW using a whole systems lens would help account for critical uncertainties and envision future pathways for the sector. Scenarios can be exploratory or normative, and qualitative, quantitative or a combination of both. Through the development and refinement of a small number of plausible scenarios, policy and governance options can be developed within these alternative futures. We recommend a scenario planning process that is inclusive and deliberative so that a wide range of views and perspectives can be incorporated into OSW policy and governance processes.

7. **How well is Government policy supporting innovation in transmission technology to improve the efficiency of electricity transmission?**
8. **Looking to the future, what can the onshore wind sector learn from the offshore success story?**

We have no evidence to provide in response to these questions at this stage.

Government recommendations:

There are a number of actions that Government could take directly:

a. Whole system approach

The OSW sector is at a critical stage of accelerated growth and has been named a key sector by the UK Government and EU for stimulating economic recovery after the CV19 crisis. Government should take a long-term whole system approach in planning and decision-making:

From the perspective of the whole lifecycle of OSW farms: Wind infrastructure that will be deployed should have sustainability and circular economy at heart. Demand on material resources to achieve the high growth rates will be high and, particularly under the current uncertain global trade relations of the UK, there is no guarantee that UK industry will have access to the required resources at an affordable price or at the right times. Government should take a strategic approach to ensuring resource access for OSW in the context of wider aspirations for the use of low-carbon infrastructure and technologies that compete for similar resources. This must go alongside conserving the materials that are already in use in the UK, by strengthening OSW decommissioning guidance in its widest sense – from design for durability, through to reuse, repair, remanufacturing, replanting, repowering, and recycling and controlled storage (if solutions are not yet available). This requires innovative approaches and technologies for sustainable, low-carbon

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[44] Cuppen (2018) https://doi.org/10.1016/j.erss.2018.01.016
[45] Evensen (2018) https://doi.org/10.1016/j.exis.2018.09.005
[46] Bomberg (2015) https://doi.org/10.1080/1523908X.2015.1053111

resource management. It is also important for safeguarding the very reasons why Government is deploying OSW in the first place – to protect energy security and to decarbonise the economy.

From the perspective of the whole energy system: OSW cannot grow without wider changes in the energy system. Barriers regarding grid access and energy storage must be solved, and Government should develop scenarios with short, medium and long-term solutions in mind. While geoassets can technically be repurposed as part of sustainable energy solutions, current regulation is a constraining factor. Government should also take a proactive stance to community engagement and learning from experiences with fossil fuels and onshore wind which, alongside the environmental, technical and economic aspects, could be covered in for example a future EAC inquiry into energy storage.

b. Collective action to improve quality of OSW decommissioning plans & guidance

While OSW deployment will increase, decommissioning operations will also reach a first peak in the UK in the next 5-7 years. Costs are forecasted to be far higher than anticipated and this poses a risk for the whole lifecycle cost of OSW farms. Poor quality decommissioning and resource management also poses risks to the overall sustainability of the sector and it is, moreover, not in line with formal Government strategies, policy and regulation on resources and waste. On a more positive note, OSW decommissioning is an emerging market in which the UK could play an important role. This could be supported by expertise from the North Sea oil & gas sector. In the immediate term, guidance for decommissioning programmes must be updated, and we refer the EAC to our detailed recommendations in response to the recent consultation by Marine Scotland[47]. In the short term Government should invest in the preparation of a roadmap for the development of end-of-use management and decommissioning solutions[48], to gauge the strategic opportunity for the UK and reach an agreement with industry to co-invest in the delivery of solutions, thereby minimising the risk to the tax payer and maximising global trade opportunities.

c. Datahub for OSW resource stocks and flows

The uptake of a whole system approach and the development of effective decommissioning solutions require the use of whole lifecycle assessment tools and supporting data, neither of which are currently available. Tools capable of integrating economic, technical, social and environmental costs and benefits into holistic assessments have been developed[49] but require further investment to ease use and integration into decision-making processes. Whole system assessments are data intensive and their use has to be accompanied by better data systems. Government could direct already allocated budgets to develop and pilot such a system on OSW (or low-carbon infrastructure in general depending on budgetary constraints) within the context of the National Materials Datahub under the coordination of ONS[50]. This can also support resource security strategy by assessing current and future resource use and availability.

While we hope the details provided for the inquiry is clear, we welcome any further questions and information requests. We would welcome the opportunity to stay in touch with the EAC throughout this inquiry because further evidence will amalgamate in our “Geoscience & The Energy Transition” project and a subsequent project starting this summer on a “Circular Economy for Offshore Wind” with the Offshore Renewable Energy Catapult and the Department for International Trade.

On behalf of the members[51] of the Geoscience & The Energy Transition and Resource Recovery from Waste teams who prepared this submission, yours sincerely,

Dr Anne Velenturf

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[47] Ibid 42

[48] E.g. integrated with the Technology Roadmaps coordinated by the Offshore Wind Innovation Hub https://offshorewindinnovationhub.com/about-roadmaps/

[49] Iacovidou et al (2017) https://www.sciencedirect.com/science/article/pii/S0959652617319893

[50] Velenturf (2019) https://rrfw.org.uk/2019/09/24/rrfw-makes-the-case-for-better-data-to-improve-circular-economy-governance/

[51] This submission was prepared by Anne Velenturf, Paul Jensen, Eric Peterson, Sandra Piazolo, Phil Purnell, Imogen Rattle and James Van Alstine.