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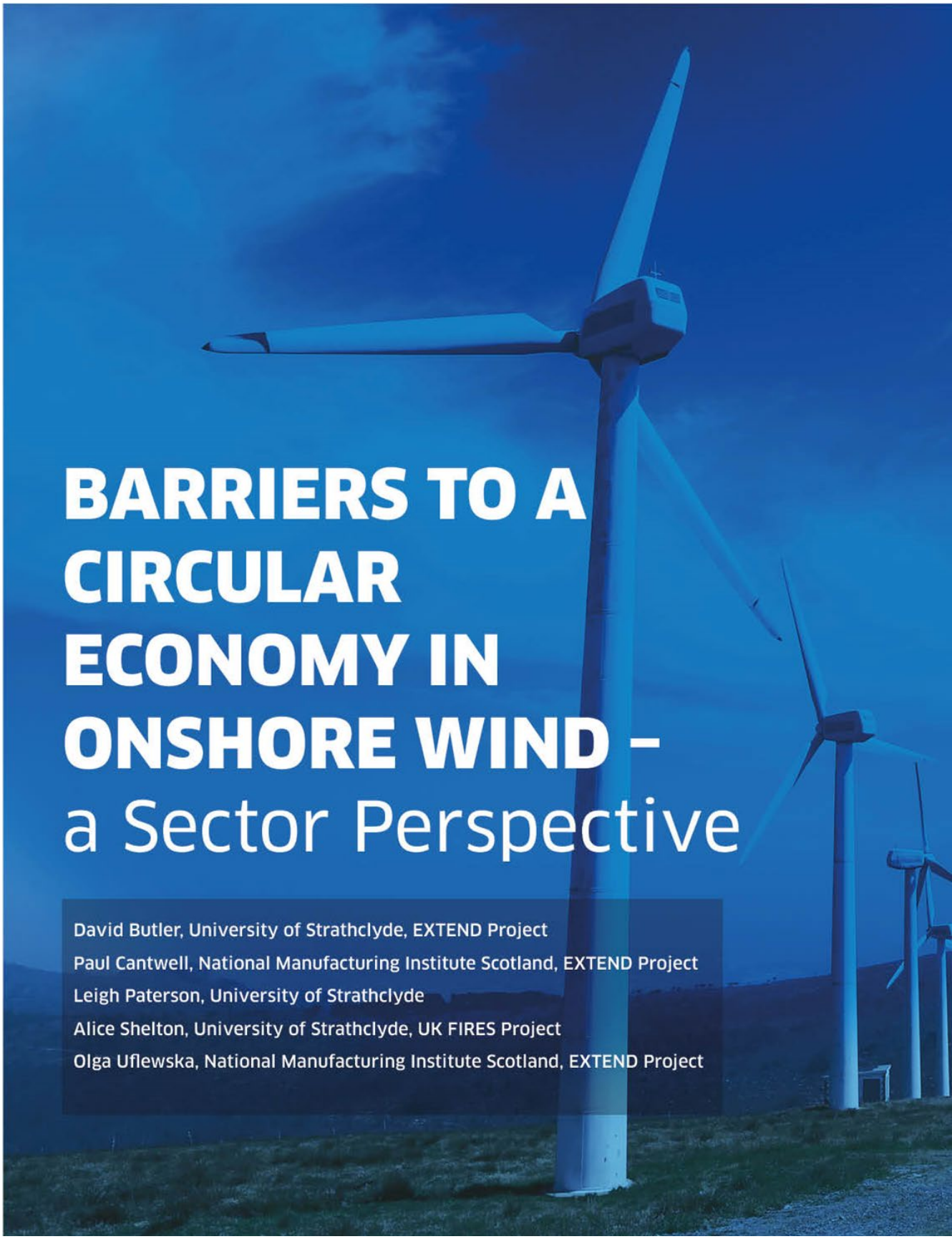

BARRIERS TO A CIRCULAR ECONOMY IN ONSHORE WIND – a Sector Perspective

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EXECUTIVE SUMMARY

Currently, onshore and offshore wind turbines in the UK have an operating life of between 20 and 25 years after which they are decommissioned and typically scrapped. Extending the life of wind turbines would make both economic and environmental sense as decommissioning is a costly and carbon-intensive activity. Activities are underway to extend such assets' lifetime to up to 40 years[1]. There is an opportunity to do the same in the UK. With between 600 and 1100 wind turbines coming to the end of their original operating lifetime by the end of this decade there is an immediate opportunity to act[2]. One route for lifetime extension involves, where possible, the recirculation of current turbine components through remanufacturing. This option offers several advantages including lower cost of ownership, shorter lead times, and reduced carbon footprint however, there are also a number of perceived barriers to a wider uptake by industry.

This report is aimed at understanding the barriers to greater adoption of recirculated parts by the onshore renewables sector. Through surveying 17 companies, a clearer picture of the challenges and opportunities has been achieved.

KEY FINDINGS:

- It is estimated that by 2050, wind turbine waste alone will contribute **43 million tonnes** without considering other components of the wind turbine or indeed its foundations.
- 50% of participants have a **specific procurement model** for attaining them, and only 40% have a specific policy in place that defines their use.
- 81% of participants stated they perceived **hesitation** to the use of recirculated parts within the industry.
- The use of recirculated components is described as a balance between minimising risk and cost. Finding the balance between **price, quality** and **procurement** speed are the key drivers when deciding whether to use recirculated components in place of new ones.
- **Life cycle cost modelling** has not yet been fully adopted but has the potential to reduce downtimes as well as schedule part replacements.
- Currently, the implementation of **sustainable practices** varies between companies and is partially **reflected in their organisational structure**.
- 77% of those asked stated that Net Zero (NZ) legislation had influenced their organization.
- There is **no standard method** used to measure or record the carbon footprint.
- Only two-thirds of participants measured their companies' carbon footprint.
- Over three-quarters of companies stated that their business models were the key driver to staying ahead of net-zero targets.
- Very few companies have an accurate system for recording their emissions across their supply chain and therefore making it hard to quantify their progress towards net zero.
- Owner/operators are very open to using recirculated components but do not have visibility of the opportunities and are reliant on SMEs taking the initiative to approach them with solutions.
- Traditionally, the Government has been reliant on industry to define the standards and targets. There is an opportunity for this to be reversed.

[1] DNV-ST-0262 Lifetime extension of wind turbines, Edition 2016-03 - Amended 2021-11
[2] The future of onshore wind decommissioning in Scotland, Zero Waste Scotland, April 2021

INTRODUCTION

To achieve a net-zero ambition, the renewable energy sector faces similar challenges to other industries. It is estimated that by 2050, wind turbine waste alone will contribute 43 million tonnes without considering other components of the wind turbine or indeed its foundations.

There is a clear need for the industry to consider how a wind turbine's value can be maximised through lifetime extension. The recirculation of parts offers an opportunity for the sector to move towards a circular economy model while also providing the advantages of reduced lead times, lower carbon footprint as opposed to virgin products, and lower cost of ownership among others. While the industry is aware of the availability of recirculated components, there appears to be some hesitation to their widespread adoption.

SURVEY BACKGROUND

Over a period of 6 months in 2021, 17 organisations within the onshore wind renewables sector were interviewed. The aim was to determine their usage of recirculated parts within assets as well as identify any major challenges. There was a variety of participants who contributed to this research, i.e., owners/operators, OEMs, finance/insurance providers, service providers, consultants/third-party management organisations and government bodies. The size of stakeholders interviewed ranged from SMEs to large corporations. Due to the size and interests of some organisations, multiple interviewees were approached resulting in a total of 25 respondents.

KEY FINDINGS

Current Attitudes to Recirculated Components

All participants in this study are aware of and use recirculated components within their wind turbines. It is most common for major components to be recirculated such as gearboxes, generators and main bearings. It was highlighted that there are economic and environmental advantages to using recirculated components. However, these benefits are less recognised when changing smaller components such as delta modules and electrical components. Therefore, recirculation and attainment of these smaller parts are less developed.

Despite all companies using recirculated parts, 50% have a specific procurement model for attaining them, and only 40% have a specific policy in place. In addition, no company has a specific role dedicated to current recirculated part pathways. This was acknowledged as an area where improvements need to be made.

ONLY 50% OF COMPANIES HAVE A SPECIFIC PROCUREMENT POLICY TOWARDS RECIRCULATED PARTS

Currently, components can go through recirculation techniques by original equipment manufacturers (OEMs), owners/operators or third-party companies. It is very rare to incorporate recirculated components in new wind turbines and this is unlikely to change.

Figure 1 – Participant responses to whether they perceive hesitation to the use of recirculated components in the industry.

81% of participants stated they perceived hesitation to the use of recirculated parts within the industry. Additionally, every participant outlined some reluctance to use, and challenges of using recirculated components. As well as this, the risk was also noted to be greater when regarding electrical components and those that have less established recirculation pathways, as shown in Figure 1.

81% OF PARTICIPANTS STATED THAT THEY PERCEIVED HESITATION TO THE USE OF RECIRCULATED PARTS

Overall, key reasons for resistance were based on emotional and behavioural responses, often experienced cross-sector or in day-to-day life. Turbine operability was identified as a barrier to the uptake of recirculated parts, due to increased perceived risk and failure rates.
In contrast to this, enabling the use of recirculated parts allows faster procurement of parts, on a more local scale. That would then have a positive impact on asset operability. Having a workforce that has experience working with early industry recirculation options, which typically had higher failure rates, increases the hesitation to incorporate circulated parts.

RESPONDENTS WERE CONCERNED ABOUT THE QUALITY OF RECIRCULATED PARTS

Additionally, there is some concern that third-party companies will not be capable of recirculating a component to an equal standard to that of an OEM (due to the intellectual property (IP) held by the OEMs). Also, third-party companies must understand the role each component has in a wind turbine and the conditions it will be exposed to.

In summary, the use of recirculated components is described as a balance between minimising risk and cost. Finding the balance between price, quality and procurement speed are the key drivers when deciding whether to use recirculated components or a new one. Some of the main benefits mentioned were cost savings (having both shorter lead times, which reduces asset downtime and cheaper individual component pricing), component upgrades, increased resource efficiency and opportunities for life-extension.

CURRENT OPERATIONAL PRACTICES

Across company operational practices, the cost is the primary concern. Remote condition monitoring through SCADA systems allows for planned maintenance, reduces asset downtime, prevents secondary damage to neighbouring components and reduces costs. Condition monitoring can also feed into inventory requirements and set thresholds for storage, which can be advantageous.

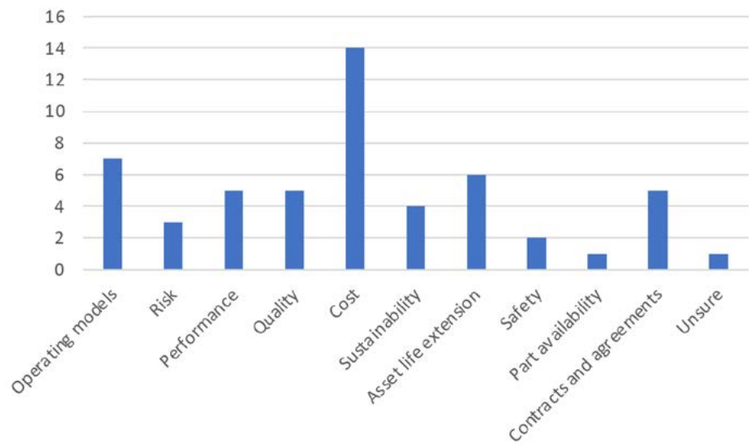


Figure 2 - Factors which influence the decision to repair a component

Cost is the most important driver when it comes to repairing processes among participants' organisations, as shown in Figure 2 above. Secondary to this was following existing operating models and asset life extension.

COST IS THE KEY DRIVER FOR PART REPAIR

At the End-of-Life (EoL) of components, the main pathways are to either harvest the part for reuse elsewhere or process it as scrap. Non-functioning components are sold or given to recirculation companies, which is determined by cost. For parts unable to enter a recirculation process, participants were unsure of what the spent good pathway entails, whether that be separation, scrap, recycling or landfill.

Cost modelling for an asset's full life cycle is not currently considered. This is likely due to operators commonly having a variety of makes and models of wind turbines of varying ages. Additionally, as well as component substitution can make component tracking and cost modelling difficult. However, onshore wind farms in remote locations can accrue significant costs through repeat part failures.

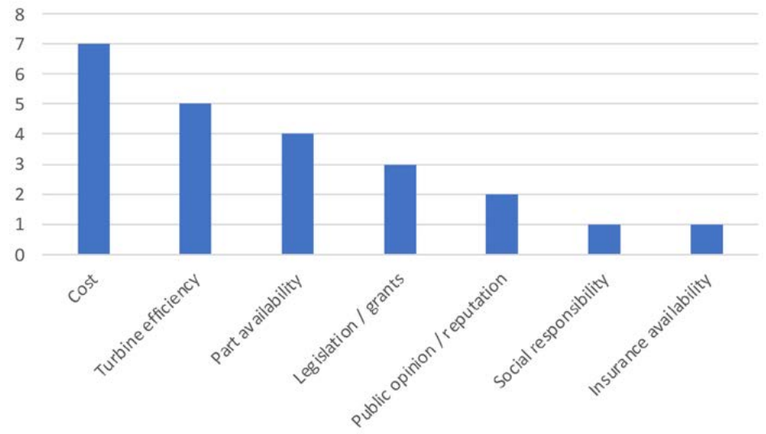


Figure 3 - Factors which influence the decision to consider a component at EoL

In summary, there are a number of key drivers which influence the decision to repair a component with cost being the most significant one. Practices such as condition monitoring can inform inventory requirements leading to cost reductions. Life cycle cost modelling has not yet been fully adopted but has the potential to reduce downtimes as well as schedule part replacements.

SUSTAINABILITY, LEGISLATION AND FUNDING

Wind energy is credited as a primary alternative to fossil-based energy. Companies should therefore be working towards making the renewable energy sector as sustainable as possible. In most companies, sustainability measures span multiple departments through internal working groups, rather than having a specific sustainability department with a Chief Sustainability Officer (CSO). However, some companies do have this position and department already established.

Nevertheless, companies are producing annual sustainability reports and setting targets to reduce their environmental impact, by increasing the use of recirculated components in their wind turbines.

While sustainability has been acknowledged of being of key importance it is evident that the scale of implementation of sustainable practices varies between companies and is partially reflected in their organisational structure.

NET ZERO

Only 77% of those asked stated that Net Zero (NZ) legislation had influenced their organisation. The remaining 23% considered the sector relatively environmentally friendly and therefore less influenced by NZ requirements.

ONLY TWO-THIRDS OF PARTICIPANTS MEASURE THEIR CARBON FOOTPRINT

Within those influenced, several changes were being made within their organisations:

- **Introducing sustainability goals and targets (science-based or aligned with SDGs), some ahead of the government dates.**
- **Altering business models – guiding business direction (i.e., closing down less sustainable areas of the business)**
- **Introducing governance groups and/or sustainability departments**
- **Financial investment and roadmaps**
- **Changing day-to-day practices (i.e., moving fleet to electric, eliminating printing needs, etc.)**

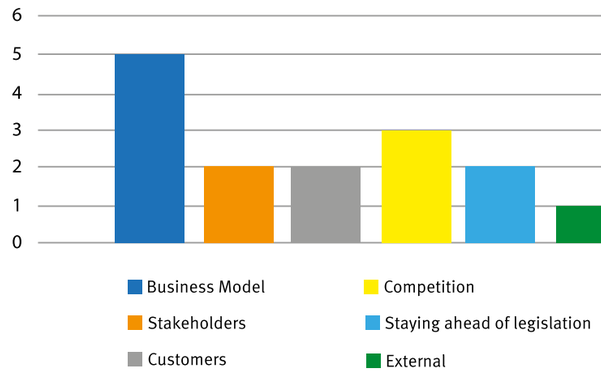


Figure 4 - Drivers for organisations to achieve emissions targets

77% OF RESPONDENTS STATED NET ZERO LEGISLATION HAD INFLUENCED THEIR ORGANISATION

Although Net Zero legislation seems like the obvious driver, the organisations were driven by their sustainable business model, with ambitions of staying ahead of legislation as well as competition.

With this in mind, it is surprising that the measuring of carbon footprint and emissions across participants is disjoined. There is no standard method used to measure or record the information, and only two-thirds of participants measured it at all, as shown in Figure 5.

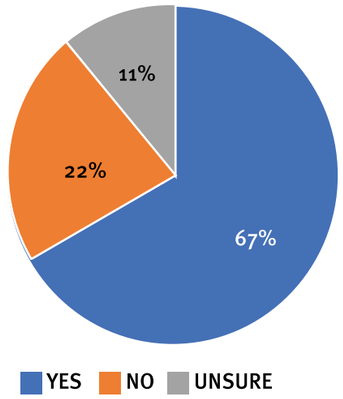


Figure 5 - Participant responses to whether they measured their carbon footprint or emissions

It was also highlighted that complexities within emissions were not fully understood within the industry, e.g., footprints across the supply chain or the asset life-cycle and its embedded carbon.

33% of the companies and participants asked stated their key driver as their own business model.". While companies are keen to stay ahead of net zero targets (such as the implementations of EVs and charging stations) very few companies have an accurate system for recording their emissions across their supply chain. Hence, it is difficult to quantify their progress towards net zero.

CURRENT WORKING RELATIONSHIPS

THERE IS GREATER AWARENESS OF THE VALUE THAT THIRD PARTY ORGANISATIONS PROVIDE

Some participants felt relationships across the supply chain could be complicated. This can lead to difficulty ensuring all suppliers are working within the boundaries of what the purchasers have requested (including from a sustainability perspective). However, all participants stated they currently work with large and small organisations, and all have relationships with SMEs providing recirculated parts. Most operators rely on them for this, and so, this aspect of the supply chain is beginning to be recognised as a value stream.

The majority of these relationships have been built by the SME approaching the larger organisation and proposing work. Although all owner/operator participants stated they wish to increase their use of recirculated parts, there is a lack of supply chain innovation. Therefore, it seems that SMEs will be driving this interaction in the near future.
Additionally, it was noted that supply chain agility had been heavily affected by Brexit and Covid-19.

However, this drove the desire for more localised content and subsequently yielded benefits, such as:

- **reducing environmental impact (through reduced supply chain length i.e., carbon emissions from logistics),**
- **economic advantages for local SMEs and their local economy,**
- **supporting community growth and expansion, and**
- **reducing costs both from the part and transportation.**

Nonetheless, participants mentioned some concerns and difficulties related to that practice. Firstly, there are multiple parameters when assessing a company's supply chain, e.g., finding a balance between cost, volume, quality control, and carbon footprint. It was also important that the quality of parts and security in supply were not overlooked when adopting more local content. Reliance on a small, local company was seen as a potential risk due to small batches and the potential of one-off quality components.

Secondly, many participants felt that OEM confidentiality could restrict third-party capability; OEMs do not make design, redesign or upgrade information readily available, which constrains third parties' recirculation practices. It was also highlighted that it could be difficult to determine who the O-OEM of a single component was, further restricting recirculation practices as there is no supply chain visibility to request information where needed.

Furthermore, there was some disparity between owner/operators and OEM participants, particularly surrounding the availability of OEM recirculated parts. All OEM participants stated they recirculate (to a degree) some components which are available for purchase. However, some owners/operators were not aware of this and had not been offered a recirculated part. It led those owners/operators to believe that OEMs only wanted to sell new parts.
At the same time, other owners/operators had received OEM recirculated parts when they had specifically ordered new ones. In response to that one OEM stated that a recirculated component through their facility was considered "as new," therefore could be used in place of a "new" part.

Service agreements, warranties and contractual arrangements all affected the working relationships of the companies involved and their subsequent use of recirculated parts. Previously, some agreements would restrict the use of recirculated parts. However, participants stated that as the industry was moving towards acceptance of recirculated parts, it will allow more avenues for third-party companies to enter the supply chain. Some companies will choose to stay with OEMs long-term, extending service agreements sometimes through the life of the asset. Other companies will try and move away from OEMs, using third-party service providers instead. This is due to cost drivers, where believed the cost of the service agreement with the OEM was excessive.

Furthermore, 53% of participants already collaborate with other SMEs and large organisations to achieve common sustainability targets. On the other hand, 47% of participants stated there were some concerns regarding collaborations through catapult, joint industrial partnerships or UK research programmes. It was due to the industry's infancy and level of competitiveness between companies, as well as KPIs not aligning in a workable manner.

53% OF PARTICIPANTS COLLABORATE WITH OTHER COMPANIES TO ACHIEVE COMMON TARGETS

Owner/operators are very open to using recirculated components but do not have visibility of the opportunities. They also rely on SMEs taking the initiative to approach them with solutions. There is some confusion in the industry regarding what recirculated parts are currently offered by OEMs. Many decisions around the adoption of recirculated parts are impacted by current service level agreements which can explicitly inhibit their use.

LIFE EXTENSION AND DECOMMISSIONING

Responsibilities for end-of-life decisions vary depending on who the final owner of the assets is. Currently, the overall goal is to gain as much financial value from the assets as possible, rather than being driven by environmental responsibility. End-of-life strategies include repowering, life extension, and decommissioning.

LIFE EXTENSION

Life extension offers the ability to maintain the embedded carbon in already manufactured goods for as long as it is financially viable. Using recirculated components is the only option available when an asset reaches the end of its original expected design life (e.g., as when the turbine model is no longer being manufactured by the OEM). Life extension is beneficial from a financial and sustainability perspective; the use of components for longer reduces the requirement for virgin materials and can still fulfil any health and safety requirements.

DENMARK AND GERMANY ARE ALREADY TARGETTING ASSET LIFESPANS OF 40 TO 50 YEARS

By extending the life of an asset, participants acknowledged that it delays the inevitable of having to decommission the asset. Also, in some cases, it allows it to be sold to a second market. Some participants argued that decommissioning and selling the turbines is not a viable long-term solution. Once the secondary market becomes saturated and it will be more difficult to sell a turbine. It is believed that more effort should be centred on the life extension of existing assets using recirculated parts, rather than developing this secondary market.

PARTICIPANTS AGREED THERE HAS NOT BEEN MUCH CONSIDERATION FOR DECOMMISSIONING IN THE UK

The insuring of assets beyond their original expected life is not yet mature within the wind industry. Having proof of asset longevity, maintenance records and plans, are all deemed to increase confidence in the insurance sector.

Denmark and Germany are leading the way for life extension in the wind energy sector with asset lifespan expected to reach 40-50 years through specialised asset maintenance programmes and statutory inspections. Scheduled activities involve identifying any areas of fatigue in tower weldings, tower structure, welding stair, and the base frame.

DECOMMISSIONING

Wind turbines that reached the end of their lives must be decommissioned. The assets may then be sold as entire products to a new owner, or stripped with parts sold, recirculated, recycled or disposed of.

The responsibility for the asset and its components lies with the last owner of it. It might be the owner/operator or a third party if sold at EoL. Participants agreed there has not been much consideration for decommissioning in the UK. However, given it will be required on a large scale in coming years, as assets come to the end of their lives, the industry will need to find suitable routes for the parts. Hence, there should be the responsibility from large developers, owners/operators, and OEMs to take the lead on the EoL management of these materials. The industry will be looked upon to take responsibility for the EoL waste from a reputational and commercial perspective.

In general, the asset is potentially costly to decommission. Because the focus is on the financial perspective, there is no collaborative effort to determine the most sustainable approach to decommissioning assets. One participant suggested there was potential for the construction companies to expand into decommissioning as there is some overlap between the industries (i.e., skillsets and processes).

Multiple participants stated that assets had been sold to new owners in developing nations for them to set up farms and demonstrate the existence of a secondary market. Another option is to sell parts for use in (newer) turbines, or to third parties who will repurpose the parts in other sectors, such as for bike shelters or aesthetics in bridge design.
Finally, where alternative methods have been exhausted, the components will enter suitable waste streams. There is a limited appetite for older assets and selling to developing nations only moves this responsibility onto another party with potentially less capability to process the EoL materials.

There are several routes at the expected end of life of wind turbines. There are a wide range of factors which can impact the chosen route including the model, age, economic justification, potential for repowering, availability of components, and location.

GOVERNMENT RESPONSE

The Scottish Government's Onshore Wind Policy Team (OWPT) was also included in this survey. A questionnaire was completed in June 2021 and their responses are discussed below.

The OWPT is dedicated to addressing the barriers to onshore wind deployment in Scotland, whilst also highlighting the benefits. Scottish Government, however, did not at the time define recirculation, refurbished, remanufactured, or repaired. It would seem that the Scottish Government relies on industrial sectors to set these definitions. By not having direct government encouragement towards improving the sustainability of the assets, their componentry and infrastructure, industry is set to do this only of their own accord. This also suggests a misunderstanding of the sustainability of the physical assets and could discourage progress by those who are trying to improve this (i.e., those in the refurbishment or remanufacturing businesses).

The OWPT stated they expect businesses to comply with carbon reporting and have a commitment to net zero, including international businesses operating here. Scottish Government and its agencies can provide action plans and tailored support to help companies achieve net-zero targets. They did not highlight if the reportable emissions were to be applied on a territorial or consumption basis but are not currently considering emissions associated with the life cycle of asset parts.

The OWPT believes that cost and subsidies are key drivers in asset management and repair decisions. This is supported by the replacement of ROCs[3] with CfDs, which are not designed to encourage repair. Cost and profitability remain key factors for end-of-life decisions. Ultimately the government are focused on onshore wind development and subsequent energy output to achieve net zero targets, rather than the lifecycle of the assets themselves. They believe developers will consider life cycles when designing sites, but do not enforce any rules around this area. In addition, they believe operators must ensure projects are compliant with regulations post-build as set by local authorities.

Both industry and government are aware of the cost of savings available through component recirculation. However, the Scottish Government is also aware that emissions through global purchases are counterproductive at the development stage.

[3] ROCs traditionally offered a commercial interest in repair and extended lifespan driven by profit potentials.

The OWPT stated they perceive a little hesitation around the use of recirculated parts within the industry. Nonetheless, the government itself has no such concerns and they wish to support the use of recirculated parts. They are also aware of emerging and evolving businesses that are offering these solutions within Scotland. In addition, the Scottish Government stated it is not within their decisions to mandate the consideration of embedded carbon in new turbine assets, but they would encourage OEMs to consider this in new designs. It is unclear how this encouragement would manifest given it would not be part of any policies.

Scottish Government have policies in place concerning circular economy, but they rely on OEMs and industry developers to make appropriate decisions in line with these policies. As policies are not mandated, this suggests the industry has the responsibility to make moves towards circularity.

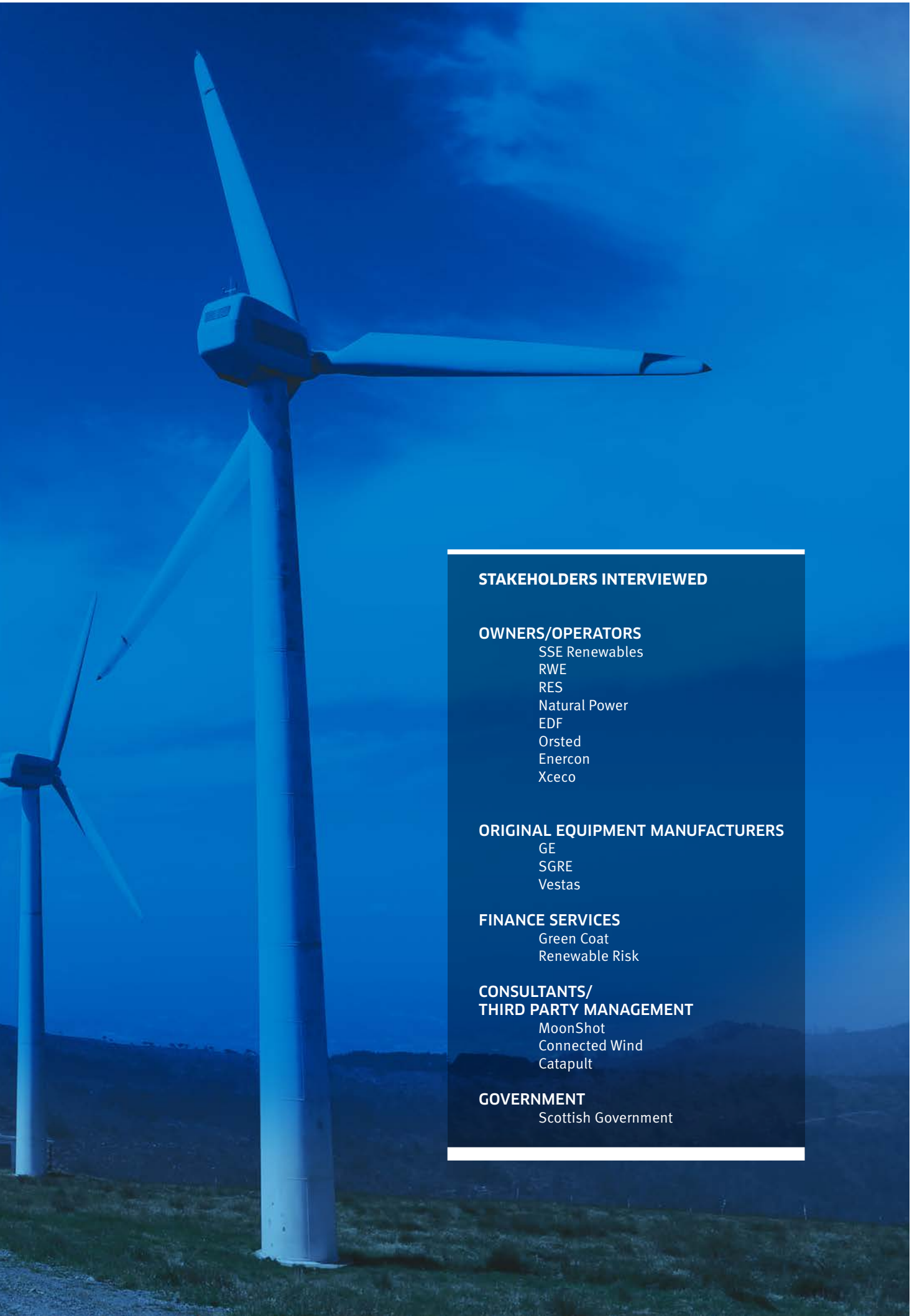
Traditionally, the Government has been relying on industry to define the standards and targets. There is an opportunity for this to be reversed with the Government taking a leadership role and aligning with Net Zero targets.

A ROUTE FORWARD

There is an appetite for the greater adoption of recirculated parts, and it can be achieved through the following actions:

- **increase confidence in the product,**
- **raise awareness of the benefits of recirculated parts,**
- **establish a dedicated supply chain, and**
- **develop up-to-date legislati**on.

Industry, academia, and Government need to be bought together to tackle the technological challenges, awareness, and skills gap, and establish a UK supply chain. There is potential for the development of an industry-wide consortium to tackle these challenges. Precedence already exists in the UK with the aerospace and automotive sectors already having established collaborative frameworks through the **Aerospace Technology Institute** (https://www.ati.org.uk/) and the **Advanced Propulsion Centre** (https://www.apcuk.co.uk/).
There is now an opportunity for the onshore renewables sector to do the same.



STAKEHOLDERS INTERVIEWED

OWNERS/OPERATORS
- SSE Renewables
- RWE
- RES
- Natural Power
- EDF
- Orsted
- Enercon
- Xceco

ORIGINAL EQUIPMENT MANUFACTURERS
- GE
- SGRE
- Vestas

FINANCE SERVICES
- Green Coat
- Renewable Risk

CONSULTANTS/ THIRD PARTY MANAGEMENT
- MoonShot
- Connected Wind
- Catapult

GOVERNMENT
- Scottish Government