SUSTAINABLE DECOMMISSIONING: WIND TURBINE BLADE RECYCLING

REPORT SUMMARY

CATAPULT Offshore Renewable Energy

Technology Driving Transition OGTC

With contributions from:

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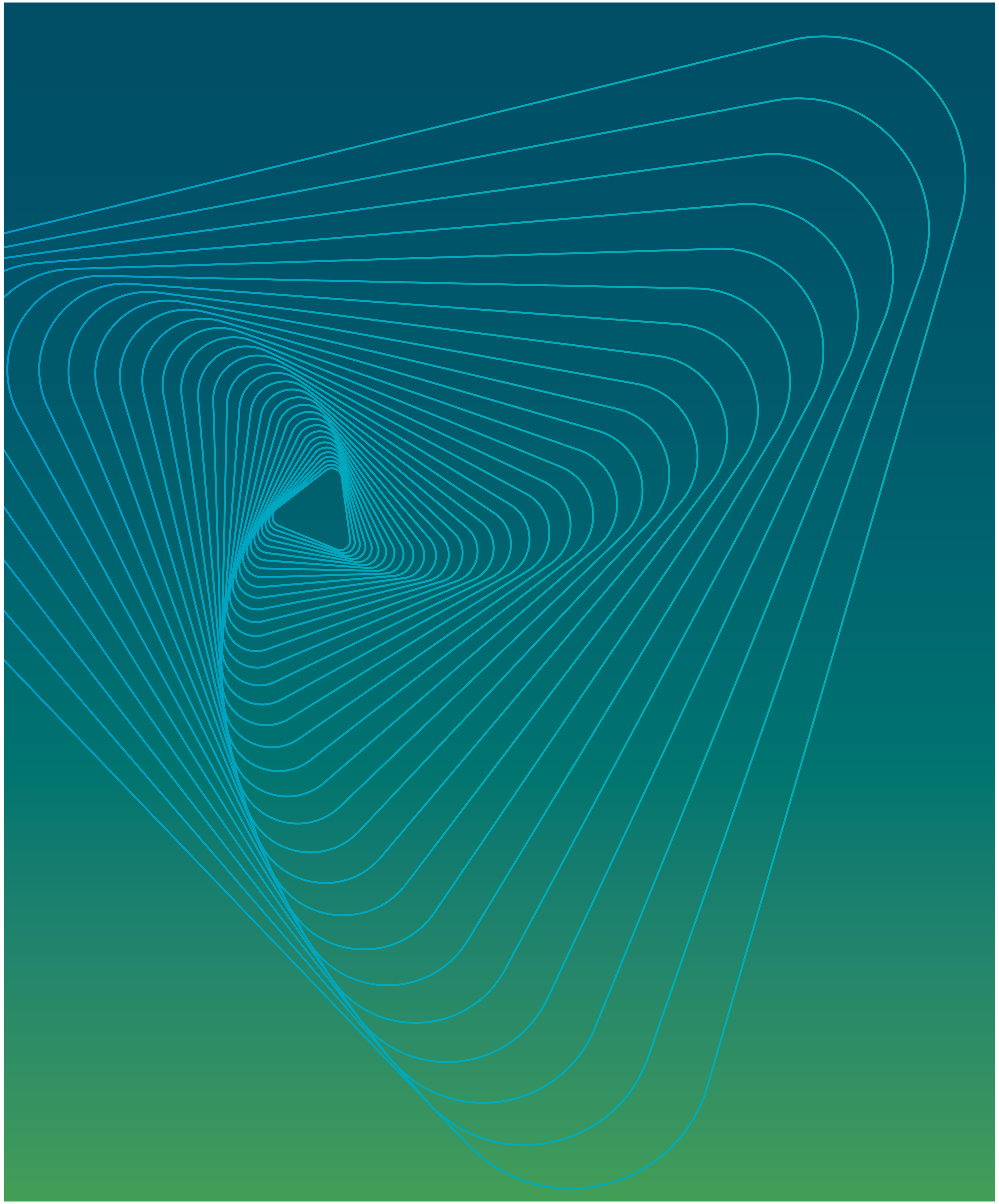


SEIZING THE UK ECONOMIC OPPORTUNITY FROM BLADE RECYCLING

Thirty years ago, it would have been hard to imagine that offshore wind could power every home in the UK. Today, that target is one of the key pillars of the UK Government's climate change policy. This vision has been driven by the passion of wind industry pioneers to forge this new sector and make renewable energy a commercial reality.

With this has come an unrelenting drive to develop high-performance, next-generation wind turbines that will achieve the necessary energy capture and cost efficiency. For the blades, composite layers of stiff carbon or glass fibres in a resin matrix were found to be the optimal material, delivering exceptional strength, stiffness-to-density and flexibility in processing.

As the wind industry has grown, it has become a major user of these materials, which have long been a solution to design challenges in the oil and gas, aerospace, automotive, defence and leisure industries. They are found in the pipe systems at oil and gas rigs, in car seats and interiors, aeroplane wings, bicycles, skis and surfboards, to name but a few applications. Across all industries, approximately 60% of waste fibre reinforced plastic is sent to landfill, while another significant portion of it is incinerated for energy recovery as heat.

Composite blades are now the final hurdle towards fully recyclable wind turbines (85-90% of a turbine can be recycled already[1]). At the end of their lives, they have proven difficult and costly to reclaim and reprocess. To fully satisfy the sector's future growth plans and sustainability goals, finding the right solution for recycling them is becoming imperative, especially as the first generation of wind farms are starting to reach the end of their 25-year lifecycles.

[1] WindEurope, "Accelerating Wind Turbine Blade Circularity," 2020.

Longer term, by 2050, the global wind industry will decommission up to 85GW of offshore wind farm capacity (cumulatively, and assuming a 25-year lifecycle); onshore wind will decommission another 1,200GW. The oil and gas sector will likely begin to decommission today's composite pipelines around the same time.

Composite material recycling therefore requires cross-sectoral solutions to meet an economic opportunity. That is why the **Energy Transition Alliance (ETA)**, a collaboration between the Offshore Renewable Energy (ORE) Catapult and OGTC, has launched a joint Wind Turbine Blade Recycling Project. In the report from its first phase, it has identified the innovation challenges that need to be resolved before blade recycling will become environmentally and financially beneficial.

This report provides a comparison and review of the very few recycling technologies that are established for composite plastics, and some emergent technologies. All remain beset with unknowns and unanswered questions relating to their environmental, energy and human health impacts for large-scale operations. Closing these gaps in knowledge through laboratory analysis of samples and scrutiny of processes is an essential next step.

ORE CATAPULT HAS SET THE TARGET FOR AN AT-SCALE DEMONSTRATION OF WIND TURBINE BLADE RECYCLING IN THE UK WITHIN FIVE YEARS.

The good news is that there is a growing body of cross-sectoral research into promising approaches to composites recycling. The wind industry is a major collaborator in many of the newest of these– **Carbo4Power, SusWIND** and the **Circular Economy in the Wind Sector Joint Industry Project - CEWS**. Under the latter project, ORE Catapult has set the target for an at-scale demonstration of wind turbine blade recycling in the UK ***within five years***.

The report sets out the huge opportunity for the UK supply chain in designing solutions to tackle the recycling challenge and capturing a global market that already encompasses 2.5 million tonnes of wind sector composites. Many of the recycling technologies discussed in the report require further study but show promise in terms of the quality of recovered materials.

Recycling is just the start. Moving turbines towards zero waste will be the next opportunity for the UK supply chain through remanufacturing, reuse, repowering and upgrading of components too. If realised, a spin-off circular economy from wind could extend the current projection for job creation in the sector by an additional 20,000 jobs by 2030[2].

The high-level conclusion of the report is that if we are to grasp this opportunity, we need to raise awareness of the circular economy business opportunity amongst UK supply chains and policymakers

The authors further conclude that:

- **The R&D focus to date has been on producing recyclates without matching these recovered materials to supply chain needs and end products. Phases 2 and 3 of the ETA Blade Recycling Project, and indeed of the CEWS JIP, will focus on creating this future supply chain for recyclates.**
- **Carbon fibre recycling at scale will pave the way for advances in glass fibre recycling but will require a steady stream of investment and consistent flow of turbine blades to reach this stage.**

As a final thought, it is important to keep in mind that finding sustainable recycling solutions for wind turbine blades is an immediate priority for the wind sector, but it is not the endpoint of the journey. Industry-led research is underway on more sustainable designs and materials, lifetime extension of blades and even some experimental concepts for bio and self-healing materials in the next generations of turbines.

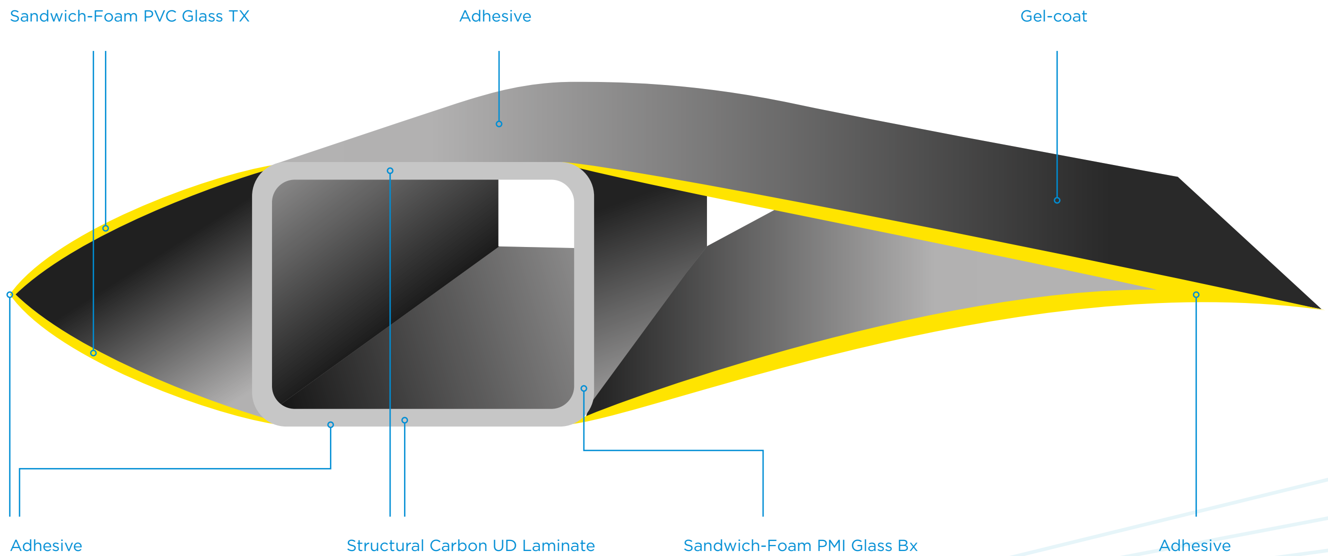
Ultimately, we should keep in mind that recycling blades will be ***an improvement on*** current disposal methods, but in the coming decades, we can do better still by using more sustainable materials and designing out waste from the start.

[2] Referencing the targets from the UK Government's Ten Point Plan for a Green Industrial Revolution of 60,000 jobs from offshore wind by 2030.

A SPIN-OFF CIRCULAR ECONOMY FROM WIND COULD EXTEND THE CURRENT PROJECTION FOR JOB CREATION IN THE SECTOR BY AN ADDITIONAL 20,000 JOBS BY 2030

ANATOMY AND LIFE-CYCLE OF A WIND TURBINE BLADE

Figure 1. Generic Composition of a Wind Turbine Blade (Source: ETIPWind: 'How Wind is Going Circular - Blade Recycling')



There are two main forms of plastic resins used in the manufacture of wind turbine blades: thermosets, which form an irreversible solid polymer, are the most common and challenging to recycle; and thermoplastics, which are simpler to remelt and recycle.

The blade's core contains a laminate material that is often made from high-density foam or balsa wood to provide additional strength. The exterior of the blade is coated for weather protection and improved aerodynamic performance. There are also some metal components associated with the lightning protection system.

From an environmental point of view, fibre reinforced composites offer benefits in the industrial use phase because they are light, strong and long-lasting. For example, they can reduce a vehicle's weight, cut fuel consumption, and reduce greenhouse gas emissions. Fibre-reinforced plastic is also vital for the ever-larger blades of wind turbines, as blades made from steel would be incredibly heavy, less efficient, and very expensive.

FROM AN ENVIRONMENTAL POINT OF VIEW, FIBRE REINFORCED COMPOSITES OFFER BENEFITS IN THE INDUSTRIAL USE PHASE BECAUSE THEY ARE LIGHT, STRONG AND LONG-LASTING.

Where fibre reinforced composites are recycled, the compromised quality of the recyclates means they are often only used for lower value applications – such as short fibre reinforcement or filler in new composite materials – limiting the economic case for using them. This is especially relevant for glass fibre reinforced plastics, as the low price of virgin glass fibres (£2-3/kg) does not incentivise the use of recycled glass fibres that may be higher price and lower quality. Addressing these issues to strengthen the business case is key to establishing a functioning supply chain for recycled glass fibre.

Landfill, which has been the most common solution for blade disposal to date, is out of the question as a future destination of these blades, primarily as it does not match the industry's own ambitions for circularity and sustainability. The report concludes that this momentum from the wind industry itself is proving to be the crucial driver towards recycling.

This momentum is evidenced by the many R&D projects with a blade recycling focus that have arisen within the past year in the UK. Aside from the Energy Transition Alliance project that has fuelled this study, notable new UK projects for scale and ambition are SusWIND, Carbo4Power, and the wind industry's Circular Economy in the Wind Sector JIP.

NOTABLE NEW UK PROJECTS FOR SCALE AND AMBITION ARE SUSWIND, CARBO4POWER, AND THE WIND INDUSTRY'S CIRCULAR ECONOMY IN THE WIND SECTOR JIP.

Cost, regulatory change and sheer logistics are bearing a more gradual pressure on this option too. Landfill used to be the most economical form of disposal for many municipal solid wastes, but fast-reducing available space and policy change are pushing prices upwards. The landfill tax in England is currently at £94.15 per tonne (2020-2021 rate), but, including the cost of gate fees and transportation, the total cost to landfill waste is typically £130 to £140 per tonne[3].

While landfilling wind turbine blades is not prohibited anywhere in the UK (as in some European countries), available landfill space is rapidly diminishing, and the landfill tax makes it economically unattractive. Scotland and Wales, along with several EU countries, have already begun severely limiting the landfill of wind turbine blades.

[3] *End of Life Options*, Composites UK, 2020.

LEGISLATIVE CHANGE

At the UK level, the policy direction is towards clean growth and a circular economy, as set out in the UK Government's Industrial Strategy. A further impetus comes from the European Commission's Circular Economy Package, which has been transposed into UK law following Brexit.

A brief overview of the strategy for the UK and devolved nations backs up these ambitions. *The Resources and Waste Strategy (RWS) for England* aims to double resource productivity and eliminate all avoidable waste by 2050. The Strategy forms part of the Government's commitment under the 25 Year Environment Plan to leave the environment in a better state than we inherited it, including eliminating all avoidable plastic waste.

Beyond Recycling, the Welsh Government's strategy, sets out its aim of making a circular, low carbon economy in Wales a reality with a set of actions to deliver the objective of zero waste by 2050. Meanwhile, the Scottish Government's circular economy strategy, *Making Things Last*, published in 2016, sets out a clear vision and priorities for action to move towards a more circular economy; and Scotland set a series of ambitious targets to drive circularity. In Northern Ireland, the Department of Agriculture, Environment & Rural Affairs (DAERA) is currently developing an Environmental Strategy.

At the UK legislative level, decommissioning of offshore wind farms falls primarily under the Energy Act 2004. In Scotland, wind farm decommissioning is a devolved matter with responsibilities transferred to the Scottish Government back in 2017, but Marine Scotland has expressed the inclination to stay close to the legislation laid out for England and Wales.

In terms of governance, the picture is complicated by responsibility for wind farm decommissioning being split between several Government departments: energy is handled by the Department for Business, Energy and Industrial Strategy (BEIS); infrastructure is part of the Treasury's activities, while resources and circular economy sit with the Department for the Environment, Food and Rural Affairs (DEFRA). That is set to change: several projects are underway to align these strands of governance more tightly, and the upcoming Environment Bill is expected to enshrine more ambitious targets into law, placing more demands upon the wind industry.

AGAINST THIS DYNAMIC EVOLUTION IN POLICY, MANY DECOMMISSIONING PROGRAMMES ARE NOT ATTUNED TO MINIMAL RESOURCES AND WASTE MANAGEMENT STANDARDS.

IT IS ESTIMATED THAT THE RESULTANT ONWARD SALE OF MATERIALS COULD RECOUP UP TO 20% OF DECOMMISSIONING COSTS FOR A WIND FARM, HELPING TO BRIDGE GAPS BETWEEN FORECAST AND ACTUAL COSTS.

Against this dynamic evolution in policy, many decommissioning programmes are not attuned to minimal resources and waste management standards. These programmes have historically been concerned with financial assurances to cover the costs of decommissioning, but with an interval of 25 years since these bonds were put in place for first-generation sites, many now fall well behind today's real costs.

There is a risk that many do not yet meet the first two obligations regarding the content of decommissioning programmes:

PROGRAMMES MUST SET OUT MEASURES TO BE TAKEN FOR DECOMMISSIONING THE RELEVANT OBJECT.

PLANS MUST CONTAIN AN ESTIMATE OF THE EXPENDITURE LIKELY TO BE INCURRED IN CARRYING OUT THOSE MEASURES.

Where the best environmental solutions are not available that would satisfy circular economy and sustainable development policies (i.e. to deliver absolute environmental improvements), then the industry can specify a knowledge gap. They can then co-produce plans, under their decommissioning programme, to support development of solutions for environmental sustainability at every lifecycle stage, including waste management. This brings additional benefits, such as reducing decommissioning costs and/or opening up new income streams for the sector.

Many programmes also need to evolve to meet the minimum resource security that will sustain offshore wind's ambitious growth pathway, given that wind turbines are increasing rapidly in number and size (turbine capacity has increased from 1.5MW in 2005 to 12MW in 2021).

The provision of a decommissioning programme is part of the consent process prior to development. In the first instance, while industry is responsible for preparing a decommissioning programme of sufficient quality, the Government can step in and prepare the programme on their behalf if necessary (under Section 107 of the Energy Act 2004). The Energy Act also applies to repowering, but more clarity is required to understand if decommissioning programmes must be amended in the case of repowering and whether this also applies to cases of lifetime extension.

In conclusion, achieving security of supply and establishing reliable and efficient recycling processes provides a financial opportunity: it is estimated that the resultant onward sale of materials could recoup up to 20% of decommissioning costs for a wind farm, helping to bridge gaps between forecast and actual costs[4].

[4] J. Chen, J. Wang, and A. Ni, *Recycling and reuse of composite materials for wind turbine blades: an overview*, J. Reinf. Plast. Compos., vol. 38, no. 12, pp. 567–577, 2019.

UK ECONOMIC OPPORTUNITY

This report summarises previous and current projects underway in the UK and globally to develop a blade recycling solution for wind turbines. A flotilla of new UK-based projects, initiated by the wind industry, has come online in the past year. Many more have been underway in countries such as Spain, Denmark and the Netherlands for some time.

IF WE CAN INVEST NOW IN THE BIRTH OF A CIRCULAR ECONOMY SECTOR, THE UK CAN EXTEND ITS WIND SECTOR JOB CREATION TARGETS BY AT LEAST A THIRD.

At present, there are few UK companies actively pursuing this opportunity. A notable pioneer is Scotland's Renewable Parts, a fast-growing enterprise focussed upon component refurbishing and reuse that is now expanding its operations into larger facilities to meet growing demand.

Overall there is low awareness amongst the UK supply chain of the economic opportunity that blade recycling, and the broader drive towards a circular economy in the wind sector brings. The University of Leeds, a contributor to the report, estimates that if we can invest now in the birth of a circular economy sector, the UK can extend its wind sector job creation targets by at least a third.

This assertion is supported by research from the Green Alliance and WRAP (2015) that focussed upon the UK waste sector. They estimated that without new initiatives, 31,000 jobs could potentially be created in that sector in the coming years (relying upon energy from waste and landfill). If we add job creation based upon recycling development, that increases to 205,000 new UK jobs. Even better, if we develop reuse and repair of products and components, we can increase this projection to 517,000 new and higher value UK jobs.

The report's authors conclude that the creation of a blade recycling segment of the wind economy could extend the UK's current job creation targets (60,000 direct and indirect jobs by 2030) by an additional 5,000 jobs. By adding more advanced circular economy approaches (reuse, remanufacturing, refurbishment, etc.) these targets could be increased by at least 20,000 jobs.

GLOBAL MARKET OPPORTUNITY

Today, 2.5 million tonnes of composite material are used in the wind energy sector globally, which is roughly equivalent 12 to 15 tonnes of glass fibre reinforced plastic per MW of power.

When it comes to other relevant composite material, carbon fibre reinforced plastic (CFRP) has seen a tripling in global demand over the past decade to around 160,000 tonnes, which represents the majority of the USD 75 billion global market for composites. Wind energy now represents the biggest sector with 24% of the global demand for this material, just surpassing the aerospace industry (23%), sports (13%) and automotive (10%) sectors.

In the UK, current landfilling rates are 35% for CFRP and 67% for GFRP, out of which only 20% of carbon and 13% of glass fibres are recycled; and 2% of carbon fibres and 6% of glass fibres are reprocessed. Recycling even 20% of these materials would be able to generate millions or even billions of pounds (dependent upon end product) for the supply chain.

The two largest sectors (wind and aerospace) have the opportunity to develop a new type of supply chain targeting reclaimed fibres from composites. Industries like sports goods currently have low retrieval rates of used goods because they are consumer goods and contain comparatively small quantities of composites. On the other hand, wind and aerospace are comprised of large quantities per product. Also, the assets are managed by a small number of companies (compared to individual consumers in sports). This allows for relatively easy predictions of the volume of composites that will be disposed of in future years, which will encourage the supply chain to develop new products that reuse blades or use recyclates of the blades.

RECYCLING EVEN 20% CARBON AND GLASS FIBRES RECOVERED FROM UK COMPOSITES WOULD GENERATE MILLIONS OR EVEN BILLIONS OF POUNDS (DEPENDENTUPON END PRODUCT) FOR THE SUPPLY CHAIN.

Globally, there was 651GW of wind capacity (onshore and offshore) in 2019 (including 29.1GW of offshore wind). It is anticipated that 40,000 to 60,000 tonnes of composite materials will be decommissioned by the wind industry by 2023 (approximately 14,000 blades).

Furthermore, by 2050, it is predicted that 85GW of global wind farm capacity will be decommissioned, adding up to 325,000 blades. It should be noted that this is a maximum estimate as it does not account for the possibility for life extension or repowering and assumes that wind farms will be decommissioned at the end of their operating life of 25 years. It also assumes that installation rates will remain as currently targeted and in plan.

INNOVATION CHALLENGES

Our technology review has shown that mechanical approaches to recycling wind turbine blades are more established than other techniques such as pyrolysis and solvolysis, alongside reprocessing composite materials into pellets, mats, chopped and milled fibres for use in construction. Thermal and chemical approaches are some way behind in their financial and environmental viability, often achieving high-quality results but at an unacceptably high environmental cost in terms of emissions, waste and/or energy use.

In particular, pyrolysis has long been tried as a composite recycling solution and has attracted most R&D investment over the years. The quality of material recovery for carbon fibre is the highest amongst the techniques available, achieving up to 90% mechanical property retention, meaning carbon fibres suffer far less degradation during the process. The high environmental footprint of this technique and the high cost of recovering the materials stubbornly remain.

Generally speaking, we are closer to a solution for recycling carbon fibre-based composites than those reinforced with glass fibres. Interest in developing technologies for recycling glass fibre materials remains muted as those tested to date have demonstrated a high cost that is not offset by a decent resale value. The low cost of new glass fibre (£1-2/kg) does not incentivise the high recycling cost, especially compared to the much higher cost equivalent for virgin carbon fibres (£15-40/kg)[6].

The higher market value of carbon fibres has conversely accelerated recycling innovation for carbon-reinforced materials. Once these solutions are optimised and mainstream, there will be more stimulus for early-stage development of glass fibre recycling and reclamation.

As we have seen, the efforts to develop these technologies is also set to receive a considerable boost by rising regulatory, logistical and socio-political pressures in the near future too, not to mention the wind industry's focus beginning to shift from cost reduction to sustainability as large-scale decommissioning looms.

You can read a full description and review of each technology in the full report, but the headline findings and the remaining innovation challenges that could be grasped by technology developers are summarised in Table 2.

ONCE CARBON FIBRE SOLUTIONS ARE MAINSTREAM, THERE WILL BE A STIMULUS FOR EARLY STAGE DEVELOPMENT OF GLASS FIBRE RECYCLING AND RECLAMATION.

[6] https://netcomposites.com/guide/reinforcements/

Table 2.
Innovation challenges for composite recycling technologies

GF = glass fibre
CF = carbon fibre
GFRP = glass fibre reinforced plastic
CFRP = carbon fibre reinforced plastic
% figures refer to material properties retained post recycling compared to virgin fibres

	PROCESS	TRL GFRP	TRL CFRP	COST	SCALE	END PRODUCT/ USES	INNOVATION CHALLENGES
Mechanical	Grinding	9	6	Low	Large	GFRP powder for filler or reprocessing	Microplastics and dust
	Cement kiln co-processing	9	N/A	Low	Large	Energy recovery and cement clinker	Potential pollutants and particulate matter
Thermal	Pyrolysis	5	9	High	Small	Low quality GF High quality CF (90%) Oils from resins	Energy Intensive
	Fluidised bed pyrolysis	4	5	High	Small	Good quality, clean CF (70-80%)	Energy Intensive
	Microwave assisted pyrolysis	N/A	4	High	Very Small	Good quality CF (75%)	Less energy intense
	Steam pyrolysis	N/A	4	High	Very Small	High quality CF (>90%)	Energy Intensive
Chemical	Solvolysis	5	6	High	Small	Good quality GF (70%) High quality CF (90%) Matrix material	Additional cleaning process required Energy Intensive
	High temperature and pressure solvolysis	4	4	High	Very Small	Good quality, clean CF	High energy intensive Corrosive, high pressure
	Low temperature and pressure solvolysis	4	4	High	Very Small	Good quality, clean CF Epoxy monomers	Less energy intensive Acids required that are difficult to dispose of
	Electrochemical	4	4	Very High	Very Small	Reasonable GF	High energy intensive Inefficient
Reprocessing	Milled fibre (post grinding)	9	6	Low	Large	Powder additive/filler for tailored electrical & thermal conductivity	Microplastics and dust
	Chopped fibre (post pyrolysis/ solvolysis)	9	6	Low	Medium	Thermoplastic compounding/SMC/ BMC, cement reinforcing, prepreg tape	Handling of dry fibres
	Pellets	6	9	Low	Medium	Injection moulding (thermoplastic)	Microplastics and dust
	Non-woven mat	9	9	Low	Medium	Press moulding, resin infusion, wet pressing, prepregs, semi-pregs and SMCs	Handling of dry fibres
	Component reuse	8	N/A	Medium	Very Small	Structural components: bridge support, bike shelter, roofing, etc	Low impact as no need for energy intensive methods to reclaim and process materials

SOLVING THE INNOVATION CHALLENGES

CONCLUSION 1.

Carbon fibre recycling at scale will pave the way for advances in glass fibre recycling.

Our view is that carbon fibre recycling at scale for wind turbine blades will be feasible within five years. ORE Catapult's Circular Economy in the Wind Sector Joint Industry Project JIP (CEWS JIP) is working towards this target.

There are two provisos:

1. **Investment in R&D must be increased to drive down costs and environmental impacts**
2. **The demonstration system receives a steady and consistent flow of blades.**

CONCLUSION 2.

The approach to R&D needs to shift to focus on the supply chain that will produce the end products rather than the production of recyclates with no clear destination.

The full report discusses the definition of 'recycling' and ambiguities in its use by UK regulatory bodies. Some count recycling as the recovery of a material, even if that material does not go on to be used in an end product. We recommend adopting the more precise definition that recycling must result in a usable end product for it to be both environmentally and economically meaningful. Only by recyclates replacing the deployment of new virgin materials, and by delaying disposal, can environmental impact be mitigated. Likewise, the chance to increase job creation (as highlighted earlier) depends upon achieving viable end products from recycling.

If ORE Catapult is to achieve its target of an at-scale blade recycling demonstration within five years, co-ordination is required with the many composite recycling projects that are underway across the world. As our review of the current R&D landscape makes clear, the focus to date has been on producing recyclates without matching these recovered materials to the supply chain needs and ultimate products. Phases 2 and 3 of the Energy Transition Alliance Project and the CEWS JIP will focus on stimulating the future supply chain for recyclates.

A further imperative is to raise awareness of the circular economy business opportunity amongst UK supply chains and policymakers. As highlighted earlier, the opportunity goes beyond the recycling of composites: it spans various remanufacturing and reprocessing solutions for every wind turbine component. Investment now presents a golden opportunity to not just support the sector's job creation targets by 2030, but also to extend them by an estimated further 20,000 jobs.

CONCLUSION 3.

Wind turbine blade recycling will only be achieved by leveraging the diversity of active R&D projects on composites across different sectors.

The study has highlighted 28 major collaborative R&D projects focusing on carbon and/or glass fibre composites and numerous in-house recycling drives by the most prominent players in industries such as aerospace and automotive. As a later adopter of composites, the wind sector is increasingly adding its considerable weight behind the development of composite recycling technologies: 2020 became a landmark year for the launch of projects specifically on wind turbine blade recycling.

We recommend that the focus is on cross-sector collaboration and finding synergies between the many disparate composite recycling projects summarised in the full report. Collaboration with the oil and gas industry, in particular, will be essential in bringing in the necessary scale of investment and prove crucial to finding good recycling solutions.

NEXT STEPS

From an economic perspective, we have a confluence of recycling technologies on the cusp of commercial viability and an urgent requirement by industry. Composite recycling can be seen as the first step towards creating an advanced circular economy that will serve UK industries and yield exportable IP, services, skills and technologies.

The wind industry can play a central role in the UK realising these economic benefits: it is the composite user that has the fastest future growth pathway thanks to its criticality for the energy transition. Our study shows that the wind industry cannot solve the composites challenge alone, however, and the collaborative cross-sector nature of many of the projects studied illustrate this point.

While that is the wind industry's ambition, the sector with the strongest track record on tackling composite recycling to date has been automotive. A great deal of the stimulus has come from EU directives that have legislated environmental assessments and impact analysis. A similar situation is developing for the wind sector. Several agencies are now working to investigate and develop similar guidance, best practice and industry standards for end-of-life wind turbine blades. We can anticipate these standards being brought into local, European, and potentially international regulations in the future.

It must be recognised that reclamation and reprocessing of recyclates from blade materials must also be a financially attractive option for the wind industry to ensure rapid adoption. That is why the next phase of the Energy Transition Alliance's Blade Recycling Project, of which this report is just the first phase, will focus upon the environmental, social, economic and technical costs and benefits of blade recycling. In Phase 3, we will take forward the most promising technologies for development and demonstration.

AN INTEGRATED ENERGY VISION FOR 2050

Technology
Driving
Transition