Wind Turbine Blade Repurposing: Opportunities, Social Benefits, and Challenges

By Ed Kirby

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THE CROWN ESTATE

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Contents

Executive Summary

As a result of an increasing global emphasis on renewable energy sources, the wind energy industry is growing rapidly. An inevitable by-product of this growth is an increasing volume of materials that could be wasted, which in the case of wind turbine generator blades made from composite materials, are exceptionally difficult to recycle. Alongside the waste disposal methods such as landfill and incineration, blade repurposing stands as a more circular solution. Repurposing involves taking a decommissioned blade as a whole, or cutting it to a certain shape and/or size, then using it for a different purpose, with current examples including playgrounds, pedestrian bridges, or urban furniture. There are several organisations that currently specialise in blade repurposing, but the repurposing industry on whole remains in its infancy.

This report compiles all existing blade repurposing companies and projects, discusses the potential social benefits that the solutions offer, and reviews the current challenges faced by the repurposing industry. Repurposing is seen as a circular and community-benefitting solution, and presents an opportunity for the wind industry to demonstrate a desire for complete sustainability, whilst also delivering tangible, positive social impacts. However, the current capacity of the industry does not appear to be mature enough to deal with the enormous volume of decommissioned blade wastage predicted over the coming years. Recommendations are made to Ørsted, the recipients of this report, to provide guidance should repurposing be further explored by the organisation in future

1. The Circular Economy

Humankind has never used as much material or created as much wastage, as now, and this only increasing. It has been projected that by 2060, the use of natural raw materials will rise to roughly 167 gigatons from the current 90 gigatons (Chen et al., 2020; Bamigboye et al., 2021). Accompanying this increase in material usage will be a proportional increase in wastage produced, if current practises remain the same. Improper waste management is not only unsustainable, it is also one of the most important environmental problems for current and future generations (Yalçıntaş et al., 2023).

“Circular Economy” (CE) is a concept that aims to steer us away from this unsustainable path of increased material consumption and wastage, and is the more sustainable alternative to the current linear “take-make-use-dispose” economy (Velenturf, 2021). Essentially, CE is a concept that aims to reduce/prevent wastage, by extending the lifetime of materials/products, or by giving them a new life in a different role. Although the term CE cannot be traced back to a single origin, it gained attention in the 1990s and continued to grow into the 2000s. Now, in the last decade, CE has seen a surge in popularity, and is applied in the UK, Denmark, Switzerland and Portugal, primarily for waste management – albeit to varying extents (Winans et al., 2017). A 2023 study (Kirchherr et al., 2023) analysed 221 recent definitions of CE, finding that over the past five years, the concept had been both consolidated and differentiated at the same time. Also, some definitional trends emerged that may have more significance for scholarship rather than in practise. In contrast to this seemingly muddled academic idea, organisations such as the Ellen MacArthur Foundation (EMF) who heavily advocate and promote CE, have concreted the term into three main principles: 1) Eliminate waste and pollution. 2) Circulate products and materials (at their highest value) and 3) Regenerate nature (Ellen MacArthur Foundation, 2024). By defining these principles, organisations such as the EMF have helped to transform CE from a somewhat abstract concept into tangible goals to strive towards. This report will use CE in the context of composite waste in the wind industry.

2. The offshore wind industry and wastage

The offshore wind (OW) industry is one of the fastest growing renewable energy industries globally (González et al., 2020; Liu et al., 2021; Pardo et al., 2023), however for the context of this report our lens will focus on the European offshore wind industry. In 2010, there was a total of 45 offshore wind farms (OWFs) in operation, with a total installed capacity of 2.95 gigawatts (GW), and by 2019 these had grown to 110 OWFs with a capacity of 22.07 GW (Soares-Ramos et al., 2020). In 2023, Europe had 34 GW of OW installed capacity, and throughout the decade these increases are expected to be dwarfed in the 2020s, with WindEurope predicting an installed capacity of over 83 GW by 2030, and the UK claiming to have up to 50 GW by this time (WindEurope, 2024; HM Government, 2023).

Although these increases in OW represent a shift towards cleaner, renewable energy sources, a prospective consequence of this increase is the potential for generation of large volumes of waste. The majority of the materials used in wind turbines can be recycled, between 85-90% (Ørsted, 2024), including the foundation, tower and nacelle, being made up of metals and concrete. An example of this is steel, a widely used metal in wind turbine towers and foundations, which can be 100% recycled without loss of quality (WindEurope, 2020). Recycling of these materials is therefore a viable option; however, turbine foundation removal is expensive, and there are arguments for leaving them in-situ as biodiversity aggregation sites, post turbine decommissioning. Floating OW is a rapidly developing sub-sector of the offshore wind industry that requires no foundation, and can be deployed in deeper waters, and is therefore currently drawing significant industry research and development (Farr et al., 2021).

Wind turbine blades, however, are mostly made from composite materials which can include glass and/or carbon fibres, thermosetting polymers, wood or foam, adhesives, coatings and metals. The nature of these composites allows for greater performance of wind energy by facilitating lighter, longer blades whilst maintaining aerodynamism, but ultimately, has also made blades notoriously difficult to recycle (Delaney et al., 2023). Because of this, the most common ways of dealing with composite waste material, including blades, are landfill and incineration (Qureshi, 2022). Alternatively to these, stockpiling of decommissioned blades is an option, in the hope that better EoL solutions are discovered, but this of course is not a long-term solution (Delaney et al., 2023). This lack of sustainable EoL solution for blades, combined with the OW sector's rapid growth, and the fact that many first-generation turbines may be decommissioned over the next 10 years, subject to decisions around lifetime extension (Velenturf, 2021), presents a significant problem to the industry. By 2025, it is predicted that the wind industry as a whole will produce 66,000 tons of composite waste annually, highlighting the global nature of this challenge (ETIPWind, 2019). Albers et al (2009) estimated that roughly 1 megawatt (MW) of installed capacity of wind energy equates to 10 tonnes of blade material, so based on this, and the Europe's prediction of 83 GW of offshore wind industry by 2030, there will be 830,000 tonnes of blade material in use.

Blade disposal has been identified as a key area in which the concept of CE can be applied to the offshore wind industry, and this report concerns potential solutions that both address this wastage and positively impact society in an observable way.

3. Repurposing

When a component or material comes to the end of its intended life, several options are available. The Waste Hierarchy is a way of conceptualising the most and least desirable ways of handling such wastage, on a purely environmental basis. The Waste Hierarchy was first put forward in the EU's 2008 waste legislation (European Parliament, 2008) and has since been used and referred to widely as a framework for preferentially dealing with waste.

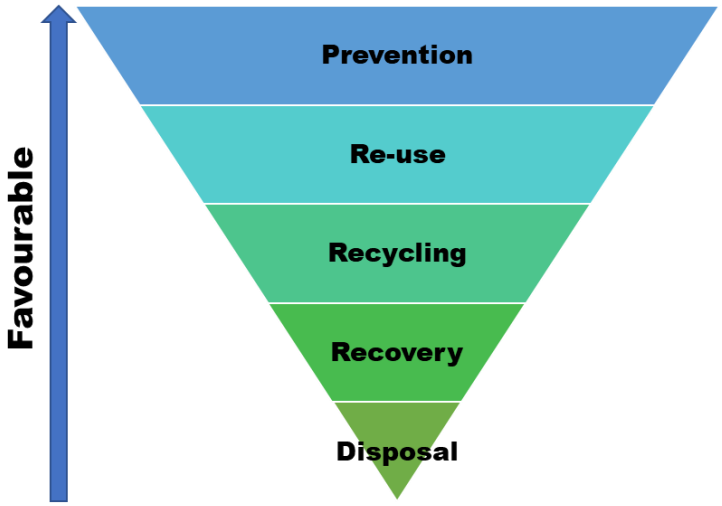

Figure 1: The Waste Hierarchy, first put forward in the Official Journal of the European Union (2008), adapted for easier interpretation. Prevention is the most favourable way of dealing with (potential) waste, and disposal is the least favourable. Repurpose falls into the wider category of re-use.

As mentioned in the previous chapter, wind turbine blades are notoriously difficult to recycle. However, looking at the Waste Hierarchy, we see that recycling is not even in the top two most desirable options of how to deal with waste. Of course, prevention of material becoming waste in the first place is the most desirable option, but below this, and above recycling, is reuse. Reuse can mean different things, with some components/materials being able to be re-used in their original, intended role after repair/maintenance. Recyclable blade material is an avenue currently being explored within the wind industry, albeit not at an industry wide scale. Siemens Gamesa appear to be at the forefront of this development, having already developed and installed "RecyclableBlade", and making a commitment to producing 100% recyclable turbines by 2040 (Siemens Gamesa, 2024).

Alternatively, **repurposing** is a solution which falls under the umbrella of reuse, and is the focus of this report. Repurposing is the reuse of products, components or materials for a different purpose from their original function, thus reducing waste and creating new value in a circular economy (Kurt et al., 2019). A simple way of understanding this is imagining a damaged wind turbine blade that has been decommissioned. If it is able to repaired and can be returned to its original role as a blade, this is true reuse, however if the blade is kept as it is but used in a different role, this is repurposing.

Figure 2: A repurposed wind turbine blade, now serving as a visual marker for a recycling centre in Maastricht, Netherlands. Credit: Blade-Made.

Currently, repurposing is not a widespread solution for end of life (EoL) blades. In order for this to be seriously considered as a legitimate option, the three pillars of sustainability must be consulted. These are: the environment, the economy, and society. Simply, a case must be made in support of blade repurposing using environmental, economic, and societal reasoning. A basic environmental argument for repurposing, specifically repurposing vs recycling, is as follows: When repurposing, a blade can be cut to a specific size or shape. However, if the entire blade is reused, none of its material goes to waste, making repurposing a more sustainable option than recycling, in which it is rare to recover 100% of the material. Thus, repurposing ranks higher on the waste hierarchy than recycling. Even so, this does not account for modern/future recycling techniques which may allow for a reduced amount of wastage, and also does not account for other potential environmental costs/benefits, such as transport to a location where repurposing is possible. Economic factors are similarly complex and it does not fall within the scope of this report to compare the economic costs with the social benefits of repurposing versus other EoL solutions. Furthermore, it is likely that wind industry businesses would need to share commercially sensitive figures for such a report, which would limit its potential for circulation. Therefore, one pillar of sustainability is left through which a case for repurposing can be made: society. Currently, offshore wind literature and the wind industry in general, lacks a cohesive report that brings together all examples of blade repurposing projects, and, importantly, discusses the social benefits of such projects, a gap that this report aims to fill.

Aims and objectives:

- Provide an overview of relevant blade repurposing organisations.
- Showcase all existing repurposing projects and concepts
- Discuss potential direct and indirect social benefits provided by such projects.
- Discuss potential challenges that may prevent the widescale adoption of blade repurposing solutions.
- Make tangible recommendations for the industry for further exploring the viability of blade repurposing solutions.

4. Existing repurposing companies and projects

Due to the durable and lightweight nature of the composite materials that make up offshore wind turbine blades, decommissioned blades can be repurposed into a variety of structures at the end of their originally intended lives. In this section, I discuss existing blade repurposing companies, examples, and projects.

4.1. BladeBridge, Ireland

BladeBridge is a blade-repurposing start-up company based in Cork, Ireland. As their name suggests, the flagship project they have produced with repurposed blades, is a bridge. This is a 5.5m long pedestrian bridge for walkers and cyclists, however in case of emergencies, it is able to support a vehicle of up to 10 tons. Two 14 metre length blades comprise the main structural elements of the bridge, in replacement of steel girders. The bridge is located in Cork County, between the towns of Midleton and Mogeely, on the new Midleton-Youghal Greenway. Ireland's Greenways are off-road paths aimed at foot pedestrians and cyclists, and are often routes of outstanding natural beauty and scenery. As such, this blade bridge offers a unique opportunity to connect people, nature, and the concept of renewable and sustainable energy sources (BladeBridge, 2024).

Figures 3 & 4: BladeBridge's pedestrian bridge on the Midleton-Youghal Greenway, Cork, Ireland

As well as the bridge, BladeBridge have explored other repurposing solutions for blades, including a seating bench with integrated bicycle parking slots, a picnic table, and a seat with a standing table combination. They are also collaborating with a local furniture design company and, and a local development company to create furniture made from blade material for use in a local community centre.

Figure 5, left, a bench with integrated bike parking and **Figure 6, right,** a picnic bench. Both examples from BladeBridge.

Future projects for BladeBridge are set to include blade towers (energy transmission poles), e-bike charging stations, and an e-mobility hub. This last project has come as a result of partnership with ESB, a leading Irish energy company, who are aiming to achieve Net Zero by 2040.

Figure 7: BladeBridge e-mobility hub demonstration in collaboration with ESB.

BladeBridge is a spin-off from the Re-Wind Network, an international research group focussed on repurposing solutions for decommissioned blades. The Re-Wind Network is comprised of staff, students, and faculty from: Georgia Institute of Technology, University College Cork, Queen's University Belfast, City University of New York and Munster Technological University – along with wind

industry affiliates. As well as pedestrian bridges, the Re-Wind Network has explored uses for EoL composite blades in other infrastructure such as housing, public art, landscaping, and general building application (Re-Wind Network, 2024).

4.2. ReBlade, England

ReBlade are one of the UK's first specialists in wind turbine decommissioning, and of being the UK's first company to decommission wind turbine blades without the use of landfill. As well as offering expert decommissioning services, ReBlade advertises customised solutions for decommissioned blades, with the opportunity to include high profile PR driven activity. Offering the ability to design and manufacture infrastructure suitable for both recreational and community-based purposes and functional boardroom furniture, ReBlade are confident that their projects can showcase both artistic design and sustainability, and express a desire to take as many blades as the wind industry can provide (ReBlade, 2024).

Figures 8 & 9: Examples of ReBlade's use of decommissioned blades as benches, and a table.

As well as repurposing blades into functional furniture such as outdoor benches, ReBlade have partnered with SSE Energy Solutions to produce canopies for an electric vehicle charging hub at Kingsway West, Dundee. This project was approved in 2023 and is awaiting completion.

Figure 10: EV charging hub in Kingsway West, Dundee, with canopies made from decommissioned blades by ReBlade.

4.3. Blade-Made, Netherlands

(BladeMade, 2024)

Globally, Blade-Made are one of the largest blade repurposing companies currently in operation. It was founded in 2021 by employees of Superuse – an award-winning circular architecture company. As well as Superuse, Blade-Made was formed by collaboration from New Citizen Design and Newton Brown Urban Design. Blade-Made see their repurposing solutions as a chance to use EOL blades in large scale design, with the organisation able to service global markets on a local level.

One of the things that Blade-Made advocate for on their website is a Circular Value Chain (CVC) (Circulair KetenProject). This involves connecting wind industry partners, and connecting these partners with relevant organisations outside of the wind industry. Blade-Made offer all project partners, such as storage facilities, contractors, and designers the chance to join their network and the CVC. Through this approach, Blade-Made are able to connect to a variety of stakeholders, from local communities and governments, to larger semi-public entities. Blade-Made have established a diverse CVC within the Netherlands, including: Business in Wind as decommissioner (removal and transport of blade), Dura Vermeer Urban Miner as storage facility, GKB Groep as contractor, Superuse as designer, The Footprinters as carbon footprint calculator and New Citizen Design as stakeholder engagement facilitator.

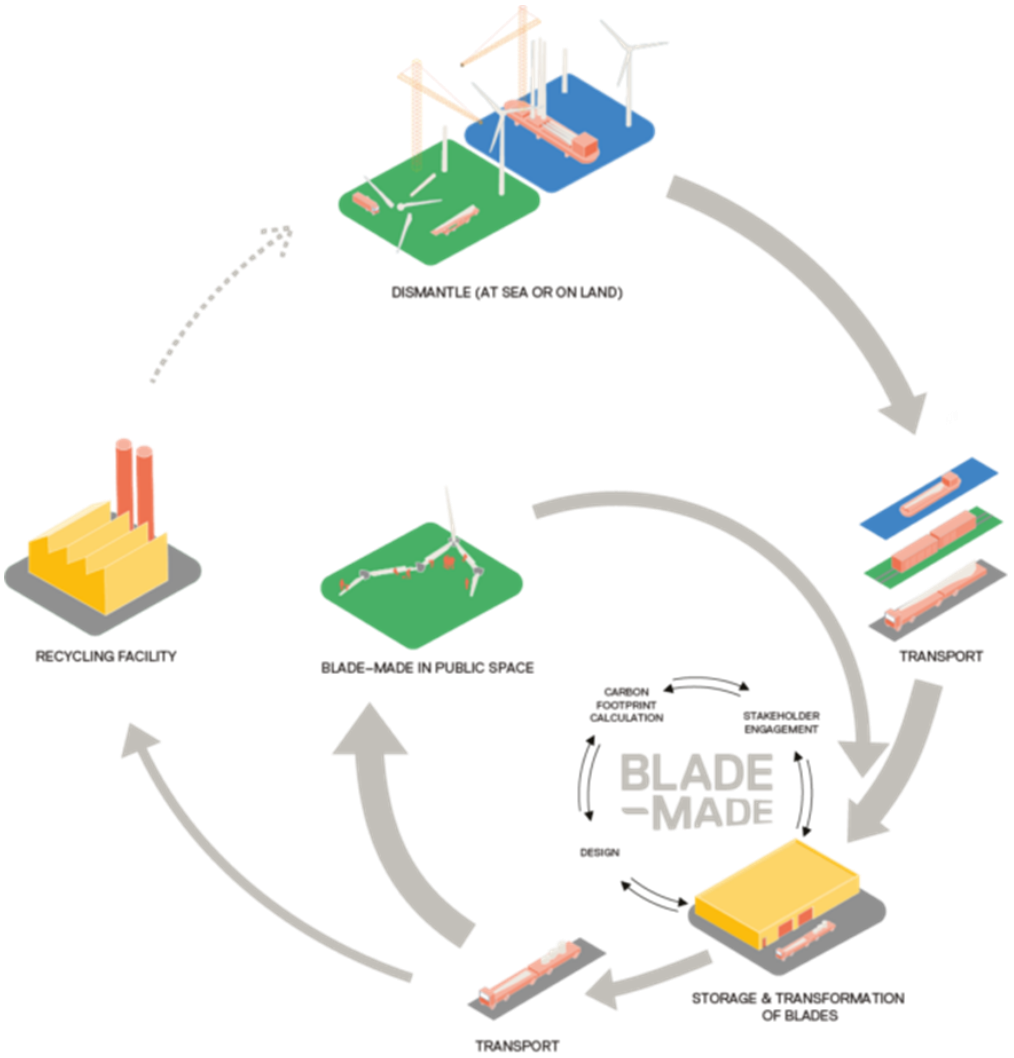

Figure 11: Blade-Made's Circular Value supply Chain for wind turbine blades

Blade-Made have a portfolio of 10+ unique repurposing projects ranging from playgrounds to bus stops. Below is a list showcasing the variety of their projects, however not all duplicate products are shown (there is more than one example of urban furniture) in the interest of report size.

Figures 12, left, playground "Wikado", Rotterdam and **Figure 13, right**, playground Terneuzen, Netherlands. Bot playgrounds are comprised primarily of decommissioned blades.

Figure 14 & 15: Pier seating in Terneuzen. This seating was installed following positive feedback from the local community regarding the playground shown in **Figure 13**.

Figures 16 & 17: Public seating in the centre of Willemsplein, Rotterdam. The blades were initially painted red, but a competition was held among artists to create a new design. The winner repainted the blades in LGBT+ colours, showcasing local collaboration and social inclusivity.

Figures 18 & 19, bus stop with integrated bike parking in Almere, Netherlands.

As well as the operational projects shown above, Blade-Made have a variety of concept repurposing projects that they express a desire to realise. These concepts include basketball court, community garden, lookout tower, promenade, urban lighting, reception desk, EV charger, bridge, bike shelter, sound barriers, and urban lighting.

Figure 20: Concept art of decommissioned blades repurposed as urban lighting.

4.4. Other

Wings for Living are a blade repurposing company based in Dresden, Germany. From their website, Wings for Living repurposing projects seem to be more focussed on private customers, leaning towards the luxury outdoor furniture market. Having said this, they do have some examples that could be implemented in a community space. (Wings for Living, 2024).

Figures 21 & 22, two examples of the outdoor furniture that Wings for Living produces. **Figure 21 (right)** shows public area seating, equipped with USB charging points. **Figure 22** shows a lounger, likely to be intended for private use.

Figures 23 & 24, planting beds made by Wings for Living.

Bike shelter, Siemens Gamesa

Figure 25. This repurposed-blade bike shelter was installed by the wind turbine manufacturer Siemens Gamesa in collaboration with the Re-Wind Network. It is located in the port of Aalborg, Denmark.

Skate structure, Red Bull

Figure 26. Red Bull professional skaters were invited by Windar Renovables to use deconstructed wind turbine blades for skateboarding.

Blade, Hull

Figure 27. In 2017, as part of Hull's city of culture showcase, a 75m Siemens Gamesa turbine blade was placed in the city centre of Hull. It is thought that "Blade" was seen by more than a million people.

5. Social benefits

5.1. Community development

Community development is arguably the most tangible area in which repurposing projects can play a significant role. Repurposed blades are able to take on new lives as structures that are both useful and durable, and that have the potential to positively impact local communities. For example the pedestrian bridge and picnic benches made by **BladeBridge** promote community use and interaction, with the bridge playing a significant role in a Greenway, one of Ireland's historic long-distance paths. BladeBridge's design and creation of local furniture for community centres is another example of this, showing how repurposing projects can enhance community spaces.

The benches and electric vehicle charging hub canopies created by **ReBlade** show the potential for community development, helping improve public infrastructure and providing tangible benefits to local communities. **Blade-Made** probably displays the greatest range of how blade repurposing can contribute to community development, showcasing projects including playgrounds, bus stops, and urban furniture. These projects directly and significantly improve community spaces. Whilst projects such as bus stops and urban furniture promote practical community use, the playgrounds are shared community spaces that represent the breadth of options available for EOL blades.

The bike shelter created by **Siemens Gamesa** is another example of a community asset that could be implemented on a wide scale, in a way that both provides important local infrastructure and promotes sustainable transport. Although the use of blade components for professional skating by **Red Bull** does not involve direct repurposing of blades, it does illustrate another potential avenue for repurposing, skate parks. This is a suggestion that has come up in the literature (Nagle et al., 2022), but so far has not been implemented. Similarly to playgrounds, the repurposing of EOL blades to create skate parks would certainly contribute to community development, and would be an exciting and innovative way to expand the range of uses for these blades.

5.2. Economic benefits

Inevitably, the creation and implementation of repurposing products and projects is a venture that will help provide opportunities for employment. If repurposed, decommissioned blades - especially those of large offshore wind turbine blades that often exceed 75m in length - would need to be cut to an appropriate size, transported to repurposing facilities and then repurposed into the desired repurposed products. The Circular Value Chain model put forward by **Blade-Made** is a clear illustration of this, creating jobs and opportunities for contractors, designers, and local government involvement (Blade-Made, 2024). In areas of lower economic opportunity, this could provide an important and valuable chance for economic growth. **BladeBridge** demonstrate the economic benefits provided by repurposing projects and supply chains through collaboration with local businesses, such as furniture designers, fostering economic growth and job creation.

In addition to opportunities for job creation, repurposing blades into novel and engaging infrastructure and artwork could help enhance local tourism and thus contributions to the local economy. It is thought that **Blade, Hull**, was seen by more than a million people (HullLive, 2023), a clear example of the attention and tourism that repurposing projects can attract. Although many of the people who saw Blade are likely to have been regular visitors to the city centre, some may have travelled to Hull specially, and contributed to the local economy whilst doing so, potentially paying for food and accommodation. Unfortunately, this is purely speculation, as no social data was gathered.

This demonstrates the importance of social data, as this would provide quantitative evidence for the local economic benefits provided by flagship projects such as Blade.

A message of custom design and PR-driven repurposing is emphasised by **ReBlade**, which is likely to stimulate economic benefits through creative industry input and tourism potential, in a similar way to **Blade**. The production of outdoor furniture pieces by **Wings for Living** and **Blade-Made** supports local economies, and provides work in both production and logistics, whilst the collaboration between the **Re-Wind Network** and **Siemens Gamesa** shows the opportunity to support local businesses by involving those with manufacturing expertise.

5.3. Environmental and educational impact

The use of EOL blades in community-based projects is not only a way of promoting the wind industry, but also the concept of sustainability in general. The circular economy is a concept which revolves around extending the lifetime of products/materials, or giving them a new life with a different purpose, principles that can be publicly showcase via repurposing projects. Implementation of repurposed wind turbine blades not only draws awareness to the wind industry, via the blades, but also to the concept of circularity via the repurposing aspect. The Greenway integration executed by **BladeBridge** demonstrates the sustainability of repurposing blades as low-carbon alternatives to steel girders. The fact that **ReBlade** were the UK's first company to decommission wind turbines without the use of landfill shows an increasing awareness and desire for circularity, also that this does not have to conflict with successful business models. Without naming all the other repurposing companies listed here, it is clear that turning waste into useful structures directly aligns with sustainability and circularity. One way in which the environmental aspect of repurposing can be amplified is through the creation of nature-based products, such as the plant pots produced by **Wings for Living** and **Blade-Made.** Although these may smaller products, and less scalable due to the size of offshore wind turbines, it demonstrates the use of EOL blade material in a sustainableway. On a small scale, these plant pots are likely to encourage local gardening and enhance environmental awareness.

5.4. Cultural impact

The potential artistic and creative aspects of blade repurposing projects cannot be overlooked. Opportunities for local collaboration are innumerable, demonstrated by the bench painted with LGBT+ colours produced by **Blade-Made**. In this way, cultural identity and inclusivity can be shown in public spaces, strengthening local identity and increasing people's affinities with their local area. The **Red Bull** skate structure merges sport and street culture with sustainability, an effective way of promoting sustainability and circularity in areas that may be harder to reach with conventional techniques. The public seating and furniture created by several of the listed companies is a way of combining aesthetics with sustainability, showing that sustainability does not have to be dull and purely industry based, but can be showcased within artistic and creative design. As well as the aesthetic features of repurposing projects, functionality can still be incorporated.

The pedestrian bridge of **BladeBridge** connects people and the environment metaphorically, through its environmentally friendly origin, but also physically, through its integration on one of Ireland's Greenways. This helps to symbolise the value of wind energy, and renewable energy in general, and helps to build long-lasting relations between communities and these industries. Repurposing projects do not always require a functional purpose, as seen in **Blade, Hull**, which served as a cultural landmark in the city centre of Hull. The social impact of a million people seeing this is unquantifiable, but at the very least it can be said that it would have raised the topic of wind power into thoughts and conversations, thus directly or indirectly bringing the concepts of sustainability and circularity into people's awareness's. Incorporating repurposed blades into communities helps to promote these

concepts on a societal level, which must be achieved for a truly sustainable future. In other words, sustainability and circularity must become culturally ingrained, and placing highly visible structures in the heart of communities that both promote these concepts and benefit the communities seem to be a positive way of doing this.

5.5. Health and lifestyle benefits

The simplest way to understand how repurposing projects can provide health and lifestyle benefits, is to observe that the majority of the projects listed here are outdoor structures. These structures encourage outdoor activity and engagement, and in some examples, such as the **Siemens Gamesa** bike shelter, actively facilitate a healthy and sustainable transport option. In a similar way, the pedestrian bridge by **BladeBridge** in Ireland is situated in a Greenway, which are long distance walking and cycling routes. The improvement of the Greenway with repurposed blades encourages outdoor activity and engagement with nature, whilst promoting sustainable building practises. The picnic tables and outdoor benches created by **ReBlade** encourage spending time in parks and nature, whilst the urban furniture of **Blade-Made** promote engagement with outdoor community spaces. The playgrounds of Blade-Made show how repurposing projects can create a shared community space but also can be used to promote physical activity of children, providing benefits in health and lifestyle.

5.6. List of potential benefits of blade repurposing projects

A high-level summary list of potential benefits associated with blade repurposing projects can be seen below.

- Creation of shared community space/resource
- Creation of jobs
- Skills development
- Promotion of the wind industry
- Promotion of sustainability
- Connect people within community
- Increased affinity with local area
- Improved affinity and perception of neighbouring windfarms
- Increased job flow into the wind industry
- Incentive to get outside/be physically active
- Incentive to engage with nature/the coast
- Educational opportunities
- Tourism
- School projects
- Local artist projects
- Strengthen local identity
- Local collaboration and innovation

6: Challenges to repurposing, and potential solutions

The challenges that blade repurposing presents must be acknowledged. This section presents the a critical analysis of the most significant challenges associated with blade repurposing solutions.

A barrier to the widescale implementation of repurposing is the enormous size of modern blades, especially those found in OWFs. Modern OWF blades can now be over 120m in length, and weigh up to 32 tons (Ju et al., 2020; Hu et al., 2021). This presents complications for transportation, storage, and adaptation for secondary uses (Arabian & Shu, 2021). One solution to this could be **modular blade design**, as suggested by Dutton (2012). This would mean a shift from blades being comprised of one large piece of composite material, to being made from multiple smaller pieces together. Modular blade design would not only facilitate easier and cheaper transportation, but also construction and maintenance, as this would allow blades to be manufactured, transported, and repaired in small sections, reducing the need for specialised machinery (Asthana et al., 2017). It is also likely that deconstruction, and preparation for use of materials in a second life would become much simpler. Modular deconstruction However, it is emphasised that structural integrity, blade performance, and cost must not be compromised, factors that must be considered when approaching different designs. Importantly, this would be a monumental change to the current approach of the wind industry, and is certain to pose significant logistical challenges.

As well as blade size, the volume of EoL blades also presents a significant problem. By 2050, it is estimated that there will be roughly 43 million tonnes of blade waste worldwide, assuming no interim disposal or stockpiling (Liu & Barlow, 2017). Currently, the size of the blade repurposing industry, listed in its entirety here, would be simply unable to handle this amount of waste, with many of the examples presented here are bespoke projects. It is important to emphasise that in order for repurposing to be a solution for all of this waste, or even a significant portion of it, the repurposing industry must grow significantly. This is highly likely to require support and input from wind industry developers, at the very least for relationships between the two industries to grow. Repurposing therefore requires an in-depth economic and environmental review from wind industry developers.

Repurposing projects have been known to face economic challenges, as transforming blades into new applications requires substantial investment in design, material testing, and construction (Ruane et al., 2023). As repurposing is currently a relatively undeveloped field, designs are not fully proven, and there are limited numbers of manufacturers that can take them on. However, as the repurposing companies discussed here grow, more cost-effective methods may be established.

Although blade repurposing addresses the issue of decommissioned blades, it only pushes back the problem of dealing with composite waste. Eventually, these repurposed blades will reach the end of their second lives, and the problem of what to do with the composite waste material re-emerges. One solution that addresses this is the use of composite waste material as reinforcement of cement and new composite products. It has been shown that composite material can be ground down and used as reinforcing materials in concrete, and new composite materials (André et al., 2020). A recent study investigated the mechanical and environmental feasibility of this, and found that the incorporation of crushed blade material into concrete not only improved the mechanical behaviour of concrete, but also its sustainability rating (Revilla-Cuesta et al., 2024). Although this paper advocates for repurposing as a solution for the increasing amount of composite blade waste, it is important to acknowledge that there are alternative circular solutions to this problem.

7. Recommendations

Recommendations set out below provide suggestions to help enable further exploration and deployment of blade repurposing for decommissioned blades in future, and increase the viability of repurposing as a large-scale solution to the problem of blade wastage. Though this report has been created for the wind developer Ørsted, it is hoped that they are relevant to a range of wind industry companies and stakeholders.

1.) Initiation of dialogue between OWF developers and blade repurposing industry

It is important for large developers to consider initiating mutually beneficial engagement with prospective blade repurposing organisations to help support and grow the industry in a collaborative way. Detailed logistics are not discussed in this report and can only be obtained via conversations with the existing repurposing companies listed here. If this is an avenue that OWF developers wish to explore, initiating discussions is the place to start.

2.) Pilot study

The first recommendation would provide more tangible details on exactly how OWF developers could begin to venture into repurposing, however a true picture of the outcome of this could only be obtained by the undertaking of a pilot repurposing study. This could be developed out of discussions with the repurposing industry, and could be performed on a small scale. An effective pilot study could include detailed economic and environmental logistics, and the gathering of social data upon implementation.

3.) Assessing demand via stakeholder engagement

An initially conceived section of this report that was not able to be included was an assessment of the demand for repurposing projects. Although many of the existing projects have received positive feedback from the communities they are placed in, no existing literature or data that addresses the demand for these projects was found. Stakeholders such as seaside communities (those adjacent to windfarms) could be approached, shown existing examples of repurposing projects, asked their opinions, and given the opportunity to express interest for projects in their local area. Although repurposing is a potential solution for a significant waste problem, the opportunities for social benefits are numerous, as discussed here.

4.) Cost-benefit analysis of blade repurposing

This report focusses purely on existing repurposing industry and projects, and the social benefits provided by these projects. it is anticipated that cost will be one of the most significant challenges for engagement in the repurposing industry and therefore it is recommended the next step would be to conduct detailed cost-benefit analysis in comparison to other existing practices for dealing with decommissioned blades

Conclusion

In conclusion, blade repurposing presents a unique opportunity to address the environmental challenges posed by EoL wind turbine blades whilst delivering significant social, economic, and cultural benefits. By repurposing blades into functional and artistic structures, as seen here, communities can enjoy enhanced public spaces, job creation, and increased awareness of sustainability and circular economy principles. These projects serve as evocative symbols of innovation, demonstrating that industrial waste can be reimagined/repurposed as valuable community assets.

However, the challenges of scale, cost, and logistics presented here highlight the need for effective collaboration and investment. Initiating dialogues with industry leaders, conducting pilot studies, and engaging stakeholders would serve as critical first steps in unlocking the full potential of blade repurposing. With the support of the wind industry, this emerging sector could not only mitigate waste but also inspire a broader cultural shift towards sustainability. By embracing this opportunity, Ørsted and other wind developers can establish themselves as pioneers in creating a truly circular and impactful future for renewable energy.

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