A CIRCULAR FUTURE FOR THE EUROPEAN MACHINERY & EQUIPMENT INDUSTRY

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EXECUTIVE
SUMMARY

The European machinery and equipment industry is integral to the clean energy transition and today's innovative and tech-driven economy. Yet despite the importance of green growth, the industry remains an energy- and resource-intensive part of the economy. There is significant unfulfilled potential to reduce its impacts and support long-term profitability by building a more circular sector. To dive into the material flows of this varied sector and recommend a circular path forward, this paper focuses on two product groups with different characteristics, circular opportunities and challenges: wind turbines and industrial water pumps. Wind turbines are only 30% circular today and while recycling rates can be quite high (64%), the levels of recycled content flowing into the construction of new wind turbines remains low (29%) and some elements are largely unrecyclable—such as blades and magnets. Many materials continuously funnel into building up wind turbine capacity, but the focus over the longer term—beyond 2040—should gradually shift to repowering and repurposing over new builds. In many sub-sectors of machinery and equipment, such as industrial water pumps, increasing the penetration of Equipment-as-a-Service (EaaS) models will provide manufacturers with the control they need to choose circular initiatives over virgin products—thereby reducing overall emissions, driving economic benefits and safeguarding the product group from an often volatile and disrupted material value chain.

Five key circular economy strategies can enable a more resilient industry and bridge the gap to net-zero. TThe production and maintenance of machinery and equipment is dependent on many scarce, valuable raw materials. It's also highly emissions-intensive due to the high rates of embodied emissions in materials.

The key circular strategies that could transform the entire industry are: 1) Design for efficiency, 2) Increase recycled inputs, 3) Remanufacture products, 4) Increase recyclability, and finally, 5) Utilise EaaS business models.

Circular business models are set to become mainstream in the industry and bring significant future earning potential. By 2030, most machinery and equipment companies will sell equipment as bundled solutions, including services, with 97% expected to have EaaS sales in the future versus 75% today.[1] These business models have the potential to improve product utilisation and extend product lifetime, while also allowing companies to embed circularity initiatives—such as remanufacturing and reuse—into these offers. Manufacturers who can rapidly increase penetration of these models stand to gain financially and unlock a differentiated advantage compared to their competitors. This is vital as margins on product sales are expected to decrease, with services and solutions providing higher profitability in the future.

Fortunately, the European machinery and equipment industry is well-positioned for the circular transition. Policies and regulations have influenced the shift to circularity in the industry—especially in Europe. The Circular Economy Action Plan (CEAP) and specifically the proposal for Ecodesign for Sustainable Products Regulation (ESPR), for example, regulates that products must be more durable, reusable, and repairable, amongst other traits—necessitating circular design and business models in many cases. However, as demand continues to rise, policy must be tailored to address specific industry challenges in the transition.

Circular economy strategies and business models are critical for the European machinery and equipment industry to sustainably and profitably deliver on net-zero ambitions, whilst strengthening supply chain resilience.

THREE ACTIONS FOR A RESILIENT, NET-ZERO AND PROFITABLE INDUSTRY

Accelerate product circularity to deliver on net-zero goals

Current policies won't get the industry to net-zero; circular strategies, however, can cut greenhouse gas emissions embodied in materials and are therefore vital. Adopting powerful circular strategies—such as developing recyclable blades and recycling decommissioned blades in the case of wind turbines—can bridge the gap to net-zero.

Continue to expand service models and embed circularity initiatives

Circularity initiatives can be embedded in service models, such as preventative maintenance, driven by the remote monitoring of equipment; on-site upgrades to software and hardware; old equipment refurbishment; and resale and buy-backs—such as when a customer purchases an upgraded model. While EaaS models are becoming more popular, there is significant room for expansion.

Secure access to circular materials to alleviate sourcing challenges

Renewable energy technology is rapidly scaling and driving up material demand. Many manufacturers already face supply chain disruptions due to geopolitical events: the war in Ukraine, for example, has increased raw material prices for wind turbine manufacturers.[2] The industry should secure cost-competitive access to recycled materials for strategic, financial and sustainability benefits.

1. GLOBAL AND EUROPEAN MACHINERY AND EQUIPMENT TRENDS

From an MRI scanner in a hospital generating medical images helping cure patients to precision-farming robots optimising agricultural production processes, machinery and equipment are at the centre of innovation in today's technology-driven economy. Technology trends shaping the future economy largely revolve around machinery and equipment, such as the renewable energy transition, digital connectivity in industrial systems via the Internet of Things (IoT) and machine autonomy through artificial intelligence (AI). Yet the sector is highly dependent on raw materials and ore extraction—increasing the already high pressure on scarce raw materials and hindering responses to demand for high-tech products.[3,4] Applying a circular lens to the design and use of these capital-intensive goods can be a source of resilience and sustainability by making better use of existing materials and recycling.

Critical dependence and increasing scarcity of metals

The machinery and equipment sector consumes more than 3.6 billion tonnes of raw materials* each year and accounts for a significant share of the world's ore extraction.[5] Furthermore, the metals required for machinery and equipment and high-tech applications are often rare—and in some cases forecast to soon reach critical scarcity thresholds.[6] These challenges are worsened by the take-make-waste approach of the linear economy: the continuous and rapid extraction of resources to produce goods and services, coupled with high disposal and waste rates. In 2019, the global economy consumed over 100 billion tonnes of resources—primarily virgin metal ores, fossil fuels, biomass and minerals—and only 8.6% of this was cycled back into use.[7] This wasteful use of resources directly increases global greenhouse gas (GHG) emissions: 70% of emissions are tied to material extraction, processing, use and disposal.[8] Pivoting towards a circular economy in both product design and business models can protect in-demand scarce metals and cut GHG emissions[9] and, in turn, support the continued growth of the machinery and equipment sector.

Policy moves in the right direction, but must be further tailored

Businesses (incumbents) are positioning themselves around important circular opportunity areas, such as refurbishing, remanufacturing and resale, and Equipment-as-a-Service (EaaS) offerings. Collaboration within the machinery sector between businesses can further mitigate raw material resource consumption. This can be achieved by, for example, facilitating the exchange of materials and components, improving recycled content quality, standardising parts to facilitate repair and reuse, and extending the lifetime of products.

Policies and regulations are further influencing the shift to circularity in the industry—especially in Europe. The European Green Deal aims to decouple economic growth from resource use with net-zero emissions by 2050. Reinforced by the Circular Economy Action Plan, it wants to stimulate circular production, consumption and end-of-life treatment—through extended producer responsibility, for example. However, to truly support the circular transition across the machinery and equipment sector, policy must be tailored to address specific industry challenges. This includes removing barriers that hinder the cross-border movement of machinery and equipment for refurbishment: regulations such as the Basel Convention can sometimes limit the import and export of refurbished and reusable parts with the intention of protecting humans and the environment from hazardous waste.

* The *Circularity Gap Report 2019* concluded that the global capital equipment sector consumes 7.2 billion tonnes of raw materials. When the product groups of motor vehicles, other transport equipment and office machinery and equipment are excluded, the number drops to 3.6 billion tonnes of raw materials.

The next chapter will visualise how key materials flow through the European machinery and equipment industry, allowing us to see how materials are processed, if at all, at end-of-use—or if they end up as waste, emitted or dispersed into the environment.

This is illustrated through two examples: wind turbines (with a focus on product-related strategies) and industrial water pumps (with a focus on business model-related strategies).

2. THE CURRENT STATE OF CIRCULARITY

To explore the current circularity in the machinery and equipment industry, we focus on two sectors with very different characteristics and challenges: wind turbines and industrial water pumps. The European market for wind turbines, onshore and offshore, is 30% circular today*. Although the majority of turbine materials (85%) are theoretically recyclable at end-of-life, only 64% are recycled in practice and only 29% of materials flowing into the construction of new turbines come from recycled content (i.e. steel, concrete, steel-foundation, cast-iron). Key challenges remain around turbine blades and magnets, which are hard to recycle today as recycling technologies have not yet been scaled. Industrial water pumps, on the other hand, have seen limited uptake of service-based (EaaS) business models that are ideal to support circular initiatives in the product group. By combining hardware, software, and services into a tightly integrated, tailored solution, companies can embed circularity initiatives, tap into a faster-growing profit pool and achieve higher margins.

Wind turbines: essential cogs to the clean energy transition

Increasing the use of renewable energy is crucial to driving Europe's net-zero ambition and improving its resilience as it reduces dependency on the import of fossil-based energy—such as petroleum and natural gas—which is susceptible to shocks and geopolitical pressures.[10] In this transition, wind turbines have a vital role to play and the industry is expanding rapidly: Europe installed 17 gigawatts in 2021, bringing the total installed capacity in Europe to 236 gigawatts, and from now to 2026 a further 116 gigawatts of new wind farms are expected.[11] However, although around 85% of wind turbine materials can be recycled,12 current levels are only 64%. Some components, such as blades, consist of fibreglass and epoxy resins and pose a significant recycling challenge—and we're set to have a lot of them on our hands as older and smaller first-generation wind turbines are now reaching the end of their operational life. We will likely see a more than fivefold increase in decommissioning capacity between 2020 to 2030 (0.8 gigawatts decommissioning capacity in 2020 to 4.8 gigawatts in 2030, and even reaching 11.2 gigawatts by 2040). The lack of consensus on the decommissioning process is limiting the uptake of appropriate recycling processes.[13]

High recycling, low circularity

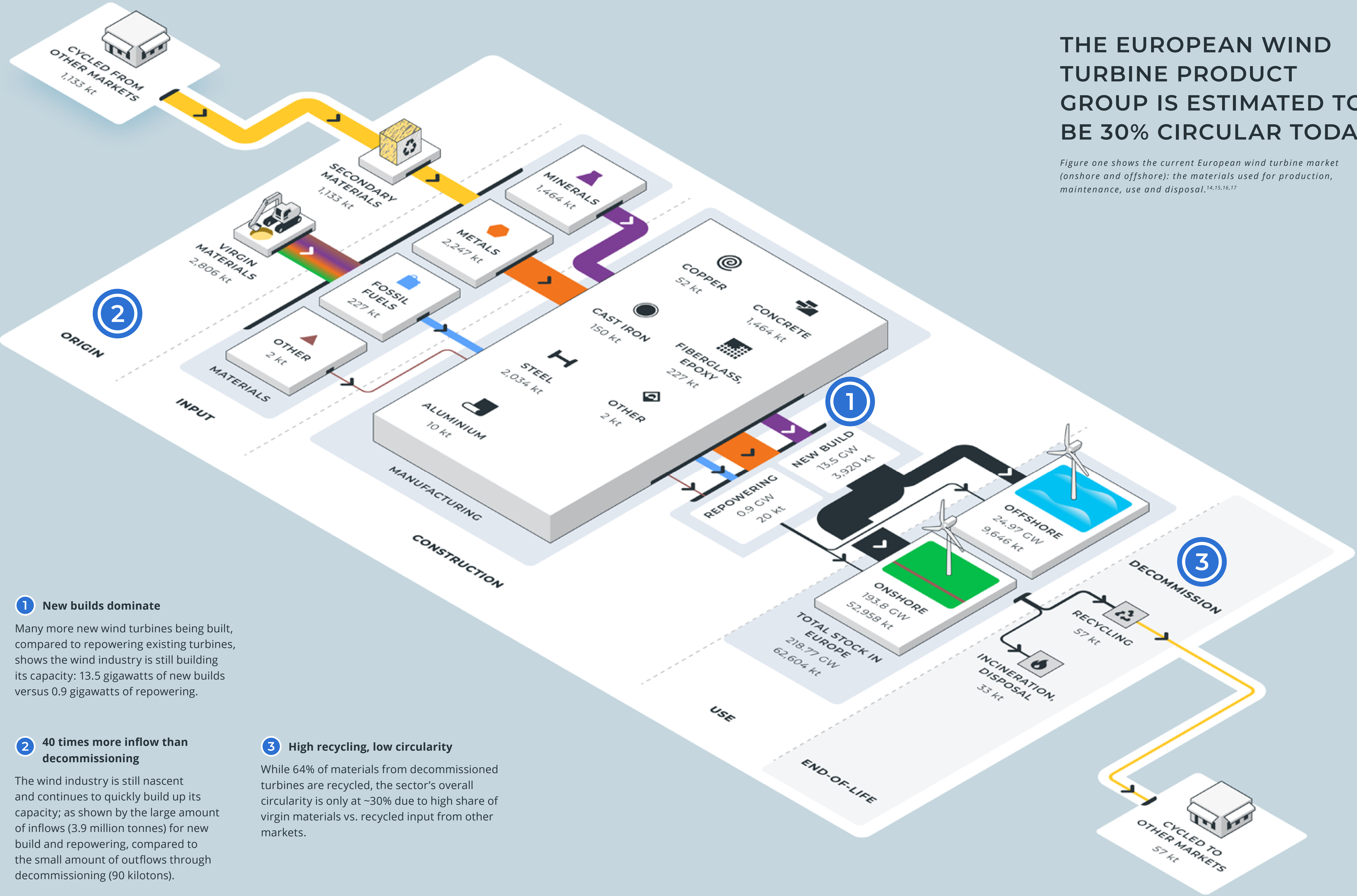
The production and maintenance of wind turbines in Europe consumes an estimated 3.9 million tonnes of virgin and secondary resources a year. The wind industry is still nascent and continues to quickly build up its capacity: illustrated by the small amount of outflows through decommissioning (791 megawatts, 90 kilotons), compared to the large amount of inflows in 2020 (14.5 gigawatts, 3.9 million tonnes). The outflow of decommissioned turbines will likely increase rapidly by 2040 (11.2 gigawatts under a business-as-usual scenario), presenting great opportunities to increase circularity by recovering and recycling this material stream.

Currently, 64% of materials from decommissioned turbines are recycled and unrecyclable components, such as turbine blades, pose a significant challenge. So, while this product group's recycling rates aren't too low, it is ultimately not very circular. Boosting circularity isn't just about recycling, but also hinges on using circular materials as inputs for new wind turbines. The levels of recycled content in the construction of new wind turbines is only 29%.

* We measure the circularity of these industry products using the Circularity Transition Indicator (CTI), an important indicator of progress toward a well-established circular flow of materials and reduced dependence on continued raw material extraction. CTI is a consumption-based measure, expressed as a percentage, representing the fraction of an industry's secondary inputs out of its total material consumption and its percentage of wastes and outflows that are reused or recycled. For wind turbines, the 30% circularity figure is calculated as the weighted average of the fraction of secondary inputs—28.8% of 3,900 kilotonnes of inflows—and the percentage of recycled waste: 63.7% of 89 kilotons of outflows.

THE EUROPEAN WIND TURBINE PRODUCT GROUP IS ESTIMATED TO BE 30% CIRCULAR TODAY

Figure one shows the current European wind turbine market (onshore and offshore): the materials used for production, maintenance, use and disposal.[14,15,16,17]



1 New builds dominate

Many more new wind turbines being built, compared to repowering existing turbines, shows the wind industry is still building its capacity: 13.5 gigawatts of new builds versus 0.9 gigawatts of repowering.

2 40 times more inflow than decommissioning

The wind industry is still nascent and continues to quickly build up its capacity; as shown by the large amount of inflows (3.9 million tonnes) for new build and repowering, compared to the small amount of outflows through decommissioning (90 kilotons).

3 High recycling, low circularity

While 64% of materials from decommissioned turbines are recycled, the sector's overall circularity is only at ~30% due to high share of virgin materials vs. recycled input from other markets.

New builds dominate but future potential lies in repowering and repurposing

The much higher rates of new wind turbines being built, compared to repowering existing turbines, shows again that the wind industry is still building its capacity: 13.5 gigawatts of new builds versus 0.9 gigawatts of repowering. Moving forward, if this process does not adapt as capacity is built up it would hugely fail to optimise the existing stock or the reuse of existing materials—key tenants of circularity. Repowering, repurposing and upgrading existing turbines makes business sense too—requiring only 5% of the mass of materials that new builds require (19.6 thousand tonnes compared to 3.9 million tonnes). In our modelling, it was assumed that repowering activity mainly affects rotors and hub raw materials, replacing old rotors, hubs, and blades with larger and higher capacity components.

Shift from onshore to offshore may increase material need, partly offset by turbine capacity improvement

Far more material is currently funnelled into building onshore wind capacity: 11 gigawatts compared to 2.5 gigawatts offshore. Onshore turbines require fewer materials than offshore—273 kilotonnes per megawatt compared to 360 kilotonnes per megawatt.[18] However, future projections estimate that offshore turbines will significantly increase in capacity (45.2 gigawatts in 2040 under a business-as-usual scenario) leading to potentially greater need for materials in the future.

FROM PRODUCT-CENTRIC TO SOLUTION-CENTRIC MODELS: THE CASE OF INDUSTRIAL WATER PUMPS

The machinery and equipment industry consists of many sectors – like water pumps – that are widely used, long-lifetime products, which experience slower product innovation. As a result, margins on product sales within this sector are expected to decrease, while services and solutions will continue to provide higher profitability. Solution businesses, therefore, will be a key contributor to revenue growth in machinery and equipment, and provide strong EBIT margins of around 13 to 20%. Suppliers, therefore, would capture more value by creating tailored solutions and adopting value-based pricing models. By combining hardware, software, and services into a tightly integrated, tailored solution, companies can tap into a faster-growing profit pool, achieve higher margins and increase sales.

In this transition from a product (ownership) to a service (stewardship), EaaS offerings play a central role. EaaS can take several forms:

- A leasing model whereby the user has the exclusive use—but not ownership—of a product for a fee, as many sharing platforms such as consumer-facing Peerby offers.
- Selling a product combined with a related service, like the maintenance or upgradability of parts—such as Grundfos[19] that offers a functional water pump that includes all necessary maintenance and replacement when broken.
- Finally, service providers can deliver a result whereby the product is just a means and customers pay for the service, such as Ekopak's customised Water-as-a-Service (WaaS)[20] offering where the supply of water in the right volume is the valued condition and the pumps themselves are a modular element that the client does not handle. Elopak's integrated service is fully delivered and maintained by its staff, with the client only paying for the water it consumes.

Different industries may want to consider which of these offers is the best fit for their product group, as well as where their customers stand in the journey.

Digital transformations, such as connected equipment and cloud platforms, create valuable information about customers and equipment, and enable wider industry adoption of value-based pricing models. Suppliers can capture more value over the lifetime of their equipment sales by retaining ownership and adopting EaaS pricing. Certain service models unlock a higher potential circularity impact, with EaaS holding the most opportunity to improve energy efficiency, but also to increase equipment utilisation, embed circular initiatives such as remanufacturing and reuse, and ensure high recycling efficiency at end-of-life. These dynamics are driven by the fact that OEM's maintain ownership of the assets and can determine the most effective approach to deliver reliable performance and extend the assets' working life.

One product group where players are beginning to pursue service-based models is industrial **water pumps**, but penetration is low, and few have embedded services beyond maintenance and repair.

- **Grundfos** utilises value-based pricing and pioneered a water-as-a-service solution using the Internet of Things and data analytics. It harnesses continuous monitoring systems and financing options for new pumps with potential energy earnings when old systems are replaced.
- **Sulzer[21]** offers long-term service agreements to manage the lifetime costs of rotating equipment. It also has a range of digital solutions to optimise maintenance and reduce operational cost, such as asset management, condition monitoring and advanced pump analytic services.
- **Wilo[22]** supplies tailor-made service contracts for routine checkups and emergency breakdowns-as well as consulting services. Regarding circularity, it has remote maintenance and monitoring systems and financing options for older pump replacement.
- **KSB[23]** offers tailor-made pump management services, including performance guarantees and inspection and repair services. Its digital systems allow customers to monitor systems online and remotely, while they also offer retrofitting and custom spare part services and support in identifying energy-saving potential.

BOOSTING RECYCLABILITY AND 'NEXT GENERATION' BLADES

Recycling technologies for composite materials are not yet mature enough, widely available at an industrial scale or cost-competitive. However, the industry can celebrate a host of innovations and cross-industry partnerships that could pave the way to a more recyclable future.

Siemens Gamesa was the first to build fully recyclable turbine blades for offshore use in 2021 (RecyclableBlade)[24] which are currently being piloted in a German offshore wind project in partnership with resin supplier Aditya Birla Advanced Materials (ABAM). The Partnership started in 2018, aiming to leverage ABAM's proprietary Recyclamine technology to formulate a resin system which allows the recycling of epoxy-based thermosets. Decommissioned blades are immersed in a heated mild acidic solution which separates resin from fibreglass, plastic, wood and metals; the separated materials can be recovered from the solution and prepared for secondary use.

Vestas also has big plans to reach its full recyclability target for wind turbines by 2030[25] and is also investigating new recycling pathways for difficult-to-recycle materials. In another example, **LM wind power (GE)** is working alongside **Arkema, CANOE, Engie and Owens Corning[26]** to develop 'next generation recyclable blades' as part of the ZEBRA (Zero Waste Blade Research) project initiated by French research centre IRT Jules Verne. The project produced the prototype of a 100% recyclable wind turbine this year, as it now eyes piloting it in projects and scaling the manufacturing process.

DecomBlades, based in Denmark since 2021, includes 10 cross-sectoral players from the wind industry.[27] The three-year project seeks to provide a basis for wind turbine blade recycling commercialisation using sustainable solutions, such as mech shredding, cement co-processing and pyrolysis.

3. MOVING THE INDUSTRY TOWARDS CIRCULARITY BY 2040

Five key circular economy strategies are relevant to move the machinery and equipment industry toward circularity. These strategies are: 1) Design for efficiency, 2) Increase recycled inputs, 3) Remanufactured products, 4) Increase recyclability, and finally, 5) Utilise Equipment-as-a-Service (EaaS) business models. In the example of wind turbines (the focus of this chapter), a focus on the first four strategies will help the sector reach 50% circularity by 2040. For industrial water pumps, a focus on the final strategy (EaaS) will provide incentives to OEMs to increase the useful life and utilisation of equipment, embed circularity initiatives such as repair and remanufacturing, and improve end-of-life recycling. The circular strategies spotlighted in this chapter use the key techniques of the circular economy: narrowing flows (using fewer materials to produce products and services), slowing flows (using materials for longer and extending product life cycles) and cycling flows (using materials again through recovery and recycling). On their own, each strategy may have limited impact on circularity, emissions reduction and financial impact, but our modelled scenario of how circular trends can accelerate by 2040 shows that together they deliver huge improvements.

Designing products with efficiency and recycling in mind will lead to a 3.8% increase in circularity by 2040. A key driver will be the material efficiency that results from larger capacity turbines that can generate more power with fewer materials. A 50% circular industry by 2040 could meet rising demand for renewable energy with fewer materials per unit of energy; the efficiency of the wind turbine stock increases from 3.5 megawatts per million tonnes of raw material to 3.8 megawatts per million tonnes: an increase of 8.5%. This assumes that the materials used would reduce by 7 to 8% by 2040 for onshore wind turbines and 15 to 16% for offshore wind turbines. The modular and efficient design of wind turbines and wind farms enables long asset life and efficient production—which also slashes greenhouse gas (GHG) emissions. Specific efforts are already underway in the industry to redesign components that are not recyclable: instead of fibreglass, wind turbine blades can be made with alternatives such as biocompatible resin and other composites, for example. Designing products to slow material flows is also reflected in wind turbine policy: in March 2022, the EU Commission proposed a package of legislative measures as part of the EU green deal to make almost all physical goods in the EU market more durable and circular.[28]

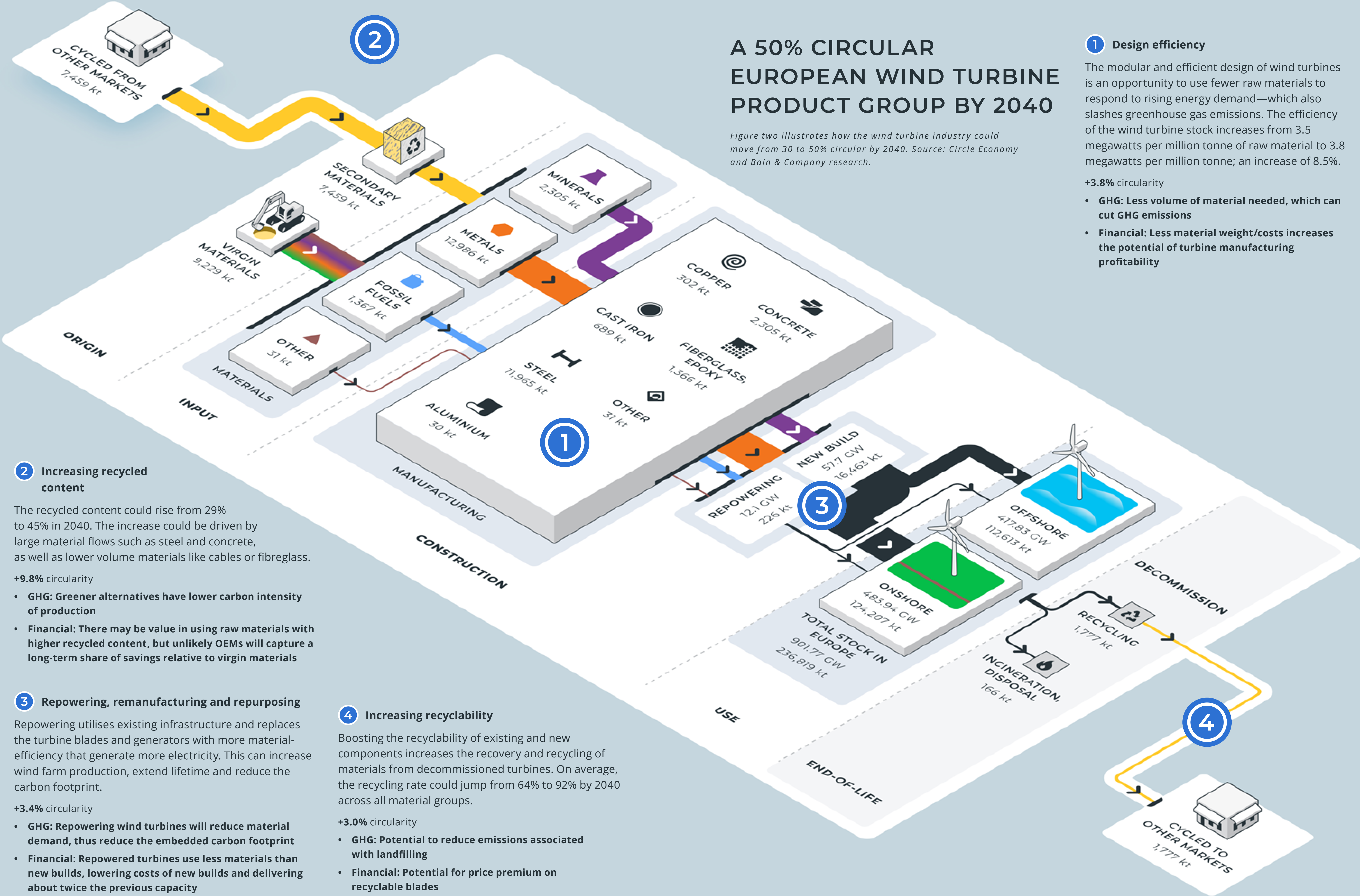
Increasing the recycled content of the various materials used in wind turbines, including leveraging waste from other industries, would lead to a 9.8% increase in circularity. On average, the recycled content used would rise from 29% to 45% in 2040, driven by large material flows such as steel (50% recycled content by 2040) and concrete (30% recycled content by 2040). Other materials that are used in lower volumes, yet in 2020 had a recycled content rate of zero, would also see large increases: cables (35% recycled content in 2040), fibreglass (20% recycled content in 2040), epoxy (30% recycled content in 2040), and rare earth materials used for magnets (30% recycled content in 2040). Ultimately, wind turbine components such as the foundation, tower and components in the nacelle of the towers can all use recycled raw materials—steel in towers can come from recycled steel scrap from other industries, for example.

Repowering wind turbines and remanufacturing and repurposing products to work like 'new' would lead to a 3.4% increase in circularity. Repowering utilises existing infrastructure and replaces the turbine blades and generators with components with increased efficiency or larger capacities that generate more electricity. The 3.4% increase in circularity is due to the assumption that repowering activity would increase by 23% by 2040[29] and that larger blades are indeed more energy efficient; yielding an 28% reduction in material requirements for blades in the same timeframe.[30] Repowering significantly increases wind farm output, extends wind farm life and reduces the embedded carbon footprint.

Increasing the recyclability of both existing and new components would lead to an increase in circularity of 3.0% by 2040. This would entail increasing the recovery and recycling of materials from decommissioned turbines and replaced blades from repowering. On average, the recycling rate could jump from 64% to 92% by 2040: concrete, for example, could go from a rate of 47% recycled in 2020 to 100% in 2040, including downcycling (based on recycling percentages from the construction sector). Smaller volume materials that have lower recycling rates in 2020 could also be recycled in the future. These include: fibreglass (15% in 2020 to 90% by 2040) through fully recyclable blades, epoxy (15% in 2020 to 85% by 2040) through the use of recyclable bio-based formulations, and rare earth materials used for magnets (5% in 2020 to 80% by 2040) through improved recovery processes from shredding motors. The development of fully recyclable blades is already well underway (see text box on page 13) and although the long lifetime of wind turbines suggests that this would not significantly impact end-of-life recycling rates by 2040, it would set the industry up for even stronger circularity rates in the years that follow. Aside from 100% recyclable blades, concrete used for tower foundations can be reused on other sites, steel and aluminium can be sent to foundries and steelworks and fibreglass can be reused for other products, such as fire hydrants or cement.

A 50% CIRCULAR EUROPEAN WIND TURBINE PRODUCT GROUP BY 2040

Figure two illustrates how the wind turbine industry could move from 30 to 50% circular by 2040. Source: Circle Economy and Bain & Company research.



1 Design efficiency

The modular and efficient design of wind turbines is an opportunity to use fewer raw materials to respond to rising energy demand—which also slashes greenhouse gas emissions. The efficiency of the wind turbine stock increases from 3.5 megawatts per million tonne of raw material to 3.8 megawatts per million tonne; an increase of 8.5%.

+3.8% circularity

- **GHG: Less volume of material needed, which can cut GHG emissions**
- **Financial: Less material weight/costs increases the potential of turbine manufacturing profitability**

2 Increasing recycled content

The recycled content could rise from 29% to 45% in 2040. The increase could be driven by large material flows such as steel and concrete, as well as lower volume materials like cables or fibreglass.

+9.8% circularity

- **GHG: Greener alternatives have lower carbon intensity of production**
- **Financial: There may be value in using raw materials with higher recycled content, but unlikely OEMs will capture a long-term share of savings relative to virgin materials**

3 Repowering, remanufacturing and repurposing

Repowering utilises existing infrastructure and replaces the turbine blades and generators with more material-efficiency that generate more electricity. This can increase wind farm production, extend lifetime and reduce the carbon footprint.

+3.4% circularity

- **GHG: Repowering wind turbines will reduce material demand, thus reduce the embedded carbon footprint**
- **Financial: Repowered turbines use less materials than new builds, lowering costs of new builds and delivering about twice the previous capacity**

4 Increasing recyclability

Boosting the recyclability of existing and new components increases the recovery and recycling of materials from decommissioned turbines. On average, the recycling rate could jump from 64% to 92% by 2040 across all material groups.

+3.0% circularity

- **GHG: Potential to reduce emissions associated with landfilling**
- **Financial: Potential for price premium on recyclable blades**

UTILISING EAAS TO UNLEASH CLIMATE MITIGATION POTENTIAL: THE CASE OF INDUSTRIAL WATER PUMPS

Suppliers can capture more value over the lifetime of their equipment sales by retaining ownership and adopting EaaS models. While 75% of suppliers today have some form of EaaS sales,[31] it is not yet a dominant market trend and the growth of EaaS models in the machinery and equipment industry is rather slow. European manufacturers do however expect the percentage of business revenue from EaaS sales to increase from 22% today to 39% in the next five years.[32]

Taking the example of industrial water pumps, we see that all water pump providers offer standard service contracts, and many have introduced preventative maintenance based on digital monitoring, but few manufacturers and customers have made the leap to full EaaS offerings.

The potential benefits of EaaS models are far-reaching. From an environmental perspective, extension of the useful life of equipment and increased recycling could reduce the demand for virgin materials, in turn reducing material extraction and manufacturing emissions, and moving the needle towards net-zero goals. From a financial perspective, circular initiatives embedded in EaaS models may provide benefits to both manufacturers and customers. For manufacturers, they provide the opportunity to improve profitability by using lower-cost refurbished parts and capturing higher value from end-of-life assets, while also building customer loyalty with huge potential future value.[33] For customers, these approaches have the potential to deliver significant savings due to less machinery downtime and reduced exposure to carbon emissions risks.

Water pump players, and broader machinery and equipment manufacturers alike, should focus on overcoming three common challenges to accelerate the move to more sustainable and profitable models:

1. **Risk/value alignment with customers:** EaaS models require sellers to understand how their equipment bolsters buyer results, and to then develop the right value proposition.

   Path forward: Buyers and sellers should collaborate to align on the right value proposition, as well as identify key risks and how to measure them.

2. **Internal changes to support the new model:** Implementing EaaS requires substantial organisational changes, impacting sales, product development, data and analytics, customer service, financial operations, and supporting services.

   Path forward: Internal alignment across all business functions around the new service mentality is imperative to the successful roll-out of an EaaS offering.

3. **'Swallowing the fish' in the transition from technology as an asset to a service:** Shifting from one-time sales (asset and ownership) to a recurring revenue model (service) can put significant pressure on firm financials early on.

   Path forward: The gradual deployment of EaaS models and the establishment of separate business units can soften financial disruption during the transition.

4. THE WAY FORWARD

The European machinery and equipment industry can incorporate five key circular strategies into their operations to improve circularity: 1) Design for efficiency, 2) Increase recycled inputs, 3) Remanufacture products, 4) Increase recyclability, and finally, 5) Utilise Equipment-as-a-Service (EaaS) business models. Different circular solutions should, however, be prioritised based on the characteristics of machinery and equipment sub-sectors. Crucially, strategies one, two and four are relevant for all sub-sectors. However, sub-sectors where equipment cost and material criticality are high should also seek to increase the penetration of EaaS business models to boost equipment sharing, reuse and repurposing (strategy five). Finally, sub-sectors with large volumes of standard products and a low speed of technological innovation can take advantage of remanufacturing opportunities (strategy three). Our analysis finds that companies pioneering the transition so far do three things well—and this must be scaled: 1) Scan the existing value chain to identify the potential for improving circular flows, 2) Combine 'today-forward and future back' perspectives to capture new opportunities and 3) Scale the ecosystem for success.

Scan the existing value chain to identify the potential for improving circular flows

While Figure one shows the materials used for production, maintenance, use and disposal for wind turbines at the industry level, the picture can look quite different for an individual company. Mapping material flows at the company level can help leaders identify resource use and waste in their own value chain and explore potential for improving circularity by enhancing utilisation and design,[34] monetising waste streams, sourcing sustainable substitute materials such as wood,[35] and better cycling end-of-life materials. One prime example for wind turbines is repowering, whereby existing infrastructure is outfitted with cutting-edge technology.

Combine 'today-forward and future-back' perspectives to capture new opportunities

Grounded in an understanding of the current value chain and circular potential, leaders should apply 'future-back' thinking to anticipate disruptions and navigate among potential futures. This will improve understanding of how value creation can shift as the industry goes circular, and allows companies to position around new control points in the value chain. For example, matching supply and demand for recycled materials with solutions such as material passports and expanding service-based models to allow for better integration of circular initiatives and to strengthen customer relationships and loyalty.

Scale the ecosystem for success

Companies can't go circular on their own. Leaders are strengthening their ecosystems with a clear perspective on where to collaborate and where to compete. Industry coalitions can help them align on new standards while providing a platform for companies to build and strengthen their own partnership ecosystems. The Capital Equipment Coalition,[36] for example, is a private-sector collaboration that catalyses the uptake of sustainable and circular practices through knowledge sharing to transform the machinery and equipment industry. And, finally, sub-sector specific project ZEBRA (Zero wastE Blade Research), led by IRT Jules Verne, brings together industrial wind turbine companies and technical centres to demonstrate the relevance of thermoplastic blades and, in 2022, innovated to create the world's first zero-waste blades.[37]

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