



The Sustainable Solution: Navigating Supply Chain Risks Through Circularity

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The offshore wind industry faces considerable challenges as it seeks to meet rising global demand in a sustainable manner. Although the sector is experiencing rapid growth, the current supply chain lacks the capacity to keep pace with future demands. As the industry transitions into its next phase of value creation, it is evident that additional capabilities are required to address these evolving needs effectively. To drive sustainable progression, governments must prioritise non-price criteria in tender processes, thereby encouraging circular and sustainable business models. Achieving these goals will also necessitate strong collaboration among diverse stakeholders across the supply chain. This paper examines these issues within the offshore wind sector, using Ørsted as a case to explore possible pathways toward a sustainable and circular future.

The Offshore Wind Imperative: Navigating Climate, Economic, and Supply Chain Challenges for a Net-Zero Future

Fossil fuels such as gas, coal, and oil are the largest contributor to global climate change, accounting for over 75% of global greenhouse gas emissions (GHG)¹. To avoid the worst impacts of climate change and remain under the 1.5°C limit of the Paris Agreement, global GHG emissions must be reduced by half before 2030 and reach net-zero by 2050². This requires a transformation of the global energy system in which renewable energy plays a key role to eliminate fossil fuels. The International Renewable Energy Agency estimates that 90% of the world's electricity will come from renewable energy by 2050³. Onshore and offshore wind energy are two of the largest renewable energy sources, and they are expected to become the primary source of energy generation by 2050, generating more than 35% of global electricity demand. Offshore wind energy has received a lot of attention in recent years as it offers complementary solutions to onshore challenges such as transmission congestion and land limits. Furthermore, advances in turbine technology and offshore wind development have reduced the cost of producing power from off-

shore wind⁴. This reduction in cost enhances the accessibility of offshore wind energy, particularly important for low- and middle-income countries, and is pivotal for decarbonising the energy sector by 2050. The shift to offshore wind energy is thereby not only a climatic imperative, but also an economic requirement.

When considering offshore wind energy in isolation, its environmental impact is subject to scrutiny due to the significant greenhouse gas emissions generated by its supply chain. For example, steel, which constitutes 89% of most offshore wind turbines⁵, is responsible for 7% of global GHG emissions annually⁶. As the offshore wind industry is projected to experience substantial growth, increasing from 228GW in 2030 to 1,000GW by 2050⁷, it underscores that the transition to a net-zero economy necessitates significant quantities of materials such as steel. The current supply chain capacity and processes for offshore wind are under considerable strain, facing both net zero challenges, supply chain risks and capacity limitations. Nonetheless, these obstacles present a valuable opportunity for energy developers such as Ørsted to innovate, mitigate risks, and deliver both financial and sustainable outcomes.

Ørsted's Transformation: From Coal Dependency to First Movers Towards Offshore Energy Leadership

Ørsted's journey from a coal-heavy energy producer to a global leader in renewable energy provides a valuable case study for implementing circular practices and building a sustainable business. Originally known as DONG Energy, the company faced the challenges of an outdated business model reliant on coal, which made up 85% of its energy production in 2008. Recognizing the shifting global landscape towards cleaner energy, DONG made the bold decision to reverse this ratio, setting a target for 85% of its revenue to come from renewable sources by 2040^{8,9}. This strategic shift, launched in 2009, marked the beginning of Ørsted's transformation. Through aggressive investment in offshore wind energy, the company significantly scaled its renewable energy portfolio. By 2019, Ørsted had exceeded its goals, achieving 86% of revenue from renewable sources—21 years ahead of the initial deadline^{10,11}. This transformation proved not only environmentally sustainable but also economically beneficial, positioning Ørsted as a leader in the renewable energy sector. The company's success led to recognition as one of the top 10 business transformations of the decade by Harvard Business Review in 2019¹².

Today, sustainability is at the core of Ørsted's long-term vision. The company aims to "create a world that runs entirely on green energy" and has embedded sustainability into its overall business strategy. One of Ørsted's goals is to become a globally recognised leader in sustainability. Additionally, Ørsted is committed to achieve net-zero emissions across its entire value chain by 2030, with interim targets to become net-zero in scopes 1 and 2 by 2025¹³⁾. In 2020, Ørsted became the first energy company to have its net-zero target validated by the Science Based Targets initiative (SBTi), underscoring its leadership in the energy transition¹⁴⁾. Despite these initiatives, energy developers like Ørsted still face a long journey toward achieving full net-zero operations. With a typical wind turbine lifespan of 25 years, the question arises: What happens at the end of its life? This challenge looms large for the offshore wind industry.

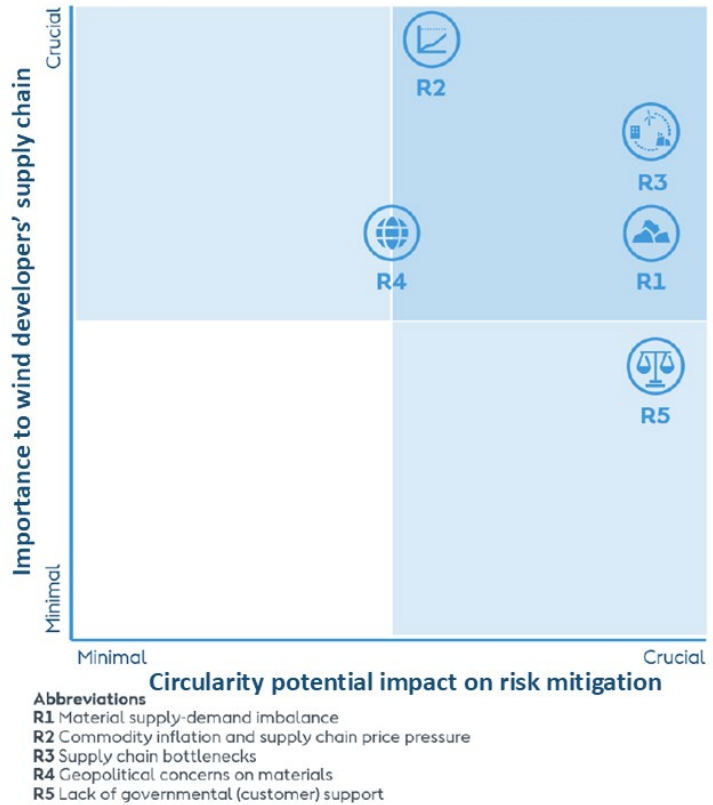


Figure 1 Risk evaluation overview
Source: Authors' contribution

The offshore wind industry currently faces the risk of material supply-demand imbalance. Building a net-zero economy is material-intensive, and the offshore wind industry is not the only clean energy technology demanding these resources. Indeed, there are more than seven different clean energy technologies that require significant quantities of key materials, including aluminium, steel, copper, and neodymium, among others¹⁵⁾. As these technologies rapidly advance to achieve a global net-zero economy, the material demand will increase substantially, exerting significant pressure on all supply chains. The current supply capacity is becoming insufficient and cannot meet the levels of demand expected in the transition from fossil fuels to a net-zero economy, leading to a supply-demand imbalance^{16 17 18 19)}. However, there are enough reserves and resources to meet the required material demand between 2022-2050²⁰⁾. The material supply challenge is a result of the current mining capacity that cannot match the global material demand^{21 22 23)}. Additionally, it takes approximately 16 years to establish a new material production including identifying the material resource, extracting the material, and bringing it to market²⁴⁾. This means that new mining methods and refinement of materials will be required to accelerate the renewable energy transition^{25 26)}.

Risks and Their Impact on the Offshore Wind Supply Chain

The offshore wind industry encounters a multitude of risks within its supply chain as it strives towards net-zero operations. While acknowledging the presence of additional risks, it is important to highlight those most pertinent to this context as illustrated in Figure 1.



Macro events such as the COVID-19 pandemic and various global conflicts, including Russia's invasion of Ukraine, have disrupted global supply chains and led to significant increases in shipping and material prices in recent years^{27 28)}. To illustrate, the price on virgin steel increased by 150% from 2020 to 2022 leading to a significant commodity inflation²⁹⁾. As prices on key materials have spiked, the manufacturers of offshore wind components have also significantly increased their prices, leading to an intense price pressure along the entire supply chain in which energy developers such as Ørsted operate within. These price volatilities have increased the costs of building an offshore wind farm by 40% in 2023³⁰⁾. The high material and supply chain prices stagnate the current growth rate of offshore wind, whereas the projected wind power required by 2030 to be on track within a 1.5°C pathway by 2050 will only account for 68% of the required wind capacity³¹⁾.

Numerous bottlenecks are currently evident in the offshore wind industry, where the rising demand for offshore wind energy has placed significant strain on existing mining and manufacturing capacities. This has extended lead times and caused various constraints within the supply chain³²⁾. As a result, more than 10 offshore wind projects have been delayed in the U.S.

and Europe during 2023 resulting in USD30 billion worth of investment that has been prolonged and put on hold due to these supply chain bottlenecks³³⁾. In the United States for instance, domestic production of offshore wind components is low whereas an entire new industry must be rebuilt adding additional pressure on the current supply chain³⁴⁾. Energy developers such as Ørsted are therefore currently operating in an environment with some level of uncertainty influencing their value chain³⁵⁻³⁶⁾.

The material supply-demand imbalance and supply chain bottlenecks give rise to geopolitical concerns regarding materials. In particular, the offshore wind energy sector is significantly affected by geopolitical complexities, with a primary focus on China’s monopolistic control over critical raw materials³⁷⁾. Besides the raw materials originating from China, materials from other parts of the world typically pass through China before becoming the final product. While dealing with China in itself is not necessarily an issue, it does increase supply chain risk. A more geopolitical supply chain risk comes from the reliance on Chinese suppliers, as they have the power to cut the supply, if energy developers, Denmark, or even EU are not on good terms with them.

The geopolitical risk is also affected by the European Union’s (EU) evolving regulatory landscape, as shown by the European Green Deal. The EU’s strategic push for circularity and increased sustainability within its boundaries aims not just to reduce environmental effect, but also to strengthen its autonomy in raw material supply chains. By pushing these efforts, the EU hopes to reduce its reliance on non-European suppliers, so fostering a more resilient and self-sufficient industrial base with stronger domestic supply chains³⁸⁾. While self-sufficiency is beneficial for sustainability and security, Ørsted have additional complications in adapting to changing supply chain dynamics and complying with new standards set by the European Union. The combination strain of geopolitical dependence and the necessity to match with EU’s sustainability goals thus creates a key area of risk for the offshore wind energy sector, necessitating precise strategic planning and active stakeholder engagement.

Finally, the offshore wind industry faces challenges due to limited governmental support. In this business-to-government (B2G) environment, where policymakers act as customers, the dynamics differ substantially from traditional business-to-consumer (B2C) relationships. Governments tend to prioritise cost over non-price criteria in tender processes, and this focus on price creates certain risks. Emphasising non-price factors could be perceived as imposing quotas, which disrupts established tender dynamics. At the same time, demand risk arises from governments’ low prioritisation of non-price criteria, limiting financial incentives for decarbonising the supply chain such as steel production and manufacturing. Consequently, the volatility in steel prices makes it difficult and costly for suppliers to adopt greenhouse gas (GHG) reduction technologies³⁹⁾. Steel production and manufacturing is difficult to decarbonise due to the high heat requirements utilising carbon, low profit margins, high capital intensity, and trade challenges. These dynamics highlight the intricate interplay of policy formulation and market demand in government procurement.

Can circularity be a lever to mitigate these supply chain risks and create value for offshore developers?

The Ellen MacArthur Foundation (2013) defines circularity as “an economy in which today’s goods are tomorrow’s resources, forming a virtuous cycle that fosters prosperity in a world of finite resources”⁴⁰⁾. Based on the right side of the Ellen MacArthur Foundation’s (2023) butterfly diagram, Figure 2 illustrates how circularity can serve as a lever to mitigate supply chain risks and create value in the offshore wind supply chain. Ørsted has already implemented measures targeting various loops, such as maintenance and recycling, to reduce GHG emissions within its operations. It is important to note that the sharing loop highlighted in the butterfly diagram is not included, as sharing offshore assets does not enhance or maximise the utilisation of offshore wind turbines.

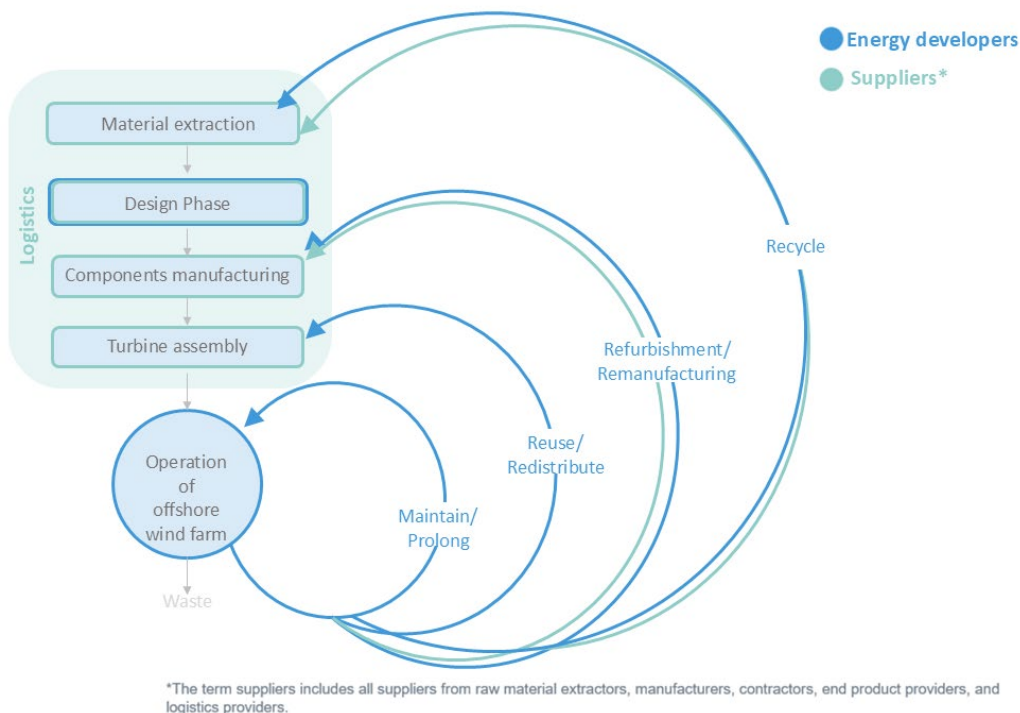


Figure 2 Example of circularity adoption for offshore wind development
Source: Authors’ contribution based on Ellen MacArthur Foundation (2013)



Foto: Ørsted

The initial loop, maintain and prolong lifetime on current offshore wind turbines, in Figure 2 encompasses the process of sustaining products at a high quality to avert breakdowns ⁴¹⁾. The typical lifespan of most offshore wind turbines is 25 years; however, with continuous maintenance, this lifespan can be extended, thus reducing the necessity to dismantle and rebuild wind farms. This extension diminishes GHG emissions and the demand for critical materials such as steel ⁴²⁾. Throughout the average 25-year operational period, wind farms require constant servicing and upkeep to maintain optimal working conditions and prevent malfunctions ⁴³⁾. Presently, Denmark is making strides in optimising wind farms. Green Power Denmark has commended the Danish Energy Agency's decision to resume processing applications for extending the operational lifetimes of existing offshore wind farms. This initiative aligns with Denmark's commitment to addressing climate change and highlights the significance of "repowering" in the global endeavour for cleaner, greener energy sources ⁴⁴⁾. Five offshore wind farms, including Ørsted's Nysted Offshore Wind Farm, are leading this initiative by Green Power Denmark⁴⁵⁾. The aim of this circularity lever is to repower operational wind farms to continuously generate green power beyond their initially planned 25-year lifespan, thereby enhancing the efficiency and sustainability of existing offshore wind. Energy developers such as Ørsted rely on governmental support to approve lifetime extensions on current wind farms.

The outer loop, Recycling, pertains to the process of converting a product back into its original materials or reprocessing them into new materials. This stage occurs when a product is no longer usable or refurbishable, thereby preventing the materials from becoming waste. Consequently, while the product's value is lost, the value of its materials is preserved through recycling ⁴⁶⁾. Ørsted has assessed that, when wind turbines reach the end of their operational life, they can recycle between 85% and 95% of turbine materials, primarily steel. Notably, for the one wind farm Ørsted has decommissioned to date, Vindeby in Denmark, 98% of the composite material was either recycled or repurposed for research or exhibition, including all turbine blades ⁴⁷⁾. Ørsted is also committed to finding effective recycling solutions for the remaining 5%. In June 2021,

Ørsted pledged never to send turbine blades to landfill, opting instead to reuse, recycle, or otherwise repurpose all blades from newly decommissioned onshore and offshore wind farms. Furthermore, Ørsted has established a partnership with its supplier, Vestas, focusing on incorporating recycled materials into new turbines and blades, showcasing Ørsted's adherence to a product development and commercialisation process ⁴⁸⁾. Recycling provides Ørsted with an additional source of material supply by processing its decommissioned turbines.

Moreover, Ørsted has formed partnerships focused on low-carbon solutions ⁴⁹⁾. The most recent partnership, announced in March 2024, involves Ørsted and Europe's largest heavy steel plate producer, Dillinger, signing a memorandum of understanding (MoU). This agreement specifies that Ørsted will be the first in the industry to utilise Dillinger's initial production of lower-emission steel plates. These steel plates will be used in the monopile foundations of wind turbines, with their production expected to reduce emissions by 55-60% compared to previously used heavy steel plates ⁵⁰⁾.

Circularity remains in its infancy within the offshore wind industry. Nonetheless, targets are being set, and incremental steps are being taken by industry peers. Ørsted has demonstrated its commitment to integrating circularity into its business model. However, the offshore wind industry still faces challenges as there are currently no comprehensive solutions for the end-of-life cycle at the decommissioning stage of a wind turbine. It is important to note that circularity should not be an end goal but rather a lever to mitigate the current supply chain risks faced by the offshore wind industry. Historically, price has been the decisive factor, but in recent years, non-tender price criteria such as environmental impact have also become significant criteria for governments such as the Netherlands and Norway ^{51) 52)}. Ørsted's journey underscores the importance of embedding sustainability into core business strategy. By making sustainability a key driver of innovation and growth, Ørsted has not only built a resilient and profitable business but also set a benchmark for other companies aiming to transition towards a circular, net-zero economy.

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Christine Klara and Johan met at Copenhagen Business School (CBS) while pursuing their Master's degree in Finance & Strategic Management in 2021. During their studies, they both worked at Ørsted as student assistants. Christine Klara worked in Global Sustainability and Johan worked in Global Operations. In 2024, they graduated from CBS, and today, Christine Klara is on the PwC Graduate Programme while Johan is on the ATP Graduate programme.