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Climate Action, Environment,
Energy, Mobility,
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Nordic Energy Research

# Circularity in the Clean Energy Transition

EXECUTIVE SUMMARY REPORT


Webinar organized under the auspices of the IEA Experts' Group on R&D Priority-setting and Evaluation (EGRD), 26 April 2021. Hosted by Nordic Energy Research and Austria Mission Innovation Week

On 26 April 2021, the EGRD organized a webinar in cooperation with Nordic Energy Research and Austria Innovation Week on circularity and the energy transition. The circular economy has gained increasing prominence as a tool which presents solutions to global sustainable development challenges. By addressing root causes of waste and pollution, the circular economy aims at keeping products and materials in use, and regenerating natural systems. It is defined as a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. Renewable energy technologies such as wind turbines, solar panels and batteries are all key to combat climate change and contribute to the low-carbon energy future. However, they also rely on the production and use of composite and critical materials that have negative impacts on the environment and society during extraction and manufacturing. From a whole system perspective, it is important to optimize resource use of components and materials of renewable energy technologies. They should be designed for durability, reuse and remanufacturing, rather than committing them to sub-optimal waste management and energy recovery pathways.

The webinar focused on the circularity from different angles: Challenges related to sourcing materials for renewable energy infrastructure, circularity in manufacturing processes and their durability and eventually disposal or reuse. These challenges were exemplified by a closer look at wind turbines and batteries.

The presentations and recording of the webinar are available here.

**Key messages from the webinar can be clustered in five statements**

**Statement 1: Circularity is still a relatively new concept**, but has increasingly been embraced by industry and decision-makers due to its benefits such as job creation, contribution to reduce $CO_2$ emissions and resources and economic prosperity. It is still rather under-researched, both regarding conceptualization and also the practical implementation related to technologies such as for example wind turbines and batteries.

**Statement 2: Strategies and roadmaps** are being developed that address the different scales of sustainability, covering a) Narrow: reduce resources and prevent waste, b) Slow: repair, life extension, and c) Close: recycling, decommissioning. Vestas is one case example of making a roadmap for making wind turbines 100% recyclable by 2040. They have broken down the elephant in smaller bites, aiming at going from down-cycling to materials designed for recycling. Northvolt and Nissan are two other case examples within the battery sector, covering end-of-life of the life cycle of batteries with several recycling routes and with solutions related to digitalisation, process technologies and life cycle design and engineering

**Statement 3: Data, methods and tools** are being gathered and developed to support decision-making. It includes a set-up of data, full life cycle circular metrics and impacts, in which KPIs can be developed and used to manage the value chain. In the design process, a holistic and perpetual approach should be used, including life cycle assessment. Circularity can also be codified in standards and certification.

**Statement 4: Circular business models** typically require new forms of partnerships and 'alliances of interests', which often pass through the entire value chain and across sectors. This, however, requires measures such as efficient information sharing about secondary resource availability (sub-products, waste and secondary raw materials), and is closely connected to the statement on data, methods and tools.

**Statement 5: RD&D priorities**

- R&D in further conceptualizing, measuring circularity of selected technologies and their impact and building reliable, committed roadmaps at different levels and sectors
- R&D in value chain management and optimisation using circularity as a key mechanism through the lens of systemic transition with the involvement of multiple stakeholder groups and citizens – significant upscaling is needed to increase the impact.
- R&D in recycling, life extension and reduction and reuse to make sustainable technologies/zero-waste technologies (incl. whole value-chain from mining over the various components to the final product) which at the same time are reliable, safe and cost-effective:
    - Dematerialisation, Durability, Reuse, Recycling

In the welcoming session, **Birte Holst Jørgensen**, chair of EGRD, gave reference to messages from the Leaders Summit of Climate, convened by US-President Biden, that the level of commitment to fight climate change had never been higher, but that this was far from enough. To get to net zero emissions in 2050, new technologies were needed, requiring massive technology research and innovation. Circularity would be a key part of that equation in order to address the root causes of waste and pollution.

**Karl Kienzl**, Austrian Federal Ministry for Climate Action, pointed out that the transformation of the linear economic system towards a circular economy requires completely new technological approaches, innovative business models, systemic interdisciplinary thinking, close networking of all actors and improved information management. With "FTI-Initiative Kreislaufwirtschaft" the Federal Ministry for Climate Action recently launched a new initiative to foster such research and development.

**Klaus Skytte,** Nordic Energy Research, explained that the Nordic countries have a vision of becoming the most sustainable and integrated region in the world, with a green transition towards carbon neutrality and a sustainable circular economy. The Nordic region is fortunate to have a high ratio of renewable energy sources in the electricity and heat supply. Further deployment and increase in renewable energy production are key enablers for decarbonizing sectors like industries as well as transportation in the Nordics.

**Herbert Greisberger**, Energy and Environment Agency of Lower Austria, chaired the first session, which focused on lessons learned from Policies designed to promote sustainable sourcing of raw materials, decommissioning and reuse of materials and energy-related infrastructure.

In his general introduction to the concept of circular economy, **Harald Friedl**, Global Circular Economy Ambassador and former CEO of Circle Economy, addressed the fundamental need of a transition from todays linear and wasteful economy to a circular one, re-defining growth and focusing on positive benefits arising for society as a whole. He emphasised that circular economy should not be seen as an "end goal" but part of the solution for a climate resilient and more sustainable economy. Friedl compared the transition as an operation on the open heart, as business operations and activities are ongoing and value chains globally connected. New ways of leadership – companies with ambitious circular roadmaps and action plans or city authorities with circular targets and innovative governance models – are needed to close circularity gaps and increase resilience. As a promising example of tools for transformative action, Friedl described the City of Amsterdam Doughnut, intended as a stimulus for cross-departmental collaboration within the City, and for connecting a network of city actors in an iterative process of change. Key take-away messages:

- Create common vision and ambitious policies: Policy makers as well as companies need to build a common vision, identify clear targets and set actions for circular economy, supported through data and digitisation. Ambitious policies should not only focus on short-term rescue, but also on long-term recovery, incorporating circularity principles in political frameworks.
- Shape incentives to enable a circular, low-carbon economy: With economic recovery there is an opportunity to re-structure SME and wider business support schemes towards long-term resilience. The removal of subsidies and the introduction of long-term carbon pricing will be needed to help align price signals with green stimulus packages (e.g. European Green Deal)

- Unlock circular investment opportunities to meet public priorities: Governments can align taxes and subsidies to promote growth and employment in ways that favour a circular economy approach. In addition, governments and financial regulators can enhance transparency by providing standardised definitions and metrics for circular economy investments that contribute to a low-carbon economic recovery.

**Anne P.M. Velenturf**, University of Leeds, introduced the concept of circular economy. There have been hundreds of definitions on what circular economy is, however the common denominator is always about making better use of products and materials and this involves minimising the input of natural resources, maximising the waste prevention and optimising the environmental, social, material and economic costs and benefits of materials and products throughout their consecutive lifecycles.

Velenturf introduced a framework of circular economy strategies co-produced with the offshore wind sector, which can also be used for other energy sectors. The strategies can be organised into four groups, i) the narrowing of flows which is reducing the amount of resources in our economy and to prevent waste, ii) the slowing of flows with strategies to repair, reuse or extend lifetimes, iii) closing which basically is recycling and decommissioning infrastructures, and finally iv) reintegrating resources that cannot be circulated in our economy safely and trusting them back into natural processes. The framework is supported by enabling strategies such as circular design, data and information and the (re-)certification of components and materials. Velenturf stressed the point that parts of our economy overly focused on recycling, which comes with high costs and energy use, thus a more transformative circular economy is needed. Velenturf brought the example of oil and gas decommissioning in the UK, drawing on conclusions of lessons that can be learned for offshore wind infrastructure. She advocated for higher regulatory ambitions to manage wastes sustainably in the UK rather than exporting it to developing countries with poor health, safety and environmental regulations.

Velenturf also showed the scale of scientific research of circular strategies in offshore wind by articles and papers published, results validated in an industry workshop to reflect current practice, concluding that nearly all circular economy strategies are under-investigated, with the exception of repair and maintenance. To maximise benefits, feasible circular strategies include dematerialisation by reduced resource use through optimisation and alternative materials or increasing the durability of components to last for longer, which is better than recycling of materials (e.g. steel).

Key take-away messages:

- The best energy is the one not used: The most important opportunity in the energy transition is to downscale the overall use of energy.
- Reduce materials: For a sustainable economy we have to reduce the average material use per person to about 7 tonnes per year, for Europe this means that we have to half our consumption by 2030.
- Make clear ownership structures and (legal) responsibilities: This is requested for robust business cases for investment and will require stronger implementation of waste legislation principles, higher regulatory ambitions for component reuse, repurposing and remanufacturing as well as recertification schemes.

**Tim C. McAloone**, the Technical University of Denmark, showcased the Nordic project CIRCit and its objective to help companies in the Nordic region towards solutions fitting into a circular economy. McAloone gave insights into the six focus areas, beginning with a screening of sustainable alternative circular solutions in terms of environmental, social and business potential. The second area was about circular economy business modelling where companies were supported in choosing the most potential business areas incorporating circular principles. The third stage was about product design and development where tools and methods came in to assess product circularity in the conceptual design stage. In focus area four, the smart circular economy, it was evaluated how digitalisation and smart products can help facilitating the transition. Questions around the availability and quality of data or the conditions to share data in a trustworthy manner (with customers) were part of this stage. Stage five, closing the loop for a circular economy, focused on how to identify and decide on the best circular strategy for take-back products as early as possible in the product design. Finally, a clear understanding of the relationships along the circular value chains was provided, in order to maximise material productivity, optimise energy, make information accessible to relevant stakeholders and put in place the necessary infrastructure to benefit the entire chain. Key take-away messages:

- Be alerted to new forms of innovation in traditional manufacturing activities and business as usual: Systematised business modelling practices for circular economy and proactive advice on potential circular business model configurations enhance strategic thinking and support companies to come up with alternative business models with reasonable and viable value propositions.
- Include circularity right from the beginning of the product design and development. Decisions, such as those concerning the type of material, assembly method, and expected lifespan, made during the early design stages will significantly influence a product's quality, cost, aesthetics, sustainability, and circularity performance over the product lifecycle.
- Create a thriving knowledge platform for circularity: Within CIRCit, over 100 companies in the Nordic Region were reached all the way down from electronics to textile, to medical equipment, to agri-food, etc. and offered a knowledge base of 100 theorized and real-world smart circular strategies.

**Johannes Tambornino**, vice-chair of EGRD, led the second session Improving the lifecycle and recyclability of wind energy infrastructures which analysed and exemplified the current efforts towards circularity on the paths towards a clean energy transition with an in-depths look into the wind energy sector. Presently, wind turbines have a lifetime of 25-30 years. 85-90 percent of the infrastructure can be recycled. Components such as the gearbox, generator, foundation and tower are all recyclable. However, turbine blades represent a significant challenge. Composite materials, glass fibre, and carbon fibres are extremely difficult to recycle.  An estimated 2.5 million tonnes of composite material are in use in this sector. In the coming five years, 15,000 wind turbine blades are due to be decommissioned. Making turbines 100% recyclable is therefore increasingly important.

**Justine Beauson**, DTU Wind Energy, gave an overview of the new Task 45 – Recycling, IEA Wind TCP. Recycling of wind turbine blades still poses a great challenge due to the complex and composite structures. Currently there is only one industrial scale solution in the European Union, following a cement-kiln co-processing route in Northern Germany. Task 45 will run from 2021 until 2024 and will bring together partners from nine countries (Denmark, USA, France, UK, The Netherlands, Sweden, Norway, Ireland, Sweden) to analyse possible future designs of wind turbine blades and routes towards their recyclability on an industrial scale and make recommendations for the future implementation of wind turbine blade recycling. The work programme includes an in-depths analysis on the requirements on future production processes. Therefore estimates on the time scale towards a widespread deployment of recycling techniques for the composite structures of wind turbine blades remain challenging.

**Richard Tusing**, US Department of Energy (DOE)/NREL gave an overview of the current US goals towards wind circular economy pathways. Under the leadership of the US Department of Energy, multiple stakeholders from research and industry had worked together to establish sustainability and circularity in the wind energy sector and included all relevant dimensions, from (scarce) materials to impacts on land and ocean to water, air and energy. The DOE's Wind Energy Technology Office (WETO) prioritised three High Impact Innovation Projects to achieve full life cycle for a complete Wind System Circular Economy:

- Increasing the lifetime of Wind Energy Turbine Components such as towers, blades and gear boxes but also with a strong focus on whole wind systems for optimized load management
- Better designs with a higher degree of reusability such as alternate materials / bioresins and new carbon fibres for the blades, reusable concrete bases for the towers or alternatives to the use of critical materials in drivetrains
- Making progress towards the recyclability of the materials used such as recyclable thermoplastics and carbon fibre development options for the blades

In line with the previous presentation the key challenge on the way towards circularity in the wind energy industry was identified with the composite materials used for the blades.

**Allan K. Poulsen**, Advanced Structures and Sustainability, Vestas Denmark, presented the company's ambitious goals towards sustainability for the years to come: Vestas aims to be a carbon neutral company by 2030 and plans to produce zero waste wind turbines by 2040. There is an increased demand worldwide for sustainable (and waste-reduced) solutions in the wind energy sector. Currently the company aims to meet this demand by increasing the recyclability of their rotors to 50% by 2025 and to 55% by 2035. Recycling of wind turbine blades still remains a major challenge. On the one hand, recovering glass fibres from glass fibre reinforced plastics is highly difficult and also energy intensive. On the other hand, market perspectives for recycled glass fibres remain unclear. To reach these goals Vestas has taken several initiatives:

- Exploring new recycling technologies that are optimal for composite waste - such as glass fiber recycling and plastic parts recovery.
- Facilitating processes around blade decommissioning providing support to customers to decrease the amount of waste material being sent to landfill.
- Development of material and value streams of recycled blade materials with the aim of stimulating recycling value-chains.

By the end of 2021, Vestas plans to launch a circular economy strategy - introducing a circular economy approach in the different phases of the value chain. Short term strategies focus on replacing the waste-to-energy approach by higher value uses of recovered glass fibres, for example in the cement industry. In the long term, the company is aiming at other, more beneficial uses of recovered glass fibres. However research and development concerning recycling options for reusable glass fibres is needed. Here the quality required by different end-markets needs to be used as a guideline.

The session chair summarized the key take-away messages:

- Recyclability of wind turbines is a major issue and should be tackled to support the role of wind energy in the overall energy mix and the overall worldwide goals towards clean.
- Use existing technologies: 85% of a typical wind turbine can already be reused or recycled at the end of its lifetime by using current technologies. Reusing is always better than recycling but further development is needed to increase the percentage of wind turbine components that qualify for reuse.
- Develop solutions for wind turbine blades whose composite nature is still a major challenge for recycling and further steps towards circularity: Further research is needed to improve the design, material mix and production techniques to improve the recyclability of wind turbine blades, especially on an industrial scale.
- Markets and regulations for recycling and reuse: Business models aiming at reusing and recycling components of wind turbines depend on regulations in individual markets and need to be further explored, especially future markets for recycled glass fibres.

The third session was led by **Atsushi Kurosawa**, vice-chair of EGRD, and focused on <u>Batteries - raw materials -production - use and re-use</u>, which highlighted the importance of circularity of mobile and stationary batteries under the pressure of raw materials supply and sustainability requirements.

**Juan Felipe Cerdas**, Life Cycle Engineering, Institute of Machine Tools and Production Technology, Technical University of Braunschweig, presented approaches and solutions towards a consistent, life-cycle oriented recycling of traction batteries. Batteries are considered as a key technology for sustainable electro-mobility and attention should be given to the End-of-Life stage of the life cycle. The Greenbat project portfolio aims at improving energy and material efficiency throughout the lifecycle and closed material cycles, including the circularity of batteries. Other projects presented were DiRectION (Data-Mining in the Recycling of Lithium-Ion Battery Cells) and SIMTEGRAL (Integrated multi-scale system simulation and sustainability assessment of primary and secondary material supply chains for traction battery cells). Key messages were:

- The end-of-life processes should be assessed as part of the overall battery lifecycle. If the emissions from avoided primary production and waste treatment exceed those from additional recycling processes, environment benefits would be justified.
- Integration of digitalization, process technology, and life cycle design & engineering, supported by basic approaches in material input & output and impact assessment, may produce synergies in optimized solutions for battery recycling.

**Emma Nehrenheim**, Northvolt, provided views on sustainable battery production. Solutions for a cleaner future is the coupling of renewable energy, electrification, with the assistance of energy storage. While lithium-ion batteries are the key to a clean future, one concern is a shortfall in supply, especially in Europe with no domestic manufacturing capacity. Northvolt will scale up battery production in the EU and build a sustainable and vertical integrated supply chain, which is managed by a raw material sustainability approach in traceability and with recycling targets. The company has a target of 50% recycled material in 2030, and carbon footprint down under 10 kg/kWh. By means of automation, data and industry 4.0, the company aims at accelerating traceability, connected batteries and automated improvement. In summary:

- Large-scale supply and a sustainable supply chain can be achieved simultaneously in lithium-ion battery production and a sustainable feed, tracing to mine level, site visits, recycling targets are considered in the business model.
- Data and decisions are crucial for traceability to each cell level, secure battery connectivity, and automated built-in improvement in factories and products.

**Makoto Yoshida**, Nissan Motor Corporation, presented battery circularity views from an EV manufacturer’s point of view. Due to its environmental benefits, the potential EV demand is huge, but may be influenced by a shortage of batteries due to material supply limitation in cobalt and lithium. Therefore, different solutions include improving the battery function, reducing/saving battery demand, establishing a battery circular economy, and utilizing battery as an energy storage device. Re-use of batteries and better recycling efficiency should be pursued.  Balanced function improvement is required in the factors of energy density, chargeability, heat resistance (durability), safety, pack cost and resource risk. Innovations in all solid-state batteries and wireless charging would change the game in the future. Also, tasks should focus on increasing collection ratio, making fair and reliable evaluation, improving design technologies and durability and create markets. In summary:

- Durable solutions to battery shortage and bottlenecks are better durability, demand saving and circularity.
- EV batteries can be recycled through product recycling and material recycling for mobile and stationary use.
- Regulation, standards, incentives, education and enlightenment are needed to address the challenges in collection, evaluation, technology, and market of batteries.

The session chair summarized the key takeaways:

- All stages of the life cycle of EVs need to be assessed and optimised, including operation and end-of-life phases. Circularity brings value to business models in terms of visibility, recycling rate, and carbon footprint. Battery recycling with refurbishment and material recycling are two major methodologies, while the extension of durability and other alternative options can decrease the demand for batteries.
- New, optimised solutions for battery recycling are needed, including integration of digitalization, process technology and life cycle design & engineering.
- Innovations in next generation battery materials (e.g. all-solid batteries) and wireless charging would be game changers to reduce the recycling requirements.
- Development of tools for decision-support is needed regarding various battery circular systems in terms of energy, GHGs, and economics.