Background paper on the environmental impact of wind energy – a contribution to the circular economy discussion

MARCH 2017

windeurope.org

Contents

1. INTRODUCTION

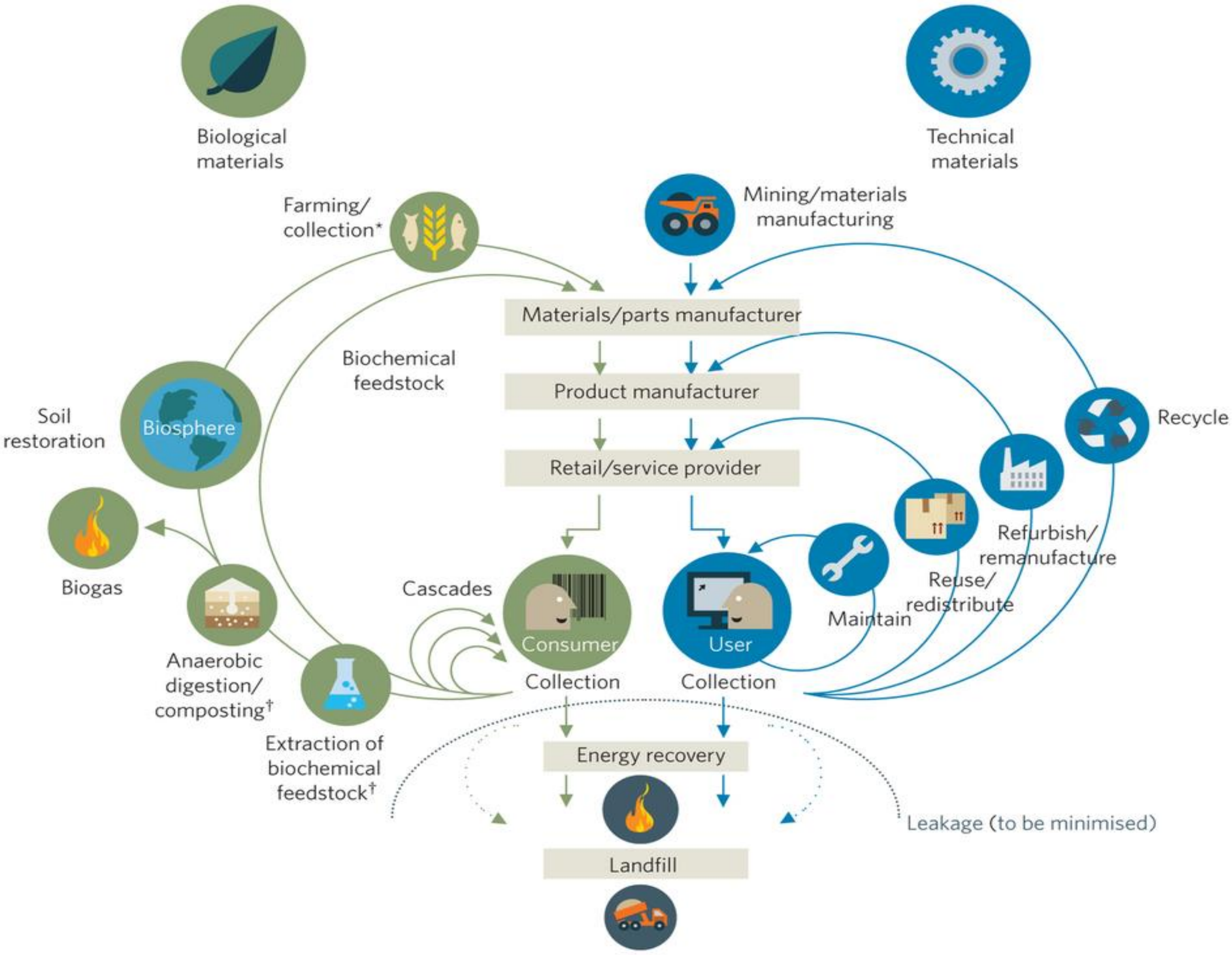
Wind energy is a part of the transition towards a circular economy for many reasons, mainly for producing clean, renewable energy with low environmental impact. A genuine circular economy would be powered in its entirety by renewable energy – creating a restorative and regenerative economic model.

The paper summarizes the current situation in the wind industry and assesses future opportunities stemming from the circular economy.

1.1. CIRCULAR ECONOMY

The 2050 vision of 'living well within the limits of the planet' as set out in the European Union (EU)'s 7th Environment Action Program is just one example among many of the relevance of adopting resilient business models.

This requires Europe and the rest of the world to move away from the current linear economic model of take-make-consume-dispose, which relies on large quantities of easily accessible resources and energy, to a circular model in which planetary boundaries are respected through resource conservation and by maximizing the use of resources already available within the economy.



The circular economy is based on three principles:

- Preserving and enhancing natural capital by controlling finite stocks and balancing renewable resource flows;

- Optimizing resource yields by controlling finite stocks and balancing renewable resource flows;
- Fostering system effectiveness by revealing and designing out negative externalities.

2. CIRCULAR ECONOMY IN EU STRATEGY AND LEGISLATION

The concept of a circular economy has recently gained traction in European policymaking as a positive, solutions-based perspective for achieving economic development within increasing environmental constraints. Studies show the potential can be significant: *"A circular economy vision for a competitive Europe reveals that by adopting circular economy principles, Europe can take advantage of the impending technology revolution to create a net benefit of €1.8 trillion by 2030, or €0.9 trillion more than in the current linear development path. This would be accompanied by better societal outcomes including an increase of €3,000 in household income, a reduction in the cost of time lost to congestion by 16%, and a halving of carbon dioxide emissions compared with current levels."*[1]

2.1. CLOSING THE LOOP – AN EU ACTION PLAN FOR THE CIRCULAR ECONOMY

In June 2016, the European Commission adopted an ambitious Circular Economy Package, which includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs.

The Circular Economy Package consists of an EU Action Plan for the Circular Economy that establishes a concrete and ambitious program of action, with measures covering the full cycle: from production and consumption to waste management and the market for secondary raw materials. The annex to the action plan sets out the timeline when the actions will be completed.

The proposed actions will contribute to "closing the loop" of product lifecycles through greater recycling and re-use, and bring benefits for both the environment and the economy.

The revised legislative proposals on waste set clear targets for reduction of waste and establish an ambitious and credible long-term path for waste management and recycling, see appendix 3. Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030;
- A ban on landfilling of separately collected waste;
- Promotion of economic instruments to discourage landfilling;
- Simplified and improved definitions and harmonized calculation methods for recycling rates throughout the EU;
- Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;
- Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

[1] The Ellen MacArthur Foundation, the McKinsey Center for Business and Environment, and SUN (Stiftungsfonds für Umweltökonomie und Nachhaltigkeit), study fron June 2015

3. WIND INDUSTRY FROM A CIRCULAR ECONOMY PERSPECTIVE – STATE OF PLAY

The following sections provide an overview of the relevance of the circular economy to the wind industry today.

3.1. TURBINE DESIGN

Circularity is considered when selecting materials and technical solutions[2]:

- Design factors in recycling of materials, today 80-85 % of a wind turbine is recyclable;
- Content of recycled material reflects the average world market mix for metals used;
- Technical lifetime is usually set to 20 years but actual life time indicates early turbines can produce far longer;
- Life cycle assessments performed ensure optimization (water, carbon footprint, hazardous materials);
- Wind turbine manufacturers are fully complying with the RoHS Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment and many manufacturers apply best practice using pro-active materials restriction lists to go beyond legal requirements in their ambitions;
- Wind turbines produce renewable energy replacing fossil energy and they do it efficiently also considering the life cycle perspective. Over the life cycle of a wind power plant it will return 30-40 times more energy than it consumed. This equals to a 6-12 months energy payback time depending mainly on site conditions and turbine type.

3.2. SOURCING AND MANUFACTURING

According to LCAs, the majority of environmental impacts in a wind turbine comes from materials and supply chain. The Wind industry addresses this with the following measures:

- Wind is a global industry but given the main components are bulky and heavy, it is resource efficient to produce near the area of development to limit transport;
- Main component transport is done by rail or vessel where possible saving fuel compared to road transport;
- Suppliers are chosen with consideration to location and environmental impact;
- Most turbine suppliers are certified according to ISO 14001 bringing commitments to continually improve environmental performance;
- Use of certain materials requires special attention given their potential environmental impact. The use of such materials is justified by efficiency as in the case of permanent magnets containing rare-earth minerals. To manage environmental risks, special attention to supply chain and production conditions is then applied.

[2] see supplier LCAs in Appendix A for references to given levels.

3.3. SITING AND INSTALLATION

Picking the right combination of site and turbine is critical to ensuring optimal efficiency and minimal local impact:

- Developers optimize the positioning of wind farms via siting studies, environmental impact assessments as well as engagement with local stakeholders. Data driven siting services gives optimal output of turbine and turbine selection to site;
- A well situated wind turbine has a limited impact on land use and effects on birds and bats can be minimized by thorough environmental impact assessment prior to siting decisions;
- During construction activities of roads, grid connection, foundation and other civil works the local flora and fauna is protected in accordance with plans made during permit and preparation phases;
- To limit use of fossil energy to power the site, early grid connection is beneficial. Before the grid is established, alternative energy can be used to avoid generators. An example is the powering of aviation lights - which is required as soon as the turbine is erected – with solar panels and fuel cells rather than with small diesel generators.

3.4. SERVICE

Local impact during the service phase is minimal, no emissions occur from standard operations of wind turbines. Offshore turbines wind are even found to contribute to local habitats development given the towers and foundations become artificial reefs.

Service activities are divided into main categories of scheduled maintenance and fault finding:

- Impact during wind turbines operational phase is minimal, land use is limited, noise and shadow impact managed, flora and fauna assessed and protected;
- Wind turbines are optimized to be steady performers with >95% availability. Service intervals are getting longer as newer models are designed to limit maintenance and thereby also limit transport and need for replacement components;
- Turbines are today connected and monitored from a distance ensuring they can be managed remotely. This allows an advanced monitoring and minor deviations can be traced early promoting preventative actions before failure occurs. This limits component failures and production losses ensuring optimal resource use during the operation phase;
- Wind turbines have significantly improved their return-on energy. Examples show a 26% improvement for the same size of turbine in 2010-15[3];
- Wind turbines do not use water. Replacing just 25 % water-intensive fossil-fuel based electricity would reduce annual CO_2 emissions by 300 million metric tons and conserve 600 billion liters of water. That is equivalent to the annual percentage of water withdrawals worldwide of the equivalent of drinking water for 643 million people[4].

3.5. DECOMMISSIONING

Operators factor in technical and economic lifetime to consider in the decision to decommission a turbine. Many smaller turbines are refurbished and re-used in less mature markets. This is resource efficient but safety aspects are of course a pre-requisite to manage:

- Decommissioning manuals and re-use programs along with well managed supply chain minimizes the impact and ensures system effectiveness;

---

[3] https://www.vestas.com/en/about/sustainability#!energy-payback

[4] http://www.ewea.org/fileadmin/files/library/publications/reports/Saving_water_with_wind_energy.pdf

- Wind turbines contains around 80% metal[5] that is well suitable for recycling without quality losses;
- A remaining challenge is the improvement of the footprint from blades which today principally contain virgin material with very limited opportunities for reusing materials. (WindEurope 2017, Discussion paper on managing composites blade waste).

4. WIND INDUSTRY FROM A CIRCULAR ECONOMY PERSPECTIVE – ISSUES FOR CONSIDERATION

The following section provides an overview of the potential for the wind industry stemming from the circular economy.

4.1. TURBINE DESIGN

Wind turbines will continue to develop and several manufacturers are officially committed to:

- Applying a structured approach through for example following standards for Eco-design;
- Product performance targets to further improve products (like carbon footprint, renewable energy usage and waste reductions for example).

Increasing technological maturity may allow:

- Further developed modularized design of nacelle components (e.g. generator, gearbox and drivetrain, pitch and clutch system);
- Extended lifetime for the full turbine or parts of it beyond 20 years;
- Replacing non-recyclable materials by recyclable materials where possible, by e.g. non-toxic plastics, light alloys, bio-based materials.

4.2. SOURCING AND MANUFACTURING

Wind is a mainstream technology that accounted in 2016 for 51% of total power capacity installations in Europe - more than any other technology[6]. Therefore the importance of assessing, monitoring and better controlling their supply chain is a priority within the industry:

- To ensure simple and effective supply chain assessments common criteria can be established in the supply chains between manufacturers and developers. Experience can be drawn from cooperation aligning safety training requirements as done under GWO[7];
- One business' waste can be another's raw material. This requires ensuring waste minimization during the wind turbine production and ensure waste created is used as raw material by another sectors. Looking ahead, this will also require investigating how local societies could build material webs to drive circularity (e.g. the city of Kalunborg[8]).

---

[5] https://www.vestas.com/~/media/vestas/about/sustainability/pdfs/lcav12633mwfinal060614.pdf

[6] https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2016.pdf

[7] http://www.globalwindsafety.org/gwo/training_standards.html

[8] The Kalundborg Symbiosis is an industrial ecosystem, where the by-product residual product of one enterprise is used as a resource by another enterprise, in a closed cycle. An industrial symbiosis is a local collaboration where

4.3. SITING AND INSTALLATION

Opportunities may lie in developing (when feasible) renewable energy solutions at site especially for transportation and site usage:

- Transport frames for wind turbine main components are designed for their purpose, some for re-use and some for one-off use. Given shipment distances to remote sites long re-use isn't always the most optimal. Further reflection should be allocated to the circular thinking of improving transport equipment utilisation.

4.4. SERVICE

The industry may exploit the potential of establishing loops for reverse cycle to minimize costs of recovery, transport, storage and remanufacturing of components:

- Mobile teams for disassembly and assembly;
- "Just-in-time" reverse logistics (transporting and storage of components, matching supply and demand);
- Remanufacturing and recycling facilities;
- Introduce "remanufactured component" product line upgrade; used spare parts to be used as new or "almost new".

Increasing efficiency may entail:

- Optimizing accessibility to remove and replace components without prolonged downtimes;
- Wind turbine onsite upgrades, extended lifetime, etc.

4.5. DECOMMISSIONING

Maximizing the effectiveness of decommissioning would require matching O&M strategies with end of life strategies:

- Scheduling replacement and upgrade of components at short enough intervals to ensure quality of decommissioned components;
- Developing product "cradle-2-cradle passports" to improve recovery and re-use of materials[9]; return / reverse logistics / take-back schemes; Invest in new recycling techniques (e.g., composite recycling);
- Building on the research projects to develop new businesses for used rotor blades, using shredded composites as additive/filling materials and long term find methods for remanufacturing and reusing whole blades.

---

public and private enterprises buy and sell residual products, resulting in mutual economic and environmental benefits. See http://www.symbiosis.dk/en

[9] https://www.ellenmacarthurfoundation.org/case-studies/using-product-passports-to-improve-the-recovery-and-reuse-of-shipping-steel

APPENDIX 1 REFERENCES

Ellen MacArthur Foundation

The European Environment Agency (EEA), EEA Report No 2/2016 Circular economy in Europe — Developing the knowledge base

LCA at Vestas, available reports

Kalundborg industrial Symbiosis http://www.symbiosis.dk/en

New materials and the circular economy, https://www.the-ies.org/sites/default/files/journals/ES_March2015_new-materials.pdf

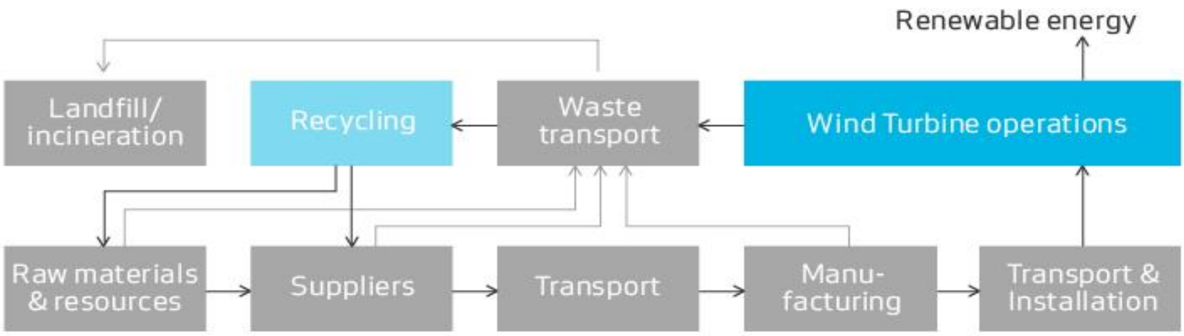
Worldsteel http://circulareconomy-worldsteel.org/

Waste Management of End-of-Service Wind Turbines, Aalborg University
http://projekter.aau.dk/projekter/files/213319772/Waste_management_of_end_of_service_wind_turbines.pdf

APPENDIX 2 PROVIDING TRANSPARENCY THROUGH LCAS

The following section examines the LCA implications of repairing a gear box in terms of CO2, resource saving and circularity indicator[10]. Vestas has investigated this for a gearbox and generator repair.

Life cycle assessments (LCAs) according to the ISO 14040/14044 standards are commonly used to evaluate the positive and negative environmental aspects from a turbine/wind farm across its life cycle stages. LCAs provide a comprehensive and consistent way to evaluate the potential environmental impacts at different life cycle stages of a wind farm, e.g. material extraction, manufacturing, construction, assembly and installation, operation and service, end of service and dismantling[11]. The studies assess a wind turbine's entire bill-of-materials accounting for the approximately 25,000 parts that make up a wind turbine. In a Life Cycle Assessment, a complete wind power plant is assessed up to the point of the connection to the electricity grid, including the wind turbine itself, foundation, site cabling and the transformer station.



The environmental aspects can be assessed based on a number of impact categories, e.g. climate change, resource use, land use, toxicity, etc. However, most wind related LCAs use climate change in terms of CO2 equivalents per unit (1 kWh) electricity generated which enables a comparison with other energy sources. The majority of greenhouse gas estimates range between 8 and 20 grams CO2 eq. per kWh[12] but a review of LCA studies since 1980 found a range between 3 and 45 grams CO2 eq. per kWh[13]. The most significant life cycle stage is manufacturing, which is corresponding to materials used in terms of amounts and types.

[10] https://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_Project-Overview_May2015.pdf

[11] EWEA (2009) Part V Environmental issues in EWEA 2009 Wind energy - the facts. A guide to the technology, economics and future of wind power. Routledge http://www.wind-energy-the-facts.org

[12] Wiser, R., Z. Yang, M. Hand, O. Hohmeyer, D. Infield, P. H. Jensen, V. Nikolaev, M. O'Malley, G. Sinden, A. Zervos, 2011: Wind Energy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[13] Dolan, S.L., Heath, G.A. 2012. Life Cycle Greenhouse Gas Emissions of Utility-Scale Wind Power. Systematic Review and Harmonization. Journal of industrial ecology 16. DOI: 10.1111/j.1530-9290.2012.00464.x