How sustainable are offshore windfarms? An assessment to quantify local to global (socio-) environmental impacts of a case study in the Belgian Continental Shelf

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Demand for sustainable energy is increasing worldwide to meet climate-neutrality targets (IEA, 2022). To meet this demand, the contribution of renewable energy sources, such as offshore wind energy, is crucial in the provisioning of global energy by 2050 (Carrara *et al.*, 2050). The offshore wind industry is expected to scale-up; in the EU alone, the total installed capacity will rise to 300 GW by 2050 (European Commission, 2020). Despite the benefit of electricity generation, the expansion of offshore wind farms (OWFs) can lead to local to global negative and positive impacts. To better understand the benefits and burdens of an OWF, a holistic sustainability assessment that incorporates these geographical impacts at different scales should be applied. To provide this full assessment, methodologies such as life cycle assessment (LCA) and ecosystem services assessment (ESA) can be combined or integrated. In this study, a recently developed LCA_{+ES}-ESA sustainability framework (Taelman *et al.*, to be submitted) was used to study the monetized (socio)-environmental footprint (burdens) and handprint (benefits) of an OWF in the Belgian Continental Shelf (BCS). This framework combines two ways of integrating LCA and ESA to capture the site-specific and site-generic effects on ecosystem services (ES) over the life-cycle of an OWF (i.e. manufacturing, transport, installation, operation and maintenance and end-of-life). While for most life cycle stages the impacts on ES were quantified in a site-generic way using newly developed characterization factors, the impacts on local marine ES were quantified for the operation and maintenance stage of the OWF. To apply the framework, different types of data (i.e. technological, biological, monetary) were collected extensively. Also, an environmental LCA was conducted using an adjusted ReCiPe (H) method to quantify the global positive (i.e. avoided materials an energy) and negative (i.e. burdens from impact categories) of the OWF. The results are monetized and then aggregated into three Areas of Protections (AoP), i.e. human health and well-being, ecosystem quality and natural resources, which are expressed in €/Gwh. Overall, the results show that the OWF has a net handprint, which is mainly due to the production of electricity and related to the AoP natural resources. Despite this large handprint, the OWF also has footprint attributed to the supply chain (i.e. manufacturing stage), which mainly affects the AoP human health and well-being. We also compared the (socio-) environmental performance of an OWF with that of a nuclear power plant (i.e. the benchmark), as nuclear energy is the largest source of electricity in Belgium. This study has a valuable contribution in the application a a comprehensive sustainability framework in a marine context and to a better understanding of the handprint and footprint of offshore wind energy, which can support decision-making.

References

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Keywords

Offshore wind farms; sustainability; ecosystem services; marine ecosystems; handprint; footprint; human activities; energy