Challenges of Greenhouse Gas Assessment of Offshore Wind Farms at the Early Design Life-stage

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1. Introduction

Motivation for GHG assessments of Offshore Wind Farms (OWF):

- identifying which specific processes and life stages make a substantial contribution to the carbon footprint for further reduction of GHG
- informing OWF design decisions
- comparing lifecycle GHG emissions of different projects.

Present assessments show that OWF generate enough electricity during their lifetime to offset their lifecycle GHG emissions [1] and that emissions resulting from electricity generation with wind energy are one of the lowest of any other sources of electricity per kWh [2]. However, there is still a need for OWF GHG assessments.

2. LCA studies review

GHG emissions assessment can be a part of a Lifecycle assessment (LCA). Although principles, framework and requirements for LCA are set by ISO standards (14040 and 14044), boundaries, databases and software used can vary between the studies.

To better demonstrate how LCA methods influence the LCA process and the interpretation of final results, Figure 1 maps what assumptions have to be made both when inputting data into assessment and when attempting to interpret the results. The LCA inputs were split into project inventory which lists all the components and activities through the lifecycle and emission database that allows to translate the inventory into emissions. LCA Outputs include metrics most used in the reviewed studies as shown in Figure 2.

For this project, methods from twenty-four OWF LCA published in peer-revied journals were compared. The focus was on the output metrics, boundaries, and data used.

3. Review results

Based on the review of LCA of OWF studies, the most commonly used practises were described and compared (Fig. 3):

- The boundaries common across almost all of the studies covered resource extraction, component manufacturing, installation, transportation, and disposal of turbines and transmission system as well as operation and maintenance.
- A third of studies aligned with the ISO standards.
- Three quarters of studies used Ecoinvent as emission factors database.
- Two thirds of studies considered recycling.
- Most studies based O&M assumptions on literature review.
- Only a few studies accounted for the electricity losses due to transmission to the shore.
- Many studies didn't disclose all the methods used which result in high % of unknown 'UN'.

4. Key Challenges of OWF GHG assessment

- Limited inventory data due to lack of detailed design and data from manufacturers not being accessible.
- Current methods not being fully adapted to account for future scenarios such as changes to inventory and result interpretation:
  - decarbonisation of maritime industry
  - changes in turbine manufacturing and recycling technology
  - type and intensity of displaced emissions.
- Difficulty in comparing results of different studies as varying methods used might have considerable influence on the results.

This makes defining boundaries and methods more challenging for projects at early-design stages.

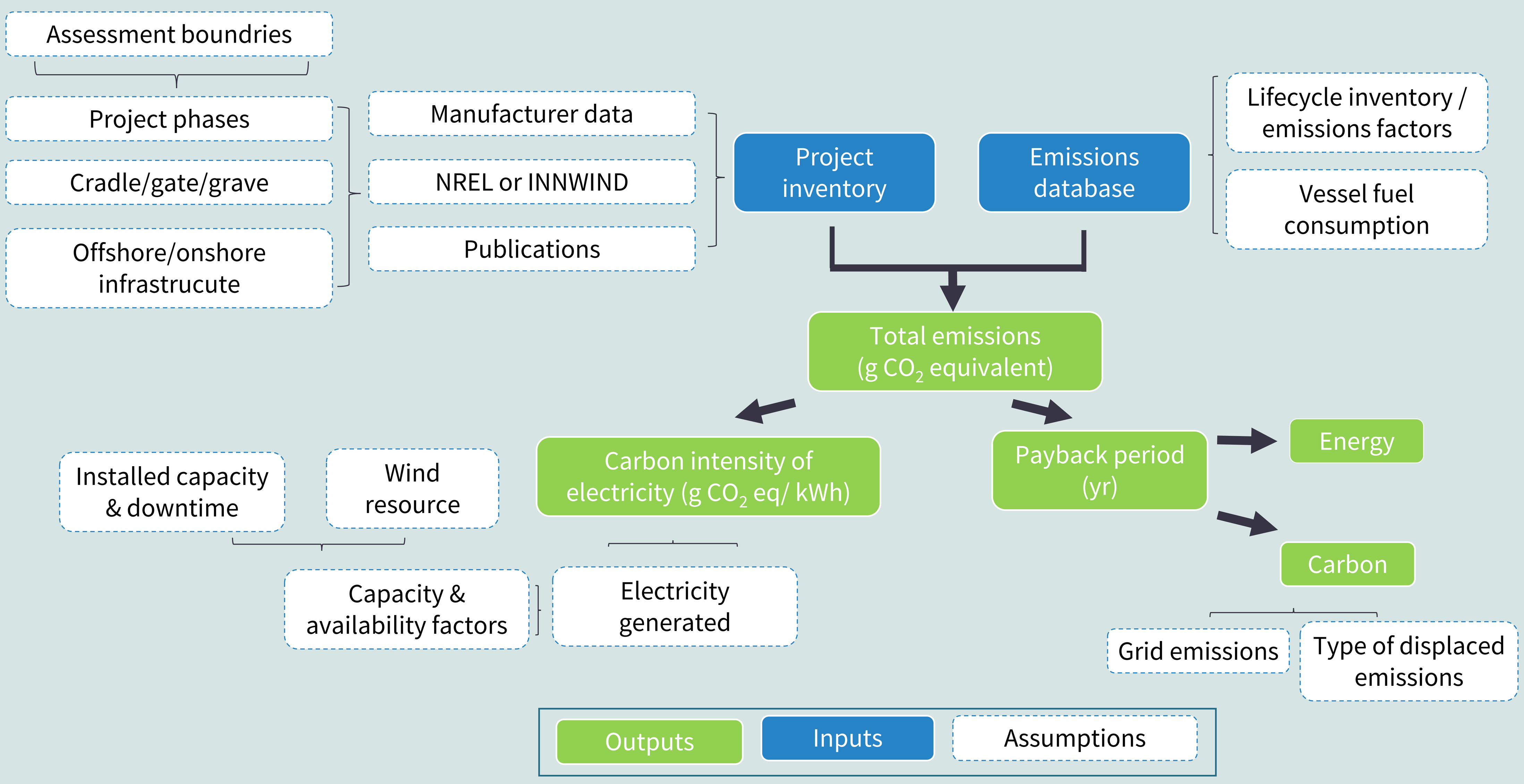

Fig. 1. Flow chart showing assumptions behind a GHG assessment.

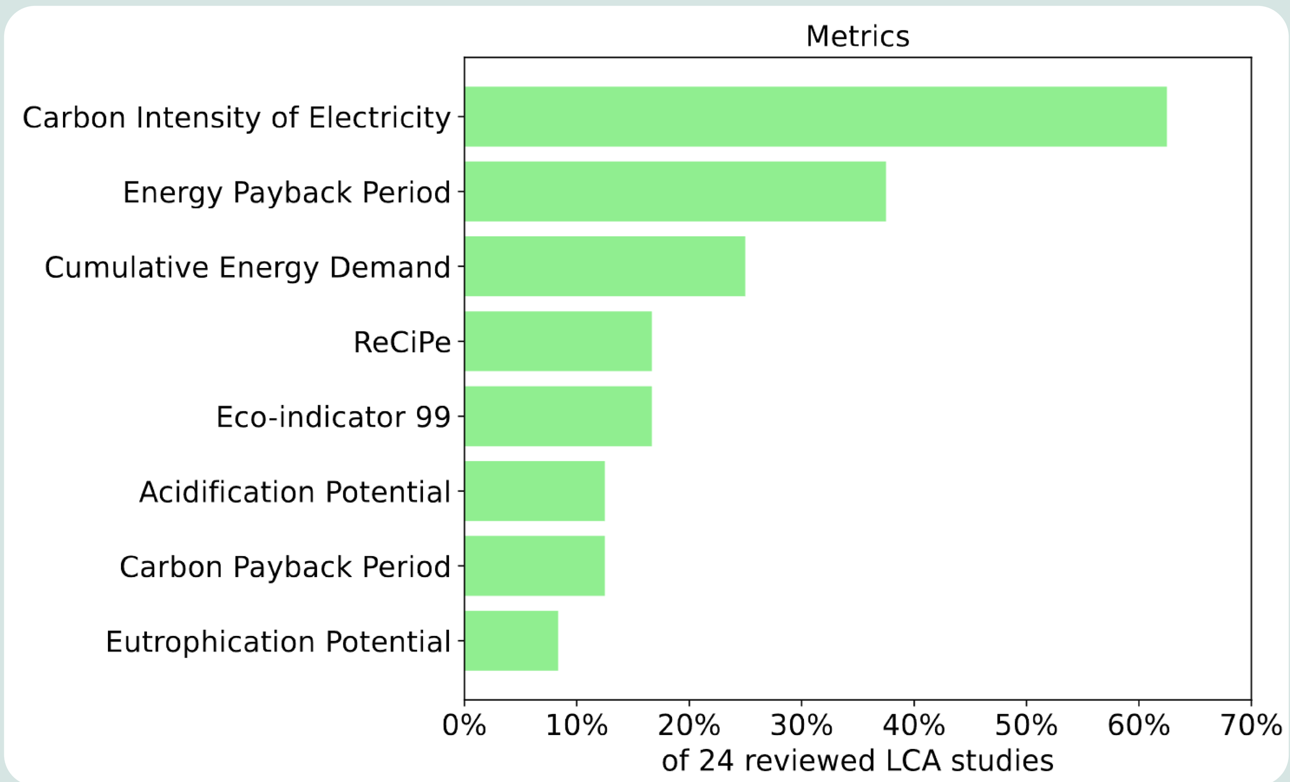

Fig. 2. List of metrics most commonly used in LCA results of OWF in the reviewed studies. ReCiPe and Eco-indicator 99: assessment methods that return numerical scores from multiple environmental and social inputs.

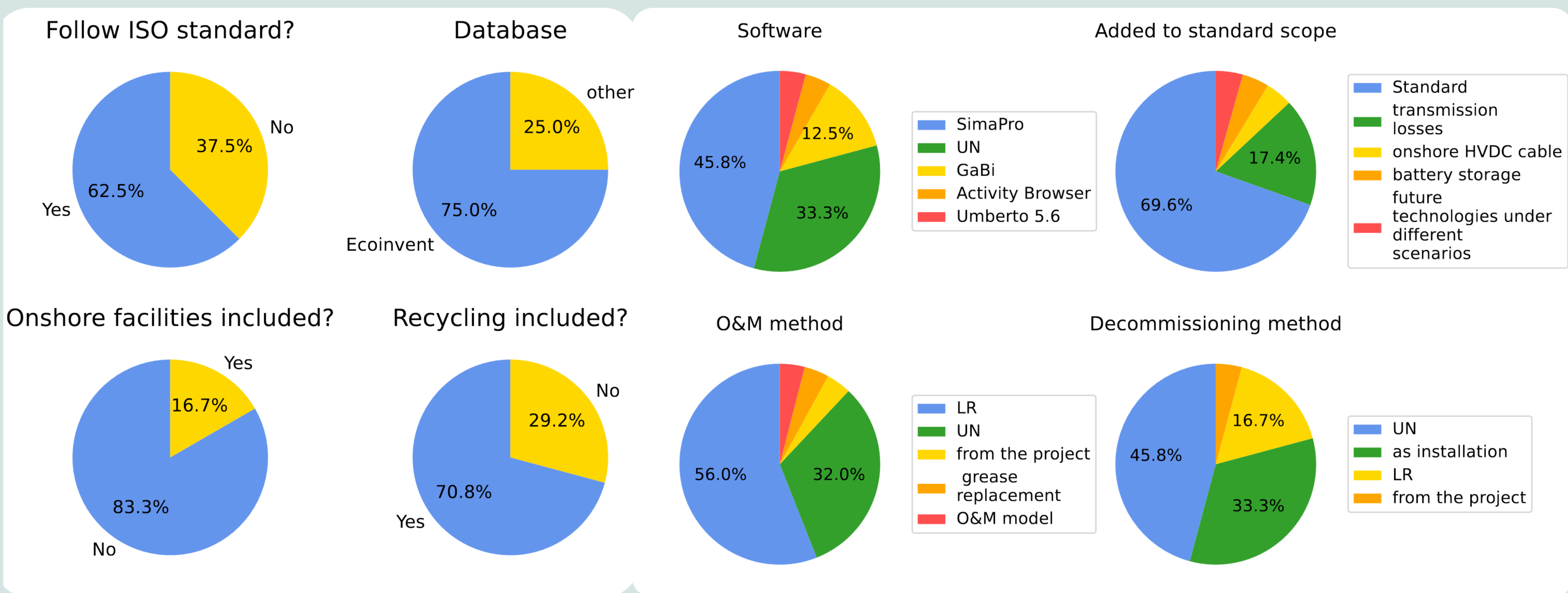

Fig. 3. Review of methods used in the reviewed 24 LCA of OWF. ISO standard refers to ISO 14040 & 14044, UN – unknown, not specified in methods, LR- methods based on literature review. Standard scope covered resource extraction, component manufacturing, construction, transportation, and disposal of turbines and transmission system as well as operation and maintenance.

5. Conclusions

- GHG intensity of OWF electricity needs to remain lower than that of the displaced energy sources.
- OWF must continue to reduce lifecycle emissions.
- OWF LCA studies often use different assessment methods.
- Need for standardised GHG assessment methods for future OWF.
- GHG assessment should account for future scenarios.

References: **1**. Chipindula et al. (2018). Life Cycle Environmental Impact of Onshore and Offshore Wind Farms in Texas. *Sustainability, 10*(6), 2022 **2**. Osman et al. (2023). Cost, environmental impact, and resilience of renewable energy under a changing climate: A review. *Environmental Chemistry Letters, 21*(2), 741–764.

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