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1. Introduction

The development of robust and reliable renewable energy systems (RES) at large scale to satisfy the increasing energy demand and replace the use of non-renewable fossil energy resources while reducing the adverse impacts currently represents a major challenge from both socio-economic and environmental perspectives [1]. Although RES are expected to have low resource consumption and pollutant emissions during the electricity production phase, manufacturing and end-of-life phases should be accounted for to ensure the environmental benefits compared to conventional energy systems. In this study, we propose the use of a geolocated Life Cycle Assessment (LCA) to evaluate the environmental performance of emerging RES. To build up the methodology, a pilot project of a floating offshore wind farm to be installed in the Mediterranean coast of France by 2021 has been selected as a reference case study.

Since the environmental performance is generally expressed as the ratio of the total impact of the technology over its life cycle to the corresponding electricity production [2], accurate estimates of both terms are essential for a reliable LCA. The total environmental impact over the life cycle of a given energy system strongly depends on the quality of the data collected during the inventory phase. However, even when the total impacts are based on high-quality inventory data, the environmental performance can be to a large extent affected by variability related to the electricity production [3]. Estimating the electricity production may be particularly challenging in the case of emerging RES, for which few or no installations are in operation yet, due to the absence of historical data of this production. The influence of uncertainty is especially significant for emerging technologies based on variable resources such as wind or solar irradiation.

As explained in more detail in the following section, we have coupled in this study a comprehensive life cycle inventory and impact assessment based on primary data from project suppliers to a geolocated parameterized model to estimate the electricity production from existing meteorological databases. The geolocated LCA model allowed obtaining the environmental performance of the facility for different impact categories and identifying the main phases and parameters contributing to these impacts.

2. Materials and methods

The life cycle impacts of the analyzed emerging RES were evaluated according to an attributional LCA with a cradle-to-grave scope. Since the wind farm components and associated suppliers were already defined at this point of the project, the inputs and outputs to the 6 stages of the system (i.e. materials, transport & assembly, installation, grid connection, maintenance and end-of-life) were mainly provided by direct measures from the project suppliers. The information was completed by calculations from the project technical team. The background data were obtained from ecoinvent database v3.3 [4]. The total impact over the life cycle of the system was assessed according to 7 mid-point categories selected according to the ILCD recommendations [5].

The electricity production over an assumed 20-year lifetime was estimated according to a 3-step approach: 1) obtaining of the parameters describing the geolocated wind resource from existing data sources, such as ANEMOC-2 and MERRA-2; 2) estimate of the power curve model specific of the wind turbine from data obtained from the online simulation tool Renewables.ninja [6] and 3) estimate of the net electricity production over the life time of the wind farm from the elements obtained in steps 1 and 2.

3. Results and discussion

The application of the geolocated LCA model to the pilot floating wind farm and associated environmental performance results are presented in Figure 1. Besides a reference scenario based on the specific design of the projected wind farm and the electricity production estimates from ANEMOC-2 database, alternative scenarios were compared, including different assumptions related to transport, floater materials and wind farm lifetime, as well as a different wind resource database (namely MERRA-2).

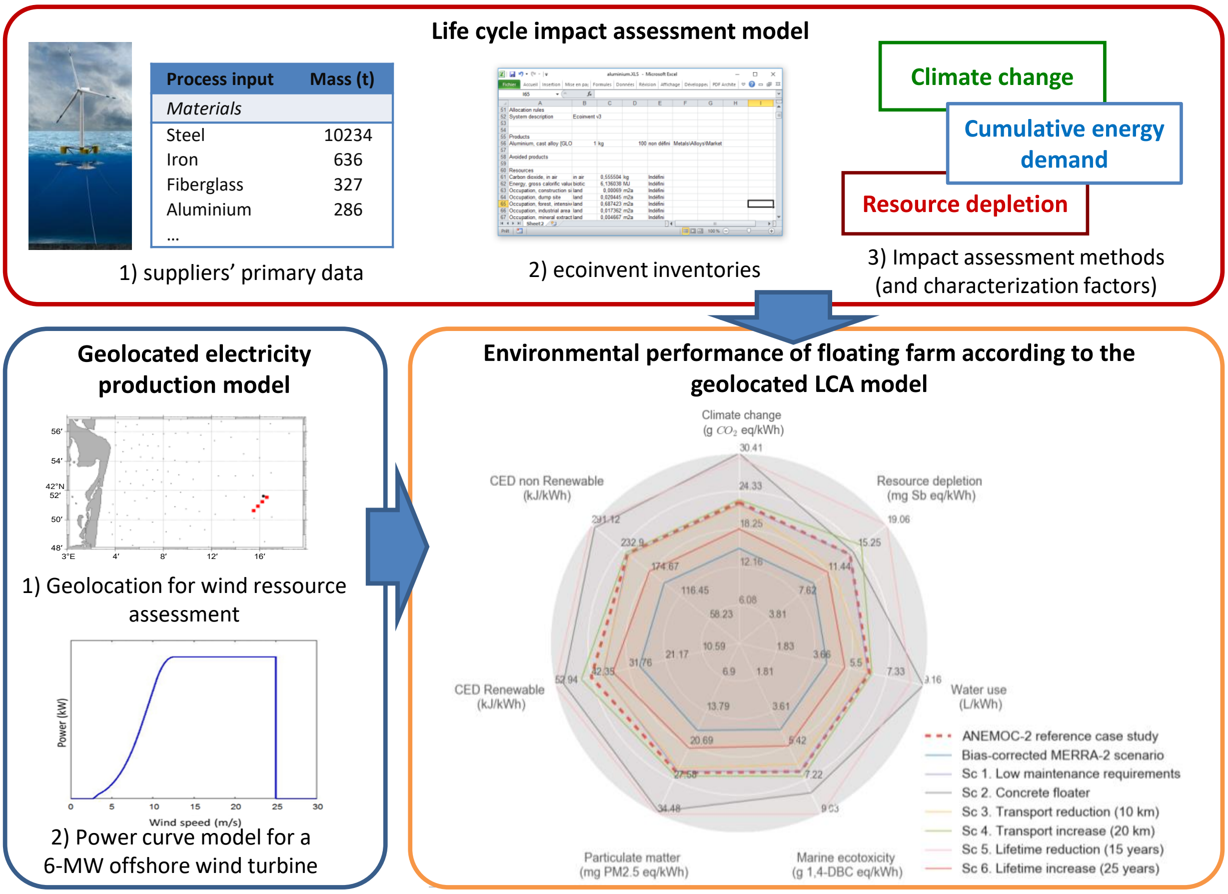

Figure 1: Components of the geolocated LCA model and environmental performance results for the baseline scenario based on ANEMOC-2 database and alternative scenarios evaluated in the sensitivity analysis

The wind data source proved to be a critical factor influencing the environmental results, since the differences between ANEMOC-2-based and MERRA-2-based electricity productions lead to 30% reduction of the environmental impacts per kWh produced. The system's lifetime (also related with the production) and materials were identified as other key components affecting the outcome of the study. The effect of the differences in the electricity production estimates could vary depending on the location, hence, the interest of building a geolocated parameterized model to allow estimating this production from different data sources.

4. References

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