Environmental impact for offshore wind farms: Geolocalized Life Cycle Assessment (LCA) approach

Catherine Guermont, Lionel Ménard, Benoît Gschwind, Isabelle Blanc, Thierry Ranchin

Environmental impact for offshore wind farms: Geolocalized Life Cycle Assessment (LCA) approach

Catherine Guermont[1], Lionel Ménard[1], BenoitGschwind[1], Isabelle Blanc[1] and Thierry Ranchin[1]
[1] MINES ParisTech, Centre Observation, Impacts, Energy
1 rue Claude Daunesse, CS 10207, Sophia Antipolis cedex, France
catherine.guermont@mines-paristech.fr, lionel.menard@mines-paristech.fr, benoit.gschwind@mines-paristech.fr, isabelle.blanc@mines-paristech.fr, thierry.ranchin@mines-paristech.fr

Abstract. This paper presents an approach for Environmental Impact Assessment through the use of geolocalized LCA approach, for fixed and floating offshore wind farms. This work was undertaken within the EU-sponsored EnerGEO project, aiming at providing a versatile modeling platform for stakeholders allowing calculation, forecasting and monitoring of environmental impacts of different sources of energy. This paper described the geolocalized LCA approach, and its use for the evaluation of environmental impacts of wind energy. The effects of offshore wind farms on global environnemental impacts are evaluated though the LCA approach. It takes into account the type of wind farm, the construction phase, all technical aspects, the operation and maintenance scheme and the decommissioning. It also includes geolocalized information such as wind resources, bathymetry, accessibility … Environmental impact parameters are accessible through a web service helping the decision makers in assessing the environnemental impacts.

1 INTRODUCTION

In order to face to climate change and decrease its dependence to energy, the EU has implemented three targets to be met by 2020 (EC, 2007). These so-called "20-20-20" targets aim at reducing the EU greenhouse gas emissions by at least 20% (below 1990 levels), increasing its average renewable energy share to 20% by 2020, and reducing its primary energy use by 20% compared to projected level for 2020. Reaching these goals needs to evaluate the global environmental impacts caused by energy generation in

Europe and the impacts of the proposed changes. No energy generating system is neutral for the environment: renewable or not, they all require primary energy and materials to manufacture operate and maintain their components. Moreover, the environmental performances of electricity generation (environmental impacts per amount of electricity produced) depend strongly on technical, methodological and geographical parameters (IPCC, 2011), (Padey *et al.*, 2012). Only a geo-dependent life cycle assessment (LCA) can handle geographical and technical issues when assessing the global environmental performances caused by electricity generation (Menard *et al.*, 2011). The FP7 co-funded project EnerGEO[1] has been launched in this perspective. Organized according to different pilots dealing with fossil fuel, biomass, solar energy and wind energy, EnerGEO aims at developing a global observation strategy to monitor and forecast the environmental impacts generated by energy resources exploitations.

This paper reports the outcomes of the EnerGEO offshore wind pilot whose main objective is to support environmental policy regarding wind energy. As a renewable energy source, wind energy has a major role to play in realizing the “20-20-20” targets. Indeed, projected technical potential for wind energy development in Europe within 2020 reaches 70,000 TWh (EEA, 2009), and wind mills are identified as a very low CO_2 equivalent emission technology (Weisser, 2007). Focusing on offshore wind energy, this pilot aims at giving an easy and free access to potential environmental impacts caused by electricity generation from a wide range of configurations and locations of offshore wind farms. A special interest is given to Northern Europe as offshore wind energy is expected to be widespread in this area in coming years (EEA, 2009).

2 GEOLOCALIZED LIFE CYCLE ASSESSMENT

The wind pilot encompasses several environmental databases which are used to provide information products for decision makers, as well as for the LCA. The databases cover north-west Europe and a part of the Atlantic. The data set includes: an 11-year wind database, a 20-year wave database, a map of the distance to shore for all offshore locations, a map of the distance to the nearest accessible harbor and a high-resolution depth chart.

2.1 Life Cycle Assessment principles

LCA is a method for studying and quantifying the environmental impacts of a product, a system or a service during its whole life cycle. This approach models impacts of a system from extraction of raw materials, including energy and transportation necessary for its manufacturing until the decommissioning or recycling phase of its end of life (see fig. 1). LCA is also called a cradle-to-grave analysis.

[1] http://www.energeo-project.eu

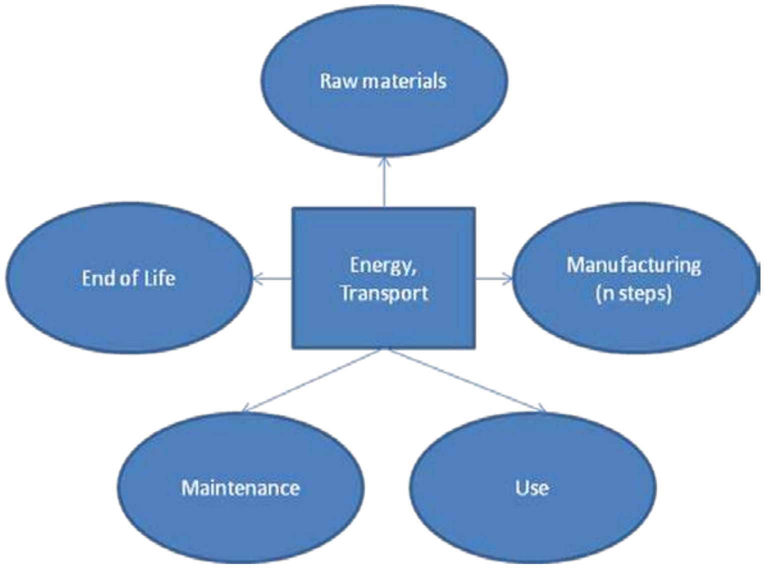

Fig. 1. LCA model

This approach was initiated in the 70's, in order to find ways to limit the energetic consumption during the design of a product. Then it was improved in order to include other types of indicators such as greenhouse gas emissions, aquatic toxicity, health impacts … It is a multi criteria approach.

This approach became a reference for environmental impact assessment and thus was normalized (ISO 14040:2006) with a methodology to follow in order to apply a LCA.

2.2 Including geo-dependent parameters in LCA of offshore wind farms

The different key components and processes characterizing an offshore wind farm have been identified. They include wind turbines (moving parts and fixed parts), transmission cables (used for the high voltage substation connection to shore), collection cables (used for turbines connection to offshore high voltage substation) and maintenance scheme (which depends on distance between the farm and the nearest relevant harbor) (See fig. 2). Apart the wind resources which are by nature geo dependant, to make our wind farm LCA model geo-dependent, we have considered all the farm's site-sensitive components and processes such as:

- The length of sub-marine cabling, which is influenced by the distance of the farm to the coast
- The marine transport scheme, which depends on distance to the relevant nearest harbor
- The foundation choice (floating vs. fixed), which depends on water depth

As a consequence, the wind farm's components that depend on these geo-dependent parameters have been modeled as a function of them. For example, the LCA of the transmission cables used to connect the high voltage transformer to coasts has been performed for one km; resulting impacts have then been combined with our variable representing distance to coast. Each identified geo-dependent parameter has been defined as a variable of our algorithm to be combined with the farm's components LCA results.

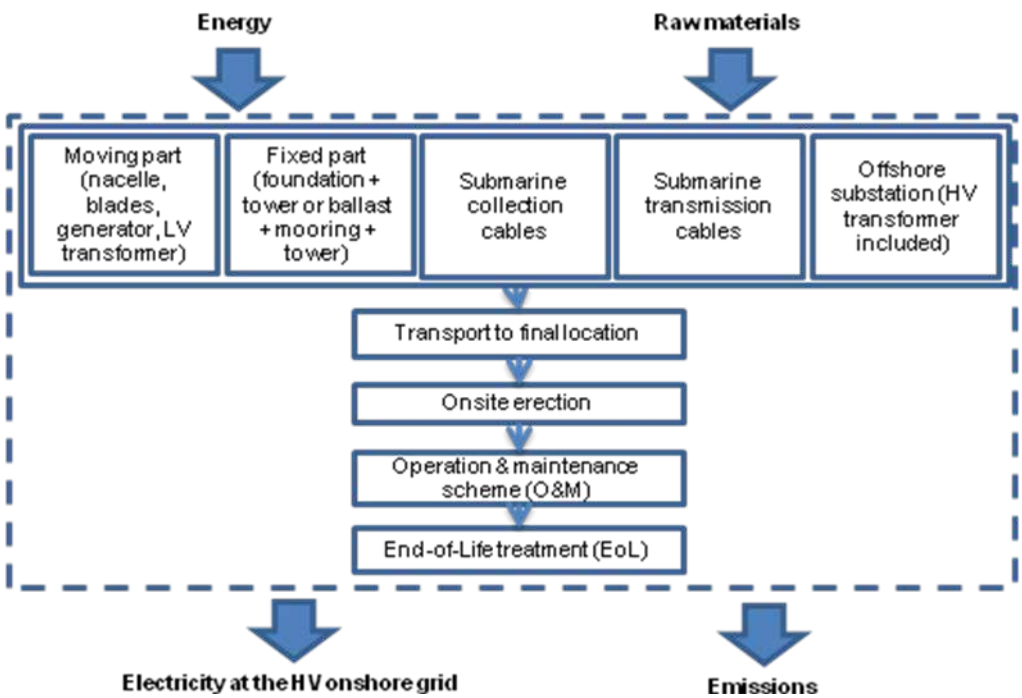

Fig. 2. Components considered for the offshore modular LCA model

2.3 Additional Parameters for realistic configurations

Taking advantage of this modular offshore wind farm model, additional parameters have been included in order to build different realistic configurations:

- The number of wind turbines per farm
- The life time of wind farm
- The type of maintenance scheme
- The failure rate level

The number of wind turbines is an integer limited by the physical capacity of the different components (cables, transformer, turbine…), the life time of wind farm is expressed in years, and the maintenance scheme and the failure rate are defined according to a range of realistic scenarios.

3 WEBGIS CLIENT TOOL

The environmental data sets and life cycle analyses are integrated into a WebGIS client tool2. This WebGIS client is easily accessible from the Internet and is meant to be used by energy operators, energy policy decision-makers as well as offshore wind parks developers. Fig. 3 shows a screenshot of the client tool. The environmental impacts and supporting data are visualized in the form of maps. These maps have been deployed in a GeoServer as Web Map Services (WMS) to ease their dissemination in line with previous works (Ménard *et al.* 2012). WMS is a standard defined by Open Geospatial Consortium (OGC) and follows the interoperability rules of the Global Earth Observation System of Systems (GEOSS)

The client tool can be used to perform a life cycle assessment for wind parks (Blanc *et al.* 2012). The environmental data on which the life cycle assessment is based can also be visualized separately. In order to achieve this, all the information described in this paper were added to the client tool in the form of map layers. These maps are prepared in advance (e.g., workability maps, wind speed maps, etc.). They are presented on an equidistant latitude-longitude grid. Since the original wind database uses a Lambert projection, the data had to be converted to the regular lat-lon grid using Delaunay triangulation. When clicking on a specific area of the map, the numerical value of the corresponding variable appears.

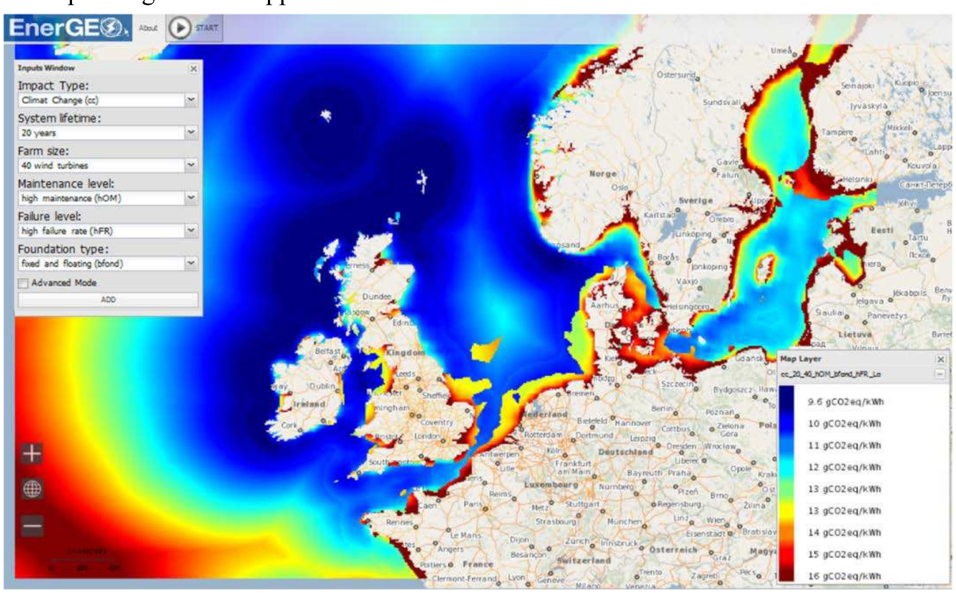

Fig. 3. Screenshot of the web map service developed for EnerGEO, showing an

[2] http://viewer.webservice-energy.org/energeo_wind_pilot/index.htm

environmental map for climate change expressed in g CO2 eq/kWh (source: http://viewer.webservice-energy.org/energeo_wind_pilot/index.htm).

4 CONCLUSION AND PERSPECTIVES

In this paper, we present a geolocalized LCA approach for evaluation of environmental impacts of offshore wind farms. Two types of wind farms are considered, fixed and floating. Geolocalized parameters are included in order to provide a realistic view of the impacts of offshore wind energy. A Web-GIS client is available allowing decisions makers to simply handle environmental impacts of implementing a wind farm in a specific area.

The modular structure of the work allows to easily improving the tools by including new parameters such as new types of wind mills. The perspective of the work is to include such an evaluation in a more global approach allowing the decisions makers to built scenarios for energetic transition. This is part of the work handled by the EnerGEO project.

REFERENCES

Blanc, I., Guermont, C., Gschwind, B., Menard, L., Calkoen, C., Zelle, H. (2012): Web tool for energy policy decision-making through geo-localized LCA models: A focus on offshore wind farms in Northern Europe. EnviroInfo 2012 - 26th International Conference on Informatics for Environmental Protection. Shaker Verlag, Part 2: Open Data and Industrial Ecological Management, pp. 499-506 - ISBN 978-3-8440-1248-4

EC, *Communication from the Commission to the European Parliament, the Council, the European economic and social committee of the regions - COM 2007.* (2007): Commission of the European Communities.

EEA. (2009): *Europe's onshore and offshore wind energy potential, An assessment of environmental and economic constraints,* EEA Technical report n° 6.

IPCC *Special Report on Renewable Energy Sources and Climate Change Mitigation.*; Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Seyboth, K.; Matschoss, P.; Kadner, S.; Zwickel, T.; Eickemeier, P.; Hansen, G.; Schlömer, S.; von Stechow, C. (2011): Eds.; Cambridge University Press: United Kingdom and New York, NY, USA, 2011.

ISO 14040:2006 – (2006) Environmental Management - Life cycle assessment - Principles and framework.

Menard, L., Gschwind, B., Blanc, I., Beloin-Saint-Pierre, D., Wald, L., Blanc, Ph., Ranchin, T., Hischier, R., Gianfranceshi, S., Smolders, S., Gilles, M., Grassin, C. (2011): Environmental impact assessment of electricity production by photovoltaics system using GEOSS recommendations in interoperability. In Proceedings of the 25th Enviroinfo Conference "Environmental Informatics", October 2011. Ispra (Italy). Part 2, pp.765-774.

Padey, P., Blanc, I., Le Boulch, D., Zhao, X. (2012) : A simplified life cycle approach for assessing greenhouse gas emission of wind electricity. *Journal of Industrial Ecology*, Issue supplement s1, s28-s38. doi : 10.1111/j.1530-9290.2012.00466.x

Weisser, D. (2007): A guide to life-cycle greenhouse gas (GHG) emissions from electricity supply technologies. *Energy*, 32 (9), pp. 1543-1559.