Environmental impacts of ocean energy devices: Life Cycle Analysis

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INTRODUCTION

Up to date, population growth and global industrial development have sustained an increase in energy demand. Fossil fuels are the most widely used source of energy. Nevertheless, the reserves of these fuels are limited and their use on a large scale contributes significantly to the Climate Change (CC), through the Greenhouse Gases (GHG) emissions [1]. In that regard, global energy policy has developed strategies for energy generation from renewable sources. Among these is ocean energy, which in recent years has seen a considerable increase in research development and application. In this sense, it is of great importance to evaluate these technologies under an environmental approach, taking into consideration the possible environmental impacts that these systems can generate throughout their life cycle. Life Cycle Assessment (LCA) is a methodology designed to quantify the environmental impacts of a technological system during its life cycle [2]. Therefore, the objective of this study is to evaluate the environmental impacts of ocean-based power generation technology systems applying LCA methodology. As an outcome, critical stages of the systems evaluated are identified, along with areas of opportunity for ocean energy technologies.

METHODOLOGY

LCA is a methodology that allows the identification of global environmental impacts generated by a process or system, considering since the raw material extraction until the end of its useful life cycle, considering the final disposal of the technology. Figure 1 shows the stages that conform an LCA, all of which are interrelated. The main objectives of LCA are to reduce the use of resources and emissions into the environment, as well as to improve the social/environmental/economic performance of a system and/or service throughout its entire life cycle. This can enable the relationship between the economic, social and environmental dimensions within an organization and along the entire value chain [3]. The study of the possible environmental impacts generated by the different ocean energy technologies is still limited at this moment, as well as their likely magnitude. Moreover, possible impacts on the environment can be associated with different stages throughout its life cycle (manufacturing, operation, and maintenance, dismantling and final disposal).

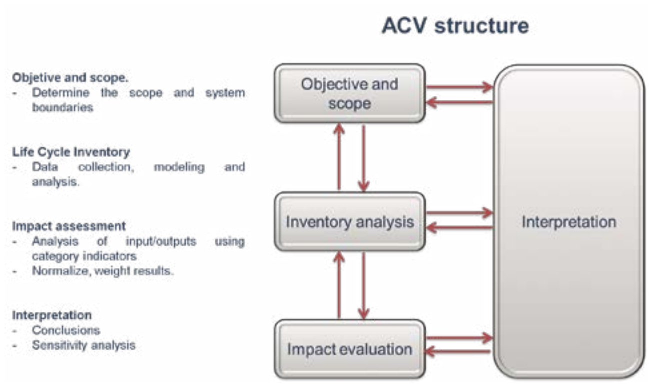

Fig. 1. LCA methodology approach [2].

A general diagram of an LCA study for ocean energies can be seen in Figure 2. However, other LCA studies may have variations in their stages. During the dismantling stage, the waste can follow different paths, including incineration, landfill, recycling, or a combination of them [4]. At this moment, LCA studies for ocean energy systems are limited, analyses have been developed mainly for wave and tidal energy converters, with a focus on field devices [5].

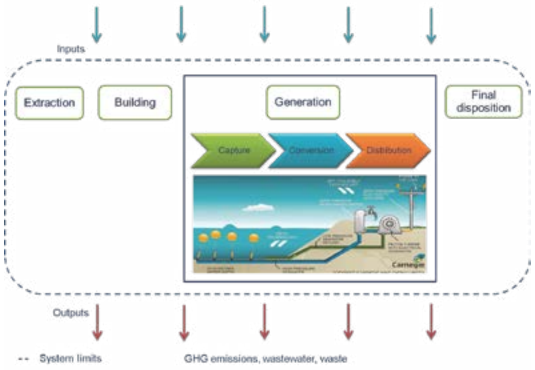

Fig. 2 General scheme of ocean energy LCA.

RESULTS AND DISCUSSION

Considerations for studies of ocean device LCAs were as follows:

- Definition and scope. Developing an LCA for the production of 1kWh of electrical energy from energy technologies: ocean currents and wave energy, under a Mexican context
- System function. Electric power generation.
- System evaluated. ocean current and tidal devices: Impulsa Hydrogenerator and SeaGen Generator.
- System limits. In all the ocean energy technologies evaluated their complete life cycle was considered, from the raw materials extraction, construction, generation and dismantling.
- Time limits. A time limit between 10-20 years of energy production was considered, which corresponds to the operating horizon of ocean power plants.
- Geographical limits. The stages of plant construction and power generation are delimited for the Mexican national territory.
- Impact categories. Climate change, ozone depletion, acidification, marine eutrophication, human toxicity, particulate matter formation, marine ecotoxicity, metal depletion, fossil fuel depletion

LIFE CYCLE INVENTORIES (LCI)

Table 1 shows the materials for the manufacture of the SeaGen Generator and Impulse Hydrogenator. Steel is used for the rotors, concrete for the anchoring system, aluminum is used for the blades and fiberglass for the casing.

Table. 1 LCI of Ocean Energy Technologies

<table>
<tr><th colspan="5">Impulsa Hidrogenator</th></tr>
<tr><th>Materials</th><th>Amount per device</th><th>Unit</th><th>Amount per UF</th><th>Unit</th></tr>
<tr><td>Fiberglass</td><td>100</td><td>kg</td><td>0.0023</td><td>kg/kWh</td></tr>
<tr><td>Aluminium</td><td>200</td><td>kg</td><td>0.0045</td><td>kg/kWh</td></tr>
<tr><td>Steel</td><td>1200</td><td>kg</td><td>0.0274</td><td>kg/kWh</td></tr>
<tr><td>Concrete</td><td>1000</td><td>Kg</td><td>2.289E-05</td><td>kg/kWh</td></tr>
<tr><th colspan="5">SeaGen Generator</th></tr>
<tr><td>Steel</td><td>3954370</td><td>kg</td><td>0.0417</td><td>kg/kWh</td></tr>
<tr><td>Fiberglass</td><td>1683</td><td>kg</td><td>1.776E-05</td><td>kg/kWh</td></tr>
<tr><td>Copper</td><td>1255.8</td><td>kg</td><td>1.325E-05</td><td>kg/kWh</td></tr>
<tr><td>Epoxi</td><td>600.426</td><td>kg</td><td>6.338E-06</td><td>kg/kWh</td></tr>
<tr><td>Foam</td><td>120.22</td><td>kg</td><td>1.269E-06</td><td>kg/kWh</td></tr>
<tr><td>Polyethylene</td><td>0.1749</td><td>kg</td><td>1.846E-09</td><td>kg/kWh</td></tr>
</table>

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

The Impulsa Hydrogenerator device (marine currents) presents the greatest environmental impacts in the construction stage for five impact categories: human toxicity, marine ecotoxicity, marine eutrophication, ozone depletion, formation of particulate matter and acidification. It is worth mentioning that the blades are the components with the greatest impact (Figure 3). Meanwhile, for the SeaGen device (Figure 4) in its construction stage, the tower is the element that requires the greatest amount of material, which is why most of the impacts are related to this element, followed by the upper part of the tower (Top). Interconnection and cabling are especially important in the human toxicity category, due to the manufacture of copper as the main material and the special coatings that it requires. As can be seen, the construction stage is the one with the highest environmental contribution in most of the categories evaluated, this is mainly due to the type of materials used to manufacture the device components. Therefore, the search for alternative materials presents a potential for environmental improvement for these devices, in order to increase their competitiveness in the market.

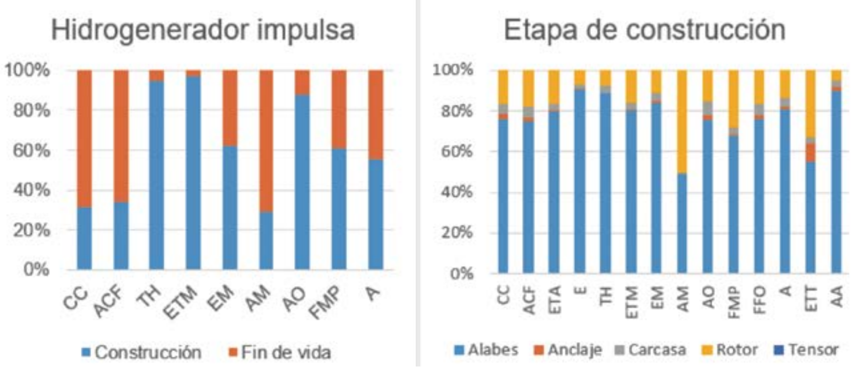

Fig. 3 Normalized environmental impacts for the Impulsa Hydrogenator

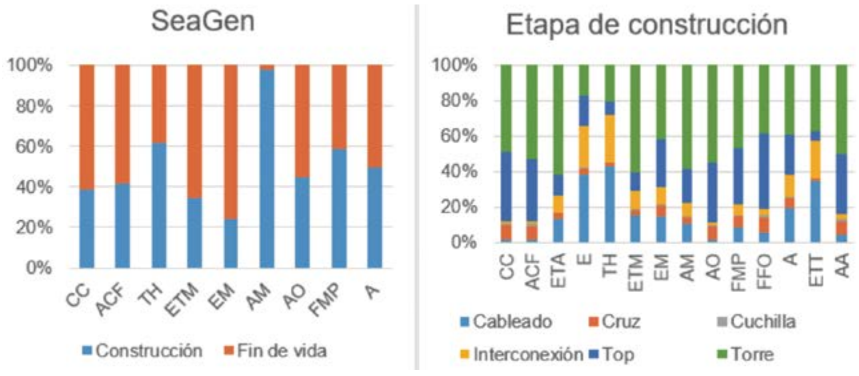

Fig. 4 3 Normalized environmental impacts for the SeaGen Generator

CONCLUSIONS

Ocean energy devices are still in an early stage of development compared to other renewable energy technologies. Wave energy systems will be an important source of renewable energy because it offers an attractive alternative conventional energy (fossil fuels). However, the success of these systems will depend on their availability at low costs, their environmental impact and the ability to generate electricity.

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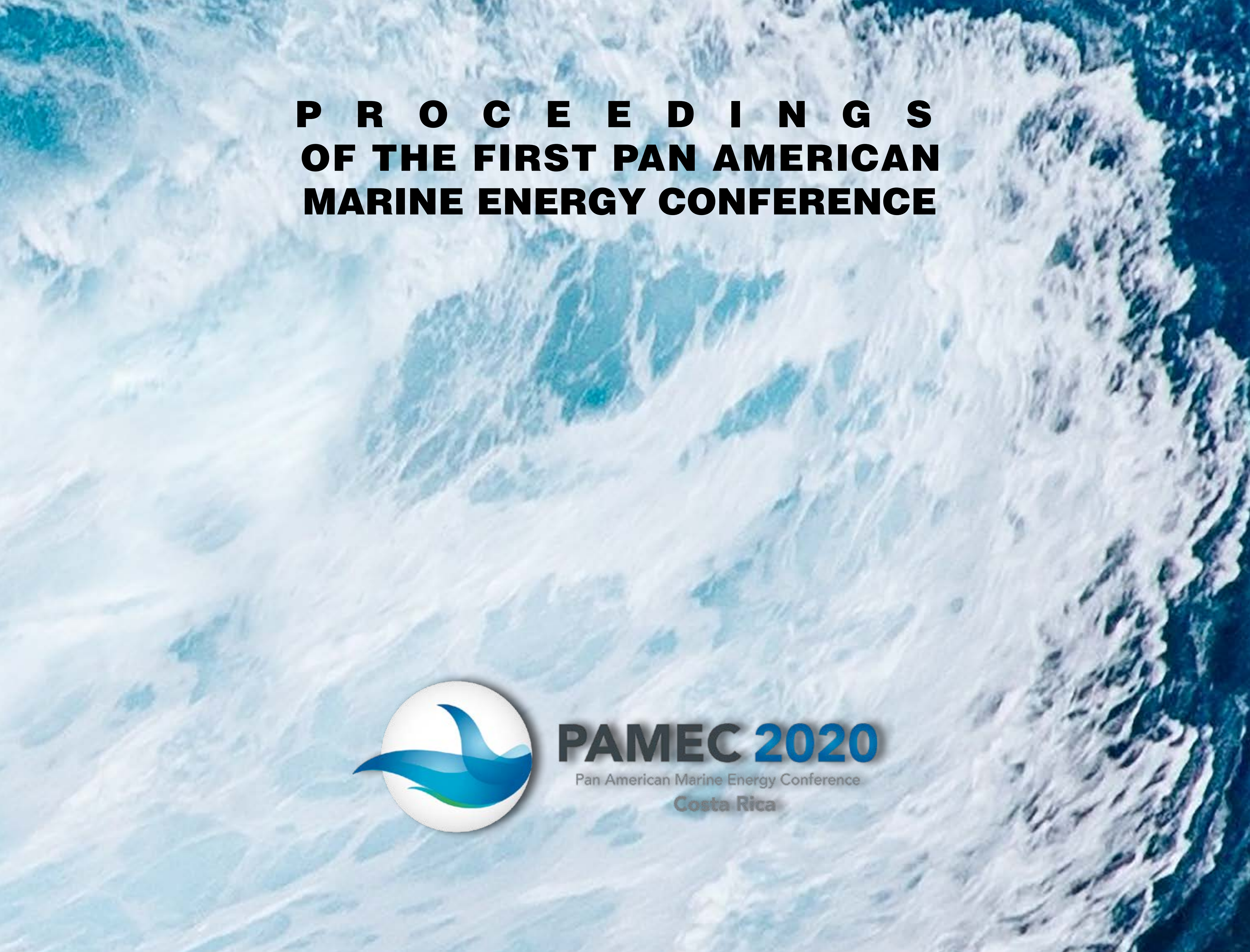

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