Constrained areas renewable energy planning and their end-of-life waste legacy

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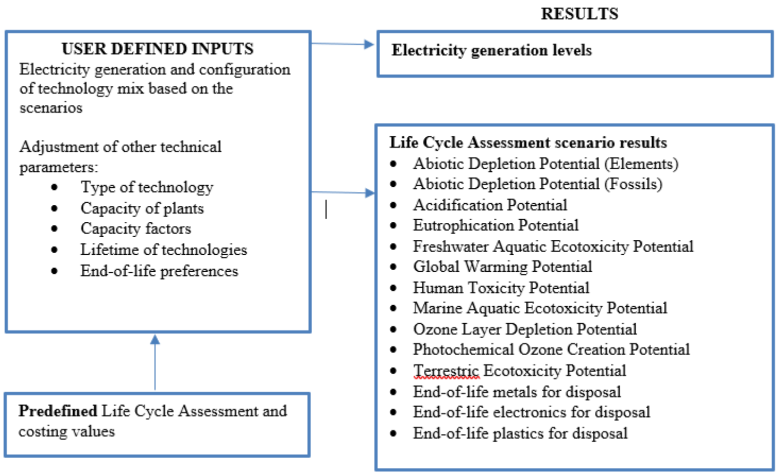
The arising of the climate emergency concept favours the drafting of energy plans that aim to decarbonize the existing electricity provision especially in constrained areas that are easier to manage such as small islands that depend on diesel generators. Nevertheless, choosing the right mix should happen in a way that does not jeopardise the arising of other environmental impacts (Kouloumpis et al., 2015). This avoiding of burden shifting has been focused mainly to other areas (Maier et al., 2017) where the manufacturing of the infrastructure components happens. Along with that, an intergenerational burden shifting might occur due to the potential threat from the arising of environmental impacts due to the waste at the end of life of the renewable energy components. The life cycle assessment (LCA) methodology approach (International Standard Organization, 2006) can take into account the whole life cycle of electricity generation and in particular the end-of-life which can be overlooked. A couple of useful models that incorporate LCA and investigate the impacts of changing the share of renewables in the total electricity generation mix have been developed in the past (Michalena et al., 2018; Stamford and Azapagic, 2012). However, on a local scale, like the small islands which are not connected to the grid, the decisions about infrastructure development must be specified in terms of technology, capacity and generation. Due to time and funding restrictions, it is not easy for local stakeholders to assess the life cycle environmental impacts of adding for example two wind turbines of 2MW capacity in a specific site where they are expected to have a 20% capacity factor. In order to provide the stakeholders with the ability to calculate the lifecycle impact of the renewable energy technologies of their preference we created a tool named Intelligent Community Electricity Lifecycle Technology Impact Calculator (iCELTIC) within the EU-funded project "Intelligent Community Energy (ICE).

The tool is developed in Excel and uses results from LCA studies developed independently. The users can add the type and capacity of their preferable renewable energy technology and see how well these scenarios perform based on a set of environmental and technical criteria as shown in Figure 1.

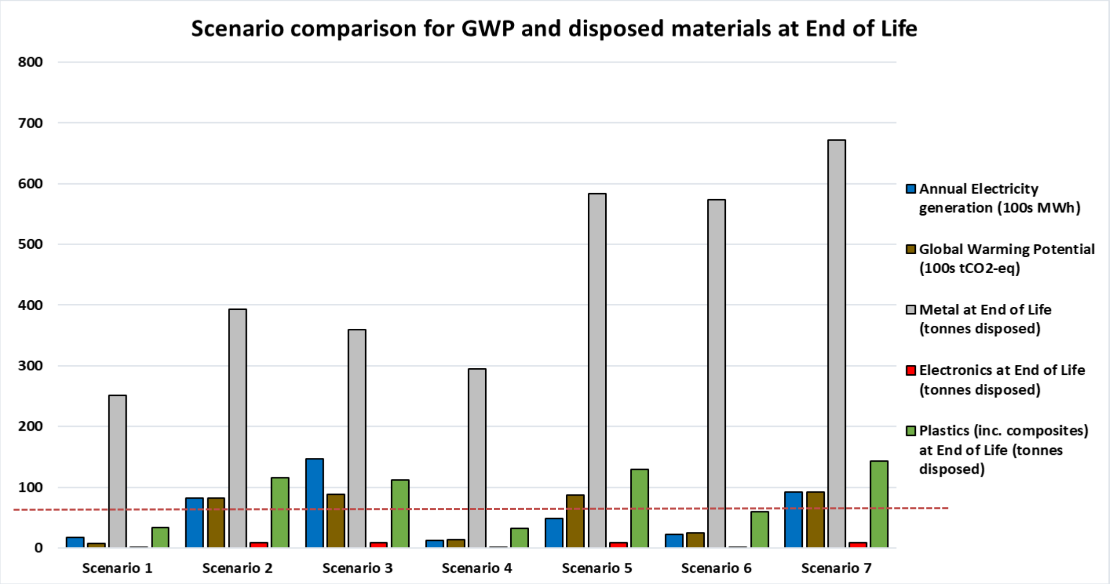


The users defines the desired electricity generation in MWh per annum as well as the names of the plants/installations (e.g. Wind farm name 1) and other technical parameters such as the type of technology (e.g. 300 kW wind turbine), the capacity (e.g. 600 kW) and the capacity factor (e.g. 20%). The tool contains predefined values for the LCA impact indicators per kW based on results of LCA models developed separately using the Ecoinvent and GaBi professional database and software (Thinkstep A.G., 2019; Wernet et al., 2016). The technologies covered include: i) onshore wind of 300kW, 800kW and 2MW capacity, ii) multi-Si roof mounted photovoltaic of 3kWp and iii) tidal turbine of 1 MW capacity based on the technical characteristics of device found in the literature (Howell et al., 2013). After the users input the necessary data, the tool calculates the electricity generated annually and compares that against the value requested indicating whether the set configuration covers that. In addition a set of indicators based on the CML2001 - Jan. 2016 life cycle impact assessment method are calculated, namely: i) Abiotic Depletion Potential (Elements), ii) Abiotic Depletion Potential (Fossils), iii) Acidification Potential, iv) Eutrophication Potential, v) Freshwater Aquatic Ecotoxicity Potential, vi) Global Warming Potential, vii) Human Toxicity Potential, viii) Marine Aquatic Ecotoxicity Potential, ix) Ozone Layer

Depletion Potential, x) Photochemical Ozone Creation Potential, xi) Terrestric Ecotoxicity Potential. Lastly, the material expected to be disposed at the end of life is calculated for a set of metals (aluminium, iron, steel, copper and zinc), for electronics and for a set of plastics including glass fiber reinforced ones used for the turbine blades.

We used this tool to assess the seven scenarios developed within ICE project for the island of Ushant in France for which the annual electricity generation demand has been set to 6808 MWh. Based on the method and the input data we acquired the results illustrated in the graph that follows.

Scenario	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Electricity generated (MWh)	489	4400	5600	1189	4600	2189	5400
Wind 300 kW	300						
Wind 800 kW		800					800
Wind 2MW			2000				
Tidal turbine 1MW				1000	1000	2000	1000
Photovoltaic roof mounted 3kWp	189	3600	3600	189	3600	189	3600



For brevity, we only present the results for the annual electricity generation, global warming potential and aggregated number of metals, electronics and plastics (incl. composites) disposed at the end of life. The results show that only three scenarios (2,3 and 7) satisfy the annual electricity generation requirements and although they all decarbonize the mix, they have different electricity level and material disposal profiles. These highlight the challenges and trade-offs appearing when configuring an optimum renewable energy mix.

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