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Sustainability assessment of electricity production using a logic models approach

Fernando Ribeiro, Paula Ferreira *, Madalena Araújo

University of Minho, Center for Industrial and Technology Management, Campus Azurem, 4800-058 Guimaraes, Portugal

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ABSTRACT

The topic Sustainable Development has brought a wide discussion across a number of sectors in our society, namely in Power Systems. Given the need to address other concerns than the economic ones, decision makers must take into account the rationale that lies beneath strategic choices, such as investing in generation technologies using renewable energy or rather doing business as usual and installing fossil fuel power plants. In this paper logic models were used as a decision-aid supporting tool, with the aim of contributing to the assessment of the possible impacts of different power plants in terms of sustainable development. The analyzed electricity generation technologies were grouped in thermal, renewable energy sources (RESs) and nuclear. The literature review fed the construction of three relational diagrams to allow the visualization of environmental, social and economic causes and effects of the three groups of technologies. Departing from these initial diagrams a set of interviews with experts was conducted to enrich and validate the logic models. The results of the literature review and of these interviews allowed to conclude that the use of RES has wider positive social impacts on the long run, despite their short-term higher costs compared to the traditional groups (nuclear and thermal). These logic models revealed to be a useful tool providing a valuable starting approach for an Impact Assessment of the ongoing change that power systems have been going through.

Contents

1. Introduction

Among the strategies envisioned by the European Union, two of them concern especially power systems: the 20-20-20 and the European Union Sustainable Development Strategy (EUSDS).

1. The EUSDS aims the building of a European Union respecting the inter-generational principle, while achieving full employment through a competitive social market economy and balanced economic growth, among other objectives [1].
2. The 20-20-20, with a horizon of 2020, points to a reduction of 20% of primary energy consumption with the improvement of

* Corresponding author. Tel.: +351 253511670.
E-mail addresses: fernandor@dps.uminho.pt (F. Ribeiro), paulaf@dps.uminho.pt (P. Ferreira), mmaraujo@dps.uminho.pt (M. Araújo).

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energy efficiency, a minimum share of renewable energy of 20% and the reduction of greenhouse gases to 20% below the 1990 values [2].

The authors addressed in past works social issues in power systems planning [3,4]. From the literature related to electricity generation they concluded that the methodologies explicitly expressing economic, social and environmental criteria fall mostly on Multi-Criteria Decision Aid (MCDA). It is clear in the literature that ultimately the economic and environmental criteria still prevail, given the "soft" aspects of the social issues. Additionally, given the inter-relation between different groups of criteria (and the expression "socio-economic" proves it) situations exist where some short term non-optimal cost choices can be supported under the perspective of inducing virtuous cycles of social welfare and long-run economic return, as it is advocated, generally, by many who support investment on renewables, as advocated in National Renewable Energy Plans, for example in the Portuguese case [5].

In these terms, it becomes necessary to organize the rationale behind the support of the strategic importance that different groups of electricity generation technologies assume. This paper aims at contributing to this issue, by exploring the construction of diagrams allowing for the visualization of impact chains associated with different technologies. These logic models should provide a good starting point for an Impact Assessment of the ongoing change that power systems have been going through.

For drawing these models, the paper follows a methodology combining both literature review and participative methods. The application of the methodology is shown for the particular case of the Portuguese electricity system. The results of this work are three logic models, one for each group of electricity generation technology: thermal, nuclear and renewables. The information was gathered using a combination of data gathering using primary sources of literature (consultant reports and government strategy documents) and interviews with experts invited to collaborate with the study team.

The remainder of the paper is as follows: Section 2 overviews the impacts of electricity generation and addresses the need of using logic models framed on an Impact Assessment perspective; Section 3 describes the used methodology; Section 4 presents the structure of the power generation in Portugal, along with the results; Section 5 focuses on discussion. Finally, Section 6 summarizes conclusions and points directions for future work.

2. Impacts of the electricity sector and perspectives for impact assessment

The ongoing changes in the electricity sectors have been influenced by policies aiming to mitigate climate change, "one of the defining challenges of our times", according to the United Nations Development Program [6]. The UNDP calls for the need of integration of climate policies in planning, so that projects that support development – a field where energy has proven to be essential – can better withstand the effects of climate change [6].

The production and use of electricity have environmental and social consequences at local, regional, and global levels. The European Commission maintains that impacts should be assessed over their lifetimes [7]. Although this introduces a good deal of uncertainty for long term impacts, such as those of global warming or high level radioactive waste disposal, to ignore them might suggest that they are unlikely to be of any importance in concrete impact assessment studies. Impact assessment of the energy sector has been widely addressed in the literature; for an overview see for example Jegarl [8], addressing the mitigation of CO_2 in the energy sector, Tolis [9] for electricity expansion planning under emissions allowances and Hugé [10] for general sustainability issues on energy policy. Most of the literature on sustainability implications of power generation appears to belong to renewable energy studies, and they tend to focus on local impacts: for example Del Río & Burguillo [11] review the literature of these aspects, and refer to social cohesion, municipal budget, industry creation and employment. They also address the importance of consuming endogenous resources and research & development induced by the introduction of new technologies.

Sastresa et al. [12] apply a methodology to measure impacts of establishing renewable energy on a regional scale. The impacts measured are job creation and its quality, as well as development of the territory in technological development, per capita income, territorial development and human capital. Another study aiming to rank the different forms of power generation under a number of sustainability criteria, also concluded that these impacts, considered "external benefits", were higher for the renewable forms of power generation. On the other hand, the ranking is the reverse for the economic factors: nuclear represents lowest costs, followed by coal and natural gas [13]. The same study places nuclear power with the lowest CO_2 emissions. Under the CO_2 emissions perspective, nuclear power still shows potential for a contribution, given it is CO_2-free [14]. But the long term impacts of radioactive waste potentially, along with large consequences of an accident such as the recent Fukushima's in Japan, is driving countries to commit to shut down nuclear power plants. On the other hand, the expansion of renewable energy technologies has resulted in increasing opposition in parts of the affected local population because of increasing negative amenity impacts. Potential impacts on local ecosystem from e.g. hydro plants, offshore wind parks or biomass plantations, in particular, have raised objections from green interest groups which traditionally consider renewable technologies as a viable alternative to nuclear power [15]. As for the RES technologies, the impacts of atmospheric emissions from these RES fuel cycles are insignificant in comparison to those from fossil fuels. The most important environmental effects of operating wind turbines are impacts on human amenity, namely noise and visual intrusion. As for the hydro fuel cycle, the main impacts are on land use, cultural objects and on aquatic and terrestrial ecosystems. The major impacts seem to be local and immediate, contrasting with fossil fuel cycles. Notwithstanding, the sustainable development goals imply that the evaluation of different technologies must include also the social dimension and, as derives from the Brundtland report [16], the wellbeing of future generations must be a priority. Employment appears to be a much cited social impact in electricity generation impact assessment. Several examples of this concern may be found in the literature addressing wind [17], photovoltaic technology [18], or even the whole energy system as is the case of Capros [19].

Impact assessment aims at structuring and supporting the development of policies [20]. According to Leeuw and Vaessen [21], "impact" is often associated with the level of welfare of households and individuals. Impact evaluation presupposes there is an institutional intervention ("*impact of what?*") that produces results ("*impact on what*?"). Leeuw and Vaessen [21] recognized that currently there is a shift in impact assessment, from small programs such as irrigation in a given district to more complex interventions, induced by international treaties such as the Kyoto Protocol. The impacts studied can focus environmental concerns (Environmental Impact Assessment), social aspects (Social Impact Assessment) or can address both in an integrated way (in the so-called Sustainability Impact Assessment) [22].

Bäcklund [23] overviews the importance of impact assessment in the European Union since 2000, and stress its increasing