C3 – Power System Environmental Perfomance

10162_2022

Inserting Crucial Environmental Issues into Energy Planning: Paths for Carbon Reduction

Ricardo C. FURTADO, Maria de Fátima R. G. FURTADO, Elena FLORISSI, Marcelo G. FURTADO, Mariana A. da SILVA

Diversa Consultancy on Sustainability

Amaro O. PEREIRA. JR

Federal University of Rio de Janeiro

Motivation

International experience has demonstrated a worldwide concern regarding the subject of climate change and an increasing use of sustainability indicators in the search for less impactful energy generation sources.

The use of energy generation sources that do not produce greenhouse gas (GHG) emissions has become part of the guidelines for expansion planning in the electricity sector in virtually all countries.

Two issues have historically guided planning in the Brazilian electric power system:

- Meeting the energy demand;
- Minimizing production costs.

The main course studied in this article addresses the importance of appreciating socio-environmental aspects in order to obtain more accurate costs and benefits of each source of electricity generation.

With this aim in mind, the research has developed a new method of analysis that considers aspects and variables related to the different dimensions of sustainability - economic, social, environmental, cultural and institutional.

Method/Approach

The creation of the indicators synthetized in the SIGS was based on a review of the international experience on the subject. The index construction incorporates the global concern on climate change and the increase of renewable sources of electricity generation. These issues have become a guideline in planning the expansion of the electricity sector in virtually all countries.

The creation of the SIGS has followed four methodological steps:

- **Consolidation of the basic concepts and political context;**
- **Analytical structuring of the indicator system;**
- **Choice of the indicators to evaluate the dimensions of the concept studied;**
- **Synthesis of the indicator scores.**

As regards synthetizing a set of indicators, two essential methodological steps are required:

- **Normalization:** Transforming the different units of measure into a homogeneous scale;
- **Parametrization:** assigning different weights to the indicators to express the specific and differential contribution of each one.

It is important to mention that the synthesis of the indicator used the null method, i.e., it gives the same importance to all dimensions, themes, aspects and indicators. Some indicators were quantified using a scale whose scores ranged from 1 to 5, with 5 being the highest sustainability value and 1 being the lowest.

Object of investigation

- The main object of the method is an indicator system. Its result is the Sustainability Index of Electric Power Generation Sources (SIGS), to be included in the model of electricity generation expansion.

Experimental setup & test results

Based on the theoretical framework and national and international experiences, in addition to the knowledge of the research team, a system of indicators with four dimensions was proposed, all derived from a discussion on the concept of sustainability:

- **environmental and social**

In general, indicators in the environmental and social dimensions measure negative aspects, since they seek to capture the negative impacts caused by enterprises, such as the potential for reducing biodiversity and the level of damage to cultural, historical and archaeological heritage.

- **economic (regional insertion) and political-institutional**

The indicators of the economic and political-institutional dimensions measure positive aspects, since they propose to measure the positive impacts on the local economy and political-institutional improvements, such as an increase in the supply of jobs and the potential to generate local benefits. Some of the scores associated with the indicators are from secondary data sources, collected in an extensive literature review (national and international).

The matrix is composed of 40 indicators distributed across the dimension mentioned above.

PARIS 2022

C3 – Power System Environmental Perfomance

10162_2022

Inserting Crucial Environmental Issues into Energy Planning: Paths for Carbon Reduction

Some observations about the matrix:

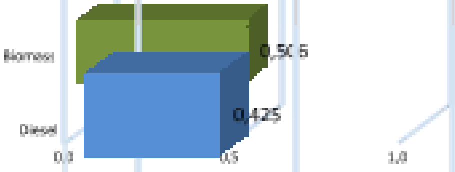
- the inclusion of the Political-Institutional dimension provided greater power to the matrix to capture the variables involved in the complexity of the concept of sustainability;
- due to the number of indicators in its composition and the dimensions of analysis, the SIGS is the most complete index amongst those used in other countries;
- another paramount observation is that the SIGS includes the local benefits brought about by the implementation of each generation source.

Renewable and non-renewable sources

The matrix presents an important comparison between renewable and non-renewable sources that reverberates to the emphasis on renewable energy investments. As expected, these presented higher SIGS scores when compared to those that are non-renewable.

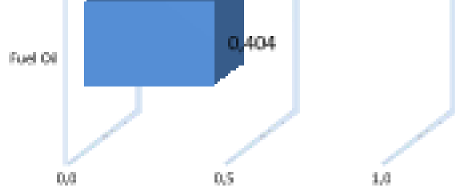
The results may be verified in the Figures 1 and 2.

Figure 1. Scores of dimensions and sustainability indexes – renewable sources



Source: Authors.

Figure 2. Scores of dimensions and sustainability indexes – non-renewable sources



Source: Authors.

Environmental dimension: Paths for Carbon Reduction

The environmental dimension has the highest number of indicators (fifteen) and represents 38% of the total matrix, In addition to the environmental dimension, the index is composed of the social, economic (regional integration) and political institutional dimensions

The dimensions include and prioritize indicators that directly or indirectly reflect the impacts on climate change, four themes are considered in the composition of the scores: soil, water, air and risks. These may be verified in Table I.

Table I. Themes, aspects and indicators of the environmental dimension

THEME	ASPECTS AND INDICATORS
Soil	**Occupied Area:** - Area occupied by energy generated
	Biodiversity Loss: - Potential for biodiversity reduction of native species of fauna and flora - Possible occurrence of conservation unit in areas with generation potential
Water	**Water Use:** - Volume of water consumed/energy generated
	Biodiversity Loss: - Potential to reduce the native biodiversity of ichthyofauna - Degree of transformation of the lotic environment into lentic by annual energy generated
	Water Diseases: - Increase in diseases caused by water vectors or by change in water quality by annual energy generated
Air	**Climate Change:** - Tons of CO_2e emitted by annual energy generated
	Impact on Health: - Tons of particulates emitted by annual energy generated - Tons of nitrous oxides emitted by annual energy generated - Tons of sulphur dioxide per annual energy generated - Increase in respiratory diseases by annual energy generated
Risks	**Risk of Human Origin:** - Potential risk of generation loss due to human error
	Risk of Origin in Natural Events - Potential risk of generation loss arising from natural events
	Risks of Technological Origin: - Potential risk of generation loss arising from technological events

Source: Authors.

PARIS 2022

DiVersa SUSTENTABILIDADE

C3 – Power System Environmental Perfomance

10163_2022

...ning: Paths for Carbon Reduction

Higher ... dimension ... solar ...).

Analysing the results for the theme air, which is one of the most relevant themes for the carbon reduction proposal, the generation sources that cause the least impact are, respectively, ... wind, obtaining a score ... hydroelectric with reservoir ... run-of-the-river hydro...

Figure 3 presents the SIGS scores of the environmental dimension for all renewable electricity sources. And for the theme air, all renewable energy sources obtained a high score ...

Figure 3. Environmental Dimension

Figure 4. Air theme scores - Source of renewable energy generation

Source: Authors.

Application of the index

The research formulates a data envelopment analysis (DEA) model, which calculated the factors of technical efficiency and socio-environmental indices for the generation sources.

The results of the case study demonstrated that, as the maximum socio-environmental impact decreases, the model tends to invest in a smaller total capacity. To generate the same amount of electricity, the model must invest in plants with a greater capacity factor, as is the case of the nuclear source.

In terms of total costs, as expected, the socio-environmentally more restrictive cases proved to be more expensive.

Conclusion

- The SIGS has enabled environmental variables to be as **important a factor as the technical and economic variables** in planning electricity generation expansion.
- Amongst the different sources of energy generation available in Brazil, all the **renewable sources obtained a higher score** than those of non-renewable sources.
- With regard to applying the index to the expansion of energy generation using DEA, the fact that the sustainability was applied only to the capacity of each source and the sensitivity of the results of the application of the model in relation to the list of candidate projects are some of the **limitations of the study conducted.**
- The SIGS is an important planning tool for the expansion of the energy matrix and may be used to define **better goals and pathways towards reducing GHG emissions**, thereby inserting crucial environmental issues into energy planning.