COUNTRY : BRAZIL
REGISTRATION NUMBER : 10162

GROUP REF. : C3
PREF. SUBJECT : PS1
QUESTION N° : 1.2

Question 1.2. The use of sustainability indexes, less or more complex, are common in the scenario analysis of generation expansion for different countries. Compacting different metrics related to different compartments (i.e., technical, economic, social, environmental) into single aggregated scores made of multi dimensions is very complex and needs a transparent approach. The ExternE approach transforms all impacts into monetary values to allow summing up, weighing ad comparing solutions according to a common base. **What is the experience from the audience in the development of sustainability indexes?** Can other examples be brought from the audience? Sustainability indexes and external costs have also been addressed in numerous CIGRE projects and published as TB650 Sustainability development performance indicators for electric power generation (2016) and TB616 Externalities of Overhead High Voltage Power Lines (2015). **What is the experience from the audience in the application of approaches like those referred to, in the process of planning of system expansion?**

The synthesis or aggregation of indicators is one of the main steps in the construction of an index. Aggregation allows a more comprehensive view of the evaluated processes, as well as the comparison of similar processes. For this, it is necessary to normalize the indicators, i.e., to transform their different units of measurement into a homogeneous scale, which implies the parameterisation of the indicator values. This may prove challenging, due to the difficulty in establishing the maximum and minimum values for each indicator. In our experience, values available in the legislation and in the literature are the most commonly used parameters.

For example, for indicators quantified by means of a scale from 1 to 5 (in which 1 is the least sustainable source and 5 the most sustainable), their values were normalized to between 0 and 1, considering 1 as equal to 0 (zero) and 5 as equal to 1 (one). The intermediate values have been proportionally distributed within this range. With regard to the numerical values of the indicators obtained by secondary sources, normalization was performed using the interpolation technique and standard indicators.

We have worked with indicator systems in some R&D Programmes for the Brazilian power sector. Besides those mentioned in Question 1.1, two more have produced indicator systems and indexes associated to the concept of Sustainability, particularly the second one that created the Sustainable Regional Insertion Index (SRII):

a) *A methodology for the evaluation, monitoring and control of efficacy and effectiveness of environmental programmes and actions resulting from environmental licensing of hydroelectric generation projects* (Cemig GT0598 Research and Development Project); and
b) *Development of a tool to monitor and evaluate the economic, social and environmental sustainability of municipalities in impact areas of hydroelectric dams"* (Cemig 475 Research and Development Project).

The study that proposes the SIGS also evaluates the costs of socio-environmental externalities of generation power projects. Based on various references (PEARCE, 1992; FURTADO, 1996; ExternE, 1998; ExternE, 2005; CASES, 2008; SANTOS, 2008; ATSE, 2009; EPE, 2010; ECOFYS, 2014) the study proposes the socio-environmental costs of renewable and non-renewable sources to be considered in the planning of the Brazilian power system. Tables 1 and 2 present these costs.

Table 1 - Proposed values of social and environmental costs of renewable technologies

Renewable Sources	Proposed values Amounts converted to US$/MWh and updated for July 2019
Hydroelectric with Reservoir	6 a 13
Small Hydroelectric (até 30 MW)	1 a 3
Run-of-the-river Hydroelectric	4 a 13
Solar Photovoltaic	11
Heliothermal Concentrated	3 a 4
Wind Offshore	2 a 3
Wind Onshore	2 a 3
Biomass	20 a 27
Geothermal	12

Source: Diversa Consultoria et al. (2019)

Table 2 - Proposed values of social and environmental costs of non-renewable technologies

Non-Renewable Sources	Proposed values Amounts converted to US$/MWh and updated for July 2019
Combined Cycle Coal	55
Coal	53 a 77
Diesel	52 a 69
Fuel Oil	62 a 92

Natural Gas	23 a 29
Combined Cycle Natural Gas	26 a 33
Lignite	110 a 113
Nuclear	12 a 31

Source: Diversa Consultoria et al. (2019)

It should be highlighted that the expansion generation model used the SIGS, but the socio-environmental costs could also have been used.

REFERENCES

ALBERICI, S.et al. Subsidies and costs of EU energy. Final report. [S. l.]: Ecofys, 2014. Available at: <https://ec.europa.eu/energy/sites/ener/βiles/documents/ECOFYS%202014%20Subsidies%20and%20costs%20of%20EU%20energy_11_Nov.pdf>. Viewed on: October 21,. 2018.

ATSE – THE AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES AND ENGINEERING. The hidden costs of electricity: externalities of power generation in Australia. Australia: ATSE, 2009. Available at: <https://apo.org.au/sites/default/βiles/resource-βiles/2009/03/apo-nid4196-1189331.pdf>. Viewed on: March 14, 2018.

BICKEL, P .; FRIEDRICH, R. (Eds.).ExternE – externalities of energy: methodology 2005 update. EUR21951 EN. Luxemburgo: Ofβice for Ofβicial Publications of the European Communities, 2004. 270 p.ISBN 92-79-00423-9. Available at:<http://www.externe.info/externe_2006/brussels/methup05a.pdf>. Viewed on: November 14, 2018.

CASES.Full Costs Estimates of the use of different energy sources. Cost Assessment of Sustainable Energy Systems. [S.l.]. 2007.

DIVERSA CONSULTORIA, COPPETEC FUNDAÇÃO, MRTS CONSULTORIA, SINERCONSULT e NTJTEC CONSULTORIA EM ENGENHARIA – WESEE. Relatório Técnico Final 09 - Incorporação da Sustentabilidade de Fontes de Geração no Planejamento da Expansão do Sistema Elétrico. Matriz Energética e Aprimoramento da Sistemática de Inserção Ambientalno Planejamento da Expansão doSistema Elétrico. Recife, 2019.

EPE – EMPRESA DE PESQUISA ENERGÉTICA. Externalidades socioambientais da geração de energia elétrica. Nota técnica. Rio de Janeiro: MME: EPE, 2010.

FURTADO, R. C. The incorporation of environmental costs into power system planning in Brazil. 1996. Ph.D Thesis. Imperial College of Science, Technology and Medicine, University of London, London, 1996.

KREWITT, W. External costs of energy – do the answers match the questions?: looking back at 10 years of ExternE. Energy Policy, v. 30, n. 10, p. 839-848, ago. 2002. Available at: <https://www.sciencedirect.com/science/article/pii/S0301421501001409?via%3Dihub>. Viewed on: August 13, 2018.

PEARCE, D.; BANN, C.; GEORGIOU, S. The social cost of fuel cycles. Final report to the UK Department of Trade and Industry by the Centre for Social and Economic Research on the Global Environment. United Kingdom: HM Stationery Ofβice, 1992. Available at: <https://inis.iaea.org/search/searchsinglerecord.aspx?recordsFor=SingleRecord&RN=24067601>. Viewed on: November 21, 2018.

RAMOS, D.S. PEREIRA JR., A.O.; SILVA, A.L.R.; MOROZOWSKI FILHO, M.; FURTADO, R.C. Planejamento Energético: inserção da variável ambiental na expansão da oferta de energia elétrica. 1 ed. Rio de Janeiro: Synergia, 2020.

SANTOS, H. L. Inserção dos custos ambientais em um modelo de expansão da geração a longo prazo. 2008. 102 p. Dissertação (Mestrado) – Pós-Graduação de Engenharia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2008. Available at: <https://www.osti.gov/etdeweb/servlets/purl/21429344>. Viewed on: August 15, 2018.