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AN APPLICATION OF FULL COST ASSESSMENT IN THE ENERGY SECTOR

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ABSTRACT

This article seeks to evaluate some plants for electricity generation existing in Brazil, among which wind, thermal, hydroelectric and nuclear power, through the Full Cost Assessment tool. Two studies were prepared, the first deals with the analysis of these plants in view of the technical-economic, environmental and social factors. The second study is the analysis of these plants in view of the cost of energy and energy production in the five Brazilian regions - South, Southeast, Midwest, North and Northeast. The final results show that in the first study the wind farm had the highest valuation, so the best option among the others. However, the second study, wind power was the one that obtained the highest valuation for the Northeast Region, and the thermoelectric and hydroelectric plants had the highest valuation for the Southeast Region.

Keywords: Full Cost Assessment; electricity; Brazilian regions

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1. INTRODUCTION

For decades, especially since the industrialization period, human activity is impacting the ecosystem and its environmental resources. Currently the world is going through a period in which the human being is placed as the center of everything, often causing an unsustainable environment. The concern focuses on quick and easy economic gain without regard to preserving the environment.

As stated by Hawken, Lovis and Lovis (2007), the process of production and mass consumption in the world today and factors arising as rapid industrialization, spatial concentration, agricultural modernization, significant population growth and increasing urbanization, climate change, depletion of productive resources, water scarcity, pollution of soil water and air, make up the main points of pressure and human awareness of global environmental issues.

The worsening environmental situation demand studies and the development of alternative proposals to overcome the contradictions of the present world scenario, being prudent to search for methods that preserve natural resources, which often requires the need to make decisions from the simplest to the most complex.

The development of a model representing reality can help in choosing the most appropriate decisions. Mathematical models use mathematical relationships to describe or represent an object or decision problem, and may, in his creative process, assist in the understanding of the problem, and as a result improve decision analysis.

In order to evaluate some plants for electric power generation that exist in Brazil, this paper makes use of a tool that helps in the process of decision making, called Full Cost Assessment (FCA) to two distinct problems. One considers the four types of power plants for electricity generation treated here in view of the environmental factors, technical- economic and social. The other problem analyzes these plants for electric power generation among the five Brazilian regions taking into account the parameters of cost and energy production.

The results show that wind energy appears as 1st choice followed by nuclear, hydro and thermal power in the application of FCA in the evaluation of these four plants for electric power generation in view of the environmental factors, technical-economic and social. Regarding the application of this tool in the study of these

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plants for the five Brazilian regions for the cost of energy production the conclusion is that the wind farm has the highest valuation for the Northeast, while the thermoelectric and hydroelectric plants have the highest valuation for Southeast region.

2. MATERIALS AND METHODS

The Full Cost Assessment tool is based on the identification and assessment of data on external impacts and costs / benefits of the activities in question.

The FCA tool was initially developed to account for the costs arising from environmental impacts of an enterprise (Burani et al., 2004). Later, according to Carvalho (2000), this concept was used to account for all costs related to the project, such as social, political and environmental factors.

In traditional assessments, normally, an economic evaluation (mainly considering the internal costs) is done at which the environmental costs, social, cultural are not considered or when considered, are delegated to the background. This form of assessment is inconsistent within an integrated resource planning, since upon disregarding the external costs, one can get to the selection of a particular resource that is not the most appropriate (Burani et al., 2004).

Regarding the power generation subject, to Boarati (2003) the FCA tool revolutionizes the way of evaluating the feasibility of a plant, for they were usually considered only aspects related to the investment, the plant's construction and its financial return, however, it is required to take into account other related factors on the venture feasibility. As pointed out by Gimenes et al. (2004), through the FCA some variables needed for decision-making can be identified and addressed, directing the application of methodologies for sustainable development and resource planning by providing treatment to elements that traditionally do not take part in the planning.

The FCA tool makes it possible to analyze the technical-economic factors, environmental, social and political with the same importance. The factors necessary for a decision-making process can be identified and addressed in order to satisfy the concepts of sustainable development and resource planning.

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Through FCA different analysis elements are valued from two types of weighting: 1) alternatives to each element under analysis and 2) the weight of each element under analysis. According Boarati (2003), these two criteria enable each analysis element to be evaluated according to the available options. The alternatives are considered by percentages, ranging from the best (100%) to the worst alternative (25%), with the following classification: excellent (100%), satisfactory (75%), regular (50%) and unsatisfactory (25%). The weight of each element of analysis varies between A, B, C, in descending order of importance.

Given that the factors considered must have the same importance, the maximum valuation for all of them is 100 points according to Eq. 1.

$$\mathrm{X(A)} + \mathrm{Y}(B) + Z(C) = 100 \quad (1)$$

Where:

A, B and C are variations of each Analysis Element - depends on the importance attached to the Analysis Element within the considered factor, being A = maximum importance (A = 300), B = 2/3 of the maximum importance (B = 200) and C = 1/3 of the maximum value (C = 100);

X, Y and Z are the numbers of occurrences of the Analysis Elements with the rating A, B or C, respectively.

From the definition of the Analysis Elements and their respective weights (A, B or C) is made the calculation of KFC given by Eq. 2.

$$\mathrm{KFC} = \frac{\mathrm{X(300)} + \mathrm{Y(200)} + \mathrm{Z(100)}}{100} = \mathrm{X(3)} + \mathrm{Y(2)} + Z(1) \quad (2)$$

Where:

KFC is the Constant of the Considered Factor.

A Eq. 3 shows VEA_i calculation

$$\mathrm{VEA_i} = \{\frac{\mathrm{weight(A,B,C)}}{\mathrm{KFC}}\} * \mathrm{alternative} \quad (3)$$

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Where:

VEA_i é is the valuation of Analysis Element *i*.

Lastly Eq 4 is obtained.

$$VF = \sum VEA_i \quad (4)$$

Where:

VF is the Factor Valuation.

Table 1: Numeric Example of Full Cost Assessment.

CONSIDERED FACTOR		Analysis Element Weight		25%	50%	75%	100%	Final Valuation assigned to the Analysis Element
	Analysis Element	**Symbol**	**KFC**					
	Element 1	A			■			10.00
	Element 2	B					■	13.33
	Element 3	A					■	20.00
	Element 4	C	15		■			3.33
	Element 5	C		■				1.66
	Element 6	A				■		15.00
	Element 7	B				■		10.00
CONSIDERED FACTOR VALUATION								73.32

Source: based in Bachi Junior, Tiago Filho e Seydell (2013).

The filled in cells at Table 1 presents the options selected according to the research on this topic (BACHI JUNIOR; TIAGO FILHO; SEYDELL, 2013).

In the numeric example of Table 1, the value of the KFC is 15 (3 * 3 + 2 * 2 + 2), because there are three analysis elements with Valuation A, two analysis elements with Valuation B and two analysis elements with Valuation C. It is highlighted the calculation made for the Valuation Analysis Element 1 (Eq. 5).

$$VEA_1 = (\frac{300}{15}) * 50\% = 10{,}00 \quad (5)$$

3. RESULTS

The section in question presents the results obtained in the application of FCA for the two studies mentioned above.

3.1. FCA application in the analysis of power plants considering the environmental factors, technical-economic and social

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The application of FCA is made to analyze the feasibility of using four plants of electricity generation in Brazil, namely, wind, hydroelectric, thermal and nuclear. An analysis considered traditional uses only technical and economic elements for the viability of an enterprise. However, it is interesting to take into account not just one factor, but three factors that are of great importance to an alleged decision making: technical, economic, environmental and social as Rutherford (1997).

According to Boarati (2003), the technical and economic factors reflects the vision of the entrepreneur and investor to seek return of their invested capital through the sale of energy to be produced by the plant that must operate in a defined period of time.

The environmental factor is the vision of the official agencies and environmental protection agencies (Boarati, 2003). Therefore, for the viability of the power plants is only possible if there is no opposition of these agencies, in other words, that the project in question does not degrade the environment.

The social factor is characterized by the population affected due to construction of the plants (Boarati, 2003). The installation of the plant causes many impacts on local society. Impacts related to the emission of pollutants or else dysfunction in local economic activities such as fishing, agriculture and tourism, causing population displacement due to the poor quality of living locally.

The central idea of the Full Cost Assessment in relation to energy resources in Brazil is studying the possibility of building and installation of power plants, in addition to analyzing the best investment option. For this, twelve tables were built following the model of Table 1, four for each factor (environmental, technical-economic and social). And, from these four, one table for each plant type (wind, nuclear, hydroelectric, thermoelectric).

For example, the following are the engineered tables for the power plant to the environmental factor (Table 2), technical-economic factors (Table 3) and the social factor (Table 4), with their respective analysis elements.

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Table 2: Hydroelectric Power Plant evaluated by the environmental factor.

Environmental Factor - Hydroelectric Plant	Analysis Element Weight		Unsatisfactory Alternative (25%)	Regular Alternative (50%)	Satisfactory Alternative (75%)	Best Alternative (100%)	Final Valuation attributed to the Hydroelectric Plant
Analysis Element	**Symbol**	**KFC**					
Fauna Degradation	B		Greatly affects the fauna	Affects the Sauna	Little effect on the fauna	No effect on the fauna	2.94
Noise Pollution	B		Emits many noises	Emits noises	Emits little noise	It does not emit noise	5.88
Atmospheric Pollution	A		SO_x Emission and CO_2 in saturated areas	CO_2 Emission in saturated areas	CO_2 emissions in small quantities in saturated areas	It does not pollute or emit CO_2 in unsaturated areas	17.64
Water Pollution	A	17	Very High	High	Reasonable	Non Existing	4.41
Ease of Obtaining License	C		Many obstacles	Reasonable obstacles	Few obstacles	No obstacles	1.47
Generation of Solid Waste	A		It produces many waste	It produces reasonable waste	It produces few waste	It produces no waste	13.23
Ground Pollution	A		Harmful waste in the soil, land changes	Affects soil quality	Affects slightly the soil quality	It does not affects soil quality	13.23
HYDROELECTRIC POWER PLANTS ENVIRONMENTAL FACTOR TOTAL SCORE							58.80

Source: author's elaboration.

Table 3: Hydroelectric Power Plant evaluated by the technical-economic factor.

Technical-Economic Factor - Hydroelectric Plant	Analysis Element Weight		Unsatisfactory Alternative (25%)	Regular Alternative (50%)	Satisfactory Alternative (75%)	Best Alternative (100%)	Final Valuation attributed to the Hydroelectric Plant
Analysis Element	**Symbol**	**KFC**					
Energy Cost US$/MW [1]	A		> 50	40 a 50	30 a 40	< 29	20.45
Annual Production MWh [2]	B		> 12 Millions	7 a 12 Millions	2 a 7 Millions	< 2 Millions	4.54
Construction Lead Time [3]	C	11	> 6	4 a 6 Years	2 a 4 Years	< 2 Years	4.54
Maintenance Cost [4]	A		Very High	High	Median	Low	27.27
Payback [5]	B		> 12 Years	8 a 12 Years	2 a 7 Years	< 2 Years	4.54
HYDROELECTRIC POWER PLANTS TECHNICAL-ECONOMIC FACTOR TOTAL SCORE							61.34

Source: author's elaboration.

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Table 4: Hydroelectric Power Plant evaluated by the social factor.

Social Factor - Hydroelectric Plant		Analysis Element Weight		Unsatisfactory Alternative (25%)	Regular Alternative (50%)	Satisfactory Alternative (75%)	Best Alternative (100%)	Final Valuation attributed to the Hydroelectric Plant
	Elemento de Análise	**Símbolo**	**KFC**					
	Job Positions Creation	A	12	No creation of direct and indirect job positions	Low creation of direct and indirect job positions	Median creation of direct and indirect job positions	High creation of direct and indirect job positions	8.33
	Project Location	A		Central area with high population density	Peripheral area with median population density	Area in remote locations with low population density	Industrial areas in remote locations with low population density	18.75
	Local Infrasctructure Development	B		No impact	Low Contribution	Median Contribution	High Contribution	12.50
	Effects of environmental imbalance in the social environment (air and noise pollution)	A		Emissions of SOx and CO_2 in saturated areas and noncompliance with sound legislation	CO_2 emission in saturated areas and partial compliance to sound legislation	CO_2 emission in small amounts in saturated areas and compliance to sound legislation	No emission of CO_2 in unsaturated areas and compliance to sound legislation	25.00
	Contribution to Quality of Life	C		________	There is no significant change	reasonably improves quality of life	Improves the quality of life	4.16
HYDROELECTRIC POWER PLANTS SOCIAL FACTOR TOTAL SCORE								68.74

Source: author's elaboration.

Following the same model, tables for wind power plants, nuclear and thermal power were built. The total scores are depicted in Table 5.

Table 5: Final Valuation Results for each factor for the Power Plants.

PLANT	NUCLEAR	WIND	THERMOELECTRIC	HYDROELECTRIC
ENVIRONMENTAL FACTOR	72.03	77.91	61.74	58.8
TECHNICAL-ECONOMIC FACTOR	43.16	79.53	65.88	61.34
SOCIAL FACTOR	79.16	72.91	58.32	68.74
TOTAL	194.35	230.35	185.94	188.88

Source: author's elaboration.

The scores shown in Table 5 indicate that, regarding the environmental factors, the best investment option is the wind farm, with the highest valuation of 77.91. For the technical-economic factor, the wind farm is also the most viable option, because of its score of 79.53. But, In relation to the social factor, the plant with the best valuation is the nuclear power plant, with 79.16.

So, to the end result, one can draw up a preliminary ranking of energy resources obtained in Brazil, 1st option: wind, 2nd option: nuclear, 3rd option: hydroelectric and 4th option: thermoelectric.

3.2. FAC application in the analysis of power plants in the Brazilian regions

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The application of FAC is made to analyze the plants for power generation: wind, hydroelectric, thermal and nuclear in five regions of Brazil.

The Analysis Elements considered in this study are only cost and energy production. It is worth noting that data on the costs of each type of energy for each region were not found and therefore these values were estimated considering that the cost of energy is inversely proportional to its production.

Table 6 presents the scores obtained for the nuclear power plant in the Southeast. It is worth noting that the analysis of this plant was made only in this region since Brazil has this plant only in Angra dos Reis, State of Rio de Janeiro.

Table 6: Nuclear Plant – Southeast Region.

SOUTHEAST REGION	Analysis Element Weight		Unsatisfactory Alternative (25%)	Regular Alternative (50%)	Satisfactory Alternative (75%)	Best Alternative (100%)	Final Valuation attributed to Southeast Region
ANALYSIS ELEMENT	Symbol	KFC					
Energy Cost US$/MW	B	5	Low	Medium	High	Very High	10.00
Energy Production	A		Low	Medium	High	Very High	60.00
TOTAL SCORE FOR SOUTHEAST REGION - NUCLEAR PLANT							70.00

Source: author's elaboration.

Similarly it was built tables for other plants and regions of Brazil. Table 7 summarizes the values obtained for each one of them.

Table 7: Final Valuation Plant/Region.

PLANTS/REGIONS	SOUTH	SOUTHEAST	MIDWEST	NORTH	NORTHEAST
NUCLEAR	0.00	70.00	0.00	0.00	0.00
WIND	65.00	65.00	45.00	50.00	70.00
THERMOELECTRIC	50.00	70.00	45.00	65.00	50.00
HIDROELECTRIC	65.00	70.00	50.00	45.00	45.00

Source: author's elaboration.

By comparing the four plants studied among the five regions of Brazil it is possible to determine, in each case, the most viable option for a possible investment.

As can be observed, it was not possible to analyze the feasibility of nuclear power among all regions as this type of Plant is only found in the Southeast. But, compared to other active plants in the regions it can be seen that the Southeast region had a high valuation so, we can consider it as a good investment option. On the other hand, the wind farm proved to be the most advisable for the Northeast region. While the thermoelectric and hydroelectric plants had a higher valuation for the Southeast region.

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4. CONCLUSIONS

The application of FCA in the first study shows that wind energy appears as 1st choice, followed by nuclear energy, hydroelectric and thermal.

The application of FCA in the second study allows to conclude that the wind farm has the highest valuation for the Northeast, while the thermoelectric and hydroelectric plants have the highest valuation for the Southeast region.

Note that the FCA tool makes it possible to analyze several factors: environmental, social, political, technical and economical with the same importance. However, in the first study, it was not considered the political factor in view of the difficulty in obtaining data. In the second study, by emphasizing the study of plants for electricity generation in different regions of the country, it was decided to only address the cost and energy production, again because of the difficulty in obtaining information regarding the environmental, social, political and technical and economic these plants for each region of Brazil.

The user-friendly handling with the calculations made by Microsoft Excel tool enables the application of FCA in several areas. However, in the study presented, as previously mentioned, the greatest difficulty was in getting the data.

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