FULL COST ACCOUNT FOR INTEGRATED ENERGY RESOURCES PLANNING USING THE ANALYTIC HIERARCHY PROCESS

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ABSTRACT

The objective of this work is to introduce the Analytic Hierarchy Process and to demonstrate that its use in energy resources selection through the Full Cost Accounting Evaluation is viable and valid. The Decision Lens software, which implements the theory, is also introduced.

Besides, it has been taken into consideration the objective of developing and applying a method of Full Cost Accounting assessed by the Stakeholders, reaching the ranking of energetic resources and comparing it to the deterministic valuation.

In order to justify the validity and feasibility of the Analytic Hierarchy Process within the Full Cost Accounting Evaluation environment, the theory on which it is based has been thoroughly and carefully explained. To that effect, an example has been developed, in which all calculations are done manually up to the definition of the final ranking of energetic resources. The same example is also developed using the Decision Lens software, thus comparing both, the manual and the software results, in order to validate the consistency of the software itself.

In order to develop and to apply a method of Full Cost Accounting assessed by the Stakeholders, certain activities have been carried out within the IRP project in Araçatuba.

The determination of the table of values and its ratings for the Full Cost Accounting deterministically valued has been conducted, as well as the pertinent data insertion along with respective results.

Finally, the comparison of results of the two Full Cost Accounting have been made. Their differences and similarities have also been commented, proving that results were compatible.

Keywords: Energy Resources, Energy Planning, Full Cost Account, AHP.

1. Objectives

- Use the A.H.P.s in the construction of a Full Cost Account (F.C.A.), including the use of a program that implements the method.
- Implement a method of constructing the F.C.A. estimated by the stakeholders that considers the resource demand and supply.
- Make a comparison between the results generated by the F.C.A. estimated by the stakeholders with the F.C.A. estimated deterministically.

2. Basics of Integrated Energy Resource Planning

Usually the energy planning priorities as the power supply and G.D.P. growth in the short term and possibly medium term. This traditional design is concerned exclusively with the difference in the forecast of energy demand (for electric load forecasting) with the forecast of supply. With that determines the amount of energy needed in the short and medium term and identify the options they have lower installation cost, maintenance and operation. In traditional energy planning, technical and economic aspects are prioritized over environmental and social aspects.
The Integrated Resource Planning (I.R.P.) meets the need to rely on planning a more complete and comprehensive than traditional, its main function is to be a tool for energy planning in the short, medium and long-term, where various energy resources, views and aspects are considered in energy planning. There have been indications that the energy industry moves slowly to fit this model for energy planning.
The goal pursued constantly by I.R.P. is the determination of the portfolios of energy resources at the lowest cost, and traditional forms of calculations fail to consider all elements of such analysis. More than that, the pressure exerted by various members of society can often make a project with great financial evaluation is prevented, it generates waste of time and money to those who believed and invested in the energy project. In the current state of the I.R.P. are expected to be intense and broad participation of society and its elements (stakeholders) so that the assessments, even though subjective, are considered in generating the final portfolio of energy resources and plans. This detailing and deep stratification of energy resources that allow the decision maker has the subsidies that help to choose the next investment, impacts, benefits and risks more clearly than the traditional planning.
Meanwhile, we consider the fact that the I.R.P. energy planning in the long run allows the entities that use it can have several possible scenarios for 15, 20, 30 years or more. And in its complete form, the I.R.P. can provide entities the ability to visualize how these scenarios will be modified according to the choices of short-term.

3. Evaluation of Full Cost Accounting F.C.A.

Inside the I.R.P. is necessary to compare the supply-side energy resources and demand side energy resources so that it generated a ranking of suggested resources, from the most suitable for the least suitable. Usually this decision making is performed with light technical and economic data, however, negative and positive impacts of the adoption of resources should be considered so that the final score reflects the highest number of points possible. Among these aspects are the Environmental, Social and Political. The major difficulties of considering these types of impacts are the subjectivity and difficulty of pricing.

3.1 Using F.C.A. on I.R.P.

In the current structure of the I.R.P., the F.C.A. is used in two different ways to integrate the same features: one to determine the deterministic and the other F.C.A. estimated by the stakeholders. Used as a premise, the two F.C.A. must have the same tree, ie, should have the same attributes, sub-attributes and alternatives.
The first use takes place in the F.C.A. called deterministic, where all scores for energy resources are estimated deterministically, there are no qualitative data considered, including the dimensions for

Environmental, Social and Political. This type of use of F.C.A. can be extremely complex because all aspects must be considered rated numerically, either in monetary form or another that proves useful. You could say that all externalities should be internalized in order to be considered quantitatively. Despite the difficulty of calculation, a complete and F.C.A.urate I.R.P. must rely on such information.

Still on the F.C.A. deterministic, unlike the scores of resources that are deterministically calculated, the weights of sub-attributes should be calculated qualitatively by experts in the region. This procedure is used to compare pair-pair in the Analytic Hierarchy Process.

Several studies, including dissertations, have been developed addressing precisely the deterministic calculation and characterization of energy resources for the pilot region of Araçatuba. These calculations and results are used in the text within the F.C.A. deterministic pilot developed.

The second use is performed in the F.C.A. estimated by stakeholders. This assessment is entirely qualitative, sub-attributes are compared in the F.C.A. as deterministic but with the option of all the Stakeholders and resources are evaluated with respect to a sub-attributes qualitatively. This evaluation is made using a verbal scale, which is also inserted into the methodology of decision making of A.H.P..

About Stakeholders the commentary is worth the frequent conflicts between them. As in the Stakeholders are inserted several entities often antagonistic interests, opinions on specific points on certain energy resources are different. There are also ideological conflicts of origin, trade, creating competition among peers. The F.C.A. should consider the option of both stakeholders, and all others who are included in the analysis, when the suggestion of ranking energy.

About energy ranking generated by the two F.C.A., it is important to note that the alternatives are not mutually exclusive, example, the F.C.A. has no single answer as energy resource, it presents a full ranking so that all alternatives considered for implementation, but being guided by the priorities calculated. Note that the rankings presented by the F.C.A. does not consider, for example, temporal issues and the issue of capacity constraint.

After preparation of the two F.C.A.s and determination of rankings of resources for the module integration of resources, which should generate only a ranking of resources. This consolidation should not be developed automatically, but after reflection and discussion of members of the team that develops the I.R.P. in conjunction with the Stakeholders. This consolidation should also consider the geographical reference and their analysis. Analysis of geo-referencing are very useful at this stage of the I.R.P..

Finally, it is important to note that the desired end state of the I.R.P. is to generate preferred plans with timeframe considered. The F.C.A. presented and your consolidation do not use this reference, behind only the ranking in a given time, with the conditions set out therein. In complete idea of I.R.P. various F.C.A. must be generated, providing many rankings and scenarios in time, thus enabling the complete generation of energy plans.

3.2 Use of A.H.P. in F.C.A.

The A.H.P. eliminates the cognitive problem, because comparisons with peer-to-peer loss of meaning because of the limitation of short-term memory does not exist.

Another very important element and A.H.P. is implicit in the use of the methodology of decision making through hierarchical trees of trials. The method helps the developers of the I.R.P. in question to reflect on the important factors include the structure of decision-making and decision-making process, when the traditional approach is to only worry about the result.

The use of A.H.P.s to the qualitative aspects within the F.C.A. under the I.R.P. is when comparing the sub-attributes with each other for both the F.C.A. estimated by the stakeholders regard to the F.C.A. deterministic. The F.C.A. estimated by A.H.P. in the stakeholders is also used to evaluate all alternatives with respect to the sub-attributes. For quantitative assessments, deterministic, A.H.P. is providing the use of scales (called ratings).

An important point to note is the suggestion that the number of sub-attributes within a criterion will be up on seven, since the number of comparisons to be made increases with the number of elements of

comparison. If the number of sub-attributes really needs to be greater than seven is suggested to create more vertical levels, with a limit of seven for each leaf of the tree.
The trees of criteria are formed by four goals, called dimensions (technical-economic, environmental, social and political) and each of them has a weight equivalent to 25%. These trees have branches up to two levels, called attributes and sub-attributes.

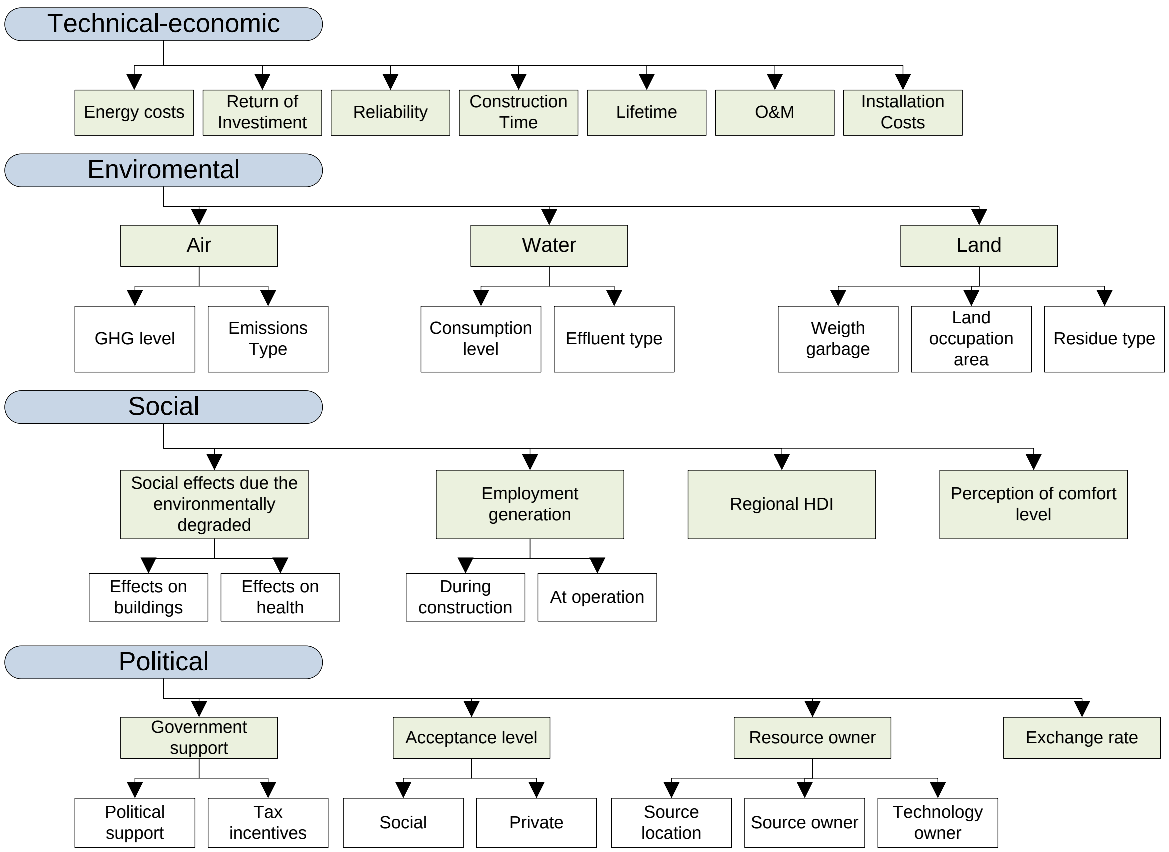

Figure 1. Dimensions Hierarchical Trees.

The authors analyzed 21 energy resources mixed between supply and demand. Each of these energy resources has been characterized in accordance with all criteria and sub-criteria in a hierarchical tree.

Table 1. Energy Resources used in the study.

Solar Water Heaters	Measures of information and education	Thermal accumulation	Replacement lamps	Bio-climatic architecture	Fuel cell	Burning of sugarcane bagasse
Hydro (peak generation)	Small hydro	Large Hydropower	Wind	Biogas for cogeneration	Biodiesel for combustion engine	Alcohol for combustion engine
Natural gas for CHP	Geothermal	Diesel engine combustion	Gasoline for combustion engine	Natural gas combustion engine	Nuclear	Coal for thermal power plant

The characterization of energy resources was made from two distinct forms, as mentioned earlier. The deterministic phase whose characterization was done by specialists based on real data collected in the study region (Araçatuba Administrative Region), these data may be of the order discrete (usually qualitative data) or dynamic (data with a numeric scale and lower limits higher). The step by filling out holistic data made by the stakeholders. Was presented to the stakeholders a questionnaire listing all the energy resources being analyzed to characterize the resources within the areas was done through a qualitative scale represented by increasing weights with five options: bad, regular, good, very good or excellent for each of the criteria and sub-criteria, where those who were completing only choose one option.

4. Results and Conclusions

With all the completed questionnaires, data were transferred to a software help decision-making, called the Decision Lens.

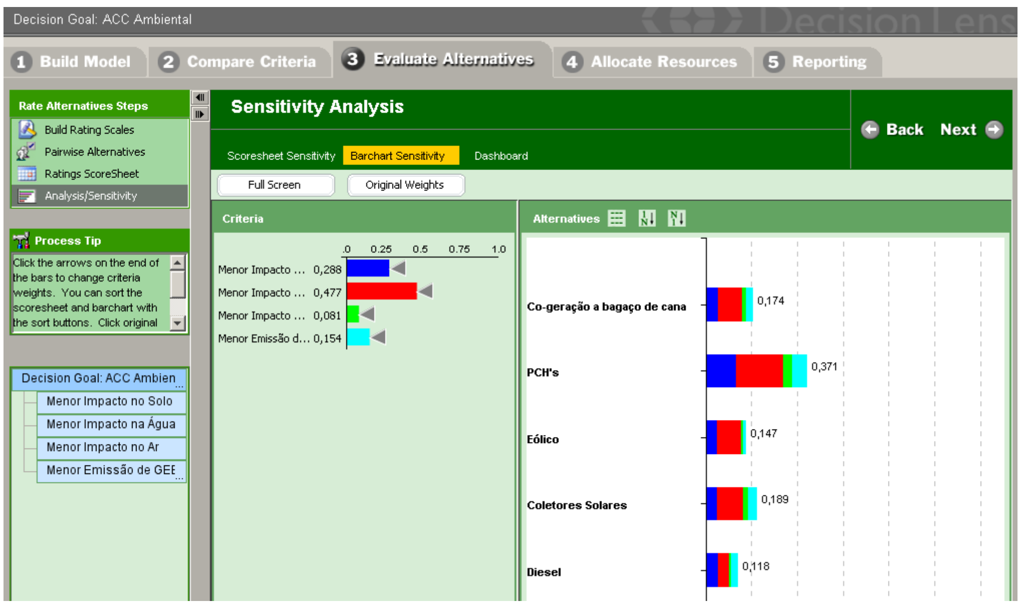

Figure 2. Screenshot of Decision Lens Software Aplication.

It was possible to determine the degree of importance of each criteria and sub criteria, and finally get two rankings of energy resources, a holistic and other deterministic, being ranked the best feature with lower full cost and the highest ranked worst full cost. The results are illustrated below.

Table 2. Comparing the rankings of energy resources in both F.C.A.

Energy Resource	Ranking Position in Deterministic F.C.A.		Ranking Position in Holistic F.C.A.	
Solar Water Heaters	84.8%	1	68.8%	1
Measures of information and education	81.3%	2	64.3%	2
Hydro (peak generation)	79.7%	3	62.3%	3
Thermal accumulation	78.5%	4	61.2%	4
Replacement lamps	77.3%	5	60.7%	5
Small hydro	73.2%	6	58.9%	7
Large Hydropower	71.3%	7	58.2%	9

Energy Resource	Ranking Position in Deterministic F.C.A.		Ranking Position in Holistic F.C.A.	
Bio-climatic architecture	71.2%	8	60.4%	6
Wind	69.8%	9	58.3%	8
Biogas for cogeneration	64.0%	10	51.9%	11
Fuel cell	62.2%	11	55.1%	10
Burning of sugarcane bagasse	59.6%	12	51.1%	12
Biodiesel for combustion engine	52.2%	13	49.2%	13
Alcohol for combustion engine	51.7%	14	48.5%	15
Natural gas for CHP	51.4%	15	44.6%	17
Geothermal	51.1%	16	49.0%	14
Diesel combustion engine	45.6%	17	42.4%	19
Gasoline for combustion engine	45.1%	18	41.4%	20
Natural gas for combustion engine	41.2%	19	44.0%	18
Nuclear	39.3%	20	46.0%	16
Coal for thermal power plant	38.0%	21	39.2%	21

Comparisons were made of the results of the two F.C.A.. First, the weights of sub-attributes of the two CCAs were presented following the structure of decision tree. Commented on the differences between the weights of the same sub-criteria and variations in the overall result that it could generate. Subsequently was analyzed the energy resources final rankings of the two F.C.A.. Was analyzed the variation that each feature had an F.C.A. in relation to another and was also discussed and shown that despite these differences, the rankings generated are coherent, that is, the generated result in an F.C.A. is compatible with results generated in another.
For the I.R.P. project Araçatuba has continued as the refinement of deterministic calculations of energy resources in the table of values. Must be remembered that these data are used for making the F.C.A. estimated deterministically. It is further recommended that the *ratings* used in the F.C.A. estimated deterministically be reviewed again by experts and that some data that was considered at this time in a discreet way can be converted into continuous data. Even as the project continued to PIR Araçatuba recommended adding other stakeholders. This will enrich the *ranking* generated precisely by considering more viewpoints.

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REFERENCES

Cicone Junior, D. (2008), Modelagem e Aplicação da Avaliação de Custos Completos através do Processo Analítico Hierárquico dentro do Planejamento Integrado de Recursos. Master's Dissertation, Polytechnic School of University of São Paulo, SP, Brazil.

Decision Lens. Available in http://www.*decisionlens*.com. Accessed on May 20, 2008.

Miller, G. A. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information; The Psychological Review, Vol. 63, 81-97.

Saaty, T. L. (1991). Processo Analítico Hierárquico, Mc Graw-Makron Books, São Paulo, SP, Brazil.