Abstract

This study was aimed at developing a methodology for comprehensive evaluation of projects in the energy sector. Comparison of different multicriteria analysis methods allowed to select the Saaty's Analytical Hierarchy Process as the methodological reference for the work. An investigation into the energy sector provided the characteristics of nineteen examined types of energy resources. This information was the basis to select a group of 76 distinctive aspects that could affect the prioritization of projects in the area. These were reduced progressively to 59, 44 and 24 main aspects that were grouped in six dimensions according to their nature: technical, economic, environmental, social, strategic and risk. Reflection and the statistical analysis of information collected in interviews with experts allowed this reduction.

An objective and a criteria were assigned to each selected aspect to evaluate the degree to which the project complies with said objective. The criteria were grouped into a three-level hierarchical structure arranged as a system of 24 qualitative/quantitative indicators. A summary sheet was created for each indicator containing the definition, the original measurement units, the possible sources of information for its estimation and a scale [1-5] for its measurement. The entire set was again validated by academics and professionals in a second series of interviews, which also collected information on the relative importance of each criterion. The data was processed using the *Expert Choice*® tool that also verified the consistency of the data provided by each participant. The final product of this phase was a hierarchical model of criteria for evaluating investment proposals in the energy sector. In the resulting model, the biggest importance corresponded to the risk (24.3%) environmental (20.5%) and cost (15.9%) dimensions. The technical (13.7%), strategic (13.5%) and social (12.2%) dimensions had lower relative importance.

The hierarchical model obtained was combined with linear programming techniques for the evaluation of possible solutions to Venezuela's electrical power crisis that had its peak in 2010. The objective was to find the best electrical grid to implement over the period 2011-2025, based on the potential of each energy source in the country and in its estimated demand, and subject to financial constraints and international commitments and agreements that the nation has signed. The electricity demand for the stated period was projected in three scenarios only differing by the expected country's economic growth. Oil, gas, coal, biomass, water resources, nuclear energy, wind and, solar and geothermal potentials were evaluated as primary energy input to electricity generation according to the designed value model. The information from

official sources was poor and not consistent, in this way much of the data used to estimate the quantitative indicators was obtained from international publications and experts working in the private sector of the country. A third series of interviews with experts in the public and private sectors, provided the information needed for estimation of the qualitative indicators. The data obtained was integrated in a *robustness coefficient* for each alternative. The coefficients allowed to identify the wind option as the best choice, followed by hydro and gas based generation. Nuclear generation was by far the worst option.

The robustness coefficients obtained were input to a linear programming model to identify the 'best mix' of electrical generation options that would meet the conditions in the country. A sensitivity analysis of the results to changes in the restrictions on the model, yielded two solutions that differ only in the participation of the nuclear option in them. Both of them include hydraulic option mostly ($\geq$32%) and a 15% contribution from wind power. Oil, gas and coal options are also incorporated. Each of them, if implemented, is able to add 120,000 GWh to power the country for 2025. The generation capacity to install through the period 2013-2025 is approximately 28 GW, and the budget required ascends to 65 billion $US. This figure increases by a factor of 1,5 to 2 if the adequacy of the electric network is included. The commissioning of the total electrical grid for the country would produce about 260,000 GWh in 2025, would have a $\geq$45% hydro participation and a 6.9% contribution from wind energy. It is estimated that it would take at least five years to have the first new power plants.

Finally, it was proposed a combined methodology for the multicriteria evaluation of institutional, technical, economic and environmentally viable investment alternatives in the energy sector. If the alternatives are mutually exclusive, the application of the hierarchical model designed would be sufficient for their evaluation; if not, this first stage should be complemented with a linear programming model approach that maximizes the robustness of the solution and places it closer to the specific circumstances of the country.