Comprehensive Comparative Assessment of National Energy and Power Systems

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1. Introduction

In the present work, various national electricity generating systems associated with conventional as well as renewable energy resources are comparatively assessed in the framework of life-cycle multicriteria (economic, environmental, health, and social) spaces.

The essential objectives of the study are (1) to comprehensively compare options of electricity supply, (2) to complementarily support nuclear power's role in the national energy sector, and (3) to contribute to sustainability-oriented research and development in the energy and power sectors.

2. Methods

An analytic hierarchy process (AHP) method is applied as a multicriteria decision-making (MCDM) methodology for aggregating both subjective degrees of importance and value estimates [8]. The reason for the choice of an AHP method is that, even if AHP assumes independency among several criteria, AHP-based quantification is both easy-to-compute and is readily extendable to a criteria-dependent framework in the near future. Here, the weighting vector is computed by an eigenvector method. To be brief, a procedure for comprehensive assessment consists of (1) problem definition, (2) choice of evaluation criteria, (3) weight estimate, (4) evaluation value estimate, (5) aggregation, and (6) interpretation.

For integrated representation of a MCDM problem, web charts are introduced to help us identify a set of option performance in multicriteria dimensions.

3. Application

Electricity system options under consideration are the conventional systems such as nuclear [4] and fossil-fuelled (coal-fired, heavy oil-fired, LNG) as well as the new and renewable energy systems (hydropower, wind power [2], photovoltaic (PV) power [5]). These seven options are evaluated in terms of several conflicting criteria: (1) economic aspects (power generation cost, land use), (2) environmental impacts (global warming, acidification, energy payback), (3) health effects (accident mortality, loss of life expectancy [1]), (4) social view (environment quality, fuel/energy supply security [3], grade of terrorism protection, grade of sustainability). Here, as for economic aspects, generation costs correspond to market prices except for wind and PV in virtue of mandatory fixed-price purchases. To quantify environmental impacts, a life-cycle assessment (LCA) is performed for various energy generation systems [6; 7]. In addition, for health effects, empirical fatality data in the literature are gathered.

In Figure 1, the hierarchy configuration for this study is shown.

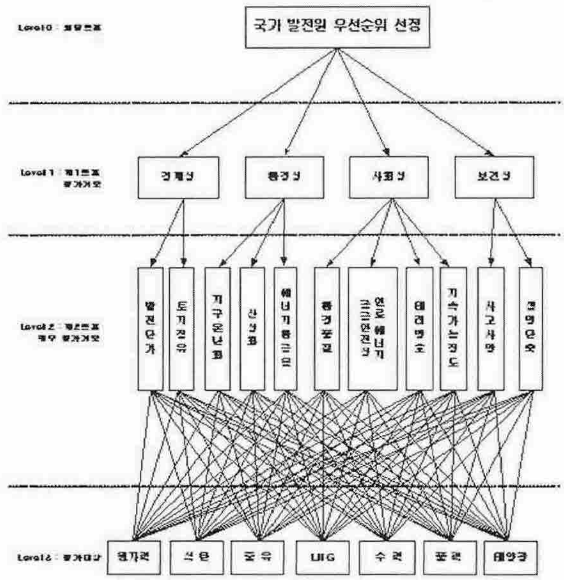

Figure 1. Hierarchical structure of electricity generation systems

As for weight estimate phase, a web-based questionnaire has been developed. Then, weight values will be obtained by surveying multiple groups of three attitudes towards a nuclear-focused electricity planning: anti-nuclear, pro-nuclear, and neutral attitude.

Concerning evaluation value estimate phase, objective evidence is used for economic, environmental, and health aspects, while subjective evidence is created in accordance to an AHP method.

Finally, as regards aggregation phase, the foregoing evidence is integrated for obtaining overall priority score.

As a preliminary stage, in Figure 2, for economic, environmental, and health aspects, various electricity supply options are represented by a web chart. Here it is assumed that each criterion has equivalent weight.

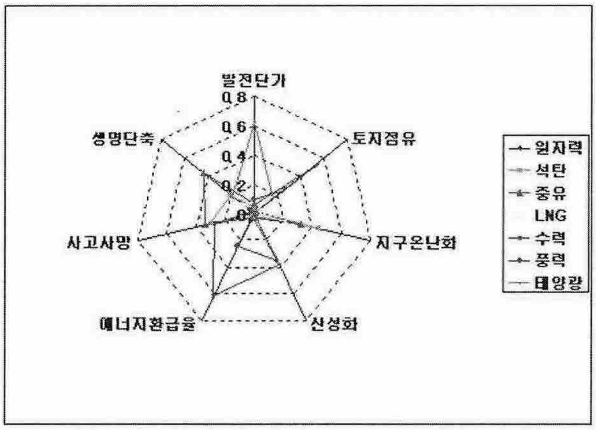

Figure 2. A web chart of various electricity supply options for economic, environmental, and health aspects.

Given weight values and evaluation values, aggregation is implemented using weighted arithmetic mean. The aggregated score for each option is used for ranking options or for managing ranking of a target option of interest.

4. Summary

An AHP-based framework for comprehensive comparison of several power technologies has been developed. A questionnaire has been designed and is about to surveyed for extracting both weight vectors and subjective evaluation values. The attitude of evaluator groups will be incorporated into these two types of quantification.

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REFERENCES

[1] European Commission (EC), ExternE project, Externality of Energy, EC, 1995.

[2] European Wind Energy Association (EWEA), Wind force 12: A blueprint to achieve 12% of the world's electricity from wind power by 2020, Greenpeace, May 2004.

[3] R. Friedrich and T. Marheineke (1994), Life cycle analysis of electricity systems: Methods and results, Proceedings of an IAEA Advisory Group Meeting/Workshop, Beijing, 67-75, 4-7 October 1994.

[4] IAEA, Sustainable development and nuclear power, Vienna, 66pp., 1997.

[5] IEA, A Photovoltaic power system programme: Annual report 2003, OECD, 109pp., 2004.

[6] D. W. Pennington, J. Potting, G. Finnveden, E. Lindeijer, O. Jolliet, T. Rydberg, and G. Rebitzer, Life cycle assessment Part 2: Current impact assessment practice, Environment International, Volume 30, Issue 5, pp.721-739, July 2004.

[7] G. Rebitzer, T. Ekvall, R. Frischknecht, D. Hunkeler, G. Norris, T. Rydberg, W. -P. Schmidt, S. Suh, B. P. Weidema and D. W. Pennington, Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications, Environment International, Volume 30, Issue 5, pp.701-720, July 2004.

[8] T.L. Saaty, The analytic hierarchy process, McGraw-Hill, New York, 1980.