Integrated Assessment of National Power Sources Using AHP Technique

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1. Introduction

Here, various national power sources including conventional as well as renewable energy systems are comparatively assessed in view of multicriteria decision-making (MCDM) spaces. The main objectives of this work are (1) to understand priority of power sources and (2) to figure out nuclear power's synergetic role in the national energy sector.

2. Methods

An integrated assessment system for comparison of power sources, as a MCDM tool, is developed. The system is based on an analytic hierarchy process (AHP) method [1] and a web-based questionnaire method [2]. The AHP modeling enables us to aggregate of both subjective and objective information. Even though AHP assumes independency among several criteria, AHP-based quantification is both easy-to-compute and its result is used at the benchmarking phase of a future dependence-modeling. In Figure 1, the assessment procedure based AHP technique is shown.

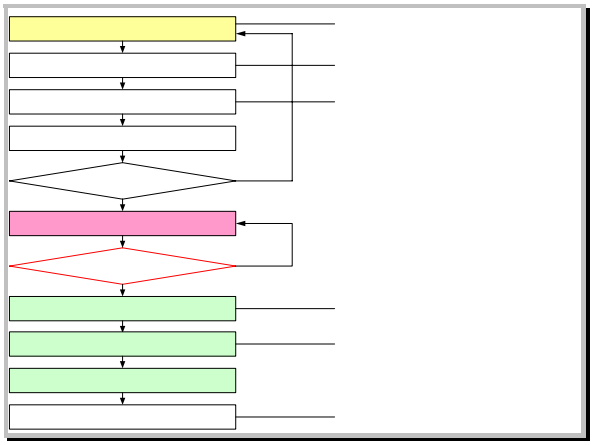

Figure 1. AHP procedure for power sources.

3. Results and Discussion

Power source alternatives under consideration are the conventional systems such as nuclear and fossil-fuelled (coal-fired, heavy oil-fired, LNG) as well as the new and renewable energy systems (hydropower, wind power, solar photovoltaic (PV) power). These seven options are evaluated in terms of several conflicting criteria shown in Figure 2. As a demonstration stage, four criteria (Level 1) and eleven sub-criteria (Level 2) spaces are chosen after other previous work [3] is reviewed.

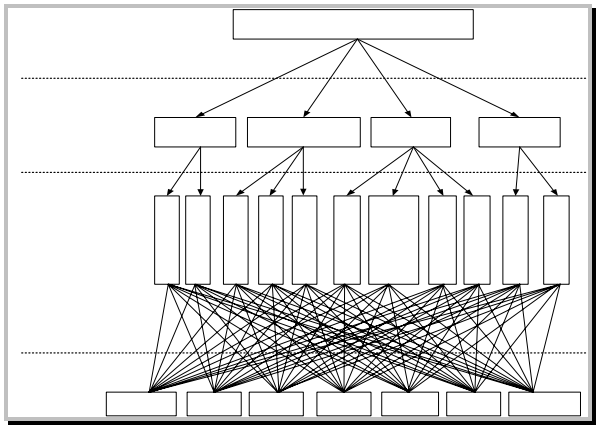

Figure 2. Hierarchical structure for integrated comparison.

As to weighting vectors, subjective opinion is extracted, in the first place, from pro-nuclear exports by using a web-based questionnaire. They are likely to expose positive attitude towards a nuclear-focused electricity planning. Figure 3 shows estimated weighting factors for each criterion.

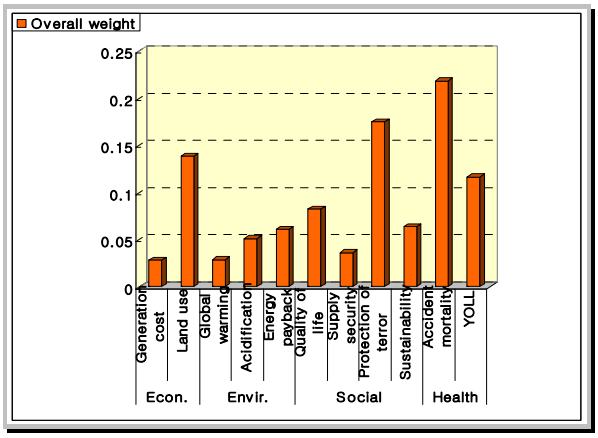

Figure 3. Level-wise weighting factors for various criteria

As shown in the Figure, the weights are obtained in an ascending order: Environment ≺ Economic ≺ Health ≺ Social. The highest weight is occupied by the accident mortality. Terrorism protection, land use, and years of lost life (YOLL) hold next weights in a descending order.

Concerning evaluation values, objective evidence is used for economic, environmental, and health aspects, while subjective evidence is gathered using the web-based questionnaire for social aspects. Here, generation costs correspond to market prices except for wind and PV in virtue of mandatory fixed-price purchases. A life-cycle assessment (LCA) for various energy sources is used for estimating other sub-criteria [4-6]. For accident mortality, empirical fatality data are collected in the literature.

Using weight vectors and estimate matrices, aggregation based on weighted arithmetic mean is conducted for yielding overall priority score. The aggregated score for each option is used for ranking options or for managing ranking of a target option of interest. In Figure 4, the aggregated scores for power sources are shown.

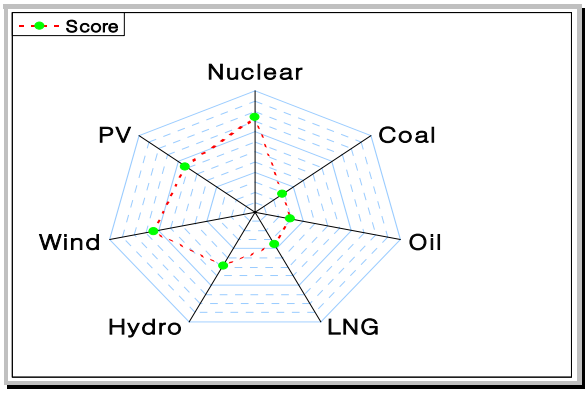

Figure 4. Priority scores of different power sources.

From the integrated point of view, overall preference of power sources can be summarized as follows: Nuclear ≻ Wind ≻ PV ≻ Hydro ≻ LNG ≻ Oil ≻ Coal. From the integrated viewpoint of the economical, the environmentally-friendly, the socially-acceptable, and the healthy aspects, nuclear power takes the first place. Renewable energy sources (i.e., PV, wind, and hydro powers) possess the second place. The last one is held by fossil-fueled power sources (i.e., LNG, heavy oil, and coal).

In Figure 5, relative contribution of various sub-criteria to each power source is shown. Weighted preference is presented to facilitate the source-wise comparison as well as the criterion-wise one. It should be noticed that nuclear power is mainly preferred due to the highest contribution of land use. Regarding renewables, it should be emphasized that wind and PV powers owe to accident mortality and global warming as well, whereas hydro is mainly attributed to YOLL and energy payback. it is found that LNG is the most preferred among fossil-fueled sources owing to the contribution of YOLL and acidification.

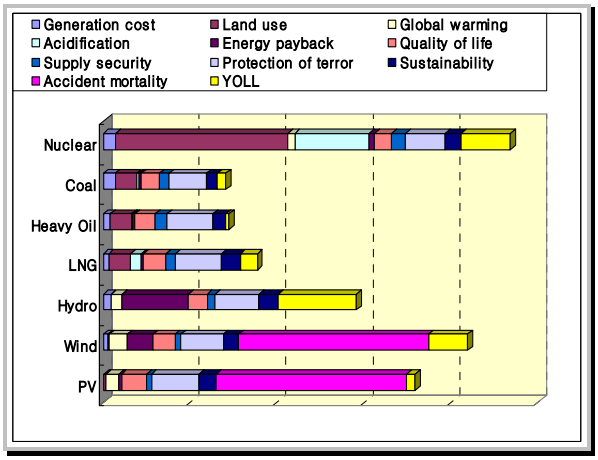

Figure 5. Contribution of sub-criteria to each power source.

4. Conclusion

An AHP-based assessment framework for integrated comparison of various power sources has been developed. The assessment model has been demonstrated using partially the opinion of pro-nuclear experts group and partially the objective evidence. The effect of attitudes of evaluator groups (e.g., pro-nuclear, anti-nuclear, neutral attitude) is about to be investigated in the near future research.

Acknowledgement

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REFERENCES

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

[2] S.J. Lee et al., Design of web-based questionnaire for comprehensive comparative assessment of various electricity generating systems, KOSEE 2004 Fall Conference, November 11, 2004, pp.283-289.

[3] B. Sorensen, The use of life cycle analysis to address energy cycle externality problems, Proceedings of an IAEA Advisory Group Meeting/Workshop, Beijing, 115-131, 4-7 October 1994.

[4] L. Gagnon et al., Life-cycle assessment of electricity generation options: The status of research in year 2001, Energy Policy, Vol. 30, pp.1267-1278, 2002.

[5] A. Rabel and J.V. Spadaro, The EXTERNE project, Workshop Proceedings Paris, 15-16 Nov. 2001, NEA, OECD.

[6] A. Voss, LCA and external costs in comparative assessment of electricity chains: Decision support for sustainable electricity provision?, 163-181, 2001.