A MULTI-OBJECTIVE ANALYSIS FOR A QUANTITATIVE EVALUATION OF NATIONAL ENERGY SECURITY

Ryosei Sai, Tohoku University, Phone: +81-22-795-6987, E-mail: ryosei.sai@dc.tohoku.ac.jp
Takaaki Furubayashi, Tohoku University, Phone: +81-22-795-6987, E-mail: furubayashi@m.tohoku.ac.jp
Toshihiko Nakata, Tohoku University, Phone: +81-22-795-7004, E-mail: nakata@m.tohoku.ac.jp

Overview

Japanese energy security is in a critical situation because imported fossil fuels account for approximately 80% of TPES in 2010 despite its low self-sufficiency and high dependency of oil from Middle East area. Therefore, it is an urgent task to create an explicit scheme for improving energy security. Thus, the purposes of this study are threefold. First one is to establish a specific definition considering significant aspects of the energy security concept. Now most researchers and institutions related to energy perceive it differently, which indicates that the study of energy security is still in its infancy and needs to elevate further. The second purpose of this study is to evaluate energy security quantitatively based on strategically selected criteria. The last one is to indicate a direction of energy policy towards a future highly secure energy supply system considering the economic feasibility by applying a multi-objective analysis.

Methods

A multi-objective analysis using augmented ε-constraint method (AUGMECON) is applied for Japan to obtain pareto frontier for optimal resource configuration from both high security energy supply and cost perspectives. GAMS is used for coding AUGMECON and figure 1 shows the algorithm of iterative calculation. Energy security index (*ES*) and total supply cost (C^{total}) are used as the objective functions in the model.

Energy security is defined as the "sufficient availability of energy supply to provide energy service demands at affordable price in harmony with both society and nature" in this study. According to the definition, *ES* is calculated by the following five criteria; Resource Diversity (*RD*), Import Price (*IP*), Import Region Diversity (*IRD*), Environmental Impact (*EI*) and Energy Efficiency (*EE*), as seen in equation (1). Each criterion is normalized between 0 and 1. All weight coefficients in the equation (1) are set 1 in this time as one case of the analysis. Total supply cost includes capital cost, O&M cost, fuel cost and other social costs. As this study is conducted on a national level aggregating supply and demand balances over a year, it does not consider time variation of supply and demand profiles and location specific constraints such as grid capacity and resource distribution.

$$ES = \alpha RD + \beta IP + \gamma IRD + \delta EI + \lambda EE \qquad (1)$$

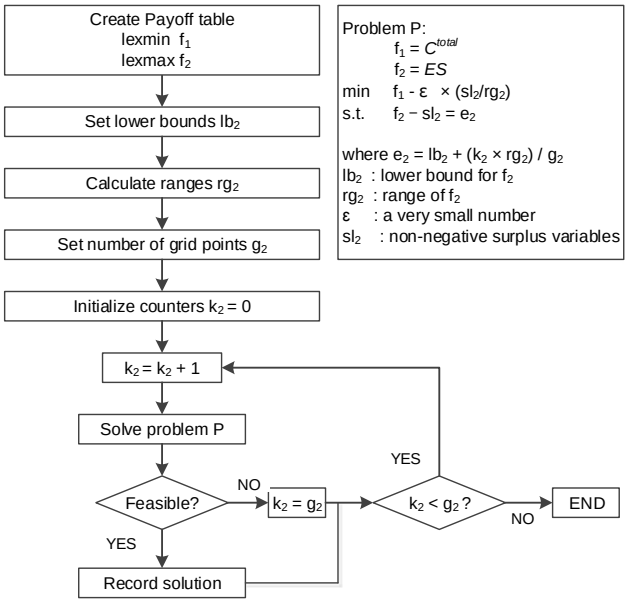
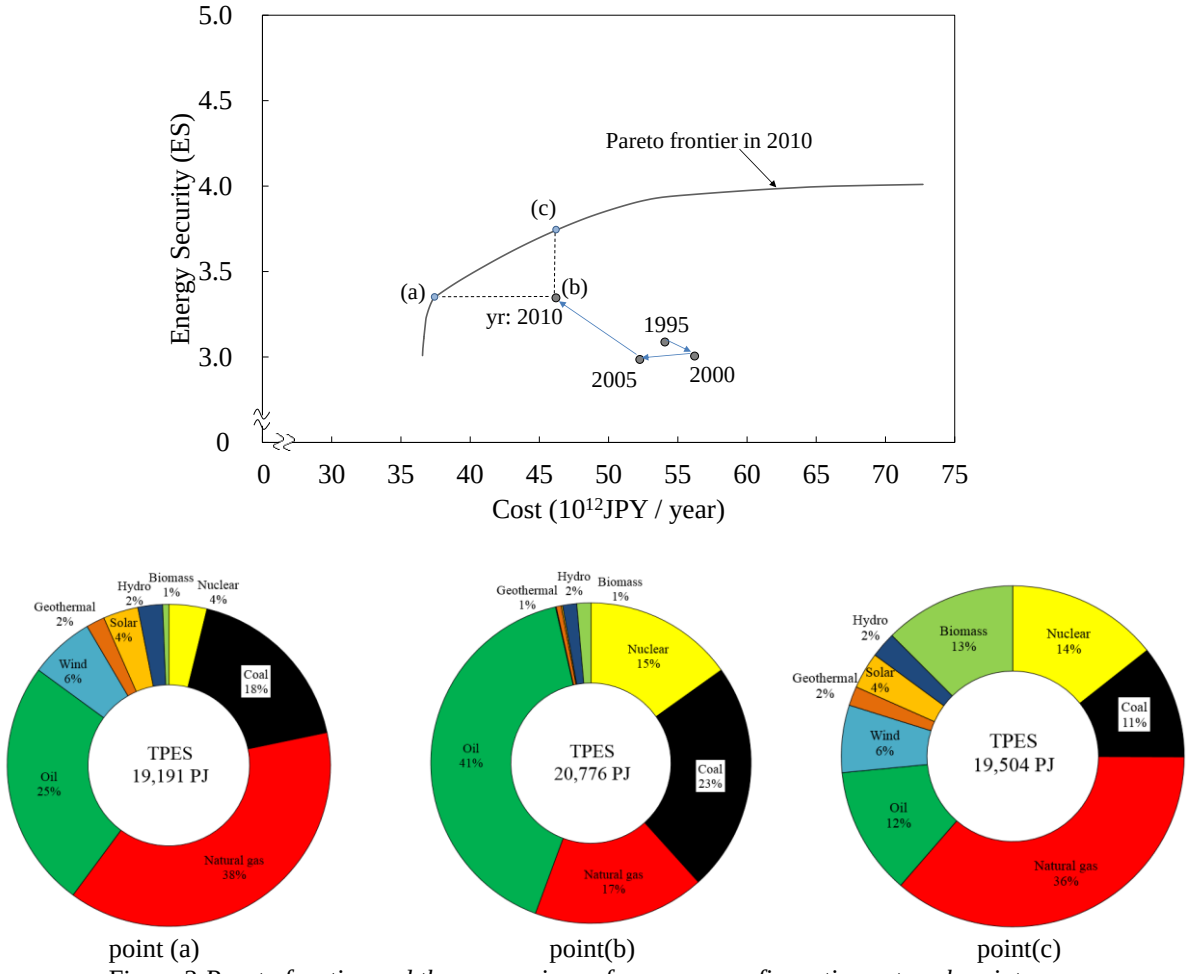


Figure 1 *Iterative calculation algorithm of AUGMECON*

Results

Through the multi-objective analysis, following are found out. (See figure 2)

- The existing energy system in 2010 is inferior to the pareto frontier although it has improved from 2000 in terms of both energy security and supply cost.
- Total supply cost can be reduced by 17% with keeping the same level of energy security at point (a)
- Japan can improve ES to the same level with Austria (ES=3.75) with the same cost in 2010 by increasing the use of renewable energy (especially biomass) and natural gas.



point (a) point(b) point(c)

Figure 2 *Pareto frontier and the comparison of resource configurations at each point*

Conclusions

This study presents a definition of energy security based on a comprehensive literature review and suggests a new evaluation framework including five key criteria representing various aspects of energy security. This enables us to evaluate the national energy security numerically for international comparison, through sound approach without the ambiguity of the concept. Moreover, owing to the multi-objective analysis applied on the analysis of energy security, the interrelation between a high secure system and its economic feasibility can be investigated.

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