Scenario Analysis using Graphical Representation for Developing Technology Introduction Strategies

その他のタイトル	技術導入戦略立案のための可視化手法を用いたシナリオ分析
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論文の内容の要旨

論 文 題 目　Scenario Analysis using Graphical Representation for Developing Technology Introduction Strategies
（技術導入戦略立案のための可視化手法を用いたシナリオ分析）

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Chapter 1 Introduction

For the last two decades, "Sustainable Development" has emerged as an important concern all over the world. While technology innovation is prompted and accelerated much faster in modern society, it is believed that appropriate management policies for emerging technologies play a significant role in the transition toward sustainable society [1-3].

There are numerous aspects in the assessment of technology, in regard to the environmental aspect, life cycle assessment (LCA) is considered a useful tool for studying the system-wide environmental impacts of respective technologies. For example, LCA has been applied widely in decision-making processes, to find the best technology options in future energy systems [4]. However, it is suggested that evaluating process for economic feasibility alone is no longer appropriate [5]. To identify major trade-offs and minimizing them through selection of less inferior alternatives have significant effects for designing a sustainable process [6]. In such decision planning, not only economic but also environmental, social, technological constraints and driving forces can affect the combination of technologies in a system.

To support strategic policy making, a framework for developing technology introduction strategies is proposed in this study. In this framework, a visualized analysis scheme which can comprehensively assess a combination of multiple technologies is developed.

Chapter 2 Scenario analysis for future technology introduction

In Chapter 2, a scenario analysis approach and how it can be applied to future technology introduction has been reviewed and discussed. Two principal approaches in LCA studies, what-if scenario and cornerstone scenario, are identified and applied according to different future situations. It is suggested that the cornerstone scenario is suitable when evaluating a complex system. The key factors for generating scenarios are categorized into five domains: social, economic, political, technological and environmental, which can serve as a framework for identifying external forces when generating future scenarios, and will be applied in this study.

Chapter 3 Visualization method for technology introduction

Chapter 3 proposed a graphical representation to systematically evaluate the interrelations among technologies, with being aware of uncertainties in choice of technologies is shown in Figure 1. In this visualization method, cradle-to-gate and gate-to-grave LCAs are conducted for technologies in production and utilization stages, respectively. As shown in Figure 1, Production (P_1~P_4) and Utilization (U_1~U_4) segments represent different technologies. The vertical axis shows the environmental impact calculated from an LCA study of the respective technologies, while the horizontal axis depicts the availability of the technology. The segments are listed in order of their gradients (P_1, …, P_4 and U_1, …, U_4) to construct the minimum environmental impact (P_{min}) and maximum environmental impact reduction (U_{max}) curves, respectively. The minimum impact (I_{min}) curve is synthesized from P_{min} and U_{max} curves, i.e. $I_{min}=P_{min}+U_{max}$. Similarly, the segments are connected into curves but in the reverse order (P_4, …, P_1 and U_4, …, U_1). The results of maximum environmental impact (P_{max}) and minimum environmental impact reduction (U_{min}) curves are used to synthesize the maximum environmental impact (I_{max}) curve, i.e. $I_{max}=P_{max}+U_{min}$.

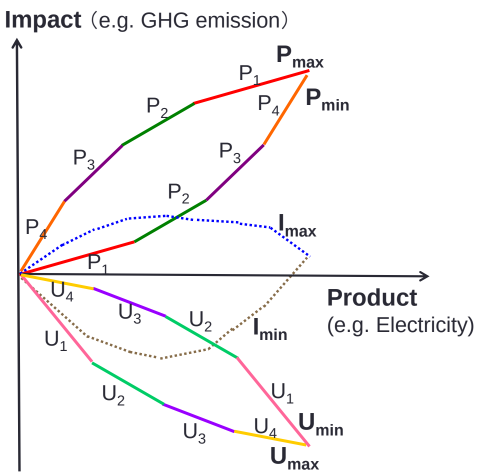

Figure 1 Graphical representations of scenario performance and behaviors by implementing different types of technologies

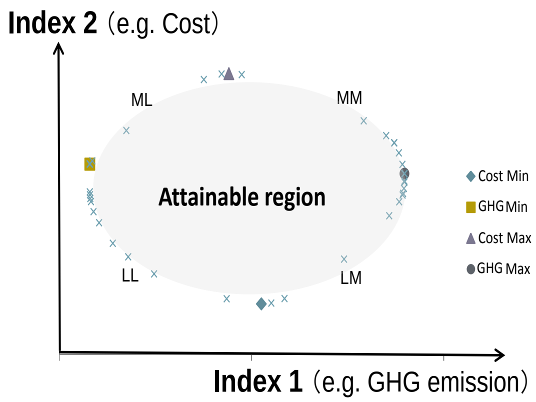

Figure 2 Visualization of relationship between two indices (cost and CO_2 emission as an example).

Visualization of trade-offs of different evaluation indices is performed in Figure 2. The comparison of possible future technology options within an environmental-economical context can help decision makers have a bird's-eye view in the development process. Furthermore, system transitions in a given time frame is also visualized. The visualization of different consequences between the present and the future makes it easier to see technology transitions and possible technological innovations.

Chapter 4 Application to the design of energy systems

In Chapter 4, two case studies are presented for demonstrating the proposed graphical representation method: a hydrogen-related technology in Taiwan and an electricity-based system in Japan. The former one is to assess a grassroots design (i.e. a new system) while the latter is discussing different technology implementation in a retrofit design (i.e. an exist system).

The case studies highlight the applicability of the visualized scenario analysis method in complicated energy systems. The applicability of this methodology is demonstrated by case studies discussing scenario performances and behaviors by implementing various power generation technologies in the energy systems.

Based on similar analyses, future technology combinations can be designed according to the required constraints. Decision makers can use this practical approach to identify key policy issues. The main benefit of this visualization approach is the capability to express scenario performance and behaviors systematically. Such analyses directly provide visual comparisons with multiple indices, ensuring that decisions can be made with confidence when designing new systems because all consequences are comparable. If the evaluated scenario does not achieve the required goal, decision makers can go back to the first step of the framework with strategic information (i.e. relationship between cost and CO_2 emission in this case study) by knowing the potential of the system.

Chapter 5 Methodological framework for technological decision making

Finally, the framework of developing technology introduction strategies is described by applying a standardized activity model (IDEF0). By this activity model, practical activities with information flows in executing the process of strategic decision making is hierarchically clarified as shown in Figure 3. The collaboration relationships among three types of stakeholders, i.e., management, assessment, and development, involved in generating new technology strategies is described by the model with the information flows among three individual activity models.

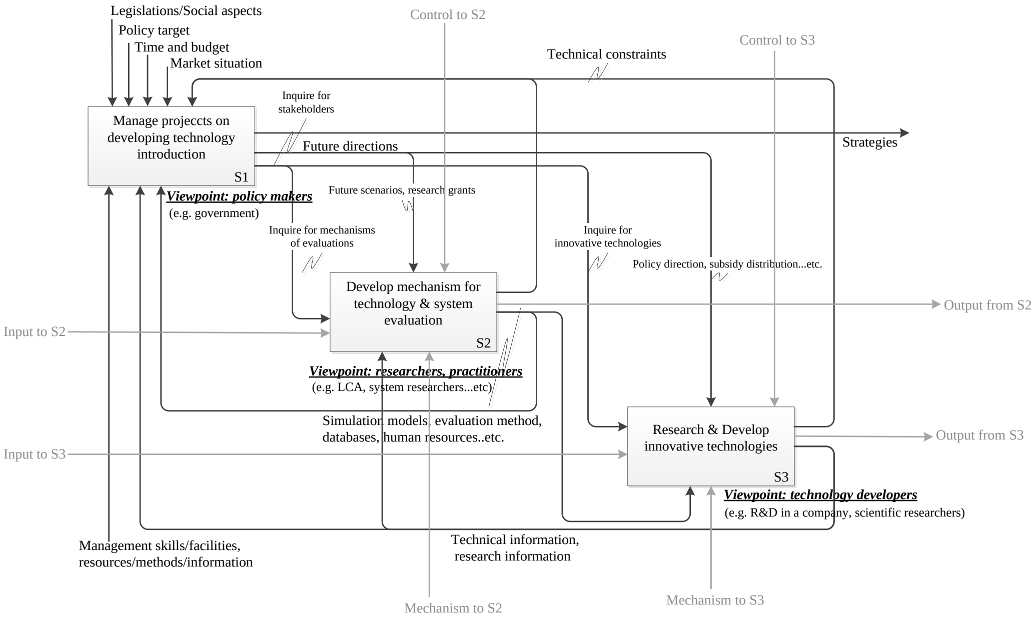

Figure 3 Cooperation and relationship among three stakeholders in generating new technology strategies

Chapter 6 Conclusions and discussions

A framework for developing technology introduction strategies was proposed in this study, using a visualized analysis approach that comprehensively assesses combinations of multiple technologies. This framework has advantages in (1) helping our understanding of performance and behavior of technology introduction scenario, (2) identifying the relationships and trade-offs among different evaluation indices, and (3) visualizing various technology introduction scenarios in which time frame is taken into account.

Chapter 7 Recommendations for future work

Extension of the covered aspects increases the comprehensiveness of the framework. Currently, the visualization method covers environmental impact and economic aspect. Integrations of other aspects such as risk assessment, social acceptance show a great importance to achieve a more comprehensive decision-making framework.

Reference

[1] Rees, *Environ Impact Assess*, 8(4), 273–291 (1998)

[2] Kørnøv and Thissen, *Impact Assess Proj Apprais*, 18(3), 191–200 (2000)

[3] Yasunaga *et al.*, *Technol Forecast Soc Change*, 76(1), 61–79. (2009)

[4] Rebitzer *et al.*, *Environ int*, 30(5), 701–20. (2004)

[5] Shadiya *et al.*, *Environ Prog Sustain Energy*, 32(32), 762–776. (2013)

[6] Gibson, *Impact Assess Proj Apprais*, 31(1), 2–12. (2013)