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Which of the technologies for producing hydrogen is the most prospective in Korea?: Evaluating the competitive priority of those in near-, mid-, and long-term

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HIGHLIGHTS

- We evaluated the alternatives for producing hydrogen in Korea using AHP approach in near-, mid-, and long-term.
- The framework is consist of goal, 4 criteria, 11 sub-criteria, and 7 alternatives.
- The questionnaire survey targets and results were divided into the R&D professional group and policy professional group.

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ABSTRACT

In order to evaluate the alternative technologies for producing hydrogen in Korea stage by stage, we searched for impact factors, calculated the weights of them and evaluated the hydrogen production technologies in Korea using analytic hierarchy process (AHP) approach. The AHP is a useful method for resolving multi-criteria decision making problems. We investigated 4 criteria (technical characteristics, economic efficiency, marketability, internal capability) and 11 sub-criteria (scale, efficiency, key barriers, carbon dioxide reduction, current production cost, expected production cost in 2017, feed-stock, technical maturity, R&D competitive level, technology gap with competing agencies, and domestic infrastructure). And the alternatives are natural gas reforming technology, coal gasification technology, biomass gasification technology, water electrolysis technology, thermochemical production technology, photoelectrochemical hydrogen production technology, and biological hydrogen production technology. In order to maintain the objectivity of the analysis result and observe the difference among the groups, the questionnaire survey targets were divided into the R&D professional group and policy professional group. This result of study is expected to serve as important basic information in the establishment of a national R&D strategy to prepare for the imminent hydrogen economy era.

1. Introduction

Currently, leading countries such as the USA, Japan and the EU have recognized the hydrogen economy as one of the potentially effective measures for coping with energy depletion and climate change in the future, and are continuing to allocate the R&D budget and invest in technology development with the aim of establishing the necessary research basis and promoting the hydrogen economy. In Korea also, the interest in hydrogen and fuel cells increased after the enactment of the 'Alternative Energy Technology Development and Usage Promotion Act' in 1987. Thereafter, the 'Hydrogen Economy National Vision and Execution Plan' was prepared in 2005 help improve public understanding of the hydrogen economy and establish a strategy. Furthermore, the Fuel Cell R&D Center (FCRC) and the Hydrogen Energy R&D Center (HERC) were formed to continuously support R&D. The most important factor in ensuring the transition from the current fossil fuel energy era to the hydrogen economy era of the future will consist in being able to supply low cost hydrogen in massive quantities stably. Since hydrogen can be produced using various energy sources, there are different hydrogen production technologies specific to each energy source, of which nuclear energy hydrogen using the intense heat of a nuclear reactor, vapor reformation using natural gas, coal gasification, and biomass

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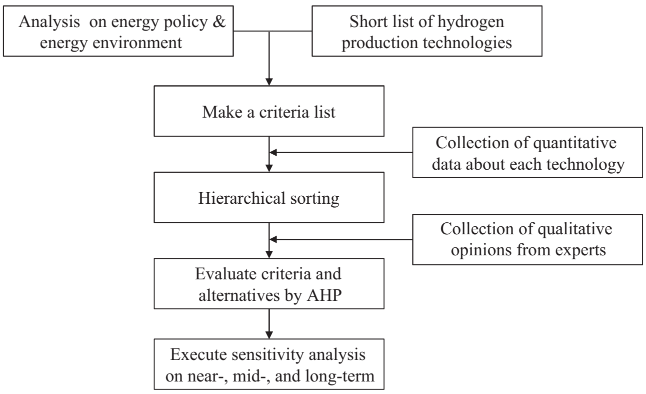

Fig. 1. Execution flow chart.

gasification are just some examples. For this study, we selected a hydrogen production technology that has a competitive edge in the near (2020), mid (2030) and long-term (2040), taking into account the hydrogen production technology R&D situation in Korea. For the evaluation, hydrogen production by natural gas reforming technology (NGR), coal gasification technology (CG), biomass gasification technology (BG), water electrolysis technology (WE), thermochemical hydrogen technology (TCH), photoelectrochemical technology (PEC), and biological technology (BL), all of which are subjects of active R&D in Korea at the moment, were considered. As the methodology for the analysis, the AHP method, the most widely used of the multi-criteria decision making methods, was used to deduce the result. Moreover, to maintain the objectivity of the analysis result and observe the difference among the groups, the questionnaire survey targets were divided into the R&D professional group and policy professional group. In this paper, Chapter 2 describes the methodology and chapter 3 introduces the empirical study. Finally, the last chapter presents the conclusion.

2. Methodology

2.1. Execution flow chart

The execution flow chart is composed of 6 steps to select more competitive technologies for producing hydrogen in near-, mid-, and long-term. Fig. 1 is a schematic diagram (Lee et al., 2008). We analyze the energy policy and environment with respect to hydrogen production in the first step. And we select the short list of hydrogen production technologies. In the second step, we make a criteria list to evaluate the technologies and collect the quantitative data about each alternative. We structuralize the problem with goal, criteria, sub-criteria, and alternatives in hierarchy structure at the third step. Next, we collect the qualitative opinions from expert in order to evaluate criteria and alternatives by AHP. Finally, we execute scenario analysis on near-, mid-, and long-term for selecting more competitive technologies.

2.2. Analytic hierarchy process (AHP)

The general structure of a multi-criteria decision making problem with K number of criteria is as follow.

$$\text{Max}\ \{f_1(a), \ldots, f_h(a), \ldots, f_k(a) | a \in K\}$$

In a multi-criteria decision making problem (MCDM), as the important thing is to find the conflicting criteria, there is not the optimal solution $\tilde{a}$ that satisfy the problem Max $\{f_1(a), \ldots, f_h(a), \ldots, f_k(a) | a \in K\}$ (Brans and Vinche, 1985). So, a multi-criteria decision making is a problem for which decisions are made by objectively measuring the priority of alternatives or mixing them when there are many criteria. The common multi-criteria decision making methods are MAUT (Multi-Attribute Utility Theory) which applied the utility functions of each criteria; AHP (Analytic Hierarchy Process) which is composed of goal, criteria, and alternatives in hierarchy framework and PROMETHEE (Preference Ranking Organization METHod Enrichment Evaluations) which uses preference functions based on a outranking background (Dyer et al., 1992; Saaty, 1980; Brans and Vinche, 1985).

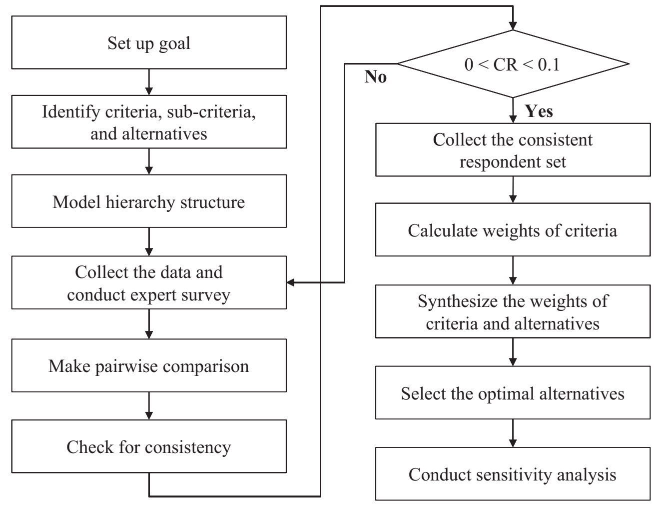

Fig. 2. The procedure of AHP application.

The analytic hierarchy process (AHP), which was developed by Saaty (1980) in the 1977, is a decision-making tool whereby several alternatives are evaluated according to multiple goals or factors. In general, the AHP is applied in variety of fields such as R&D planning, the selection of the best policy alternatives, the allocation of resources, the determination of requirements, prediction of outcomes, design systems, measurement of performance, and the optimization and resolution of decision conflicts (Saaty, 1986; Forman and Selly, 2002). And in order to establish Korean energy policy with respect to CO_2 reduction, renewable energy, nuclear energy, greenhouse gas and energy efficiency, AHP was used importantly (Lee et al., 2007a, 2007b; Hong et al., 2008, 2011; Lee and Hwang, 2010). In order to evaluate hydrogen energy technologies, Ren et al. (2013), Brey et al. (2012), and Lee et al. (2008) used AHP method, Heo et al. (2012) and Lee et al. (2011) used Fuzzy-AHP method, and Chang et al. (2011) used Fuzzy-Delphi.

AHP makes use of pairwise comparisons, hierarchy structures, 9-point ration scaling, and consistency ratio to calculate criteria's weights and priority of alternatives. Fig. 2 shows the process of AHP application (Lee et al., 2008). First of all, we set up the goal in a problem. The second stage identifies criteria and sub-criteria for evaluating the alternatives. The third stage makes hierarchy structures, which decomposes the complicated problem into a variety of components and structures the components into a hierarchical form. The fourth stage collects the data and conducts expert survey as input information of the model. We carry out pairwise comparison and then check for consistency in the fifth and sixth stages, respectively. In the seventh stage, we go over the consistency ratio (CR), which should be between 0 and 0.1. We collect the only consistent respondent set, which CR is greater than 0 and less than 0.1 in the eighth stage. We calculate the weights of criteria and synthesize the weights of criteria and alternatives in the ninth and tenth stages, respectively. Finally, we select the optimal alternatives and conduct the sensitivity analysis if necessary.