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Commercial application scenario using patent analysis: Fermentative hydrogen production from biomass

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ABSTRACT

Keywords:

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The main purpose of this study is to use patent analysis to investigate scenarios for future commercial applications of dark fermentation or anaerobic fermentation using biomass or organic matter as feedstock materials. The first step in this study includes a patent search procedure and patent content interpretation, in which 29 technology patents were identified from the US patent database and divided into five groups in accordance with the scope of their technical applications. The following five scenarios of commercial applications of biomass fermentation for hydrogen production were established through a combination of group applications: screening and cultivation of hydrogen-producing bacteria, biomass waste sources, biomass energization application, value enhancement of waste or wastewater treatment systems, and the application of a multi-functional hydrogen production system integrated with other technologies.

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Introduction

The development of hydrogen production technology, hydrogen applications, and the hydrogen economy is a very important set of solutions for reducing global dependence on fossil fuels and developing a sustainable energy supply. Hydrogen production is an extremely important aspect of the development and application of hydrogen energy technology. Currently, the predominant hydrogen production methods include coal gasification, natural gas reforming, water electrolysis, solar photocatalysis, thermochemical cycles by

nuclear energy, and hydrogen from biomass (or biohydrogen) [1]. Among the biohydrogen production methods, dark fermentation has excellent potential for practical application, and thus, it can be integrated with emerging hydrogen and fuel cell technologies [2]. The advantages of using biological hydrogen production include carbon emission reduction through the reuse of biomass, increase of crop revenue through the reuse of hydrogen production from waste biomass, sustainability of biomass energy, and the reduction of urban waste disposal costs [3].

The commercial production of biohydrogen must go through various developmental stages to move from the

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technology to its widespread application. Vijay reported that there are four stages of the commercialization of a new technology [4]: imagination, incubation, demonstration, and promotion. In the imagination stage, the new technology will be linked to the potential market demand and lead to new products, service concepts, and patent ideas. In the initial incubation stage of an emerging technology, the results of fundamental research will usually be presented through academic papers, while the results of application research will be reflected in the patents. Patents are useful sources of knowledge about technical progress [5]. Patent analysis, therefore, can be applied as a strategy for planning and modeling specific emerging technology developments from the macro level or the micro level [6,7].

Patent analysis is a valuable approach that uses patent data to derive information about a particular industry or technology for use in forecasting [8]. Because the patent process is costly and might take several years, filing a patent generally means that there is optimism about the economic prospects or technical contribution [9]. Levy indicated that the key features of patents, from an economic perspective, are that they encompass new knowledge and they confer monopoly rights to the owner that arise from the right to exclude [10].

Patent data analysis can be used to analyze industry trends in technological innovations [11]. Lee et al. suggested the use of patent data as a proxy measure of technological capability for business planning and building a technology-driven roadmap [12]. Patent analysis can also be used as a tool for enterprises to choose between technology options [13].

Lee et al. also pointed out that conventional patent analysis focuses on understanding the status of technology development and technology information. It does not integrate technology development and commercial perspectives, but it does confirm possible future business opportunities. Lee et al. proposed a technology-driven roadmapping process that starts from capability analysis for technology planning and ends with business opportunity analysis for market planning. They also suggested the use of patent data as a proxy measure for technological capability to complete this process [12].

To investigate the R&D status and trends in hydrogen energy and fuel cells, many scholars have conducted research on these aspects through patent analysis. Pilkington introduced a statistically driven patent-based method that identifies the technological portfolios of industry players; this method was tested using the case of fuel cell technology development [14]. Dongsheng and Xin [15] focused on the research on patents for proton exchange membrane fuel cells (PEMFC). They used the social network analysis (SNA) method to analyze the core patents and assignees of General Motors and Panasonic, and to obtain future trends of technology and other important information. Chen et al. [16] presented the technological S-curves that integrate bibliometric and patent analysis into the Logistic growth curve model for hydrogen energy and fuel cell technologies, and they identified the optimal patent strategy for the fuel cell industry, including PEMFC, solid oxide fuel cells (SOFC), and direct methanol fuel cells (DMFC)/direct alcohol fuel cells (DAFC).

Patents play a key role in fostering innovation and the commercialization of hydrogen production methods and

associated technology. Olivo et al. [17] used the patent analysis method to compare the priorities of advanced hydrogen production technology development among China, Japan, South Korea, the European Union, and the United States (US). They observed the scope and competitiveness of these technologies, and the developmental trends of biological hydrogen production technologies. In the research conducted by Lai et al., the differences in biological hydrogen energy fuel cell technologies among Taiwan, the US, and Japan have been compared based on patent and market analysis. The research indicated that Taiwan has put more focus on the R&D of feedstock and biological hydrogen production technology, while the US and Japan have emphasized the development of rear-end application products, and the integration of hydrogen energy and fuel cell applications with other industries [18].

However, the results of these studies based on patent information and patent analysis are mostly statistical, and there have not been any specific results related to application situations or commercialization trends in hydrogen energy and fuel cells. For technology R&D staff, investors, and government personnel in charge of formulating technological and industrial policies, an understanding of specific application situations and commercialization trends will help in the decision making with respect to issues such as investment in technology R&D and technology commercialization strategy. By establishing commercial application scenarios of fermentative hydrogen production from biomass through patent content analysis, this study has attempted to overcome the limitations in patent analysis research on hydrogen energy technologies in addition to the provision of specific application scenarios.

Materials and methods

A typical application of fermentative hydrogen production technology includes three important types of commercial information: type of feedstock source, hydrogen production method/procedure/device, and system application function or product. In this study, prospective patents will first be identified through a patent search procedure before confirmation, and content analysis is conducted manually by experts. The focuses of the analysis include feedstock sources, hydrogen production method/procedure/device, and applications and products involved in all patents. Finally, commercial application scenarios are summarized based on the patent analysis.

The method used in this study includes identifying patents related to fermentative hydrogen production from biomass through patent search and content analysis. These patents will then be categorized into different groups in accordance with the analysis results and the possibility of their individual application. Eventually, the possible commercial application scenarios (Fig. 1) are introduced through the categorization and combination of all patent groups. The specific research methods include patent information search, interpretation of retrieved data, and patent analysis.

Chang et al. [19] reported the correlations of wastewater treatment and hydrogen production (Fig. 1). In the original

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