論文の内容の要旨

Thesis Summary

論文題目

Title of Dissertation

Feasibility of Hydrogen Based Economy in the Gulf Cooperation Council (GCC) Countries

（湾岸協力理事会国における水素社会の実現可能性）

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The countries of the Cooperation Council for the Arab States of the Gulf, or the Gulf Cooperation Council (GCC), have a large resource base of hydrogen, either embedded in hydrocarbons or attainable through electrolysis with abundant renewable energy. This paper builds the case for a hydrogen economy in GCC countries. A hydrogen economy in the GCC would include not only the economic activities of producing and consuming hydrogen within the GCC but also of benefiting from its export remunerations. In this paper, the cost of producing hydrogen from natural gas and oil was found to be more competitive in GCC countries than it was in other locations throughout the world. Moreover, the cost of Carbon Capture and Sequestration (CCS) was also investigated, as was the economic and technical feasibility of producing hydrogen from solar energy. The economic impact of introducing a hydrogen industry was measured in terms of its effect on Gross Domestic Product (GDP). To determine this, the paper reviewed drivers that potentially contribute to the realization of a sustainable hydrogen-based economy for GCC countries. Here, the paper presents a cost analysis of two major solar hydrogen production routes—photovoltaic solar power and electrolyzers. In addition, the research qualitatively assessed the viability of a proposed solar-assisted hydrogen production system for the oil and gas industry, which is challenged by an increasing demand for hydrogen for hydro-processing. Finally, the paper examined

possibilities for measuring the economic impact of a hydrogen economy in GCC countries using frameworks such as the Leontief input–output table analysis. After establishing the economic imperatives, the paper summarizes the vision for a hydrogen economy in GCC countries and projects the impact of new technologies in the field. Japan has much to offer in this regard, not only as a hydrogen consumer but also as a hydrogen technology pioneer.

This paper assesses the feasibility of producing hydrogen from solar energy. The concept of harvesting solar resources has been the subject of extensive research and record-breaking projects. In 1977, the New York Times reported the establishment of what was then "the world's largest solar project," the Solar Village (40km north of Riyadh, Saudi Arabia). The Solar Village paid US$100 million for 350 kilowatts of various solar technologies (US$286/Wp). Today, more than forty years later, the price for photovoltaic solar has dropped to the 285th fraction of the nominal price, nearing just US$1/Wp. The region has embarked on staggering renewable development plans, chief of which are Masdar in the United Arab Emirates (UAE) and, more recently, the plans of NEOM Technology Hub for massive solar projects as part of Saudi Vision 2030 of the Kingdom of Saudi Arabia (KSA).

In a recent review of hydrogen production methods, Yilmaz and Balta et al. [2] first reviewed the work of Joshi and Reddy, [3] who performed an exergy analysis of hydrogen production methods, then categorized hydrogen production technologies that use solar energy into four main areas: (1) photoelectrolysis, (2) concentrated solar thermal and thermochemical processes, (3) photobiological generation, and (4) electrolysis combined with solar electricity. Within these categories, some production methods have evolved and are now used on a large commercial scale, while others remain in pilot or laboratory stages.

Utilizing the SAUDIO input–output table analytical model, which was developed to assess the economics of the future Saudi energy mix, the cost of electricity from the PV and CPV systems was evaluated and found to range from 5 to 10 ¢/kwh, and the cost of solar hydrogen was found to be between 2.5 and 8 $/kg. These results suggest that harvesting hydrogen from solar and exporting to the Japanese market is feasible. In particular, there is high potential to export hydrogen as a fuel. However, the economics of using hydrogen in passenger vehicles face some impeding factors, chief of which is the cost of fuel cell powertrains and the lack of a distribution infrastructure. When measured in mileage driven, the unit cost of hydrogen fuel was found to be more expensive than that of gasoline at the current prices. Nevertheless, this gap will narrow as the solar hydrogen cost declines following the learning curve decline in photovoltaic panel prices. This research also investigated the economic impact of introducing a hydrogen economy in GCC countries in terms of GPD and the economic ripple effect of the hydrogen sector on other economic sectors.

This research also investigated the margin build up along the hydrogen value chain and concluded that a relatively large portion of the value chain margin was allocated to the shipping, distribution, and retail of hydrogen. The research concluded that these value chain segments could also offer new business opportunities for hydrogen producers in GCC countries in the future.