Possibility of hydrogen energy For development of sustainable society

Kuniko Urashima, Seiji Maeda, Masahiko Katagiri, and Nagahiro Saito

***Abstract*—** Hydrogen energy research is not only solving environmental issue such as a fossil fuel resources and alternative energy reduction measures, but also tailored for the issues important to the future of the automotive industry are one of the green innovations. In order to achieve a hydrogen energy systems, and infrastructure development, technology development are important elements relating to the use of hydrogen production, transport and storage. The fuel cell electric vehicle (FCEV) has been trying to commercialize since 1970's and many researcher has been solving many problem and it's almost time to sell it. Although Toyota Motor Corp. and Honda Motor Co., Ltd. made the fuel cell passenger car put in practical use for the first time in the world on December, 2002. Moreover, development of hydrogen storage technology was very expensive and set to one of the keys was infrastructure as well as cost. Furthermore, instead of a gasoline station, a hydrogen refueling station needs to be improved as an infrastructure. Fortunately, such a subject is solved, and car maker will put FCEV car into the market by 2015 in Japan. Moreover, in each country which makes the auto industry including the United States, the spread strategy is built as a next-generation car. For enhancing of market, we have to set up "Hydrogen society" where must be providing enough volume of necessary hydrogen and that should be enough ability of safe technologies. And based on the trend of each country, it looks down about the possibility of the hydrogen energy given to energy supply-demand structure reform of Japan. The subject about innovation systems, such as financing and a regulatory system is summarized especially. Also we are going to review what is the important key issue of hydrogen storage material that based on each countries policy and related energy issue for enhancing of market and cost of FCEV.

***Keywords*—**hydrogen, energy, hydrogen society, hydrogen storage, sustainable society

I. Introduction

THE hydrogen energy research is not only solving environmental issue such as a fossil fuel resources and alternative energy reduction measures, but also tailored for the issues important to the future of the automotive industry are one of the green innovations. In order to achieve a hydrogen energy systems, and infrastructure development, technology development are important elements relating to the use of hydrogen production, transport and storage [1-5].

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The fuel cell electric vehicle (FCEV) has been trying to commercialize since 1970's and many researcher has been solving many problem and it's almost time to sell it. However there are still many challenges such as hydrogen storage material, supplying system in society, and cost is the biggest task for commercial of FCEV. Although Toyota Motor Corp. and Honda Motor Co., Ltd. made the fuel cell passenger car put in practical use for the first time in the world on December, 2002. Moreover, development of hydrogen storage technology was very expensive and set to one of the keys was infrastructure as well as cost. The characteristics of requirement of hydrogen storage are 1) occlusion is emitted effectively, can be used, and / an occlusion-discharge cycle is high, 2) compact, 3) light weights, 4) it is easy to take hydrogen by the usual environmental condition, 5) cycling characteristics is high, 6) equipment cost, and a running cost are cheap, and 7) it is safe and easy to deal with it etc. Furthermore, instead of a gasoline station, a hydrogen refueling station needs to be improved as an infrastructure. Fortunately, such a subject is solved, and car maker will put FCEV car into the market by 2015 in Japan. Moreover, in each country which makes the auto industry including the United States, the spread strategy is built as a next-generation car. For enhancing of market, we have to set up "Hydrogen society" where must be providing enough volume of necessary hydrogen and that should be enough ability of safe technologies. Then, the next-generation automobile strategy which each country is examining and reviewed. And based on the trend of each country, it looks down about the possibility of the hydrogen energy given to energy supply-demand structure reform of Japan. The subject about innovation systems, such as financing and a regulatory system is summarized especially. Also we are going to review what is the important key issue of hydrogen storage material that based on each countries policy and related energy issue for enhancing of market and cost of FCEV.

II. The situation of Hyrdrogen energy

A. What is the Hydrogen energy

While hydrogen reacts with oxygen to generate water, it is also considered as a medium for converting energy. It is converted to heat energy when it is simply burnt, to mechanical energy when used for internal combustion engines such as hydrogen engines, and directly to electric energy when used for fuel cells. In any of these processes, the reaction between

hydrogen and oxygen generates only water and does not emit CO_2 that causes global warming. Since hydrogen is a secondary energy that can be produced by such methods as the electrolytic decomposition and thermal decomposition of water, by combining with renewable energies such as sunlight, it is possible to construct a hydrogen energy cycle based on the hydrogen generated from water as an ideal clean energy system that is not affected by resource restrictions and also decreases the environmental burden. This is the reason why hydrogen is called the ultimate clean energy. Because hydrogen is a material, it is superior to electricity in that it can be stored in large quantities, and this fact provides the unique feature of hydrogen as a chemical energy.

To realize hydrogen energy systems, it is a premise to develop elemental technologies related to the production, transportation, storage, and utilization of hydrogen and to build the social infrastructure. The hydrogen energy systems must be discussed in the total framework including technologies for production, transportation, storage, and utilization as shown in Fig. 1[1].

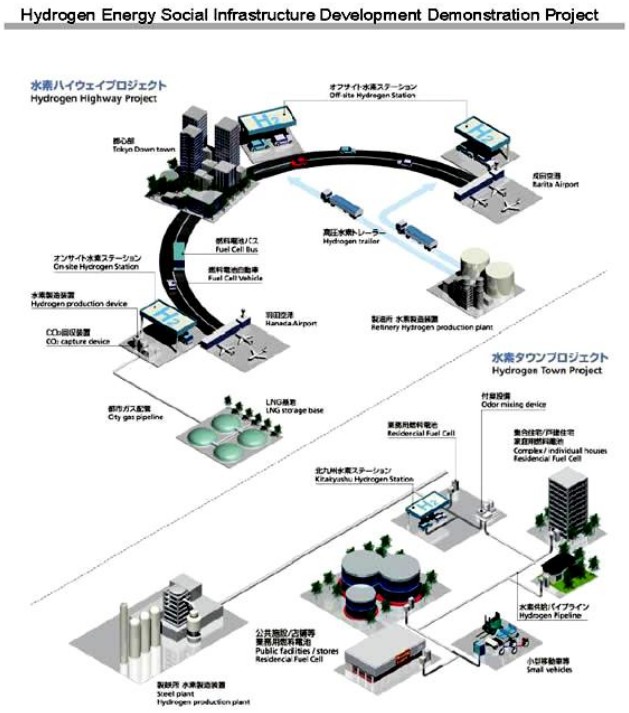

Fig. 1 Image of hydrogen energy society [1]

B. Usage of hydrogen energy

Hydrogen is utilized in many application fields including the chemical industry such as the synthesis of ammonia and methanol and desulfurization refining of petroleum, the metal industry such as the reduction of ores, the electronics industry such as the production of semiconductors, and the glass industry such as the production of optical fibers and glass. In the future, hydrogen is also expected to be used for stationary fuel cells as distributed energy sources that utilize its energy conversion function and automobiles equipped with fuel cells.

To expand the use of fuel-cell-powered vehicles that use hydrogen as fuel, in-vehicleon-board hydrogen storage units that replace the gasoline tanks of gasoline-fueled vehicles are required. Furthermore, hydrogen supply stations corresponding to gasoline stations are required as an infrastructure. These needs require hydrogen technology that enables temporary storage as well as stable and safe supply of hydrogen as required at an appropriate speed.

III. The Trend of Hydrogen Energy in the World

Making full use of hydrogen as the fuel for fuel cellsfuel-cell-powered vehicles will solve the environmental problems in urban areas with heavy traffic, and, from the long-term point of view, we can expect that hydrogen will become the ultimate clean energy that starts with renewable energy, substituting the fossil fuels on which our present automobile society depends.

A. Japan

Figure 2 shows the transportation roadmap by 2030. According to this map, driving distance by hydrogen vehicles is 800km by 2020[2]. Actually, Toyota announced that they are going to bring HV by 2015 so that infrastructure such as supply station is key of this subject.

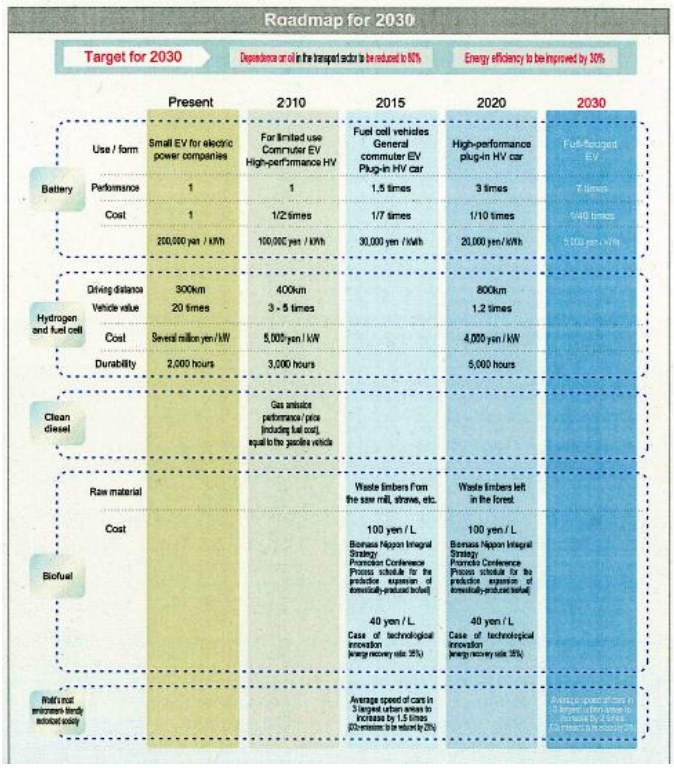

Fig.2 Roadmap of transportation by METI [2]

B. EU

In order to build a hydrogen storage facility in the Purrya state in Italy, seven European organizations established the consortium. In this construction project "Ingrid", Under initiative of Engineering Ingegneria Informatics of Italy which

deals with ICT (information and communication technology: Information and communication Technology), Regional Agency of Technology and Innovation (ARTI) which is a technical innovation office of a state government, Enel Distribution which is an electric power company in Italy, Two research institutions (RSE of Italy and TECNALIA of Spain) besides McPhy Energy of France which deals with Hydrogenics and the storage technology of hydrogen which are the electrolytic apparatus makers of Belgium specially have participated. The consortium is proposing the system which combined the electrolytic apparatus using smart grid-oriented advanced ICT with the hydrogen storage facility, and intends to promote exploitation of renewable energy. The hydrogen storage technology (notes) of McPhy, the electrolysis technology of Hydrogenic, and a fuel cell electric power system are introduced into the storage facility of the schedule built [3].

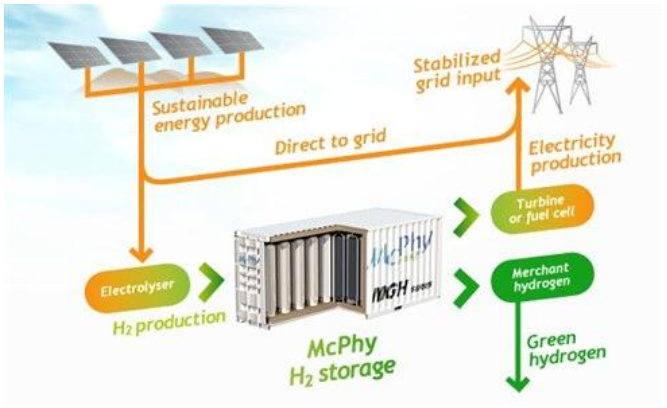

Fig.3 View of INGRID Project [3]

C. North America

Development of hydrogen energy technology in the U.S. has been started in 1992 by the Hydrogen Program of DOE. The development has been mainly carried out as part of PNGV (Partnership for a New Generation of Vehicles), which is a development project of the federal government for the next-generation automobiles started in 1993, as well as part of CaFCP (California Fuel Cell Partnership) by the state of California. After a "hydrogen fuel initiative" rises in 2003 under a Bush administration, the research and development about a fuel cell and a hydrogen infrastructure have progressed steadily. The test about an aspect of practical use is also carried out completely. Vehicles offers were received from major automakers, such as Daimler and GM, and the actual proof experiment of FCV and a hydrogen station was conducted in each state of the United States. As a result, it turned out that "the performances as a car", such as the number of times of supply of the durability of a fuel cell or hydrogen and a cruising range, is in a level almost equivalent to a gasoline-powered car. It was likely to continue the development of a fuel cell and the maintenance of a hydrogen infrastructure which have been advanced from their Bush administration days under the Obama Administration. However, since the budget cut of the infrastructure building of a hydrogen station was hammered out as the Department of Energy, the future is opaque.

Hydrogen Highway was due to complete arrangement and to work towards the Winter Olympics and the Paralympics which will be held by Vancouver and Wisler Canada in 2010. In order that the Canadian Federalism government may promote development of the vehicles using a fuel cell "Vancouver Fuel Cell Vehicle Project: Vancouver fuel-cell vehicle both projects", "A Hydrogen High-Pressure Valve Development Project: hydrogen high-pressure valve development project", "Hydrogen-Powered Delivery Van Project: hydrogen fuel delivery van both projects" was carried out. This project puts a fuel cell in practical use for broad uses, such as a fuel cell for vehicles, an object for fixation, portable, and use to micro power, and it aims at using the infrastructure of hydrogen fuel effectively.

IV. Advantage of Hydrogen Energy

Since Japan has the world's top level technology in the field of energy, actively contribute to substantial global emissions reductions while reinforcing and maintaining our competitiveness. This can be done both by focusing our research and development resources on the technology fields where we can lead the world and by accelerating and promoting technology development with the recognition that technology is an important resource for Japan as shown in Fig. 4.

It is possible that technologies that are just emerging may develop into those that can contribute to substantial reductions in carbon dioxide emissions with future research and development and some breakthroughs. Therefore, HEMS (House Energy Management System) is key of energy management and controls the energy for individual houses, and BEMS (Building Energy Management System) controls the energy in individual buildings to optimize the energy utilization. Local-level EMS is an energy control system with a wider areas.

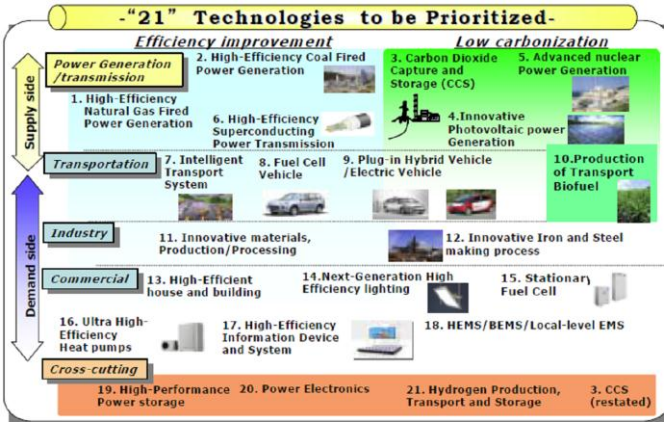

Fig.4 21 technologies related energy demand/supply [2]

A. Reduction of GHG

Moreover, if desert photovoltaic, wind force on the ocean, etc. are utilized and hydrogen is manufactured, carbon-free hydrogen is realizable.

B. Energy security

Hydrogen can be manufactured from primary resources. For example, if lignite is gasified in a resource-rich nation and hydrogen is taken out, unused resources to economic merit can be induced from the ability to supply in the form of hydrogen to a demand place.

C. Contribution of economy

The market size which sells hydrogen as fuel will amount to 130 billion yen in 2025. In the hydrogen associated equipment overall markets including a hydrogen station, it is likely to amount to 250 billion yen in 2025. Since a fuel cell, the component of high-pressure apparatus, and manufacture are a Japanese maker's special provinces, the business not only in domestic but the world is expected. Hence, it contributes solving a problem such as unemployment and job creation of a new industry.

V. THE SUBJECT FOR REALIZING HYDROGEN SOCIETY

A. Hydroegen Storage

The hydrogen is a substance that has the advantage of being compared to the bulk storage of electrical energy as shown in Fig. 5. In order to disseminate the fuel cell vehicles and hydrogen fuel is in fuel cell vehicles, alternative fuel vehicles fuel tank will need a board hydrogen storage system. There needs to be improved as a hydrogen refueling infrastructure also temporarily storing hydrogen, the hydrogen with the ability to provide a stable and secure an appropriate speed when the required amount of hydrogen required storage technologies are required. Therefore, in order to disseminate the energy will be strongly urged to develop hydrogen storage technologies for practical and economical hydrogen [4-9].

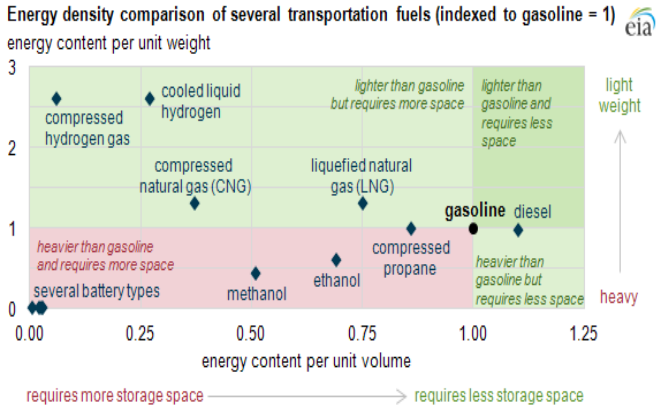

Fig. 5 Comparison of energy density by several transportation fuels [9]

B. Development of Infrastructure

It is necessary to build the supply chain which is cheap to use expansion of hydrogen, is stabilized in it, and supplies a lot of carbon-free hydrogen to it from a producing district to a demand place. For that purpose, storage technology needs hydrogen production, transportation, and to be breakthrough realized.

C. Concencus of society

Residents' consensus building is also needed for use expansion of hydrogen with city planning. Making an organization for using the result of an actual proof experiment effectively and solving a subject, an exploitation campaign, etc. are important.

VI. CONCLUSION

To realize a hydrogen energy society, the final picture of ultimate clean energy systems that start with renewable energy must be drawn as a long-term vision. On the other hand, it is also indispensable for the social acceptance and propagation of hydrogen energy to draw up intermediate strategic scenarios. Through realistic promotional measures including effective utilization of fossil energy and educational campaigns, creation of an atmosphere of public acceptance, establishment of regulations and systems, and standardization should be promoted.

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