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A NEW HYDROGEN ECONOMY FOR JAPAN

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Abstract

Research was conducted on the vehicular fuel cell infrastructure in Japan. Reasons for the switch to a hydrogen economy were found; and the past, present and future roles of supporting organizations were determined. The results were analyzed and an estimate to Japan's progress toward a hydrogen economy was made.

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Chapter 1 Introduction

1.1 Japan

Japan would benefit from switching to a hydrogen economy for two main reasons. It lacks domestic sources of energy, in 1998 their dependence on energy related imports stood at more than 80% requiring that they import large amounts of crude oil, natural gas, and other energy resources. They also realize that the burning of fossil fuels to make energy is unhealthy and is destroying the environment.

Japan has become a world leader in the development and implementation of pollution control technologies and energy efficiency innovations. The reason they have become so involved in environmental awareness and technology is because the past few decades marked a time when the government pursued economic development with no regard to its environmental impact. This focus on economic development led to significant health problems like "minamata" disease, caused by industrial emissions released in waste water. Japan still faces many environmental challenges including increased energy consumption as a result of economic growth which has led to increases in nuclear waste, road traffic, pollution, and multiple other energy related environmental problems.

Replacing the way Japan currently creates energy, with a new hydrogen economy will alleviate it from some of these environmental problems. However, moving from one energy economy to another is no easy feet; it requires both a financial and communal backing. The move has begun, as there are many government, private, and public organizations working toward this cleaner more efficient energy. A look at where Japan is today, what it's mid and long term goals are, and where it plans on going to create a hydrogen infrastructure, will be explored in this report.

1.2 Pollution

Perhaps the biggest push for hydrogen is due to a need for reducing air pollution on both the local and national levels. Air pollution was first addressed in 1968 through the Air Pollution Control Law most recently amended in 1996. The Air Pollution Control Law makes air quality monitoring stations mandatory in several parts of the country. The stations check whether nitrogen dioxide (NO_2), suspended particulate matter (SPM), sulfur dioxide (SO_2), carbon monoxide (CO), and photochemical oxidants (O_x) fall within national emission standards. All of these standards have certain parameters. The limits on sulfur oxide emission for stationary sources vary according to their geographic location of the facility and height of the exhaust stack. While nitrogen oxide emission limit values vary according to the type of boiler of furnace.

Automobile traffic is a major cause of urban air pollution in Japan. There are approximately 126 and a half million people in Japan spread across 37.79 million hectares of land area. This means that the population density is 335 persons per square kilometer and goes to show that most of the population lives in urban areas. Also, there are approximately 86 million people between the ages of 15 and 64 meaning there are approximately that many with licenses. Both of these details combine to influence the urban air pollution in Japan due to the automobile. With larger population densities come more pollution problems, meaning that Japan would benefit greatly from switching to the much cleaner hydrogen fuel cell.

Japan was the fourth largest energy consumer in the world in 2001, behind the United States, China and Russia, accounting for 5.4% of the world total. Fossil fuels, accounted for the majority of this energy consumption; 50.2% from oil, 16.8% from coal, and 13.6% from natural gas, totaling 80.6%. This doesn't leave much room for non-carbon energy sources, the most prominent being nuclear energy, accounting for 14.4% of Japan's total energy consumption. Ironically, Japan is the world leader in renewable energy technologies, and non-hydroelectric renewables accounted for only 1% of the total. Carbon emissions in Japan contribute 4.8% of the world's total energy-related carbon emissions.

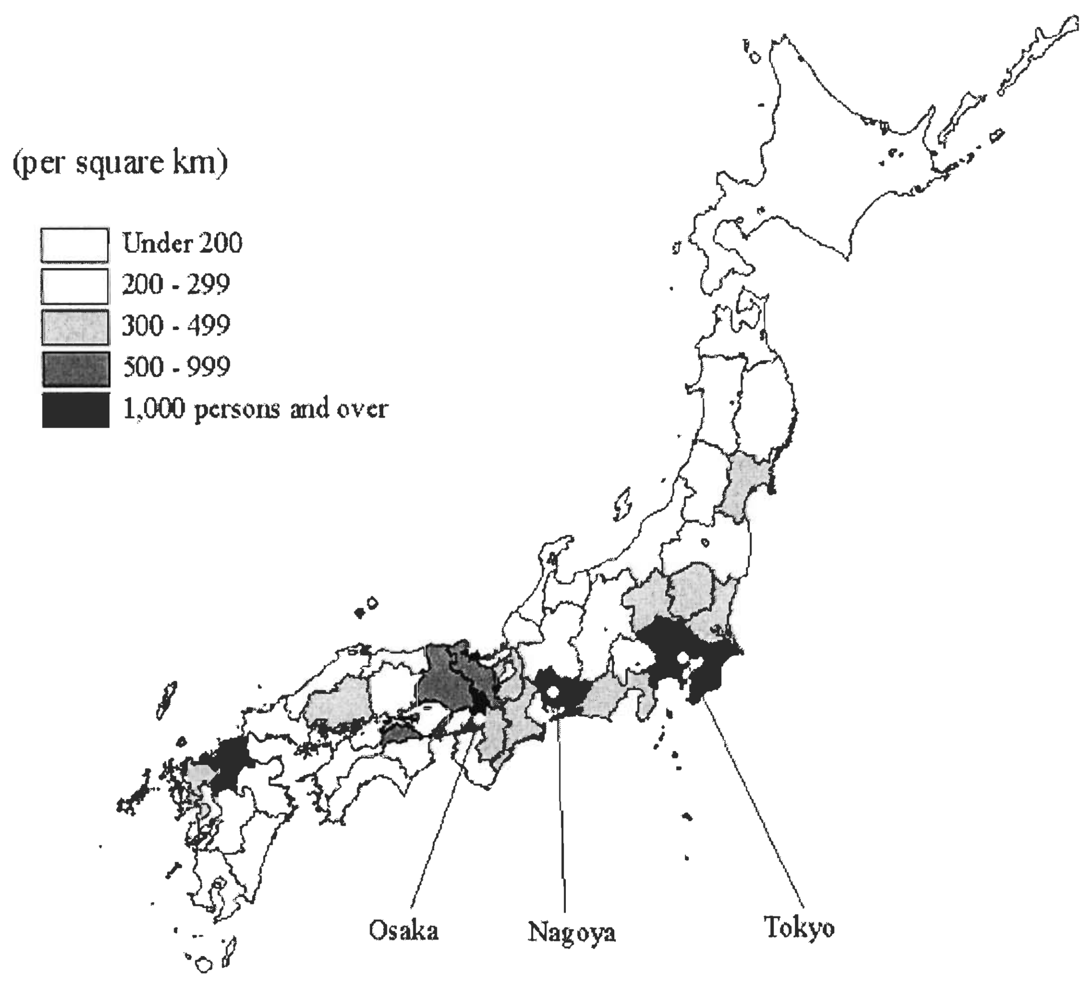

Figure 1 Population Density

Chapter 2 Supporting Organizations

The Basic Environmental Law of Japan was enacted in November 1993 and defines the roles of the different Japanese authorities involved in environmental protection. The Ministry of the Environment (MOE) is the chief national authority for environmental matters. Among other things it is responsible for coordinating policies and budgets and setting many of the environmental standards. Other agencies involved in environmental protection include METI, the Ministry of Health, Labor, and Welfare; and the Ministry of Agriculture, Forestry, and Fisheries. The Environmental Dispute Co-Ordination Commission, which was created in 1972 to mediate disputes over pollution, is managed by the Ministry of Public Management, Home Affairs, Posts, and Telecommunications. Working alongside these government organizations are automobile manufacturers, mineral oil companies, energy suppliers, and other industries that feel this is a major issue.

2.1 Government Role

The Japanese government has been taking an active role through creating new laws and providing financial assistance in developing new energy for the past 20 years. In 1992, the Agency of Industrial Science and Technology in the Ministry of Trade and Industry (METI) presented a project entitled International Clean Energy Network Using Hydrogen Conversion (WE-NET: World Energy Network) as a part of the New Sunlight Project.

2.1.1 METI's Targets

METI put its focus on the commercialization of fuel cells, fuel cell vehicles and a hydrogen infrastructure and set targets in 2001. Such targets included:

Year	FC Vehicles	Stationary FC
2010	50000	2100 MW
2020	5 million	10000 MW

Table 1 Fuel Cell Targets

Targets for development of technologies behind the fuel cell include increasing;

- Cell Performance
- System Efficiency
    - FC Stack >55% HHV (direct H_2)
    - FC System >40% HHV (reformate gas)
- Life Time
    - Stationary FC 40,000 hours
    - Vehicular FC 5,000 hours

Issues to be solved for H_2 and fuel cell commercialization

- Cost Reduction
    - Residential FC $2500/unit (1 kW system)
    - On-Site FC $1250/kW
    - Vehicular FC $41.6/kW
- Fuel Infrastructure
- Deregulation
- Partnership of government, industry, and academia

Gaining a market entrance will require proving to the population that this is a worthwhile investment for them. The fuel cell therefore must compete with other energy producing technologies. To contend they must attain a high performance, low-cost system which ultimately translates into one that has a long life span, highly efficient, compact, and lightweight while at the same time available at a low cost. Another obstacle they must pass includes creating a fuel infrastructure. Just like the fuel infrastructure that is present today, hydrogen stations must be set up to keep the consumer on the road. Far less hydrogen refueling stations will be needed in the beginning as there will be very few cars to service. In 2002 there were six stations throughout Japan including three in Yokohama, two in Tokyo, and one in Kawasaki with 5 more completed in 2003. But in the year 2020 it is estimated that 4,000 stations will be needed to service the 5 million fuel cell vehicles. This represents a hydrogen demand of 6.2 billion Nm^3/Year. Finally, codes and standards will need to be created until 2005 for safety standards, test procedures, and deregulation of fuel cells.

The WE-NET project aimed at efficient utilization of energy with its focus on renewable energy. The project included hydrogen production from water by harnessing renewable energy, transportation of hydrogen by converting it to a form suitable for transportation, and the supply to large energy consuming areas. The goals behind WE-NET were to contribute to the reduction of carbon dioxide, to alleviate international energy supply and demand, to create opportunities for more energy production, and to foster export industries in countries with large sources of renewable energy. WE-NET is the biggest force in Japan behind the move to a hydrogen economy. Their work has given birth to countless solutions for the switch as well as finding new problems that need to be dealt with before it can be successful.

Japan's Demo Project which is apart of the larger European Bus Project includes Daimler Chrysler, Mazda, Nippon Mitsubishi Oil Corporation and the Ministry of Economy Trade and Industry (METI). There main goals are to demonstrate technology, emissions testing for CO, NOx, and HC, prove a willingness to cooperate, and bring ideas into Japanese technology discussion.

In March of 2003, the WE-NET program was complete after spending $69 million in Phase 1 and $72 million in Phase 2, totaling $141 million in the last 10 years. MITI has opened a new project that started as WE-NET ended and will last until 2007, requesting an additional $250 million. Its objectives include supporting market introduction of hydrogen fueled fuel cell vehicles from 2005; establishing a hydrogen infrastructure for vehicles; and contributing to the global environment and securing energy sources. Some of the research and development priorities incorporated into the project are the validation and evaluation for safety of hydrogen in order to enact regulations, codes, and standards required for market introduction; develop related technologies needed to establish hydrogen infrastructure such as compressors and 70MPa hydrogen cylinders; micro fuel cell systems for electronic devices.

2.1.2 Government Law

The Japanese government enacted the Law Concerning Promotion of the Use of New Energies in June of 1997. The law was put in place to encourage the introduction of renewable and non-conventional energy sources by providing financial assistance to businesses which use new energy sources. In April of 1999 the law was revised so that both central and local governments offered economic incentives to promote the use of green products and technologies, including solar cells and lower emission vehicles.

2.1.3 Other Government Projects

The Japanese market will play a major role in the commercialization of the fuel cell. The government has been working to reduce hydrocarbon consumption through two projects. The before mentioned Sunlight Project supports the development and commercialization of renewable energies, and the Moonlight Project provides government support for the development of efficient energy conversion systems. The government has made significant expenditures in the area of the fuel cell, and some of the largest Japanese industrial companies have provided substantial resources. Government subsidies have included 100% of the costs for Research and Development, 50% of the costs for pilot plants, and 33% of the costs of construction and operation of fuel cell power generation systems.

The Ministry of Economy, Trade and Industry has set aside approximately 21.5 million dollars for the next year. This money will be given to projects whose aim is to see what problems arise when using fuel cells and developing an infrastructure. In one project, several automakers will participate in road tests for the fuel cell vehicles or FCV including Toyota, Honda, Nissan, General Motors, and Daimler Chrysler. Each automaker will provide one FCV for the tests. Five hydrogen supply stations in different parts of Japan will be set up to test different ways of refilling the hydrogen and examine safety issues. Most automakers have now had fuel cell vehicles on the market since 2003 and 2004, however Toyota and Honda had some available by the end of 2002. The

Japanese government is encouraging the development of fuel cell vehicles by setting a goal of 50,000 fuel cell cars on the road by 2010.

2.2 Honda Motor Company

Honda Motor Company has their sights set on the starting abilities of fuel cell vehicles in cold weather conditions. The fuel cell produces water while generating power, therefore cold conditions will turn the water to ice and prevent the fuel cell from starting. Today's cars use anti-freeze to keep the water in liquid state, but the fuel cell cars can not apply this system. Honda will design insulation for the fuel cell and then aim to establish anti-freezing technologies without a heating system. Mr. Yoshino, president of Honda made the major push to commercialize the fuel cell vehicle with these technologies late in 2002, earlier than the original schedule.

2.3 Toyota Motor Company

Toyota started development of the fuel cell in 1992. They have developed a number of prototype models but the first one to get everyone's attention was the FCHV-3, introduced in March 2001 in Tokyo. It featured a hydrogen-absorbing alloy tank and had a body resembling the Highlander SUV, acknowledging the recent calls for cuts in carbon dioxide emissions among SUVs. The FCHV-3 also had a secondary battery for storing energy that is created during braking. In June 2001, the development of the FCHV-4 was announced. This new fuel cell vehicle received a certified license plate from the Minister of Land, Infrastructure and Transport, allowing it to be used on public roads in Japan. With these specially certified license plates, Toyota began road tests to demonstrate the performance of its fully independently developed fuel cell system.

These tests included a three year period of data gathering in demanding environments like expressways and steep roads. The FCHV-4 stored its hydrogen directly in high pressure tanks and also featured the Toyota FC Stack with an output of 90 kW. The FCHV-5 generated its electricity from hydrogen derived from Clean Hydrogen Fuel. CHF is seen as the next generation liquid fuel as it can be produced from crude oil, natural gas or coal and has low sulfur content. Clean Hydrogen Fuel can also be used for fuel in gasoline engine vehicles and can be supplied by current gasoline pumps. This makes the FCHV-5 useful where hydrogen supply infrastructure is not available. A fuel cell hybrid bus was developed jointly with Hino Motors, Ltd. in June 2001. This low-floor, 63 passenger, city bus is apart of an effort to improve urban air quality and reducing urban noise. Toyota put fuel cell vehicles on sale in 2002 in both Japan and the United States. They had carried out test drives totaling 110,000 km in Japan and the United States in June and July 2001 and received good results. Even though there are still problems with costs and driving performances in cold weather conditions, they put 20 cars on the market, including Japan and the US. After the project was over they leased these cars to government agents, research agents and energy related companies. The sales area will be confined to California, Tokyo and Yokohama because of the availability of hydrogen gas stations. Toyota will also exhibit and demonstrate a fuel cell bus at the Japan International Exposition held in 2005, where the bus will be used to transport visitors around the main site.

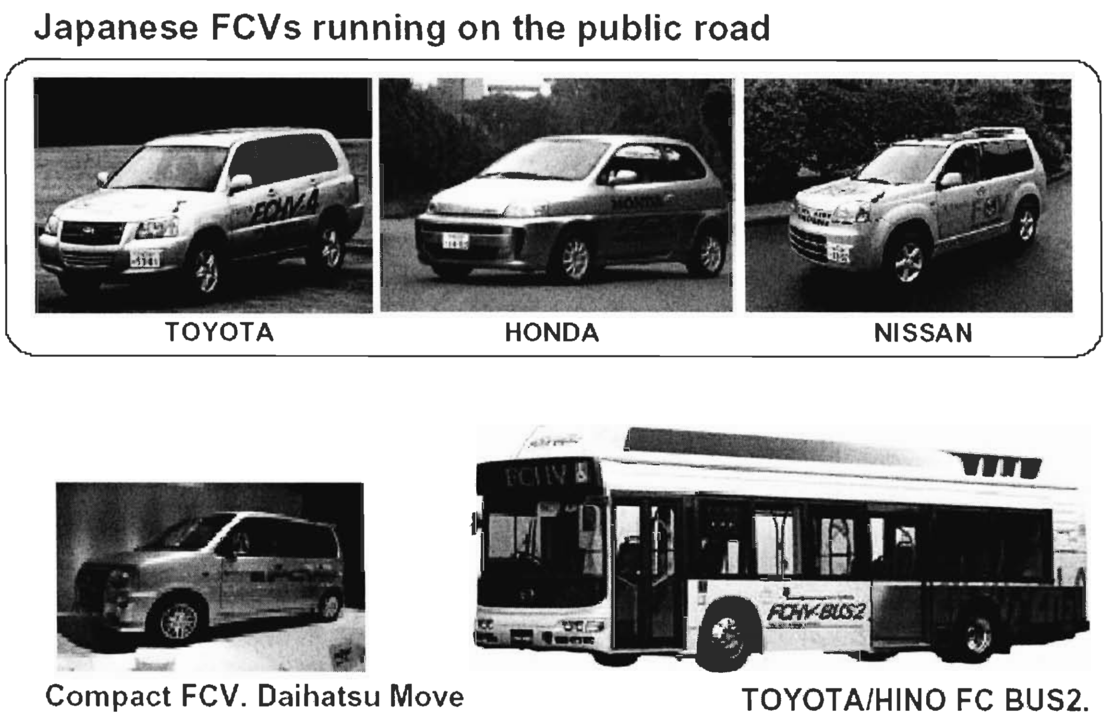

Figure 2 Fuel Cell Vehicles on the Market

Toyota Motor Corporation has begun to research hydrogen-storing technologies with carbon nanotubes. They intend to put it into practical use as the hydrogen tank of FCV. They want to establish evaluation methods of the hydrogen-storing ratio and then develop the compact, high efficiency hydrogen tank based on these methods. Researchers have been developing the carbon nanotube to increase the storing ratio of hydrogen; however the evaluation methods of the test data have not been established yet. Toyota is now establishing international standards so they can test the nanotubes against the eventual goals of the fuel cell. Toyota also initiated research on a wide range of fuel sources such as gasoline, natural gas and liquid hydrogen, as well as development of components for use with such types of fuel. In January 2001, they announced a plan for the development of clean hydrocarbon fuel, an evolved form of gasoline.

2.4 Mitsubishi and Daimler Chrysler

Mitsubishi Motors Corporation decided to start to develop FCV with the direct hydrogen injection systems with the cooperation of Daimler Chrysler. The Japanese government will carry out public road tests on FCV in 2003 with Mitsubishi and Daimler Chrysler.

Since 1990 Daimler Chrysler has been developing fuel cell technology. With the first fuel cell vehicle worldwide, NECAR 1, presented in 1994 they proved that the technology is suitable for the automobile. This first model looked more like a rolling lab, with only enough room for two passengers. Two years later, its successor NECAR 2, was able to reach a maximum speed of 110 km/h and could travel 250 km on one tank of fuel and had 6 seats making it a usable station wagon. In the fall of 1997, NECAR 3 demonstrated that the hydrogen for the fuel cell can also be produced from a fluid cell like methanol directly onboard. NECAR 4 runs on liquid hydrogen and reached velocities of 145 km/h and could cover a distance of 450 km on a single tank. Daimler Chrysler is now presenting the first fuel cell vehicles which will be deployed in fleets and tested by customers in a few countries including Japan and Singapore. The project involves practical testing of 60 Mercedes-Benz A-Class "F-Cell" models by customers in Europe, the US, Japan and Singapore.

Chapter 3 Hydrogen Infrastructure

Introducing a hydrogen infrastructure for vehicles into an environment that has only ever seen petroleum is an extremely difficult feet. In order to establish it into Japanese culture they need to prove that the benefits to changing outweigh the negatives. To demonstrate this, fuel cells will need to be tested and gain exposure to the public. Refueling stations need to be put in place or it wouldn't be worthwhile to invest in an FCV. There are a few different organizations that have operational refueling stations in Japan already and are gaining valuable information everyday to things that must be done in order for the new economy to work.

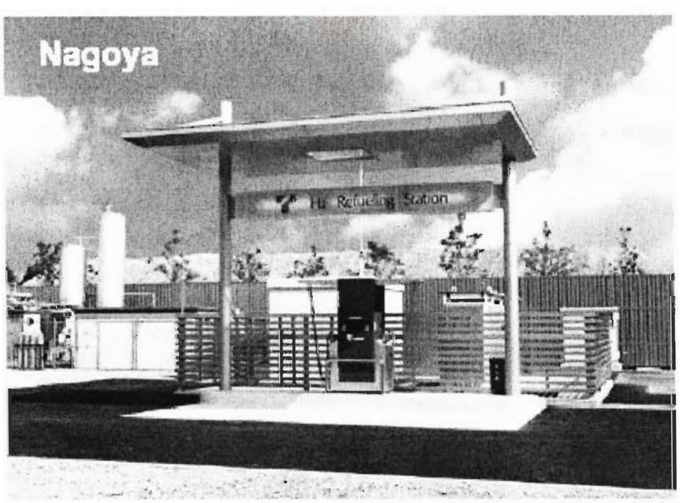

Figure 3 Hydrogen Refueling Station

The Toho Gas Co., a major supplier of natural gas in Japan, is working on developing technologies for the production and supply of hydrogen to fuel cell vehicles. The company aimed to establish the technology by 2003/2004 to meet future demand for fuel cell vehicles. Toho Gas will set up a hydrogen station at its research institute in Tokai, Aichi Prefecture, and study technologies for the production, storage, and fueling of hydrogen. The planned station will be able to produce 40Nm/h of hydrogen and supply it to 30 fuel cell vehicles a day. Toho Gas has also developed a hybrid battery fuel cell delivery vehicle. The prototype vehicle is based on a one seat battery car designed for pizza delivery. Two 250 W Proton Exchange Membrane fuel cells have been installed on the vehicle. The vehicle is a great way to study the effects of difficult stop and go driving on the fuel cell.

WE-NET contributed to the hydrogen infrastructure with work on hydrogen refueling stations as well. In order for the stations to be put in place a number of different objectives must be fulfilled. They must prove reliable and safe operation through the entire system as well as the process of refueling hydrogen. Design instructions and standards must be established for the reformer, elecrtolyzer, metal hydride storage, compressor, high pressure storage, dispenser, control system, refueling operation, and safety consideration. Demonstrations for hydrogen fuel utilization will need to be made to the public.

WE-NET has developed a fuel tank system for fuel cells after conducting multiple safety and quick refueling tests on MH fuel tanks. They have also developed three hydrogen filling stations. The stations use PEM electrolysis, natural gas reforming and by-product hydrogen systems. METI completed five hydrogen refueling stations using various fuels in March through August 2003 for a demonstration of FCV's conducted by Toyota, Honda, Nissan, GM and Daimler-Chrysler.

H_2 sources	Location
1. By-Product H_2 . WE-NET)	Yokohama
2. LPG reforming	Tokyo
3. Liquid H_2	Tokyo
4. Methanol ref.	Kawasaki
5. Naphtha ref.	Yokohama
6. Desulfurized gasoline ref.	Yokohama

Table 2 Hydrogen Sources and Locations

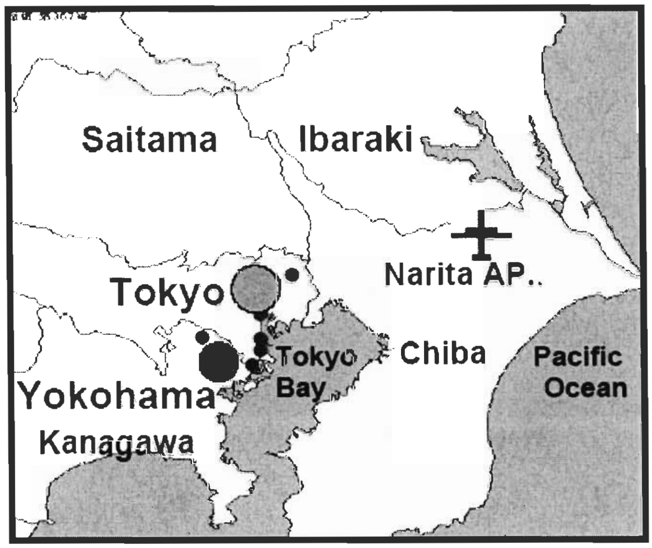

Figure 4 Locations of Hydrogen Stations

Chapter 4 Conclusion

After researching Japan's past, current and future involvement with a new hydrogen economy, it can be concluded that they are advancing the technology very quickly but will not be able to implement it until the infrastructure catches up. The tanks used to store the hydrogen fuel, and the fuel cell that will power the vehicle are at the end of the development stage. Therefore, the fuel cell vehicle is nearly ready to compete with the conventional combustion engine. However, the infrastructure needed for the use of fuel cell vehicles is not near complete. There are few laws and regulations set up for the use of the fuel cell. These take time to be implemented as they must gain the approval of the government. It appears that Japan's roadmap for the future of the fuel cell is a gradual one, where in the year 2020, 5 million of the estimated 85 million cars will be powered by a fuel cell. Fifteen years from now only 6% of the total driving population will own a fuel cell vehicle which gives plenty of time for the 15 to 20 hydrogen fueling stations to grow into the 4,000 needed to accommodate that number of cars. In conclusion, although slowly developing, the roadmap that Japan has set up for itself will ultimately be a successful one.

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