Technical Feasibility and Market Potential for Fuel cell Scooters in Taiwan

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Abstract

Fuel cell is the star industry in 21st century. To probe into the current development and prospect for fuel cell scooters, this article commences with the technical feasibility for fuel cell scooters, including the introduction of fuel cells, the critical technologies of fuel cell stacks, hydrogen storage in scooters, hydrogen distribution infrastructure and the system integration of fuel cell scooters. Taiwan's accomplishments of fuel cell scooters presently are introduced as well.

Secondly, the market potential for fuel cell scooters is well discussed. The famous "Zero Emission Scooter Policy" of Taiwan includes "Electric Motorcycle Development Action Plan", more strict air exhaust standard, subsidy for purchasing electric scooters, and encouraging R&D. The policy impact will thus affect the scooter market's structure in Taiwan. Furthermore, Taiwan's and global scooter markets are also analyzed. Finally, the theory of industrial competition is provided to analyze the strengths, weaknesses, opportunities and threats for Taiwan to develop fuel cell scooters.

In conclusion, with the fuel cell technique for scooters in its mature stage and the solid foundation of Taiwan's scooter industry, Taiwan is suitable for developing fuel cell scooters. In addition, since Taiwan has proven on account of developing prototype fuel cell scooters-ZES I and ZES II, it has the technical capability for fuel cell scooters. Fuel cell scooters are supposed to replace current gasoline engine scooters, which make much pollution, in Taiwan and global markets with significant potential.

1. Introduction

1.Introduction

Due to the awareness of environmental protection recently, the request for improving living quality and the voice for regulation over vehicles' emission is growing year by year. To improve the situation of severe pollution and shortage of petroleum in the vehicle industry, developing scooters with zero emission, low noise and high efficiency is of great urgency. Therefore, fuel cell scooters, most helpful to reduce carbon dioxide, are suitable in the consideration of energy efficiency and environmental protection benefit.

Fuel cell is one of the most important innovative technologies in 21st centuries and, it can apply to vehicles, electric power system and 3C (computer, communication and consumer electronics) products extensively. It is a great benefit to the earth. On the solid basis of Taiwan's scooter industry, developing fuel cell scooters not only breaks the bottleneck of promoting rechargeable electric scooters, which many efforts have been put in for many years, but also procures the request for environmental protection. Furthermore, it fits in with the regulation of "Framework Convention on Climate Change (FCCC)" as well as consumers' demand of scooters.

2. Technological Feasibility for Fuel Cell Scooters

2.1. Introduction of Fuel Cell

Hydrogen, the principal fuel material of fuel cells, could be abstracted from coal, oil, petroleum, natural gas by reforming. Furthermore, it could be made by electrolysis of water as well. There are many kinds of fuel cells, classified by the electrolyte what the fuel cells employ. These include proton exchange membrane (or polymer electrolyte) fuel cell (PEMFC), phosphoric acid fuel cell (PAFC), solid oxide fuel cell (SOFC), alkaline fuel cell (AFC), molten carbonate fuel cell (MCFC), direct methanol fuel cell (DMFC), etc. Fuel cells have some superior characteristics as following: (1) high efficiency, the efficiency of transforming energy is up to 40%, greater than internal-combustion-engine vehicles; (2) zero emission, the production after fuel cells reacting is pure water without any pollution; (3) quiet, fuel cells don't employ any mechanical component, therefore, there is no noise at all; (4) no power failure, electric power can be generated as long as supplying fuels, hydrogen and atmosphere. Among the fuel cells mentioned above, PEMFC has the potential to be commercialized because the temperature when reacting is just 40~80 centigrade degree. It also has the advantage of starting up rapidly. At present, major automobile companies such as Daimler Chrysler, GM, Ford Motor, Toyota, Honda, Nissan and so on, are devoted to develop proton exchange membrane fuel cell (PEMFC) electric cars and they are expected to commercialize fuel cells automobiles in 2005.

2.2 The critical technologies of fuel cell scooters

Contrast to the development of fuel cell automobiles in Europe, American and Japan, Taiwan focus on exploiting fuel cell scooters. The followings are the critical technologies for fuel cell scooters.

（1） Fuel Cell Stack

Fuel cell Stack is the core of a fuel cell engine as shown in figure 1. It is made of several independent fuel cells. As long as hydrogen and oxygen are put into the cells, the oxyhydrogen ignites electrochemistry and result in electricity. The power of a fuel cell scooter is between 1~6kW, depending on performance and specification. Therefore, the technology of fuel cell stack, which is sufficient to install in a scooter, is mature technically. The point is how to produce a PEM fuel cell stack with high efficiency and stability economically.

Figure 1. Fuel Cell Stack

Source: APFCT, 2001.

（2） Hydrogen Storage in Scooter

The methods suitable for vehicles to store hydrogen include compressed gas, liquefied gas, methanol and reformation, and metal hydride, etc. Table 1 is a comparison of these methodologies by the storage density, convenience, cost and safety for scooters. The storage density and safety of compressed gas are both low and take too much space in scooters. Although the liquefied gas has higher storage density, its safety is low and the cost is high. Currently vehicle manufacturers are conducting intensive R&D on reformatting petroleum and methanol to abstract hydrogen. However, considering the limited space and weight of a scooter, this kind of fuel storage is not suitable. Therefore, in terms of storage density, convenience, safety and cost, the hydrogen storage alloy metal hydride, which uses FeTi as its main material, is the best way to store hydrogen currently. In addition, the metal hydride hydrogen storage canisters can be designed with quick disengagement connectors, like a swappable one for exchanging when the vehicle cover is opened, for easy replacements. Consumers do not need to be in direct contact with hydrogen when refilling their fuels. The metal hydride canister, as shown in figure 2, will have safety devices with pressure releasing valve. Even if the hydrogen is leaking, it will burn internally and not set fire. During the gun shot test, the metal hydride canister only melted at the shot hole not explode. In addition, to relieve the pressure of supplying hydrogen currently, the metal hydride canister is indeed the most suitable storage way for scooters. (APFCT, 2001)

Table 1. Storage Scheme Comparison Matrix

	Relative rating for scooter application			
	Storage density	Convenience	Cost	Safety
Compressed gas	Low	Low	Low	Low
Liquefied gas	High	Low	High	Low
Methanol reformation	High	Low	Medium	High
Metal hydride	High	High	Low	High

Source: APFCT, TIER, 2001.

Figure 2. Metal hydride hydrogen storage canister

Source: APFCT, 2001.

Apart from the above the newest hydrogen storage technology is Nanotube Graphite Fiber. It uses na-meter fiber in leveled structure and the hydrogen molecule that is under the high pressure of 100atm becomes liquid like capillary phenomenon and is stored between the fibers. In this way, hydrogen can be stored 5 to 10 times compared to storing alloy and storing hydrogen (for releasing heat) and releasing hydrogen (for absorbing heat) can counter react. Its disadvantages, however, are the slow speed of absorbing hydrogen, high pressure of storage and short live of recycle. They all have technical bottlenecks to be overcome.

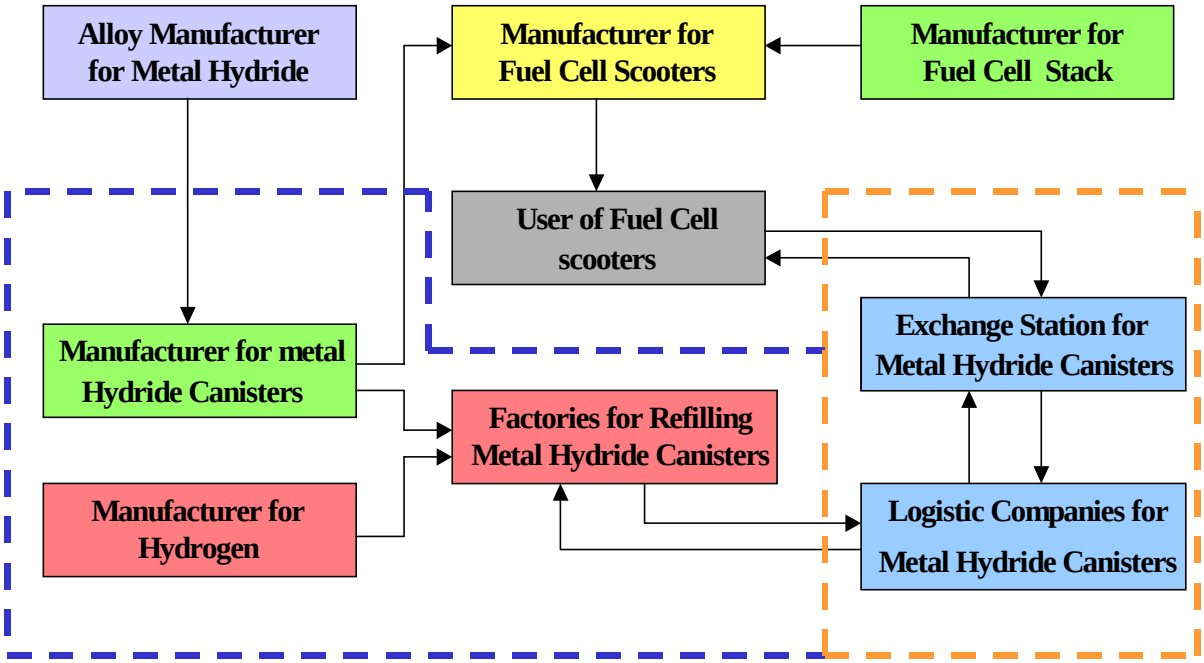
（3）Hydrogen Fuel Distribution Infrastructure

If fuel cell scooters are to be accepted by the consumer market, a hydrogen fuel

distribution supply system has to be set up to avoid pitfalls such as Taiwan's failures of developing liquefied petroleum taxi in early years and promoting recharged-battery driven scooters recently.

From the hydrogen distribution system shown in Fig 3 we can see that when fuel cell scooters need to refill hydrogen fuels, the scooter drivers can drive to fuel stations, scooter repair centers or convenient stores for exchanging empty metal hydride canisters with filled ones. Logistic companies will circulate the empty metal hydride canisters. This means the filled metal hydride canisters can be refilled and delivered to the exchange stations, while empty metal hydride canisters can be delivered in the other way round.

Figure 3. Hydrogen Fuel Infrastructure Concept Schematics



Source: APFCT, 2001.

The major hydrogen manufacturers currently in Taiwan are Chinese Petroleum Corp., San Fu Chemical Co., Ltd. and Lienhwa Industrial Gases Co., Ltd. In the future, they can also be factories for refilling metal Hydride canisters. The technology for manufacturing, storing and transporting hydrogen are well developed. There are many industrial standard operation ways and products on the market. Lienhwa applies electrolysis way for producing hydrogen with high purity. But its cost is quite high, ca. US$0.6/cubic meter. Manufacturers in semiconductor industry mainly use it. San Fu, on the other hand, applies pressure swing absorption for producing hydrogen with down graded hydrogen as raw material from oil or petroleum manufacturers and processes it to pure one. Its cost is around US$0.3/cubic meter. In addition, according to the prices supplied by San Fu, the prices for hydrogen by distribution factories are significantly high, i.e. US$1.5/cubic meter. However, if twelve bottles are bought at one stroke, the selling price can be US$0.9/cubic meter. For special customers the price can even go down to US$0.6/cubic meter. The current hydrogen market in Taiwan is over 18 million cubic meter per year with a market value of US$14.7 million.

In terms of the hydrogen usage amount, according to the estimation of Asian Pacific Fuel Cell Technology Co. Ltd (APFCT), each scooter can carry three metal hydride canisters. Each canister, containing 250 liters hydrogen, can be used for driving 30 to 40 km. If calculated with 5,000 km for each scooter, the annul hydrogen consumption is about one million cubic meter, which composes only 5% of the current hydrogen market in Taiwan. Therefore, supply of hydrogen for fuel cell scooters are quite abundant.

(4) Fuel Cell Scooter Integration

There is no technical problem for integrating fuel cell engine onto scooters (Yang, J., Tso, C. and Wu, K., 2000). On the contrary, since fuel cell replaces traditional internal-combustion engine as power supply, the components for assembling scooters become easier and the whole system and planning become simpler than traditional scooters. This makes repairing easier as well. How to place a fuel cell stack and metal hydride canisters is key to fabricate a fuel cell scooter. In addition, it needs advanced system integration technology with competitive prices for assembling.

The scooter industry in Taiwan has a strong base. With its cooperative relationship for technology with international scooter firms in Japan and Europe, it has not only established comprehensive center-satellite firms of supply systems but also accumulated experiences in the past decades, making the assembling technology quite mature. In recent years, under the intensive promotion of the government, Taiwan has manufacturers for electricity driven scooters e.g. Kang Yang, Jing Shing Fa, KYMCO, EVT and E-Ton. They have launched rechargeable battery for electricity driven scooters on the market. The whole vehicle technology for electricity driven scooters becomes more and more developed. Among these manufacturers, KYMCO and EVT work with Taiwan fuel cell manufacturer together for researching and assembling fuel cell scooters. With Taiwan's advanced scooter technology and capability, they can create a very competitive fuel cell scooter industry in the world.

2.3. Accomplishments of fuel cell scooters in Taiwan

To promote fuel cell scooters in Taiwan, Taiwan Institute of Economic Research (TIER) and other related organizations have been working together for more than three years. In 1998, TIER has collaborated with local motorcycle manufactures as well as its partners in US, W. Alton Jones Foundation, to promote fuel cell technology for scooters. Through their sponsorship and efforts, the world's first prototype of fuel cell Zero Emission Scooter (ZES I), as shown in figure 4, has come into being. ZES I was remodeled from an existing battery powered scooter. All fuel cell engine components were purchased from commercially available sources. Obviously, almost all components, including the 2kW PEM fuel cell stack, were bulky and not design optimized for scooter integration. ZES I was tested at the Automotive Research and Testing Center (ARTC) in Taiwan and as expected, its performance was not spectacular, mainly due to low stack output power. Nevertheless, ZES I fulfilled its purpose of demonstration the applicability and technical feasibility for fuel cell technology onto the scooter. Since April 2000, Asia Pacific Fuel Cell Technologies Ltd. collaborated with Kwang-Yang Motor Co., Ltd. to develop the 2nd generation prototype of fuel cell scooter, ZES II, as shown in figure 5. ZES II is equipped with a specially designed ambient pressure PEM fuel cell stack and metal hydride hydrogen supply system. Although, ZES II doesn't achieve an objective function the same as internal–combustion-engine scooters, its purpose

for serving as a test bed for verification of the fuel cell engine system concept and integration is successful. ZES II also shows the commercial potential. ZES II schematic block diagram is shown in figure 6.

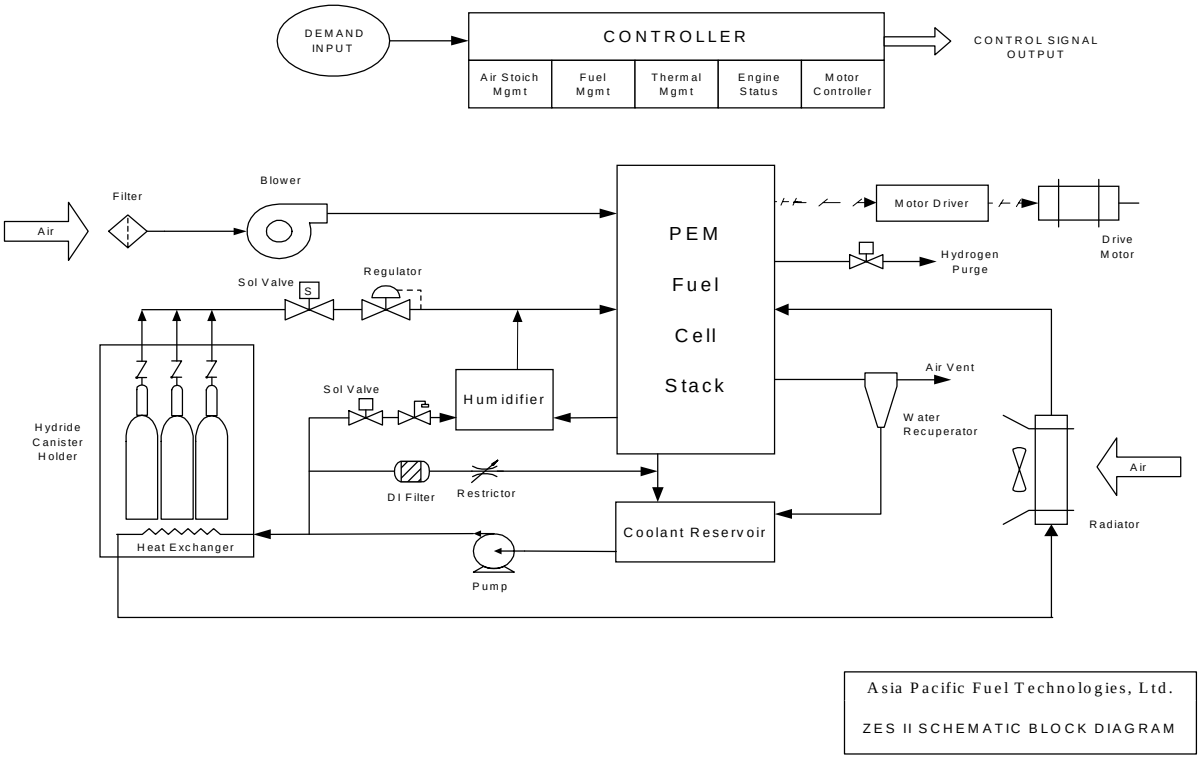
Figure 4. Zero Emission Scooter I (ZES I)

Source: TIER, April 2001.

Figure 5. Zero Emission Scooter II (ZES II)

Source: APFCT, October 2001.

Figure 6. ZES II Schematic Block Diagram



Source: APFCT, October 2001.

From the comparison table 2 for functions of various scooters it shows, although the performance of lead-acid battery driven scooters, ZES I and ZES II scooters have not reached that level of internal-combustion engine scooters, it is expected that after fuel cell scooters enter the market in year 2002, not only the functions like max speed, climb and continued driving capability, weight, energy usage at constant speed, fuel refill time and low noise will be satisfied, but the new environmental standard will also be reached for non-pollution scooters.

Table 2. Performance of Various Scooter Types

			125C.C IC Engine	Lead-Acid Battery	ZES I	ZES II	ZES IV (Target)
Max Speed		Km/h	85	50	35	65	85
Climb (8 degrees with 90 kg load)		Km/h	60	24	18	50	60
Range		Km	180	38	25	70	160
Weight		Kg	105	125	130	105	100
Energy Usage （30km/hr）		wh/km	315	22	27	25	20
Fuel Refill (Recharge) Time		hr	0.1	7	1	0.1	0.07
Noise Pollution		db	75	65	70	65	65
Pollutant Emission	Sox	gm/km	0.21	0	0	0	0
	CO	gm/km	3.5	0	0	0	0
	CO2	gm/km	57	0	0	0	0
	NOx	gm/km	2	0	0	0	0

Source: APFCT, 2001.

According to the estimation of Asian Pacific Fuel Cell Technology Co. Ltd., the company will develop a commercial model for fuel cell scooters ZES IV at the end of 2001 and establish a factory for manufacturing fuel cell stacks in 2002. The annual output of fuel cell scooters will be 10,000. When the annual output reaches 100,000, the estimated selling price for each fuel cell scooter will be about US$2,353. With government support for purchasing vehicles, consumers will buy the scooters at US$1,470 to US$1,765, just like they pay for the 125CC scooters on the current market.

3. Market Potential for Fuel Cell Scooters

There are no fuel cell scooters in the world market yet. However, in line with environmental protection as well as energy saving, they will soon replace the current gasoline engine scooters. The followings are the analyses for government policy, Taiwan's and global scooter markets as well as industry competition analysis with the example of Taiwan for discussing fuel cell scooters' future potential market.

3.1 Government Policy

（1） Strict Exhaust Standard

According to the estimation by the Environmental Protection Administration of the Executive Yuan, the total air pollution generated by scooters in Taiwan amounts to 330 thousand tons carbon monoxide, 90 thousand tons chemical compounds of carbon hydroxide per year. Among these the carbon monoxide exhausted by five million two-stroke engine scooters is 1.5 times of those made by four-stroke engine scooters. The carbon hydroxide is 4.5 times. Each four-stroke engine scooter exhausts two to three times waste gas per km as a 2000C.C.car does. Two-stroke engine scooters are even worse: three to seven times. The waste gas exhausted by scooters is really the main source of air pollution in cities, especially by great numbers of two-stroke engine scooters. To bring the pollution made by internal-combustion-engine scooters under control, the Environmental Protection Administration sets strict regulations against it year by year and has implemented the strictest exhaust standard in the world. We can expect the fourth exhaust standard to be implemented in 2004 will phase out the internal-combustion-engine scooters gradually, especially for high pollution two-stroke engine scooters, and replaced by zero-emission scooters intensively promoted by the government.

In addition, the environment administration estimates that fuel cell scooters will replace internal-combustion-engine scooters in the future. This will reduce carbon dioxide by 1.04 million tons annually and increase the air quality substantially.

（2） Electric Motorcycle Development Action Plan

Since the electric scooters can help environment quality substantially, the Executive Yuan has launched the development of electric scooters as one of the six major technological industries since 1988. In the same year, it also passed the "Electric Motorcycle Development Action Plan", proposed by the Environmental Protection Administration with estimated US$185 million budgets. It states clearly in this plan that from 2000 no two-stroke engine scooters will be allowed to apply for new type and 2% of the scooter manufacturers' sales have to be electric scooters. In 2001, all two-stroke engine scooters will be terminated for production. IN 2006, it is expected that there will be 400-thousand sale amount of electric scooters, making 40% of annual scooters sales. This will generate more than US$1.5 billion business for related industries.

Until the end of 2000, only 17,530 license plates have been issued for electric scooters, still far away from the ideal amount of 40 thousand. The 10,052 license plates for electric scooters in the year of 2000 also did not meet the target of 2% sales amount set by the Environment Protection Administration. Since the result of promoting electric scooters with rechargeable battery was not successful, the Environmental Protection Administration will

start promoting fuel cell scooters with zero emission. According to the plan at least 10 thousand fuel cell scooters will be developed by the year 2002. In the meantime, the plan of zero emission vehicles partnership will be promoted.

（3） Subsidy for Purchasing Electric Scooters

To improve air quality, the Executive Yuan subsidizes purchasing electric scooters for promoting the usage of clean-powered vehicles. The subsidy standard is in two stages. The 1st phase starts from May 20th 1998 and ends on December 31st 1999. Each purchased electric scooter will receive a financial support of US$147. Other accessories will be aided another US$60 to US$70, depending on the type and other aspects. The 2nd one starts from January 1st 2000 and ends on December 31st 2002. The subsidy will be US$90 to US$150, depending on the type of scooters purchased. In addition, according to the function of battery, another subsidy will be supplied on an average of US$735 to US$970 for each scooter purchased. The payment consumer's actual pay is about US$880 for each scooter, approximately the price for 50C.C.scooters. Due to the bad sales performance of electric scooters, however, the Environmental Protection Administration announced in December 2000 that from 2001 the supporting financial aid for each electric scooter sold would be descended to between US$ 380 to US$620. This, however, suppresses the promotion of electric scooters substantially. The Environmental Protection Administration declared that this decrease should not be considered as non-support for electric scooters' development, but as support for fuel cell scooters with real environmental and economic consideration.

（4） Encouraging R&D and Industrial Development

In order to catch up the global R&D trend for fuel cells, the government is increasing the budget and building up a fuel cell promotion team across the ministries (e. g. the Environmental Protection Administration, the Ministry of Communications, the Ministry of Economics, etc) to enable the industrial development. In addition, fuel cell companies, oil and gas companies, scooter manufactures as well as research institute and government agents are also planning to follow "California Fuel Cell Partnership" to build up "Taiwan fuel cell partnership" for promoting fuel cells.

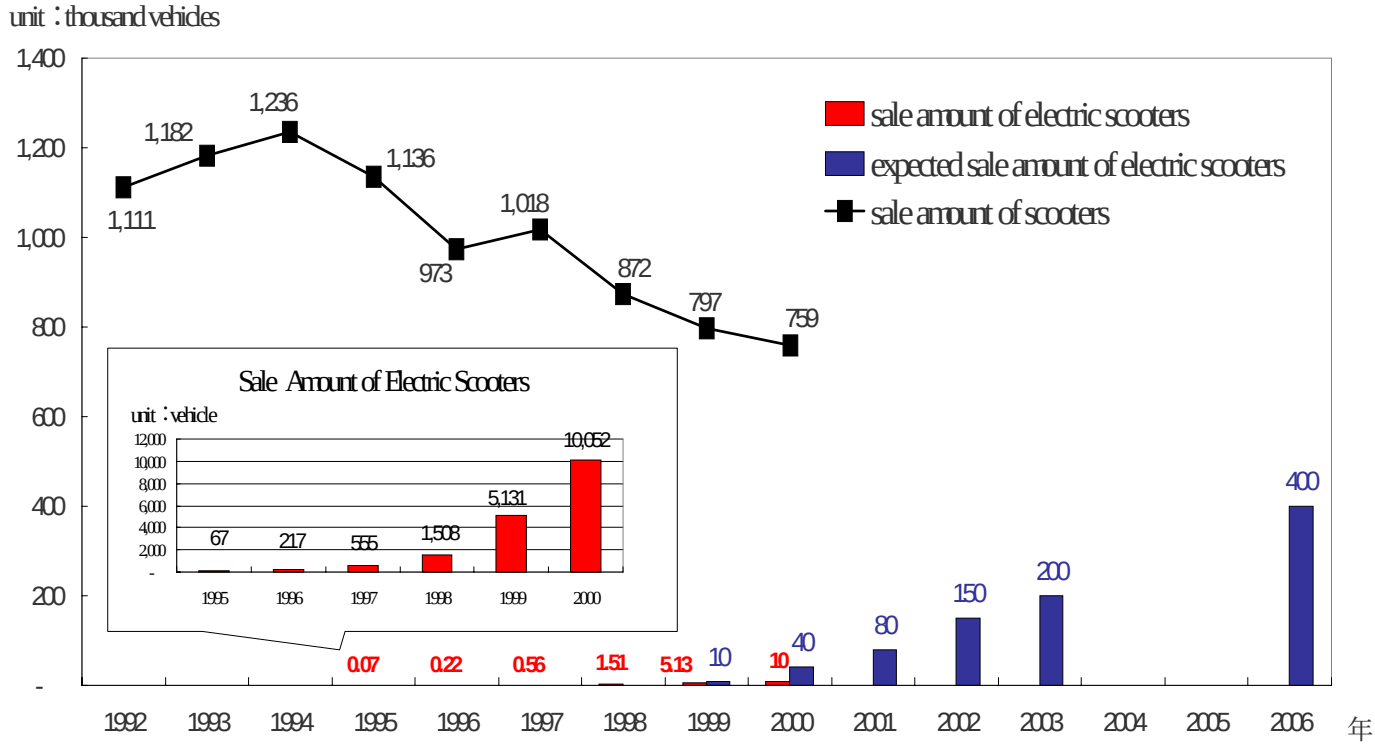
3.2 Taiwan's Scooter Market

Taiwan is a mild climate island where people live not far away from their working place. Taiwan is one of the highest population density countries in the world. Therefore, scooters are very popular traffic tool. According to the vehicle statistic made by the Ministry of Communications, by the end of February 2000, vehicles in Taiwan amounted to over 16 million sets, among which 11 million are scooters, composing 67% of all kinds of vehicles. If calculated by density, there are 295 scooters for each square km, making Taiwan an area with the highest scooter density in the world. On average every 2.03 people own one scooter.

Because internal-combustion-engine scooters cause serious environmental pollution, Taiwan authority promotes intensively the electric scooters, making their amount increasing every year. But from 1.32% of 10,052 sets of electric scooters sold compared to 759,000 sets scooters sales in 2000 domestically, as shown in figure 7, it has not yet reached the goal of 2% set by "Electric Motorcycle Development Action Plan", formulated by the Environmental

Protection Administration of the Executive Yuan. This is still far from the estimated 40,000 sets sales target. The idea of promoting electric scooters is fine and the government supports it intensively. However, limited by the factors like performance and infrastructure for rechargeable electric scooters, it is quite difficult to get the acceptance by consumers. Only developing fuel cell scooters can break through the technical limitation directly. Although recent years the scooter market has matured and the use of rapid transit system in great Taipei area, making the demand on scooters in Taiwan decreasing year by year from 1.236 million in 1994 to not even 0.8 million currently, there are still more than 0.75 million sets sold each year. Whenever fuel cell scooters reach the commercialized production amount, the market potential will be tremendous in align with support by government policy.

Figure 7. The Amount of Taiwan Scooter Market



Source: TIER, 2001.

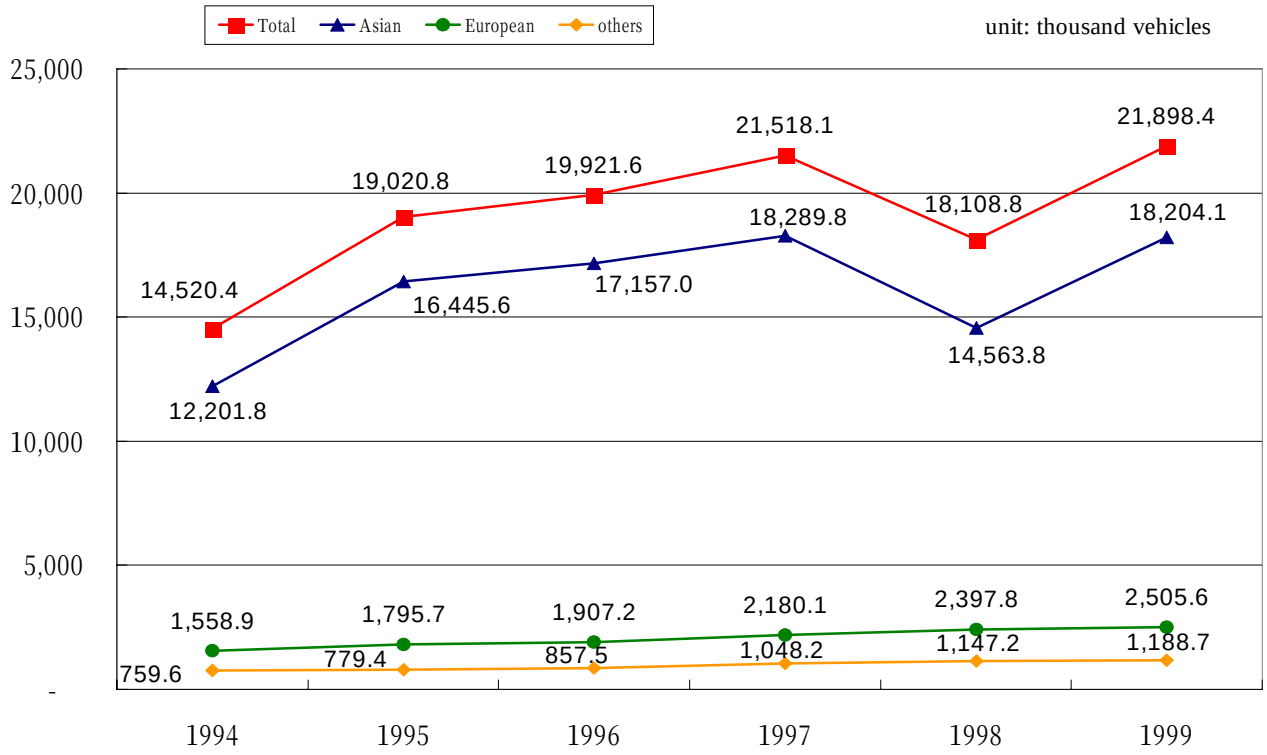
The fuel cell technology in developed countries has become well developed. Apart from being applied in power stations, it is also used for traffic tools successfully, e.g. on buses and cars. If Taiwan can develop fuel cell technology on scooters, it can not only be ahead of the technology and market for fuel cell scooters globally, but also meet people's habit of using scooters as traffic tools in line with steady stricter environmental requirement.

3.3 Global Scooter Market

Due to the pattern of economic development and the geographic environment, the major scooter sale markets concentrate in Asian countries, as shown in figure 8. The scooter sales in nine Asian countries like Japan, Indonesia, Malaysia, Philippines, Mainland China, South

Korea, Taiwan, Thailand, and India totaled more than 18 million sets in 1999, while those of Belgium, France, Germany, Greece, Italy, Holland, Spain and UK ware 2.5 million sets. Other countries with more than 50 thousand sets annually include USA, Argentine, Brazil, Columbia and Australia. This made the total sales of the five countries 1.19 million sets and the global sales of 21.9 million sets in 1999. Apart from the decrease of 20.37% due to financial crisis South East Asia in 1998, the global scooter market has been in steady growth. After fuel cell scooters become commercialized, they will replace internal-combustion-engine scooters. The potential market in the world will be tremendous.

Figure 8. The Sale Amount of Scooters in Major Countries



Source: TIER, 2001.

3.4 Analysis of Industrial Competition

With the competitive analyzing model of Michael E. Porter, a SWOT-analysis, as shown in table 3, will be herewith outlined for Taiwan's developing fuel cell scooters and its competitiveness and profitability:

(1) Strengths

With the great efforts have put in over 50 years, Taiwan's scooter industry has developed successfully already. The solid scooters manufacturing basis, the complex electronic and mechanical supports in related industries and their expertise talents as well as mature management capability in manufacturing processes, all these make developing fuel cell scooters not only in accordance to the trend of environmental protection vehicles, but also expand the sales channels with the fame of "Kingdom of Scooter Manufacturers" for promoting fuel cell scooters to global market.

（2） Weaknesses

Fuel cell scooters belong to new products with limited suppliers for related components and high production and labor costs. The infrastructure for refilling (exchanging) hydrogen fuel (metal hydride canisters) initially has not yet established and thus, needs lots of financial and manpower for completing planning and construction. Using hydrogen as power supply for fuel cell scooters needs lots of education efforts and promotion to change the wrong impression of general public towards hydrogen safety. Fuel cell scooters are still in the stage of R&D, not commercialized yet. Although their functions and effectiveness are both more advanced than current rechargeable battery driven scooters, they still cannot compete against the internal-combustion-engine scooters in short time. When fuel cell scooters launch on the market, they will have quite limited competitiveness in terms of price and thus need the government to provide competitive subsidy for purchasing this kind of clean-powered scooters.

（3） Opportunities

Facing the threat of green house effect and the crisis of fossil energy shortage, people have created a trend of developing fuel cells worldwide. Taiwan government also supports the R&D of promoting fuel cell scooters. With the help of domestic and global scooter markets, the potential of replacing fuel cell scooters will be tremendous in the future. Currently, there is still no other country developing fuel cell scooters. After it becomes commercialized, Taiwan will enjoy the first entry advantages in the market and set the related standard system worldwide, minimizing the competition of same industry in other countries.

（4） Threats

Fuel cell stack is like the heart of fuel cell scooters. Therefore, those fuel cell manufacturers or scooter assemblers that own the core technology of fuel cells and master its functionality of fuel cells can be potential competitors. Many developed countries are applying intensively fuel cells onto vehicles enthusiastically. If they apply the technology also onto scooters and launch fuel cell scooters, this will generate competitive threat. Mainland China has close economic relationship with Taiwan. In line with its fast growing scooter industry and its cheap manufacturer and labor cost, Mainland China will have a competitive cost advantage compared with the production in Taiwan if it develops fuel cell scooters at the same time, apart from the consideration on technical level. In addition, the current makers of electric scooters are trying to break through, increasing steadily the functionality of rechargeable electric scooters.

Table 3. Analysis of competitiveness for Taiwan's fuel cell scooter industry

Strengths	Weaknesses
● Solid basis of scooter production industry ● Complex supporting industries of electronic and mechanical accessories and components ● Many talents of technical integration in mechanical and electronic fields ● Mature management for manufacture and processing ● Fame of "Kingdom of scooter Manufacture" ● Complex sales channel for scooters domestically and globally	● Limited suppliers for related fuel cell components ● Relatively higher manufacture and labor costs ● Infrastructure for refilling (exchanging) hydrogen fuel (metal hydride canisters) are not established yet ● Wrong impression by general public towards hydrogen safety ● Currently still in commercialized R&D stage ● Government doesn't subsidize purchasing yet
Opportunities	**Threats**
● Steady worse air pollution ● Shortage and crisis of fossil oil ● Global trend of environment protection ● Government policy for environmental protection ● Tremendous domestic scooters market and potential replacement requirement ● First entry advantage getting into world market	● Developed countries may enter the fuel cell scooter industry ● Low production cost in Mainland China ● Increased functionality of rechargeable electric scooters and gradual popularization of electrifying infrastructure

Source: TIER, 2001.

4.Conclution

The fuel cell technology plays an important role in the viewpoint of energy and environmental protection, giving its characteristics of high efficiency, zero emission and diversified fuel resources. Taiwan has the vigorous base for developing fuel cell scooters. Traditional scooter industry is very competitive in the whole world. Taiwan also has three years experience in developing battery electric scooters. Therefore, fuel cell scooter is a proper target for the next stage of promoting electric scooters.

The main techniques of fuel cell scooters include fuel cell stacks, hydrogen storage in scooters, hydrogen distribution infrastructure, and the system of integration of fuel cell scooters. Taiwan has developed prototype of fuel cell scooters-ZES I and ZES II successfully, therefore, it has been proven to have the technical capability for fuel cell scooters. Furthermore, it is about to accomplish the commercialized type of fuel cell scooters in the end of 2001 and it's expected to become available in the market after the year of 2002.

Due to limited traffic space and large quantity of transportation, gasoline engine scooters are prevalence in Taiwan. The density of every two people owing one scooter creates serious air pollution. Under the support of Taiwan authority by legislating severe emission standard for scooters, formulating "Electric Motorcycle Development action Plan", subsiding

environmental protection scooters and encouraging R&D, fuel cells scooters has a bright future. There are over 750 thousands domestic scooter market In Taiwan as well as over 20 millions in global scooter market every year. Fuel cell scooters after commercialized will create a considerable potential market in the future.

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