A Viable Niche Market--Fuel Cell Scooters in Taiwan

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Abstract

Taiwan is a place marketed by intensive scooter use because of limited space and transportation habits. Because internal-combustion-engine scooters cause serious environmental pollution, the Environmental Protection Administration (EPA) executes policies—such as the strict exhaust standard, “Electric Motorcycle Development Action plan”-- and provides a subsidy for purchasing electric scooters. The main objective of the EPA has been to encourage the use of electric scooters and gradually weed out the highly polluting engine scooters. However, the policies have not worked well because of the poor performance of lead-acid or nickel-hydrogen batteries as well as the lack of recharge stations. Therefore, consumers have not been willing to purchase electric scooters. To overcome the problems of battery powered electric scooters, producers have been working to apply fuel cell technology. This paper will discuss the current situation of battery powered electric scooters under the Taiwan government’s supports, as well as the expected development of fuel cell scooters in view of commercial aspects, such as economics, consumer demand, niche markets and government intervention.

In order to integrate the development of fuel cell technology with the capabilities of industry, government, and academic research, the Taiwan Institute of Economic Research (TIER) is organizing the Taiwan Fuel Cell Partnership (TFCP). Among the projects of the TFCP, promoting fuel cell scooters is the most important in the beginning phase. Furthermore, in alliance with associates, TIER is planning to hold a demonstration program of fuel cell scooters on Green Island, an islet close to Taiwan. Hopefully, fuel cell scooters will be commercialized in 2004.

Taiwan is one of the world’s major producers of engine scooters. There are over 18 million scooters sold in Asia every year. Taiwan is now making an effort to apply new technology for developing fuel cell scooters. In addition to eliminating the pollutants made by engine scooters in Taiwan, the fuel cell scooters should be promoted to the huge scooter market in Asia.

Key Word: Fuel Cell, Electric Scooter, Air Pollution, Metal Hydride, Hydrogen Energy

1. Why the Scooter Is A Niche Market for Fuel Cells in Taiwan

Owing to limited space, population density, and the tropical climate, scooters have become the most popular mode of transportation in Taiwan. According to statistical information provided by the Ministry of Communications, by the end of 2001, there were 17 million vehicles in Taiwan, 11 million (65%) of which were scooters. If calculated by density, there were 326 scooters per square kilometer, the highest scooter density in the world. On average, every two people own one scooter.

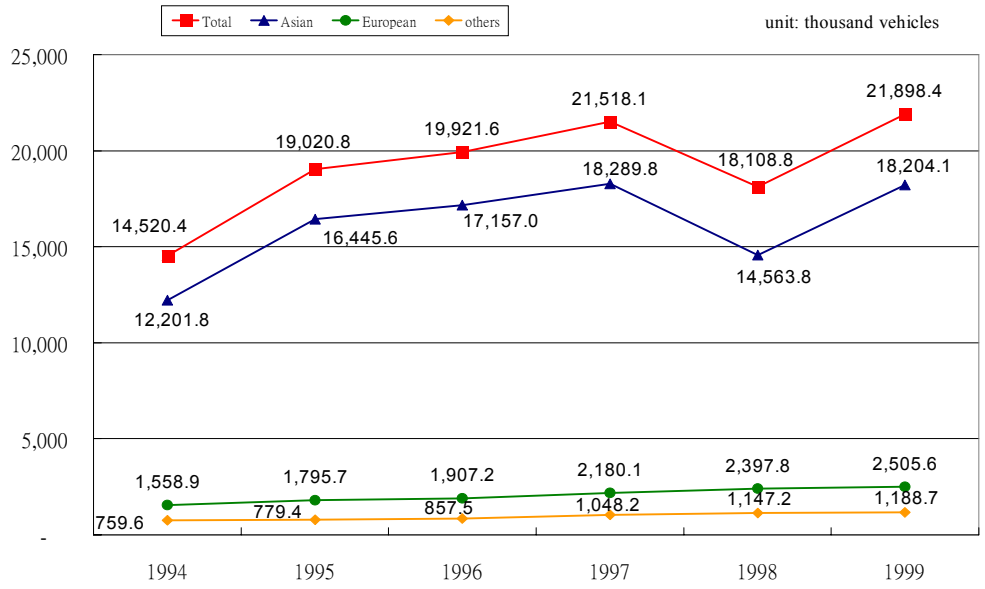
According to estimates by the Environmental Protection Administration of the Executive Yuan, the total air pollution generated by scooters in Taiwan amounts to 330,000 tons of carbon monoxide and 90,000 tons of chemical compounds containing carbon hydroxide per year. Of this amount, five million two-stroke engine scooters generate 1.5 times more carbon monoxide than four-stroke engine scooters, and 4.5 times more carbon hydroxide. Moreover, each four-stroke engine scooter produces two to three times more waste gas per kilometer than a 2000 c.c. car, while two-stroke engine scooters are even worse, producing three to seven times more. In Taiwan's cities, the main source of air pollution is the waste gas exhausted by scooters, especially by the great number of two-stroke engine scooters.

To solve the serious pollution problem caused by engine scooters in Taiwan, there is an urgent need to apply environmentally friendly technologies to power the two-wheeled--as well as four-wheeled--vehicles. Fuel cell technology is a potential solution with the brightest prospects for Taiwan and elsewhere.

2. Scooter Market

Due to the pattern of economic development and the geographic environment, the major scooter markets are concentrated in Asian countries (see Figure 1). In 1999, the number of scooters sold in nine Asian countries (Japan, Indonesia, Malaysia, Philippines, Mainland China, South Korea, Taiwan, Thailand, and India) totaled more than 18 million, while the number sold in Belgium, France, Germany, Greece, Italy, Holland, Spain and the UK was 2.5 million. Other countries with more than 50,000 scooters sold annually include the USA, Argentine, Brazil, Columbia and Australia, with a combined total of 1.19 million sold in 1999. This makes a total of 21.9 million scooters sold in the world in 1999. Apart from the decrease of 20.37% due to the South East Asia financial crisis in 1998, the global scooter market has been growing steadily. Once fuel cell scooters become commercialized, they will be a viable replacement for internal-combustion-engine scooters and the potential global market will be tremendous, especially in Asia.

Figure 1. Scooter Sales in Major Countries



Note：The Asia countries include the Philippines, Malaysia, South Korea, Indonesia, Thailand, Taiwan, Japan, India, and China.

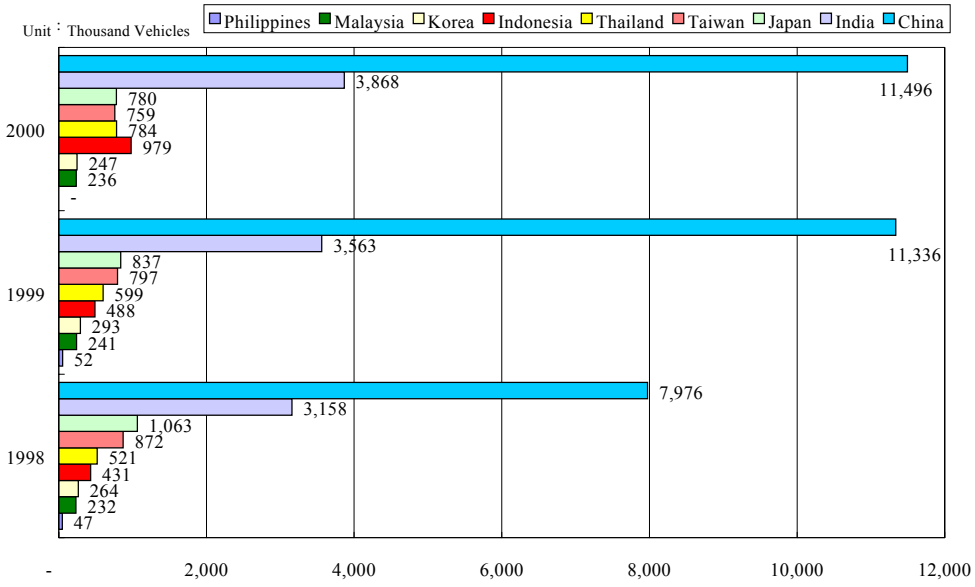
The European countries include Greece, Belgium, the Netherlands, the United Kingdom, Germany, France, Spain, and Italy.

The Other countries include Australia, Columbia, Argentina, Brazil, and the United States.

Source: TIER, 2002.

In Asia, China constitutes the largest scooter market, with annual sales exceeding 11 million scooters since 1999 (see Figure 2). The second largest market is India, with sales of over 3 million. Japan and Taiwan are next, with sales of around 800,000 scooters each, although these markets appear to have been shrinking in resent years. For example, the scooter market in Taiwan declined to 629,000 in 2001 (see Figure 3).

Figure 2. Two-Wheeler Sales in Asia



Source: TIER, 2002.

Apart form Japan, Taiwan is the most important scooter producer in Asia. Based on Taiwan's superior integration of scooter related industries, including scooter components and fabricating factors, as well as its proximity to China and other Asia countries, developing fuel cell scooters in Taiwan is ideal for reaching the greater Asia market.

3. Government Policies

Because internal-combustion-engine scooters cause serious environmental pollution, the EPA executes some policies--such as the strict exhaust standard, "Electric Motorcycle Development Action plan"--and provides a subsidy for purchasing electric scooters. The main objective of the EPA is to encourage the public to use electric scooters and to gradually weed out the highly polluting engine scooters.

（1） Strict Exhaust Standard

To bring the pollution made by internal-combustion-engine scooters under control, the Environmental Protection Administration (EPA) has been setting strict regulations and has implemented the most stringent exhaust standard in the world (see Table1). We can expect that the fourth exhaust standard to be implemented in 2004 will phase out the polluting internal-combustion-engine scooters, especially the highly contaminating two-stroke engine scooters, and replace them with zero-emission scooters intensively promoted by the government. (Tso, C. and Chang, S., 2001)

Table 1. Exhaust Standard

Test Item		Unit	Criterion Ⅱ (Practice： 1991/7/1)	Criterion Ⅲ (Practice： 1998/1/1)	Criterion Ⅳ(Estimated Practice：2004/1/1)	
					Two Stroke	Four Stroke
Movement	CO	g/k	4.5	3.5	7.0	7.0
	HC+Nox	g/k	3.0	2.0	1.0	2.0
Idle	CO	%	4.5	4	3.0	3.0
	HC+Nox	PPM	7000	6000	2000	2000
Particulate Pollutant		%	15	15	15	15

Note: Criterion Ⅲ adopts the test criteria of warm-car states; Criterion Ⅳ adopts that of cold-car states.

Source: EPA, 2002.

（2） Electric Motorcycle Development Action Plan

Since electric scooters can substantially help environmental quality, the Executive Yuan has launched the development of electric scooters as one of the six major technological industries in 1998. In the same year, it also passed the "Electric Motorcycle Development Action Plan", proposed by the EPA with an estimated budget of US$185 million. This plan states clearly that beginning in 2000 no two-stroke engine scooters will be allowed to apply for new type scooters and 2% of each scooter manufacturers' sales must be from electric scooters. In 2001, production of all two-stroke engine scooters will be terminated. In 2006, it is estimated that 400,000 electric scooters will be sold, comprising 40% of annual scooter sales. This will generate more than US$1.5 billion for related industries. (EPA, 1998)

（3） Subsidy for Purchasing Electric Scooters

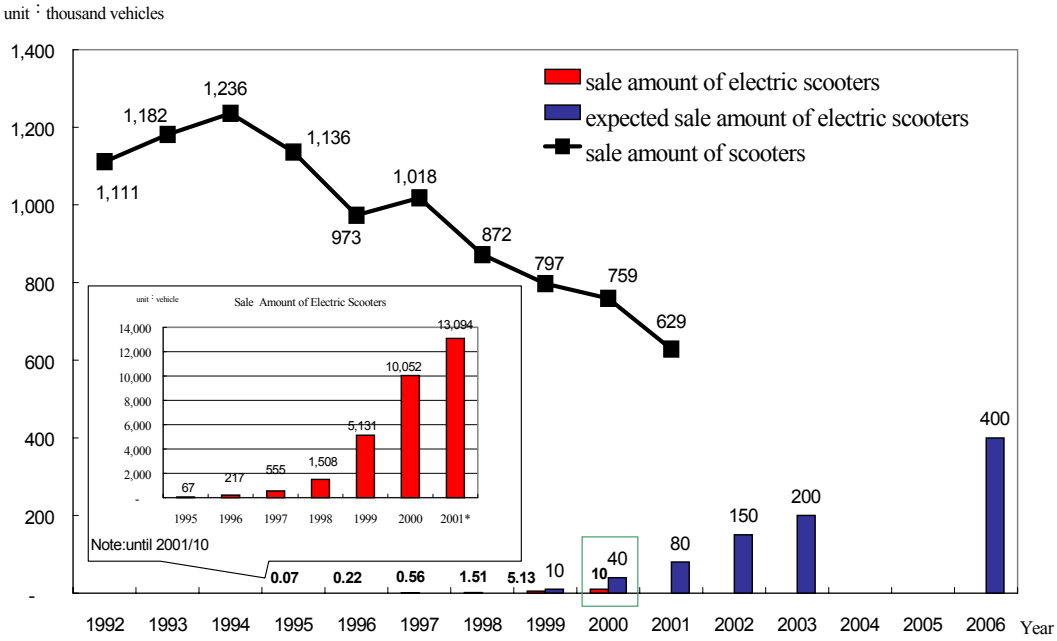
To improve air quality and promote the usage of clean-powered vehicles, the Executive Yuan subsidizes the purchase of electric scooters. The subsidy standard is in two stages. The first phase began on 20 May 1998 and ended on 31 December 1999. Each electric scooter purchased received a financial subsidy of US$150. Other accessories were supported with another US$60 to US$75, depending on the type and other aspects. The second phase began on 1 January 2000 and ends on 31 December 2002. This subsidy is US$90 to US$150, depending on the type of scooter purchased. In addition, depending on the function of the battery, another subsidy is provided of between US$735 and US$970 for each scooter purchased. Ultimately, the consumer actually pays about US$880 for each scooter, approximately the price of a 50 c.c. scooter. (EPA, 1998)

（4） Outcome

Because internal-combustion-engine scooters cause serious environmental pollution, Taiwan authorities have intensively promoted electric scooters, with sales increasing every year. Initial policies didn't work well because of the poor performance of lead-acid or nickel-hydrogen batteries, as well as the lack of recharge stations. Therefore, consumers have been unwilling to purchase electric scooters. At the end of 2000, only 17,530 electric scoters had been sold, far from the ideal amount of 40 thousand. Of the 759,000 scooters sold domestically in 2000, only 10,052 (1.32%) were electric scooters (see Figure 3). This amount has not yet reached the goal of 2% set by the "Electric Motorcycle Development Action Plan" formulated by the EPA.

The goal of promoting rechargeable electric scooters is a highly worthwhile one and the government supports it enthusiastically. However, due to limiting performance and infrastructural factors, electric scooters have had difficulty winning the acceptance of consumers. Therefore, the government and the industrial field have been applying other technologies to power the scooters with zero emissions. Fuel cell technology is quickly proving to be one of the most promising power sources.

Figure 3. Taiwan Scooter Market



Source: TIER, 2002.

4. Latest Promotional Activities of Fuel Cell Scooters

（1） Accomplishments of Fuel Cell Scooters in Taiwan

To promote fuel cell scooters in Taiwan, the Taiwan Institute of Economic Research (TIER) and other related organizations have been working together for more than four years. In 1998, TIER collaborated with local motorcycle manufactures as well as its partner in the USA, the W. Alton Jones Foundation, to promote fuel cell technology for scooters. Through their sponsorship and efforts, the world's first fuel cell scooter prototype--Zero Emission Scooter (ZES I; see Figure 4)--was built by Desert Research Institute (DRI), USA. 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 designed for optimal 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 demonstrating the applicability and feasibility of fuel cell technology for scooters.

In October 2000, Asia Pacific Fuel Cell Technologies Ltd. (APFCT),in collaboration with Kwang-Yang Motor Co., completed the second generation Zero Emission Scooter (ZES II; see Figure 4), which was exhibited during the 2000 Fuel Cell Seminar conference on October 30 in Portland, Oregon. ZES II was equipped with a specially designed ambient pressure PEM fuel cell stack and metal hydride hydrogen supply system. Although ZES II did not achieve an objective function equal to internal–combustion-engine scooters, its purpose for serving as a test bed for verification of the fuel cell engine system concept and integration was successful. ZES II also showed commercial potential. ZES II was a conversion electric scooter powered by the APFCT fuel cell engine and metal hydride hydrogen storage system. The ZES prototype has since been through several developmental generations as a test bed to verify improvements in fuel cell engine components.

In June 2001, the developmental scooter ZES II.5 (see Figure 4) was unveiled. It embodies an improved cooling system and fuel cell stack for higher performance and thermal management.

Developmental scooter ZES II.6 (see Figure 4) was produced in December 2001 and incorporates the most advanced fuel cell stack and on-board hydrogen supply systems. It was tested at the ARTC in February 2002.

Development of the third generation scooter began in December 2000 and was scheduled for completion in June 2002. ZES III (see Figure 4) is a totally new integrated fuel cell/chassis scooter designed from the ground-up. Its modern European styling compliments its advanced fuel cell engine technology. It rationally matches the fuel cell engine with the drive train. The fuel cell components and scooter body are engineered and integrated for optimum scooter handling, stability and performance.

Commercial production of ZES is projected to commence in 2004. The scooter's design and performance will be comparable to conventional gasoline engine scooters and it will be competitively priced. (APFCT, 2002)

Figure 4. Fuel Cell Scooters

Source: APFCT, 2002.

From the comparison of various scooters in Table 2, ZES I and ZES II did not reach the performance level of internal-combustion engine scooters, it is expected, however, that after fuel cell scooters enter the market, not only will maximum speed, climb and continued drive capability, weight, energy usage at constant speed, fuel refill time and low noise be satisfactorily improved, but the new environmental standard for non-pollution scooters will also be reached.

Table 2. Performance of Various Scooter Types

		125 c.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	65	25	70	160
Weight	Kg	105	120	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		Yes	No	No	No	No

Source: APFCT, 2002.

In 2004, APFCT anticipates completing the production of a commercial model fuel cell scooter ZES IV, and also of a factory for manufacturing fuel cells. When annual output reaches 100,000 scooters, the estimated selling price for each fuel cell scooter will be about US$2,200. As output doubles, the estimated price will drop to about US$1,730, roughly the current market price of a 125 c.c. scooter. (APFCT, 2002)

（2）Taiwan Fuel Cell Partnership

In order to integrate the development of fuel cell technology with the capabilities of industry, government, and academic research, the TIER is organizing the Taiwan Fuel Cell Partnership.

The mission of the Taiwan Fuel Cell Partnership is as follows:

a. To develop the standards and regulations of fuel cells, fuel supply systems, and fuel cell scooters;

b. To hold The Domestic Fuel Cell Forum and The International Fuel Cell Conference;

c. To test and verify fuel cell scooters;

d. To demonstrate the fuel cell scooter fleet; and

e. To establish the Taiwan Fuel Cell Partnership website and publish the “Taiwan Fuel Cell Development” newsletter.

Among these tasks, promoting fuel cell scooters will be the most important objective in the beginning phase.

（3）Fuel Cell Scooter Demonstration Fleet

In alliance with associates, including the National Science Council, the Industrial Technology Research Institute (ITRI), and other companies, TIER is conduction a total plan for Green Island, an islet close to Taiwan, to make it a zero-emission island for tourism. As part of this program, one of the most important missions is to form a demonstration fleet of fuel cell scooters. These scooters will be driven by tourists, who will record actual road performance results. Hopefully, fuel cell scooters will replace the polluting gasoline engine ones in the near future.

5.Conclusion

Air pollution in Taiwan is rapidly increasing to dangerous levels. A major source of emission comes from the exhausts of gasoline scooters. The Taiwan government executes several policies, therefore, to promote battery powered electric scooters. However, because of the poor performance of lead-acid or nickel-hydrogen batteries as well as the lack of recharge stations. The goal to replace polluting gasoline scooters with battery powered ones has been failed. Now, the government and the industrial fields are making an effort to apply new technology for developing fuel cell scooters.

Fuel cell technology in developed countries is already very advanced. Apart from being applied in power stations, it is also being successfully used in transportation vehicles, e.g. buses and cars. If Taiwan can successfully develop fuel cell technology for scooters, it will not only emerge as the global leader of the fuel cell scooter market, but will also enable people to continue using scooters as a desired mode of transportation while also complying with increasingly strict environmental requirements.

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