Potential for the Commercialization of Fuel Cells in Taiwan

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CONTENTS

VELOPMENT OF ENERGY SAVING AND CLEAN ENERGY TECHN

ssing energy needs and growing pollution problems prompted the Ta ad range of clean energy policies and support various clean energy t ewable energy. Before embarking on a description of Taiwan's polici energy efficiency, wepresent an overview of energy challenges in Ta rall energy consumption, related organization and technology develo kground information for understanding the policy and research grou elopment.

van's Energy Mix

of 2003, there were approximately six million automobiles and ten m ual electricity consumption on this island nation is about 160,000 G n hydropower, 75% from thermal, and 21% from nuclear. Although erators, cogeneration is on the rise. Despite the diversity in energy ty ill from fossil fuel, with petroleum consumption over the past twent ually. (See Table 1 for petroleum consumption trends).

le 1. Petroleum Consumption Trends in Taiwan (Million liter of

Item	1983		1993		
	MLOE	%	MLOE	%	ML
al Consumption	18,909	100	32,036	100	45,
Industrial	7,752	41	10,375	32	18,

Successful Energy Conservation Initiatives and Policies

In the area of energy conservation, some major policy achievements in Taiwan (as reported by the Bureau of Energy) include:

- Implementation of an energy auditing system, resulting in savings of 660 GWh of electricity, 61,000 kiloliters of oil, and 161,000 tons of coal in 2003.
- Execution of energy-consumption management standards for electrical appliances in 2003, resulting in an average annual peak load power saving of 130 MW.
- Implementation of fuel economy standards for new vehicles and fishing boat engines in 2003, resulting in an annual fuel oil saving of 130,000 kiloliters.
- Promotion of energy conservation technical services, leading to an annual saving of 130 GWh of electricity and 9,000 kiloliters of fuel oil, and average peak load power saving of 27 GWh in 2003.
- Promotion of measures to shift on-peak energy usage to off-peak hours; by end of 2003 these measures had clipped 4,422 MW off peak load.
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facilitate the sustainable utilization of renewable energy. In the area of renewable energy, the government's policies and subsidies led to the following major results:

Taiwan.

PROGRESS IN DEVELOPING ELECTRIC VEHICLES IN TAIWAN

Since one of the potential major applications for fuel cells is in the transportation sector—mainly as substitute for conventional internal combustion vehicles (ICVs) and scooters—it is worth mentioning the current status of electric vehicles (EVs) in Taiwan. If fuel cell vehicles (FCVs) should become a commercial reality in the future, most likely they would still be in a hybrid form coupled with battery or super-capacitor to provide specific performance needs. These hybrid vehicles all use electric propulsion to replace combustion energy and share many common motor, control and body technologies.

When the energy crisis hit Taiwan in the early 1970s, Taiwan launched its first EV program with National Tsing-Hua University collaborating with Yuasa Battery Company of Taiwan and Tanyon Iron works, aiming to develop a lead-acid battery based EV, mainly for use in the postal service. Approximately 200 vehicles were produced and the program continued for about 10 years until the energy crisis subsided.

The second phase for development of these cleaner energy vehicles started about ten years ago in response to a renewed interest worldwide in EV development, motivated mainly by air pollution concerns instead of oil substitution. Since Taiwan is a scooter kingdom and very likely has the highest density of scooter distribution in the world, the central government felt it would be more realistic if the country's research institutions focused on electric scooters in light of the Taiwan's robust scooter industry. In response to the central government's new priorities for promoting EV, in 1997 the Taiwanese Environmental Protection Agency (EPA) announced a subsidy program to encourage the purchase of electric scooters. This subsidy program led to more than five new start-up EV scooter companies, and sparked several existing scooter factories to start developing various EV models. Unfortunately, inconsistent quality and inadequate maintenance of these EV scooters began to dampen the enthusiasm of many customers.

The annual domestic purchase of EV scooters reached a peak over 10,000 in 2000 and quickly dropped to less than 3,000 in 2002 (see Table 2). The EPA canceled the subsidy program in 2003 claiming the number of electric scooters could not reduce air pollution in any significant way, although the EPA has maintained a subsidy program for electric bicycles at NT$3000/unit sold. However the local EV scooter industry manifested its resilience by changing into an export market for scooters and other related electric vehicles. In fact, Taiwan has become the world's leading producer of electric assisted vehicles for the handicapped as shown in Table 3, with Taiwan producing more than 50% of the electric wheelchairs in the world.

Table 2. Number of Electric Bike and Scooter Production in Taiwan

Year	e-bike export	e-scooter export	e-bike domestic	e-scooter domestic	Total production
1998	6,209	214	300	1,508	8,231
1999	18,110	1,038	300	5,132	24,580
2000	37,018	8,407	500	13,257	59,182
2001	19,462	43,359	4,733	3,806	71,360
2002*	42,819	6,762	4,373	2,266	56,220
2003	11,811	86,514	3,173	0	101,498

* The fluctuating figures of e-bike and e-scooter exports are due producers using these two terms interchangeably when reporting their products

electrochemical energy industry is a useful measure of the potential for it to develop a fuel cell industry in the future.

Taiwan has moved its primary cell production to mainland China, and the only traditional battery industry remaining is the lead-acid battery. A few of these lead-acid battery firms have partial Japanese ownership or are in technical cooperation with Japanese firms, such as Taiwan Yuasa Company, but most of them are independent local manufacturers. These battery manufacturers supply local needs for automobiles, scooters and other industrial applications, with total annual sales in recent years amounting to almost 20 billion NT dollars, as shown in Figure 1.

Figure 1. Production Quantity and Sales Volume of Taiwan Lead Acid Batteries

Source: Bureau of Energy, Ministry of Economic Affairs computers their capacities are in the watt-hour range—not large enough for application in the transportation sector. However, a couple of Taiwanese producers like Ultra Life and Pacific-Energytech have started working on larger batteries for transportation application. They have gradually acquired experience in designing KWh-range power sources.

Rechargeable batteries are also useful for practical operation of fuel cells. Fuel cell systems equipped with reformers need seconds or minutes to reach full power. Fuel cell systems designed for applications that require fast start-up—such as back up or emergency power—contain rechargeable batteries. This is responsible for fuel cell demonstration projects and promotion.

(3) All agencies should allocate sufficient funding for fuel cell development.

This recent government roadmap for fuel cells actually builds on the fuel cell development that started in Taiwan in the mid-1980 with major funding from MOEA and Taiwan Power Company, which is a national company supplying most of the electricity in Taiwan. Despite this early start, in 2000, the only institute that had been continuously working on fuel cells was the Energy and Resources Laboratories (ERL) of the Industrial Technology Re

Other universities such as National Taiwan University, National Tsing-Hua University, and Chung Gung University have all received funding from the NSC to undertake fuel cell research. Across these universities the major research topics have included: simulation of fluid channel design, new catalyst formulation, and characterization.

R&D on a more systematic basis is mainly carried out by Taiwan's national laboratories, which have long-term full-time personnel and the larger funding necessary for development-type work. Three important national laboratory examples are highlighted below to illustrate the technology level of fuel cell R&D in Taiwan.

Materials Research Laboratories of ITRI

development.

In hydrogen production, INER has investigated several types of plasma reformers. Reformers with natural gas transformation rate up to 93% and CO content lower than 100ppm have been demonstrated in the INER laboratory. The process route from bio-fiber through ethanol to hydrogen production is under investigation. In hydrogen storage, multi-walled carbon nanotubes were synthesized by catalytic thermal decomposition of natural gas. Hydrogen storage capacity of 3.3wt% was obtained upon conventional fuel cell. However, at the anode, it uses metallic zinc instead of hydrogen as a fuel, thereby eliminating the problems of hydrogen handling and reformer operation. Although it has its own technological problems, zinc air batteries can be considered fuel cells in a broad sense. The technology is well suited for countries like Taiwan with medium-level technology capability. This observation on air zinc batteries highlights that while Taiwan may never be a major player in fuel cell business it can find a niche in special-type fuel cell subsystems, particular applications or original equipment manufacturer (OEM) operations.

Since it is well recognized that the establishment of a fuel cell industry involves complex coordination among various government departments, research institutes and industries, the Taiwanese government encouraged the creation of an alliance of various parties from the public and private sectors, which was called the Taiwan Fuel Cell Partnership, which is also described below.

The largest local gasoline producer in Taiwan, China Petroleum, is interested in the hydrogen supply and distribution business since it has large number of gas stations available. This company also has experience handling natural gas. Another private firm, San-Fu, which is partially owned by Air Products, is also involved in the development of H2-storage canisters and related technologies. Other firms that supply material or components for fuel cells have also emerged, forming a stronger base for fuel cell industry in Taiwan—two such firms include: (1) Yonyu Applied Technology Material Company for carbon material and (2) Green Hydrotec for oxidation catalyst and hydrogen purification.

Taiwan Fuel Cell Partnership (TFCP)

Taiwan Fuel Cell Partnership (TFCP), formed in July 2001, carries out the mission of the Executive Yuan's Fuel Cell Research and Development Society to promote and develop the fuel cell industry in Taiwan. The EPA and Bureau of Energy both help fund the Partnership. The Partnership unites industry, government agencies, and academic and research centers to help promote and develop fuel cell technology and industry in Taiwan.

TFCP has appointed a steering committee—made up mainly of representatives of government departments—to supervise its general operation. The organization consists of the Secretariat and Staff Unit, and mission-oriented Policy Working Units. The current working units and their objectives are the outlined in Table 5.

Under the support of relevant government departments and industries, TFCP has established a Taiwan Fuel Cell Information website (see list at end of paper), which sends relevant reports via email and organizes fuel cell discussions and conferences to promote industrial research and development exchange. TFCP also invites many experts and academics to discuss with governmental agencies issues related to the future policies and directions of the Taiwan fuel cell industry. TFCP recently started to focus on the

stationary application.

Closely working with ITRI, the Tatung Fuel Cell team has developed a range of multi-fuel cell products including customer designed fuel cell stack 1~5 KW, 1 KW & 5 KW converter with inverter module, 1 KW backup system of fuel cell power generator, and 2KW methanol fuel processing system. Tatung will continuously work to develop more compact, efficient, durable, and low cost fuel cell products for niche markets in the near term.

cell technology and in its progress towards commercialization.

From 2002 through 2004, APFCT continued its advancement in developing a market-focused scooter with ZES III, ZES IV and ZES IV.5. These fuel cell scooters were exhibited at the annual international Fuel Cell Seminar and offered for a test drive. APFCT has plans to unveil ever-advanced fuel cell modules manufacturing and metal fuel regeneration. EVT established its mass production site in Chung-Li, Taiwan in 2001. Now, the Chung-Li factory has facilities to: (1) manufacture all key components, such as air cathode, metal fuel and solid state membrane; (2) produce various types of zinc metal fuel modules as power sources for portable devices and transportation; and (3) simulate road-test in a Roller Bench Lab for e-bike, e-scooter and, electrical vehicles.

EVT has successfully developed a variety of portable power supplies, including long shelf life reserve power products; a portable AC power source; portable long-service lamp sets; multifunctional light sets; a high performance, one-time use zinc air battery for charging; and an environmentally benign reusable D size battery. EVT also is developing a moveable energy storage system together with Taiwan Power Research Institute (TPRI), designed to test the feasibility of applying metal fuel technology as energy storage for renewable power stations.[3]

In the transportation sector, EVT had passed a series of tests in drive range, gra.4(e)3cw.8(a.4(a)59)-.6((3.6(es).7(b85.7(0,)4.6(g)-

SUMMARY OF TAIWAN'S FUEL CELL R & D

The above review of the general research and policy activities supporting fuel cells underscores two major conclusions on this area of research:

1. Although Taiwan is small in size, the fuel cell R&D program is quite balanced and covers basic research in the academic sphere, applied research in the national laboratories, and product development in the industry.
2. The manufactures are aggressive in pursuing commercialization of fuel cell technologies. Some firms like Tatung have fully exploited its inherent strength in power electronics and control devices and already developed niche markets for its inverter module. Others like Asia Pacific and eVionyx Taiwan obtained core technology from abroad and designed specialized products. Thus, while every company is still struggling in the developing stage, some progress has already been made in creating marketable products and these firms are gaining experience very quickly.

FUEL CELL DEVELOPMENT & COMMERCIALIZATION IN NORTH AMERICA, EUROPE, AND JAPAN

Hydrogen and fuel cell transition studies are under way in at least 22 countries, and in most cases the analysis is supported by government investment. In the United States, for example, Breakthrough Technologies, Inc. estimates that the budget for fuel cell research, demonstration, purchase and installation in 2005 exceeds $400 million overall when state and federal support programs are combined. This investment is matched more than two to one by private investment. Substantial investments are envisioned in Europe and Japan, with significant programs in Germany, Canada, Singapore, Korea, Australia, China, and a growing number of other countries. Some examples of these international programs are listed below[4] and in Table 6.

● The European Community's "Sixth Framework" research program in energy has a budget of €2 billion. This amount must support renewable energy research as well as hydrogen and fuel cells.
● The Canadian government has announced a five-year, $350 million fuel cell program.
● Japan's annual investment in fuel cells and hydrogen is estimated at ¥30 billion yen, and is coupled with commercialization benchmarks out to 2030.
● The German national government and many German states have fuel cell programs, estimated at €8 ti €10 million annually.
● Public sector fuel cell investment in Korea is estimated to reach $586 million between 2004 and 2011.
● Many countries are pursuing collaborative fuel cell activities through the International Energy Agency as well as the International Partnership for a Hydrogen Economy.

[4] *Source: Hydrogen and Fuel Cells*, IEA, Paris, 2004, supplemented by our estimates

Table 6. Selected Vehicle Research and Demonstration Projects

which highlights the wide range of technologies and

authorities are taking every measure to improve it. One of the many ambitious plans is to have 20,000 zero-emission busses on Beijing's streets by 2008. This kind of national effort would certainly make China one of the major green energy giants within ten years. One promising project preparing the city for the Olympics is a collaboration among MOST, Global Environment Facility, and the United Nations Development Programme in a $32 million project to catalyze the cost-reduction of fuel-cell buses for public transit applications in Chinese cities and stimulate technology transfer activities by supporting

The central government could also provide incentives for local governments to establish regional demonstration projects. For instance, an FCV program coupled with the Kaohsiung subway system that is currently under construction could greatly reduce the notorious air pollution in southern Taiwan.

Problem 2: Insufficient coordination among government agencies, private industries, national laboratories and academia.

Professors in Taiwan receive funding for fuel cell research mainly from the NSC to carry out research in areas such as synthesizing new catalyst and polymeric material, and flow channel simulation. These

It has been argued that since a total replacement of combustion-based industry by fuel cells may be the ultimate goal, any intermediate successful product is not the final solution and can only serve to lengthen the life of the existing industrial structure. That is why major American automobile producers have concentrated their effort on fuel cell vehicles. However the phenomenal success of Toyota Prius hybrid car significantly changed their strategy. Taiwan should devote a part of their resources to technology that can lead to near-term commercialization based on existing capability locally available. Especially in the case of Taiwan, duplicating the fuel cell R&D activities being carried out in the United States and Japan is actually a waste of precious resources available for fuel cell development in Taiwan.

Recommendation 3:

A broad range of technologies for clean energy and their possible combinations should be included and coordinated. The goal of fuel cells is to supply a substitutive and clean energy, so every other technology aiming towards that goal also should be welcomed. The fuel cell enthusiasts therefore need not look upon other clean energy technologies with hostility. The gradual acceptance by the general public to shift from conventional power generation and transportation methods to some substitutes needs cooperative efforts especially in the beginning stage since most of the firms are relatively small and do not have worldwide reputation or international networks. The government can use its information network to promote cooperation.

This kind of cooperation is a win-win situation in the sense that foreign companies can fully utilize Taiwan's cost-down specialty to reduce development cost and to facilitate earlier commercialization while the local firms can learn through those collaborative works and improve their capabilities.

ACRONYMS

APFCT	Asia Pacific Fuel Cell Technologies, Ltd
BE	Bureau of Energy
CZEI	Century Zincatec Energy Inc.
DIT	Department of Industry Technology
DMFC	Direct Methanol Fuel Cell
EPA	Environmental Protection Agency
ERL	Energy and Resources Laboratories of ITRI
EV	Electric Vehicle
EVI	eVionyx Inc. USA
EVT	eVionyx Taiwan, Inc.
FCV	Fuel Cell Vehicle
ICV	Internal Combustion Vehicle
IDB	Industrial Development Bureau
ITRI	Industrial Technology Research Institute
MEA	Membrane Electrode Assembly
MOEA	Ministry of Economic Affairs
MRL	Materials Research Laboratories of ITRI
NSC	National Science Council
PAFC	Phosphoric Acid Fuel Cell
PEMFC	Proton Exchange Membrane Fuel Cell
SOFC	Solid Oxide Fuel Cell
TFCP	Taiwan Fuel Cell Partnership

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Websites

eVionyx Taiwan, Inc.	www.evionyx-taiwan.com
Taiwan Fuel Cell Partnership	www.tfci.org.tw