Development of New Collaborative Business Model In Stationary Fuel Cell Industry

by

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ABSTRACT

The stationary fuel cell industry is currently witnessing an unstable period because of current technology barriers and business barriers at the same time that society has high expectations for fuel cell technology to solve current environmental problems. In order to overcome these barriers as well as to accelerate the commercialization of the stationary fuel cell business, companies in the industry must consider their long-term business development models based on a deeper understanding of their present business and technology positions as well as incumbents' rivalry technologies.

This thesis identifies significant barriers for the early commercialization of stationary fuel cells in the U.S. and Japan through interviews with ten business experts in the industry. The concepts of dominant design, disruptive technology and public–private consortium are than analyzed in the context of the stationary fuel cell industry. Finally, future collaborative business development models for each stationary fuel cell industry in the U.S. and Japan are proposed based on the interview data and research analysis.

The largest technology barriers and business barriers in both countries are, respectively, durability and high cost. On the other hand, the U.S. and Japanese perceptions of dominant design, disruptive technology and public–private consortium differ. The U.S. industry expects that a dominant design and public-private consortium will materialize although two interviewees responded that it is still too early for a dominant design and a consortium to enable invention and innovation. The Japanese industry is reluctant to adopt the dominant design and the public-private consortium. It would prefer a conference held for only private companies to share information and knowledge. In terms of disruptive technology, the U.S. industry thinks that external factors such as energy security issues and global warming will make stationary fuel cells become a disruptive technology. In Japan, however, industry participants believe that internal factors such as the mass production of fuel cell vehicles and deregulation in the retail electricity market will make stationary fuel cells become a disruptive technology.

In order to realize and accelerate the stationary fuel cell business, industry must consider both cooperation and competition strategy in the long-term since it confronts not only high barriers that need a long time to be solved but also since it requires promising technology breakthroughs for successful commercialization.

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Tomonari Komiyama
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1. Introduction

1.1 Background of the Fuel Cell Industry

Automobile companies, energy companies and fuel cell developers are currently focusing on advanced fuel cell technology and its rapid business development because of increasing government and consumer pressure to contribute to the solution of environmental problems. Due to increasing emissions of carbon dioxide in the transportation sector, and more dependence on OPEC for the supply of crude oil in the world [1], automobile companies have recently invested over $2 billion in fuel cell research and development – both internally and in support of joint ventures such as DaimlerCrysler's collaboration with fuel cell developer, Ballard Power Systems [2]. It is estimated that the commercialization of stationary fuel cells for distributed power generation will be realized earlier than that for fuel cell vehicles because it can be sold at a relatively higher price per power unit (kW) than that of fuel cell vehicles [2]. In addition, stationary fuel cells have an advantage because of the recent deregulation in the electricity market and frequent power outages in California, which is leading states in the U.S. to reform environmental policies. Therefore, various fuel cell developers are now focusing on the distributed electricity market in collaboration with energy, automobile companies and governments. Table 1-1(See Appendix1) shows the strategic alliances of the representative fuel cell developers with other industry for the business and technology development of stationary fuel cells [4,5,6,7,8].

1.2. Fuel Cell Partnerships and Collaboration

1.2.1 California Fuel Cell Partnership

The California Fuel Cell Partnership (CFCP) is a collaboration in which several companies and government entities are independent participants [9]. However, the collaboration is not a joint venture, legal partnership or unincorporated association. In particular, this collaborative effort is focusing on fuel cell vehicle development. The California Fuel Cell Partnership intends to place more than 70 fuel cell passenger cars and fuel cell buses on the road between 2000 and 2003. In addition to testing the fuel cell vehicles, the partnership will also identify fuel infrastructure issues and prepare the Californian market for this new technology. The current CFCP test fuel-cell vehicles were designed for hydrogen fuel; the hydrogen fueling station in CFCP's Sacramento headquarters facility was jointly designed and constructed by five of the world leaders in energy and industrial gas supply: Air Products and Chemicals, Praxair, British Petroleum, Shell and Texaco. In the near future, both a methanol fueling station and gasoline station will be installed at the headquarters. Two transit agencies joined the consortium as associate partners in January 2000 — AC Transit (in the San Francisco Bay Area) and SunLine Transit Agency (in the Palm Springs area). The buses are expected to operate a regular schedule and carry fare-paying customers in the near future. By 2003, the automobile and fuel partners will have invested several million dollars for vehicles, fuel, fueling infrastructure, staff and facilities to support them. Each partner makes an annual contribution of approximately $100,000 towards the common budget. Furthermore, the partnership is seeking $27 million in state and federal funds to help acquire 20 fuel cell-powered buses and fueling infrastructure.

1.2.2 California Stationary Fuel Cell Collaborative

The collaborative organization was formed in June 2001 [10] for the purpose of promoting a wide variety of fuel cell technologies and sizes for installation in California. Specifically, the collaboration will facilitate the installation of at least 20 MW of fuel cells by 2002, 100MW by 2003 and 500 MW by 2004 [11]. While many government organizations, such as the California Air Resources Board, California Energy Commission, National Fuel Cell Research Center, US Department of Energy, US Environmental Protection Agency and the US Fuel Cell Council join the collaborative effort as core groups, fuel cell developers and fuel suppliers are expected to join as advisory committees.

Two months after the formation of the collaboration, representatives from the California Air Resources Board and the National Fuel Cell Research Center interviewed four stationary fuel cell manufacturers, including FuelCell Energy, United Technology Corporation Fuel Cells, Siemens-Westinghouse Power Corporation and Ballard Generation Systems. Each of the manufacturers presented their expectations for: (1)

the development and growth of the fuel cell market, (2) their manufacturing capability and plans for manufacturing development, (3) their projected product portfolio and anticipated performance, and (4) the applications targeted for their products according to their business plans. The manufacturing capability planned range from 5MW/yr to 500MW/yr by 2004, from 100MW/yr to 2000MW/yr by 2006, respectively. The cost of fuel cell systems ranges from the current price of $4,500/kW to $2,800/kW in 2002 with most manufacturers predicting costs in the order of $1,000/kW by 2010. Several manufacturers indicated that a volume order of 50MW for their product would have a significant impact on lowering the installed cost and increasing manufacturing capacity.

A summary of fuel cell unit availability for the upcoming years is presented in Figure1-1. The numbers in Figure1-1 represent total capacity in MW and average cost estimates in the stationary fuel cell in California. Table 1-2 presents a summary of the pricing that is currently projected in the absence of firm large orders, and pricing for the case when firm orders for significant installed capacity (e.g., >50MW per manufacturer) are received.

Table 1-2 Average cost estimates ($/kW) for fuel cell systems

Case	June'02	June'03	June'04	June'05	June'06
Current Projections	$4,500/KW	$3,500/KW	$2,500/KW	$2,000/KW	$1,000/KW
Substantial California Power Plant Orders	$3,600/KW	$2,500/KW	$2,000/KW	$1,500/KW	$1,000/KW

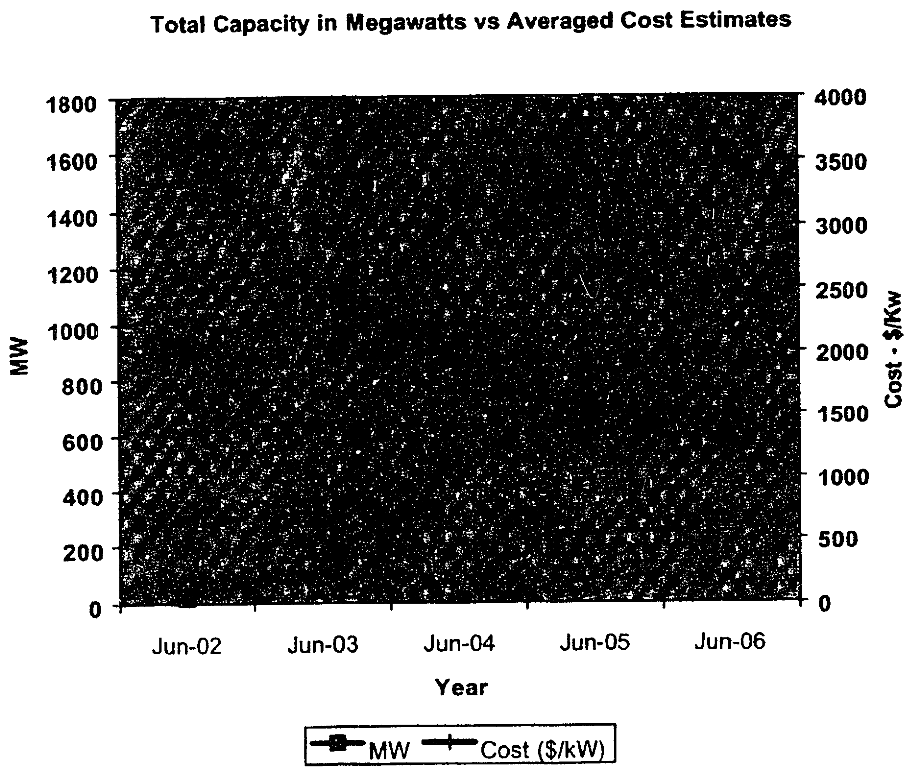


Figure 1-1 Total capacity and average cost estimates for stationary fuel cells in California

1.2.3 Freedom CAR

On January 16, 2002, the Department of Energy in the U.S. and the "big three" Automakers – Ford, General Motors and Daimler Chrysler – announced a public-private partnership called "Freedom CAR" with $1.5 billion in funds for an eight-year project to develop the hydrogen economy of the future [12]. Under this partnership, the government and private sector will fund research into advanced, efficient technology that uses hydrogen to power automobiles without creating any pollution. Freedom CAR will replace and greatly improve upon the Partnership for a New Generation of Vehicles (PNGV) program, which is another partnership between the U.S. government and the U.S. Council for Automotive Research (USCAR), which represents Ford, General Motors and DaimlerChrysler, for the development of environmentally friendly vehicles with three times the fuel efficiency of conventional vehicles. Freedom CAR will focus on technologies to enable mass production of affordable hydrogen-powered fuel cell vehicles and the hydrogen-supply infrastructure necessary to support them.

1.2.4 Fuel Cell Commercialization Conference in Japan (FCCJ)

The Fuel Cell Commercialization Conference of Japan (FCCJ) seeks the early commercialization and spread of polymer electrolyte fuel cells, which are seen as having great potential for use in cars and homes [13]. Development is moving ahead with a view to their commercialization in a broad range of products, including motor vehicles, stationary and residential cogeneration systems, and mobile devices. FCCJ highlights the need to create a scheme for the private sector to take part in examinations and discussions on the commercialization and widespread use of fuel cells. The objects of the FCCJ are to examine those issues that specifically affect the commercialization and widespread use of fuel cells, and to develop the findings into policy proposals with a view to enabling member companies to take steps to resolve the issues themselves, in addition to having these findings reflected in government measures. Through this, the FCCJ can make an important contribution to the commercialization and widespread use of fuel cells in Japan, and to the growth of Japan's fuel cell industry. In this organization, experts from member companies in the various fields connected with fuel cells carry out a broad range of activities aimed at the commercialization and widespread use of fuel cells through activities such as sharing information and experience and discussing issues to propose to the government in order to further deregulation.

1.3. International affairs – Global warming

Climate change is a result of the large volume of carbon dioxide emitted from automobiles and power plants. Towards an attempt to slow global warming, the third

Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3), which consists of the representatives of over 150 countries, was held in Kyoto in December 1997. The conference produced a protocol – the Kyoto Protocol – to the framework codifying commitments for reductions in greenhouse gas emissions after 2000. "The protocol commits Annex I parties (mainly developed countries) to reduce greenhouse gas emissions by 5-8 percent below 1990 levels between 2008 and 2012 and to make demonstrable progress towards achieving these commitments by 2005 "[14].

In November 2002, COP7 was held in Morocco; the conference closed upon completion of the legal documents based on the Kyoto Protocol. As a result, the only remaining hurdle is for the international treaty to be ratified in each country even if the U.S. decides to secede from the treaty. The protocol also permits Annex I countries to trade "emission reduction units" with each other. That is, if one Annex I country's emission is below its limit, it may sell or barter the difference to another Annex I country that would otherwise be over its limit. According to the "Clean Development Mechanism" defined in the protocol, Annex I parties may also apply certified emission reductions toward meeting their limits [15]. Certified reduction units can be accrued through joint projects with non-Annex I countries that reduce emissions outside Annex I countries. As the market to treat carbon dioxide and to transfer energy-efficient technology between countries emerges in the future, fuel cell technology that drastically reduces carbon dioxide emissions may become a very promising solution.

1.4 Potential market in fuel cells

The current market for fuel cells is about $218 million and is expected to increase to $2.4billion by 2004, reaching $7 billion by 2009, according to studies by the Business Communications Company. The estimations for the fuel cell market in 2004 are shown in Table 1-3. According to Allied Business Intelligence Inc., the current $40 million stationary fuel cell market will grow to more than $10 billion by 2010, and the overall fuel cell energy generating capacity will increase by a factor of 250, with global stationary fuel cell electricity generating capacity jumping to over 15,000 megawatts (MW) by 2011 from just 75 MW in 2001. Moreover, Allied Business Intelligence makes the following prediction for the automotive fuel cell market. It predicts that automotive fuel cells will have nearly a 4% market share of the U.S. automotive market, with 608,000 vehicles by 2010. Market penetration could rise as high as 1.2 million fuel cell vehicles, which would represent 7.6% of the total U.S. automotive market in 2010[16].

Table 1-3 Breakdown of the potential fuel cell market in 2004

Application	Market size ($ million)
Electric power generation	850
Motor vehicles	750
Portable electronic equipment	200
Military/aerospace	200
Other	400

Morgan Stanley Dean Witter estimates that the total installed stationary power generation capacity in North America, Europe and Japan is currently about 2,600,000 MW [17]. Also, annual new capacity addition is estimated at about 80,000 MW and annual replacement capacity at about 45,000 MW. MSDF has projected that market share for fuel cell stationary power will reach 0.7% of capacity additions and replacements, or 900 MW by 2010. The price of a fuel cell depends on the size and the supplier. A 100-watt Dais fuel cell costs $4,000. A miniaturized 100-watt unit used in defense applications from Ball Aerospace costs $35,000. A 1-kw cell from Hydrogenics costs $75,000 and a 200-kw fuel cell from ONSI Corp., a subsidiary of United Technologies, costs $600,000 [17].

1.5. Cost competitiveness in Stationary Fuel Cell Systems

Directed Technologies Inc. has shown that stationary fuel cell systems are only competitive in size 50kWe, as shown in Figure1-2, based on average California electric utility and natural gas commercial rates, and assuming that 10,000 systems are produced [18]. The lower line in Figure1-2 illustrates that selling only electricity from these systems would not be economic, and would generate a negative return on investment. Adding heat co-generation provides a positive return on investment for systems larger than 50kWe, but the total system would still only provide 10% real, after-tax return on investment if hydrogen were also produced during off-peak hours for use in fuel cell vehicles or other industrial hydrogen applications.

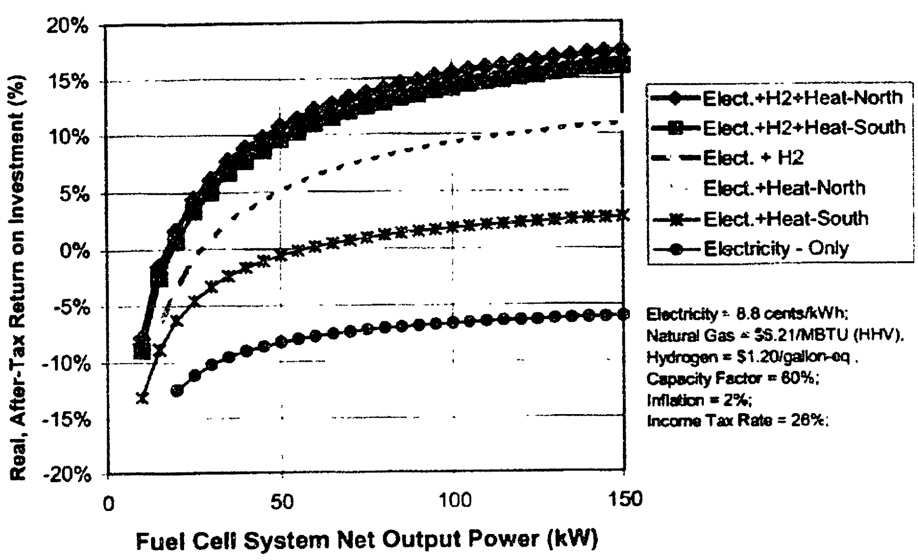


Figure 1-2 Return on Investment for Commercial Fuel Cell Systems

Estimated capital cost projections for residential fuel cell systems with/without a battery, and with a peak power of 3.4kWe AC to private homes, are shown in Figure 1-3, and estimated electricity costs are shown in Figure 1-4, assuming 100 production and 10,000 production quantities, respectively. Without the battery-augmented system, the pure fuel cell system has a 3.4kWe peak output power capacity. On the other hand, the fuel cell system with a batter-augmented system has a nominal 1.2kWe power output ,and the battery which can store the surplus power supplies the power when the power consumption reach the peak. As shown in Figure 1-4, adding the battery system to the fuel cell system has very little effect on the price of electricity necessary to provide the desired 10% real after-tax return on capital.

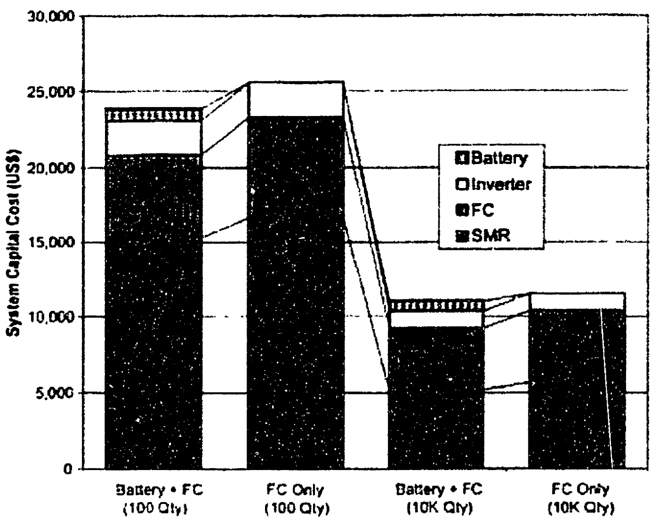
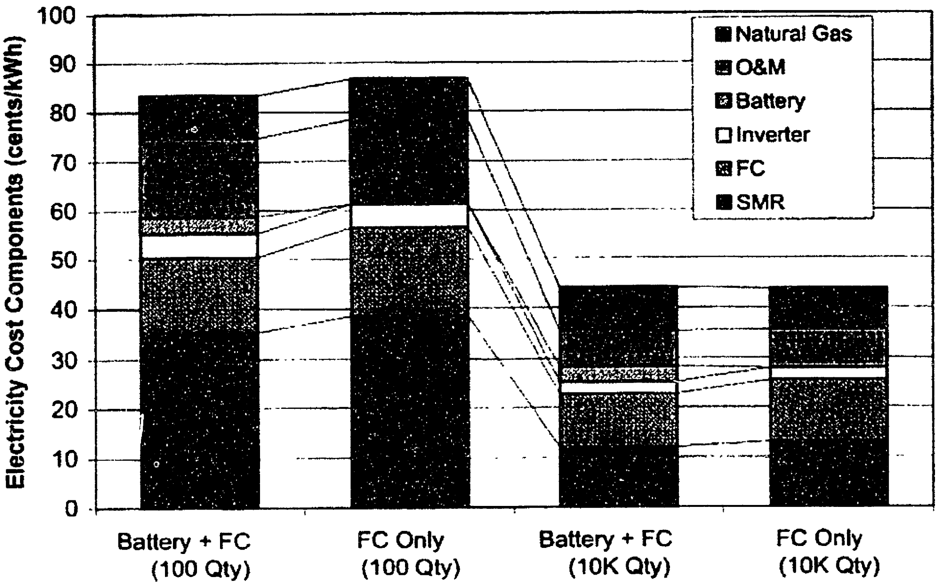


Figure 1-3 Capital Cost Estimates for a 3.4kWe Fuel Cell System

Even in the preferable 10,000 production case, the required electricity price in the range of 44¢/kWh is four times the average residential utility rate of 11.2¢/kWh in California. Adding the battery has negligible effect, and the system remains grossly uneconomic under the assumptions in Direct Technologies Inc.'s cost model.



California Case	(Residential Rates)
Natural Gas Cost:	$6.55 /MBTU
Grid Electricity Avoided Cost	11.20 cents/kWh
Battery Cost/kWh:	$100 /kWh
Battery Energy:	6.74 kWh-DC
Real, After-Tax Return:	10%

	100 Qty:	10,000 Qty:
Natrual Gas Reformer Cost:	$15,281	$5,184
Fuel Cell System Cost:	$5,570	$4,019
Inverter Cost:	$2,249	$1,117
Battery Cost:	$759	$664
Total System Cost:	$23,839	$10,984

Figure 1-4 Electricity Price Required to Yield 10% Real After-Tax Return on Investment for a Residential Fuel Cell System in California

2. Purpose of this research and methodology used

2.1 Purpose

- To make a significant contribution to the acceleration of stationary fuel cell technology and business development by 2010, when the Kyoto Protocol will come into force.
- To propose a new concept of collaboration style among fuel cell developers, component makers, fuel suppliers and governments to the fuel cell industry.

2.2 Methodology

Between January and April 2002, chief executive officers, directors, senior managers, government officers and a professor in the stationary fuel cell industry both in the U.S. and Japan were interviewed to ascertain their views for the future outlook of the industry from the perspectives of both business and technology. This thesis is the first piece of research that in addition to analyzing the frank views of representatives from major fuel cell developers, fuel suppliers, governments and universities in the U.S. and Japan also applies the data collected to academic concepts such as "Next Generation Manufacturing (NGM)"[19], "Disruptive Technology"[20] and "Dominant Design"[21]. As shown in Figure 2-1, the NGM Model is applied to the current stationary fuel cell industry. The questionnaire used for the interviews, which includes 10 questions, is attached in the Appendix2.

2.3 Interview survey

The organizations that cooperated for this research are presented in Table 2-1. Fuel cell developers and the government, both of which are very active in stationary fuel cell business were focused on in the U.S. In the case of Japan, the government and two fuel suppliers, which in addition to already having launched their distributed generation business using co-generation technology have also tried to start the stationary fuel cell business by utilizing their hydrogen production technology through alliances with fuel cell developers, were interviewed. All of the organizations that were interviewed are focusing on the proton exchange membrane type of fuel cell technology, which is developed for fuel cell vehicle applications and stationary fuel cell applications.

Table2-1 Ten organizations for the interview survey

	U.S.A.	Japan
Government	• California state (California Stationary Fuel Cell Collaborative)	• Ministry of Economy, Trade and Industry
Fuel Cell Developers	• Ballard Power Generation • United Technology Corporation Fuel Cells • Proton Energy System • Nuvera • PlugPower	-------------------------------------
Fuel Suppliers	-------------------------------------	• Tokyo Gas • Nippon Mitsubishi Oil Corporation
University	• Massachusetts Institute of Technology (Sloan School)	-------------------------------------
Total	7	3

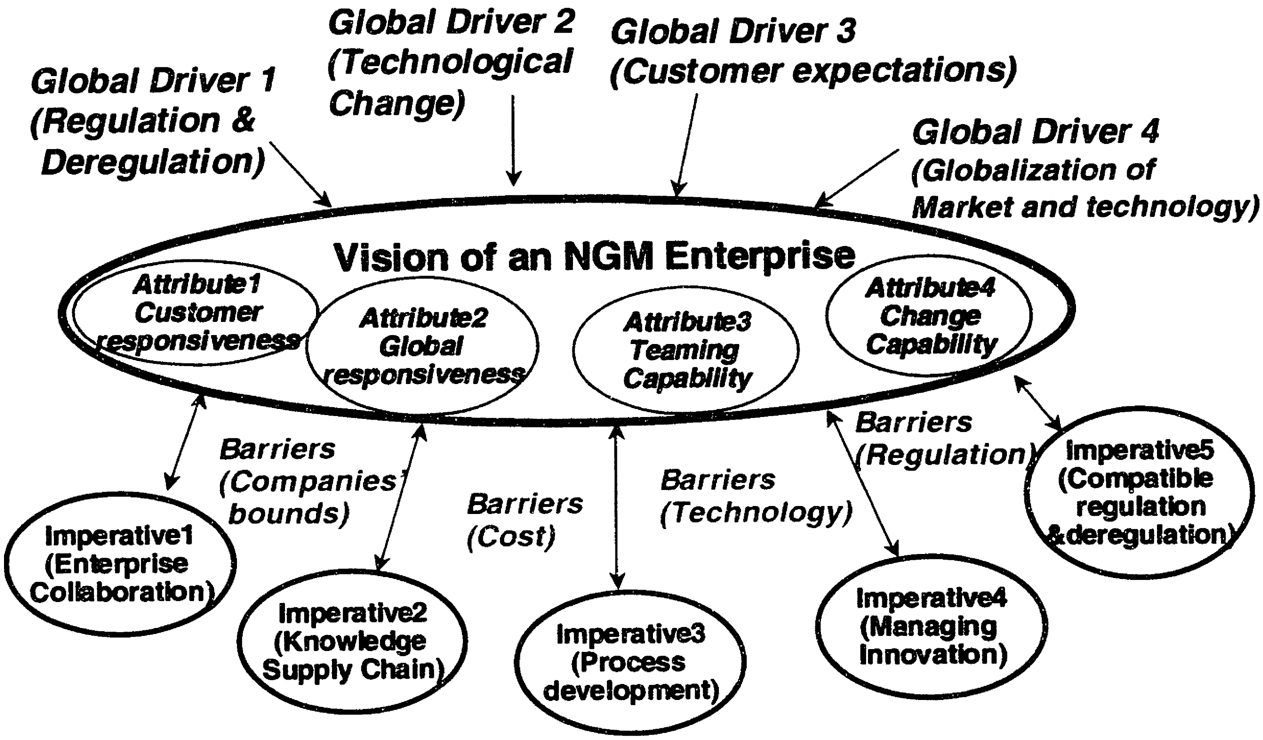


Figure 2-1 Imperatives in the stationary fuel cell business

2.4 Hypotheses

One of the goals of the interviews was to ask organizations about the effectiveness the below hypotheses.

- The discovery of a new concept of collaboration style between players in the development arena enables the stationary fuel cell industry to sharply decrease the cost and the uncertainty of technology in addition to increasing product reliability.
- The new concept of collaboration style can make the stationary fuel cell generation become a disruptive technology in the electricity industry.

2.5 Goal

- Identify the significant barriers to the early commercialization of the stationary fuel cell generation.
- Discover methods to overcome those barriers by applying various frameworks such as "Next Generation manufacturing" Model, Disruptive Technology and Dominant Design to the interview data and results.

2.6 Influence of this research on the fuel cell industry

In order to encourage the fuel cell industry to share its viewpoints on the current and future outlook in terms of technology and business and to motivate the industry to implement the proposals developed in this thesis, the results of the research will be provided to each of the interviewees that participated in the research.

- Summary of the interview surveys

(Comparison of the U.S and Japan from the the perspective of views on future technology, the market, electricity deregulation and government support)

- Proposals for a new style of collaborative enterprise based on these surveys

3. Predicted Market for the Stationary Fuel Cell Industry and Distributed Generation

3.1 Distributed generation market

According to Resource Dynamics Corporation's estimation[22], by 1999, about 22 GW of distributed power had been installed in the U.S. without backup units, which add about 18GW (see Figure 3-1). Distributed power in the U.S. is defined as follows.

- For non-renewables, units with > 10% of generation consumed on-site
- Includes the following units under 50MW
  - Non-utility generation
  - Non-hydro renewables

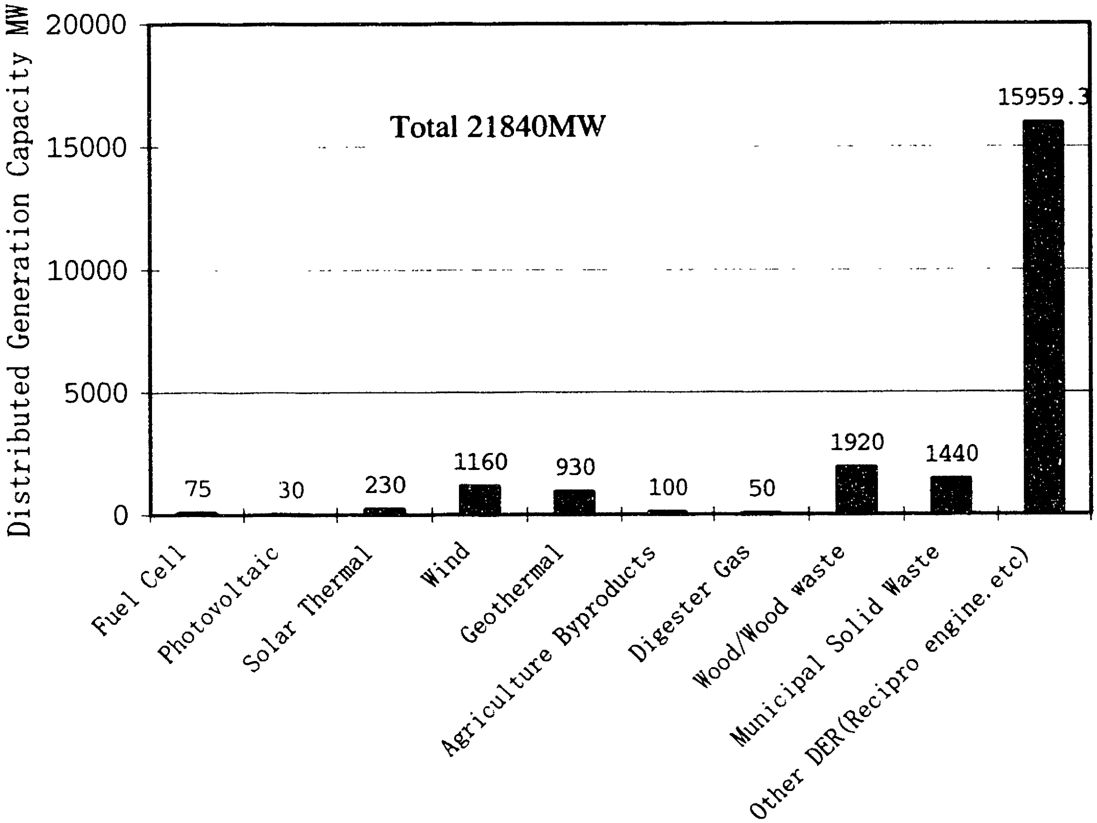


Figure 3-1 Installed Distributed Generation Capacity by 1999

National Energy Policy data, which shows that total generation capacity is about 800,000 MW, estimates that the share of distributed generation in total generation capacity in the U.S. is 2.73%. Moreover, the share of stationary fuel cells of total distribution generation capacity is only 0.094%. Even though the potential market for stationary fuel cells as a distribution generation is often said to be larger than solar and wind energy, the fact is that the utilization rate of stationary fuel cells is still very limited. As another attractive distributed generation technology, microturbine shipments exceeded 1,200 units in 2000 (representing 53MW), a 400% increase from the 1999 level. In 2001, it is estimated that from 3,500-5,500 units are likely to be shipped (representing 200-300MW).

3.2 Strategic Market Plan by DOE

According to the "Strategic Plan For Distributed Energy Resources" published in September 2000 by the Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy in U.S. Department of Energy, its mid-term goal for 2010 is to reduce costs and emissions [23]. In other words, the goal of achieving 20 percent of capacity additions requires adding approximately 26.5 GW of new distributed energy resource capacity by 2010. Besides that goal, the U.S. Department of Energy described its other strategic goals as follows.

- Enhance the use of renewable energy, triple the installed capacity of non-hydroelectric renewables by 2010
- Maintain the present high reliability of the nation's electricity system.

In order to reduce the dependency on oil imports from foreign countries, DOE is encouraging industry to develop renewable and energy-efficient technology.

3.3 Market Prediction of Distributed Generation in 2010

Ten representatives, who can discuss the business and technology of stationary fuel cells from the viewpoint of senior management, from different organizations in the stationary fuel cell industry were interviewed. The following are the questions asked and answers received.

Question1

" What percentage of total market share of new generating capacity do you expect the distributed generation to have acquired in 2010? "

(Results)

The summary of the stationary fuel cell industry's perceptions about the distributed generation market in 2010 is presented in Figure 3-2.

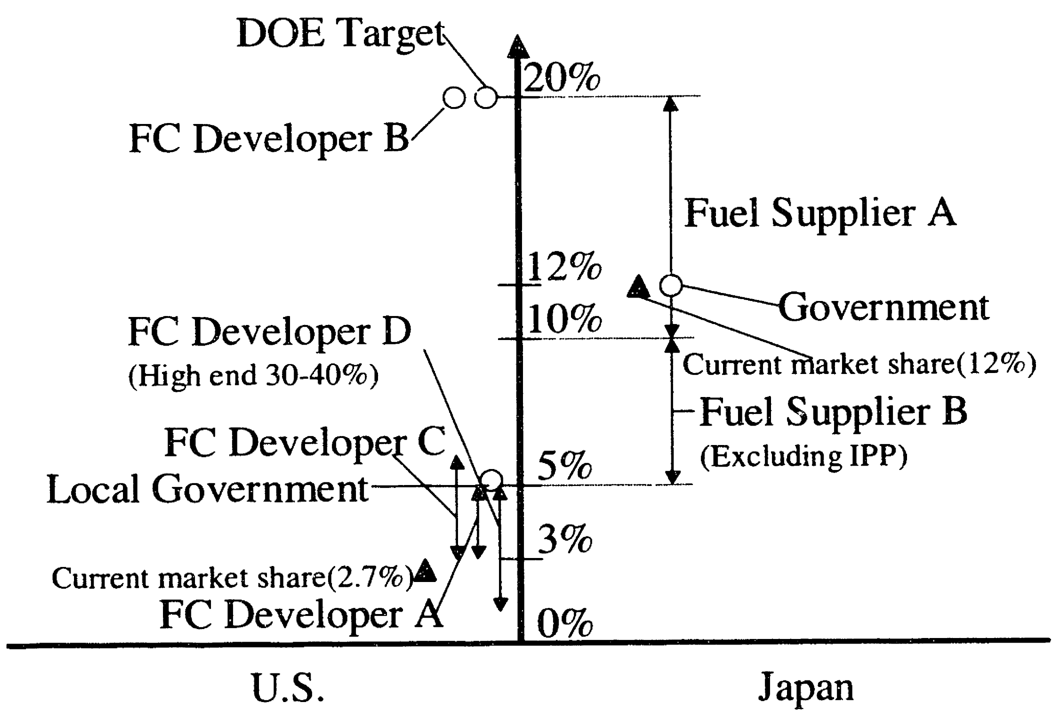


Figure 3-2 Market prediction of distributed generation in 2010

In general, the share of distributed generation out of new distributed energy resource capacity ranges from 1-6% in the U.S., with the exception of the perspective of one particular fuel cell developer, which seems to be in greater contact with the DOE than the other companies. This company is actually proactive in participating in the DOE's five fuel cell projects and received government funding of nearly total $20 million in 2000. In the U.S., in general, the interview data regarding market share is quite reasonable considering the current distributed generation market whose share is currently 2.7%. On the other hand, the distribution generation market share in Japan in 2010, as predicted by two fuel suppliers, ranges from 5 –20%. The reason why fuel supplier B's predicted market share of distributed generation is between 5 to 10 % is that independent power plants were excluded in its estimation. Taking the above points into account, the predicted shares given by the fuel suppliers is consistent with the Japanese government's own prediction and current market share, which is calculated as 12% based on the definition that large independent power plants belong to the distributed power generation.

(Analysis)

Japanese fuel suppliers appear to conduct intensive research regarding the distributed generation market for their future business because they are developing the stationary fuel cell type of co-generation systems to capture the future potential profit in Japan's electricity markets. In the U.S. there is a significant gap in perceived market share distributed generation for 2010 between the DOE strategic target (20%) and the fuel cell companies' perception. This is probably because the DOE's strategic target plan is usually more ambitious than what the government predicts based on incremental development. Also, the government has specific reasons for wanting distributed generation to make up for the predicted large gap between increased power demand and the limiting power distribution grid in 2010. As a whole, both in the U.S. and Japan, the stationary fuel cell industry expects incremental growth rather than rapid growth in the distributed generation market. They are realistic in their perspectives of the market because they understand the present market situation.

(Conclusion)

Based on Figure3-2, the companies in the stationary fuel cell industry in both countries don't expect a rapid increase in the distribution market by 2010. They are familiar with the current situation of the distributed generation market. Even though the government has a strategic and ambitious plan, companies in the stationary fuel cell industry understand the difficulty in obtaining a significant increased share of the distributed generation in eight years. The difference between the U.S. and Japan is the current share of the distributed generation market. This comes mainly from the price gap between the U.S and Japan and from each country's definition of distributed power generation. Electricity prices in Japan are said to be much more expensive than in the U.S., sometimes twice as much according to 1999 data from the International Energy Agency [24]. Several large companies that consume a large amount of electricity have their own independent power generation plants to save electricity costs instead of busing the electricity from the electric companies. This is one of the main reasons why the distributed market share in Japan seems to be higher than that in the U.S.

3.4 Market prediction of the stationary fuel cells in 2010

3.4.1 Present market position in the stationary fuel cell industry

There are two segments of the stationary fuel cell market, the industrial market and the residential market. There are also four types of fuel cell technology what have so far been applied to the stationary fuel cell market. Table 3-1 presents the current position of each fuel cell in terms of technology and market[13].

[Industrial market]

Phosphoric acid fuel cells (PAFC), mainly developed and sold by United Technology Corporation Fuel Cell (UTCFC), are currently in the market entry phase. More than two hundred PAFC units in the 200kW size range have been manufactured by UTCFC for sale to customers worldwide. Molten carbonate fuel cells (MCFC) and solid oxide fuel cells (SOFC) units are currently undergoing full-scale demonstration in several fuel cell developers, such as FuelCell Energy and Ztek, and proton exchange membrane fuel cell (PEMFC) units, which are focused on in this research, are in the early development and testing stage by Ballard Power Generations, PlugPower and UTCFC. PEM is also being intensively developed for fuel cell vehicles by the automobile industry.

Table3-1 Present position of four types of fuel cells

	Cost ($/kW)	Durability (hr)	Efficiency (%)	Market current position (Application)
PAFC	4,500	N/A	36-38	Market Entry Phase (Cogeneration)
MCFC	N/A	N/A	50-55	Full Scale Demonstration (Large scale power supply)
SOFC	1000-1500 (Projection in 2003)	6500-25,000	55-60	Full Scale Demonstration (Next generation cogeneration)
PEMFC	10,000	1,000-1,500	35-40	Early Development (Commercialization in a broad range such as stationary fuel cells)

[Residential market]

As Figure3-3 indicates, *FUEL CELL TODAY* (20 February 2002) summarized that a total of 550 residential-style fuel cell systems have been built and are now operating worldwide [25]. This number not only includes systems installed in homes but also units in the 0.5-20kW range operated in uninterruptible and back-up power supply and remote locations. Development in the residential fuel cell market accelerated over the past two years (2000 - 2001) with over 90 of the prototype systems being built.

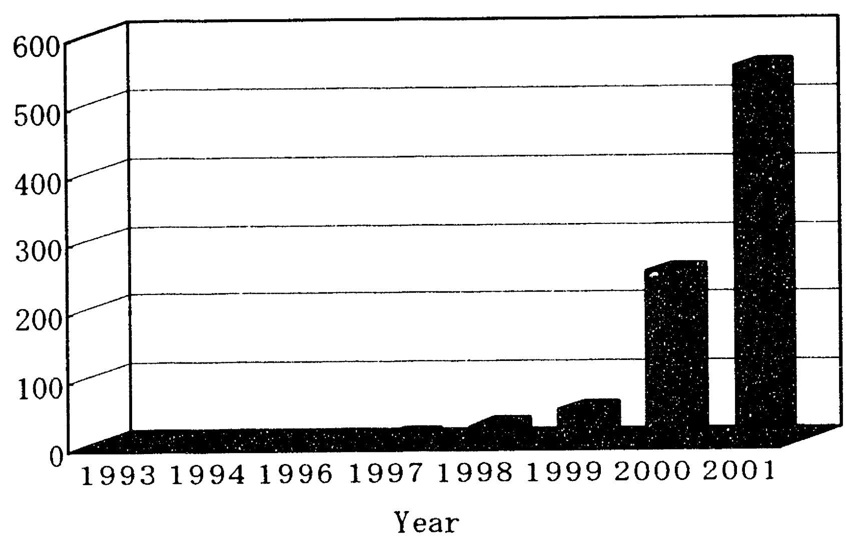


Figure3-3 Cumulative number of residential fuel cell units

(Strategic goals of the Japanese and U.S. governments)

The "Strategic Plan For Distributed Energy Resources," published in September 2000 by the Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy in the U.S. Department of Energy, does not have a clear-cut goal in terms of the future stationary fuel cell market [25]. However, it declares that the goal for 2003 is to commercially introduce high-temperature natural gas-fueled MCFC and SOFC at $1,000-$1,500 per kilowatt that are capable of 60% efficiency, ultra-low emissions, and 40,000-hour stack life.

In Japan, the Ministry of Economy, Trade and Industry (METI) is planning to motivate the industry to install 2200MW (correspond to a 2% share of total new generating capacity) stationary fuel cells for power generation by 2010 [26]. According to METI's plan, it will consist of 2100MW of PEMFC and 100MW of PAFC as a small-distributed generation for buildings and residential use.

3.4.2 Market Prediction of stationary fuel cells in 2010 from the interview data

Question2

"What percentage of total market share of new generating capacity do you expect stationary fuel cells to have acquired by 2010? "

(Results)

The stationary fuel cell market share in 2010 as predicted by Japanese and U.D. industry is presented in Figure 3-4.

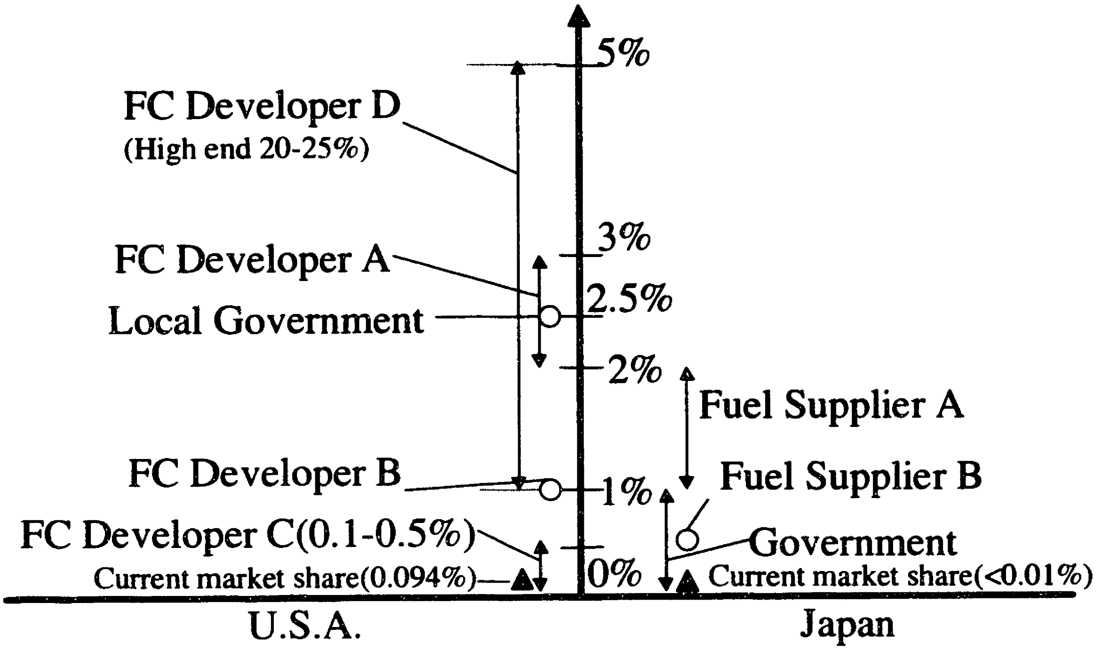


Figure3-4 Market prediction for stationary fuel cell in 2010

(Analysis)

As shown in Figure 3-4, the predicted market share for stationary fuel cells in 2010 in the U.S ranges between 0.1 and 3.0%, with the exception of one projection from a leading fuel cell developer. Based on the current share of stationary fuel cells in the total generation capacity, which is less than 0.01% in both the U.S. and Japanese electricity markets, their predicted share in 2010 is more than 10 to 300 times the current share. , Taking into account the industry technology and business barriers, which are analyzed in chapters 3 and 4, it appears that the high-end number (of 3%) would be a big challenge for the stationary fuel cell industry since it requires raising the share more than 300-fold in only 8 years.

One interesting opinion about market prediction from two interviewees in both the U.S. and Japan is that the share of stationary fuel cells will be about 10 to 20% of total distributed generation in 2010. They measured the penetration rate of stationary fuel cells in the electricity market based on total distributed generation market, because issues such as customer awareness, maintenance network, regulatory issues and operating costs in the stationary fuel cell industry are also shared by rival distributed generations such as micro gas turbines and wind power. There does not appear to be a strong correlation between the interviewees predicted market share for distributed generation and predicted market share for stationary fuel cells. There was one very different opinion from one of the leading fuel cell developers in the industry that saw a very wide range for about market share, ranging from 1-5% at the low end and 20-25% at high end.

(Conclusion)

In general, there is not a particularly large difference in U.S. and Japanese perceptions of the future market share of stationary fuel cells. All companies in the stationary fuel cell industry, with the exception of one fuel cell developer, predict that stationary fuel cells share of the total power generation market will range from 0.1 – 3.0%. Taking into account that the current share of the stationary fuel cell systems is less than 0.01 %, the high-end number (3%) in the above prediction may be difficult to realize in just eight years.

3.4.3 Other latest resources about the predicted stationary fuel cell market

Table 3-2 is the projected stationary fuel cell capacity in 2010 presented by several fuel cell developers and a consulting firm, which presented at the New York fuel cell dynamics conference on February 6 and 7, 2002[27].

Table3-2 Projected stationary fuel cell capacity in 2010

	Capacity (GW) in 2010	Share % out of total new generation capacity
Ztek (SOFC type of fuel cell developer)	75	57%
Allied Business Intelligence (Consulting firm)	11-15 (in 2011)	8.3-11.4%
Nextech (Fuel cell component supplier)	5	3.8%

(Each share is calculated based on the projected new generation capacity in the U.S. in 2010.)

The market prediction of Ztek, which is a SOFC manufacturer of 200kW stationary fuel cell systems, is far higher than that obtained from the interview research data as shown in Figure3-4. One of the main reasons that SOFC manufacturers think they will acquire more share than the PEM type of fuel cell developers is that they have already confirmed their product durability since the prototype reformer of the 25kW SOFC has run nearly nonstop for some 24,000hours with very little downtime beyond scheduled maintenance [28]. Furthermore, they are also planning to mass produce the 100-200kW SOFCs in 2002 and start launching the business in 2003, because they are likely to achieve the cost target that is $1,200/kW in 2003 as total system unit cost. As for the MCFC type of fuel cells, in 2002, FuelCell Energy achieved mass production[29]; the company has constructed a new manufacturing facility in Connecticut for a total amount of 400MW as stationary fuel cells, and is receiving funding support, including $40 million, by way of a three-year contract with the DOE.

On the other hand, in terms of PEMFC, DOE is still targeting 1,000-hour operation durability for the commercialization of fuel cell vehicles. The limited durability of PEM, which is very short of the required durability of at least 40,000 hours for stationary fuel cells, is one of the main reasons for the different market perspectives of PEMFC manufacturers and manufacturers of other types of fuel cells. Nextech, which is a component supplier for fuel cell manufacturers predicts that the market share of stationary fuel cells will be 3.8% in 2010. This number is very close to most of predictions obtained in interviews; it is possible that Nextech may be carefully observing its customers, which include fuel cell technology developers, so as to ensure a reasonable prediction. Moreover, the company clearly understands that it takes a lot of time for fuel cell manufacturers to penetrate the market through technological development and developing business with their customers

Allied Business Intelligence's market share prediction is larger than most of the other received predictions. The company, which conducts marketing research in the fuel cell industry, may take into account the effective technology transfer from fuel cell vehicles to stationary fuel cells, because it estimates that the market in the fuel cell vehicles will grow significantly by 2010.

In comparing the interview data with other recent data resources, it was found that different types of fuel cell developers, for instance, SOFC and MCFC manufacturers, are likely to be the strongest rivals to PEM stationary fuel cell developers in the distributed generation business. It is also apparent that the fuel cell consulting firm's data is not always based on the perspectives of the companies within the stationary fuel cell industry.

3.5 Largest business barriers

Question 8-1

"What are the largest barriers for the stationary fuel cell technology and business development from your company's viewpoint?"

(Results)

Figure 3-5 presents the largest business barriers in the stationary fuel cells industry based on the interview data. The representative comments about the largest business barrier are shown in Table 3-3.

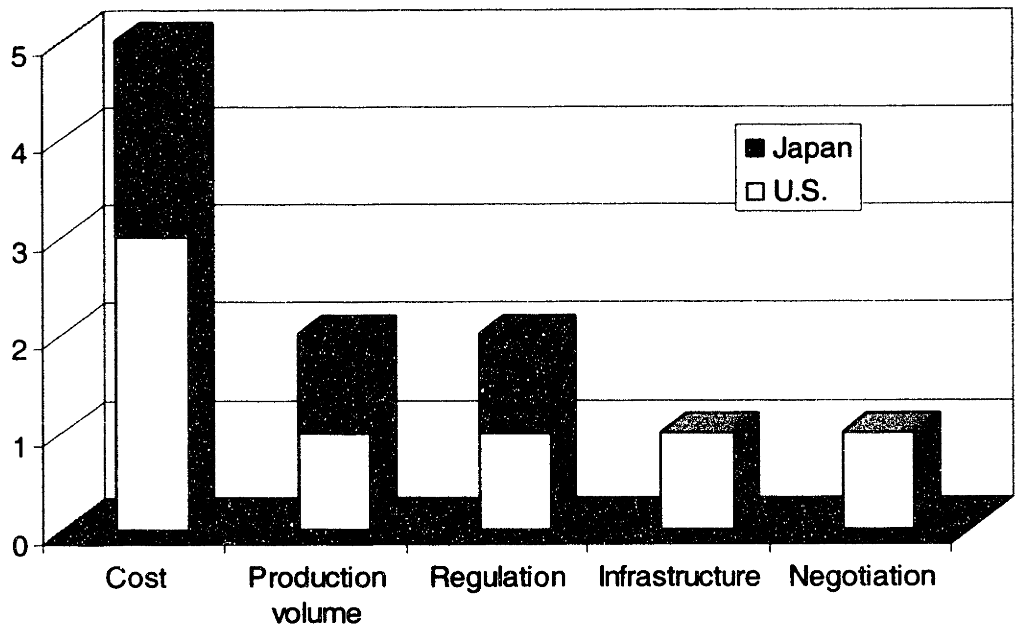


Figure 3-5 Largest business barriers in the stationary fuel cells industry

(Analysis)

As shown in Figure3-5, five of the nine interviewees responded that the high cost to produce fuel cell systems is the largest business barrier. Generally speaking, the initial cost of producing fuel cells is said to be about $10,000/kW, although this cost depends on the fuel cell developers. The cost is about ten times that of the unit cost of conventional power generation. The next largest barriers are limited production volume and regulation. According to the cost structure of fuel cell systems shown in Figure 3-6, as estimated by Direted Technologies Inc., the cost is expected to decrease significantly because of mass production to range from 1 to 10,000 units of 100Kw type of stationary fuel cells[30]. Although, based on Figure 3-6, the system capital cost will decrease to one one-ninth of the current estimated market price after the 10,000th unit is produced, the unit capital cost of the system ($/kW) will still be higher than that of the conventional power generation, which is estimated to be about $1,000/kW.

Table 3-3 Representative about largest business barriers (• U.S., o Japan)

	U.S.	Japan	Representative opinions (reasons)
High cost	3	2	• High cot is the largest barrier. o Specifically the cost of components is expensive.
Production volume	1	1	• Large procurement order is necessary for the stationary fuel cell business.
Infrastructure	1	0	--
Regulation	1	1	• Present utility regulation is not helpful for the business now. o Current regulation can be flexibly changed in proportion as the fuel cell technology developed.
Negotiation	1	0	• Negotiations are sometimes difficult to reach the agreement for partnership.

The California government mentioned that a large amount of procurement orders from the government and the introduction of green accounting might help reduce costs effectively. In fact, in 2000, the California Stationary Fuel Cell Collaborative was formed to encourage fuel cell manufacturers to speed up development through offered incentives such as a $400 million pledge from the California Consumer Power and Conservation Financing Authority to invest in stationary fuel cells, aggregating purchases on behalf of all government agencies[31]. One Japanese and one U.S. interviewee mentioned that current regulations in the electric utility industry are the largest business barrier in the stationary fuel cell industry. The interviewee in the U.S. insisted that current regulations are not helpful for their business. In Japan, the government said that current regulations could be changed flexibly in accordance with the development of the fuel cell technology.

(Conclusion)

This research confirms that the high cost of stationary fuel cells is the largest business barrier. As for the limited production volume, which is one of the next largest barriers, the 10,000 level of mass production will not enable stationary fuel cells to be sufficiently competitive with conventional power plants in terms of unit cost.

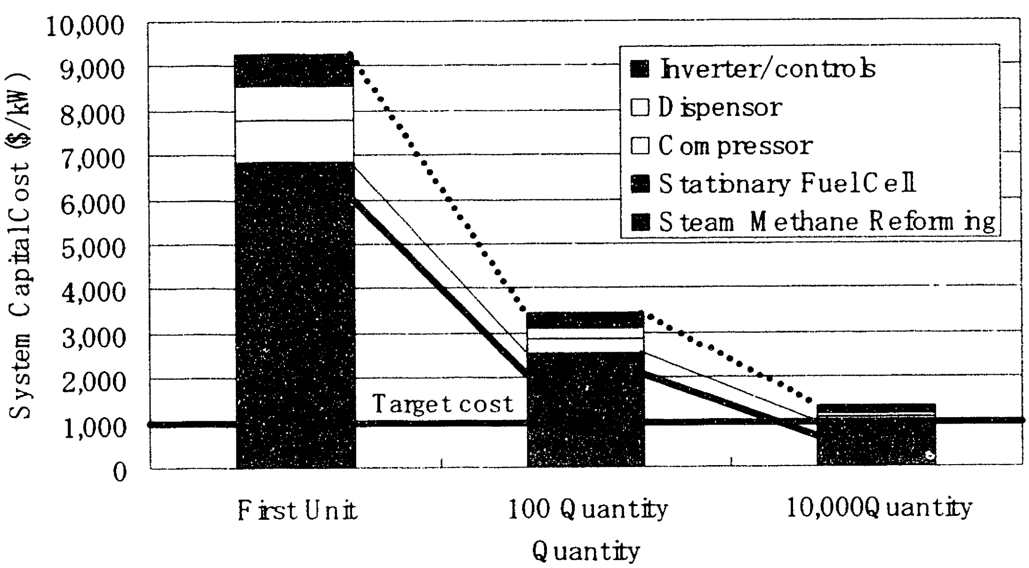


Figure3-6 The cost structure of the stationary fuel cell system

3.6 Estimation of market size of stationary fuel cell industry in 2010

Based on the stationary fuel cell's market share in 2010 predicted by the interviewees, possible market size and business magnitude in 2010 was estimated with the results shown in Table 3- 4. The following assumptions were made for the calculations:

- The system size of the stationary fuel cells is 100kW, which is the same as the system size in Figure 3-6 estimated by Direted Technologies Inc.
- Total added capacity by 2010 is 132.5 GW according to DOE's strategic plan.
- Based on Figure 3-5, the unit cost of stationary fuel cells can be under $1000/kW only when production exceeds 10,000 units.
- The unit cost of stationary fuel cells is $3,000/kW when the number of systems is lower than 10,000 systems.
- The U.S. government can subsidize $2,000/kW for users to install stationary fuel cells.

(Results & Analysis)

Table 3-4 shows the predictions for the stationary fuel cell industry in 2010 based on the interview data. First, the share of stationary fuel cells in the new generation capacity is assumed to be 0.1% as in Case 1. Given this, the figures for production and market size will only be 1325 and $398million, respectively, even though users can utilize more subsidies from the government than unit costs. On the other hand, in Case 2, the fuel cell developers can mass produce the stationary fuel cell systems and reduce the cost to $1,000/kW, based on the estimations of Direted Technologies Inc. In this case, the stationary fuel cell industry will make the production and market size grow to be 39,750 and $39,750 million, respectively. This prediction appears to be more reasonable than the $7 billion estimated by Business Communications Company.

Table 3-4 Case study for the stationary fuel cell industry in 2010

	Case 1	Case 2
System Size (kW)	100	100
Marjket Share (%)	3.0	0.1
Number of systems	39,750	1,325
Predicted market size(MW)	3,975	133
Unit cost ($/kW)	1,000 (No subsidy)	3,000 (Subsidy-$2,000/kW)
Market penetration ($million)	3,975	398

(Conclusion)

Based on the interview data, the predicted market size of stationary fuel cells will range from $400million to $4billion. The total number of stationary fuel cell systems will be at most 40,000 by 2010, even though market share could reach 3% of the total new generation capacity. In order to make further production volume, the mass production of fuel cell vehicles will be necessary by 2010.

4. Technology Development

4.1 Technology transfer from stationary fuel cells to fuel cell vehicles

Question 3

" Do you think that commercialization of stationary fuel cells is essential before the fuel cell vehicles are mass-produced? "

(Results)

Figure 4-1 shows that there are three separate opinions about the technology transfer from stationary fuel cells to the mass–production of fuel cell vehicles. Table 4-1 shows the representative comments from each response.

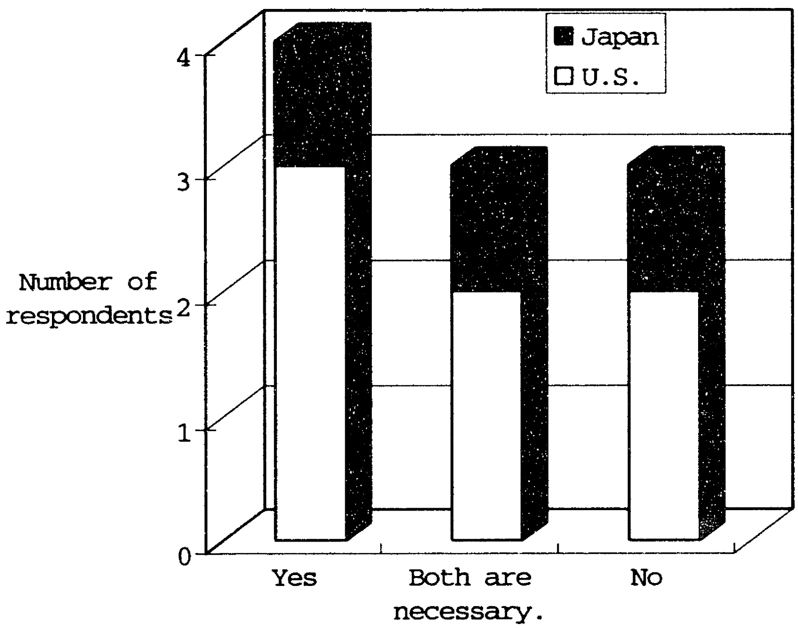


Figure 4-1 Technology transfer from stationary fuel cells to the mass-production of fuel cell vehicles

Table 4-1 Representative opinions about the technology transfer from stationary fuel cells to fuel cell vehicles (• U.S., o Japan)

	U.S.	Japan	Representative opinions (reasons)
Yes	3	1	• High cost is allowable in Stationary fuel cells. Components can be shared between each application. o Cost target in stationary is not severer than in FC vehicles.
Both development are necessary	1	1	• Both applications should work together for the market size.
No (Unlikely)	3	1	• Different performance is necessary for each application. • Expected reliability and cost are different between stationary fuel cells and fuel cell vehicles. o Automobile industry is developing the fuel cell technology independently.

(Analysis)

The respondents are divided almost equally among the three following categories: "Yes", "No" and "Both are necessary". Four interviewees responded that stationary fuel cell commercialization has to be realized before mass production of fuel cell vehicles can be started due to the advantage of having a high target cost. Three interviewees insisted that there should be collaborative development of stationary fuel cells and fuel cell vehicles to develop total market growth for fuel cells. The remaining three interviewees maintain that the development of stationary fuel cells is different from that of fuel cell vehicles because the desired reliability and cost are different from each other.

Interestingly, the three fuel cell developers that are developing both stationary fuel cells and fuel cell vehicles responded "Both are necessary" or "No" to the question, because it appears that through experience they can clearly recognize the big differences in required performance and cost between stationary fuel cells and fuel cell vehicles. For this question, there was little difference of opinion between the industry in the US and Japan, except that the Japanese automobile industry is independently developing the fuel cell technology.

It is generally accepted that the basic technology for stationary applications and vehicle applications, with the exception of the hydrogen storage technology, is the same. According to MIT Technology Review [2], fuel cell manufacturers now believe that the best way to explore the automobile market is to first build the necessary fuel cell production infrastructure and economies of scale by selling the devices in a smaller but less challenger-resistant market. In the article, business experts said that the first market would probably be electrical power generation. However, from a business perspective, there is a large difference between both applications, which is the issue of cost. The higher relative cost is considered to be acceptable in the stationary fuel cell market, because the unit cost ($/kW) of the conventional power generation is about $1,000/kW, which is about six times as much as the cost of automobile engines as shown in Table 4-2 [27].

Table 4-2 Target unit cost comparison among applications

Markets	Unit Cost ($/kW)
Aerospace	30,000
R&D Equipment	20,000
Military	3,000 – 7,000
Utility power generation	2,000 – 5,000
Commercial power generation	***1,000 – 2,000***
Automotive Consumer	50 – 150

(Reference: Fuel Cell Dynamics 2002)

However, interviews for this research show that, along with fuel cell developers, fuel suppliers also clearly recognize different requirements in durability for stationary fuel cells and fuel cell vehicles as is shown in Table 4-3[27,32]. This table shows that overcoming the durability hurdle is as important as achieving the cost target for the commercialization of stationary fuel cells. In other words, that requirement that stationary fuel cells will have to have much better durability than fuel cell vehicles for the commercialization is a significant challenge.

Table 4-3 Required durability and cost in stationary fuel cells and fuel cell vehicles

	Durability (hour)	Cost ($/kW)
Stationary fuel cells	40,000 (5 year continuous operation)	1,000 – 2,000
Fuel cell vehicles	5,000 (300,000mile) *Based on 60mile /hour	50 –150

(Conclusion)

Based on the results of the interviews, it appears that the first market for fuel cell technology is likely to be in the power generation market. However, the commercialization of stationary fuel cells may not always be necessary for the mass production of fuel cell vehicles for the following two reasons. First, the market for stationary fuel cells is a niche market for effective mass production. Second, each application of fuel cell technology is thought to have different required performance. Therefore, it may be more appropriate for both applications to work together to enlarge the size of the fuel cell market

4.2 Disruptive Technology

Question 4

"Do you think the stationary fuel cell could be a disruptive technology for the electricity industry in 2010?"

(Results)

Figure 4-2 presents the possibility that stationary fuel cells could be a disruptive technology in 2010.

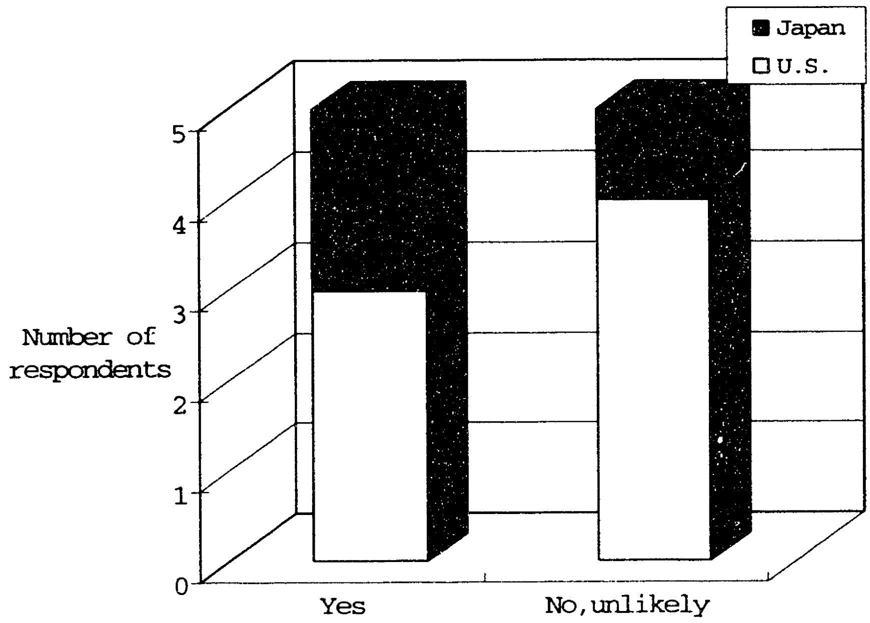


Figure 4-2 The possibility that stationary fuel cells could be a disruptive technology in 2010

(Analysis)

Figure4-2 shows that half of the interviewees believe it is possible that stationary fuel cells could become a disruptive technology in 2010, while the other half believe that not to be the case. The reasons given for why stationary fuel cells might not become a disruptive technology in 2010 are common to both Japanese and U.S. industry. Both industries believe that limited market size will prevent stationary fuel cells from being mass-produced and will, therefore, prevent cost reduction. Interestingly, the reasons given for why the stationary fuel cells could become a disruptive technology vary between the two countries industries.

Table 4-4 Representative opinions about disruptive technology

	U.S.	Japan	Representative opinions (reasons)
Yes	3	2	• Security reasons for the protection from terrorists • External factors (Major oil disruption and global warming) • Market will expand in the developing countries. o It can be after the mass-production of fuel cell vehicles. o Deregulations in electricity retail market will give the consumers two choices to buy electricity or to produce electricity by themselves from gas.
Unlikely	4	1	• Limited installed equipment and service network • High cost, market uptake, incumbent technology and utility disruption • On-grid management • Monopoly of electric industry o Small market size (Limited mass-production)

As a reason for the fuel cell to become disruptive technology the U.S. industry expects mainly external factors such as energy security reasons, global warming and market growth in developing countries, which comes from outside of the industry or from international affairs. On the other hand, Japan expects internal factors such as mass-production of fuel cell vehicles in the automobile industry and deregulation in the retail electricity market, which can be achieved by self-effort of the industry itself.

The most common opinion regarding the current Japanese energy market was that stationary fuel cells could give consumers the alternative to produce electricity from other energy resources themselves. This means that consumers can compare the price gap between the retail price of electricity and that of gas. It is generally agreed that the price of electricity is much more expensive in Japan than in other countries. However, stationary fuel cells allow consumers to make a simple comparison between the price of electricity and the price of producing electricity by other energy resources such as gas and residential oil. According to Clayton M. Christensen, the author of "The Innovator's Dilemma," the simplification process can be one of the most important factors for the technology to become disruptive.

However, it will be difficult for stationary fuel cells to be a disruptive technology in terms of Christensen's definition of a disruptive technology. Christensen argues that a disruptive technology usually comes from simplicity, low initial price and low quality. Stationary fuel cells, however, do not meet any of these conditions, and are in fact the exact opposite. For example, maintenance for stationary fuel cells is necessary and expensive installment costs are also required, which is unlike just buying electricity from electric companies. Consequently, stationary fuel cells are at a disadvantage in terms of simplicity and price to conventional power. In terms of the quality of electricity, it depends on the country.

There is some data that suggests that in Japan power quality is superior to that in the U.S. In 1996, the annual power outage time per customer in Japan was six minutes on average; in Florida it was 123 minutes, and in California 73 minutes[33]. The Japanese electric industry has invested huge sums of money to ensure it can meet demand; in fact, the industry has over invested by constructing central power generation and preparing for an overestimated peak demand. So while the quality of electricity is very high in Japan, the price is higher in other developed countries such as the U.S. Therefore, there should be some demand in Japan by customers to produce electricity by themselves for their own use in order to cut costs, even if some maintenance is required. On the other hand, in the U.S., consumers have already experienced serious and frequent power outages and power cuts, not only in California but also Massachusetts, in recent years. For example, "after a wave of power cuts rolled through California in 2000, Dr. Scott Samuelsen, an engineering professor at the University of California in Irvine, and director of the National Fuel Cell Research Center, started receiving frantic telephone calls from all round the state. As the blackouts continued into early 2001, he logged nearly 1,000 calls from organizations interested in installing stationary fuel cells at their sites – in business parks, universities, hotels, schools, high-rise office blocks, apartment buildings or shopping malls" [31].This event shows that quite a few people in the U.S. are not satisfied with the quality of electricity supplied by electric companies through the power grid. Instead, they are looking for new devices to produce electricity by themselves so that they can protect themselves from frequent power outages. In that sense, they are seeking more reliable electricity. Interestingly, their need is the exact opposite to that of the Japanese consumer. It is worth paying attention to the future trend in the quality of electricity in each country given Christensen's definitions.

(Conclusion)

Based on the interview research, the possibility that stationary fuel cells will be a disruptive technology in 2010 is estimated to be about fifty percent. In the U.S., external factors such as energy security issues, global warming and market needs in developing countries for distribution generation may cause stationary fuel cells to be a disruptive technology in 2010, while in Japan internal factors such as the mass production of fuel cell vehicles by Japanese automakers and deregulation in the retail electricity market may cause stationary fuel cells to become a disruptive technology in 2010.

4.3 Dominant Design

Question 5

"Do you think an industry-wide dominant design could be effective for your company to reduce fuel cell system cost?"

(Results)

Figure 4-3 presents the effectiveness of Dominant Design for the cost reduction of stationary fuel cells.

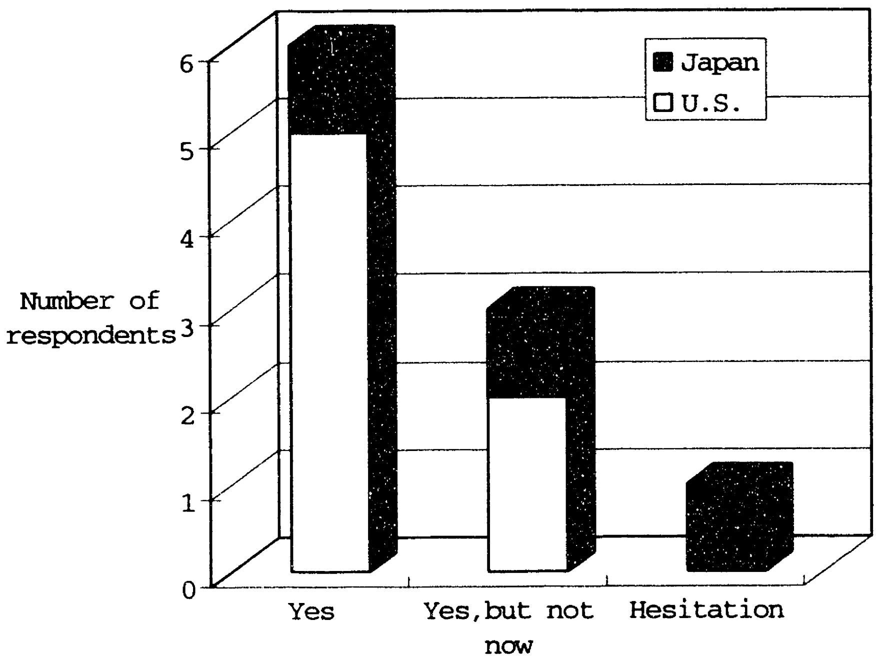


Figure 4-3 Effectiveness of Dominant Design for the cost reduction of stationary fuel cells

(Analysis)

As shown Figure 4-3, almost all the U.S. interviewees agreed on setting a dominant design for the commercialization of stationary fuel cells sooner or later, while two companies expect a dominant design to emerge within 5- 10 years. These companies appear to be leading companies not only in the technology but in marketing. They have already started quite a number of field tests for residential use. Nonetheless, they feel the necessity to pursue the more advanced technology and predict the emergence of a dominant design within 5-10 years. In other words, they consider current technology to be still developing.

Table 4-5 Representative opinions about Dominant Design

	U.S.	Japan	Representative opinions (reasons)
Yes	5	1	• Government should get involved more with standard design. • Necessary for the enough volume (mass production) o Strategic standardization is so important that Japan started setting the standard method for product performance and durability instead of standard design.
Yes, but not now	2	1	• Both applications should work together for the market size. o To some extent standardization is necessary like Balance of plant. But early standardization prevents the further development.
Hesitation	0	1	o At this moment it is not effective. We need future breakthrough.

Table 4-5 shows the representative opinions regarding the effectiveness of Dominant Design for cost reduction. Local governments in the U.S. think about facilitating the standard design for stationary fuel cell industry. This movement is consistent with the three US fuel cell developers' comments that they expect a dominant design for reducing the cost by mass production. Moreover, a leading fuel cell developer responded that a dominant design will be realized if other companies agree on the design. It appears that they are very confident in their current technology, which they believe is close to being considered a dominant design by the market. Although there is slightly different opinion in terms of Dominant Design in the stationary fuel cell industry in the U.S., the general view is that a dominant design will emerge.

The number of stationary fuel cell developers in the U.S has been increasingly rapidly since 1990 as shown in Figure4-4. According to Professor Utterback, who invented the concept "Dominant Design", there is weak symptom in this figure that a dominant design will emerge in the future because the total number of fuel cell manufacturers has been decreasing over the past two years. However, a greater possibility is that, based on his intensive research in other industries such as the automobile, semiconductor and typewriter industries, it will be several years after the technological development in this industry that a dominant design will emerge.

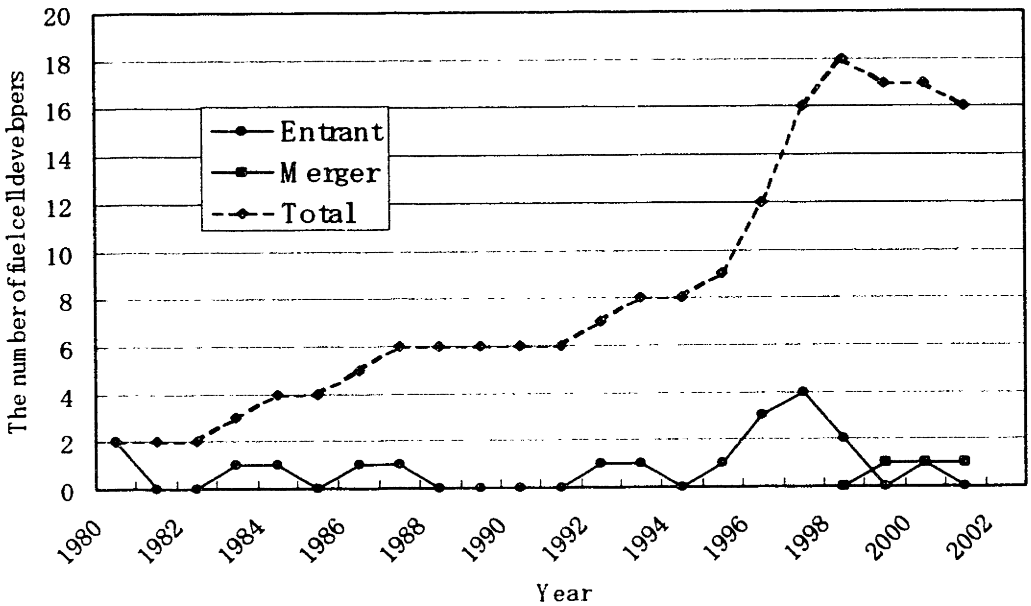


Figure 4-4 The growing number of fuel cell developers in the U.S.

In Japan, there are three separate opinions regarding dominant design. Instead of considering dominant design in fuel cells, respondents mentioned peripheral dominant design (standardization) for balance of plant as well as the methods to fairly evaluate product performance and durability. Even if there is to be a dominant design in the future they emphasized the need for further technology development and breakthroughs. The Japanese respondents are still not satisfied with the performance of current and available fuel cell products. Moreover, the government is trying to help establish a standardized method for private companies to evaluate their products fairly. In Japan, companies do not appear to be only concerned with dominant design. Instead, at this stage, they appear to be emphasizing product performance improvement. It appears that they don't expect a dominant design, for example, as is the case in the automobile industry. There is a particular Japanese method of continuously improving technology, known as "Kaizen" in Japanese. Once a dominant design is determined between the government and private companies, it is quite difficult to change the design and compete against one another. Therefore, in Japan, companies are more reluctant to set a dominant design for further product improvement.

The interview data shows that the current situation of the stationary industries in the U.S. and Japan may be slightly different, as shown in Figure 5-5, where the present situation of the stationary fuel cell industry is applied to the dynamics of innovation model created by Utterback. In Japan, all interviewees insisted that further technology development is still necessary for the stationary fuel cell industry. In other words, they are still close to the top of the product innovation curve. On the other hand, in the U.S., at least three out of seven interviewees responded that standardization would make mass production possible because of cost reductions, which implies that they see a possibility for process innovation for fuel cell products. This may imply that the stationary fuel cell industry in the U.S. is gearing up for mass production in the near future.

(Conclusion)

In the U.S., the stationary fuel cell industry seems to expect that a Dominant Design will emerge sooner or later in order to reduce the fuel cell cost. According to Figure 4-4 and considering Utterback's predictions, it is likely that it will take several years after technology competition among the companies has begun for a dominant design in the stationary fuel cell industry to emerge spontaneously. Another possibility is that increased government involvement in the industry may help accelerate the establishment of a strategic standard design after agreement is reached within the industry. In Japan, companies are reluctant to set a standard design for the core components of fuel cells. They seem to favor competition and technology breakthroughs as a means to improve product performance. The government has tried to set a standard measure to evaluate the product performance for the companies in the fuel cell industry.

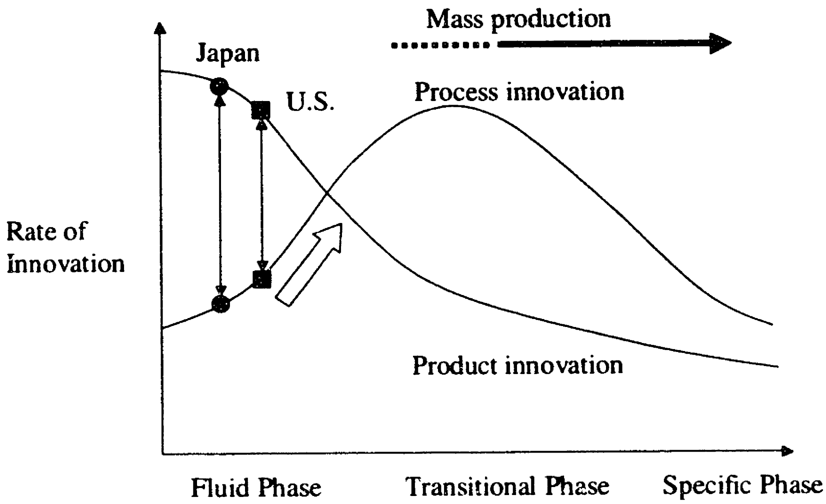


Figure 4-5 The current phase of stationary fuel cell industry

4.4 Largest technology barriers

Question8-2

"What are the largest barriers for stationary fuel cell technology and business development from the viewpoint of your company?"

(Results)

Figure 4-6 shows the largest technology barriers in the stationary fuel cells industry in the U.S. and Japan according to the interviewees responses. Comments about the the largest technology barriers are presented in Table 4-6.

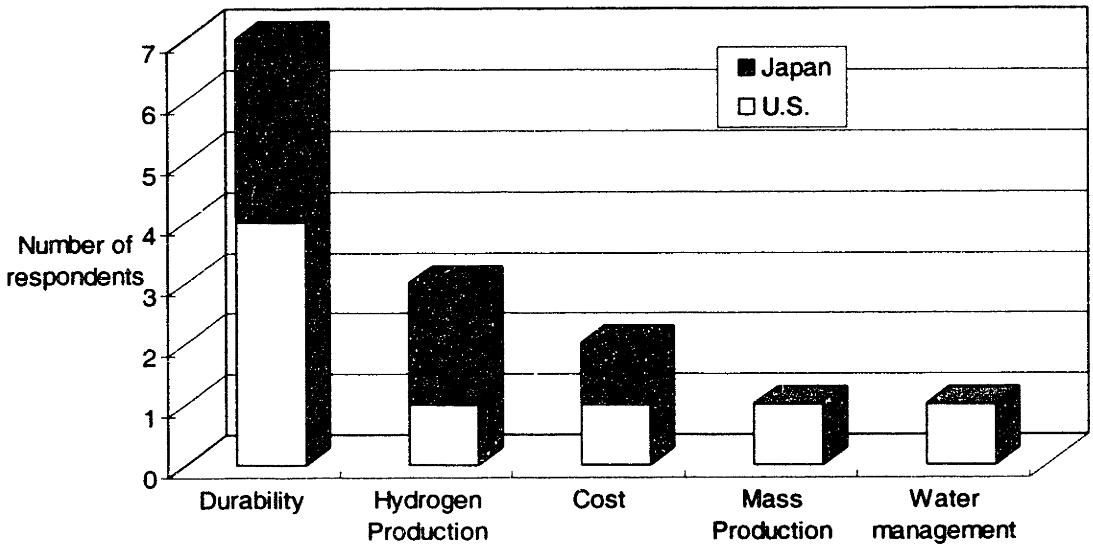


Figure 4-6 Largest technology barriers in the stationary fuel cell industry

Table 4-6 Representative opinions in terms of technology barriers

	U.S.	Japan	Representative opinions (reasons)
Durability	4	3	• Few product with enough durability • Membrane robustness o Reforming catalysts (at least 10 years).
Hydrogen Production	1	2	• Efficient hydrogen supply and delivery (Infrastructure issue) o Reforming process from oil to hydrogen
Cost	1	1	• Cost competitiveness to incumbent technology.
Mass production	1	0	• According to the hearing from the stationary fuel cell industry, only technological barrier is mass production.
Water management	1	0	--

(Analysis)

Seven of the interviewees responded that durability is the largest technology barrier to the commercialization of stationary fuel cells. As shown in Table 4-6, the respondents are not satisfied with the present durability of the fuel stack, its components and the reforming catalysts. In terms of durability, there is little published data on fuel cell stacks and reforming catalysts, as is shown in Table 4-7. According to the proceedings of the 2002 spring national meeting of the American Institute of Chemical Engineering, the best operating lifetime that has been reported for a PEM type of fuel cell stack is about 5,000 hours while the minimum operating lifetime required would have to be at least 40,000 hours. Moreover, the only commercial PEM type of product made by Ballard has a warranted lifetime of only 1,500 hours and then only if high-purity hydrogen is utilized. Current and near-term fuel cell technology capabilities are considered insufficient for the product requirements for stationary fuel cells. Nuvera has published data for durability performance for its reforming catalysts, which have been developed as a project that has been subsidized by the Department of Energy for several years, used to produce hydrogen from fuels such as natural gas and oil [34]

As in the case of fuel cell stack durability, the durability of reforming catalysts is so limited that further improvements are necessary to significantly extend durability. This limited durability in both fuel cell stacks and reforming catalysts is the most important factor hindering PEM type stationary fuel cells from easily entering the distribution generation market at the initial stage. Therefore, durability is the first and largest hurdle that should be overcome in order to achieve cost targets and to the need for frequent maintenance. In the near term, however, the developing fuel cell technology can be applied to backup power systems for residential and commercial markets, uninterruptible power supplies, fuel cell buses and portable power systems for recreational activities, all of which don't require long durability for their use. Three interviewees responded that efficient hydrogen production and distribution is the largest technology barrier.

(Conclusion)

Based on the interview research, the highest hurdle in the path of developing the technology of stationary fuel cells is the durability of the fuel cell stack and reforming catalysts. This durability is currently so limited that it seems likely that, without a significant breakthrough in technology, it will at least several years before a lifetime durability of 40,000 hours is achieved.

Table 4-7 Durability and application of fuel cells

	Present durability (hours)	Target (hours)
Fuel Cell Stack (Made by Ballard)	1,500 – 5,000	40,000
Reforming Catalyst (Developed by Nuvera)	2,000	40,000
Application	• Back up power	• Stationary fuel cells, • Fuel cell vehicles • Back up power

4.5 Present perspective from the stationary fuel cell industry

Based on the interviewees responses on the questions regarding technology transfer from stationary to fuel cell vehicles, disruptive technology, dominant design and technology largest barriers, the future predicted technology development of stationary fuel cells and fuel cell vehicles in the U.S. and Japan was constructed, as shown in Figures 4-7 and 4-8. The problem of durability, which is hampering further business development of stationary fuel cells, is common to both Japan and the U.S. Solving this problem must be the first priority for companies in both countries attempting to enter the stationary fuel cell market.

On the other hand, there appear to be three different stances in the stationary fuel cell industry between the U.S. and Japan. The first difference, which is large, is that the Japanese automobile industry is totally independent from the Japanese stationary fuel cell industry in terms of not only technology but also business development, while in the U.S. most leading fuel cell developers have stationary fuel cell and transportation divisions, in addition to having various alliances with automobile companies like the well-known relationship between Ballard and DaimlerChrysler. The second difference is that the stationary fuel cell industry in the U.S. is expecting the emergence of a dominant design sooner or later, whereas in Japan, companies would like to have standard measures to evaluate product performance fairly rather than a dominant design. This stance may be partly due to Japan's inherent ability at improving the product performance through the well-known concept "Kaizen" used by Japanese manufacturers. The third difference is that the stationary fuel cell industry in the U.S. expects external factors such as energy security and global warming to help realize stationary fuel cells as a disruptive technology, whereas in Japan internal factors such as deregulation in the retail electricity market and the mass production of fuel cell vehicles by the automobile industry are considered more likely to transform fuel cell technology into a disruptive technology.

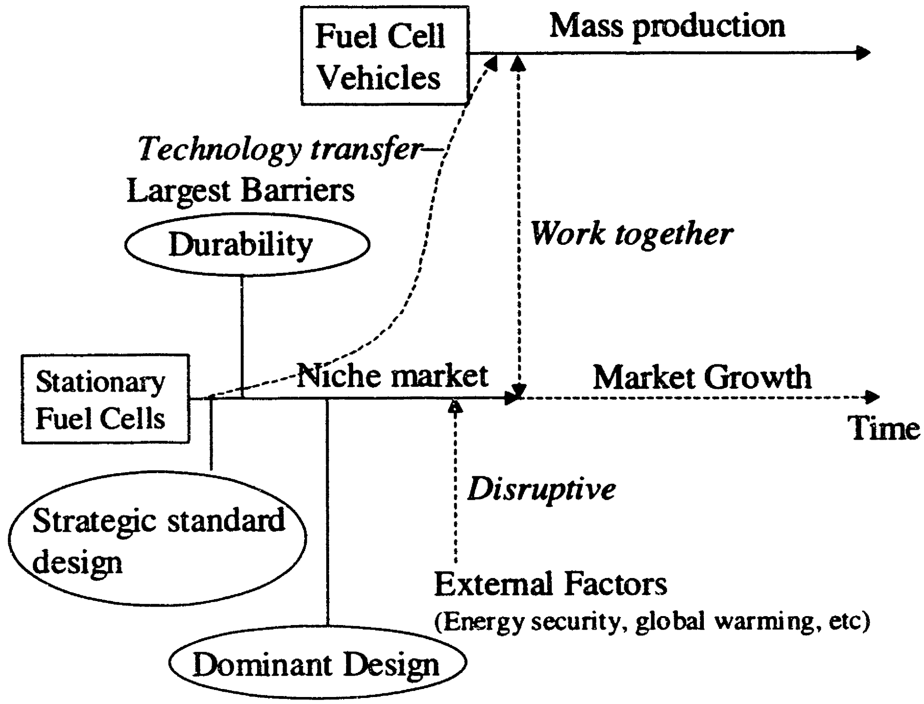


Figure4-7 Predicted Technology Development in the U.S.

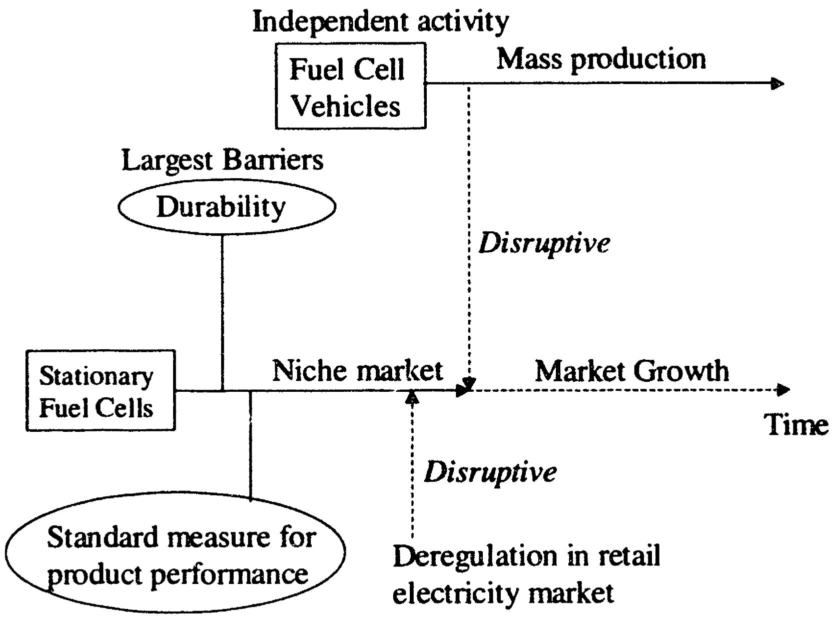


Figure4-8 Predicted Technology Development in Japan

5. Extended Enterprise in the Stationary Fuel Cell Industry

5.1 Present Enterprise Model in the Current Stationary Fuel Cell Industry

Question 6

"In your opinion, which model in Figure 5.1 best represents the current state of the stationary fuel cell industry?"

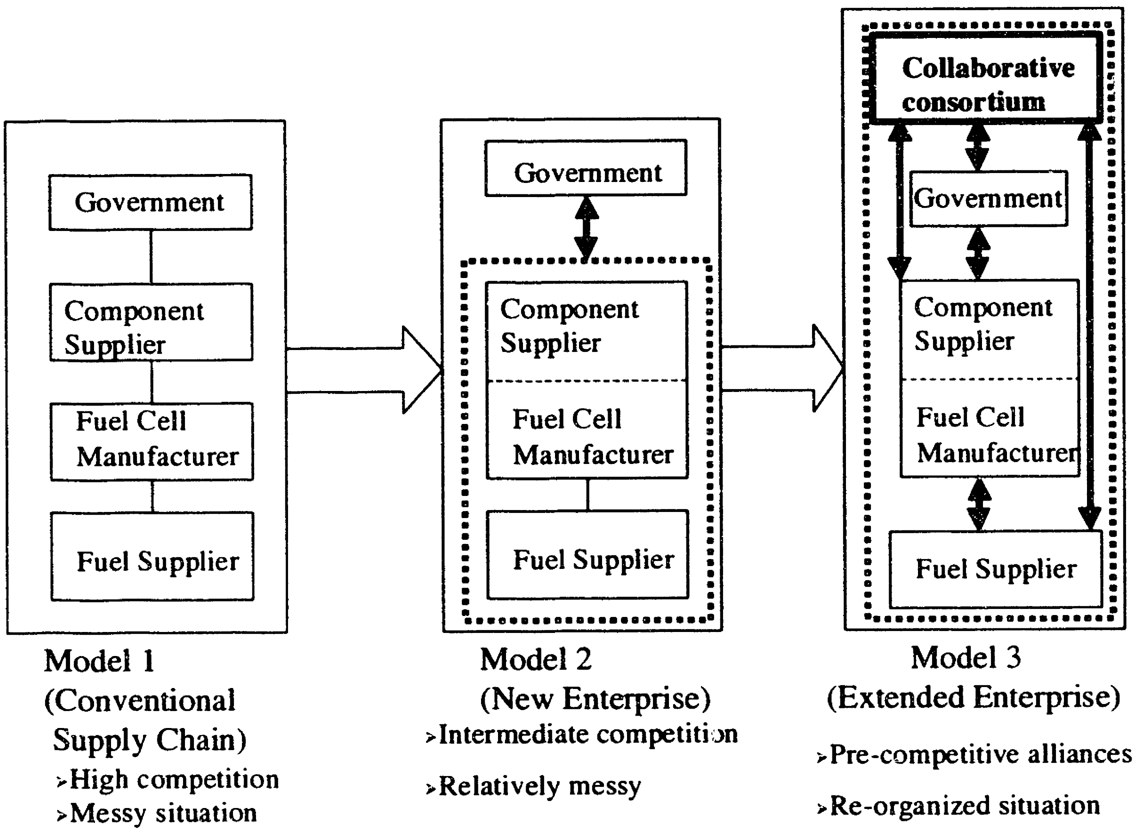


Figure 5-1 Possible Evolution of the Enterprise Style

Figure 5-1 shows the theoretical evolution model of enterprise that is applied to the current stationary fuel cell industry. Model 1 shows that each player in the industry is connected through a conventional supply chain. Model 2 represents the various enterprises, which includes those participants that have formed partnerships. Model 3 represents the ultimate situation where the model has completely evolved. In this case, both companies and the government, through pre-competitive alliances and active cooperation, can accelerate their business and technology development.

(Results)

Figure 5-2 summarizes the U.S. and Japanese respondents' perceptions of the current stationary fuel cell industry. A summary of representative comments is presented in Table 5-1.

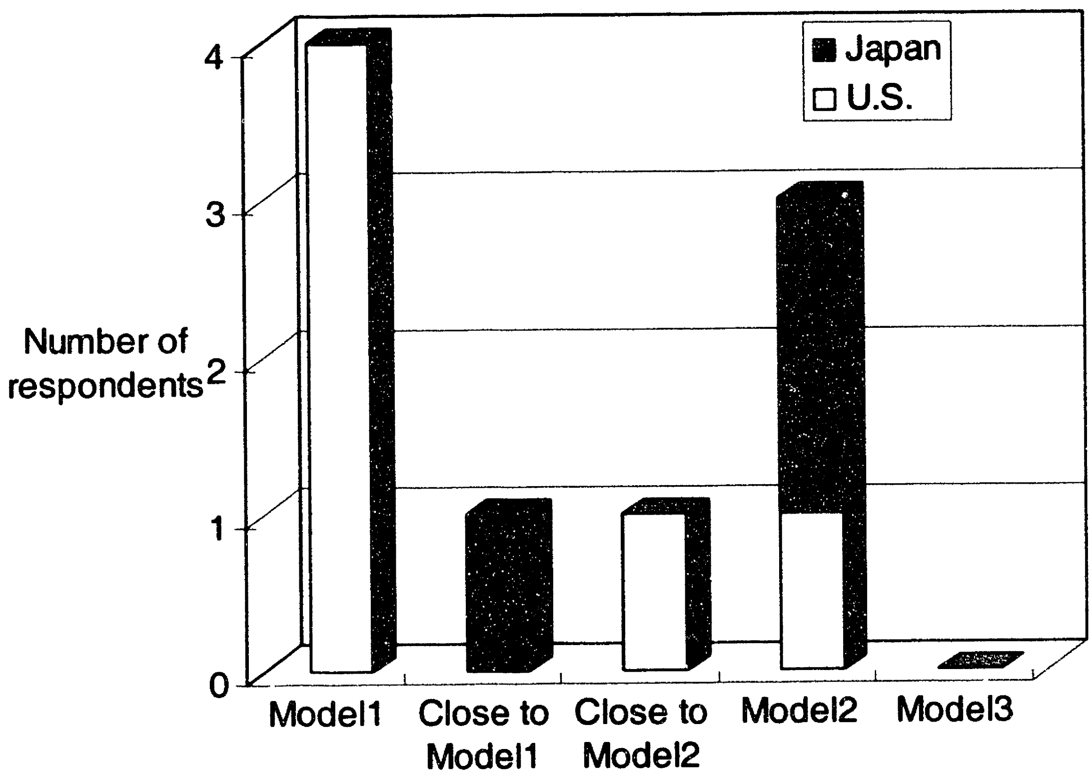


Figure 5-2 Current models in the stationary fuel cell industry

Table 5-1 Representative opinions about current model in stationary fuel cell industry

	U.S.	Japan	Representative opinions (reasons)
Model 1	4	0	• Messy situation • Model 3 is a target model.
Close to Model 1	0	1	o Japanese automobile industry is far from this model.
Close to Model 2	1	0	• Fuel suppliers and component maker is not in this model at his moment.
Model 2	1	2	o Except the automotive companies the stationary fuel cell industry in Japan is in model2.
Model 3	0	0	---

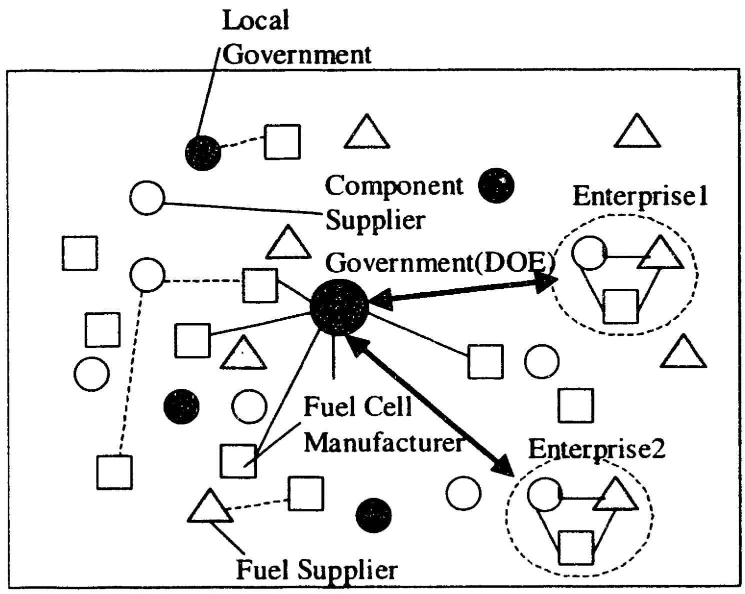
(Analysis)

Figure 5-2 shows that seven interviewees believe the current state of the stationary fuel cell industry is best represented by Model 1 while four companies believe it is best represented by Model 2. No company believes that the current stationary fuel cell industry is represented by Model 3. Three interviewees agreed that Model 3 is the ideal situation for the future stationary fuel cell industry. The reality of the current state, however, is that it is still in a chaotic and disorganized situation that is represented somewhere between Model 1 and Model 2. Based on Figure 4-4, which shows the growing number of new entrants in the stationary fuel cell industry in the U.S, it seems reasonable to assume that the situation will continue in the near future. One fuel cell developer mentioned that the best case example, that of General Motors, is very close to Model 2, because the company has built a good relationship with the federal government as well as with fuel cell component suppliers such as Hydrogenics and QUANTUM

Technologies; also, they have an internal development program. The same respondent believes expects so see an evolution from Model 1 to Model 3 in the stationary fuel cell industry in the future. Interestingly, two interviewees said that the automobile industry in Japan does not correspond with this evolutionary model. Instead, the Japanese automobile industry is independently developing fuel cell products to avoid government and other industry interference.

(Conclusion)

The current state of the stationary fuel cell industry in the U.S. and Japan, based on an analysis of the interview data, is shown in Figure 5-3. The current stationary fuel cell industry in both countries is still in a chaotic situation and is still in the early stages of development. Most companies are still looking for good business and technology partners for their future business. Also, it is possible that some new entrants may enter the industry in near term. Moreover, most companies expect the transition from Model 1 to Model 3 in the U.S. In Japan, however, the automobile industry is not developing along the lines proposed by this evolutionary model but is independently developing fuel cell products.



Present situation

Mixed situation between Model 1 and Model 2
(Conventional Supply Chain & New Enterprise)

- High competition
- Messy situation
- No dominant design
- Insufficient partnership

Figure 5-3 The current stationary fuel cell industry situation

5.2 Present Partnership

Question 7

"Are your company's current partnerships sufficiently successful to ensure the commercialization of your company's fuel cell technology?"

(Results)

Figure 5-4 presents the respondents' level of satisfaction with current the partnership in the stationary fuel cell industry in the U.S. and Japan. Table 5-2 presents representative comments about current partnerships.

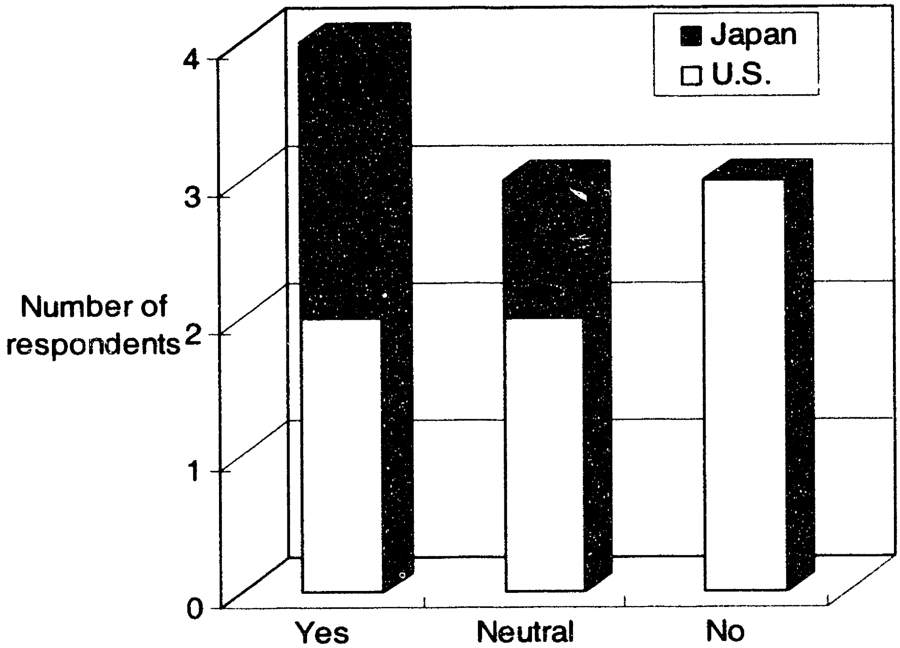


Figure 5-4 Current satisfaction with partnerships

As shown in Figure 5-4, there are three separate opinions about current partnerships. The U.S. fuel cell developers who answered, "Yes" have already started several field tests for specific customers. These respondents generally expect that their partnerships can s significantly accelerate the commercialization of the stationary fuel cell industry. In Japan, those companies responding with positive answers appear to have good partnerships not only with foreign manufacturers such as DaimlerChrysler and Ballard but also with domestic manufacturers in Japan. These partnerships allow them to combine their reforming process with their partner's fuel cell stack. Those respondents who gave neutral answers believe that it is too early to determine whether the partnerships will be successful in promoting the commercialization of the stationary fuell cell industry. Those companies that answered " No" are not satisfied that commercialization and market access will ensue even if they built partnerships with specific companies. It also appears that local governments in the U.S. are urging companies to form partnerships to encourage early commercialization that would help local regions meet local demand for a reliable power supply and less pollution.

Table 5-2 Representative opinions about present satisfaction in partnerships

	U.S.	Japan	Representative opinions (reasons)
Yes	2	2	• Partnership will accelerate the fuel cell business. ◦ 100% satisfactory. Fuel cell suppliers need to ally with manufacturers for their business.
Neutral	1	1	• Some partnerships are successful but perhaps not sufficiently so to promote commercialization. ◦ With the exception of recent contracts with Ballard, there are no partnerships.
No	3	0	• More consolidation is necessary under government cooperation. • The commercial relationship with an industrial gas supplier is not significant yet. • It may not be sufficient, but it's too early to say.

(Conclusion)

In the U.S., partnerships may be an essential factor for commercial success in the stationary fuel cell industry because companies that have already commenced field tests appear to be generally satisfied with their partnerships. On the other hand, the three companies that are not satisfied with their current partnerships say that the relationship with their current partners is not sufficient to promote commercialization. In Japan, as a whole, companies appear to be satisfied with their current partnerships because they have found adequate fuel cell manufacturers to combine their reforming processes with the fuel cell stack produced by the manufacturers.

5.3 Benefits of a Public-private Consortium

Question 9

"What is the most significant benefit of public-private partnerships, such as PNGV and Freedom CAR, for the commercialization of your company's fuel cell technology?

(Results)

Figure 5-5 presents the benefits of public-private partnerships in the stationary fuel cell industry in the U.S. and Japan based on the interview research. Table 5-3 describes the representative comments about the benefits of public-private partnership presented in Figure 5-5.

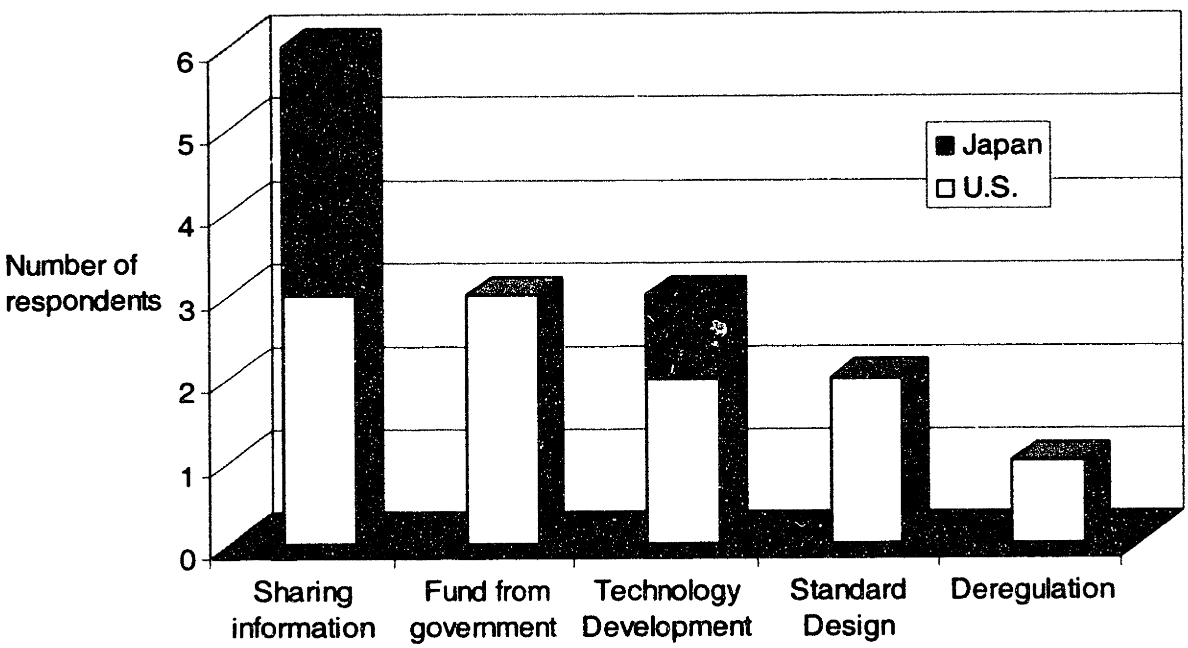


Figure 5-5 Benefits of public-private partnerships

Table 5-3 Representative opinions about the benefits of public-private partnership

	U.S.	Japan	Representative opinions (reasons)
Sharing information	3	3	• More dialogue is possible between large companies and small companies • Government can study the technology. ◦ Fuel Cell Commercialization Conference is useful to share the information.
Fund from government	3	0	• Increase the government fund
Technology Development	2	1	• Close the technology gap and develop the enabling the technology. ◦ Improve the efficiency in R&D by sharing the experiences.
Standard design	2	0	• Useful for the standard fuel for fuel cells
Deregulation	1	0	• Opportunity to discuss regulatory issues

(Analysis)

As shown in Figure 5-5, the largest benefits of public-private partnerships are the sharing of information among participants in the stationary fuel cell industry. As shown in Table 5-3, one interviewee from an U.S. fuel cell developer insisted that partnerships encourage more dialogue between large companies and small companies. Usually it is difficult for small companies to have dialogue with large companies. However, frequent communication in a public–private partnership makes it possible to combine the best innovation from small companies with significant utilization (market and fund) from large companies. Another opinion was that public-partnerships allow the government to carefully study the latest technology and other relevant issues. They also allow the government to recognize what kind of R&D is worth funding and what kind of regulatory issues should be discussed. The same opinions about the public-private partnerships were held by the Japanese respondents. The only point of difference was that Japanese industry participants are already satisfied with the existing style of collaboration, involving only private companies, which is called the Fuel Cell Commercialization Conference in Japan (FCCJ) where representatives from each company in the stationary fuel cell industry regularly meet to discuss the latest business and technology issues. However, in this case, the Japanese government is not involved with the conference. The conference also doesn't provide funds for each company to allow research into common technology problems. Instead, the conference is created by the fuel cell industry so that they can share information on common issues through small working group discussions and at the same time respect each other's independent activity for the further technology and business development. The companies in the stationary fuel cell industry in Japan seem to feel more comfortable with a FCCJ style partnership than a public-private partnership. In the U.S., government funds play an important role, particularly for fuel cell developers, in public-private partnerships. Figure 5-6 shows the financial situation between 1998 and 2000 for fuel cell developers, including Ballard, PlugPower and Proton Energy System who were interviewed for this thesis[3,4,7,8]. While the revenue of these companies has been almost constant for the past three years, the extent of their losses has been accelerating yearly. This is especially apparent in the case of PlugPower, which posted a loss of more than 8 times its annual revenue in 2000. Ballard, the world's best-known developer of fuel cells, also posted a loss of twice its annual revenue in 2000. Figure 5-7 shows the R&D expenses for each fuel cell developer for the past three years as well as the U.S. Department of Energy's annual budget in stationary fuel cell research and development. Over the past three years, fuel cell developers rapidly increased their R&D investment[3,4,7,8]. In 2000, particularly, PlugPower increased its previous year's budge for R&D by about $ 45.4 million. The increase of $45.4 million was primarily attributable to the growth of their research and development activities, which included a 60% increase in the labor base to approximately 500 employees and 113 test and evaluation residential PEM fuel cell systems[4]. Because of their financial situation, fuel cell developers are demanding government funds to contribute towards product development. In addition, comparing Figures 5-6 and 5-7, it is clear that most of the annual losses of each fuel cell developer are due to R&D expenses rather than operational expenses.

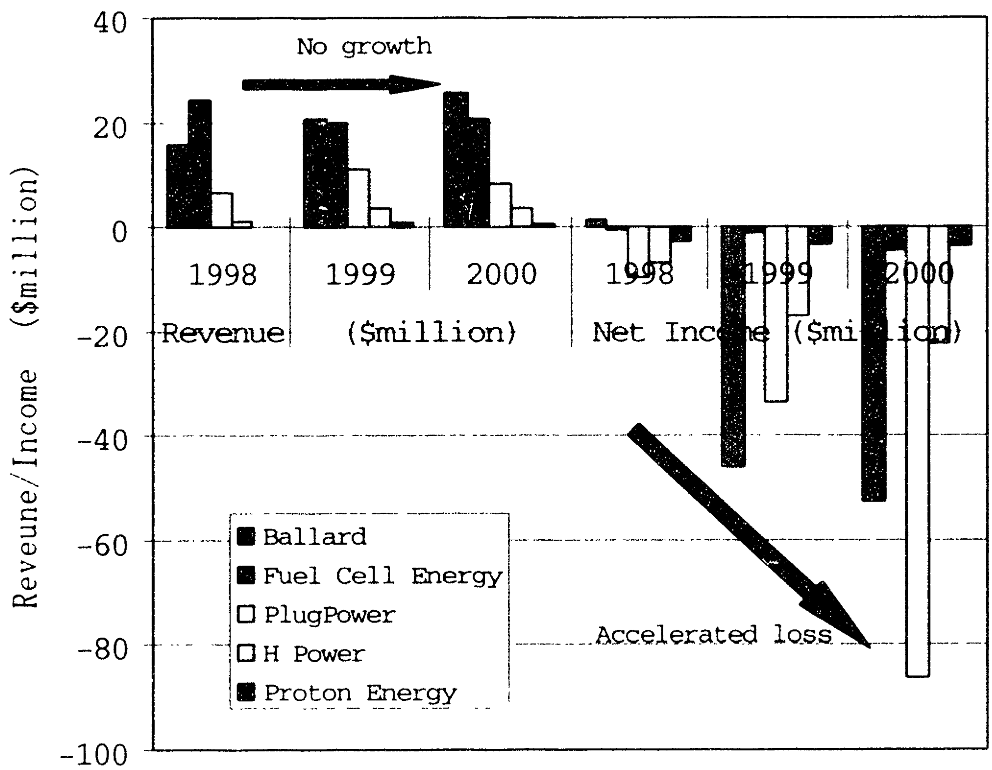


Figure 5-6 Financial situation of representative fuel cell developers

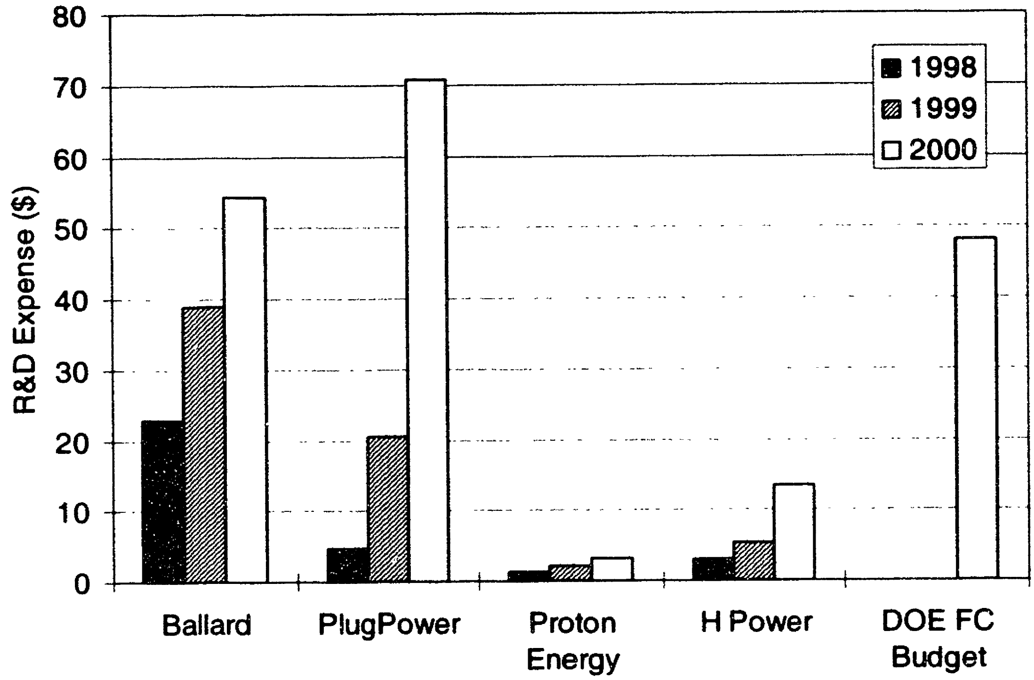


Figure 5- 7 R&D Expenses for U.S. Fuel Cell developers

On the other hand, in Japan, where both interviewed fuel suppliers are large companies with respective annual sales $33billion, $9billion[35,36], the companies didn't have as strong a need R&D funds as the fuel cell developers in the U.S., even if the fuel suppliers are spending a large amount of their internal R&D funds in their original hydrogen production processes. Interestingly, interviews revealed that automobile companies have no government funds whatsoever for conducting R&D for fuel cell products. The government respects their position to the extent that it tries to refrain from interrupting fuel cell R&D in the automobile industry.

It is interesting that one U.S. respondent was of the opinion that public-private partnerships could help close the technology gap between the current technology and the target technology in addition to increasing R&D efficiency. This is the one of the important functions that public–private partnership can have towards solving current technology problems and accelerating the commercialization of fuel cells.

(Conclusion)

Based on Figure 5-3 and Table 5-3 and on interview data, the benefits of public-private partnership are described, as shown in Figure 5-7. In the U.S., fuel cell developers that need R&D funds want to have a common forum so that they can communicate easily and regularly with the government and large companies in order to help obtain government R&D funding in addition to helping selling the innovative technology to large companies. From the government's viewpoint, such as forum helps it understand the latest technology and regulatory issues. Large companies also benefits in that they can learn about innovative technologies from the fuel cell developers in addition to finding potential business partners that they can invest in.

In Japan, currently, the Fuel Cell Commercialization Conference consists only of private companies. Through this conference, companies in the fuel cell industry can share the latest information and knowledge about technology and business; they may also feel more comfortable than when the government gets involved with the conference. There doesn't appear to be much demand from the industry for a public-private consortium in Japan.

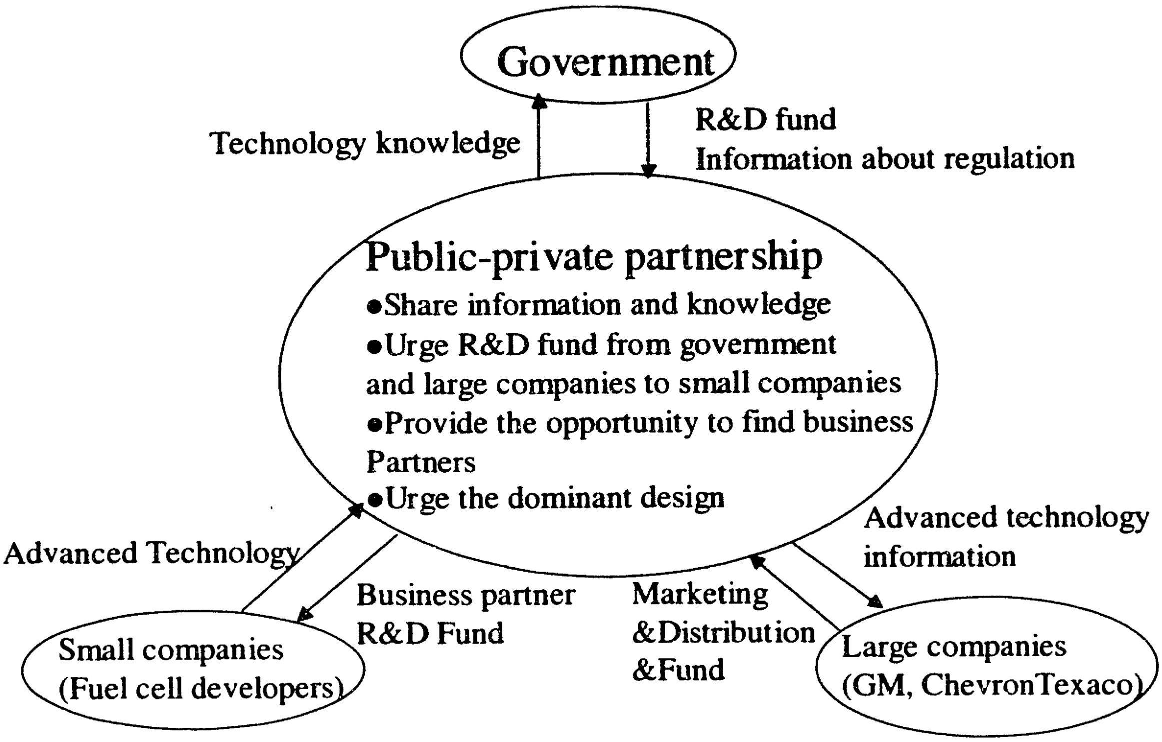


Figure5-8 Benefits of public-private partnerships in the stationary fuel cell industry

5.4 Super Collaborative Consortium

Question 10

"Are super-collaborative consortiums, such as Sematech, enabling the stationary fuel cell industry to accelerate product cost reductions and technology reliability? Please explain your reasoning in the context of the current situation of the fuel cell industry situation"

(Results)

Figure 5- 9 shows the results of whether the companies agree that a public-private consortium can help accelerate product reliability and cost reductions for the early commercialization of stationary fuel cells.

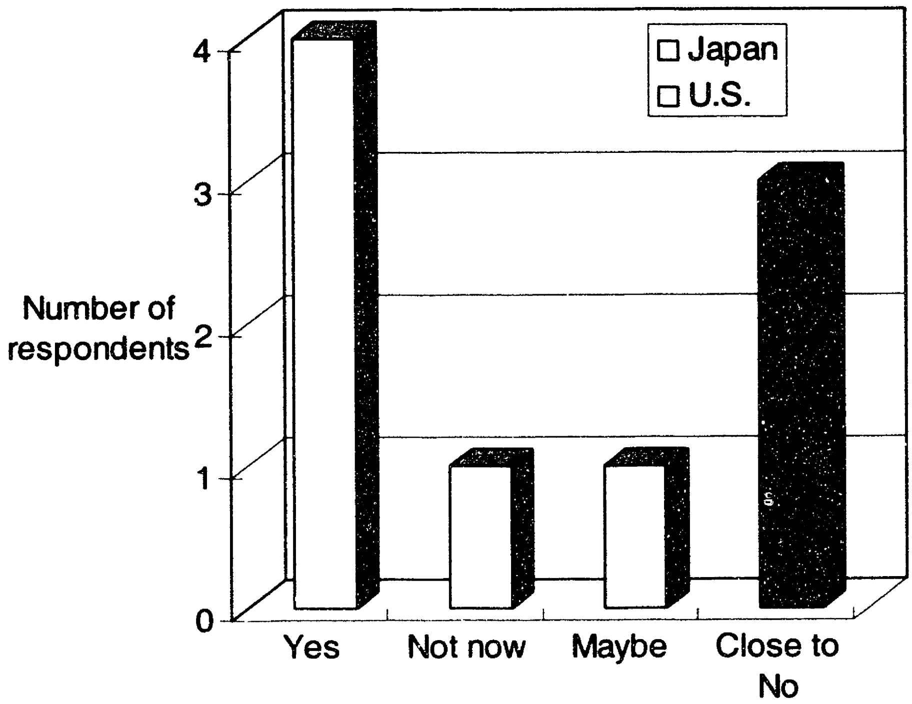


Figure 5-9 The public-private consortium in the stationary fuel cell industry

(Analysis)

There is an obvious difference in the results between U.S. and Japanese opinions. In the U.S., companies basically agree on the necessity of a public–private consortium sooner or later. According to Table 5- 4, which descries the representative comments about the public-private consortium, four interviewees agreed that a super collaborative consortium could help share costs and accelerate cost reductions. One fuel cell developer wants the government to increase R&D budget through the consortium. The same respondent also said that a consortium would be useful for sharing intellectual property and know-how among companies. Within the industry, there were also two different comments in the

U.S. One fuel cell developer's CEO insisted that it is too early for a consortium and that technology should remain independent until inventions have been made and an integrated market has developed. One interviewee from a leading fuel cell developer responded that while a consortium might be effective it would require a common industry vision.

Table 5-4 Representative comments about the public-private consortium

	U.S.	Japan	Representative opinions (reasons)
Yes	4	0	• Absolutely. It can contribute to the cost target and the increased volume. • I think so. It does help sharing the cost. • The government budget is too small for the R&D. o Through the consortium it should be more proactive and encourage the sharing the intellectual property and know-how.
Not now	1	0	• It is too early to create the consortium.
Maybe	1	0	• It depends on coming common visions.
Hesitation	0	3	o Basically private companies should compete with one another without the government's involvement. o It may accelerate or delay the product development.

On the other hand, in Japan companies have different perspectives from those in the U.S. They basically think the government should not get involved in the competition in business among private companies. The Japanese government basically believes that product development should be dependent on competition among private companies.

The government tries to encourage competition by introducing standard measures to evaluate the product performance fairly. One fuel supplier responded that a consortium might accelerate product reliability and cost reduction by three years but that equally it could also delay them by three years because of the fact that the consortium could possibly prevent technology breakthroughs that come from totally different ideas. He also mentioned this might happen only in Japan.

(Conclusion)

Based on the interview research in the stationary fuel cell industry in the U.S. and Japan, it is evident that a super collaborative consortium between the government and private companies is not necessarily an effective method of reducing costs and increasing product reliability. In the U.S., companies in the stationary fuel cell industry believe that a consortium will possibly work well for the early commercialization of stationary fuel cells, and they also expects that a consortium will emerge sooner or later. Figure 5-8 shows the possibility of a super-collaborative consortium accelerating stationary fuel cell commercialization in the U.S. On the other hand, in Japan, companies are reluctant to create a public-private consortium, because they are afraid that the consortium will prevent technology breakthroughs as well as competition among companies. Japanese companies would prefer to share their experiences and information through the FCCJ rather than through a consortium. The Japanese government will encourage competition between companies by setting standard measures to evaluate the product performance and will refrain from getting involved in the industry.

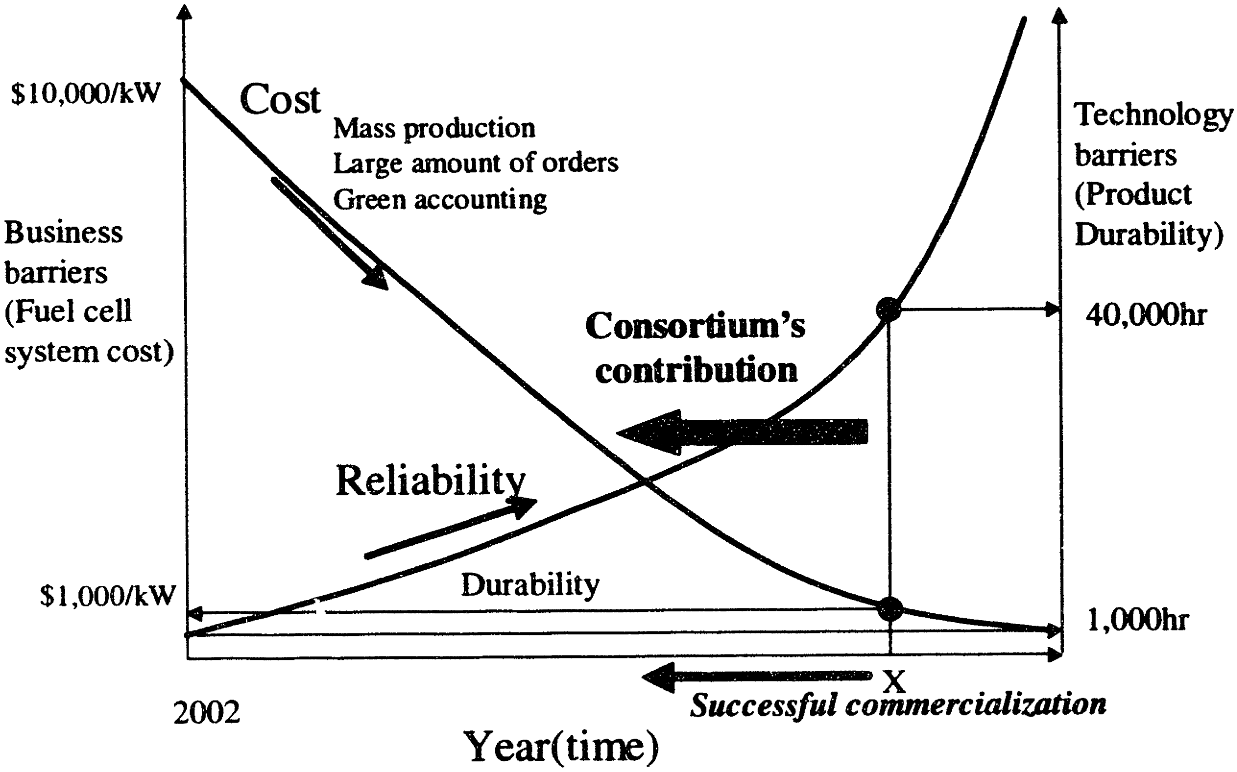


Figure 5-10 Consortium's contribution to accelerate the stationary fuel cell commercialization in the U.S.

5.5 Summary of Extended Enterprise

In Table 5-5, the extended enterprise in the stationary fuel cell industry in the U.S. and Japan are summarized. While there are some slight differences in terms of business situation between the U.S. and Japan, the largest difference in perception between both countries is the attitude towards the public-private consortium. The US fuel cell developers consider that a public-private consortium can be used to help obtain government funding, while in Japan both the government and the fuel suppliers maintain a certain distance between each other so that they can pursue technology breakthroughs through increased competition.

Table 5-5 Summary of extended enterprises

	U.S.	Japan
Present situation (Extended enterprise model)	Chaotic (Model 1 and2) - Expectation to Model 3	Relatively chaotic (Close to Model 2) - Little expectation to model3
Present partnership	Half –Satisfied Half - Dissatisfied	Relative satisfaction
Public-private partnership	Share the information Funds from the government	Share the information
Public–private Consortium	Basically agree. Not now (One opinion) Maybe (One opinion)	Hesitation They prefer a conference among only private companies.

6. Proposal for the Stationary Fuel Cell Industry

First, based on the interview data and the analysis in chapters 1 – 5, this paper creates a collaborative business model and long-term business development model for the stationary fuel cell industry in both the U.S. and Japan. Specific proposals for business development at every stage are then made based on the business models.

6.1 Proposal for the Stationary Fuel Cell Industry in the U.S.

Figure 6-1 shows a collaborative business model in the stationary fuel cell industry in the U.S. based on the current business environment as understood through the interview research. Figure 6-2 describes the long-term business development model for the early commercialization of the stationary fuel cell industry in the U.S.

(Proposal 1) – Starting point

As shown Figure 6-1, it is proposed that in the case of the U.S. a new collaborative consortium should be created by enlarging the public-private partnership Freedom CAR to the stationary fuel cell industry. The reasons for this are as follows:

- The stationary fuel cell industry wants a collaborative consortium

Based on the interview data in Figure 5-9, in general, the stationary fuel cell industry in the U.S. wants a public-private consortium to improve product reliability and reduce cost. Furthermore, in Figure 5-2 seven out of ten interviewees insisted that the commercialization of stationary fuel cells can be utilized for mass production or that both stationary and vehicle application in fuel cells should be worked together. The stationary fuel cell industry expects synergy effects from collaborating with the automobile industry.

- Freedom CAR will start in 2003.

This public-private partnership Freedom CAR can easily be utilized for synergy effects through the cooperation of the development of fuel cell vehicles and the development of stationary fuel cells in terms of common components such as fuel cell stacks and the reforming process for hydrogen. The concept of Freedom CAR with $1.5 billion to fund an eight-year project to develop the hydrogen economy of the future was recently announced in January 2002. Since Freedom CAR is a long-term strategic plan it allows the government to take into account the stationary fuel cell industry's participation in the Freedom CAR to bring about synergy effects and cooperation between the fuel cell vehicle manufacturers and the fuel cell developers that focus on stationary fuel cells.

- Various fuel cell programs in DOE

The Department of Energy has various kinds of fuel cell R&D budgets in 2003. Fuel Cell Industry Report in March says that there are six types of fund for fuel cell technology as shown in Table 6-1[37].

Table6-1 DOE's budget request about fuel cell development in 2003

		Budget request ($ million)
1	The Freedom CAR partnership	150
2	Fuel Cell Research	50
3	Hydrogen Program	39.9
4	Fuel cells in buildings	7.5
5	Fuel cells program of distributed power generation	49.5
6	Vision 21 program (Hybrid fuel cell/turbine engine system)	66.3
	Total	363.2

Therefore, in order for R&D for the PEM type of fuel cell to be efficient, the DOE can reorganize the various kinds of fuel cell programs to focus on only one program so that participating companies in the fuel cell program can share as much information and knowledge as possible through the new collaborative consortium. The above table shows the DOE's budget request for fuel cell development in 2003. Of the above six programs, Freedom CAR is organized by the Office of Transportation Technologies (OTT) while Fuel Cell Research, Fuel Cells in buildings and Hydrogen program are supported by the Office of Energy Efficiency and Renewable Energy (EERE). The Office of Fossil Energy is organizing the fuel cell program of distributed power generation systems. By integrating these six programs DOE can restructure the program to achieve possible synergy effects through the collaboration of the fuel cell vehicle industry and the development of stationary fuel cells.

- Extensive networks in the fuel cell industry

Among the different players in the fuel cell industry in the U.S. there are extensive networks through the business partnerships and strategic alliances as evidenced by the relationships between Ballard and DaimlerChrysler, and United Technology Fuel Cell and BMW. Therefore, it may be feasible for the fuel cell industry in the U.S. to realize extended collaboratives beyond the FreedomCAR for both stationary and vehicle applications by cooperating with the government.

(Proposal 2) – First stage

Through the new collaborative consortium, the fuel cell industry in the U.S. should accelerate "Cooperation and Competition" to further product performance and improvements in durability.

The reasons for the above are as follows:

- Concerns about durability and product performance

From Figure 4-6, it is clear that U.S. industry participants are very concerned about the durability of the current fuel cell technology. Therefore, it is in their interest to cooperate towards finding a solution for the durability problem, which requires a long-term approach, large sums of money and a large workforce in order to improve the lifetime of the fuel cell systems. They can also utilize the new collaborative consortium to learn the experiences of other companies and to cooperate with other companies, and particularly with component makers, which would help improve product life significantly. On the other hand, in terms of product performance, information sharing and knowledge of the latest technologies, the collaborative consortium would accelerate the competition of product performance, such as in the area of power density of fuel cell stacks, among several fuel cell developers. This is because the companies can recognize the state of their product performance by comparing with other participants in the consortium. In addition, when there is no measure to fairly evaluate the product in the market, the consortium could prove to be an effective method for participants to motivate the establishment of a fair standard measure to evaluate the product performance.

- Financial situation

As shown in Figures 5-6 and 5-7, over the past three years, fuel cell developers in the stationary fuel cell industry have accumulated losses annually. They have also been spending large amounts of money on R&D, sums that exceed their annual sales, every year while annual sales revenue has been constant during the same period. In order to solve future possible financial problems in the stationary fuel cell industry, a collaborative consortium would be very useful in that it would allow companies to reduce R&D expenses through sharing technology advances as well as providing more government funding for R&D, as is apparent from Figure 5-3.

- Threat of other competitors

In Figure 6-2, the business environment for the current PEM type of stationary fuel cell industry was described by applying Porter's five forces model. Based on this analysis, industry participants will be threatened by five factors except external force factors such as energy security, deregulation and global warming. The first threat is that of future severe and tough competition in the stationary fuel cell industry. In the stationary fuel cell industry there are not only more than 10 PEM type of fuel cell competitors but also other type of fuel cell competitors that are closer to realizing commercialization and mass production. For example, FuelCell Energy Inc. has already constructed a facility so that it can mass-produce 400 MW of MC type of fuel cells per year in 2002. As the threat of substitutes, there are also promising technology products such as micro gas turbine and wind power. As mentioned in chapter 3, in 2000, micro gas turbine shipments exceeded 1,200 units that represented 53 MW, a 400 % increase from 1999 levels. Furthermore, some component suppliers are now considered to have stronger power than fuel cell developers. For example, for the membrane filer that is one of the most expensive components in the fuel cell stack, only three or four large manufacturers, including Dupont, Gore and Asahi Glass can manufacture the qualified membrane. In the early stages when the stationary fuel cell is still a niche business, the suppliers will have an advantage over the fuel cell developers in the negotiation of the price because of limited product volume. Also, since buyers, such as residents, factories and building owners, know that stationary fuel cells are much more expensive than conventional power generation, they will therefore have stronger power in negotiating price. Moreover, in the future, the stationary fuel cell industry may face its largest threat from the automobile industry, which can best utilize mass production for fuel cell vehicles. After the automobile companies succeed in commercializing fuel cell vehicles by mass production, they can easily enter the stationary fuel cell industry with their distribution channels, brand image and a competitive priced fuel cell stack. The advantages for the stationary fuel cell industry are favorable external factor such as energy security, further deregulation and global warming. In the case of global warming, with the exception of in the U.S., Europe, Japan, Canada and other developed countries are expected to significantly reduce amounts of emitted carbon dioxides between 2008 and 2012 from 1990 levels.

(Proposal 3) – Second stage

The fuel cell industry in the U.S. should reach the Dominant Design as soon as possible by making the best use of the "Cooperation and Competition" concept, and will then prepare for the mass production stage.

- Stationary fuel cell industry expects Dominant Design

Based on Figure 4-3, industry participants expect that the Dominant Design will reduce product cost. According to Professor Utterback in "Mastering the Dynamics of Innovation," after the emergence of the Dominant Design the industry will focusing on process development rather than product development. In other words, the earlier the stationary fuel cell industry reaches this second stage, the more preparation they can make for mass production, which in turn will lead to significant success incommercialization.

- Severer business conditions

As shown in Figure 6-2, concerning the five forces in the PEM fuel cell industry, if PEM type fuel cell developers are far behind the other type of fuel cell developers in terms of commercialization then these other types of fuel cell developers will acquire a significant market share out of the total distributed generation demand by using first mover advantages.

(Proposal 4) – Third stage

The stationary fuel cell industry should make the best use of the government subsidy system in California and from the federal government for the large volume of production.

As an example, in June 2001, the California Stationary Fuel Cell Collaborative was formed to encourage fuel cell manufacturers to speed up development. This organization offered incentives such as a $400 million pledge from the California Consumer Power and Conservation Financing Authority to invest in stationary fuel cells, aggregating purchases on behalf of all government agencies and integrating the technology into the state's power grid.

6.2 Proposal for the Stationary Fuel Cell Industry in Japan

Figure 6-4 shows the collaborative business model in the stationary fuel cell industry in Japan based on the current business environment as understood through the interview research. Figure 6-5 describes the long-term business development model for the early commercialization of the stationary fuel cell industry in Japan.

(Proposal 1)

As shown in Figure 6-4, the stationary fuel cell industry should create a strategic working group or institution under the Fuel Cell Commercialization Conference. This institution can be cooperated by its national laboratory and focus solely on durability tests that, in terms of commercialization, are common barriers for all companies in the fuel cell industry. At the same time, the Japanese government will continue to move towards establishing a standard measure to evaluate the product performance.

The reasons for the above proposal are as follows.

- Stationary fuel cell industry is very concerned about the durability issue.

All the interviewees mentioned durability shortage of the current fuel cell products, such as fuel cell stacks and reforming process catalysts, as the largest technology barriers, as is shown in Figure 4-6. Interestingly, one fuel supplier interviewee responded that if the consortium focused on durability tests instead of each company having to do it individually it would be very attractive to his company. This is because it is difficult for private companies to concentrate on research on durability.

- Necessary standard measure to fairly evaluate product performance

Based on Figure 4-3 regarding Dominant Design and Figure 5-9 regarding public-private consortium, industry participants are reluctant to establish a public-private consortium and a dominant design. Instead, they prefer to concentrate on promoting competition for increased product performance through more advanced technology. They also consider that a standard measure to evaluate fairly product performance encourages private companies to compete fairly with one another. This view is held by the Japanese government and private companies.

(Proposal 2)

The government should encourage competition between energy companies, such as electricity companies, gas suppliers and oil companies, by deregulating the retail electricity market. Even if the market is still a niche, competition may destroy the current business model in the Japanese electricity industry. This would encourage the acceleration of competition in the stationary fuel cell business development bringing the industry closer to the mass production stage.

- Deregulation in the retail electricity market

The government believes that deregulation in the retail electricity market would allow stationary fuel cells to provide general consumers multiple choices, and the ability to compare prices when selecting between various energies such as electricity, gas and oil. In other words, consumers can compare the electricity price with that of self-production of electricity from oil or gas using their stationary fuel cells. One fuel supplier also mentioned the possibility that stationary fuel cells can destroy the current business model in electricity industry.

- Large potential market

As mentioned in chapter 2, Japanese electricity prices are higher than in other countries. Therefore, when compared to the U.S., there is larger potential distributed generation market in Japan as shown by the fact that the current distributed generation market share in Japan is about 12% while that in the U.S. is about 2.7%.

- Reforming process technology for hydrogen in fuel suppliers

Most Japanese fuel suppliers are not only very interested in distributed generation as a promising market but are also very proactive in developing their own reforming process and catalysts. In the current business environment, fuel suppliers are important key players in the Japanese stationary fuel cell industry in the context of market accessibility and the hydrogen production process. One important piece of evidence for this is the fact that last year Osaka Gas and Tokyo Gas signed an agreement with Ballard to provide the reforming process technology to Ballard.

- Preparation for fuel cell vehicles

Technological knowledge and experience, particular that regarding fuel for fuel cells and the hydrogen production process, in the stationary fuel cell industry can be transferred from stationary fuel cell applications to fuel cell vehicle applications in the next stage. Even if automobile companies are acting independently in the fuel cell industry, they may be able to learn about fuel for fuel cells and reforming process issues from fuel suppliers.

(Proposal 3)

Automobile companies should prepare for the emergence of gasoline fuel cell vehicles by forming alliances with fuel suppliers so that they can share experiences in the fuel reforming process as well as in fuel design for fuel cells. Then automobile companies should mass-produce the fuel cell systems for both the stationary and vehicle applications in order to achieve synergy effects in production.

- Infrastructure

The fuel decision for fuel cells has much to do with fuel availability. Consumers must be able to buy the fuel easily and conveniently. Therefore, automobile manufacturers and fuel suppliers need to collaborate in the commercialization process for fuel cell vehicles. During that time, experiences in the reforming process in stationary fuel cells will be help automobile manufacturers and fuel suppliers to discuss the practical problems based on the accumulated field test data.

- Synergy effects

Based on the data calculated in chapter 3, the size of the market for stationary fuel cells is not sufficient for manufacturers to obtain learning effects through mass production. Therefore, in order to significantly decrease the cost of fuel cell systems, the automobile industry needs to produce fuel cell systems for both vehicle and stationary applications.

- Business competition

In this stage, competition in the fuel cell industry may be expanded to a worldwide scale. To survive the intense competition and ensure profitability, each fuel cell manufacturer needs a certain amount of production volume.

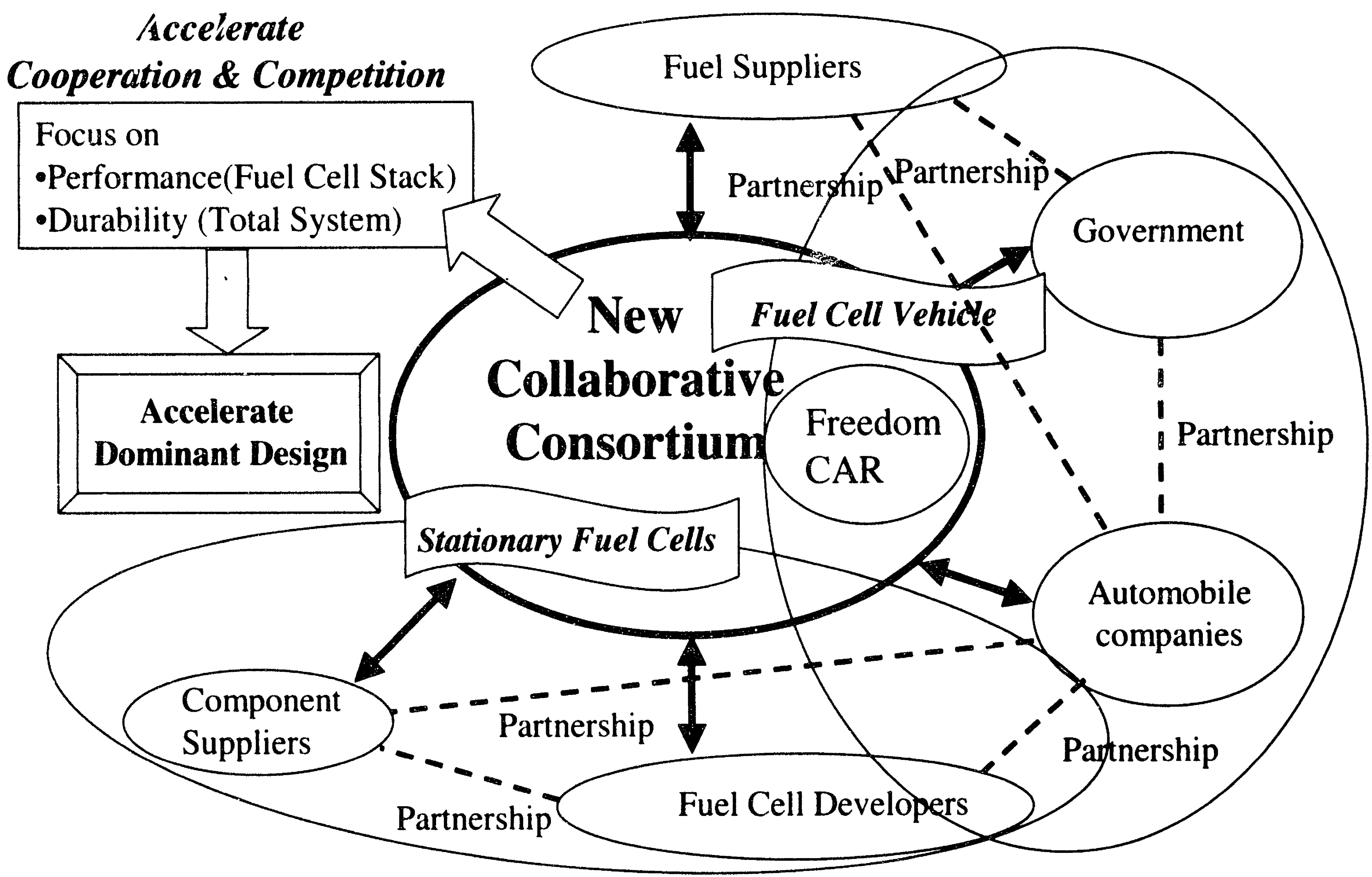


Figure6-1 Collaborative Business Model in the Fuel Cell Industry in the U.S.

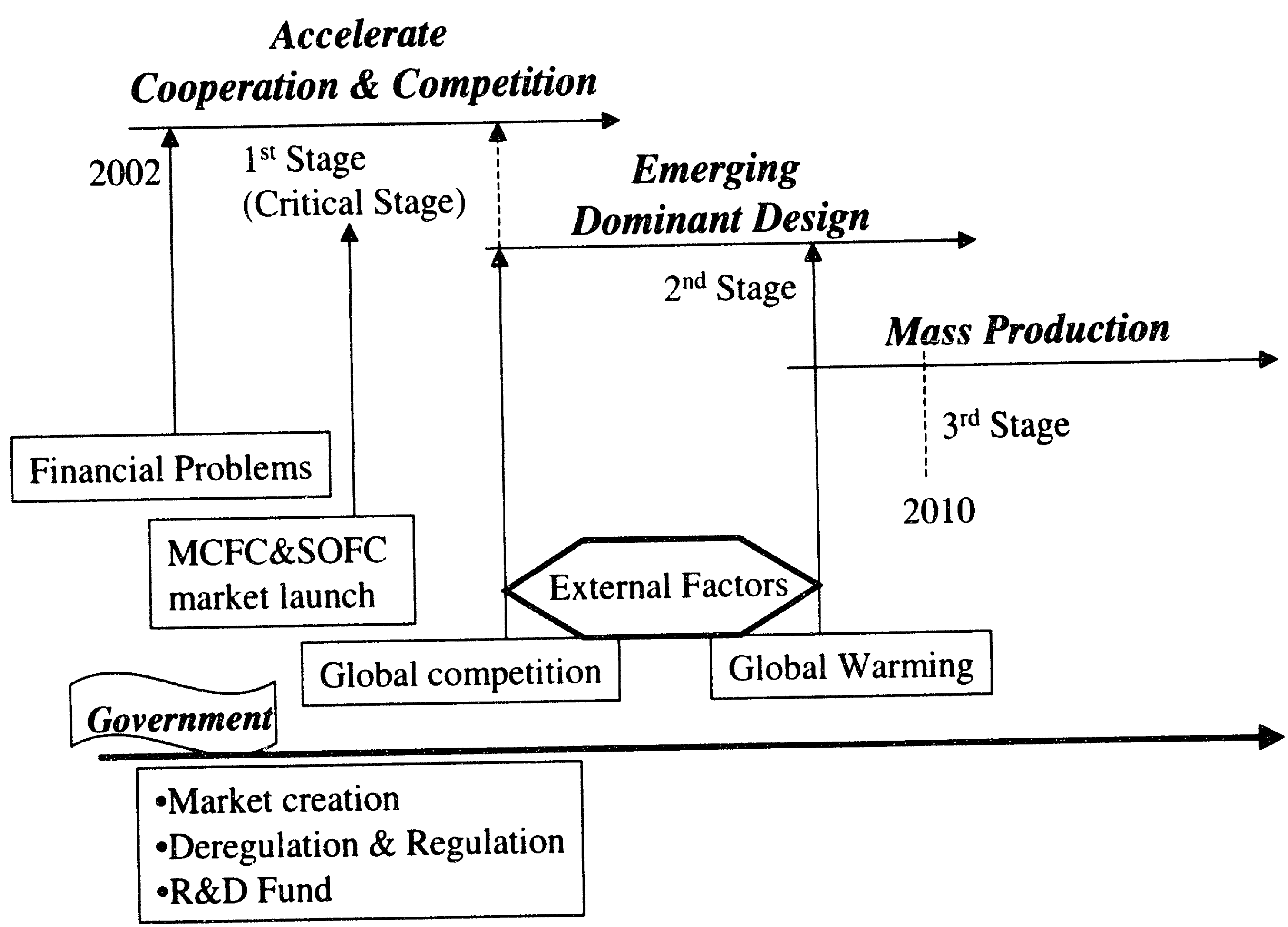


Figure 6-2 Long-term Business Development of fuel cells in the U.S.

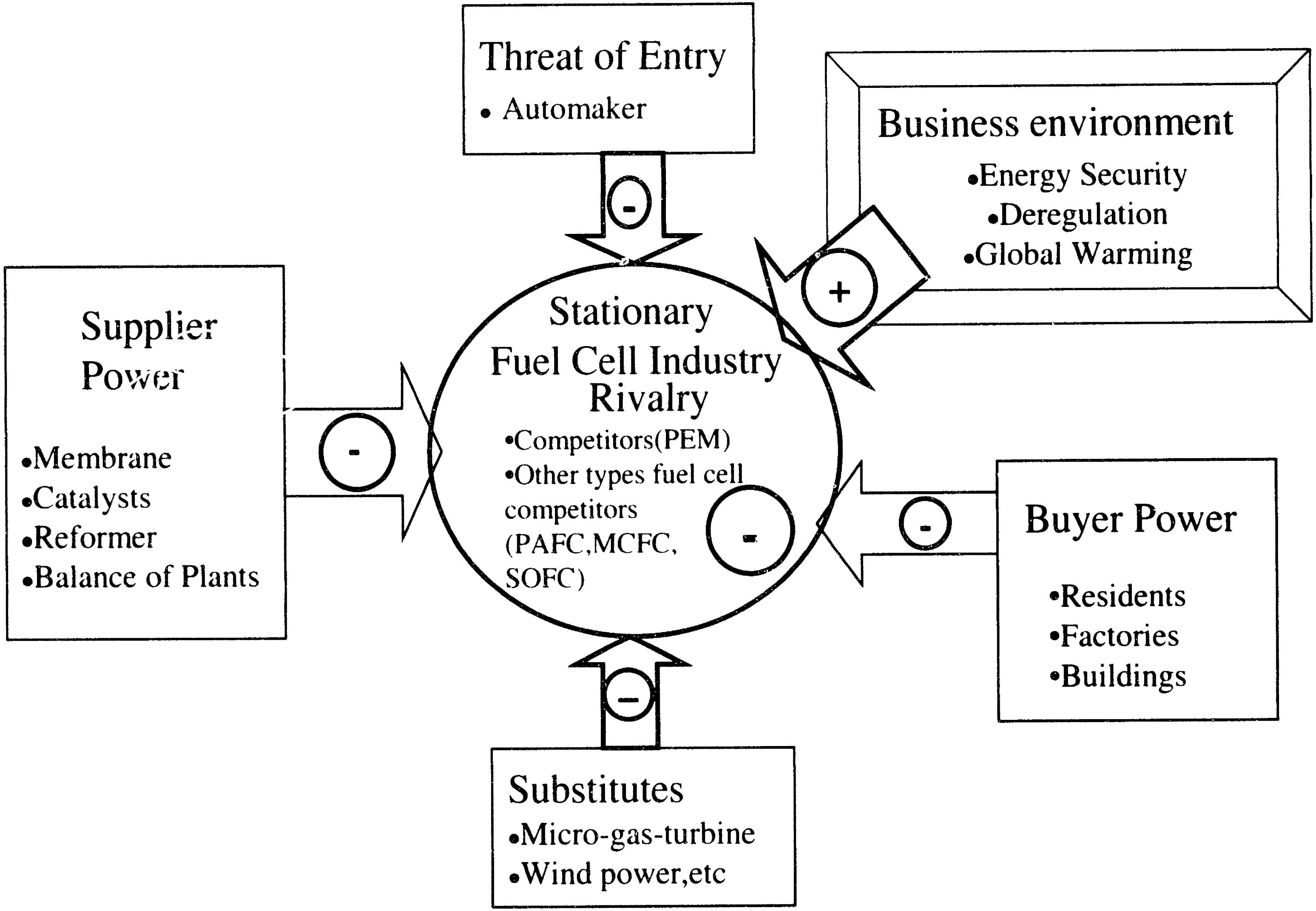


Figure 6-3 Six Forces in Stationary Fuel Cell Industry in the U.S.

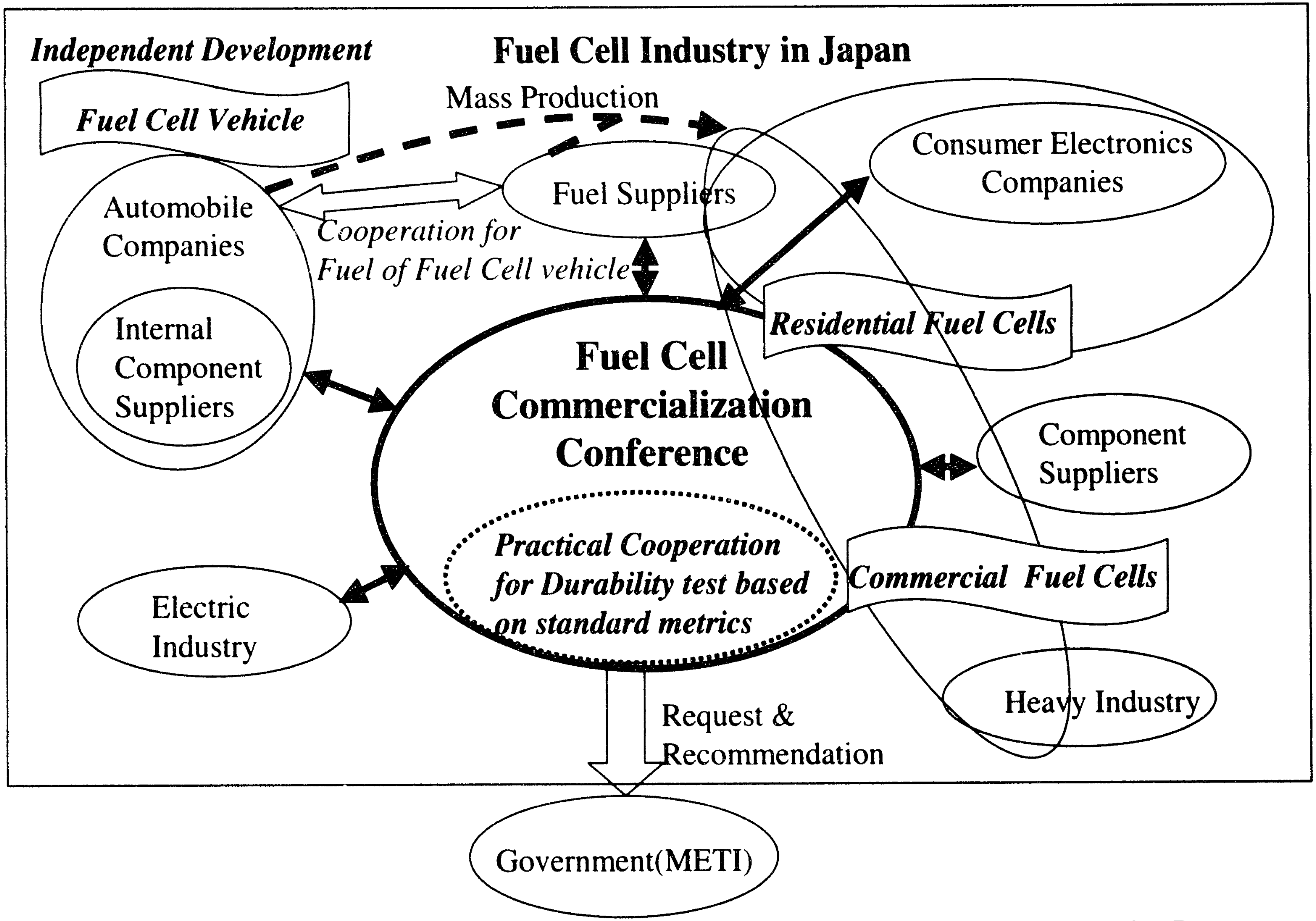


Figure 6-4 Collaborative Business Model in Fuel Cell Industry in Japan

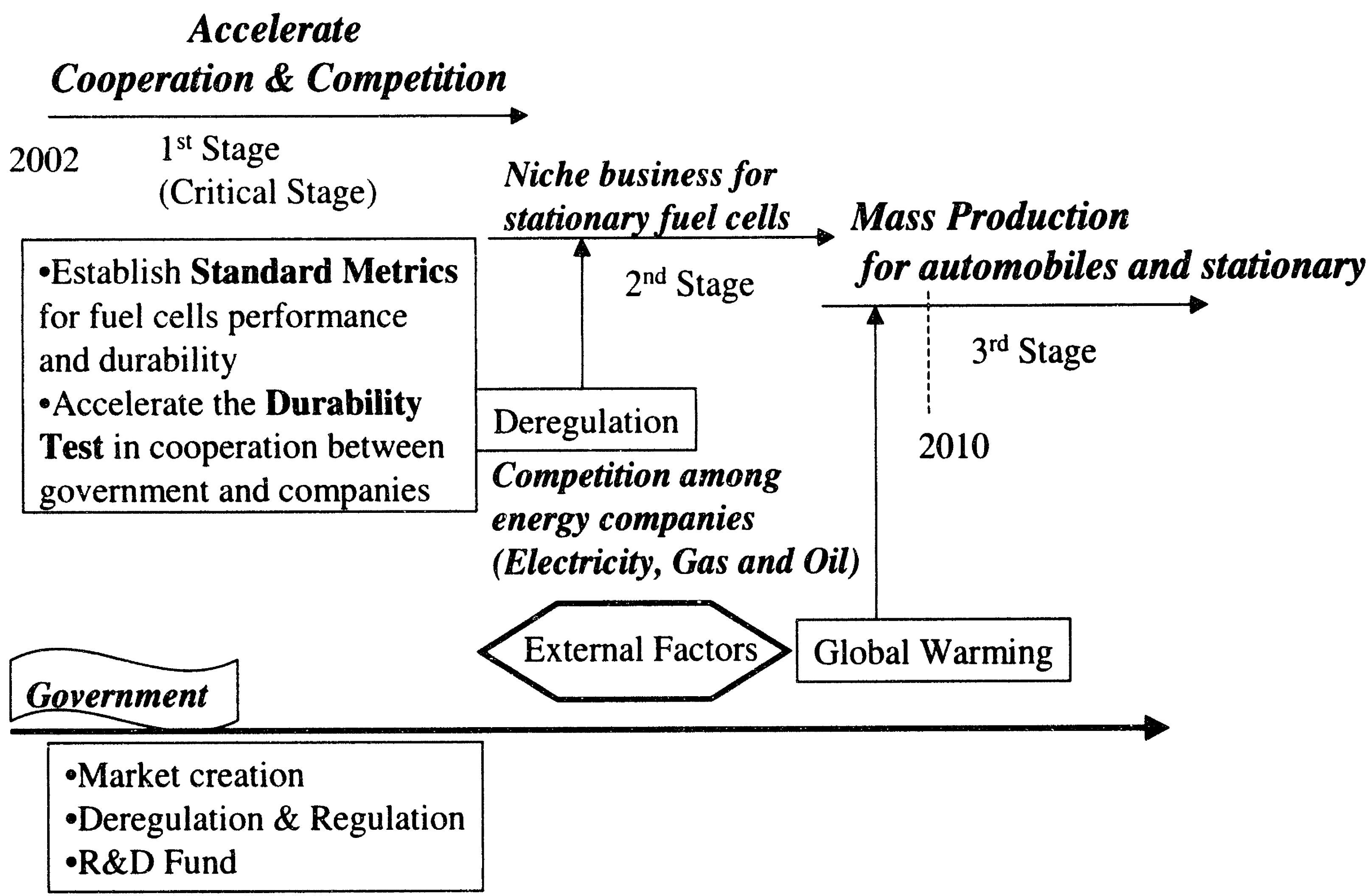


Figure 6-5 Long-term Business Development of fuel cells in Japan

7. Conclusions

This paper has reached various conclusions for business development, technology development and extended enterprise in the stationary fuel cell industry in the U.S. and Japan. Based on these conclusions, a long-term business development model for the stationary fuel cell industry in both countries was developed and proposals are made for each business stage.

The conclusions are as follows:

(Business development)

- Predicted stationary fuel cell market in 2010 ranges from 0.1 to 3.0 %.
- The predicted market size of stationary fuel cell industry will range from $400million to $4 billion in 2010.
- Largest business barrier is high cost and a 10,000-unit level of mass production may not be sufficient to compete with conventional power generation.
- PEM type of fuel cells may be threatened by other types of fuel cells such as SOFC and MCFC.

(Technology)

- Technology transfer from stationary fuel cells to fuel cell vehicles for fuel cell mass production is not always necessary.
- Half of the interviewees in the stationary fuel cell industry believe fuel cells will become

a disruptive technology in 2010. In the U.S., the industry expects external factors such as global warming to make stationary fuel cells become disruptive technology while in Japan participants expect internal factors such as the mass production of fuel cell vehicles.

- In the U.S., industry participants expects the emergence of a Dominant Design for the stationary fuel cell industry sooner or later, while in Japan industry participants would prefer to have a standard measure to fairly evaluate product performance.
- The largest technology barrier is the durability of fuel cell stacks and reforming catalysts. Without significant improvement in durability, successful commercialization of the stationary fuel cell business will be difficult to achieve.

(Extended Enterprise)

- The stationary fuel cell industry is still in the development stage.
- Half of the companies interviewed were not satisfied with their current partnerships in terms of how the partnerships will contribute to commercialization.
- In both the U.S. and Japan, the largest benefit of a public-private consortium is considered to be information sharing. The other benefit, in the U.S., is considered to be government funding.
- The Japanese stationary fuel cell industry is reluctant to form a collaborative public-private consortium, while in the U.S., industry participants are likely to accept such a consortium.

This paper outlines a long-term business development model for the stationary fuel cell industry in the U.S. and Japan based on the above conclusions and analysis of the interview data.

In order to realize the business development model in the future, the following further research and implementation will be necessary.

(1) Increase the number of companies conducting research

In the U.S., the participation of the DOE and automobile companies will make research more reliable and feasible. The opinions of component suppliers and fuel suppliers can help this research significantly. In Japan, the participation of automobile companies and fuel cell manufacturers will make the proposed model more reliable.

(2) Feasibility study in the implementation of the business models and proposals

In order to support the business models and proposals, further supporting data will be necessary to persuade the companies as well as the industry.

(3) Feedback to the companies about this research survey

The feedback of this research survey and analysis will make companies and governments in the stationary fuel cell industry aware of the common issues and the methods to solve the problems. This is the starting point for them to cooperate with one another to tackle the uncertain business environment in the stationary fuel cell industry.

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Appendix1

Table 1-1 Strategic alliances of representative fuel cell developers for the stationary fuel cell developments

	Fuel Cell Developers	Fuel Cell Component Maker	Fuel Cell Market Partnership	Fuel Supplier	Automobile companies	International company
1	Ballard Power Systems	GPU International Inc	------	-----	DaimlerChrysler, Ford Motor	Ebara, ALSTOM SA, Tokyo Gas Osaka Gas
2	Plug Power	MTI, Vaillant, Celanese, Engelhard,	GE MicroGen, DTE Energy	Southern California Gas Company	-----	-----
3	Nuvera	-----	Arthur D. Little	------	-----	Mitsui De Nora
4	United Technologies Fuel Cells	-----	-----	-----	Hyundai, BMW	Toshiba
5	Proton Energy Systems	-----	Matheson Tri-Gas	------	------	Sumitomo
6	H Power	-----	Energy Co-Opportunity	------	------	Mitsui, Osaka Gas, Naps System Oy and Fortum Oy, Gaz de France, SGL Carbon, Kurita Water Industries

Appendix2

Questionnaire for the interviews

March 2002

Tomonari Komiyama
E-mail: tomonari@mit.edu

1. My thesis's purpose
   - Contribute significantly to the acceleration of stationary fuel cell technology and business development by 2010, when Kyoto Protocol will become effective.
   - Propose fuel cell industry new concept of collaboration style among fuel cell ventures, manufacturers, fuel suppliers and governments.

2. Interview

I would like to reach the interview's goal by asking some organizations the questions to learn how effective the hypotheses below are.

Hypotheses

- The discovery of new concept of collaboration style between players in the development arena enables stationary fuel cell industry to decrease the cost sharply and the technology uncertainty as well as to increase the product reliability.
- The new concept of collaboration style can make the stationary fuel cell generation become a disruptive technology in electricity industry.

Goal

- Identify what significant barriers are for the early commercialization of stationary fuel cell generation.
- Discover how to get over those barriers by applying some frameworks MIT professors created to the data and results from interviews.

3. Benefits for the organizations to accept the interview

- Feedback of my thesis's research
  - Summary of this interview survey
    (Comparison of U.S and Japan in terms of the perspectives of the future technology, market, electricity deregulation and government supports)
  - Proposals about new style of collaborative enterprise based on these surveys

4. My brief background

Company: Nippon Mitsubishi Oil Corporation(NMOC) Tokyo, Japan
Title: Chief Research Engineer (Pres-2000)
Department: Central Technical Research Laboratory
Responsible for designing the total system of 50-member NMOC original Oil-Based Fuel Cell co-generation project by focusing on heat and mass balance.
Title: Project Manager
Department: Research and Development Dept. (1996-2000)
Responsible for the Diesel Particulate Filter System to reduce particulate materials(PM).

5. Questions
(Your responses are strictly confidential and anonymous.)

(Market and Disruptive technology)

(1) What percent of market share and what size (MW or GW) do you expect the distributed generation to acquire in 2010 out of the new generating capacity?

(2) What percent of market share and what size (MW or GW) do you expect the stationary fuel cells to acquire in 2010 out of the new generating capacity?

(3) Do you think the commercialization of stationary fuel cells is essential before the fuel cell vehicles are mass-produced?

(4) Do you think the stationary fuel cell could be a disruptive technology for the electricity industry in 2010?

(5) Do you think an industry-wide dominant design could be effective for your company to reduce the fuel cell system cost?

(Extended Enterprise)

(1) Which model do you think represent the present stationary fuel cell industry in Figure1?

(2) Do you think the several present partnerships in your company are successful and sufficient for the commercialization of your company's fuel cell technology?

(3) What do you think the largest barriers are for the stationary fuel cell technology and business development from the viewpoint of your company, respectively?

(4) What do you think is the most significant benefit of public-private partnerships such as PNGV and Freedom CAR for the commercialization of your company's fuel cell technology?

(5) Do you think the super-collaborative consortium such as Sematech could enable the stationary fuel cell to accelerate the product cost reduction and technology reliability in the future? Please explain your reason while considering the present fuel cell industry situation?

Appendix 3
Summary of responses from interviewees

A1 Predicted distributed generation market in 2010

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	Optimistically 5%	------------	------------	------------	------------
Fuel cell developers	3-4%, optimistically 5%	Close to DOE target (20%)	3-6%	High End 30-40 % Low End 1-5%	------------
DOE strategic target	20%	------------	------------	------------	------------
Fuel suppliers in Japan	10-20%	5-10%(+1% if including wind power and solar)	------------	------------	------------
Ministry of Economy, Trade and Industry in Japan	12% (Same share as current situation)	------------	------------	------------	------------

A2 Predicted Stationary Fuel Cell Market share in 2010

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	2.5% (Optimistically)	----------------	----------------	----------------	----------------
Fuel cell developers	2-3%	1%	0.1-0.5%	High 20 – 25 % Low 1-5%	------------
Fuel suppliers in Japan	1-2%	0.5%	----------------	----------------	----------------
Ministry of Economy, Trade and Industry in Japan	Less than 1%	----------------	----------------	----------------	----------------

A3 Technology transfer from Stationary fuel cells to Fuel cell vehicles

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	Yes, unless technological breakthrough happens to hydrogen storage.	------------------------	------------------------	------------------------	------------------------
Fuel cell developers	Sure. The stationary is first market entry because of the much higher cost is allowable than the vehicles.	Both should be work together for the market size. (Fuel cell vehicles contribute to the mass production.)	Not necessary. Fuel, processing technology and BOP can be also used for fuel cell vehicles.	No. Different application, and quality necessary for each application. (Vehicle-more frequent on-off)	No. Unlikely. Reliability (Car 5000hr, Stationary-24000hr, Cost (Stationary is much higher than car.)
Fuel suppliers in Japan	Yes, First market is Stationary, second is Vehicles and next is to expand the stationary due to the vehicle mass-production	No, I don't think so. The mass production is necessary in fuel cell vehicles to reduce the cell stack cost.	------------------------	------------------------	------------------------
Ministry of Economy, Trade and Industry in Japan	Both stationary and vehicle development is necessary for mass production.	------------------------	------------------------	------------------------	------------------------
University (MIT)	Likely. Economical viewpoint, components and fuel for fuel cells can be shared.	------------------------	------------------------	------------------------	------------------------

A4. Disruptive technology

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	Yes, even if the projected markets share in 2010 is pretty small.	-------------------------	-------------------------	-------------------------	-------------------------
Fuel cell developers	No doubt in the far future. But it is doubtful in 2010 because of limited (installed) equipment and service.	It can be, but unlikely, because of three advantages of central power station: economy of scale, the on-grid management and its monopoly.	No unlikely. Very low percentage. But it could be.	Maybe, but unlikely, because of cost, market uptake, existing incumbent technology and utility disruption.	Possible, on the external factors: security reasons, major oil disruption and global climate change
Fuel suppliers in Japan	It can be when the cost is competitive by mass-production of vehicles. The electric industry may also cope with this new business model.	Impossible, because the market size is too small in 2010. It may be realized in 2030.	-------------------------	-------------------------	-------------------------
Ministry of Economy, Trade and Industry in Japan	Possible because of deregulation for retail markets in the electric industry.	-------------------------	-------------------------	-------------------------	-------------------------
University (MIT)	Likely. It could be in Christensen's definition. The market will expand in small manufacturers in developing countries.	-------------------------	-------------------------	-------------------------	-------------------------

A5. Dominant Design

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	Yes. Very important. Government should get involved with it and encourage the industry to set up it.	------------------------	----------------------	------------------------	------------------------
Fuel cell developers	Exactly necessary. The more standardization is necessary. It will facilitate market acceptance.	Necessary for the enough production volume. It may emerge in 5-10 years.	Yes, Membrane and other elements should be cheaper and help to save the cost.	Yes, maybe if the companies agree dominate design.	Yes, dominant design of membrane will be effective for the cost reduction. In the future several emerging design will be appeared and need competition.
Fuel suppliers in Japan	Necessary in BOP (Balance of plant), but now too early to develop the further technology.	At this moment it is not effective, because it interrupts the technology development. Still we need technology breakthrough.	----------------------	------------------------	------------------------
Ministry of Economy, Trade and Industry in Japan	Yes. Effective. The standardized metrics for the product performance is important.	----------------------	----------------------	------------------------	------------------------
University	Yes, if same catalysts are applicable to natural gas and gasoline, kerosene.	----------------------	----------------------	------------------------	------------------------

A6. Extended Enterprise

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	Model1. Model3 is a target model.	--------------------------	--------------------------	--------------------------	--------------------------
Fuel cell developers	Model1. Messy situation. This has to be changed to reach Model3. (GM's situation – Close to Model2)	Very close to Model2. But fuel suppliers and component maker don't get involved with it.	Model 2	Model 1	Model 1
Fuel suppliers in Japan	Between Model1 and Model2. Very close to Model1. Japanese automotives seems to be far from this model.	Superficially model 3. But in fact model2.	--------------------------	--------------------------	--------------------------
Ministry of Economy, Trade and Industry in Japan	Model 2.	--------------------------	--------------------------	--------------------------	--------------------------

A7. Present Partnership

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	No. The more consolidation is necessary by the more government involvement for the market pull.	------------------------------	----------------------------	------------------------	--------------------
Fuel cell developers	Not significant and important now even with commercial relationship with industrial gas group	It may not be sufficient. But it's too early to say now.	Yes, some are successful. But it is not sufficient for the commercialization in market partner and channel.	Yes. The partnership like model 3 is challenging but will accelerate the fuel cell business.	It will be sufficient if one more partnership negotiation is successful.
Fuel suppliers in Japan	Basically so far no partnership, except the recent contract with Ebara-Ballard to license the fuel reforming process technology	It is useful at 100%. Fuel supplier needs to ally with manufacturers for its business.	----------------------------	------------------------	-------------------------
Ministry of Economy, Trade and Industry in Japan	Useful like the examples of business agreements between Japanese gas companies and Ballard.	------------------------------	----------------------------	------------------------	--------------------

A8-1 Largest Business Barriers

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	High cost Solution Large procurement order from the government Green accounting	--------------------------------	----------------------	----------------------	----------------------
Fuel cell developers	Cost (Price) Ten times of the cost of conventional power generation	Limited marketing and product volume	Cost, Negotiations with partner, Competing existing technology and alternatives	Infrastructure	Utility regulation is not helpful for the business right now.
Fuel suppliers in Japan	Cost (Price)	Cost. Specifically in the cost of components.	----------------------	----------------------	----------------------
Ministry of Economy, Trade and Industry in Japan	Regulation, but this is changeable in accordance with the fuel cell technology development.	--------------------------------	----------------------	----------------------	----------------------

A8-2 Largest Technology Barriers

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	No technology barrier according to the hearing from fuel cell industry. Only technical barrier is mass production.	------------------------	------------------------	------------------------	------------------------
Fuel cell developers	Performance (especially durability), How to produce and deliver hydrogen	Technical challenge & maintenance (at least 8760hr)	Durability & cost	Cost competitiveness as compared to incumbent technology	Membrane robustness, water management
Fuel suppliers in Japan	Durability of fuel reforming process	Reforming process from oil to hydrogen, Specifically the durability in the catalysts (more than 10 years)	------------------------	------------------------	------------------------
Ministry of Economy, Trade and Industry in Japan	Cost and durability	------------------------	------------------------	------------------------	------------------------

A9. Benefit of public-private consortium

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	Sharing the information and knowledge among companies. Finally it helps the industry to set up the common design (dominant design).	------------------------	--------------------	-------------------------	----------------------
Fuel cell developers	More dialogue between large companies and small companies. It also helps the government interaction.	The government can study the technology, sources and issues significantly. Also it worthwhile the fund and regulatory issues.	Funding available from the government is important. Marketing R&D fund is crucial.	Increase the government fund. Visibility of fuel cell products. Closing the technology gap. Developing the enabling technology.	Useful for common standard in fuel (refuel): liquid or gas.
Fuel suppliers in Japan	FCCJ is useful. The concern in Consortium is difficult to distinguish what technology should be shared and be open to public. The consortium will be attractive if National laboratories do the durability tests.	Very useful for alliances. It improves the efficiency in R&D by sharing the experiences of other companies.	--------------------	-------------------------	----------------------
Ministry of Economy, Trade and Industry in Japan	FCCJ is useful to share the information among fuel cell related companies.	--------------------	--------------------	-------------------------	----------------------

FCCJ; Fuel Cell Commercialization Conference in Japan

A10 Super Collaborative Consortium

	Company A	Company B	Company C	Company D	Company E
CA government (Stationary Fuel Cell Collaborative)	He hopes so. Nobody can't predict future situation. The only thing he can say is the government may set up the right direction.	----------------------	----------------------	----------------------	----------------------
Fuel cell developers	Yes, but not now. It is too early. Until enabling invention and integrated market occur, technology should be independent.	Absolutely, yes. It can contribute to the cost target and the increased volume.	I think so. Requirement of shareholders is short-term view. It does help sharing the cost.	Maybe. It depends on coming common visions.	Yes. The government budgets like $75million is too little money to spend. It should be much more proactive. The consortium is useful for sharing intellectual property and know-how.
Fuel suppliers in Japan	It may accelerate the product reliability if the consortium tests the durability instead of the companies. More attractive if the consortium consisted of only private companies.	It can accelerate them by 3 years, while it may make them late by 3 years, because the consortium may disturb the breakthrough.	----------------------	----------------------	----------------------
Ministry of Economy, Trade and Industry in Japan	Basically private companies should compete with one another without the interference from government.	----------------------	----------------------	----------------------	----------------------

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