Task 1 Study of System Evaluation

1.1 Research and Development Goals

The aim of surveys and studies of Task 1 Systems analysis in WE-NET Phase II is to study an optional scenario for introduction of hydrogen energy and to formulate a strategy for its introduction. With short- and medium-range views, therefore, efforts should be exerted to identify promising technologies and research and development tasks based on the results of assessing the energy consumption, environmental impacts and economical efficiency of various hydrogen utilization systems, including those designed to use hydrogen produced not only from renewable energy sources but also from fossil energy resources. Additionally, as the introduction and the penetration of the fuel cell are being promoted now by the Government, the introduction and penetration scenario of hydrogen energy combined with the fuel cell introduction scenario were examined toward the hydrogen energy society in the future.

Major items of the FY2001 survey and study plan included: ① The life cycle assessment (LCA) of the promising systems; The data for making introduction scenario of fuel cell vehicles were accumulated and LCA method with which a fuel was treated as a final product was improved, ② A study of systems; surveys of cost of hydrogen refueling station and business possibility were performed and cost analysis on fuel cell systems by learning curve was done, ③ Making introduction scenario of fuel cell; an introduction scenario of fuel cell vehicles was investigated and made, and the data were summarized for making an introduction scenario of stationary fuel cell, ④ Investigation of the introduction and penetration scenario and the strategy for introduction of hydrogen energy with a long-term perspective.

Also a research coordination meeting was organized and held to coordinate research activities under the WE-NET Project in general. This report summarizes the results of the FY2001 researches.

1.2 Results in FY 2001

1.2.1 Study on Systems

(1) Study on cost and business possibility of hydrogen refueling station

In this study, as a part of making of hydrogen introduction scenario for the fuel cell vehicles, the cost of the off-site hydrogen refueling station supplied with by-product hydrogen and the on-site station and business possibility were evaluated based on the hydrogen demand corresponding to the introduction stages of the fuel cell vehicles, and clarified a image of the hydrogen supply infrastructure for the diffusion of the fuel cell vehicles.

In this study, the hydrogen demand calculated for making of introduction scenario in chapter 3 and the number of the hydrogen refueling station shown in Table 1.2.1-1 were assumed to be a base and total of four cases shown in Table 1.2.1-2 which three were the off-site stations and one was the on-site station, were assumed.

Table 1.2.1-1 Hydrogen demand and the Number of Hydrogen Refueling Station by "Introduction Scenario" (Whole Country)

Penetration Category		Incunabula	Beginning of Introduction	Middle of Introduction	Diffusion Period
Assumed Year	Year	2006	2010	2015	2020
Number of All FCV	―	4,732	50,255	514,117	4,999,315
Number of Hydrogen FCV	―	4,732	50,255	389,703	3,051,904
Hydrogen Demand	Billion Nm^3/year	0.2	1.6	7.4	42.5
Number of Station	―	56	169	533	2,344
[Breakdown of Station Type]					
・100Nm^3/h-Off Site		56	56	56	56
・300Nm^3/h-Off Site		0	100	290	463
・500Nm^3/h-Off Site		0	13	119	1,201
・500Nm^3/h-On Site		0	0	68	624

a) Hydrogen supply cost of each hydrogen refueling station

Hydrogen supply costs of four hydrogen refueling stations shown in Table1.2.1-2 were estimated. The costs for the off-site stations of case 1 to case 3 are the sum of cost of

Table1.2.1- 2 Evaluation cases of Hydrogen Supply Cost

Case	Station Type	Hydrogen Production	Transportation Equipment	Type of Storage and Refueling	Abbreviation
1	Off-Site	Compressed H2	CH Trailer	CH Storage― CH Refueling	CH
2	Off-Site	Liquid H2	LH Lorry	LH Storage― CH Refueling	LCH
3	Off-Site	Liquid H2	LH Lorry	LH Storage― LH Refueling	LH
4	On-Site	―	―	NG Reforming― CH Refueling	RCH

each stage hydrogen production, transportation and refueling station. As for the costs of hydrogen production and transportation, various conditions were revised and adjusted based on the calculation results of "Assessment of hydrogen supply system with by-product hydrogen of coke oven gas" reported in FY 2000.

As for the cost of the hydrogen refueling station, the specifications of four stations were decided and the present costs were estimated. Additionally, the cumulative number of the hydrogen refueling stations was calculated in accordance with the hydrogen demand of each penetration category shown in Table 1.2.1-1 and the future cost was estimated by using a learning curve.

Table1.2.1-3 indicates the cost reduction rate of the hydrogen refueling station of scale of 300Nm^3/h and Fig1.2.1- 1 indicates the hydrogen supply cost at each period of hydrogen introduction.

Table1.2.1- 3 Cost Reduction of Hydrogen Refueling Station by Learning Curve

Penetration Category		Present	Incunabula	Beginning of Introduction	Middle of Introduction	Diffusion Period
Hydrogen Demand	Million Nm^3/y	—	21.7	164.7	744.6	4,254.9
Cumulative Number	—	1	18	137	616	3517
CH-300	Million ¥	307.4	238.6	203.5	182.7	162.9
LCH-300	Million ¥	304.9	233.3	197.2	175.8	155.7
LH-300	Million ¥	244.4	193.7	167.6	152.0	137.0
RCH-300	Million ¥	538.3	386.6	311.8	268.5	228.4

b) Business Possibility of the hydrogen refueling station

The statement of receipts and disbursement was made in accordance with the calculated hydrogen supply cost mentioned above, business possibility of the hydrogen refueling station was evaluated by using the net present value (NPV) which was the profit after taxation and before deducting depreciation expense. Hydrogen sales price, which became the income of the station, was set to 103.5¥/Nm^3 which was calculated on the assumption that the efficiency of the fuel cell vehicle is three times the efficiency of present internal combustion engine, and it was equal to 95 ¥/L of

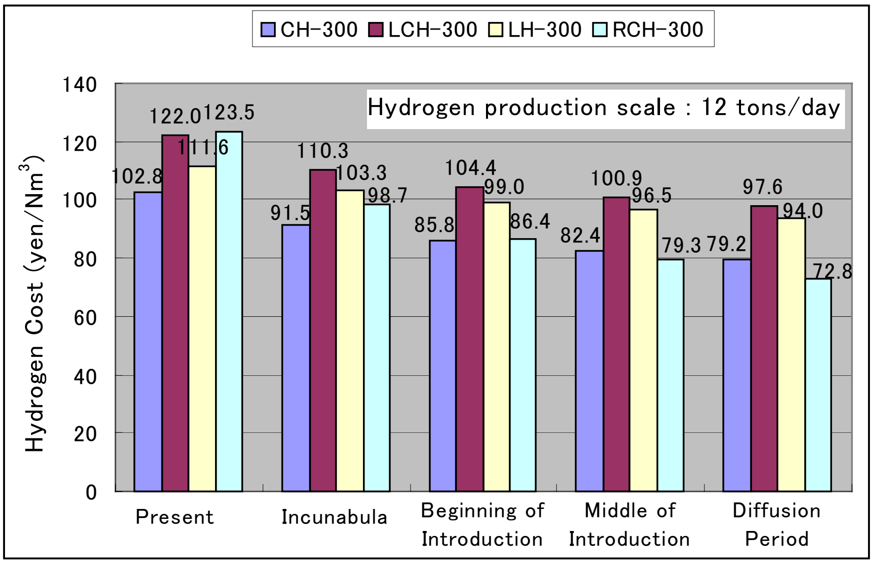

Fig. 1.2.1-1 Hydrogen Price at Each Stations (Hydrogen production scale : 12 tons/day)

gasoline sales price. Hydrogen buying prices, which became the expense of the off-site station, were 43.6 ¥/Nm^3 in the case of compressed hydrogen and 64.1 ¥/Nm^3 in the case of liquid hydrogen, which were calculated based on hydrogen production scale of 12ton/day and one way distance of transportation of 50km. Redemption year of the station was set to 8 year, which was the legal durable years, and availability factor of facility was set to 85%.

Fig.1.2.1-2 indicates the profit performance of each station of scale of 300 Nm^3/h. Zero net present value indicates the break even point in the case of the cut rate by 4%, and plus NPV means the business possibility. The business possibility of each station was improved accordance with cost reduction of a hydrogen refueling station from Incunabula to diffusion period, however, some subsidizing policies were needed at the period when the net present value was a minus. The subsidy to assume net present value was zero at each penetration stage was shown in Table 1.2.1-4.

(2) Cost Analysis on fuel cell systems by the learning curve

In order to commercialize the fuel cell, it is said that a substantial cost reduction is necessary and various technical developments are now performed. Additionally research, which analyzes and predicts the possibility of cost reduction by mass production with learning curve, is performed. In this report we investigated a possibility of cost reduction of fuel cell systems by using the learning curve.

The learning curve expresses a tendency that the manufacturing cost is reduced by accumulation of knowledge and it has already been used for analysis about various industrial products. Progress ratio is generally used to express concisely the situation

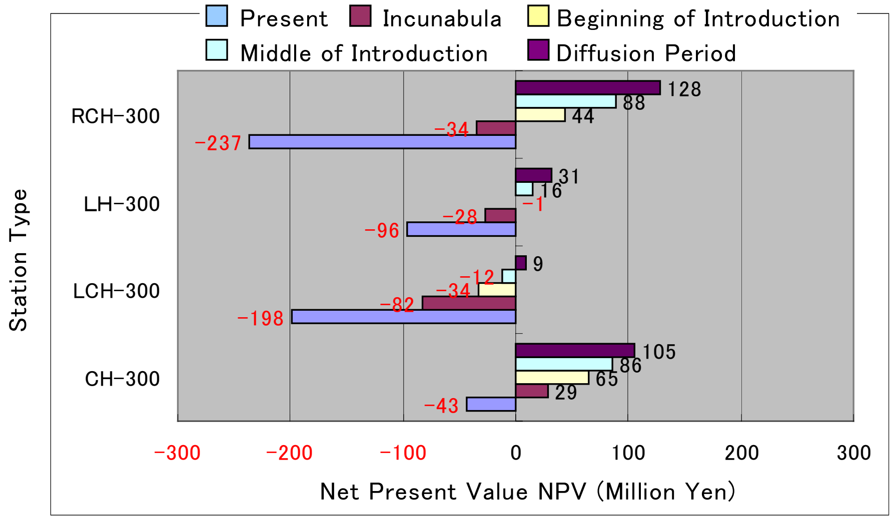

Fig.1.2.1- 2 Change of Net Present Value of Each Stations in accodance with Future Cost Reduction

Table1.2.1- 4 Supplementary Amount for Business Approval of Hydrogen Refueling Station

(Unit：Million yen/one station)

Penetration Category		Present	Incunabula	Beginning of Introduction	Middle of Introduction	Diffusion Period
CH－300	Initial Cost	307.4	238.6	203.5	182.7	162.9
① Hydrogen Price	Subsidy	47.6	(Independence without subsidy)			
103.5 ¥/Nm³	Ratio	15.5%	－	－	－	－
② Hydrogen Price	Subsidy	149.9	71.0	30.8	6.9	－
86.2 ¥/Nm³	Ratio	48.8%	29.7%	15.1%	3.8%	
③ Hydrogen Price	Subsidy	149.9	334.2	292.8	268.2	244.7
44.9 ¥/Nm³	Ratio	135.2%	140.1%	143.9%	146.8%	150.2%
④ Hydrogen Price	Subsidy	470.9	389.4	348.0	323.4	300.0
37.4 ¥/Nm³	Ratio	153.2%	163.3%	171.0%	177.0%	184.2%
RH－300	Initial Cost	538.8	386.6	311.8	268.5	228.4
① Hydrogen Price	Subsidy	211.6	37.7	(Independence without subsidy)		
103.5 ¥/Nm³	Ratio	39.3%	9.7%	－	－	－
② Hydrogen Price	Subsidy	314.0	140.0	54.2	4.6	－
86.2 ¥/Nm³	Ratio	58.3%	36.2%	17.4%	1.7%	
③ Hydrogen Price	Subsidy	563.9	385.1	298.6	249.0	202.9
44.9¥/Nm³	Ratio	183.4%	161.4%	146.7%	136.2%	124.6%
④ Hydrogen Price	Subsidy	618.6	439.2	350.9	299.9	252.6
37.4¥/Nm³	Ratio	202.1%	184.1%	172.4%	164.1%	155.1%

of the cost reduction indicated by the learning curve. Progress ratio is the numerical value that indicates how much cost decreases when an accumulation of products becomes twice. As past examples, it is known that in semiconductor industry progress ratio is between 70% and 80%, in machine assembly industry that value is between 85% and 95%. The smaller this numerical value is, the more abruptly a cost becomes low.

In this study, at first the parts and the present cost composition of the fuel cell for vehicles were investigated, and the technical possibility of the performance improvement and cost reduction in the future was investigated. As data, the papers published in International Journal of Hydrogen Energy, the report of A.D.L (The Arthur Day Little) which is a think tank in U.S. and so on were examined. Furthermore, the overseas papers, which evaluated the cost reduction of fuel cells by the learning curve, were investigated. These reported the research results that the cost reduction of fuel cells was explained by the learning curve. It is described in these papers that the careful and important points, which should be noted when the learning curve is applied, are the accumulation amount of production and the cost at an initial stage, the lower limit of the cost and the progress ratio.

Next, a technical possibility of the cost reduction of fuel cells in Japan was examined. As a preliminary survey, the accumulation amount of product and the cost by present were first examined and the lower limit of the cost reduction at the time of mass production of the component parts was examined. We investigated them as the component parts were divided into an electrolytic membrane, an electrode, platinum, a separator and auxiliary parts. It goes without saying that the costs of an electrolytic membrane and platinum are important of the component parts. However, as a result of considering cost and weight composition, under the present condition, a separator occupies 80% or more in fuel cell weight and it became clear that the ratio of the separator cost is high. For the cost reduction of the fuel cell, it turns out that the cost reduction of a separator is important.

It is targeted by The Agency of Natural Resources and Energy, METI that 50 thousand fuel cell vehicles (FCV) in 2010 and 5 million FCV in 2020 will penetrate in Japan, so the growth of the production amount of the fuel cell for vehicles was assumed according to this target, and we applied the learning curve in the time frame of 2000 to 2020 and calculated the cost reduction of FCV.

As the component, each initial cost and the progress ratio of an electrolytic membrane, an electrode, platinum, a separator and auxiliary parts were assumed and we calculated the fuel cell cost. The electrolytic membrane, the electrode, platinum, and the separator are expressible as the cost per each unit area of the fuel cell, and the manufacturing cost decreases by the accumulation of knowledge. On the other hand there is a possibility that the power density per unit area improves by the research and development. Therefore, the cost reduction by the accumulation of knowledge and the performance improvement were dealt with separately at first and then these results were combined to express as a cost of the fuel cell per kW. It is said that an expected mass production cost of the fuel cell is about 40 dollars per kW, which almost equals to that of the internal-combustion engine in some published reports. It has been clarified that the range of an progress ratio necessary to achieve this level at the time that the accumulation production amount to 5 million is between 78% and 82% by calculation results for some scenarios as shown in Table 1.2.1-5.For the installation cost of the hydrogen refueling station, in order to predict and analyze the cost reduction of hydrogen we investigated some overseas reports for the penetration scenario of fuel cell vehicles. In an example of the United States, the problems have been examined whether the pure hydrogen FCV or the on-board reforming FCV were preferable, and how to produce, to store, and to transport hydrogen. The liquid fuels such as gasoline and methanol were considered to be advantageous for the on-board reforming FCV from the point of view of the storage and handling of the fuel. The following fuel selection scenario was also considered. It is thought that hydrogen can be supplied from the by-product gas of a chemical industry and/or the product line for aeronautics and astronautics industries at first.

Table 1.2.1-5　Calculation Results：Fuel Cell Cost per 1kW

（①～⑨are assumed case No.）

（Prevalent Fuel Cell Vehicle－Upper Case Value：　50 thousands、Lower Case Value：5million）

	Scenario Progress Ratio	High Power（H）	Middle Power（M）	Low Power（L）
		Power Density 2→5kW/m^2	Power Density 2→4kW/m^2	Power Density 2→3kW/m^2
High A	Membrane 78 Electrode 78 Separator 78 Peripheral Device 95 Platinum 0.4mg→0.05mg/cm^2	①　HA 11,500 ¥/kW 1,977 ¥/kW	②　MA 13,447 ¥/kW 2,507 ¥/kW	③　LA 15,700 ¥/kW 3,186 ¥/kW
Middle B	Membrane 82 Electrode 82 Separator 82 Peripheral Device 95 Platinum 0.4mg→0.1mg/cm^2	④　HB 18,550 ¥/kW 3,874 ¥/kW	⑤　MB 21,737 ¥/kW 4,984 ¥/kW	⑥　LB 25,423 ¥/kW 6,406 ¥/kW
Low C	Membrane 88 Electrode 88 Separator 88 Peripheral Device 95 Platinum 0.4mg→0.2mg/cm^2	⑦　HC 37,061 ¥/kW 11,406 ¥/kW	⑧　MC 43,504 ¥/kW 14,817 ¥/kW	⑨　LC 50,954 ¥/kW 19,192 ¥/kW

（Amount of Fuel Cell production until　2000：2,000kW、Cost：240thousand yen/kW）

At the next stage hydrogen is assumed to be produced from natural gas at the concentrated large-scale reforming factories, and the transportation in the form of gaseous hydrogen and liquefied hydrogen are assumed. The on-site natural gas reforming at the refueling station and hydrogen production by electrolysis using a domestic electricity grid are also considered. Furthermore, the hydrogen production using solar cell, wind power and biomass are considered to be plausible in the future.

In an example of research for hydrogen penetration scenario, the assumption is set up that ZEV (zero emission vehicle) regulation, which is to introduce ZEV by 10% in 2003, in California, will bring about a introduction of fuel cell vehicles with a ratio of about 50% of all ZEV. It is expected that the cost reduction is caused in accordance with the expansion of the hydrogen supply scale in the scenario for the hydrogen supply infrastructure. When the hydrogen cost is compared with the gasoline cost in terms of the cost per running mile, it has been suggested that the hydrogen price will be equal to that of gasoline or less in accordance with the expansion of hydrogen energy supply.

This process is an effect of mass production similar to an effect explained by the learning curve. The increase of the number of the fuel cell vehicles supported by the hydrogen refueling station and the production scale of on-site reformers will result in the decrease of hydrogen supply price.

The numerical value of hydrogen cost used in the report was applied to the learning curve and regression analysis was done to see the trend of price decrease caused in this process, and the progress ratios were calculated. It was clarified that the progress ratio of the cost reduction by the increase of the number of FCV supported by the hydrogen refueling station was between 75% and 88%, and the progress ratio of the cost reduction by the increase of the production number of on-site reformers was between 88% and 96%. These progress ratios were in the range of that known experientially. This finding strongly supports the conclusion that the hydrogen supply price will becomes equal to that of gasoline.

As mentioned above, this study is investigation and research about analysis and prediction by the learning curve used in cost prediction and its penetration scenario of fuel cells, and these available results as a reference for research and development of a fuel cell in Japan was obtained.

1.2.2 Life Cycle Assessment (LCA)

Life cycle assessment for vehicle fuels, which covered from fuel production to fuel consumption reported last fiscal year, was brushed up from three points of view; the first was reevaluation of energy efficiency of each process and the second was reevaluation of energy input for each process in terms of amount of primary energy. In the later case, energy consumption of primary energy required for each process was calculated using reciprocal value of efficiency of each process. The third point was the evaluation of energy consumption and CO_2 emission within Japan. For this purpose, the systems considered were divided into two processed; the domestic process and the foreign one.

As for the second point described above, the energy consumption and CO_2 emission were calculated by the method of cumulation of absolute amount of energy consumption of each process. The consumed energy at each process of well-to-tank was calculated in terms of amount of primary energy by tracing back to primary. The energy consumption at the last stage, fuel consumption stage, was calculated as energy required for 1 km running. Total primary energy required for 1 km running in well-to-wheel and total CO_2 emission were calculated for each system. As a result of this study it was made possible to compare energy consumption and CO_2 emission with absolute values, which the comparison reported last fiscal year was relative one based only on energy efficiency of each process. The method used in this report will be improved further and the accuracy of data required for analysis of energy efficiencies and CO_2 emission of each process will be reevaluated, and improved in the future.

1.2.3 Making of Introduction Scenario

(1) Making of introduction scenario of fuel cell vehicle

In this study, we investigated and examined an introduction way of fuel cell vehicles (FCV) until 2020 taking into consideration both types of FCV and the fuel supply infrastructure. As for FCV, two types of FCV were considered; one was pure hydrogen FCV which was equipped with pure hydrogen tank, and the other was on-board reforming FCV which was equipped with hydro carbon fuel tank such as clean gasoline. In the investigation two or more FCV introduction scenarios were composed, and they were compared by various evaluation indices. Indices included number of vehicles by kinds, number of hydrogen refueling station, social benefits such as CO_2 emission reduction, energy substitution effect, costs of FCV introduction and station construction, and benefits of FCV users and station owners. The requirement to introduce FCV smoothly and the problems to be overcome were clarified based on the result of this study.

a) Composition of scenario, assumptions and evaluation method

Composition of scenario, assumptions and evaluation method used in this study are as follows;

① Number of FCV were set to 50 thousand in 2010 and 5 million in 2020 in accordance with the target quantity by The Agency of Natural Resources and Energy, METI.

② The region for the FCV introduction and the kinds of FCV were set to bus and passenger car in Japan's three major megalopolises, Tokyo, Nagoya, and Osaka at the incunabula stage until 2006 and the initial stage of the introduction until 2010. Afterwards, it was assumed that the FCV will be gradually penetrated to the surrounding areas, and the vehicle kind will expand to trucks and the special cars, such as garbage truck. The OBR vehicles were assumed to be introduced only for passenger cars.

③ Hydrogen supply capacity was assumed to be $100Nm^3/h$、$300Nm^3/h$ and $500Nm^3/h$ for on-site stations and $500Nm^3/h$ for off-site station. All stations were assumed to have compressed hydrogen refueling facility.

④ Based on the estimation of the annual transition of the number of the FCV and the required number of hydrogen refueling stations, cost for the introduction of FCVs and stations were estimated. It was assumed to be displayed in this cost estimation the effect of the cost reduction by mass production according to a learning curve.

⑤ FCV user's profit was assumed to be represented by the additional cost which was generated by substituting FCVs for existing fuel vehicles (the vehicle acquisition cost and fuel cost for the vehicle duration of service).

⑥ Station owner's profit was assumed to be represented by the value which was obtained by deducing the initial investment from the present value of the accumulated profit during business period of the station (net present value: NTV). The value necessary for keeping NPV positive was considered to be the amount of the subsidy.

b) Evaluation results of scenarios

In this study, two FCV introduction scenarios were evaluated. Pure hydrogen FCV and on-board hydrogen reforming FCV were assumed to coexiste in one scenario (scenario A) and in another scenario only pure hydrogen FCV was assumed (scenario B). These two scenarios were analyzed by using the evaluation method described in a). The summary of the analysis result is as follows;

① Fig.1.2.3-1 indicates the penetration transition of the number of the FCV stock. The figure was obtained on the assumption that the transition penetration accorded to the logistic curve expressing a general growth curve. The penetration transition was decided by both of the numbers of FCV stock at two time points and the supposed higher limit value. The numbers of FCV stock at two time points were 50 thousand in 2010 and 5 million in 2020 (target values of ANRE, METI). As for the higher limit, 50 million was assumed including numbers of all kinds of vehicle considered in this study. It was however assumed that the number of present vehicle stock and the composition of vehicle kind did not change and it was difficult to introduce FCV into the light weight vehicle, the heavy duty truck, the taxi and so on.

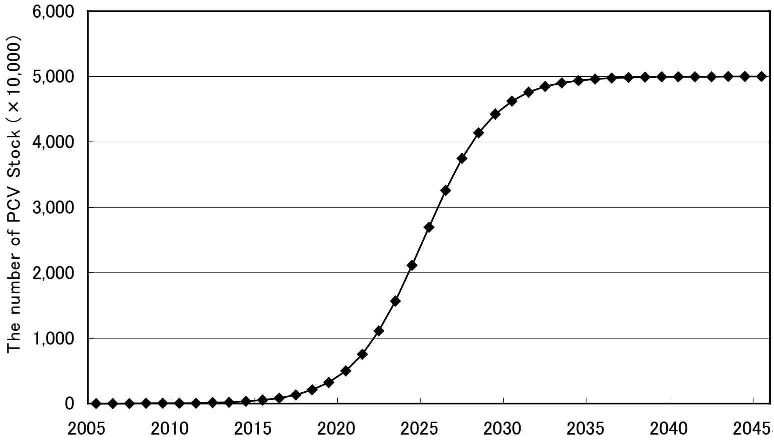

Fig. 1.2.3-1 Transition of FCV Penetration

② Table 1.2.3-1 indicates the change of the number of FCVs by vehicle kinds for each scenario with time. The data shown in the table were well adjusted to the penetration transition obtained by ① until 2020 in the scenario A, it was assumed that OBR vehicle would be introduced in accordance with the condition shown in Table1.2.3-2. The number of the OBR vehicle penetration in the scenario A would reach to more or less 2 million which was 40% or less of the whole in 2020.

Table 1.2.3-1 The number of FCVs by Vehicle Kinds for each Scenario

（Unit：×10,000）

Vehicle Type	Scenario A		Scenario B	
	2010	2020	2010	2020
Light Duty Truck	0.2	42.2	0.2	42.2
Standard-Sized Truck	0.0	5.9	0.0	5.9
Bus	0.6	3.8	0.6	3.8
Passenger Car (Pure Hydrogen)	4.1	251.1	4.1	445.8
Passenger Car (OBR)	0.0	194.7	0.0	0.0
Garbage Car	0.2	2.2	0.2	2.2
Total	5.0	499.9	5.0	499.9

Table 1.2.3-2 OBR FCV Ratio in Scenario A (to the number of Passenger FCV Stock)

2011	2020	Note
20 %	50 %	OBR FCV will increase gradually from 2011 to 2020 and will decrease after 2020.

③ Table 1.2.3-3 indicates the required number of hydrogen refueling stations for running of FCV by the station types. The number of the stations in the scenario A, which pure hydrogen and OBR FCV coexisted, was 2,300 and that value in the scenario B, which only pure hydrogen FCV was introduced, was 3,300 in 2020. The number of hydrogen refueling stations can be little in the scenario A because the OBR FCV can use existing service stations.

Table 1.2.3-3 The Required Number of Hydrogen Refueling Station by Hydrogen Supply Capacities

Supply Capacity and Conformation	Scenario A		Scenario B	
	2010	2020	2010	2020
100Nm^3/h Off-Site	56	56	56	56
300Nm^3/h Off-Site	100	463	100	580
500Nm^3/h Off-Site	13	1,201	13	1,779
500Nm^3/h On-Site	0	624	0	926
Total	169	2,344	169	3,341

④ Table1.2.3-4 indicates the initial investment cost which is the total cost for the FCV purchase and the installation of the hydrogen refueling station needed for FCV penetration until 2020. It became 950 and 1,000 billion yen respectively in the scenario A and in the scenario B. The difference between the initial investment costs in the scenario A and that in the scenario B was about 50 billion yen, however the breakdown costs were greatly different between both scenarios. The influence of the vehicle cost was larger in the scenario A because the reformer on-board was required. On the other hand the influence of installation cost of the hydrogen refueling stations was larger in scenario B.

Table1.2.3-4 The Cumulative Amount of Initial Investment Cost for FCV Introduction

（Unit：Billion Yen）

Category	Scenario A		Scenario B	
	2010	2020	2010	2020
FCV	48.1	2,93.3	48.1	74.6
Station	34.9	6,55.4	34.9	9,23.7
Total	83.0	9,48.7	83.0	9,98.3

⑤ Table 1.2.3-5 shows the amount of hydrogen demand. That value in the scenario B in which only pure hydrogen vehicle was assumed to be introduced at the market was larger by about 2 billion Nm^3/year in 2020.

Table1.2.3-5 Amount of Hydrogen Demand in accordance with FCV Introduction

（Unit：Billion Nm^3）

Scenario	2010	2020
Scenario A	0.17	4.26
Scenario B	0.17	6.17

⑥ Table1.2.3-6 shows the amount of the CO_2 emission reduction by introduction of FCV. The amounts of the CO_2 emission reduction in the scenario A and B were almost equal. LCA for fuel was performed on the assumption that hydrogen was produced from the imported fossil fuel. Primary energy imported to Japan was, therefore, the starting point and hydrogen production, supply and vehicle running (Port to Wheel) were the range of analysis. As a result, substantially difference between both scenarios was caused only by the difference of the efficiencies at running stage of the vehicle. The amount of the CO_2 emission reduction in the scenario B increased greatly if considered only running stage of a vehicle, because the amount of CO_2 emission of the pure hydrogen FCV at the running stage was zero.

Table 1.2.3-6 CO_2 Emission Reduction in Accordance with FCV Introduction

（Unit：×10,000t-C/year）

Scenario	2010	2020
Scenario A	4.5	255.1
Scenario B	4.5	260.7

⑦ Table1.2.3-7 indicates the profit and loss break-even hydrogen cost for FCV users in 2010. The hydrogen price should be 66 yen/Nm^3 or less for the users to obtain an economical advantage who substituted a pure hydrogen FCV for a conventional small gasoline passenger vehicle manufactured in 2010. However, the above-mentioned break-even hydrogen cost became 98 yen/Nm^3, if the acceleration of the FCV production by the regulation of ZEV (Zero Emission Vehicle) executed in California, U.S was supposed to give a positive effect on the vehicle manufacturing cost, because it was expected that the vehicle manufacturing cost decreased earlier.

Table 1.2.3-7 The Break-Even Hydrogen Cost for FCV Users in 2010

Scenario and Case		Hydrogen Cost （Yen/Nm^3）	Gasoline Equivalent Cost （Yen/L）
Scenario A	No ZEV Regulation	66.2	60.8
	Under ZEV Regulation	98.9	90.9
Scenario B	No ZEV Regulation	66.2	60.8
	Under ZEV Regulation	98.9	90.9

⑧ Table 1.2.3-8 shows the amount of the subsidy which should compensate the station entrepreneur's income so that they did not receive an economic loss in the business period when they sold hydrogen with the break-even price calculated in ⑦. The analysis was performed for eight cases in total because two hydrogen prime costs of the station entrepreneur were assumed for each scenario. As for the amount of the subsidy per one station, it was only about 100 million yen and was almost equal to the amount of the subsidy, 90 million yen, to the CNG station in a present eco-station business.

c) Problems to be solved concerning the introduction of FCV

There are some important problems to be solved for introduction of FCV in various

Table 1.2.3-8 The Required Subsidy for Entrepreneur of Hydrogen Refueling Station to Obtain Profit

(Unit：Billion Yen)

Scenario and Case			Total Amount of Subsidy (Accumulated Amount in 2020)	Subsidy per One Station
Scenario A	No ZEV Regulation (66¥/Nm^3) ＊1	High Prime Cost＊2	2,553	1.09
		Low Prime Cost	2,233	0.95
	Under ZEV Regulation (98¥/Nm^3)	High Prime Cost	28	0.01
		Low Prime Cost	23	0.01
Scenario B	No ZEV Regulation (66¥/Nm^3)	High Prime Cost	3,437	1.03
		Low Prime Cost	2,964	0.89
	Under ZEV Regulation (98¥/Nm^3)	High Prime Cost	28	0.01
		Low Prime Cost	23	0.01

Note ＊1 Hydrogen sales price is indicated in parentheses.
＊2 High Prime cost is 43.6¥/Nm^3 and low prime cost is 40.0¥/Nm^3.

aspects; technology, finance, legislation and scenario planning.

◇ Technology

・Hydrogen on-board storage technology of pure hydrogen FCV. Development and improvement of on-board reforming technology.

・Improvement of running efficiency of FCV

◇ Finance and Legislation

・Deregulation and technical standard for hydrogen production facilities and hydrogen refueling station.

・Acceleration of investment to FCV production facilities by automobile companies.

◇ Scenario Planning

・Clarification of possibility of cost reduction of hydrogen refueling station

・Review and clarification of the types and kinds of FCV

・Promotion policy and management of progress for both vehicle side and station side.

・Arrangement of contributory information for selection of an adequate and optimal pass covering primary energy of hydrogen source, hydrogen production, transportation, storage, utilization (running).

(2) Study of introduction scenario of stationary fuel cell systems

For making the introduction scenario of the stationary fuel cells, the heat and mass balance was examined based on a basic system flow and the characteristics of FC performance, such as efficiencies, economical and environmental benefits in various operation modes were evaluated based on the examination results on heat mass balance. Additionally, an image of the stationary fuel cell systems introduced into household sector was drawn and types of business in which the introduction of fuel cell systems could be expected to bring about economical and environmental benefits were summarized.

In the stationary fuel cell system which used hydrogen from city gas, the net power generation efficiency (AC edge, auxiliary power considered) was about 30% (HHV), the heat recovery efficiency was about 30% and the overall thermal efficiency was approximately 60% in the case of 50% fuel cell stack efficiency. The efficiency of a fuel cell system was evaluated using fuel cell stack efficiency, steam/carbon ratio, the inverter efficiency and so on as parameters. As a result, net power generation efficiency improved by 3.3% in accordance with an improvement of the fuel cell stack efficiency by 5%. However, the overall thermal efficiency including heat recovery hardly changed. It was found to be necessary to recover the latent heat in an exhaust gas for the improvement of heat recovery efficiency. In the stationary fuel cell systems, for which pure hydrogen was supplied, the net power generation efficiency (AC edge, auxiliary power considered) was about 41% and the overall thermal efficiency was 70% in the case of 50% fuel cell stack efficiency. If hydrogen was assumed to be produced from city gas and delivered, the net power generation efficiency and the overall thermal efficiency turned out to be about 25% and 42 %, respectively.

From an evaluation result for various operating patterns of the fuel cell system, it became clear that an operating pattern mainly for electric power supply was effective for the fuel cell system with hot water tank. Power generation beyond the heat demand for hot-water supply was ineffective, and further, even with the same gross thermal efficiency, economical benefit was superior in the case that power generation efficiency was high. Fig.1.2.3-2 indicates the relation between city gas price and retrenchment amount of utility expense for each efficiencies of a household fuel cell system. For obtaining an economical benefit from introduction of a fuel cell system, it was expected that the system efficiency of the fuel cell became higher and city gas price became lower.

The city gas was used in 50% of total personal residences, and LPG was used in the remainder. As for LPG, the fuel price was high and much economic benefit can not be expected by the fuel cell introduction. On the other hand, the fuel cell fueled by kerosene was the most excellent for the economy. It was thought that the stationary fuel cells in household would be introduced and penetrated mainly to the region where city gas grid of 13A and 12A is provided from the point of vies economical and environmental benefit. The number of personal houses of three people family or

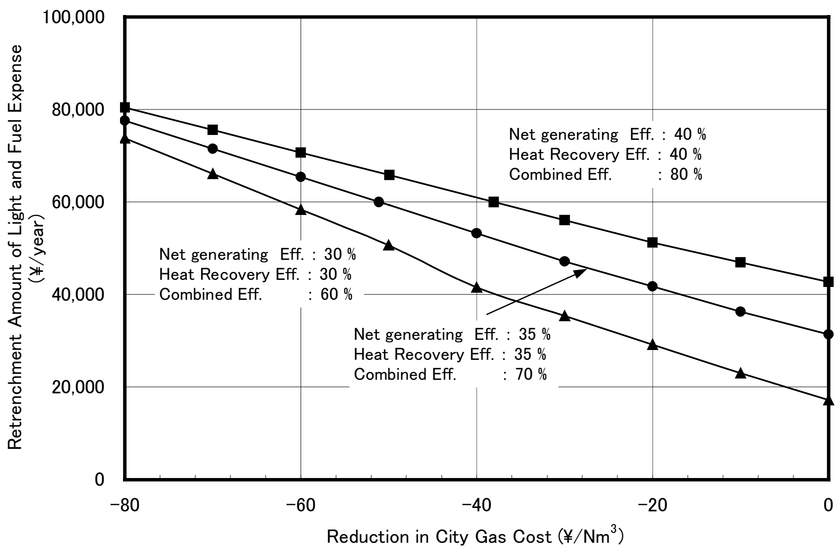

Fig.1.2.3-2 Relation between City Gas Cost and Retrenchment Amount of Utility Expense for each Fuel cell System Efficiency in Household

more was about 8.67 million in the large megalopolis area where city gas grid was provided, and when introducing a fuel cell of 1kW capacity into these houses, 5.7 million kW of the target in 2020 corresponded to about 66%. Especially, the introduction in the Keihinyou region, the Keihanshin region and the Chykyo region could be expected. As about half of total number of personal houses in Japan was supplied with city gas other than 13A and 12A, LPG and kerosene, it was expected that the introduction region of the fuel cell system expanded as fuel price of LPG became cheaper. Additionally, the introduction and the penetration of the fuel cell systems fueled by pure hydrogen and that kerosene reforming was also expected in these regions.

The energy consumption in the business sector was investigated and the type of business, for which fuel cell systems were expected to be introduced, was summarized. The introduction could be expected in restaurant, preschool, hotel, inn, hospital, welfare institution, hair and beauty salon, laundry, fitness club and so on. The possible generation capacity of fuel cell systems was found to be about 5.8 million kW by a simple trial calculation and 4.4 million kW of the target in 2020 corresponds to about 75%.

Although the data, such as efficiency, economical and environmental benefits and so on were collected and examined an evaluation of the introduction time, the introduction scale and demand and supply scale including construction of the infrastructure and so on was not concretely executed in this fiscal year. An examination with consideration of the momentary load fluctuation and the partial load efficiency was also not performed. The data will be collected and arranged in the following fiscal year. On the other hand, a technology validation project of stationary fuel cell systems is now planned by Fuel Cell Commercialization Conference of Japan (FCCJ). A concrete introduction scenario will be planned based on FCCJ's data. As for business use of fuel cell systems, it is necessary to collect data, such as business type, scale (total floor space) and load factor of each business sector and introduction region. After then, an evaluation of an optimum fuel cell capacity, economical and environment benefit for business use will be performed.

(3) Making of hydrogen energy penetration scenario with a long-term perspective

For the purpose of estimation of the target amount of hydrogen energy introduced in Japan, the following studies were conducted in this FY.

a) Cost competitiveness of hydrogen energy in the future was evaluated using a long-term demand and supply model.

b) The hydrogen demand in Japan was estimated.

c) A target amount of hydrogen introduction was evaluated.

Additionally, as an approach from the technological aspect, the examination results of optimization model were investigated and the work frame of the hydrogen introduction scenario planning was examined.

In the analysis by the long-term energy model, the amount of the resource of conventional and non-conventional fossil fuel and renewable energy were investigated, and "Super-long-term energy demand and supply model" was constructed, which could analyze the energy demand and supply in the world and so on logically, adjusting, and quantitatively. And the possibility of the economy, demand and supply was examined about the hydrogen energy of the renewable energy origin.

To achieve the above-mentioned purpose, four scenarios of ①BAU (business as usual) case, ②energy saving promotion case, ③hydrogen introduction promotion case, and ④energy saving and the hydrogen introduction promotion case were set. The economic indicator, energy prices, the final energy demand and the composition of primary energy supply (hydrogen introduction time of the renewable energy origin, the introduction amount and so on) and CO_2 emission reduction were provisionally calculated by various regions in the world and the time series.

Fig. 1.2.3-3 shows the result of energy saving and hydrogen introduction promotion case and it indicated that the primary energy consumption increased from 9 billion tons oil equivalent to 20.7 billion tons oil equivalent in the world.. The share of renewable energy as the hydrogen source increased to 49.5% along with the introduction of the hydrogen energy and the subsequent market extension.

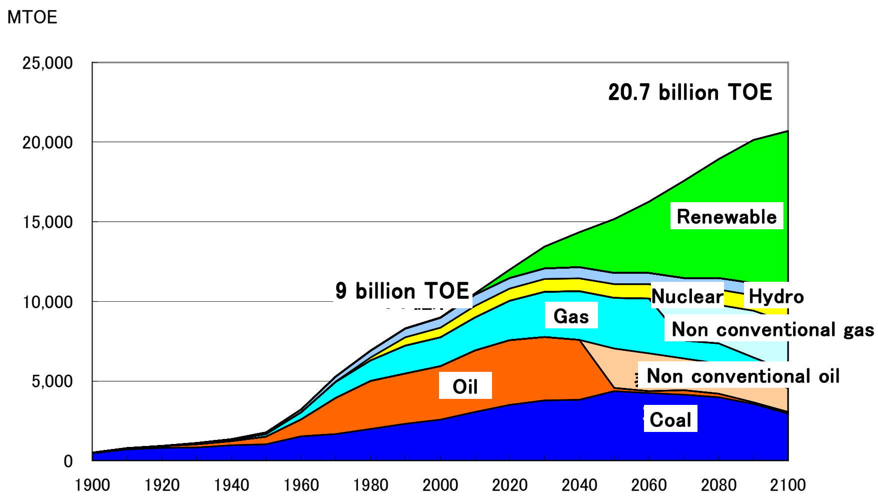

Fig.1.2.3-3 The amount of primary energy supply
(Energy saving and hydrogen introduction promotion case

The amount of the hydrogen energy, which occupied in the final energy demand, in this case was that about 200 million tons oil equivalent began to be introduced from 2020, 1,700 tons oil equivalent in 2050 whose shared was 16.7% (4.2% in BAU case), and 4,900 million tons oil equivalent were introduced in 2100 which occupied the share by 37.2% (11.8% in BAU case).

If cost reduction was achieved by the investment to research and development, technological progress and the scale advantage advancing from the prospect of fuel cell systems, the introduction to the market of hydrogen energy was accelerated from the first half of 21st and had a possibility of becoming one of the main.

1.3 Subject in Future

The introduction scenario of the fuel cell vehicle was made on the assumption of the target penetration values indicated by The Advisory Panel for Commercialization of The Fuel Cell in this FY. And as for making the introduction scenario of the stationary fuel cell, the base data for the scenario planning were examined and assembled. From now on, the brush-up of the scenario will be done together with improvement of accuracy of the examination. It is necessary to make the introduction and penetration scenario of the hydrogen energy, which covers from the fuel cell introduction to the subsequent realization of the hydrogen energy society in the future.

For making of the introduction scenario of the fuel cell vehicle, the scenario is to be high probable by reviewing of the introduction amounts and by examining the following items;

- The penetration of the fuel cell depends on the system cost of fuel cell and hydrogen cost. The accuracy of the estimation of the future cost is to be improved by the brush-up of results of this FY.
- The fuel and the energy route, which will well fit to the fuel cell vehicles, will be selected. For this purpose, as for the hydrogen fuel cell vehicle, liquid hydrogen and metal hydride will be examined and the future costs of the hydrogen fuel cell vehicle will be analyzed according to the fuel tank types of hydrogen.
- For the hydrogen fuel cell vehicle, the way of construction of the infrastructure with an eye to the future will be made as a scenario based on the analysis of the characteristic of the on-site and the off-site hydrogen refueling stations.

For making of a introduction scenario of the stationary fuel cell, the efficiency, economical and environmental benefits were examined, However, the introduction scenario is on the way of planning at present. The prediction of a system cost and a introduction scenario will be made in accordance with the following studies;

- For examination of the possibility of the fuel cell introduction to the region except for the regions where city gas grid of 13A and 12A is provided, applicability to the fuel cell of 6A, 6B, 6C and so on will be evaluated.
- For examination of the stationary fuel cell economy, the operating conditions in accordance with weather condition in various locations will be designed and the relationship between the operation condition and economy will be estimated. Especially as for business use, the relationship of optimum fuel cell generation capacity to various flour area of each business category and economy will be clarified.

For planning of the hydrogen energy penetration scenario, hydrogen produced from fossil fuel will be combined with the economical simulation model used in this FY. The sources of hydrogen production will be diversified. More realistic hydrogen demand will be examined and the hydrogen energy penetration scenario including a fuel cell introduction scenario will be reinforced. Additionally, hydrogen technologies of high cost performance searched by an optimization energy model, and technical specifications of the scenario will be examined, and a technical road map of the development of hydrogen technologies will be made.

As for LCA of candidate systems, the analysis of gross energy efficiency will be performed for the vehicles and the result will be applied to the fuel choice. The energy efficiencies of hydrogen energy systems including fuel cell are examined continuously for more accurate and precise evaluation.