Stationary Fuel Cell Programme in Japan

IEA EGRD Workshop

– Transforming Innovation into Realistic Market Implementation Programmes –

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International Energy Agency, Paris

Makoto Akai

National Institute of Advanced Industrial Science and Technology

Background

Fuel Cell/Hydrogen Technology in Government Policies

- Science and Technology Basic Plan (Mar. 2006)
- New National Energy Strategy (May 2006)
- Basic Energy Plan (Mar. 2007)
- Next-Generation Automobile Fuel Initiative (May 2007)
- Cool Earth – Innovative Energy Technology (Mar. 2008)

- Hatoyama Initiative (22 Sep. 2009)
  - Japan will aim to reduce its emissions by 25% by 2020, if compared to the 1990 level." Statement by Prime Minister Yukio Hatoyama at UN Summit on Climate Change
- Press Conference by PM Yukio Hatoyama following meetings at the UN and the Pittsburgh G20 Summit
  - Needless to say, solar panels, fuel cells and various other types of green technology need to be mobilized. Hydrogen energy is also likely to become available in the future.

21 Key Innovative Energy Technologies

	Efficiency improvement	***Low carbon technologies***
	Oil LNG Coal	Nuclear Power Biomass Solar Wind

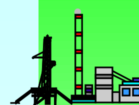
Supply side

Electric Power

Efficient coal-fired power plant

Efficient LNG-fired power plants

CCS



Innovative solar power

Advanced nuclear power

Superconducting power transmission

Demand side

Transport

ITS

FCV

PHEV/EV

Biofuel

Industry

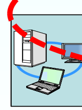
Innovative materials/ manufacturing process

Steel making process with Hydrogen

Residences/ Buildings

Efficient houses/buildings

Efficient lighting



Fuel Cell for residential use

Efficient Heat pumps

Efficient IT devices/networks

HEMS/BEMS/Regional EMS

Cross sectroral

Power storage

Power electronics

Hydrogen production/storage/ transport

CCS (restated)

Framework for R&D of Hydrogen and Fuel Cells under METI

METI
(Hydrogen & Fuel Cell Promotion Office) ↔ **Other Ministries**

↓ **Funding**

NEDO (New Energy and Industrial Technology Development Organization)

{ **PEFC programs, SOFC programs, hydrogen storage materials program, hydrogen science project, JHFC project** }

↓ **Funding, operation & management**

Universities, Private companies, National lab, etc.

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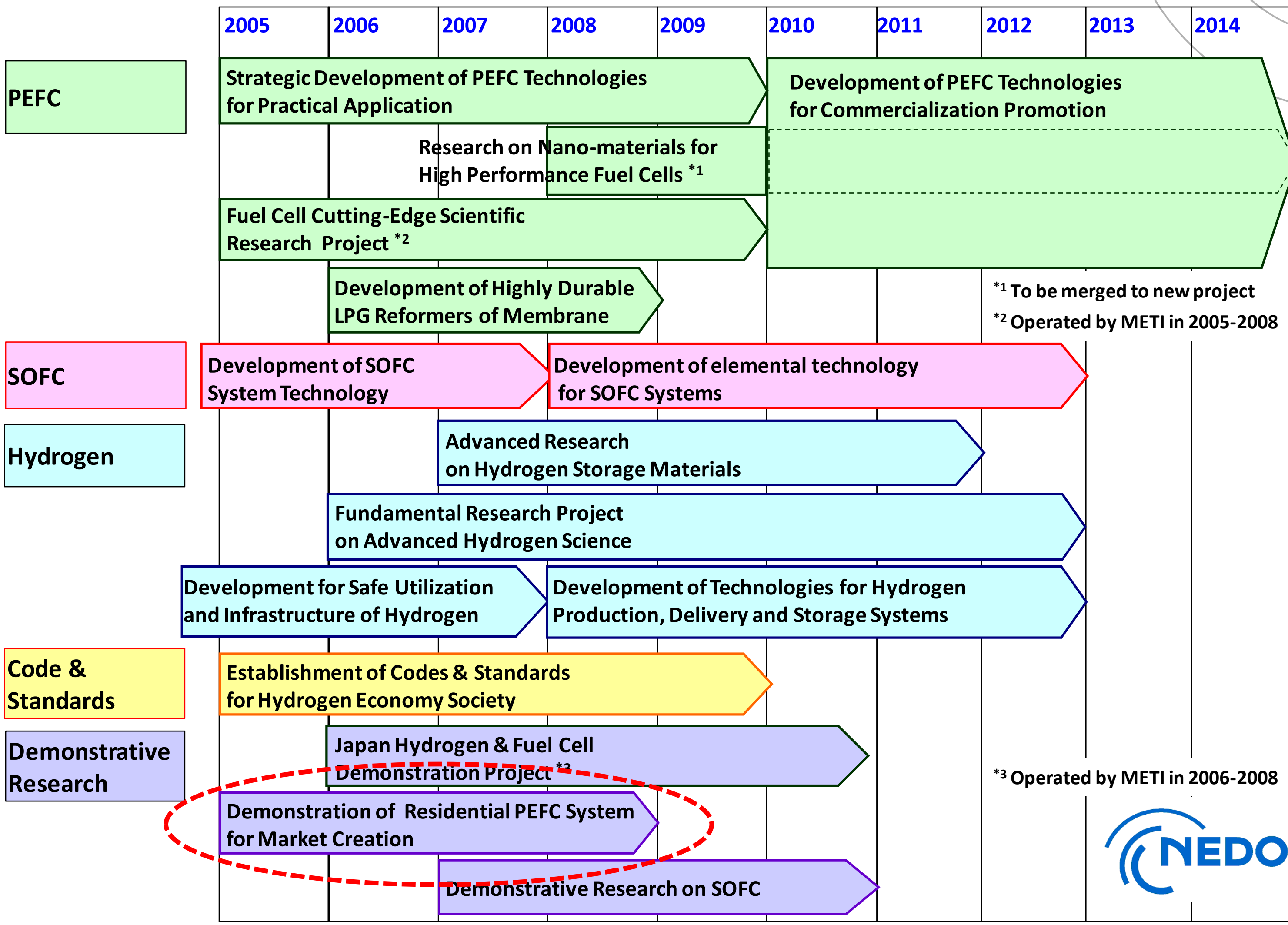
R&D on Fuel Cell and Hydrogen Technologies by NEDO



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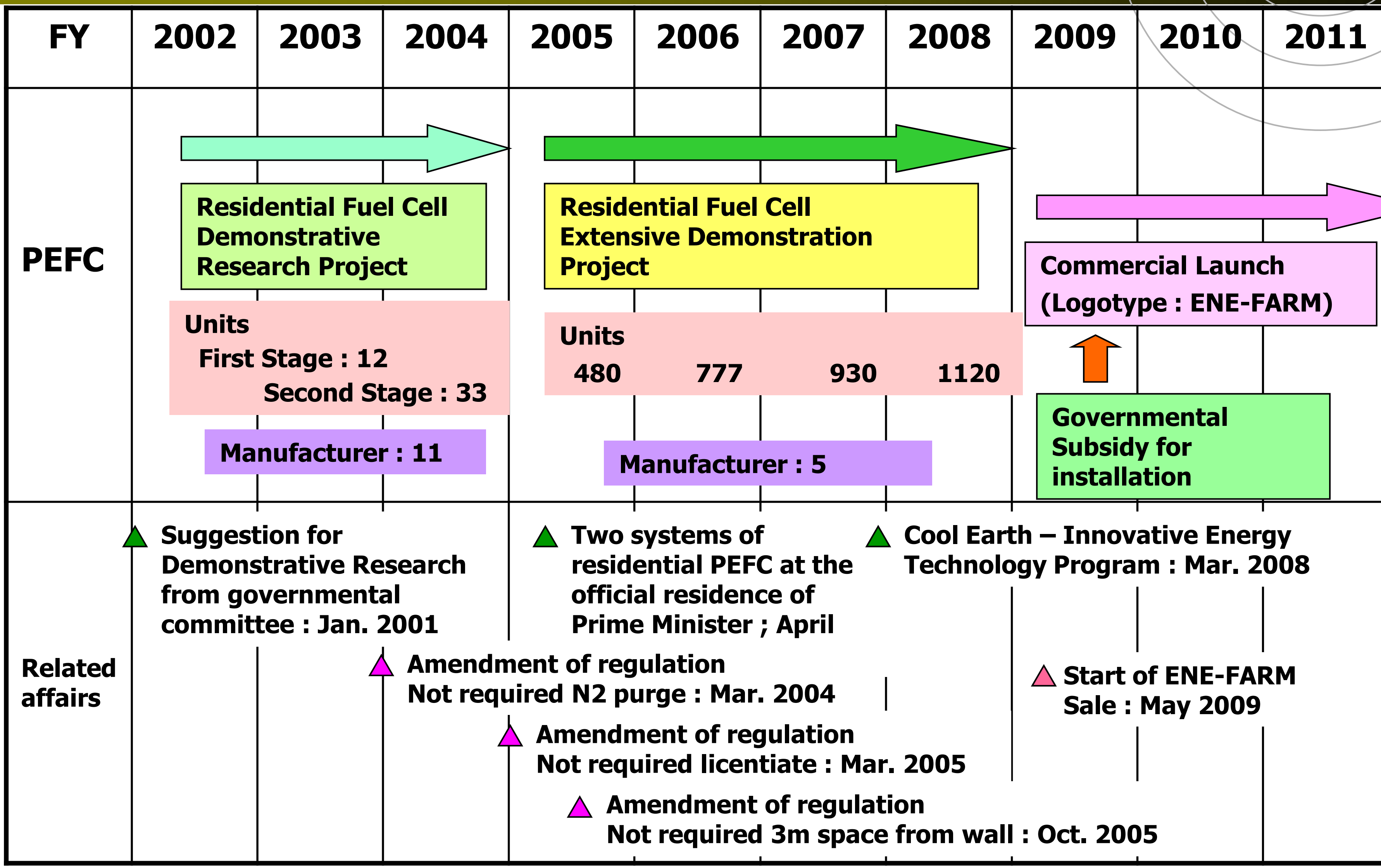
Residential PEFC
Extensive Demonstration Project

Steps of the Fuel Cell Demonstration Projects



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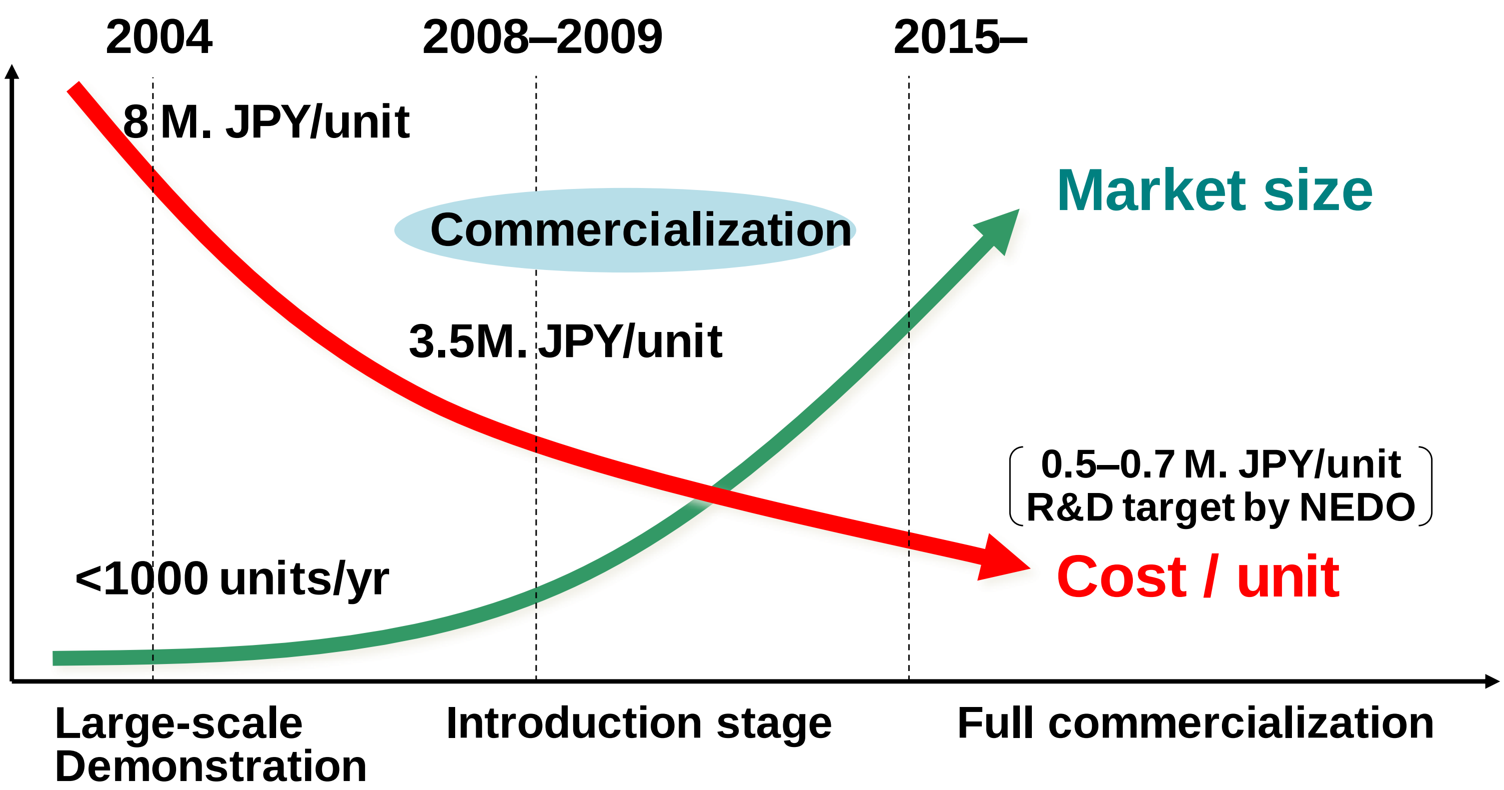
Scenario of Market Creation for Residential Full Cell

Large-scale Demonstration project → Market creation by government support (subsidization) → Full commercialization self sustained and growing market



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Residential PEFC Extensive Demonstration Project

Term of the Project : FY2005 ～ FY2008 (for 4 years)

(in FY2009, no additional installation but continuing data acquisition)

System : 1kW class PEFC cogeneration system for residential use

- Installation of stationary PEFC cogeneration system for residential use at many individual houses
- To accumulate and analyze the actual operation data

↓

Determining and solving the technological problems of residential PEFC system for commercialization

Improvement of cost reduction & pre-mass production

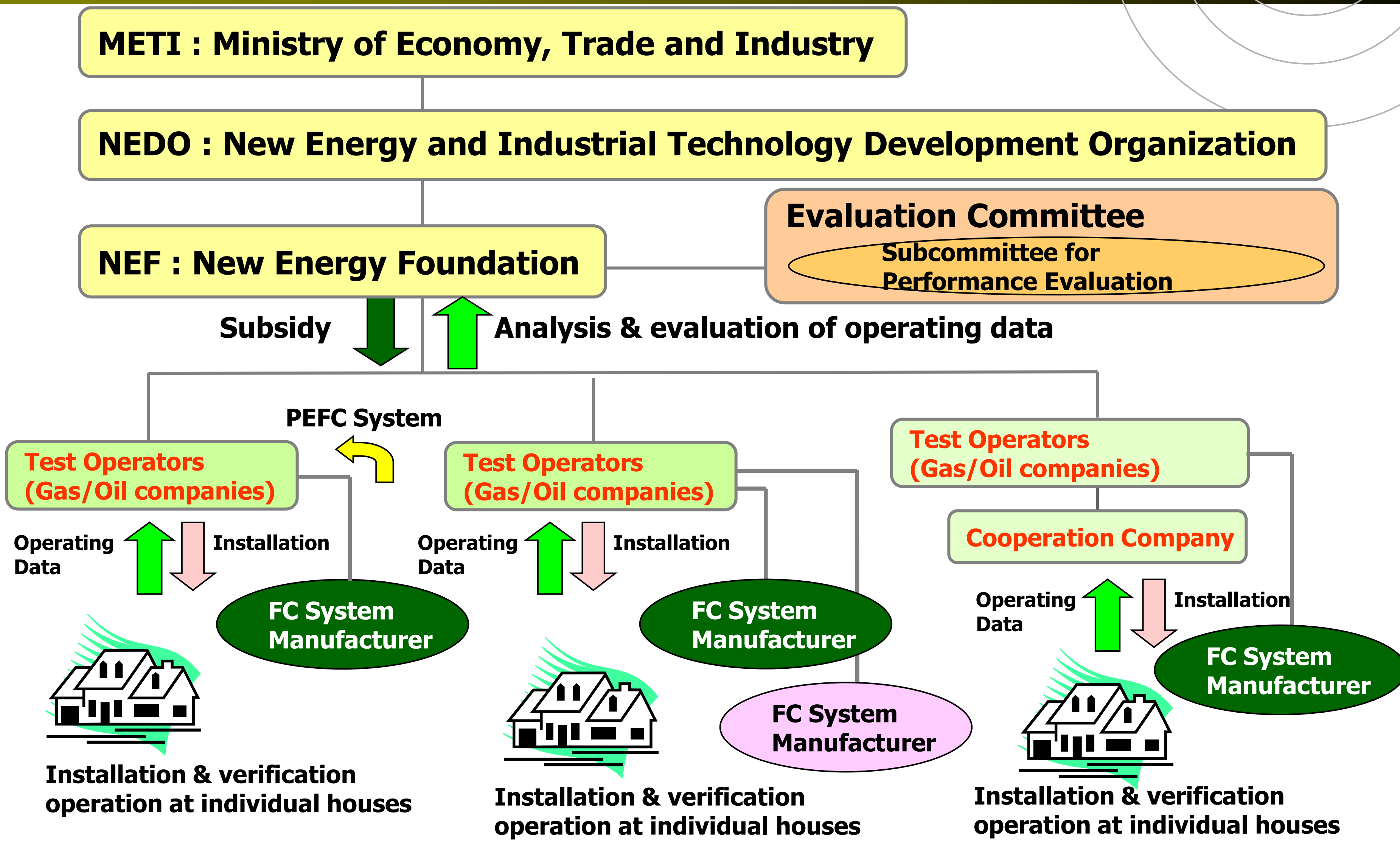
Improvement of durability & reliability

Improvement of public recognition

↓

To expedite the commercialization of residential PEFC system and to establish the early entry market

Scheme of the Project



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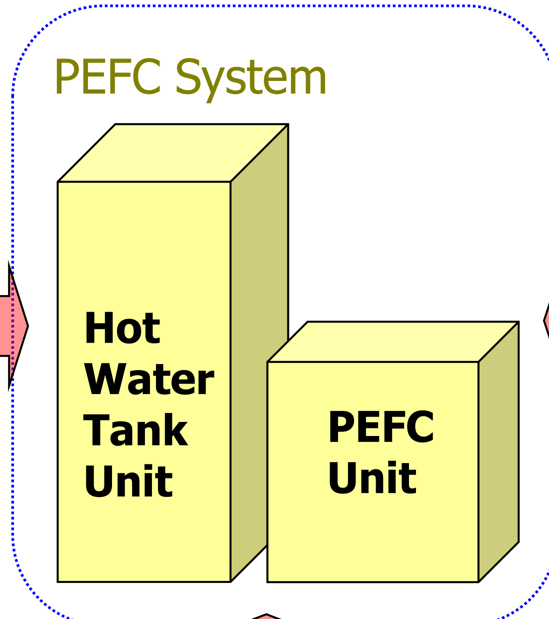
Requirements for the System

1kW class PEFC cogeneration system for residential installation

[Efficiencies (%HHV)]

	Electrical Efficiency	Overall Efficiency
Rated	30	65
Half load operation	27	54

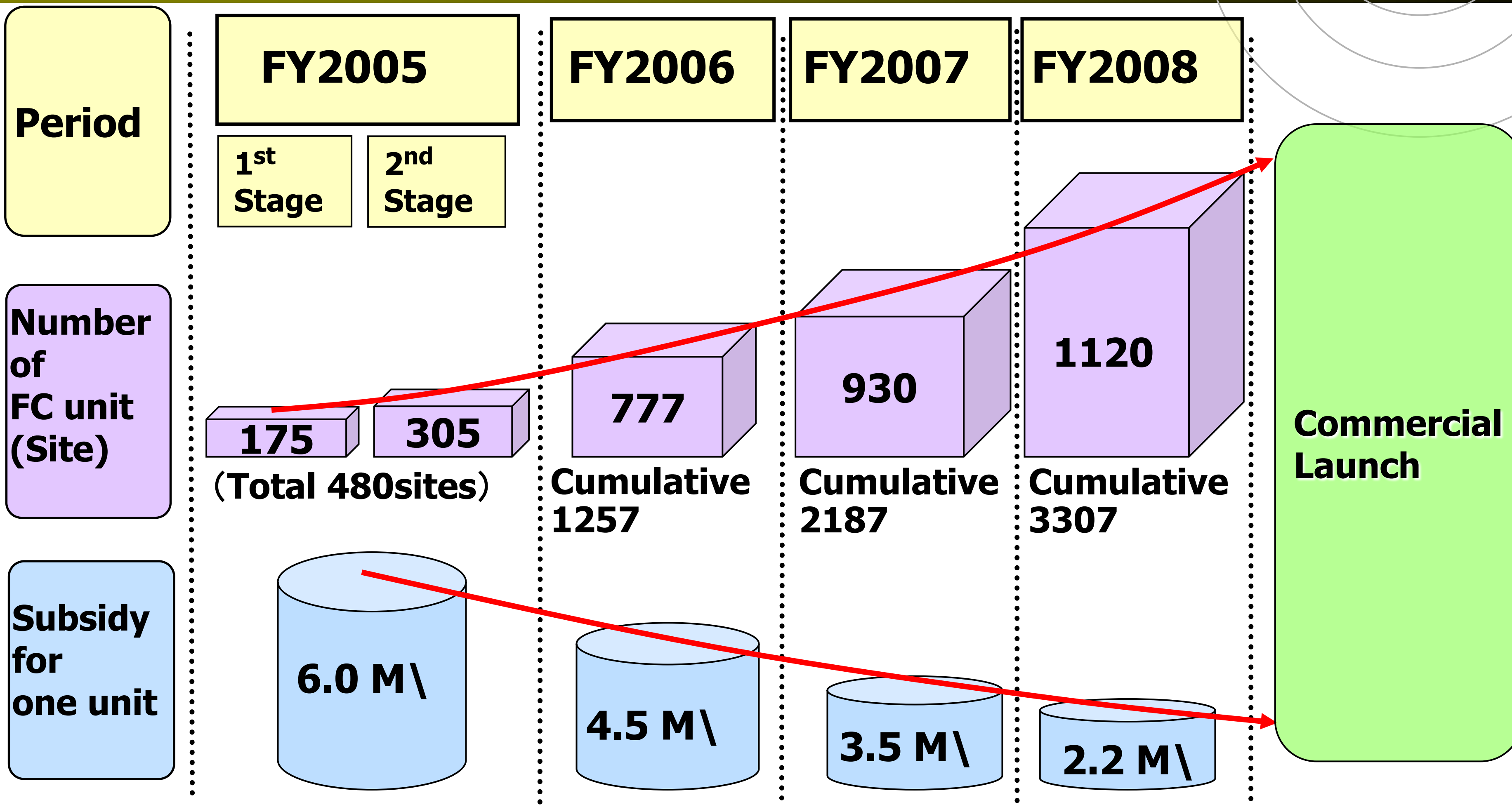
＊2% lower efficiency is allowable for kerosene fuel



[System Durability]
- Over 2 years operation

[Requirement to the manufacturers]
- Over 30 units must be supplied per every year
  (Cost reduction, improvement of the reliability, etc. are expected)

Number of the PEFC Units and Subsidy for Installation



Subsidy for the installation of one unit has been dropped every year, in accordance with the progress of the cost reduction.

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Number of Units Installed in the Project

Energy Supplier	Fuel	FY2005	FY2006	FY2007	FY2008	Total
Tokyo Gas	City Gas	150	160	210	276	796
Osaka Gas	City Gas	63	80	81	141	365
Toho Gas	City Gas	12	40	38	34	124
Saibu Gas	City Gas	10	10	13	10	43
Hokkaido Gas	City Gas	-	10	10	5	25
Nippon Gas	LPG／ City Gas	-	10	10	10	30
Nippon Oil	LPG ／Kerosene／ City Gas	134	301	396	497	1328
Idemitsu Kosan	LPG	33	40	50	28	151
Japan Energy	LPG	30	40	34	40	144
Iwatani Int'l	LPG	10	34	29	10	83
Cosmo Oil	LPG ／ Kerosene	10	19	19	18	66
Taiyo Oil	LPG ／ City Gas	8	13	18	11	50
Kyusyu Oil*	LPG	8	10	12	10	40
Showa Shell Sekiyu	LPG	6	10	10	10	36
Lemon Gas	LPG	6	-	-	-	6
Eneurge	LPG	-	-	-	10	10
Saisan	LPG ／ City Gas	-	-	-	10	10
Total		480	777	930	1120	3307

*Kyusyu Oil merged Nippon Oil in October, 2008

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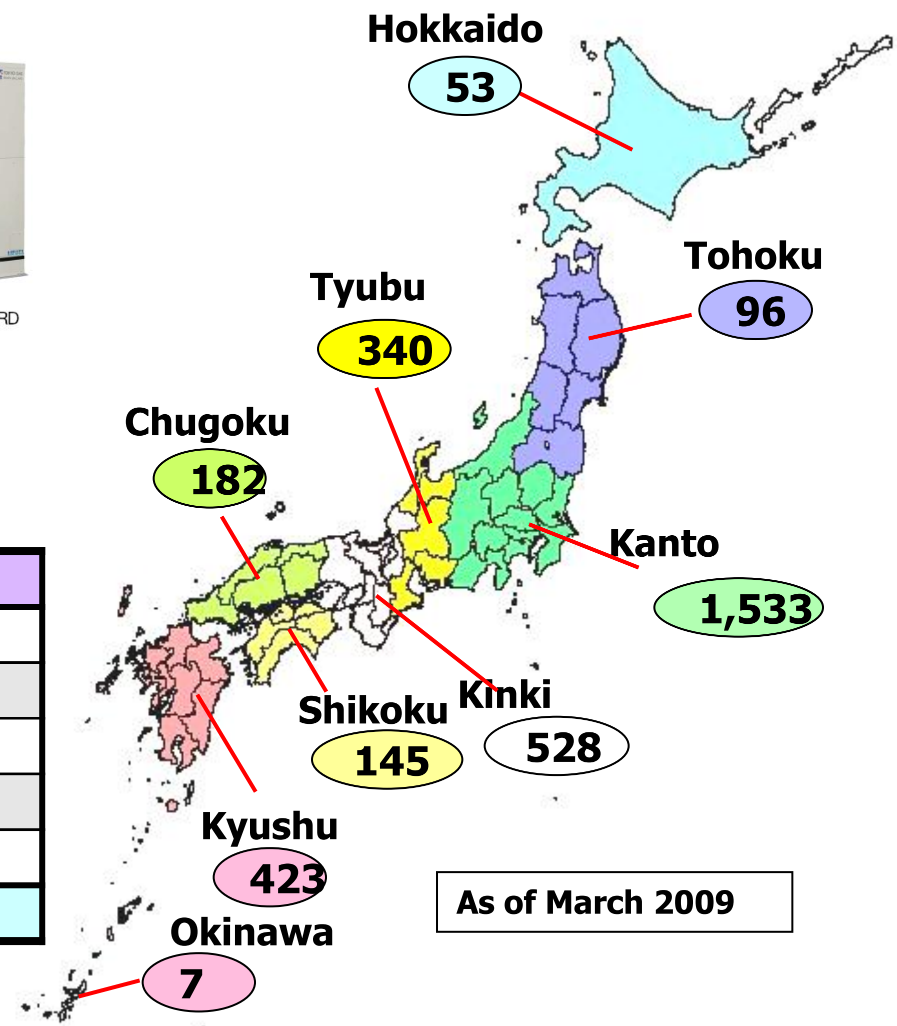
PEFC Systems Provided for the Project

Manufacturer	LPG	City Gas	Kerosene	Total
ENEOS Celltech	1,062	191	0	1,253
Ebara Ballard	0	396	314	710
Toshiba FCP	552	196	0	748
Panasonic	0	520	0	520
Toyota	0	76	0	76
Total	1,614	1,379	314	3,307



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Specification of Demo. Units in FY2008
5 manufacturer; 8 types

Manufacturer	Fuel	Output	HW Tank	HW Temp.
Panasonic	City Gas	1000 W	200 Liter	60 °C
Toshiba FCP	City Gas LPG	700 W 700 W	200 Liter 200 Liter	60 °C 60 °C
ENEOS Celltech	City Gas LPG	750 W 750 W	200 Liter 200 Liter	60 °C 60 °C
Ebara Ballard	City Gas Kerosene (lower sulfur)	1000 W 900 W	200 Liter 200 Liter	60 °C 60 °C
Toyota	City Gas	1000 W	200 Liter	60 °C

	Electrical Efficiency	Total Efficiency
City Gas	36～38% LHV（33～35% HHV）	86～93% LHV（78～85% HHV）
LPG	34～36% LHV（31～32% HHV）	84% LHV（76% HHV）
Kerosene	33% LHV （31% HHV）	84% LHV（78% HHV）

	Unit Size	Weight (Dry)
FC unit	W 600～900 ×D 300～500 ×H 860～960 mm	100～148 kg
HW tank unit	W 750～800 ×D 440～500 ×H 1840～1900 mm	95～140 kg

Function：Full Automatic operation following electrical load with reflection of learning the load pattern in each house、equipped back-up burner for hot water supply

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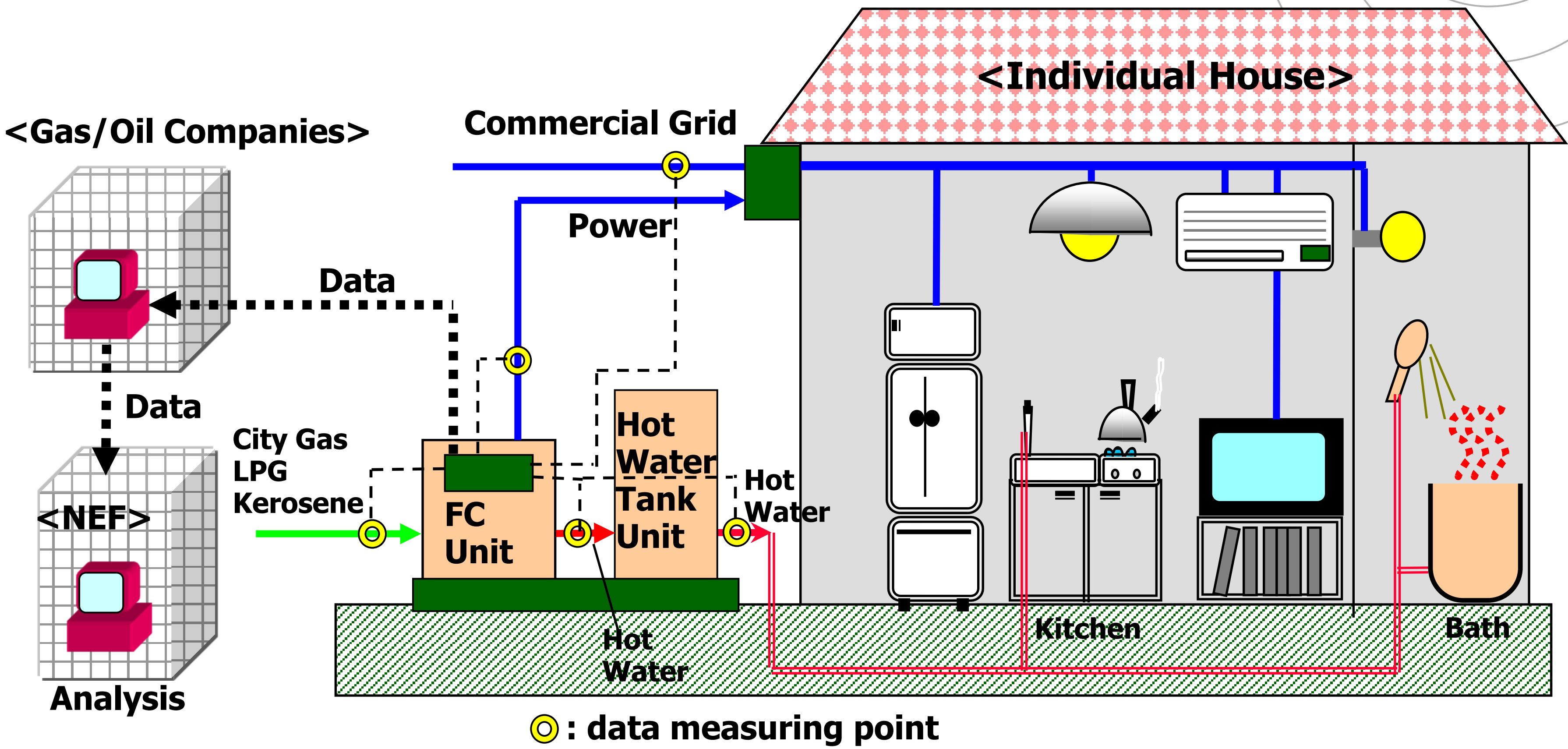
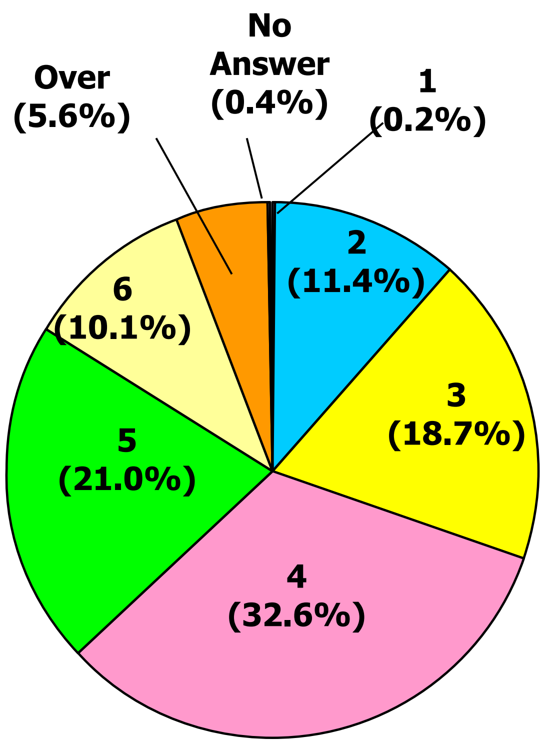
PEFC Installation and Data Collection



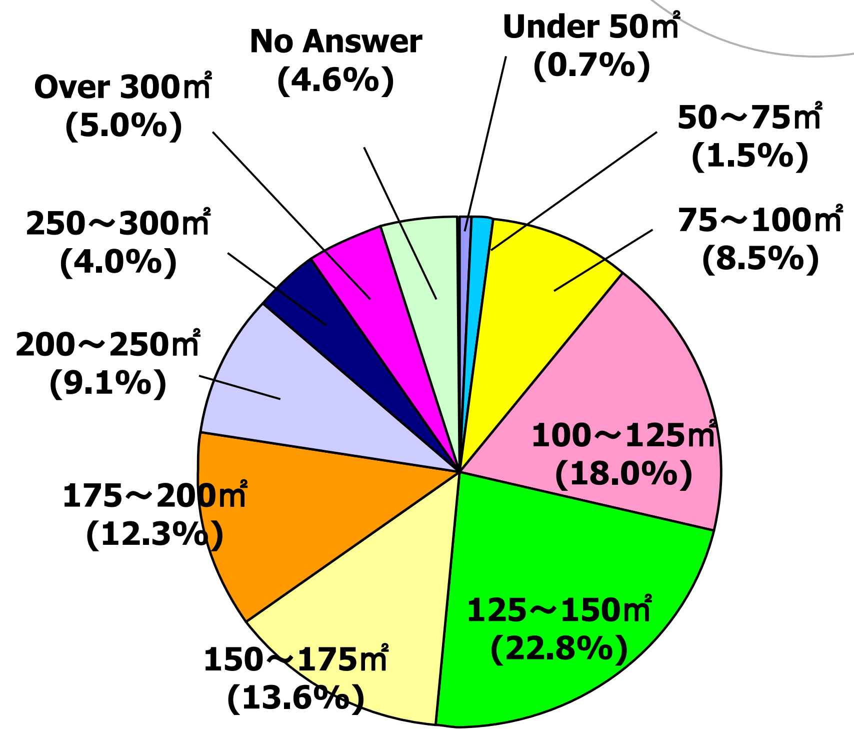
Power output of the PEFC system is controlled in accordance with the electrical demand change at each house. Since the output cable is connected to the utility grid, when the electricity demand exceeds the PEFC rated power, grid electricity fills the gap.

Distribution of the Family Size and Living Space (FY2006 Installation Sites)

Family Size
(number of people)



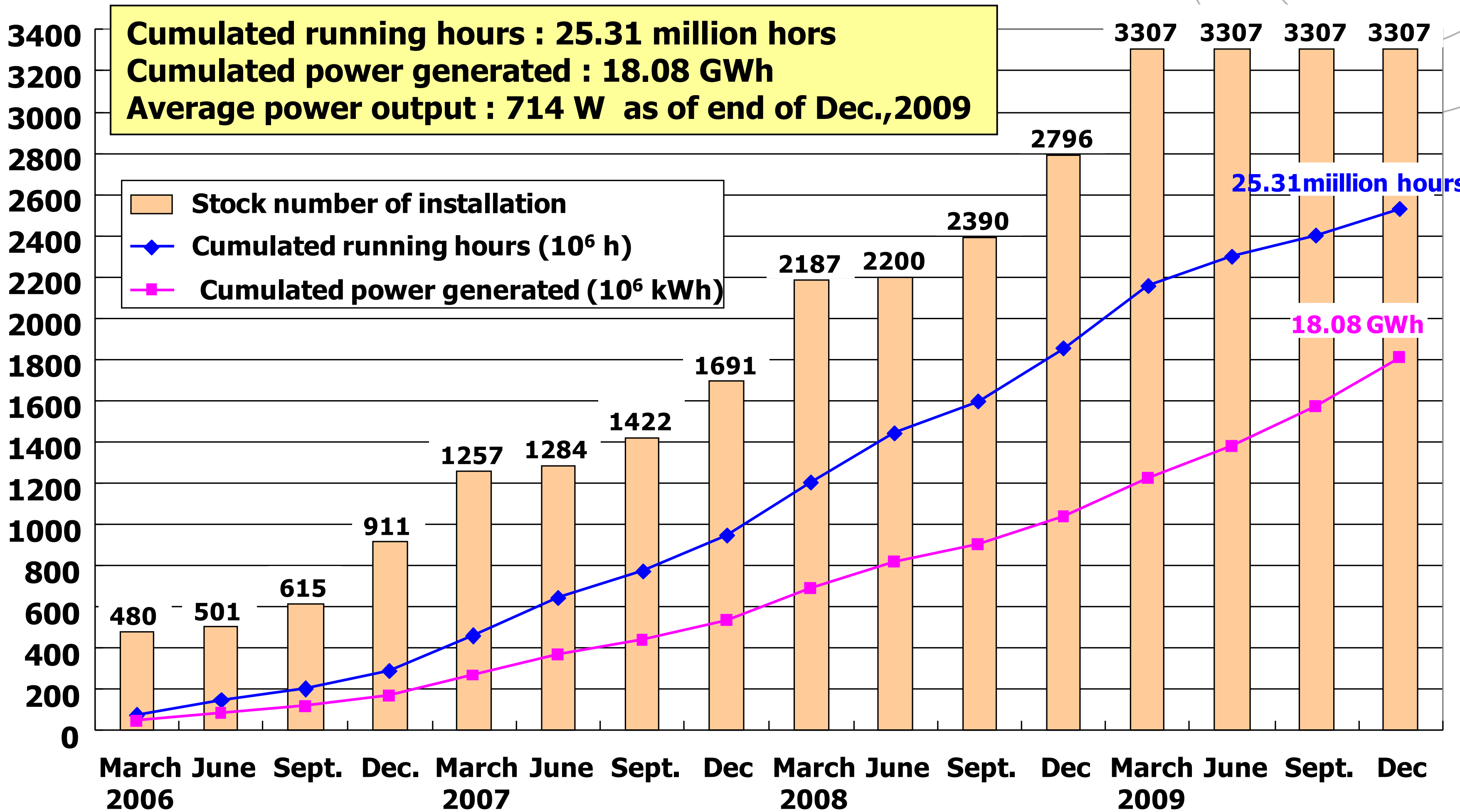
Living Space (m²)



PEFC systems have been installed and operated at a variety of homes. Average family is sized from 3 to 5 persons and living in the house of floor area from 100 to 200 m².

Results of the Project

Accumulated Running Experience



No accident to hurt person & damage surrounding objects happened and verified the safety of PEFC system, which is required for commercial equipment.

Regulations and Standardization

Establishment of codes & standards for hydrogen economy society

- **In this project, the amendment of related regulations and new standards for stationary PEFC system were established after the ensuring the system safety by certification test and evaluation techniques.**

- **The amendments of regulation which are no requiring licentiate & 3m space from wall were especially to ease the installation for individual houses and the execution of the demonstration project.**

①Amendments of electricity regulations

Mar. 2004 **Not required N2 purge**

Mar. 2005 **Not required licentiate for system supervision**

②Amendments of fire protection regulations

Oct. 2008 **Not required 3m space from the wall of house**

Addition

③Standardization (establishment of JIS ; Japanese Industrial Standard）

2008 **7 Japanese Industrial Standards were newly established for small size PEFC system for terminology, safety, testing method, etc.**

④Certification

Sept. 2007 **PEFC system certification was authorized.**

Improvement of Performance

New Energy Foundation

- Analysis of operating data
- Identification of problems
- Comparison of performance data, etc.

Operating data

Test operators

Subcommittee of Performance Evaluation

Participation of Manufacturers & test operators
- Performance data
- Discussion the characteristic of performance
- Discussion on the possible improvement

Manufacturers

Energy companies (test operators)

Improvement of components system configuration software

Refinement of operation control

Improvement of performance

The performance has been improving

	FY2005	FY2008
Electrical Efficiency (HHV)	29.4%	31.5%
Primary energy reduction	13.6%	17.1%
CO2 emission reduction	25.8%	28.9%

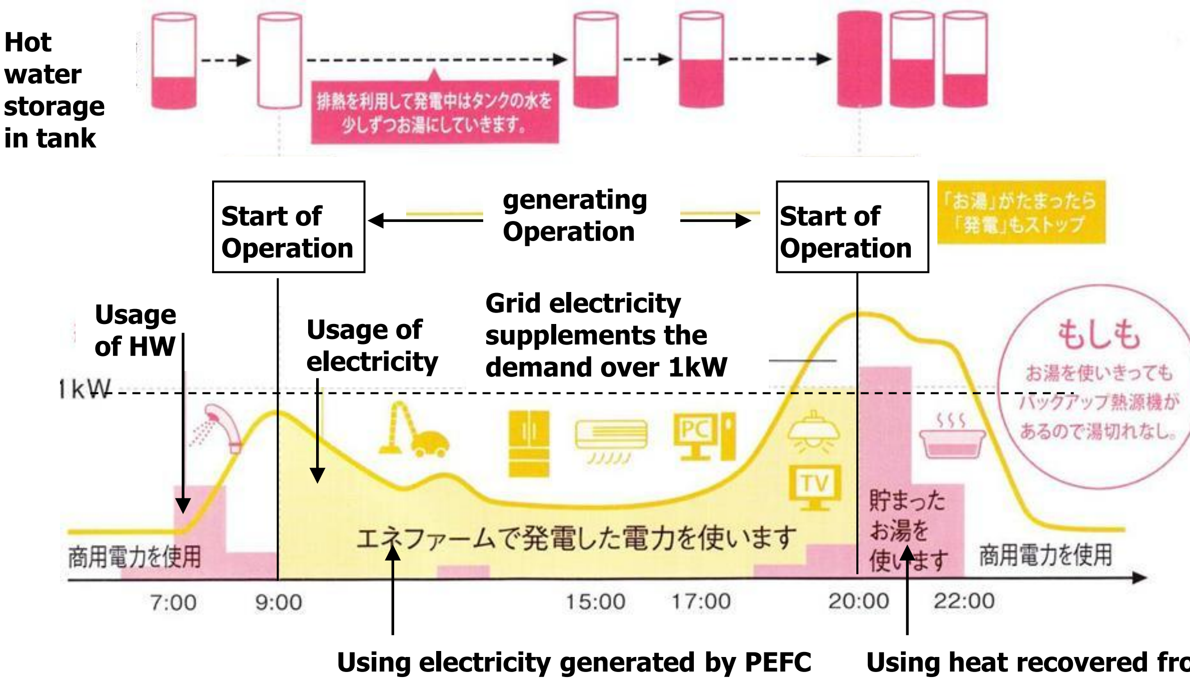
※ Comparison of annual average (NG, LPG type)

Improvement of Performance (City Gas & LPG units)

Content	FY2005		FY2006	FY2007	FY2008
Average electricity demand (kWh/month)	First stage	727	673	652	656
	Second stage	664			
Average heat (hot water) demand (MJ/month)	First stage	1870	1527	1570	1478
	Second stage	1825			
Electrical efficiency (% HHV)	First stage	29.1	30.1	31.0	31.5
	Second stage	29.4			
Electricity utilization efficiency (% HHV)	First stage	26.0	26.4	27.7	28.9
	Second stage	26.0			
Heat utilization efficiency (% HHV)	First stage	37.1	36.8	37.1	33.0
	Second stage	35.0			
Rate of primary energy reduction (%)	First stage	15.3	15.8	18.5	17.1
	Second stage	13.6			
Primary energy reduction (MJ/month/site)	First stage	601	576	693	621
	Second stage	529			
Rate of CO2 emission reduction (%)	First stage	28.0	28.0	30.8	28.9
	Second stage	25.8			
CO2 emission reduction (kg-CO2/month/site)	First stage	65.2	66.0	75.1	71.3
	Second stage	70.5			

- **Electrical efficiency has been improved year by year. Electricity utilization efficiency has been also improved with reflection of learning the load pattern in each house.**
- **Heat utilization efficiency, primary energy reduction and CO2 emission reduction are largely affected by hot water demand of each site. These indexes have been also improved.**
- **Eliciting the technological subjects and the feedback for them caused the improvement of system performance.**

Improvement of Operating Control



Fundamental operating pattern
DSS（Daily Start & Stop）

- **Following electricity demand in each house**
- **Stop operation when hot water tank becomes full**

Evaluation & analysis of operating data

→

Memorizing the demand & supply of electricity & hot water, the control sequence has been refined for the most effective operation

Customer's opinion has also incorporated about the monitor & remote controller.

→

Establishment of full automatic system control with learning operation pattern.

This automatic control contributes the larger reduction of primary energy and user friendly applicability.

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Social Benefits

Data of the most effective type in FY2008 models through Jan. to Dec. in 2009

Reduction of primary energy:
12,230 MJ/year
(23% lower than conventional system)

Reduction of CO_2 emission:
1,330 kg-CO_2/year
(38% lower than conventional system)

↓

Approx. 1,000 MJ primary energy reduction and approx. 100kg CO_2 emission reduction per month & site are expected.

- Primary energy reduction → Reservation of fissile fuel resources & cheaper expenses
- CO_2 emission reduction → Prevention of global warming

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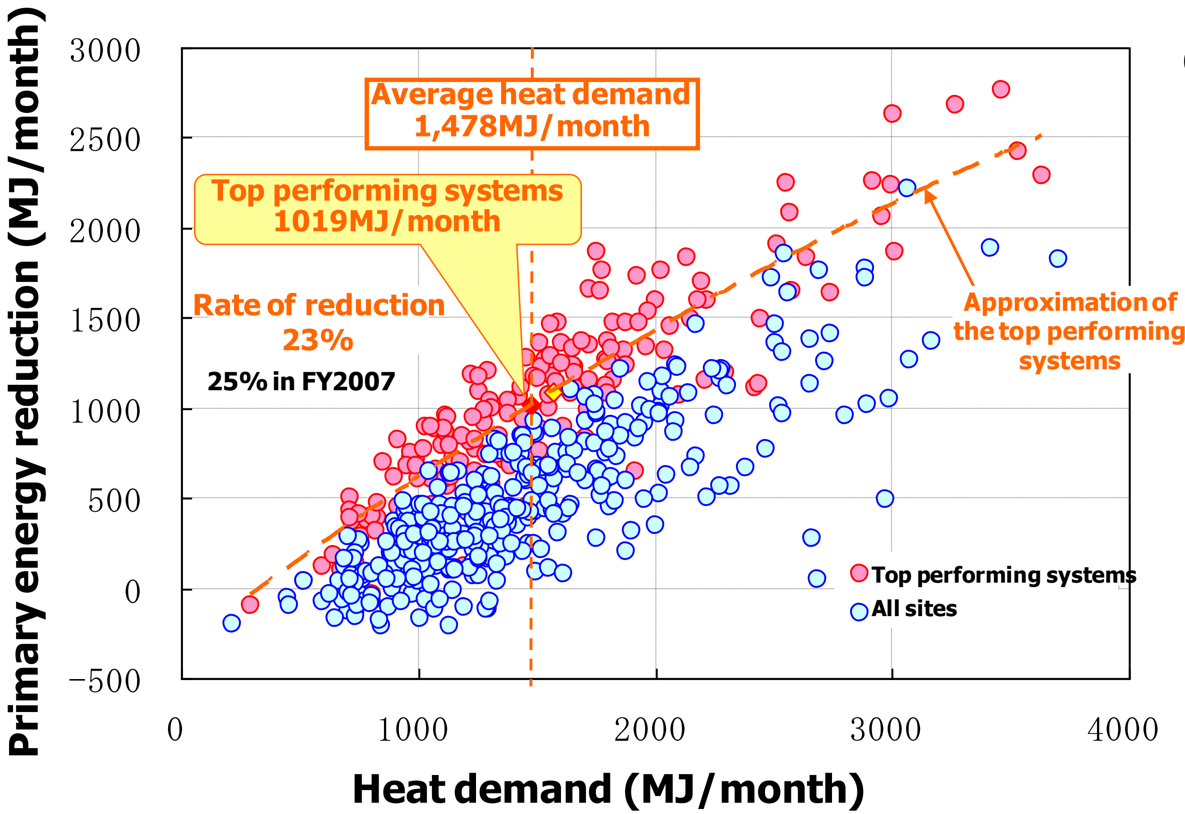
Verification of the effect of residential PEFC cogeneration system

Primary Energy Reduction

One year operation data from Jan. 2009 to Dec. 2009; 523 sites of FY2008 installation; NG & LPG fueled



Primary energy reduction
(Top performing systems)
12,230MJ/year
Equivalent to

* Heating value of kerosene is 36.7MJ/ℓ

- Primary energy reduction characteristics is deeply affected by the heat demand. Top performing systems at FY2008 installation reduced 1019 MJ/month, which is equivalent to the heating value of 330 liters kerosene. Average primary energy reduction for all system is 621MJ/month, equivalent to 203liters kerosene.

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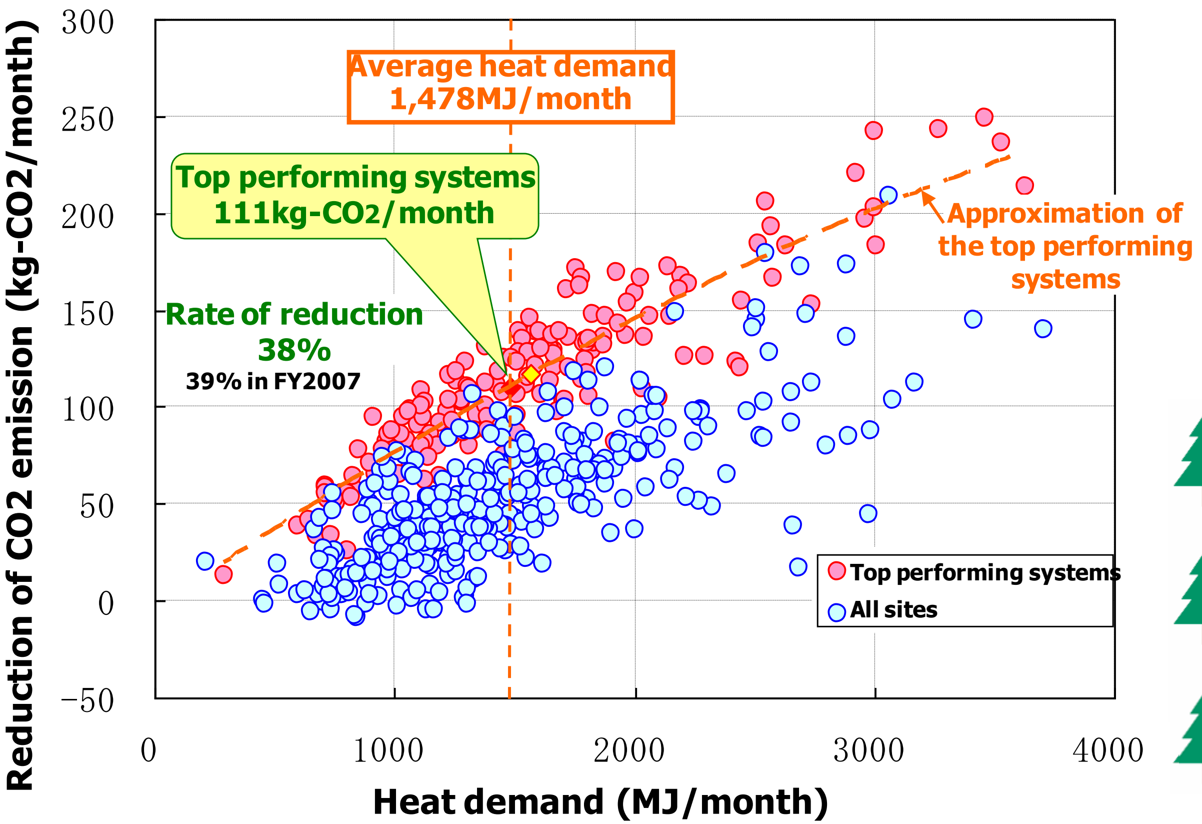
CO_2 reduction

One year operation data from Jan. 2009 to Dec. 2009; 523 sites of FY2008 installation; NG & LPG fueled



CO_2 reduction (Top performing systems)
1,330kg-CO_2/year

Equivalent to

Absorption by 2,460m^2 of forest

* Absorption rate by forest area: 5.4ton-CO2/ha·year

- CO2 reduction characteristics is also affected by the heat demand. Top performing systems at FY2008 installation reduced 111kg-CO2/month at average houses (average of all sites is 71.3kg-CO2 month)
- The increase of CO2 emission reduction is caused by the improvement of electrical efficiency.

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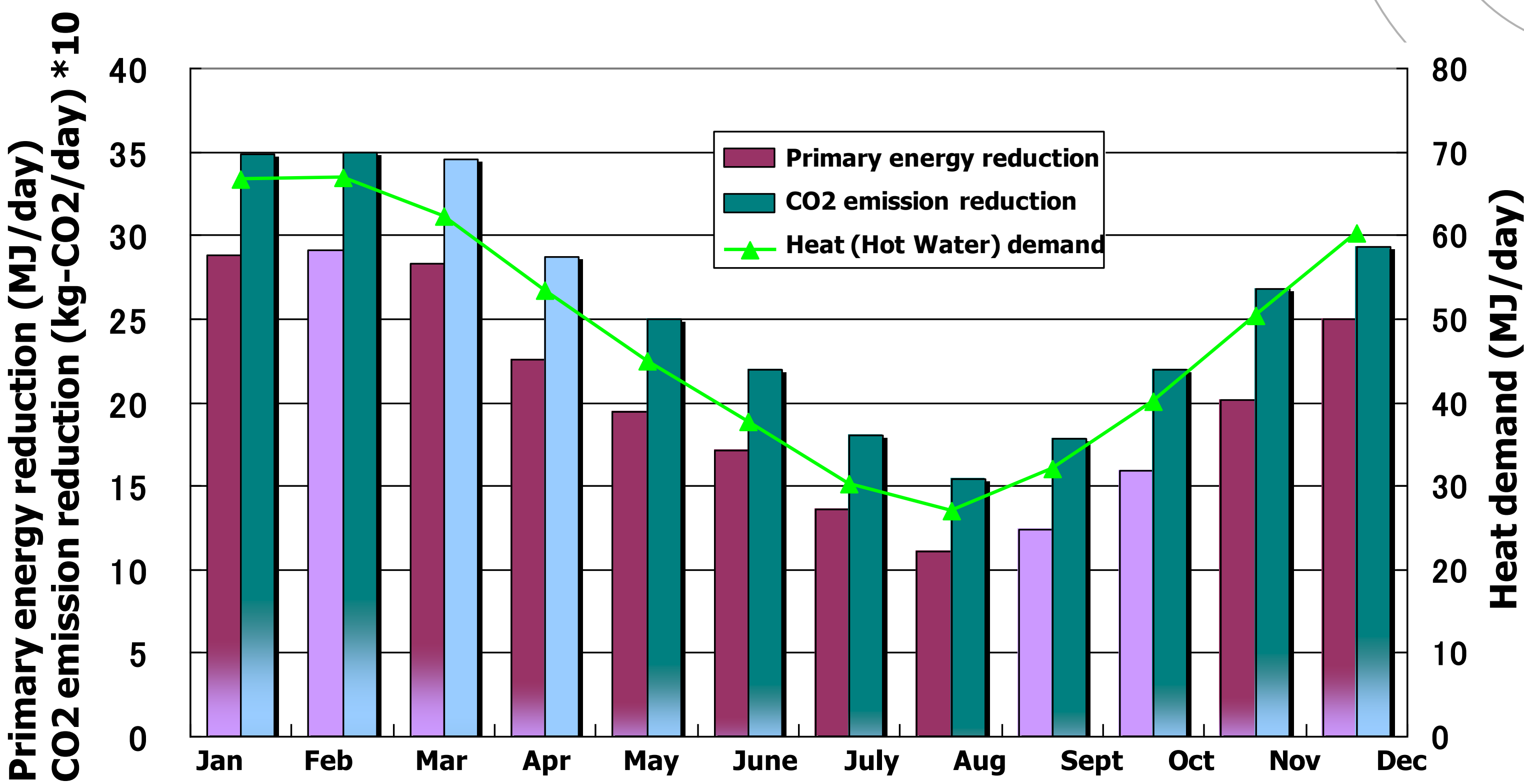
Reduction in Primary Energy & CO_2 Emission

One year operation data from Jan. 2009 to Dec. 2009; 523 sites of FY2008 installation; NG & LPG fueled



- As heat demand is smaller in summer season, both of electricity & hot water supply from PEFC are also smaller. Then, both of primary energy & CO2 emission reduction are smaller in summer season.
- None the less, it was verified that a certain amount of primary energy & CO2 emission reduction are secured even in August when the demand is smallest.

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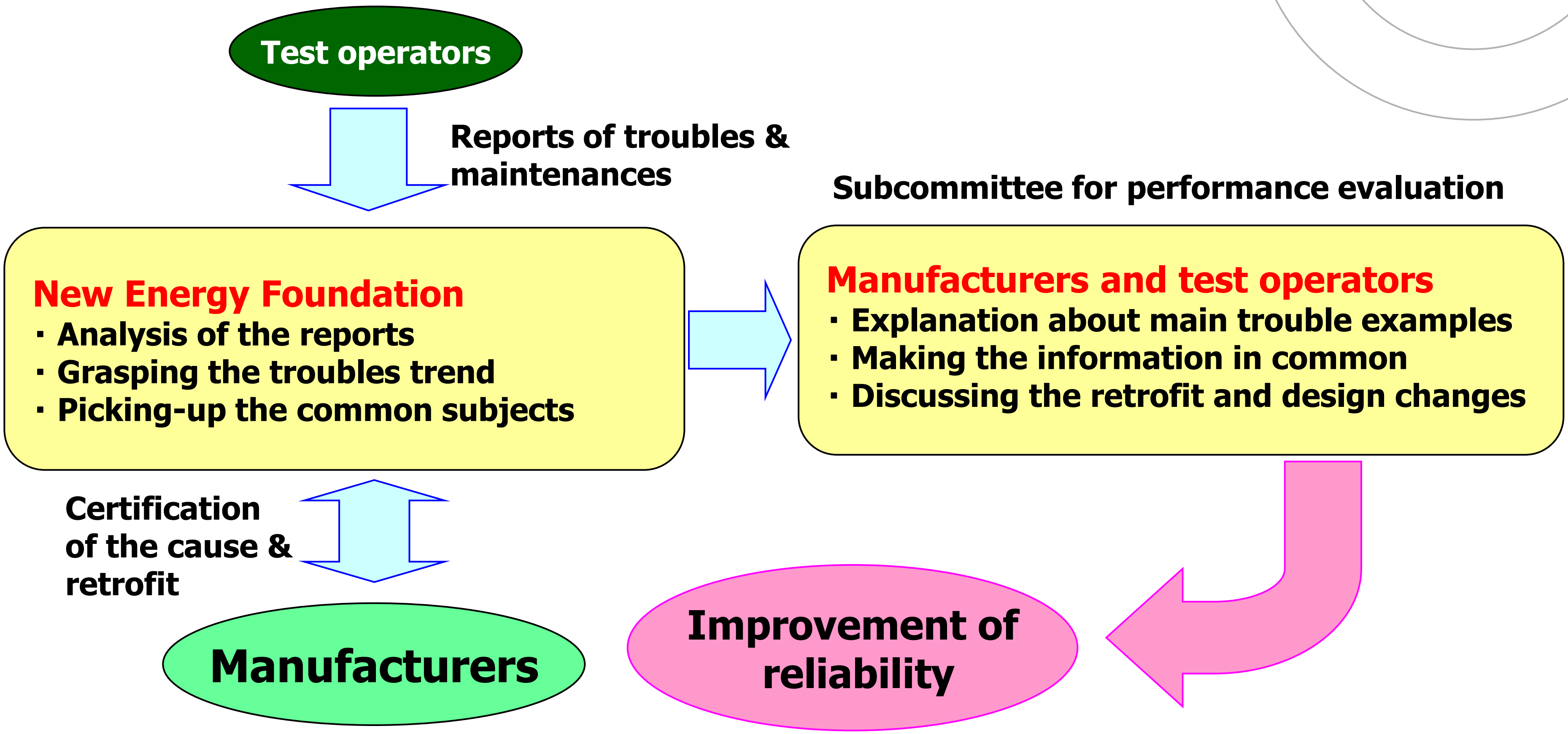
Improvement of System Reliability



· **Frequency of unexpected shutdown has been decreased, making the troubles information in common and so on.**

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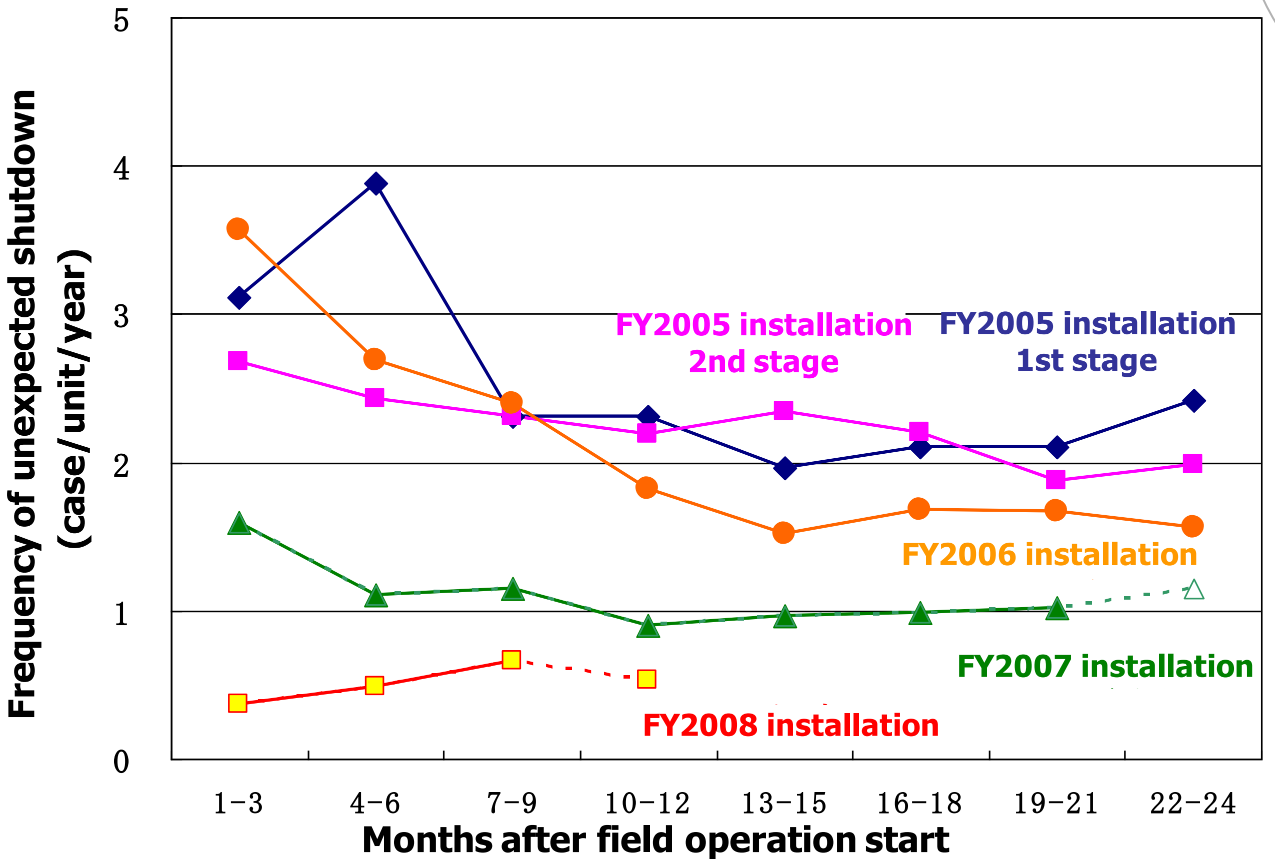
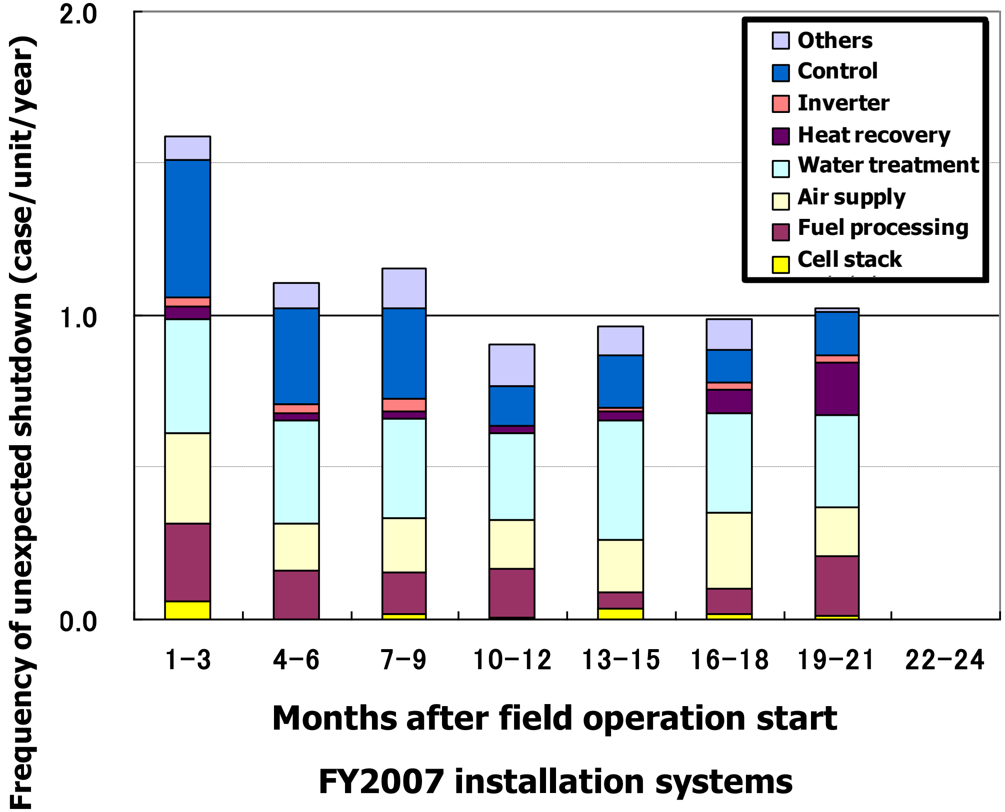
Transition of Unexpected Shutdown Frequency

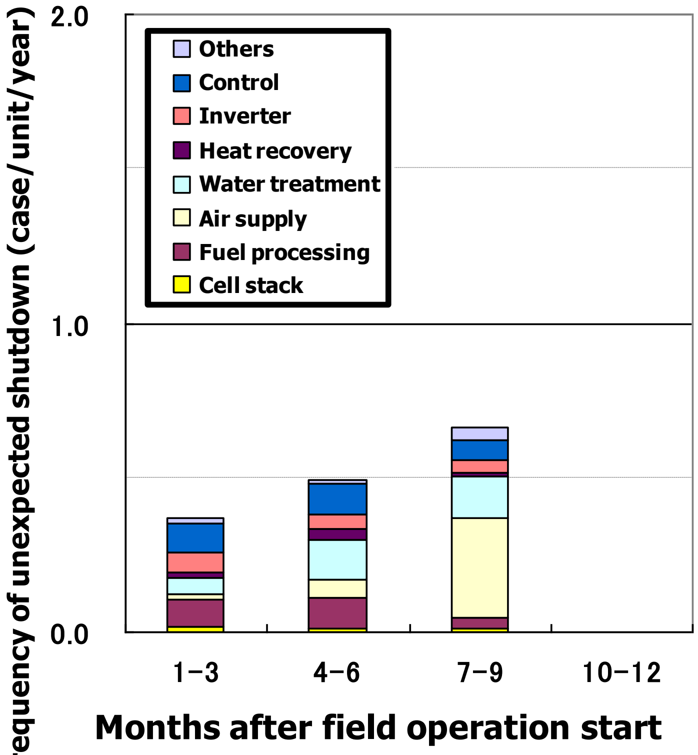


- System and design improvement have been made to decrease the occurrences of troubles in accordance with the retrofit & design change year by year.
- Frequency of unexpected shutdown has been decreased year by year to the level of 0.5 case/unit/year for FY2008 model.

Trend of Unexpected Shutdown



FY2007 installation systems



FY2008 installation systems

- FY2007 installation systems ; Troubles at heat recovery and fuel processing subsystem relatively increased.
- FY2008 installation systems ; The frequency is lower than FY2007system. Troubles at air supply subsystem is to be solved.

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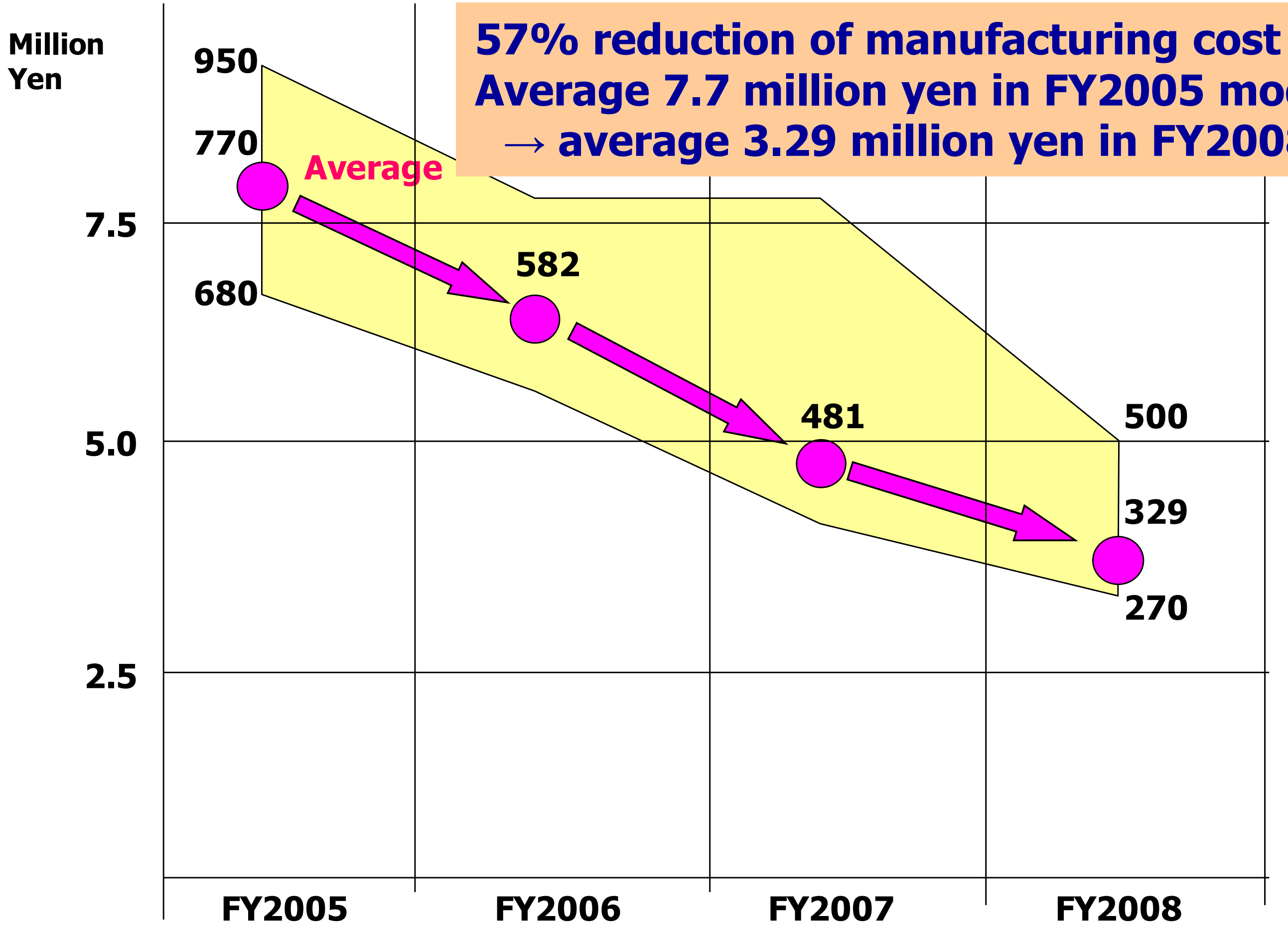
Cost Reduction

57% reduction of manufacturing cost during the project
Average 7.7 million yen in FY2005 model
→ average 3.29 million yen in FY2008 model



Based on the amount of the money which operators paid to the manufacturers.
(Fuel cell unit + Hot well tank unit; not including installation expense)

Cost Reduction through R&D Projects on BOP Components

R&D on BOP components for residential fuel cell systems

In this project, the improvement of durability, cost reduction and common specification provision of BOP components for residential PEFC system were executed.

These results have been applied to the components of residential PEFC system in the extensive demonstration project causing the improvement of system performances.

①Performance & durability ･･･ Verifying the prospect of accumulating 40,000 operating hours with the satisfaction of required common specification

Components 2005～2007 Blower, pomp, shut-off valve, flow meter, pressure sensor
2008～2009 Water treatment, heat exchanger, power conditioner

Scheme 5 PEFC system manufacturers & 22 component manufacturers

②Cost ･･･ Achieved approx. 110,000 Yen (original estimate of 410,000 yen based on production volume of 10,000 units/year)

③Common specification ･･･ NEDO published the paper of common specification in Jan. 2008, which revised in Feb. 2009

↓

The components applying the results of the project were fabricated into FY2008 installation units up to 70%.

Market Entry of Residential PEFC

Commercial Launch of Residential PEFC system

Subsidy for PEFC system installation in Extensive Demonstration Project ceased in FY2008.
Obligatory field operation & data acquisition continued till the end of March in 2009.

The commercial model of residential PEFC system logotyped "ENE-FARM" has started the selling in May, 2009.

June 25, 2008
FCCJ (Fuel cell Commercialization Conference of Japan) announced the uniformed logotype "ENE-FARM" and its commercial launch from FY2009.

January 28, 2009
6 energy companies expressed the declaration for the commercial launch of "ENE-FARM" and its market diffusion.

The evaluation of operating data in FY2008 is feed backed for the improvement to make "ENE-FARM" more effective & reliable.

Commercialization of Residential Fuel Cells

Production lines are working at three manufactures

"The first shipping" ceremony at Panasonic in Shiga Pref. on July 1, 2008.

"The first shipping" ceremony at ENEOS in Gunma Pref. on July 1, 2009.

Commercialization of Residential Fuel Cells

- **Residential fuel cell systems commercialized in 2009.**
- **0.7–1.0 kW PEFC + heat recovery (CHP)**
- **Three manufactures**
- **Subsidization program initiated**
  - **1/2 of users' costs (system + installation) up to 1.4M JPY**
  - **1,500 units installed (as of Sep. 2009)**
    (+ 3,307 by demonstration project in 2004-2008)

ENE-FARM: Unified logo for Residential Fuel Cells

The Price of "ENE-FARM"

Manufacturer	Panasonic	Toshiba FCS	ENEOS Celltech
Output	1kW	700W	750W
Electrical Efficiency	> 37% LHV	> 35% LHV	> 35% LHV
Heat recovery Efficiency	> 52% LHV	> 45% LHV	> 50% LHV
Capacity of HW Tank	200 liters	200 liters	200 liters
Fuel	City gas	City ga	LPG
FC Unit	780W＊400D＊860H 125kg	890W＊300D＊895H 104kg	900W＊350D＊900H 125kg
HW Tank Unit	750W＊480D＊1883H 125kg	750W＊440D＊1900H 105kg	750W＊440D＊1900H 95kg
Price	3.465 million yen	3.255 million yen	3.200 million yen

- **Price of residential PEFC system "ENE-FARM" which started the selling since May, 2009 is between 3.20 to 3.465 million yen.**
- **New governmental subsidy for the installation of "ENE-FARM" lightens the burden of customer's purchase. Up to 1.40 million yen for the installation in FY2009**

Further cost reduction is required applying cell stack & components improvement. Cost reduction by mass production is also expected through market diffusion.

Governmental Subsidy for the Installation of Residential PEFC System

METI subsidizes for the installation of PEFC system since FY2009 for accelerating the diffusion of residential fuel cell system so as to contribute the reduction of CO2 emission in the domestic energy section.

The situation in FY2009

Budget：60.65 billion Yen (additional 20.40 billion Yen) in FY2009
Subsidy for installation：up to 1.4 million Yen per unit
(unit cost－230 thousand Yen)×1/2＋installation expense×1/2
Receiver： Person who installs and operates PEFC system, and company that furnish PEFC system for lease
System requirement：Residential PEFC system designated by FCA
1）Rated power output: 0.5kW～1.5kW
2）Electrical efficiency at rated power over 33%(LHV)
3）Overall efficiency at rated power over 80%(LHV)
4）Capacity of hot water tank over 150 liters
Obligation：over 6 years operation after the installation
Implementing Organization： Fuel Cell Association（FCA）

Conclusion

Results of the Extensive Demonstration Project

1. **Large scale field demonstration of residential PEFC system up to 3,307 units has been executed.**
2. **Gathering and analyzing over 2 years operation data at many individual houses with various conditions nationwide.**
3. **Accumulated 25.31 GWh generating power has achieved as of the end of December, 2009.**
4. **The results and status of the project have been informed widely through the public exhibition such as FC EXPO, ENEX etc. and internet homepage.**
   Toyako Summit held in 2008 was a good opportunity to inform the status of the project to foreign opinion leaders.
   These activities contributed to make the better circumstances for the market entry of PEFC system.
5. **The collaboration of manufacturers and energy supply companies was well executed for the commercialization.**

Accomplishments and Way Forward

1. Accumulating plenty of field operation and verification of system safety needed for commercialization
2. Verifying the effect of primary energy reduction and CO_2 emission reduction
3. Improvement of efficiencies and performances, utilizing operating data
4. Improvement of reliability and durability, making the information in common and feed backing
5. Over 50% cost reduction was achieved during 4 years

Realizing the commercialization of residential PEFC system in 2009

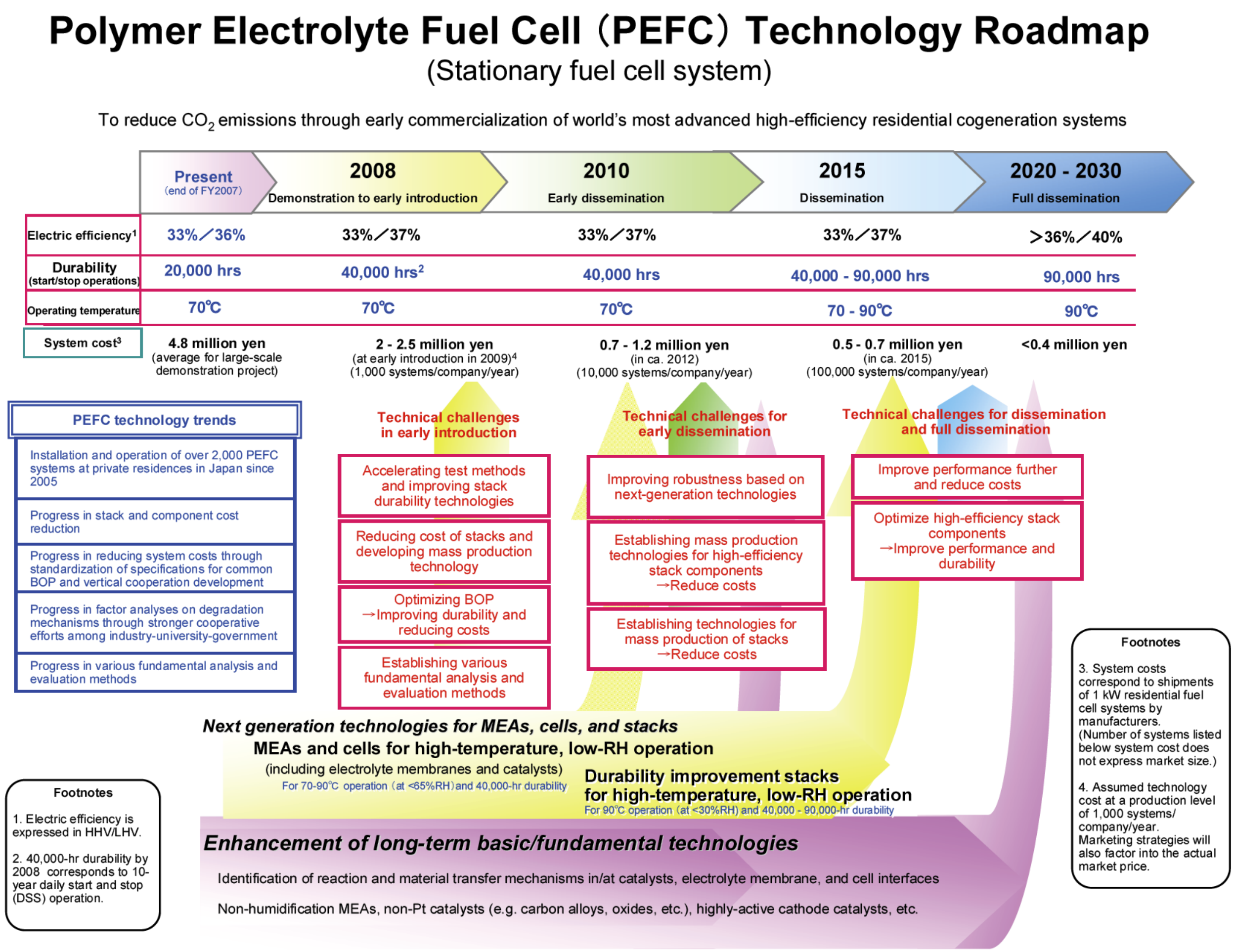
Further cost reduction is required for more diffusion of residential PEFC system .

Roadmap made by NEDO in June, 2008

Target price : 500 to 700 thousand yen per unit at around 2015
at the level of 100 thousand production per year per one manufacturer

Target durability : 40,000 to 90,000 hours

PEFC Technology Roadmap (NEDO; June, 2008)



Further development and market diffusion are expected for the cost reduction to 500 – 700 thousand Yen per unit around 2015, which is described in the roadmap.

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Addendum
SOFC Demonstration Project

SOFC Demonstration Project

To collect data and experience of practical operation of residential SOFC systems.

- Degradation by impurity
- Influence of current density, operating temperature
- Troubles of equipment

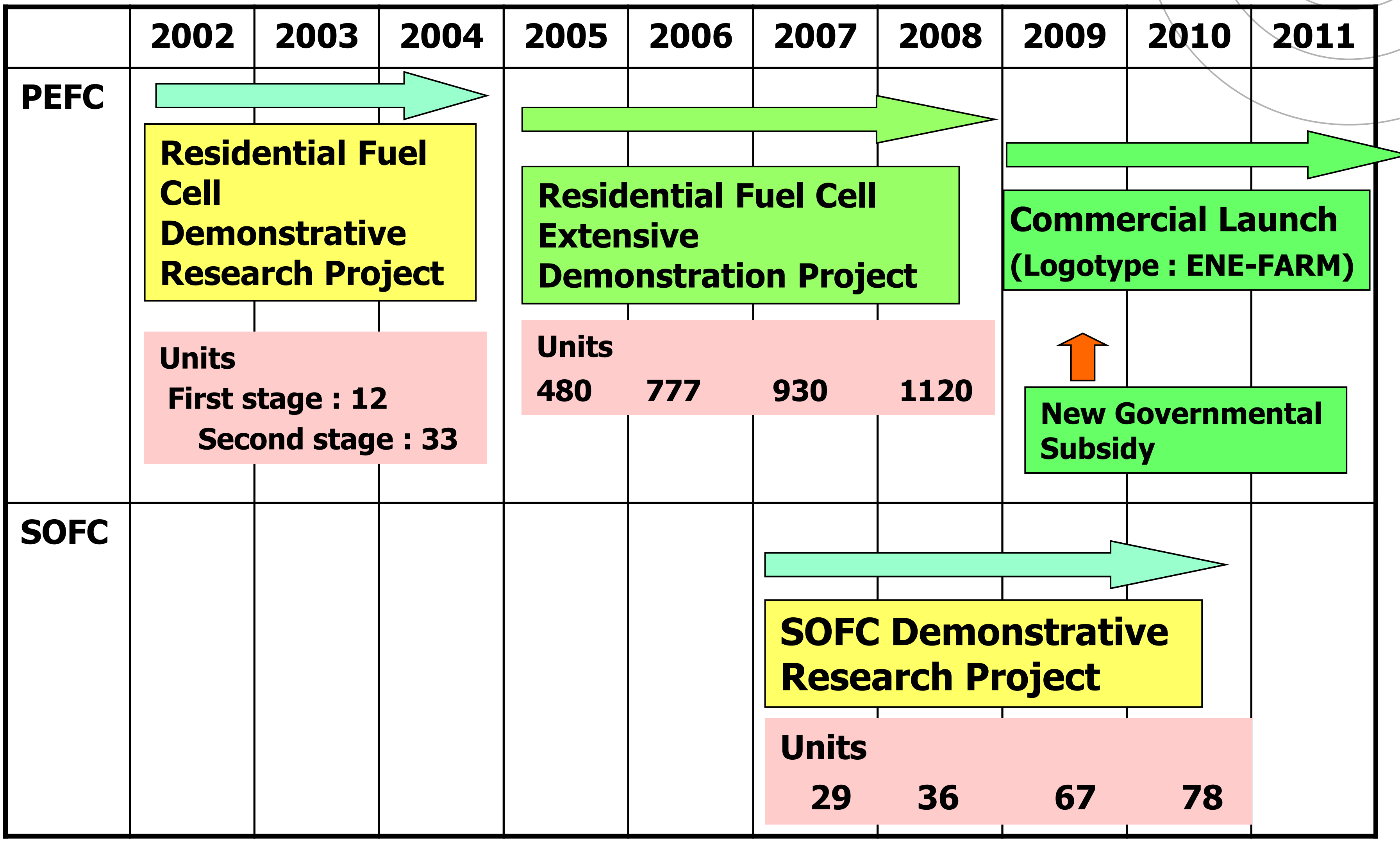
➡ **Durability improvement by modification of cell stack structure and system design**

Project period: FY2007-2010

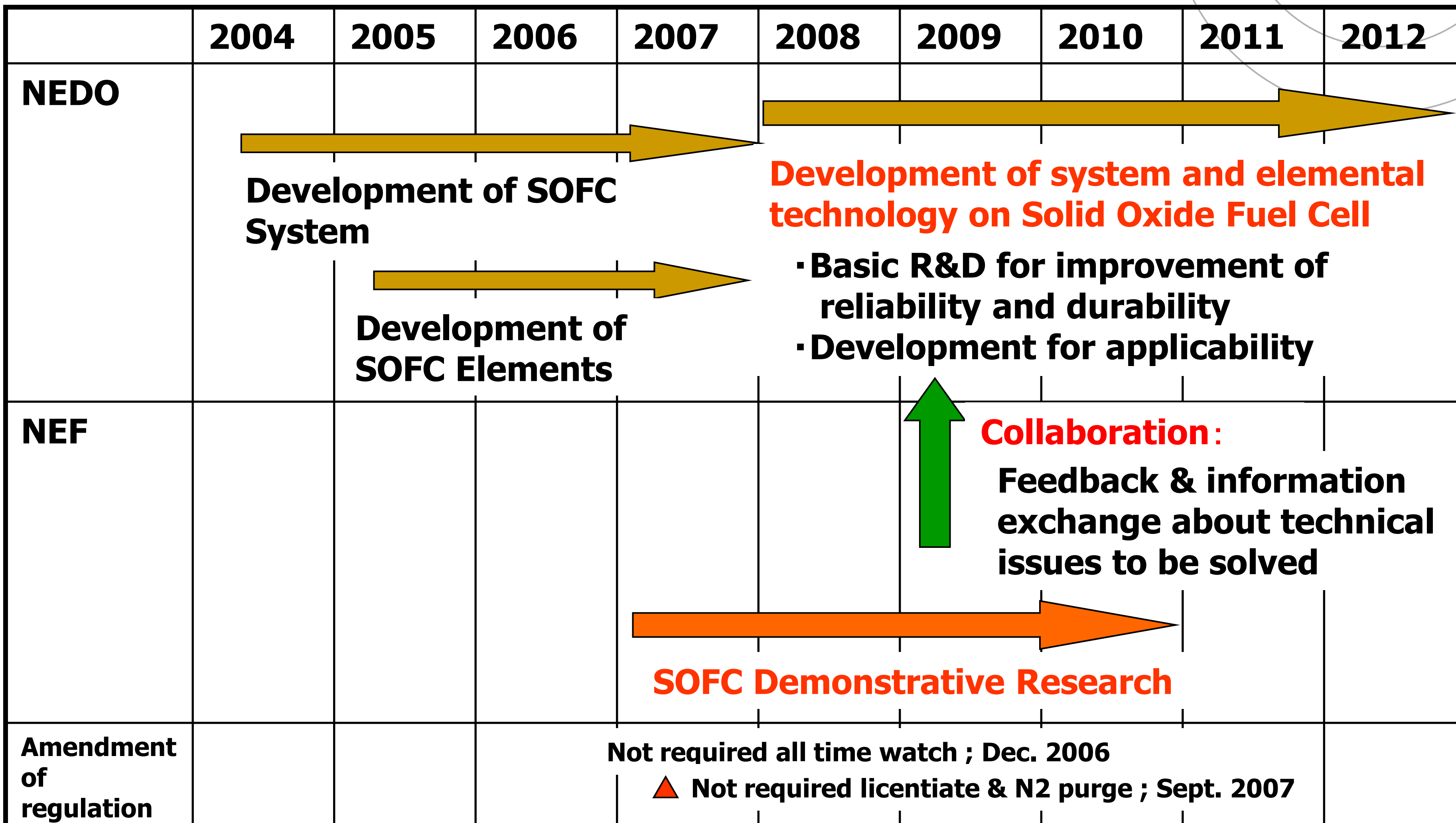
Characteristics of SOFC

- High efficiency of electric power generation
- No expensive catalysts (Pt etc.) needed
- Mature ceramic technology applicable
- Scale-up

Steps of the Fuel cell Demonstration projects

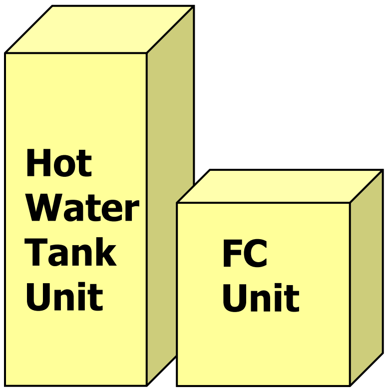


Collaboration with other SOFC Projects



Target System and

SOFC System



The system is mainly for cogeneration.

Example of the specification of SOFC system

Generation Power (rated) : 700W
Electrical Efficiency (rated) : 38～40%(HHV)
Heat Recovery Efficiency (rated) : 32～36%(HHV)
Capacity of HW Tank : 50, 70, 80, 130, 200 liters
5 kinds of the capacity are tested for optimization
HW temperature : 70～80 °C
Operation Mode : Continuous operation during day & night
Electrical load following control

To evaluate the issues below, analyzing the actual operating data over obligatory 6 months

- How is the practical efficiency under actual operating condition?
- Will the merits of primary energy reduction or CO_2 emission reduction be confirmed?
- How is the degradation of performance after long time operation?
- What troubles and maintenance issues happen and be took the countermeasure?

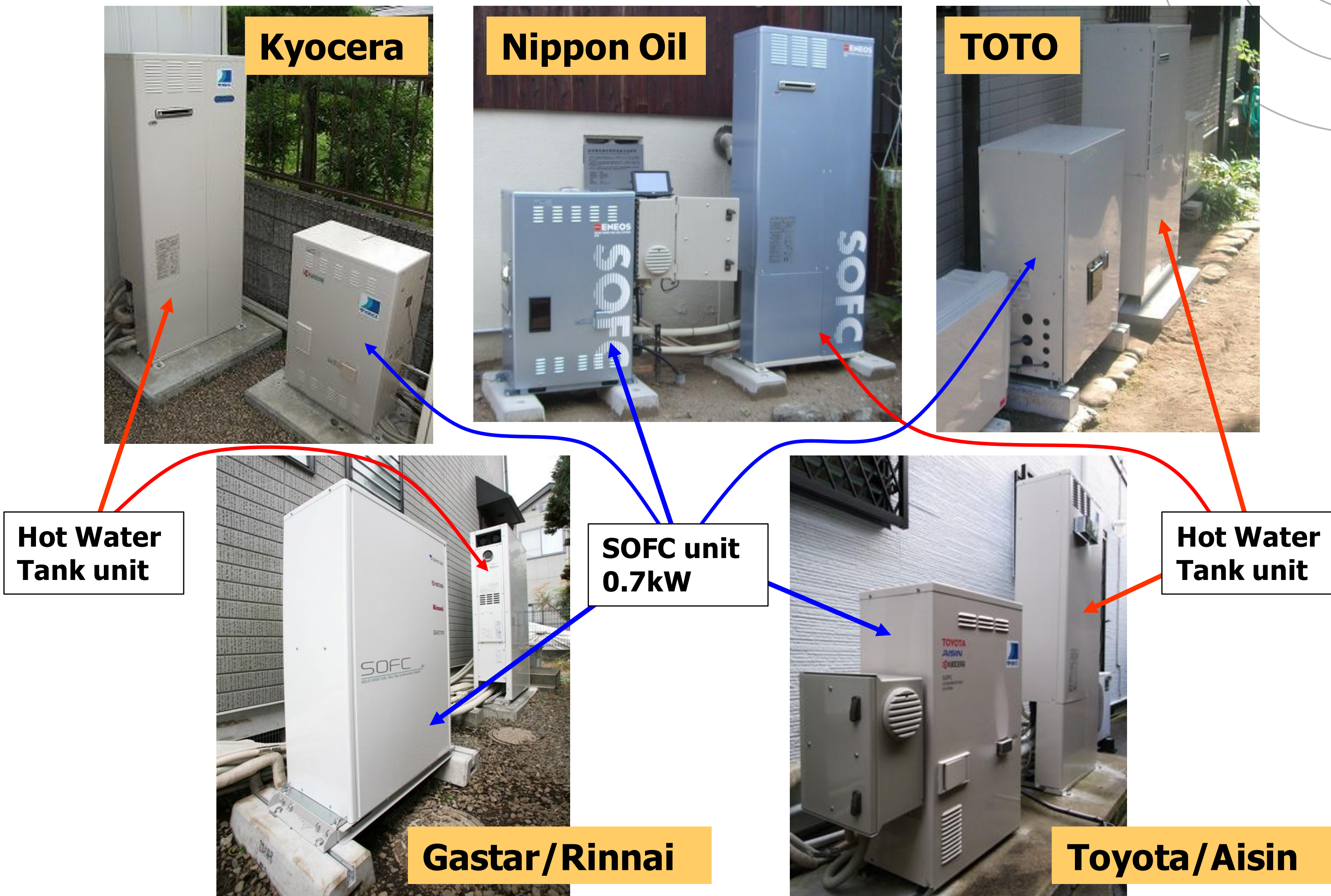
Identifying the technological development issues and to reflect these results in the improvement of the SOFC system for practical application.

Project Participants

Installation & Operation company	Fuel	Manufacturer	Rated Power	FY 2007	FY 2008	FY 2009	FY 2010
Osaka Gas	City Gas	Kyocera	0.7 kW	20	25	12	—
		Toyota/Aisin		—	—	23	34
		TOTO		—	—	—	2
Tokyo Gas	City Gas	Kyocera	0.7 kW	3	2	—	—
		Toyota/Aisin		—	—	4	4
		Gastar/Rinnai		—	—	2	4
Hokkaido Gas	City Gas	Kyocera	0.7 kW	1	1	—	—
		Toyota/Aisin		—	—	1	2
Saibu Gas	City Gas	Kyocera	0.7 kW	1	1	—	—
		Toyota/Aisin		—	—	1	1
Toho Gas	City Gas	Toyota/Aisin	0.7 kW	—	—	1	—
		NGK Spark Plug		—	—	—	2
Tokyo Electric Power	City Gas	Kyocera	0.7 kW	—	1	1	—
Tohoku Electric Power	City Gas	Kyocera	0.7 kW	—	—	1	—
Nippon Oil	LPG	Nippon Oil	0.7 kW	1	2	14	20
	Kerosene			1	1	1	1
TOTO	City Gas	TOTO	0.7 kW	—	2	6	8
			2 kW	2	—	—	—
			8 kW	—	1	—	—
9 Companies		7		29	36	67	78

* FY2010 ; the number described is for already selected, and additional units will be included.

SOFC System Installation at Individual Houses



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Results of Operating Data

		FY2007 Units	FY2008 Units	FY2009 Units
Total number of operating month	Month＊Site	304	415	64
Electricity demand	kWh/month	473	568	621
Electricity supply	kWh/month	317	348	361
Electrical efficiency	% HHV	33.8	35.3	35.2
Electricity utilization efficiency	% HHV	33.5	34.8	34.7
Electricity supply rate	%	71.3	66.2	65.2
Heat demand	MJ/month	1187	1251	1281
Heat (Hot water) supply	MJ/month	718	746	744
Heat recovery efficiency	% HHV	37.4	37.0	38.6
Heat utilization efficiency	% HHV	21.3	20.7	20.1
Heat (Hot water) supply rate	%	68.1	67.2	65.2
Rate of primary energy reduction	%	14.8	16.3	16.2
Amount of primary energy reduction	MJ/month	632	772	761
Rate of CO2 emission reduction	%	33.9	35.2	34.3
Amount of CO2 emission reduction	Kg-CO2/month	92.0	105.0	105.0

＊ The results of operating data as of the end of Dec. 2009
(not including the data of kerosene fueled system & small commercial system)

・The data of FY2008 is not enough now to compare because of short operation.

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Summary

- **Plenty of operating data to be able to evaluate the performance of SOFC system statistically and comprehensively have been accumulated during this verification project.**
- **Analyzing and evaluation for annual term should be made accumulating longer operating data in next year for economic feasibility of SOFC system.**
- **SOFC's characteristic continuous operation during day & night is recognized to affect the performances such as electrical efficiency. And, it is thought that the utilization of recovered heat should be optimized.**
- **The environmental acceptability of SOFC system is certified about pollutants in exhaust & drain and level of noise & vibration below the criteria of regulations.**
- **The size of FY2008 installation units were smaller & thinner than that of FY2007 installation units. It will be considered to apply SOFC system to smaller houses & multi-family residences.**
- **Durability and reliability are most important to be evaluated during longer field operation.**
- **It is necessary to cooperate with the NEDO's project "Development of System and Elemental Technology on Solid Oxide Fuel Cells", exchanging the information mainly about the subject of cell stack degradation to be feed backed for the improvement and promotion for the commercialization effort.**

Acknowledgements

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ANNEX

Definition of the Terms used in the Presentation

Electrical efficiency (% HHV)	(Power generated by FC system (kWh) × 3.6) ／Fuel supplied to FC system (MJ HHV) × 100
Heat recovery efficiency (% HHV)	$\frac{\text{Heat recovered from FC system (MJ)}}{\text{Fuel supplied to FC stemma HHV)}} \times 100$
Electricity utilization efficiency (% HHV)	$\frac{\text{Power generated by FC system and used at house (kWh)} \times 3.6}{\text{Fuel supplied to FC system (MJ HHV)}} \times 100$
Heat utilization efficiency (% HHV)	$\frac{\text{Heat recovered from FC system and used at house (MJ)}}{\text{Fuel supplied to FC system (MJ HHV)}} \times 100$
Rate of primary energy reduction (%)	$\left(1 - \frac{\text{Fuel supplied to FC system (MJ HHV)}}{\frac{\text{Heat recovered from FC system and used at house (MJ)}}{\text{Gas boiler efficiency (=0.78)}} + \frac{\text{Power generated by FC system and used at house (kWh)} \times 3.6}{\text{Efficiency of thermal power plant at demand side (=0.369)}}}\right) \times 100$
Amount of primary energy reduction (MJ)	$\frac{\text{Heat recovered from FC system and used at house (MJ)}}{\text{Gas boiler efficiency (=0.78)}} + \frac{\text{Power generated by FC system and used at house (kWh)} \times 3.6}{\text{Efficiency of thermal power plant at demand side (=0.369)}} - \text{Fuel supplied to FC stemma HHV)}$
Rate of CO2 emission reduction (%)	$\left(1 - \frac{\text{Fuel supplied to FC stemma HHV)} \times \text{CO2 emission rate of the fuel (kg-CO2/MJ)}}{\frac{\text{Heat recovered from FC system and used at house (MJ)}}{\text{Gas boiler efficiency (=0.78)}} \times \text{CO2 emission rate of the fuel (kg-CO2/MJ)} + \text{Power generated by FC system and used at house (kWh)} \times \text{Average CO2 emission rate from thermal power plant (kg-CO2/kWh)}}\right) \times 100$
Amount of CO2 emission reduction (kg-CO_2)	$\frac{\text{Heat recovered from FC system and used at house (MJ HHV)}}{\text{Gas boiler efficiency (=0.78)}} \times \text{CO2 emission rate of the fuel (kg-CO2/MJ)} + \text{Power generated by FC system and used at house (kWh)} \times \text{Average CO2 emission rate from thermal power plant (kg-CO2/kWh)} - \text{Fuel supplied to FC stemma HHV)} \times \text{CO2 emission rate of the fuel (kg-CO2/MJ)}$

CO2 emission rate of the fuel : City gas 0.05125 (kg-CO2/MJ), LPG (Propane) 0.0587 (kg-CO2/MJ)
Average CO2 emission rate from thermal power plant : 0.69 (kg-CO2/kWh)

M. Akai, AIST