Development of A New Model of Residential PEM fuel cell CHP System

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1. Background

Tokyo Gas has been developing proton exchange membrane fuel cell (PEMFC) based combined heat and power (CHP) system for residential use from 1998. After the successful world's first market entry of residential PEMFC CHP systems for detached houses through "the Large Scale Demonstration Project" (2005-2008) that is conducted by New Energy and Industrial Technology Development Organization (NEDO) through New Energy Foundation (NEF) and supported by Ministry of Economy, Trade and Industry (METI), the first commercial model of a residential PEMFC CHP system in 2009 by the name of "Ene-Farm" that is a common trademark in Japan. Approximately 4,000 systems were sold in two years by Tokyo Gas and their high performance and user-friendly interface satisfied its customers. Fig.1 shows a trend of annual introduction of residential PEMFC CHP systems in Japan and Tokyo Gas from FY2004 to FY2010.

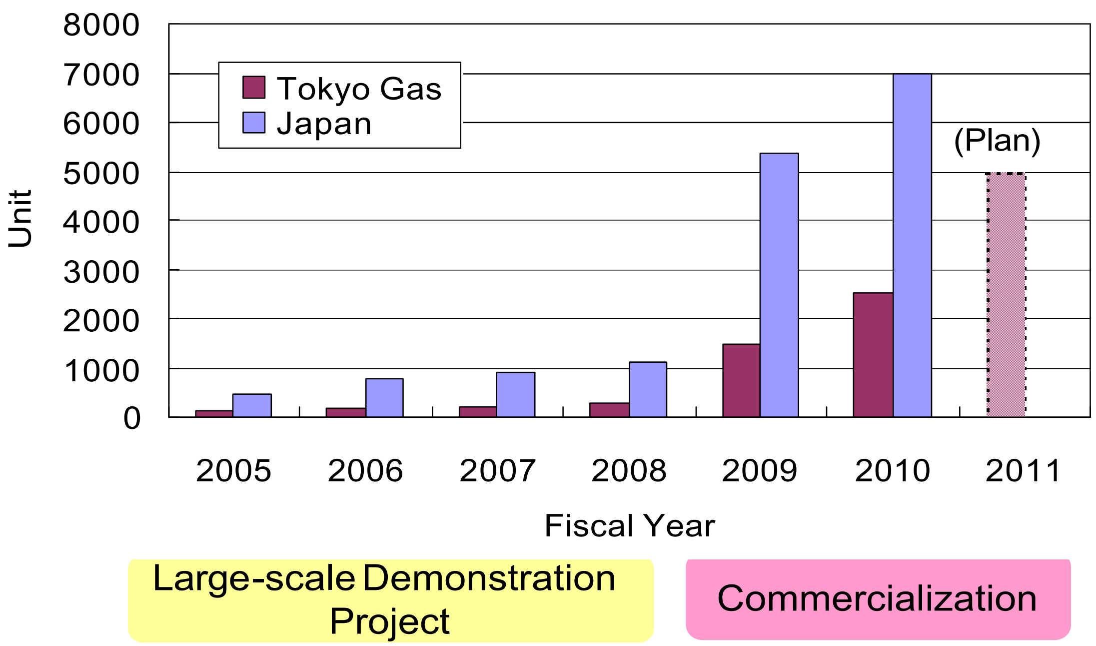


Fig.1 Trend of annual introduction of PEMFC CHP system in Japan and Tokyo Gas

2. Aim

Although the first model was successfully launched, some issues for the sales promotion, such as smaller installation space, cost reduction (system itself, installation, maintenance),

improvement of user interface, fit for smaller energy demand customers, were provided from the experience of sales activities of the first model.
Tackling these issues is the aim of the new model development.

3. Development

As well as the first model, the new model was developed jointly with Panasonic. After about three years' development, the new model was released in April, 2011.

3.1. Specifications

Table 1 shows the specifications of the new model, listed with those of the first model.

Table 1: Specifications of the first model and the new model

		First model	New model
Fuel type		LNG based natural gas (category 13A)	
Fuel cell Unit	Max. output	1 kW	0.75 kW
	Min. output	0.3 kW	0.25 kW
	Electrical efficiency	37 % LHV / 33 % HHV	40 % LHV / 36 % HHV
	Heat recovery efficiency	52 % LHV / 47 % HHV	50 % LHV / 45 % HHV
	Heat recovery temp.	60 ˚C	
	Dimensions	W 780 D 400 H 860 mm	W 315 D 480 H 1883 mm
	Dry weight	125 kg	100 kg
Hot water storage unit	Dimensions	W 750 D 480 H 1883 mm	
	Dry weight	125 kg	
	Tank capacity	200 L	
	Backup burner input	64.7 kW HHV	
Appearance			 connected all-in-one design installation

In the new model, the maximum power output and the minimum power output are decreased compared to the first model. Because selling reverse power to the electric utilities is not feasible in Japan, electricity generated by PEMFC CHP system should be regulated to the extent of consumption at the installed house. Therefore it is important to lowering the minimum power output and improving efficiency at lower output in order to increase primary energy saving merits to customers with small energy demand.

By making the height and the depth of the fuel cell unit and the hot water storage unit the same, all-in-one design installation becomes possible by connecting them. This contributes to lowering installation space.

3.2. Cost reduction

About 0.7 million yen cost reduction at the fixed price of the system was achieved by simplification of the system design, reduction of the number of components and cost reduction of components itself. The major components such as fuel cell stack and fuel processor are redesigned adopting new technologies for reducing not only cost but size and weight. And the costs of the balances of plant (BOP), such as pumps, valves and so on, were reduced thanks to a NEDO's development project, in which all major PEMFC system manufacturers in Japan tried to unify their specification requirements for each component aiming cost reduction by mass-production effect.

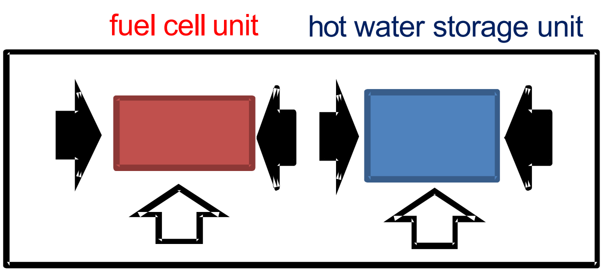
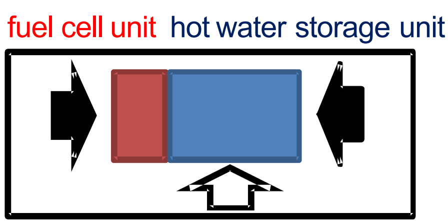
As mentioned in 3.1, the new model can be installed in connected all-in-one design. Ready-made heat collection piping parts, which are available in this installation style, reduce the labour cost for installation by reducing the piping processing work.

In addition, reducing cost relating to maintenance is also important. The maintenance interval is extended to typically 2.5 years from 1 year of the first model. And the number of parts replaced at scheduled maintenance is reduced to 6 from 9 of the first model.

3.3. Smaller installation space

A PEMFC CHP system is installed outside a house in Japan. But in Japanese crowded residential condition, there is very small room to install it in many cases especially in Tokyo metropolitan area. Therefore decreasing the installation space was one of the most important issues. Aiming reduction of the working space and direction for maintenance, internal arrangements of fuel cell unit and hot water storage unit had been improved thorough trial maintenance tests using prototype units. This contributed to enabling maintenance from only one direction and connected all-in-one design installation. As a result, the installation space for the new model becomes about a half of the first model. (Table 2) In Table 2, "main maintenance side" means the direction that requires a space for a maintenance person and "sub maintenance side" means the direction that requires a smaller space not for the person but the working hand of the person.

Table 2: Comparison of the installation space

First model	New model
 D1.2m × W3.3m (3.9m2)	 D0.9m × W2.3m (2.0m2)
main maintenance side	sub maintenance side

3.4. Improved user interface

A residential PEMFC CHP system has two control devices. One is typically installed in the kitchen typically and another in the bathroom. Their functions are interfaces for hot water temperature control, automatic control of bath such as temperature and level of hot water in bathtub and indication of the information relating to CHP, such as electricity, heat, and index for CO2 reduction.

From the experiences of the Large Scale Demonstration Project and sales of the first model, it became clear that easier access to the information relating to CHP is very important to improve the customer satisfaction.

The display of each control device of the new model is greatly enlarged compared with that of the first model for the purpose of easy viewing and enrichment of content. (Fig. 2)

The first model

The new model

Fig. 2 Control devices of the first model and the new model

3.5. Improved durability

In order to improve the running merit for the lifetime of the system, durability of the new model is improved to bear 50000 hours generation with 4000 start-up and shutdown (SS) cycles, where the first model can for 40000 hours with the same SS cycles.

For not only major components, such as fuel cell stack and fuel processor, but also all the other BOP components, the durability is examined by accelerated evaluation method for each of them.

4. Performance at the real households

Fig. 3 and Fig. 4 show the field trial data of the final prototype systems for mass production, which has the same performance with commercial product of the new model, compared with the field trial data of the first models. Each small circle in both two graphs indicates an averaged data of fixed term, which is a year for the first model and is a month for the new model.

The new model demonstrated higher electrical efficiency than the first model especially in lower power output range. (Fig. 3)

And although the rated power of the new model is smaller than the first model, its primary energy saving (*) is about the same level as that of the first model that demonstrated superior performance at the Large Scale Demonstration Project. (Fig. 4)

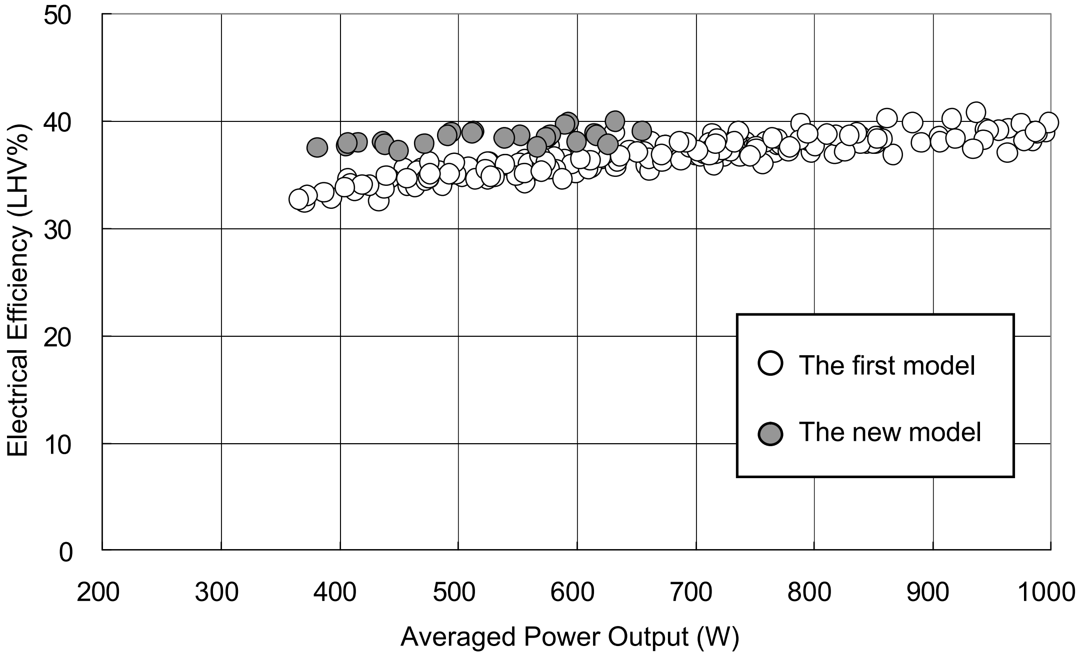


Fig. 3 Comparison of electrical efficiency at field trial between the first model and the new model

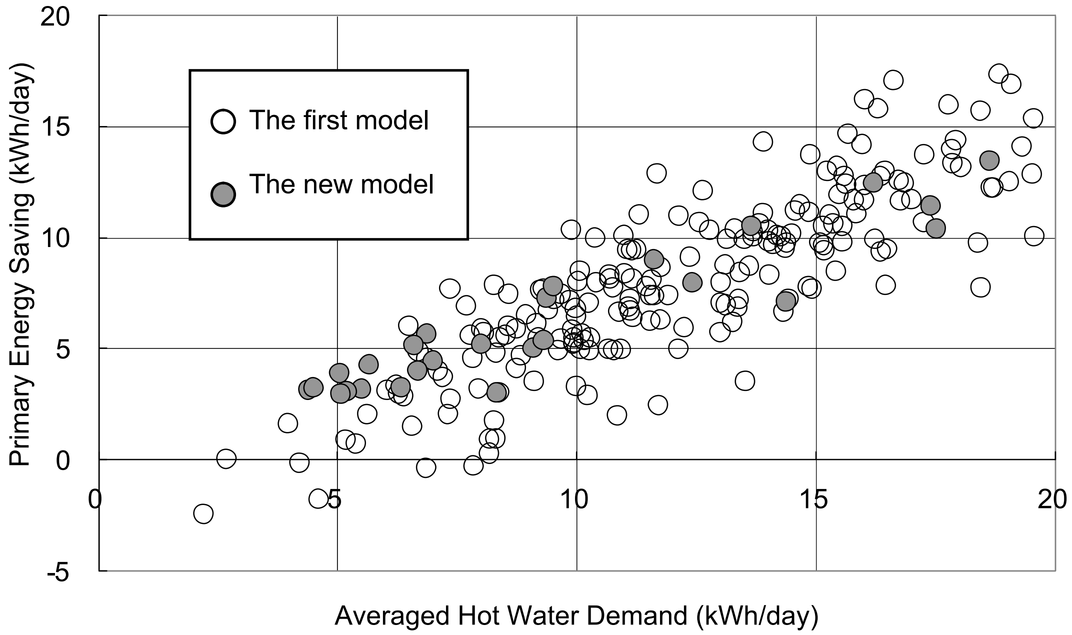


Fig. 4 Comparison of primary energy saving at field trial between the first model and the new model

(*) Primary energy saving is a difference between the primary energy consumed at a house equipped with PEMFC CHP system and the primary energy consumption calculated assuming absence of PEMFC CHP system.

5. Sales

The sale of the new model is going smoothly. As of January 2012, Tokyo Gas has already accepted orders of more than 5,500 that exceed the annual sales target, which is 5,000, by the end of March 2012 and is more than a double of the first model sales of the last fiscal year. In addition to the business activities based on two years' experiences of the first model, the improvement at the new model mentioned above is thought to contribute to this smooth sale.

6. Summary

Tokyo Gas succeeded in developing the new model of its residential PEMFC CHP system, which went on sale in April 2011.

The new model is designed to be cheaper, to have smaller space for installation, to have a user-friendly interface, to have better durability maintaining superior performance like the first model. Its superior performance was verified by field trial. And its sale is going smoothly.