Current status of commercialization for small scale stationary fuel cell systems in Korea

Bonggyu Kim, Dal-Ryung Park[1], Jin-Wook Kim and Jae-Dong Kim

1 R&D Division, Korea Gas Corporation, 1248, Suin-ro, Sangnok-gu, Ansan-si, Kyeonggi-do, South Korea, 426-790

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Abstract

Because of the global warming and to decrease reliance on fossil fuel, the world is trying to increase new renewable energy use and many national policies are being established by the government in Korea to increase the use of new renewable energy. Out of the many new renewable energy sources, fuel energy is receiving the spotlight as the optimized alternative for the PRS system as it requires less surface area than solar and wind power, has high usage, is able to create heat with electricity, and can be installed in a short period of time. In particular, the distributed fuel cell is receiving the spotlight recently, and rather than power generating massive fuel MCFC, proton exchange membrane fuel cell (PEMFC) and solid oxide fuel cell (SOFC) are more appropriate as household fuel cells. These two can be easily operated to be started and stopped and the durability is comparatively high. Many study and localization efforts are being in place for a PEMFC that is appropriate for small forms.

This study explains the domestic fuel cell related national policy, domestic market trends, technology development trends and attempts to introduce the research trend of KOGAS and their development results, which is the corporation that leads domestic PEMFC.

1. Introduction

Household fuel cell is a device that uses natural gas as fuel to cogenerate through the electrochemical reaction in the stack interior and it is a new renewable energy which has the characteristics of high efficiency and environment friendliness (more than 30% decrease of CO2 production) and supplies household residential building's electricity and hot water. Fuel cell power generation module is composed of the reformer module that reforms the natural gas and produces hydrogen gas, fuel cell stack module that uses the hydrogen gas to electrochemically produce DC electricity, power converter and other miscellaneous main components that converts the DC electricity produced in the above stack to AC electricity, water and air flow control necessary for reaction that adds to each main components, pump for water quality control and temperature control, blower, sensor, and other balance of plants (BOP) components. Furthermore, the waste heat recovery unit is composed of the hot water tank that recovers the heat produced in the fuel cell power generation module through the heat exchanger and an auxiliary burner that is responsible of extra heat when necessary.

This study attempts to introduce the fuel cell market and technology development trend in Korea and the results of KOGAS's fuel cell research and development based on this trend will be explained.

2. Fuel cell related government policy trends

The established government policy regarding new renewable energy including the fuel cell by the Korean government is as displayed on table 1 and it is considered that the Korean fuel cell industry will be lead forth based on these policies.

Table1. New renewable energy related government policy

Policy/System	Main Content
New Renewable Energy Feed-in Tariff (FIT*)	· Cost difference of 283KRW/kWh is supported for fuel cell since Oct. 2006 (equipment capacity support limit 50MW) · Since 2008 difference support is paid for 15 years, decreasing the amount 3% every year compared to the previous year · Sscheduled to be replaced with the RPS system in 2012
New Renewable Energy Renewable Portfolio Standards (RPS**)	· Scheduled to be enforced from 2012 and by 2020, 10% of power generation is planned to be supplied as new renewable energy · When the government selects a mandatory subject (500 MW and above), the mandatory subject must complete the goal in a specified time. The goal of 2% in 2012 is to be progressively increased to 10% in 2020. · Mandatory subject can operate the obligations by investing in the new renewable energy field directly or by trading the REC (Renewable Energy Certificate).
Million Green Home Supply Business	· Until 2020, new renewable energy equipment installation fee is partially supported and a million green homes are supplied · In the case of fuel cells, 80% of the current installation fee is supported by the government (other energy sources are supported for a maximum of 50%)
Mandatory New Renewable Energy Installation System for Public Buildings	· After 2011, new construction, addition, or renovations over Gross Floor Area of 3,000㎡ or above by a public institution must cover 10% or above of the total energy usage with new renewable energy. (previously it was 5% based on the construction fee and since 2009 additions and renovations in construction became included) · The mandatory ratio is increased from 10% in 2011 to 20% by year 2020 and the subject construction is adjusted to 1000㎡ or above (year 2012)
Green Car Development Strategy	· The pan-governmental green car development roadmap presented on Dec.7th 2010 states that the fuel cell car will localize the stack by 2015 and will be mass produce mid-size cars and develop fuel cell bus by 2018 · As a hydrogen fuel cell vehicle monitoring business in 2006, 30 passenger cars, 4 buses, and 7 hydrogen recharge stations were operated till 2010 and in 2011 100 fuel cell car and 6 hydrogen recharge stations are scheduled to operate as demonstration.
5 kW-class Building Fuel Cell Demonstration Business	· For two years from Dec. 2009 to Nov. 2011, the 5kW-class building fuel cell demonstration project was proceeded as a new renewable energy development business · Installation of localized 5 kW building fuel cell system core component of fuel converter and stack inverter in daytime and nighttime energy consumption demonstration site and operation as demonstration · Establish commercialization technology basis through acquiring durability and reliability

*Feed-in Tariff: The system where electricity produced with new renewable energy has a price set by the government and the power providers are obligated to purchase this energy.

** Renewable Portfolio Standard: A system that obligates a specified size or larger power provider to make their total produced energy provided with new renewable energy for a specified ratio and above. Detailed enforcement decree is currently under review.

3. Fuel cell market trend within Korea

Based on the policies of national green growth and greenhouse gas reduction, the Korean government will enforce the RPS(Renewable Portfolio Standard) system starting in 2012. Fuel cell fuel

energy is expected to receive the spotlight as the optimized alternative for the PRS system as it requires less surface area than solar and wind power (fuel cell 179, solar power 19,800, wind power 39,600㎡/MW), has high usage (fuel cell 90%, solar power 15%, wind power 25%), is able to create heat with electricity, and can be installed in a short period of time.

New renewable energy supply quantity has continually increased with the help of active private sector participation as they respond external factors such as Convention on Climate Change that came to effect and persistence of high oil prices. In particular, the range increase became large with the wind, solar, fuel cell power development complex composition increase. The geothermal and bio field are also increasing its rate through the million green home supply business expansion and etc.

The government made an announcement reflecting the Electricity Supply Plan on December 2010 5th which state the introduction of 660 MW fuel cell development equipment by 2024. In 2009, Seoul city established and announced the 『Low Carbon and Green Growth Master Plan』. It is scheduled to supply 47.6%(700 MW-scale) of Seoul city's new renewable energy with hydrogen fuel cell by 2030 and 600MW of this will be installed with urban and distributed power generating fuel cells. Furthermore the distributed power generation MCFC market is predicted to have a rapid market growth in the future as it is stably operating with the supply through the Feed-in Tariff. With the Southeast development as a start in 2006, the FCE product from the United States was supplied to currently have 16 locations with around 40MW supply nationally.

Apart from this, based on the expansion of public building usage obligation and the introduction of construction certification system, it is expected that introduction of the fuel cell power generating system, with the smallest surface area, highest efficiency, and usage in all of the new renewable energy sources will have its installation expanded (market scale 60MW/year). Regulations regarding the replacement of current industry and building's emergency generator when installing the fuel cell are also under review (market scale 75MW/year).

In the domestic power market, fuel cell applicable potential households are 16.4 million, and with the start of market introduction through 10 thousand supply demonstration business by 2012, it is expected to be expanded to 2 million houses and above by 2020. The household fuel cell was first commercialized in the fuel cell field with the implementation of governmental businesses of 1 million green home supply business, green village business, and etc. By 2010, 200 devices were installed in normal household, building, and facilities (around 20 billion market formation). Furthermore in 2011, 300 devices were installed and in 2012, 500 devices were installed. The domestic building fuel cell market is forecast to obtain the initial competitiveness through technology development under government support and then it will form its own markets.

Separate from this, based on 2004, the hydrogen produced in the petrochemical industry that is not self-consumed and circulated in the market is around 48,000 ton and the small by-product of steel mills reach around 355,000 tons. Households that use LPG on the basis of 2009 are 6.6 million households and is 47% of the natural gas utilizing households (around 13.9 million households) and the DME production quantity based on 2008 is 3,000 ton by LG Chemical, and 4,000 ton by Daehung Industries. Considering the production scale of 7,000 ton per year, if the hydrogen by-product, LPG, DME, and etc. fuel cell are efficiently used through fuel diversification, market expansion through the function auxiliary power supply and UPS is thought to be possible. Based on this, the diversification of fuel use through fuel cell fuel diversification is expected to have supply expansion even in regions where LNG infrastructure is not supplied because it is able to be installed in building fuel cells where LPG, gasoline, kerosene, and etc. are used.

4. Fuel cell technology development trend within Korea

The various companies' fuel cell technology development trend within Korea is observed as follows.

POSCO Power has implemented a 250kW interior reformer MCFC demonstration business from 2004 to 2007 with the United States FCE company's 250kW product. In 2007 a contract was signed with the United States FCE company and the localization of BOP was complete through technology acquisition and yearly construction of 150MW scale BOP factory, and gradually acquiring installation, maintenance,

and service technology. On April of 2014, the stack manufacturing plant construction was complete and the localization of the stack is in progress with the manufacturing technology and with 10MW-class as a start in 2011, a 100MW-class development is scheduled by 2014.

The Korea Electric Power Research Institute undertook the 250kW-class cogeneration MCFC system development research and MCFC stack mass production research, and in the long term they are driving the core technology localization with the goal of a concentrated central power generating MCFC class system development to replace thermal power plants.

Doosan Heavy Industries have produced and operated 25 kW-class internal reforming MCFC stack with their own technology in 2006 and are currently developing the 300 kW-class interior reforming MCFC system and plant connected MW-class internal MCFC system localization as an assignment given by the government. Starting 2009, as part of the application technology development for the plant connected fuel cell a Feasibility Study for MCFC/PCC (Post Carbon Capture) was implemented to achieve the result that if the existing thermal power was Retrofit as MCFC/PCC, the entire plant's efficiency reduction can be reduced within 2%.

As a part of the governmental assignment, KOGAS progressed 210 fuel cell system devices for demonstration research with various fuel cell production companies since 2006 as 'household fuel cell monitoring business' for 5 years until 2011, and with this monitoring business the system reliability and durability was obtained to compose a base for commercialization (Chart 1)

GS Fuel Cell, a building PEMFC fuel cell manufacturer, exceeded 20,000 hours domestically for the first time with the cumulative power generation standard on October of 2010, reaching the level of Japanese demonstration, who are the leader of household fuel cell field, and verified the reliability, durability, and stability. As a result of 3 years of monitoring business, the household PEMFC's localization has reached 80% and above (price standard) and simultaneously the system design, production, and operation technology is obtaining the level of a developed country.

In the case of building PEMFC with 5 kW and above, the fuel cell power 10 kW class fuel cell system development research was progressed through the national project. In the case of GS Fuel Cell, the core component of fuel converter, stack, and inverter was developed through localization. The 5 kW building fuel cell system was developed and a daytime and nighttime energy consumption demonstration site was selected and operated for a demonstration study. Furthermore GS Fuel Cell participated in the smart grid business, developing a 1 kW-class LPG system and installed it at Jeju Island. In 2011, 1 kW-class/5 kW-class LPG system was installed at the Jeju demonstration complex and it is planned to be joint operated with miscellaneous new renewable energy such as solar and wind power generators.

5. Technology development trend of KOGAS

5.1 Development of desulfurization material and color changing material.

To easily detect the leak of natural gas that is generally used in fuel cell, the artificially added odorants such as dimethylsulfides(DMS), tert-butylmercaptan(TBM), tetrahydrothiophene(THT) and etc. are included in a compound form of organic sulfur compounds. In our country, the natural gas includes a 3.8ppm amount with a 3:7 ratio of TBM and THT.

When these sulfur components are supplied to the fuel cell system, it poisons the catalyst (Ru, N type) within the reformer that produces hydrogen and it not only decreases the durability of the catalyst but poisons both poles (Pt/C) of the stack and decreases the performance. Therefore in the case of proton exchange membrane fuel cell for household fuel cell, the sulfur density must controlled to be a level less than 10ppb.

Furthermore desulfurization material within the natural gas uses the method of removing the sulfur by absorbing and the absorption function decreases in time, leading to the inflow of sulfur components into the fuel cell so the desulfurization material must be exchanged regularly. However, the desulfurization material's decreased performance is not visible with the eye, so the sulfur density in the natural gas that has gone through the desulfurization material must be measured with the gas

analyzer to verify the performance decrease, hence the exact desulfurization material exchange period cannot be known. Therefore the desulfurization material within the fuel cell is not checked for performance decrease after a period of time but exchanged to a new desulfurization material right away, leading to a tendency where the costs are steep.

KOGAS developed a color changing material for this reason which changes color when sulfur components are absorbed so that the desulfurizing material can be exchanged based on the change of color, leading to an excellent cut on costs. Figure 1 shows the results that the color of discolor material changed

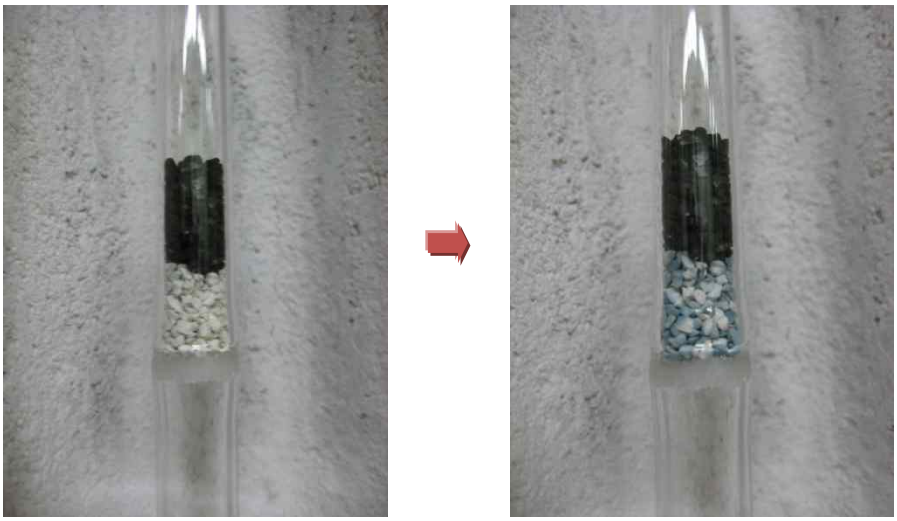


Figure 1. color changed discolor material

5.2 Reformer Development

KOGAS is developing the reformer which produces the hydrogen that is supplied to the stack in the fuel cell system with various quantities and has currently completed developing 1kW, 5kW, and 10kW-class reformers. In particular the 5kW-class reformer was developed as a high temperature PEMFC reformer as a government assignment and the 10kW-class reformer was selected the strategy assignment within KOGAS and it is scheduled to develop up to 50kW-class in 10 years.

5.2.1 1kW-class reformer development

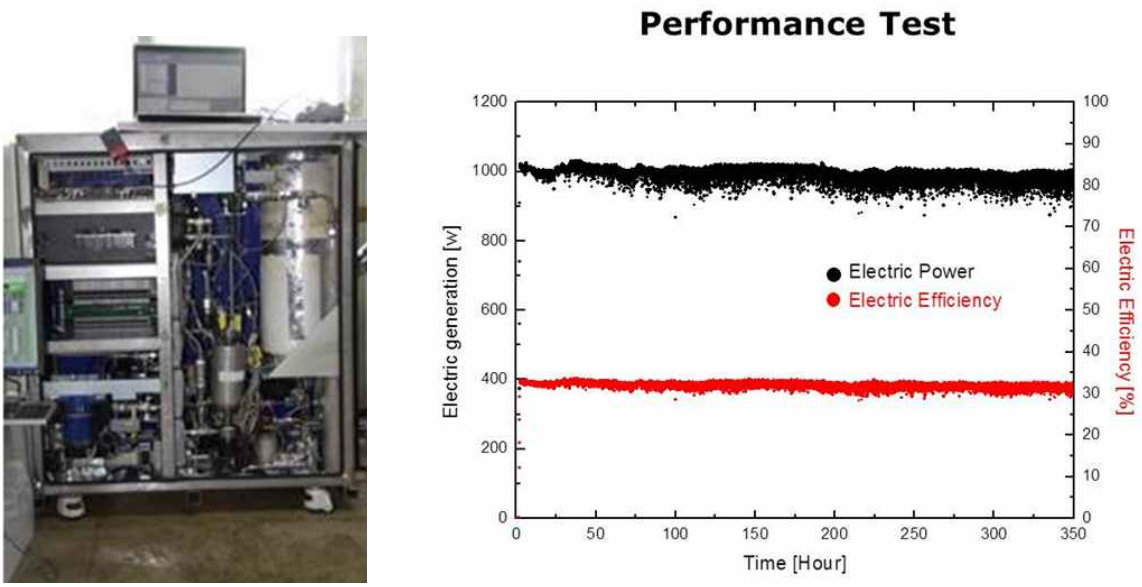


Figure 2. The performance of 1kW-class reformer developed by KOGAS

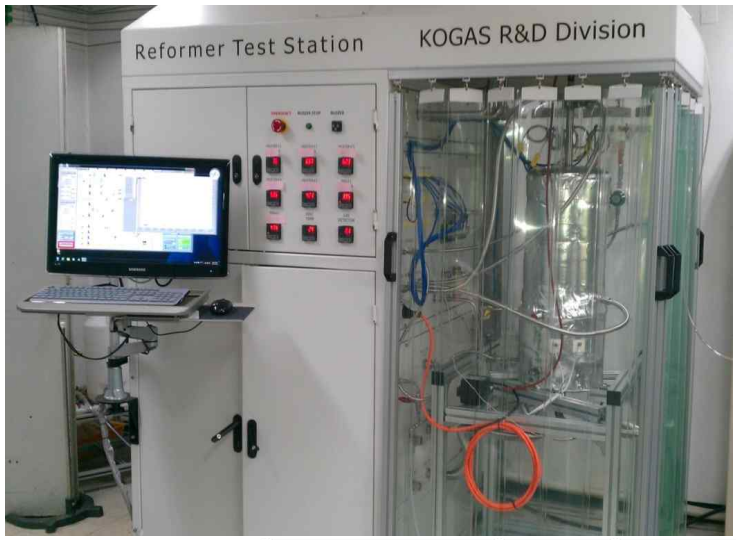
Since 2006 to 2009, cylindrical 1kW-class reformer was developed and demonstration study was performed with the reformer developed between 2010 and 2011 regarding fuel cell system application. Form and performance are displayed on figure 2. As shown on this figure, the surface area is 15L and the efficiency is 75%, methane conversion rate 95%, and PrOx front end CO density is 0.5%, displaying a high performance.

5.2.2 5kW-class reformer development

This is part of the high-temperature polymer fuel cell development assignment that is performed in accordance to the governmental assignment from 2011 to 2015 and as shown on figure 3, it was developed into the world's smallest level compact reformer with 23L of surface area. The reformer that was developed in this assignment has the efficiency of 77%, methane conversion rate of 97%, PrOx front end CO density of 0.25%, revealing a small size but high performance.

Furthermore, the interior reformer's operating pressure's maximum is 20kPa, which is relatively not a high burden to the BOP.

Utilizing the developed reformer, the fuel cell system is developed as a commercial product and it is installed and operated within the KOGAS's supply management station to function in supplying heat to gas temperature auxiliary gas heater and supplying power to the management station. It is considered that through this, the KOGAS form reformer's durability and performance will be tested to increase applicable fields and bring closer the commercialization date.



name	input data	Volumetric flow
	[-]	[l/min]
nat. gas reformer	(Natural gas)	20.000
nat. gas burner	(AOG)	45.44
A/F-burner	1.1	
S/C-Reformer	3.000	

Operation conditions

name	Efficiency(LHV)
standard (behind shift)	77.66

Efficiency of reformer

name	symbol	fraction x_i (dry)
	[-]	[mol %]
methane	CH_4	0.64
hydrogen	H_2	79.1
carbon monoxide	CO	0.25
carbon dioxide	CO_2	20.01
nitrogen	N_2	0.00
water	H_2O	0

Analysis of reformate gas

Figure 3 the 5kW-class reformer developed by KOGAS and its performance

5.2.3 10kW-class reformer development

From 2012 to 2015, KOGAS is developing the 10kW-class reformer as an internal assignment. The developing 10kW-class reformer as shown on figure 4 is a world smallest level compact reformer and is under performance testing. It is revealing a similar performance as the previously developed 5kW-class reformer.

Figure 4 the 10kW-class reformer developed by KOGAS and its application to fuel cell system

6. Conclusion

- The demand for new renewable energy is becoming stronger and in the current situation the government also is forcing the process by creating legislations.
- The domestic fuel cell market is currently being largely expanded and technology development is actively in progress.
- In accordance to this, KOGAS has spurred the development domestic small size reformers and has displayed the highest level of performance. Furthermore, KOGAS will lead in the supply of domestic fuel cell in the future through commercialization.