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

- Government policies related with new & renewable energy in Korea
- Domestic Fuel Cell market trend in Korea
- Domestic Fuel Cell development trend in Korea
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- Fuel Cell development trend in KOGAS
- Conclusion
Government policies related with new & renewable energy in Korea

| New Renewable Energy Feed-in Tariff (FIT*) | · Cost difference of electric power generation for fuel cell is supported since Oct. 2006  
· The cost difference support is decreasing the amount 3% every year compared to the previous year for 15 years, since 2008  
· Scheduled to be replaced with the RPS system in 2012 |
|-------------------------------------------|--------------------------------------------------------------------------------------------------|
| **Renewable Portfolio Standards (RPS**)** | · 10% of total power generation is planned to be supplied as new & renewable energy from 2012 to 2020  
· The government selects some mandatory subjects (500 MW and above), and the mandatory subject must complete the goal in a specified time. The goal is to be progressively increased from 2% in 2012 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). |
| **1 Million Green Home Supply Business** | · Until 2020, new & renewable energy equipment installation cost will be partially supported and a million green homes are planning to be supplied  
· In the case of fuel cells, 80% of the current installation cost is supported by the government |

*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.
| Obligation of New Renewable Energy use for Public Buildings | · After 2011, all public buildings over Gross Floor Area of 3,000㎡ built 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 cost)  
· The obligation ratio is increased from 10% in 2011 to 20% in 2020 and the gross floor area of subject building was adjusted to 1000㎡ or above in 2012 |
| 5 kW-class Building Fuel Cell Demonstration Business | · For two years from Dec. 2009 to Nov. 2011, the 5kW-class fuel cell demonstration project for building was proceeded as a new & renewable energy development business  
· 5 kW fuel cell system for building were installed and operated as demonstration in the different site for daytime and for nighttime energy consumption  
· Established commercialization technology basis through acquiring durability and reliability during this project |
Domestic Fuel Cell market trend in Korea

- Fuel cell is suitable to cope with RPS (Renewable Portfolio Standard)
- Government decided to introduce 660MW of fuel cell power plant until 2024 as national electric power supply plan, and Seoul city decided to install fuel cell systems on 700MW (47.6% of total new & renewable energy of Seoul) scale as distributed generation
- Government is under consideration for fuel cell system to be able to substitute for emergency generator (75MW/yr.)
- In the domestic power market, fuel cell applicable potential households are 16.4 million, and it is expected to be expanded to 2 million houses and above by 2020
Domestic Fuel Cell development trend in Korea

- POSCO power built stack factory at 2011, is expected to manufacture the stack in the 10MW to 100MW class
- KEPRI (Korea Electric Power Research Institute) undertook the 250kW-class cogeneration MCFC system development research and MCFC stack mass production research
- Doosan Heavy Industries have produced and operated 25 kW-class internal reforming MCFC stack in 2006 and are currently developing the 300 kW-class interior reforming MCFC system
- KOGAS installed and operated 210 fuel cell systems for demonstration research with various fuel cell production companies since 2006 as ‘residential fuel cell monitoring business’ for 5 years until 2011
Strategy roadmap for Fuel Cell development in KOGAS

- **Project**
  - Hydrogen Production and Utilization under 50Nm³

- **Final Target**
  - Development of 50Nm³ Reformer and Hydrogen Utilization
    - Commercialization of Steam reformer (PEMFC, SOFC)
    - Commercialization of SMR, WGS Catalyst and Desulfurizer
    - **Heat Efficiency 75% (Reformer), Durability 40,000hrs Catalyst**

- **Period**
  - 1st Stage (‘11.9~’14.12, 40 months) : 10Nm³ Hydrogen Production
  - 2nd Stage (‘15.1~’17.12, 3years) : 30Nm³ Hydrogen Production
  - 3rd Stage (‘18.1~’20.12, 3years) : 50Nm³ Hydrogen Production

- **Particular Object**
  - 1st Stage : Heat Eff. 75%, Sulfur conc.<50ppb, Durability 5,000hr
  - 2nd Stage : Heat Eff. 77%, Sulfur conc. <10ppb, Durability 10,000hr
  - 3rd Stage : Commercialization of 50Nm³ Reformer
# Research Plan for Fuel cell in KOGAS

1. **1st Stage**: Development of PEMFC System and Evaluation ('15)
2. **2nd Stage**: Core component improvement and Cost down ('17)
3. **3rd Stage**: Domestic market entry of 5-50kW System ('18) 및 Overseas Market ('20)

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<th>National Roadmap &amp; National Project</th>
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Desulfurization

- **Types of Ordorant (sulfur compound)**
  - Tertiary-butyl mercaptan (TBM)
  - Tetra-hydro-thiophene (THT)

- **Concentration of Sulfur Compound**
  - Total Concentration: 3.8ppm
  - THT : TBM = 70% : 30%

- **Role of Desulfurizer**

- Natural gas used as City gas in Korea contains organic sulfur compound (3-4ppm) such as tertiary-butyl mercaptan (TBM) and tetra hydro thiophene (THT) as odorants to make it easy to detect leakage of the gas.

- However, sulfur compounds easily poisoned steam reforming catalysts containing Ni. Therefore, sulfur components have to decrease to ppb level in fuel cell system.
Desulfurization

- Evaluation of desulfurization material for Power plant MCFC (Posco Power)
- Evaluation of desulfurization material for Residential fuel cell

Desulfurization for Molten Carbonate fuel Cell
Basic experiment for simulation of PEM reformer

Chemical modeling in SR region

- **Steam Reforming**
  
  \[ CH_4 + H_2O \rightarrow CO + 3H_2 \quad \Delta H = -206.1 \, \text{kJ/mol} \]

  \[ r_1 = \frac{k_1}{P_{H_2}^{2.5}} \left( \frac{P_{CH_4}P_{H_2O}}{P_{H_2}^3P_{CO}} \right) / (DEN)^2 \]

- **Water Gas Shift**
  
  \[ CO + H_2O \rightarrow CO_2 + H_2 \quad \Delta H = +41.15 \, \text{kJ/mol} \]

  \[ r_2 = \frac{k_2}{P_{H_2}} \left( \frac{P_{CO}P_{H_2O}}{P_{H_2}^3P_{CO}} \right) / (DEN)^2 \]

- **Direct Steam Reforming**
  
  \[ CH_4 + 2H_2O \rightarrow CO_2 + 4H_2 \quad \Delta H = -165 \, \text{kJ/mol} \]

  \[ r_3 = \frac{k_3}{P_{H_2}^{3.5}} \left( \frac{P_{CH_4}P_{H_2O}^2}{P_{H_2}^4P_{CO}} \right) / (DEN)^2 \]
Results of simulation

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<tr>
<th>Species</th>
<th>Simulation</th>
<th>Experiment</th>
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<tr>
<td>CH₄</td>
<td>0.56%</td>
<td>2.43%</td>
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<tr>
<td>H₂</td>
<td>77.33%</td>
<td>77.16%</td>
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<tr>
<td>CO</td>
<td>0%</td>
<td>0.32%</td>
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<tr>
<td>CO₂</td>
<td>20.29%</td>
<td>18.86%</td>
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Comparison between simulation data and experiment data
Reformer for 1kW PEMFC System

Performance Test

Temp. of Reformer

![Image of reformer for PEMFC system]

- Electric Power
- Electric Efficiency

- SR-H Temp.
- SR-M Temp.
- HTS Temp.
- LTS Temp.
Reformer for 5kW HT-PEMFC developed by KOGAS

Developed compact reformer for 5kW HT-PEMFC
Results of performance test for 5kW-class reformer

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<tr>
<th>Name</th>
<th>Input Data</th>
<th>Volumetric Flow</th>
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<tr>
<td>Nat. gas reformer</td>
<td>Natural gas</td>
<td>20.000 [l/min]</td>
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<tr>
<td>Nat. gas burner</td>
<td>AOG</td>
<td>45.44</td>
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<tr>
<td>A/F-burner</td>
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<tr>
<td>S/C-Reformer</td>
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<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
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<td>Methane</td>
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<td>Hydrogen</td>
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<td>CO_2</td>
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<thead>
<tr>
<th>Name</th>
<th>Efficiency (LHV)</th>
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<td>Standard (behind shift)</td>
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Reformer for 10kW for PEMFC
Application of developed 10kW-reformer to fuel cell system
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 developed many sizes of reformers (1~10kW-class) and displayed the highest level of performance.
- Furthermore, KOGAS has specific strategy for Fuel Cell development and plan to develop under 50kW-class reformers according to this strategy.
- Through development and commercialization of reliable reformers, KOGAS will lead in the supply of fuel cell systems in Korea.
Thank You!!
Application to Gas Supply station

Heating 1.22 ton/hr of natural gas with heat generated from 10kW fuel cell

- Reduce the pressure of gas in pipe line in order to supply desired gas pressure to city gas companies or power plants at the gas supply station.
- Use gas heater usually to prevent pipe line, gauges and metering facilities from low temperature gas flow caused by pressure drop.
- 5 or 10kW fuel cell system can be used as auxiliary heat supplier to heat natural gas during reducing gas pressure.
Prototype burners for 5kW HT-PEMFC

Type A
Nozzle burner

Type B
Surface combustion (Cylindrical)

Type B
Surface combustion (Round flat)

Nozzle shape

Flame pattern1

Flame pattern2

Fuel: NG (7.3kW)

Fuel: Offgas (5.9kW)

Temperature profile of flame according to fuel

λ=1.15

λ=1.15