Prepared Future

H₂

O₂
About POSCO ENERGY

POSCO ENERGY engages in a wide range of business activities in the energy sector with the belief that "cleaner energy can lead to a better world to live in." We have been responsible for the reliable supply of electricity for over four decades through our LNG Combined Cycle Power Plant. We are also pushing ahead with projects involving off-gas combined cycle power generation, coal-fired power generation, fuel cell power generation, renewable energy, and waste-to-energy solutions. Powered by our experience and expertise accumulated in the Korean market, we are continually gaining wider recognition and reinforcing our presence overseas. We will build a better, happier world by providing the energy people need in a reliable manner as a comprehensive energy provider with a global presence.

POSCO selected the fuel cell business as a future growth engine in 2003 and handed over the business to POSCO ENERGY as a move to bring all energy-related businesses together and manage them in an intensive manner. We provide total fuel cell solutions from technological development to manufacturing, installation and construction, and maintenance and repair based on our fuel cell manufacturing facility, the largest-scale such plant in the world, and our world-class Fuel Cell Technology Institute. We will focus on providing the optimum solution for customers.

History

2003 • Selected the fuel cell business as the next-generation growth engine of POSCO.
2004 • Conducted the demonstration for the three 250kW-capacity fuel cell units. (RIST, Chosun University, and the Seoul Tancheon Water Treatment Center)
2006 • Installed Korea’s first commercial fuel cell at Korea South-East Power Co. (250kW)
2007 • Handing over of the fuel cell business from POSCO
   Concluded a business tie-up with FCE of the US to transfer its production technology and copyrights for local and overseas markets as well as its repair and installation technology.
2008 • Completed the fuel cell BOP manufacturing facility in Pohang. (100MW a year)
2009 • Established the Korea Technical Assistance Center
   Established the Fuel Cell Technology Research Institute.
2011 • The fuel cell stack production plant in Pohang is completed. (100MW a year).
2012 • Completed Korea’s first 100kW-capacity fuel cell for a building
   Signed the cell technology transfer agreement.
2013 • Began the construction of the cell manufacturing facility for the fuel cell
   Completed Gyeonggi Green Energy Fuel Cell Power Plant, the world’s largest. (58.8MW)
2014 • Completed the world’s first BOG (Boil Off-Gas) fuel cell in Samcheok. (300kW)
2015 • Completed the cell manufacturing facility for the fuel cell.
POSCO ENERGY is working hard to open up a better future. To realize a more fulfilling, convenient lifestyle, to better preserve our environment, and to ensure safety and happiness, POSCO ENERGY continues to pioneer fuel cell technology that advances a brighter future.
The Fuel Cell Ensures a Cleaner, Safer Future

Energy is necessary for humankind to subsist. However, many existing power generation methods pose serious problems such as environmental pollution and safety. This is why we have focused our resources on developing and sharing eco-friendly, safe, and high-efficiency energy sources with infinite possibilities. Fuel cell technology is an innovative, forward-looking energy source that helps us build a cleaner, safer future.
A fuel cell is a high-efficiency, eco-friendly energy system that generates electricity and heat by using electrochemical reactions between hydrogen and oxygen. It is an optimum alternative to replace the power generation methods of yesterday and build a greener, brighter world.

### Principles of Fuel Cell Power Generation

**Stack**
- Mechanical devices that provide hydrogen and oxygen (including heat exchangers, humidifiers, and reformers)
- Referring to the structure of layers of a cell that consists of electrodes, electrolytes, and divider plates
- Producing electricity using electrochemical reactions of hydrogen and oxygen
- Converting direct current generated from the stack to alternating current and controlling the system

<table>
<thead>
<tr>
<th>MBOP</th>
<th>Stack</th>
<th>EBOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG / Biogas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- \( \text{H}_2 \) 
- \( \text{O}_2 \) | 
- Cathode 
- Electrolyte 
- Anode | 
- Direct current | 
- Power converter | 
- Electric power |
| Heat recovery unit | 
- Heat | 
- Steam/Hot water |
Advantages of the Fuel Cell

POSCO ENERGY’s fuel cells are designed to make up for the disadvantages of existing renewable energy sources and provide a wide range of benefits. Fuel cells are an innovative energy solution with distinct advantages, thereby ensuring customer satisfaction.

🔗 Eco-Friendly

Fuel cells are non-polluting and quiet. They do not generate air pollutants such as NOx and SOx. Also, the CO₂ emissions of fuel cells are 50% lower than existing thermal power plants. They are nearly noiseless and thus suitable to be installed even in densely populated areas.

🔗 Decentralized

Fuel cells can be installed at locations with high demand to generate electricity directly. Fuel cells can contribute to the reduction of electricity loss during transmission and the number of transmission towers by supplying electricity directly or from nearby locations. Thus, they can reduce possible conflicts with local communities and prevent environmental pollution. This can lead to the prevention of environmental pollution and the reduction of possible conflicts with local communities.

🔗 Cost-Efficient

Fuel cells are outstanding in terms of cost-efficiency. Unlike existing power generation systems that require multiple stages of energy conversion, fuel cells can convert chemical energy directly to electrical energy. This minimizes energy loss generated during the conversion process and ensures high efficiency (power efficiency higher by at least 47% and overall efficiency by at least 80%).

🔗 Space-Efficient

Fuel cells generate notably high amounts of power considering the space they occupy. They require only about 0.18m² of space to generate 1kW, boasting far greater space-efficiency than existing renewable energy sources. They are small-sized and versatile, thus optimized for facilities in dense areas.

🔗 Reliable

Fuel cell technology boasts high operating reliability. Fuel cells can generate power around-the-clock all year round as they have little operating restrictions with a very low environmental impact. They are suitable to serve as an emergency power system, an uninterruptible power system, and an auxiliary power system with their over 90-percent operating rate.

🔗 Safe

The safety of fuel cells has been scientifically proven. They have no risk of explosion due to hydrogen accumulation. They are equipped with cutting-edge safety devices such as pressure regulators, flame and smoke detectors, gas leakage detectors, and ESDs (emergency shutdown devices). Our fuel cells have satisfied stringent safety management standards.
Our 300kW fuel cell is capable of producing electricity for over 690 households and heat for over 120 households with an installation area of 95m². The environmental benefits are equivalent to planting about 50,000 trees and reducing the air pollutants emitted from 160 vehicles.
Product Dimensions

300kW-Fuel Cell Diagram

End user

Electricity generated
480V

Ex-PLC

Communication
300 kW

Water feed pump

Water supply 4.0kg/cm² | 170liter/hr

Fuel supply 1.4kg/cm² | 61.9Nm³/hr

Fuel supplier
(LNG pressure regulator)

Electricity generated

MBOP

Stack

EBOP
2.5MW Fuel Cell Power Generation System

Our 2.5MW fuel cell is capable of producing electricity for about 3,200 households and heat for over 1,000 households with an installation area of 500m². The environmental benefits are equivalent to planting about 450,000 trees and reducing the air pollutants emitted from 1,500 vehicles.

### 2.5MW Fuel Cell Power Generation System

<table>
<thead>
<tr>
<th>Production per year</th>
<th>Providing electricity for 3,200 households and heat for 1,000 households</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation area</td>
<td>500m²</td>
</tr>
<tr>
<td>Fuels used</td>
<td>LNG, Bio Gas, and SNG</td>
</tr>
<tr>
<td>Eco-friendly effect</td>
<td>Equivalent to planting about 450,000 trees and reducing the NOx emissions from 1,500 vehicles</td>
</tr>
</tbody>
</table>

### Power output

<table>
<thead>
<tr>
<th>Power output</th>
<th>2,500 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>13.8 kVAC</td>
</tr>
<tr>
<td>Standard frequency</td>
<td>60 Hz</td>
</tr>
</tbody>
</table>

### Power generation efficiency

| LHV | 47% ± 2% |

### Pollutant emissions

<table>
<thead>
<tr>
<th>NOx</th>
<th>0.4 ppm or less</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOx</td>
<td>0.01 ppm or less</td>
</tr>
<tr>
<td>CO</td>
<td>10 ppm or less</td>
</tr>
<tr>
<td>Noise</td>
<td>72 dB(A)(3m)</td>
</tr>
</tbody>
</table>

### Exhaust gases

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Utilizing hot water and steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust temperature</td>
<td>358°C ± 25°C</td>
</tr>
<tr>
<td>Exhaust flow</td>
<td>16,866 kg/hr</td>
</tr>
<tr>
<td>Exhaust pressure</td>
<td>127 mmH2O</td>
</tr>
</tbody>
</table>

### Water consumption

| Water supply | 2,010 liter/hr |

### LNG consumption

| LNG | 507 Nm³/hr |
| LHV | 9,347 kcal/Nm³ |
2.5MW-Fuel Cell Diagram

- **Electricity generated**
- **Ex-PLC**
- **End user**
- **Communication**
- **2.5MW**
- **Heat exchanger**
- **Heat generated**
  - 358°C ± 25°C
  - 22m³/hr
  - 60°C
  - 22m³/hr
  - 120°C
- **Medium-temperature water recovery**
- **Medium-temperature water supply**
- **Water supply**
  - 4.0kg/cm² | 2.010 liter/hr
- **Fuel supply**
  - 1.4kg/cm² | 507Nm³/hr
- **Fuel supplier**
  - (LNG pressure regulator)
- **Water feed pump**
Extensive Application

Fuel cells are already being used in a wide range of areas including industrial complexes and national infrastructure. They are expected to be utilized in more areas and for more purposes in the near future.

**Decentralized Power Supply**

For heat supply for multiple communities, micro-CHP, CES (community energy supply), etc.

**Grid Support**

For large-scale fuel cell power generation complexes, industrial complexes, national infrastructure, etc.

**Fuel Cells Utilizing Off-Gas and Biogas/Fuel Cells for Ships**

For used water treatment facilities, landfills, and gas storage facilities/For LNG tankers, oil tankers, and container vessels.

**For Residential and Commercial Buildings**

For apartment complexes, housing complexes, hotels, office buildings, shopping malls, etc.
Status of Fuel Cell Installation

We are supplying clean energy in a reliable manner through our fuel cells across the nation. We will continue to create greater value for customers in Korea and beyond.

149.2MW
In operation in over 20 locations

As of January 1, 2015
Fuel Cell Hub in Pohang

We are equipped with the world's largest fuel cell manufacturing facility. We have been pushing ahead with R&D and investment in this field since 2007 to secure original technology, develop commercial technology, and establish leading-edge production facilities. We achieved 100% localization of fuel cell production based on the phased plan from the installation and construction of fuel cells to the production of the cell – the key components of a fuel cell. We also provide total fuel cell solutions from the development to the manufacturing, installation and construction, and maintenance and repair of fuel cell power generation systems through our industry-leading Fuel Cell Research Institute.

BOP Manufacturing Facility

**Area:** 8,479m²  
**Completed in:** August 2008

The BOP Manufacturing Facility produces MBOP, the fuel supplier for fuel cells, and EBOP, which converts power to eco-friendly energy. It can produce 100MW at maximum per year.

Stack Manufacturing Facility

**Area:** 7,200m²  
**Completed in:** March 2011

The Stack Manufacturing Facility manufactures the stack module, the key part of a fuel cell that generates electricity and heat through electrochemical reactions between hydrogen and oxygen. The Stack Manufacturing Facility is capable of producing stack modules equivalent to 50MW per year.

Cell Manufacturing Facility

**Area:** 16,830m²  
**Completed in:** July 2015

The Cell Manufacturing Facility produces the cells, which refer to the end cell laminated inside the stack. The Cell Manufacturing Facility has one underground level and two stories above the ground and can manufacture cells equivalent to 100MW per year.

Conditioning Plant

**Area:** 946m²  
**Completed in:** March 2011

The Conditioning Plant conducts the trial-run process aimed at stabilizing and optimizing the manufactured stacks.
We guarantee the agreed output and reliable operation of our fuel cells through the LTSA. We strive to always put our customers first and provide optimized customer service.

**LTSA**
Long-Term Service Agreement

**Monitoring**
A 24-hour remote-control monitoring system and quick-response communication system for emergencies are in operation.

**Plant Operation Condition Guarantee**
A preset amount of electricity generated is ensured at all times to improve the reliability and operating rate of the plant.

**Timely maintenance**
Timely maintenance is provided to promptly restore the conditions to normal when signs of abnormality are detected through remote-control monitoring.

**Preventive maintenance**
Preventive maintenance is provided for technological services as well as the supply, replacement, and examination of components and consumables as scheduled.
We remain at the forefront of fuel cell R&D powered by the POSCO Group’s aggressive investment. We will reinforce our foothold as a globally renowned fuel cell provider by further improving our technological prowess and business competence.

**Development of World-Class Technology**

- We are powered by the POSCO Group’s continued research and investment for the development of original technology and commercial technology for fuel cells.
- We collaborate with experts in other areas to develop fuel cells specialized for different purposes beyond commercial power generation, including those for buildings and ships.

**SOFC (Solid Oxide Fuel Cell)**

We are focusing our resources on developing ways to commercialize the next-generation SOFCs (Solid Oxide Fuel Cells) that are more efficient than the existing fuel cells and more effective in reducing greenhouse gas emissions. We will continue to strive to develop outstanding products based on our technological prowess.

- Power generation efficiency of 50-60% (efficiency of 70% or higher achievable with combined cycle generation)
- Cell output per unit area ~2-5 times higher than MCFC
- System output per unit volume ~2-3 times higher than MCFC (number of BOP components reduced by about 30% compared to PEMFC)
- The stack preconditioning process reduced (from 11 days to no more than about 3 days)
- Start-up time reduced (from 83 hours to no more than 10 hours)
- Use of various fuels possible, including natural gas, LNG, hydrogen, and coal gas, without the need for preconditioning equipment
- Fueled by various energy sources
- Convenient in manufacturing and maintenance and repair
- Economical
- Highly efficient
- Space-saving

*Projected by the US Department of Energy* 700USD per kW (by 2020)
High-Efficiency MCFC and MCFC Convergence Technology Development

**High-Efficiency MCFC (connected to the Organic Rankine cycle)**
- The high-temperature exhaust gases of a fuel cell are connected to the Organic Rankine cycle system for power generation.
- The Organic Rankine cycle refers to a system that generates power with low- and mid-temperature heat sources using working fluid with a low boiling point.

**High-Efficiency MCFC (connected to a turbine)**
- High efficiency convergence fuel cell enables higher extent of fuel utilization. Integration with other power generation technology makes the extra amount of electricity generated without having to consume additional fuel.

**MCFC-H for Hydrogen Supply**
- MCFC-H produces hydrogen while it generates electricity and heat. The system collects unreactive hydrogen from the stack module and concentrate it into usable form such as hydrogen fueling and other industrial purposes.

**MCFC-CCS (Carbon Capture and Storage)**
- MCFC can concentrate CO₂ and thus enables the capture of CO₂ generated from steelworks, power plants, and businesses.
Future of Fuel Cells

Fuel cells are an energy source of unlimited possibilities that can be utilized as a charging device for electrical and hydrogen vehicles, a decentralized power supply device for rural communities, and a power supply device for railways and subways. They can also be fused with other renewable energy sources. In the future, fuel cells will be developed into a perfectly eco-friendly energy source that generates power with only the hydrogen extracted from water and oxygen extracted from the air.

**Convergence with Renewable Energy Sources**

- This technology aims to overcome the limitations and disadvantages of individual renewable energy sources through technological convergence with other renewable energy sources and EMS (Energy Management System).

**Fuel Cell for Eco-Friendly Vehicle Charging Stations**

- Electricity generated by fuel cells can be used to charge electric vehicles.
- Non-reactive hydrogen within fuel cell can be captured and used to charge hydrogen vehicles.

**Fuel Cell for Farming**

- Rural communities can achieve energy independence by installing fuel cell – a decentralized power source.
- Greenhouse gas emissions can be reduced and high-added-value farming can be nurtured by fusing agriculture and cutting-edge technology.

**Fuel Cell for Railways and Subways**

- Fuel cell can be used as the main power supply for car depots.
- Fuel cell can be installed at railway stations and supply power for light-rail and high-speed rail systems as well as the railway stations themselves.

We are developing a wide range of business models based on our exclusive sales right over the Asian market obtained after the signing of the cell technology transfer agreement with FCE. We are pushing ahead with our plan to advance into global markets such as China, Indonesia, and the Middle East by taking advantage of the POSCO Group’s worldwide presence. We will contribute to building a more convenient, cleaner world by providing our fuel cell solutions to more regions and industries.
Beyond Energy, Better Life

POSCO ENERGY is determined to march forward. We will continue to achieve innovation based on our creativity and deliver greater value to our customers. We will build a cleaner, safer world by providing products of outstanding quality and value.

Headquarters
16F, POSCO Center West Wing, 440, Teheran-ro, Gangnam-gu, Seoul, Korea

Pohang Fuel Cell Manufacturing Facility and R&D Center
153 – 154, Sindan-ro 88 beon-gil, Yeongil-man, Heunghae-eup, Buk-gu, Pohang, Gyeongsangbuk-do