

# DEVELOPMENT & DEPLOYMENT STATUS OF **STATIONARY FUEL CELLS** IN KOREA

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- MCFC Deployment Status in Korea
- On-going Activities for Product Improvement

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- Background
- Cell and Stack Technology
- BOP Technology



# Fuel Cell History in POSCO Energy



## Manufacturing Facility in Pohang

Annual Production: 100MW

Total Area: 210,000m<sup>2</sup>

### 2007

- Strategic Collaboration with FCE, US
- RIST/POSCO Energy initiated SOFC R&D

### 2008

- Production of MCFC BOP in Pohang initiated

### 2011

- Production of MCFC Stack in Pohang initiated
- ISO9001 Certification

### 2013

- 60MW Gyeonggi Green Energy in Operation
- 10MW MCFC BOP Developed

### 2014

- MCFC/SOFC R&D Reorganized & Expanded

### 2015

- Cell production will be initiated in October, 2015 (100MW/yr)

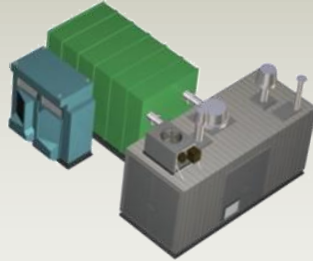


# Products

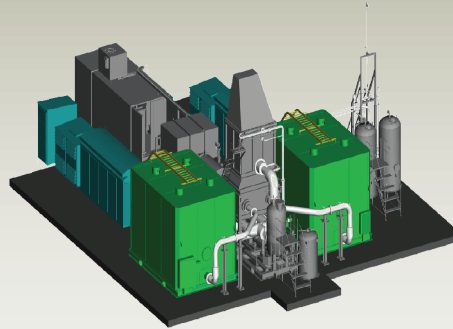
## MCFC Platform Products



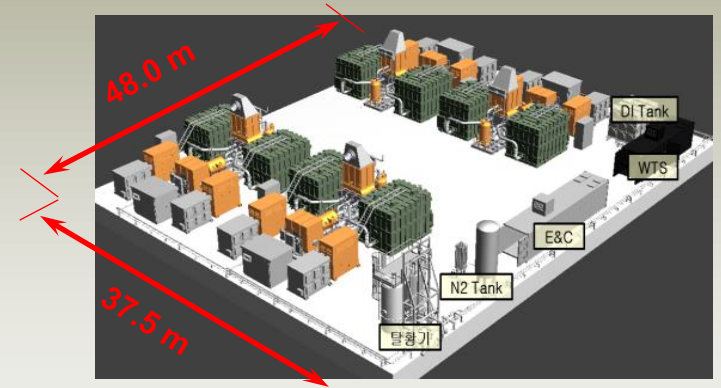
100kW



300kW



2.5MW



8x1.3MW Module + 10MW BOP

## SOFC Prototype in 2017



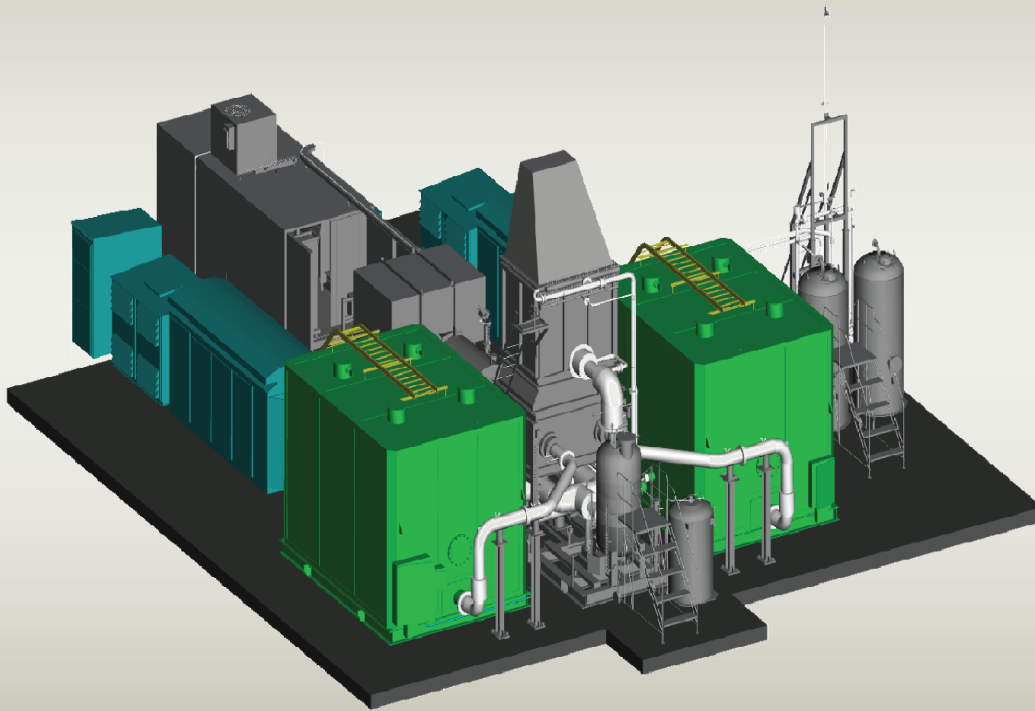
10-50kW

- Advanced MCFC
- MCFC Hybrids (Cascade, Turbine, ORC etc.)
- MCFC-Methanator/Membrane Reactor
- Hybrids MCFC-SOFC Cascade

👉 Near-term Derivative Products by 2020



# 2.5MW Product Specifications



- **2.5MW Main Products: 2 x 1.25MW Module**
- **Each Module = 4 Stacks**
- **Nominal Operation at 2.5-2.6MW**
- **Max. Power Generation at 2.8MW**
- **5 years of Useful Life**
  
- **High-Grade Heat Recovery Available**
- **Low-Grade Heat Recovery will be Available in 2015**

## Design Basis

Item	Spec.
Power Output, MW	2.5
Operating Temperature, °C	650
Elec. Efficiency (LHV), %	44~49
Available heat, MW (to 120°C)	1.10
Available heat, MW (to 50°C)	1.86



# 100kW/300kW Building Applications

- Sub-megawatt products has been improved & diversified for niche market.
  - 100kW : 2 units in Seoul (One advanced unit being operated since Jan. 2012.)
  - 300kW : Under operation in Samchuk ('14, w/ BOG), Namdong ('10) & JAKARTA ('14)



SeoBuk Hospital

Children's Grand Park

100kW MCFC System under Operation in Korea



300kW MCFC System in Jakarta

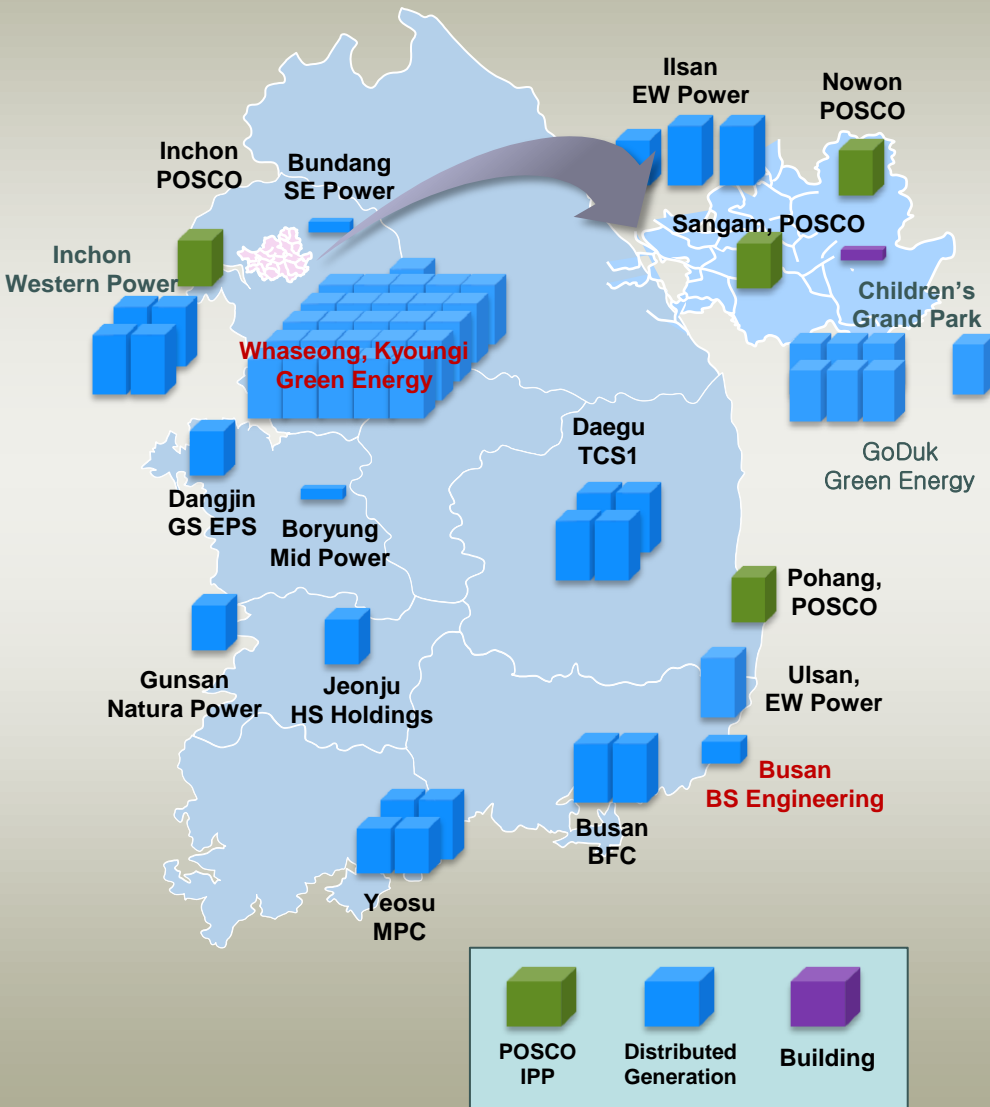


# *Subsidy for Stationary Fuel Cell*

- **FIT (Feed-in-Tariff): 2006-2011**
  - 274.08 Won/KWh to >200kW scale stationary (fixed rate)
  - Total 50MW capacity deployed until 2011
- **RPS (Renewable Portfolio Standard): 2012- 2024**
  - Mandatory power production from new & renewables with increasing percentage: 5% in '15 to 10% in '22
  - Obligation to utility companies generating over 500MW
  - REC (Renewable Certificate Credit) = 2 for stationary fuel cells
- **Public Building Regulations**
  - Mandatory installation of new & renewables in the new or reconstructed buildings of over 1000m<sup>2</sup> floor area
  - >10% of expected energy consumption by new & renewables
  - Heat for buildings from new & renewables (RHO: '16)
- **Seoul City Master-plan: Plan to substitute 1 nuclear power plant with new & renewables by 2020**
  - Reduction of 200 million TOE of CO<sub>2</sub> by 2017
  - Increase self-sufficiency rate of power from 2.8% to 8% by '14, and upto 20% by '20



# Stationary Generation in Korea



- Total 149.5MW under operation at 25 sites (as of March 2015)
  - Distributed Power: 149.4MW at 24 sites
  - Buildings: 100kW at 1 site
  - 300kW in 3 sites
- MOU Completed : 115MW at 5 sites & more
- The scale becomes larger as the demand for RPS continues to grow.
  - Largest site: 60MW at Hwaseong
  - 20-100MW scale being planned at 9 places.



# 60MW MCFC Power Plant in Operation



- **Kyeonggi Green Energy at Hwaseong, Korea ('13.12~)**
  - **Capacity: 58.8MW (2.8MW x 21Units)**
  - **Installation Area: 20,000 m<sup>2</sup>**
  - **Construction Period: '12.11~'13.12**
  - **Annual Production: 464GWh w/ 195,000Gcal heat**



# 250kW MCFC Power Plant on Biogas



- **Tancheon Sewage Treatment Plant in Seoul ('04~'07)**
  - **Governmental Program for Demonstration of FC on Biogas**
  - **Drawn Issues:**
    - Impurities and impurity contents are changed with season (sulfur compounds, siloxanes, ...).
    - Caloric value of biogas continues to fluctuate.



# 1.2MW MCFC Power Plant on Biogas



- **Haeundae Sewage Treatment Plant in Busan ('10.05~)**
  - **Construction Period: '09.8~'10.3**
  - **Fuel: Biogas 80%, LNG 20%**
  - **Greenhouse Gas Mitigation: ~7,000 ton/yr**

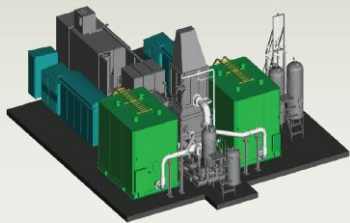
Period	Biogas Production (Nm <sup>3</sup> /day)	Biogas Consumption (Nm <sup>3</sup> /day)		
		Digestion Tank Heating	Fuel Cell	Incineration
~'09 (before FC)	10,000	7,000	-	3,000
'10~ (after FC)	13,000	4,000	9,000	-



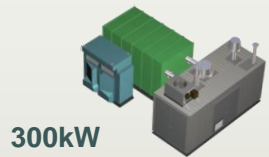
# Future Derivative Products

- Additional value proposition via technology convergence has been actively explored.

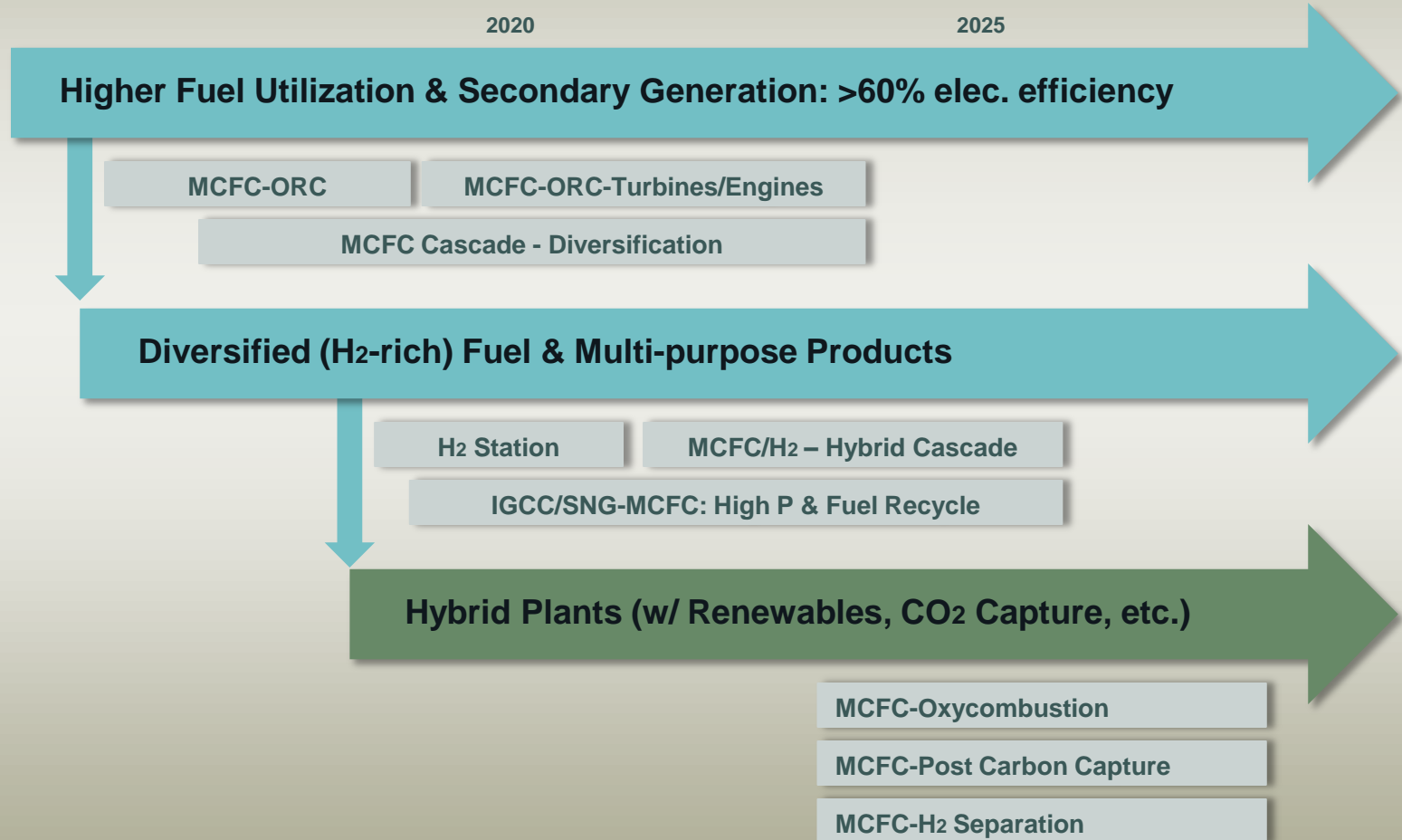
## Platform Products



2.5MW



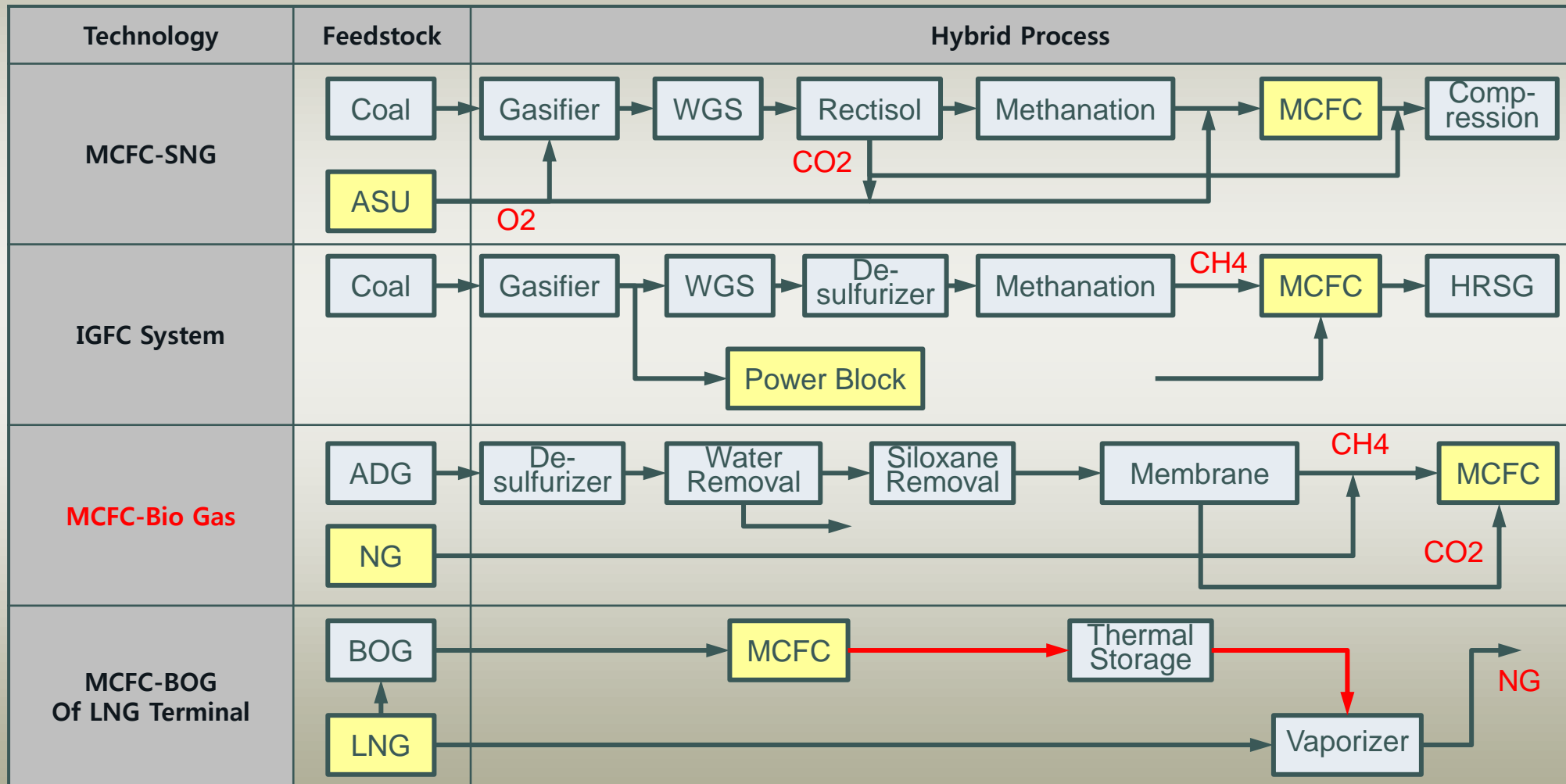
300kW





# Applications for Diversified Fuel

- Process engineering has been advanced for the variety of hydrogen-rich fuel and other feedstock.

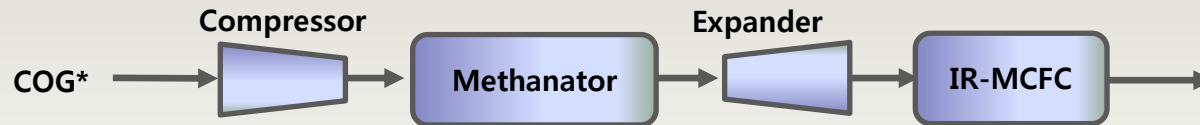




# Methanator for COG & IGFC

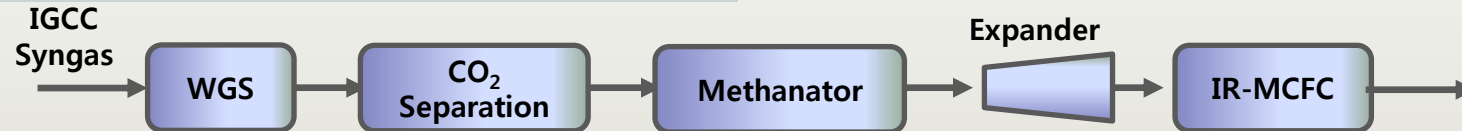
- With methanation of H<sub>2</sub>, electrical efficiency from the hybrid plant reaches 40~43%, which is still higher than that of conventional thermal power plants.
- Cascade operation, fuel recycle or higher pressure operation will be effective to improve electrical efficiency further (by 5-7%).

## Case 1. IR-MCFC System for COG



\* Coke Oven Gas: H<sub>2</sub> 56%, CH<sub>4</sub> 27%, CO 8%

## Case 2. Integrated Gasification IR-MCFC System



	Case 1	Case 2
Stack Power(AC, kW)	2,501	2,506
Comp. Power Consumption (kW)	222.1	-
Expander Power (kW)	110.7	189.2
Net Power (kW)	2,389.3	2,695.2
Fuel LHV (kW)	5,529.5	6,783.8
<b>Electrical Efficiency (%)</b>	<b>43.2</b>	<b>39.7</b>

※ U<sub>f</sub> : 70%, S/C ratio : 1.9 (@135mA/cm<sup>2</sup>)



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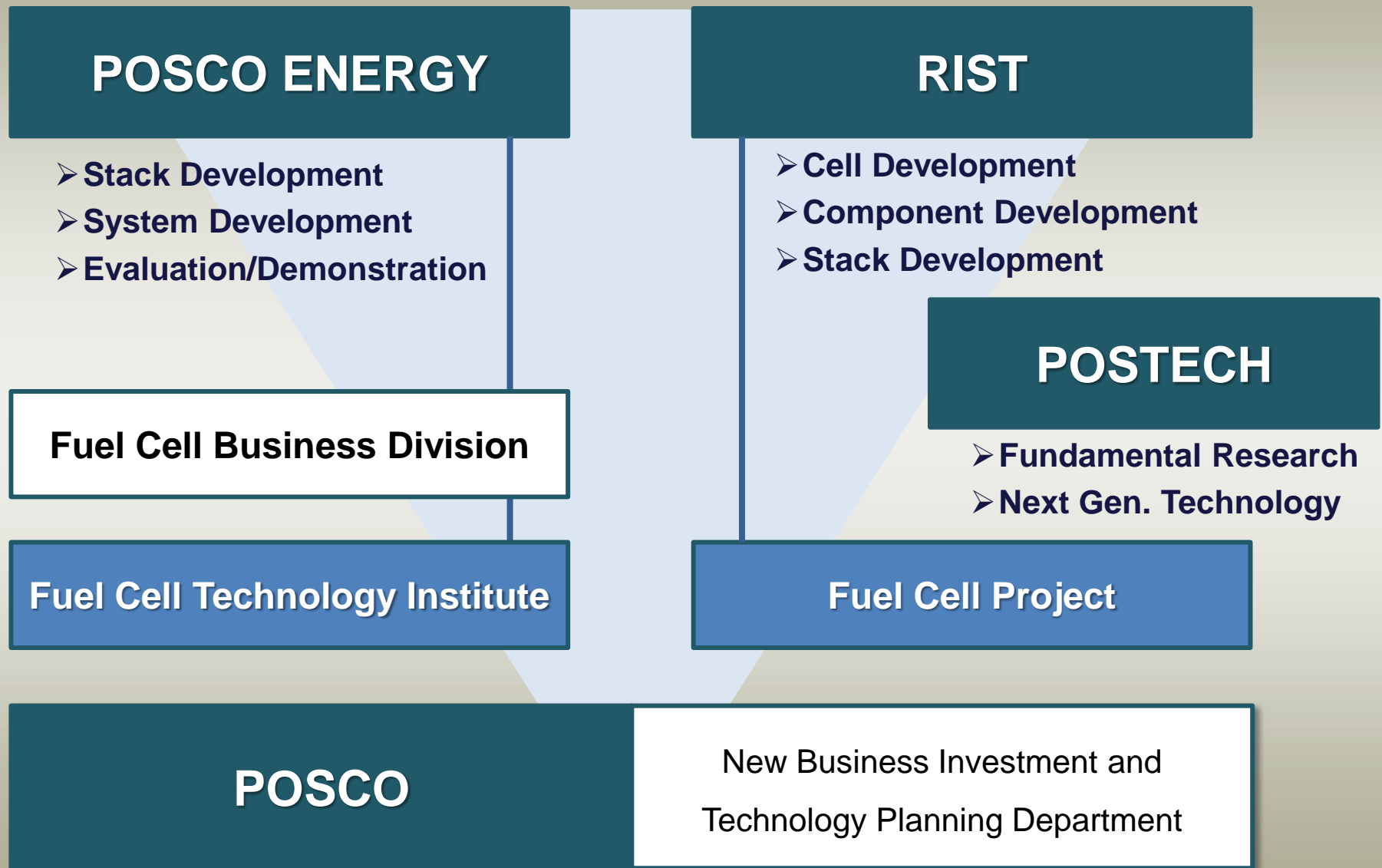
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# R&D Organization for SOFC



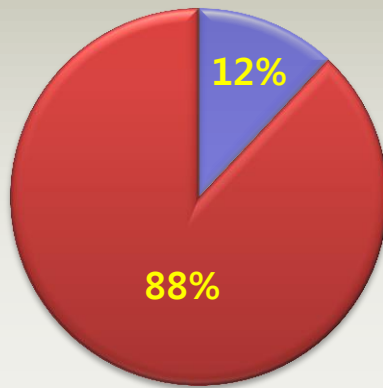
- R&D Planning and Funding



# Market Forecast for Building Application

- 265MW for the next decade by conservative prediction

Buildings larger than 10,000m<sup>2</sup>



100kW

115MW for 10 years



10~50kW

150MW for 10 years

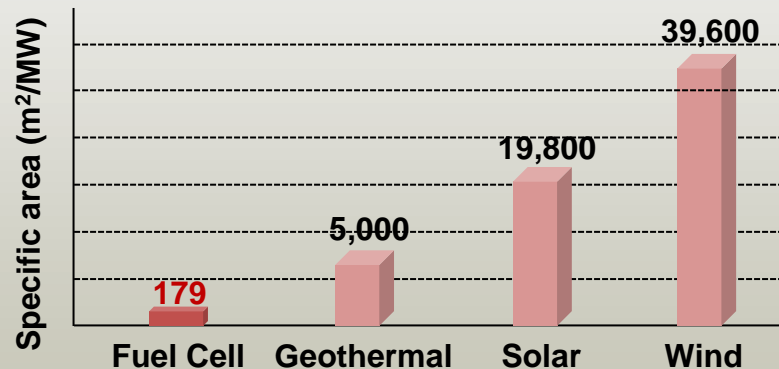


Predicted Market Size with conservative assumptions

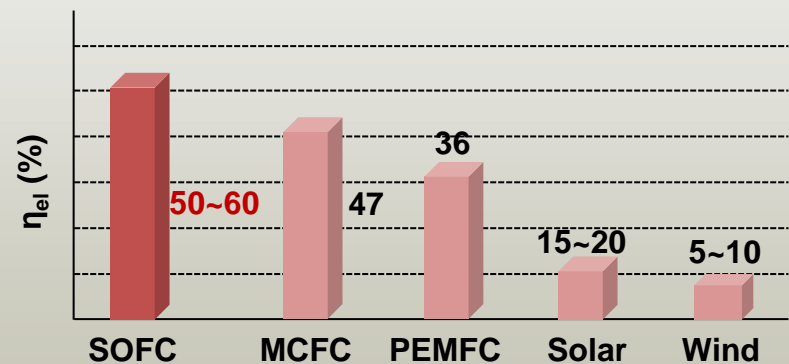
Buildings of 1,000 to 10,000m<sup>2</sup>

- Critical requirements : System size, Electrical efficiency

## ➤ System Foot Print



## ➤ Electrical efficiency





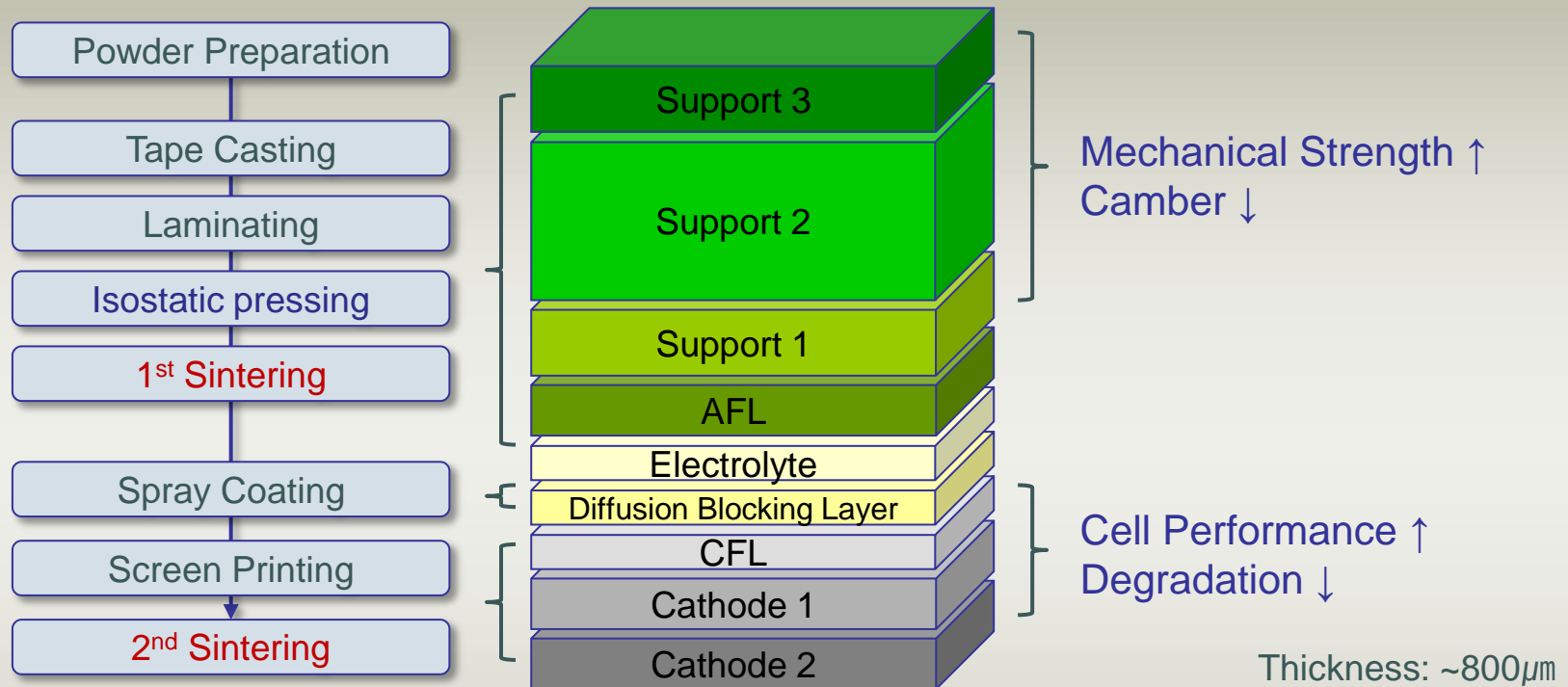
# R&D Projects

- **Demonstration of 10kW SOFC System for Building Application (2014-2017): PE, RIST, KIST, ...**
  - Develop 10kW class stack and BOPs.
  - Operate 10kW class SOFC system for 3,000h continuously to estimate economic feasibility.
- **Test of 5kW SOFC Stack on Biogas (2015- 2018): RIST, KOGAS-Tech, ...**
  - Develop biogas purification system for FC with economic feasibility.
  - Evaluate the performance of SOFC stack on biogas.
  - Optimize the system design and process for the biogas fueled SOFC.
- **Development of SOFC Stack with High Reliability (2015-2019): RIST, KIST, ...**
  - Development of 1kW stack unit with the degradation of <10%/20kh.
  - Operate 3,000 h continuously with load cycles, load trips, and thermal cycles.

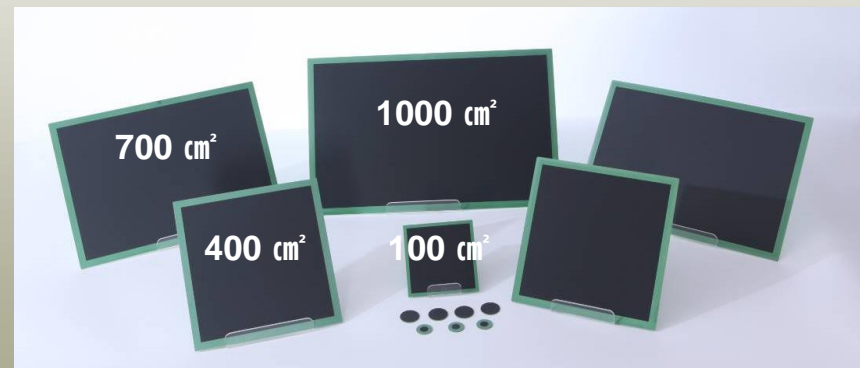


# Cell Development

## ➤ Structure and Fabrication Process



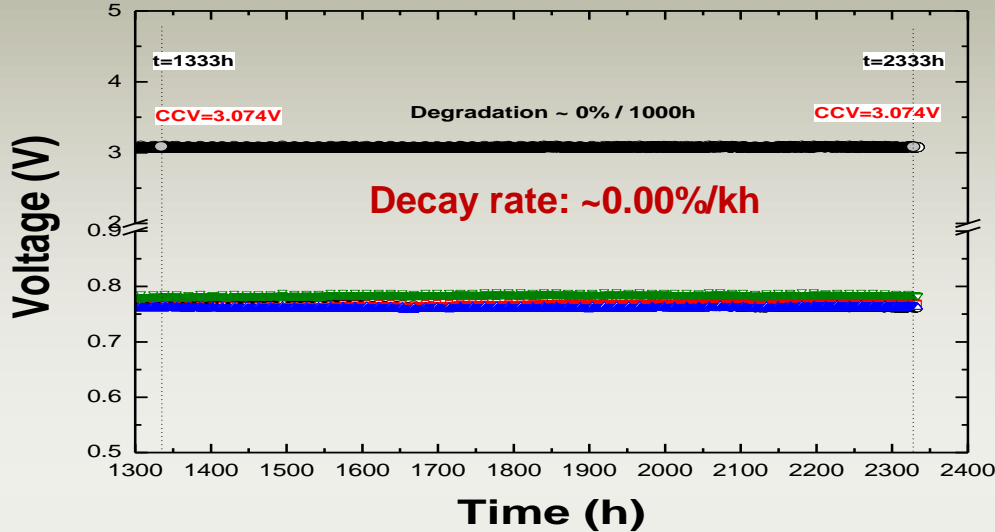
- Cell fabrication is based on tape casting & sintering processes
- Maximum size of cell, fabricated and tested, is 1,000 cm<sup>2</sup>



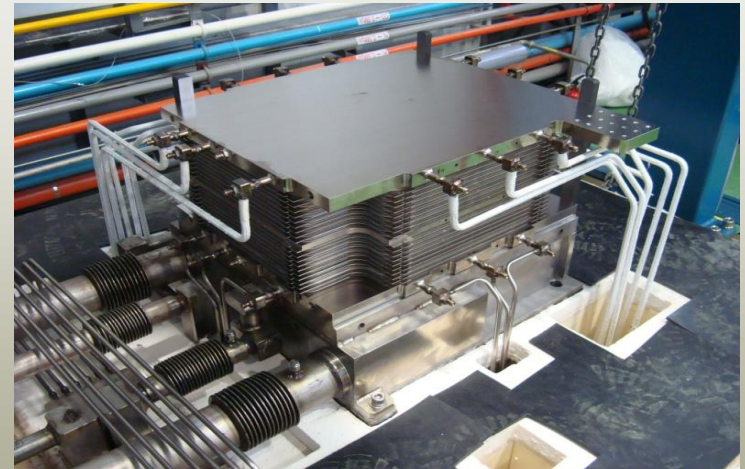
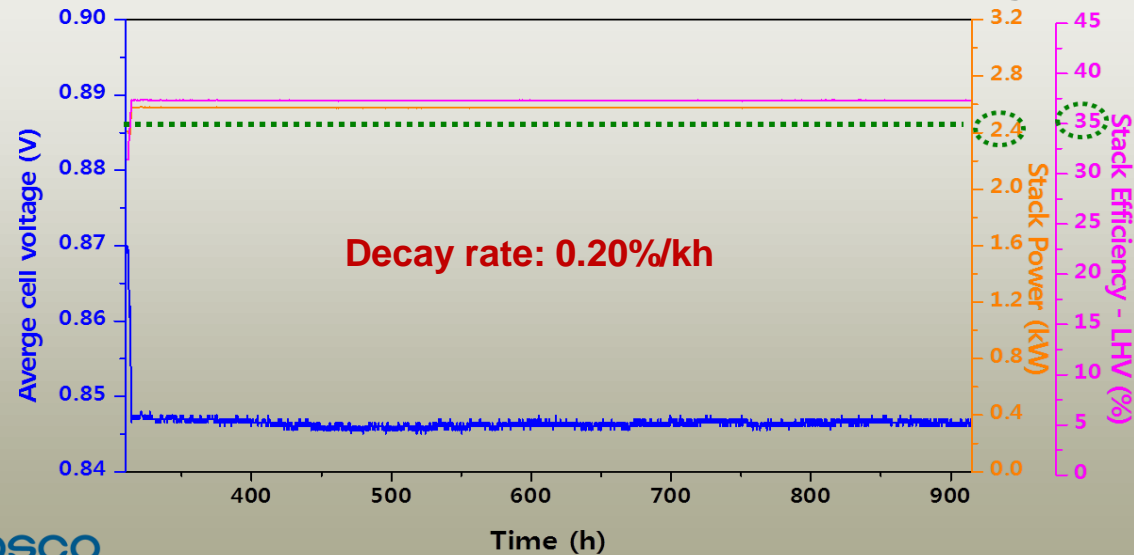


# Cell and Stack Components Validation

## ➤ 4-cell stack test : validation of materials set



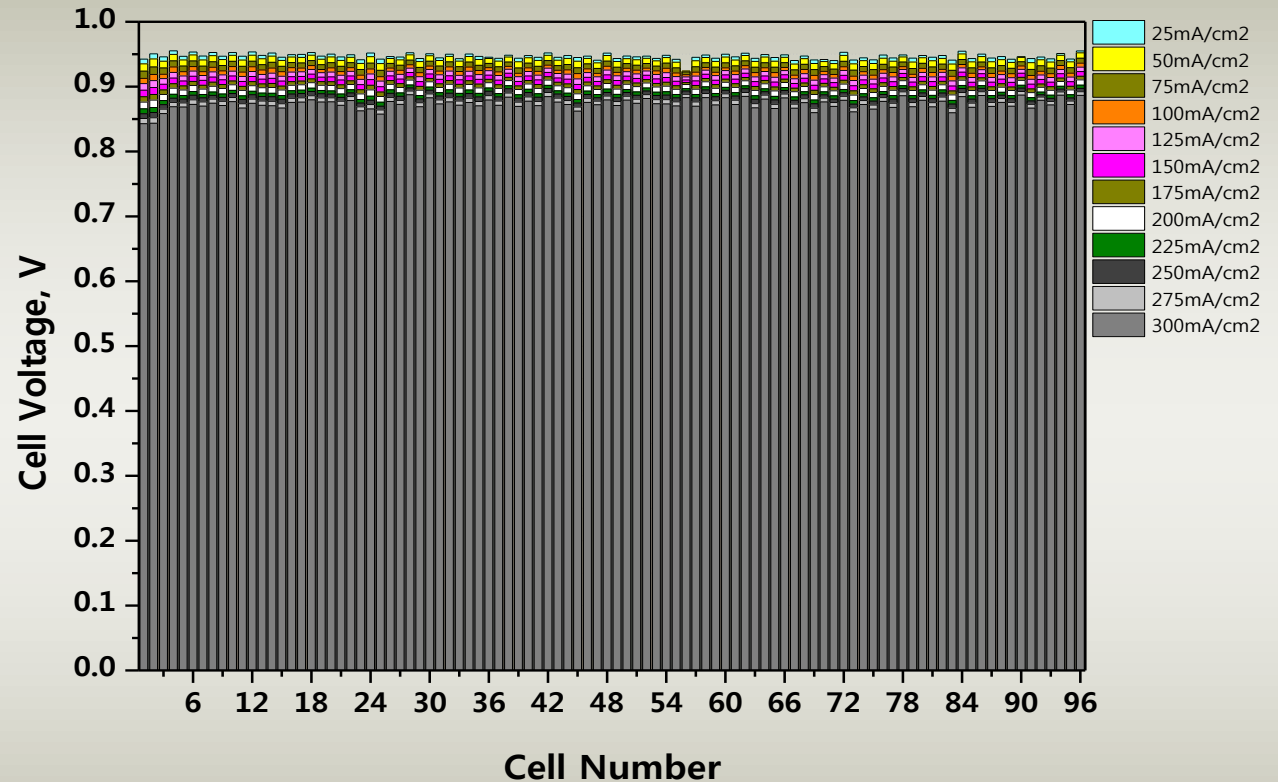
## ➤ 20-cell stack test : validation of structural design





# Stack Evaluation

## ➤ 10kW Class Stack



- **25 × 25cm<sup>2</sup> cells**
- **13.5kW DC @ 300mA/cm<sup>2</sup> (U<sub>f</sub> = 65%, U<sub>a</sub> = 30%)**
- **η = 53%**
- **Avg. V = 0.85V**
- **Thermal Cycle and Redox Cycle are still open issues.**



# BOP Development

## ➤ Anode Recycle Blower

- Parasitic load : 485W
- Flow rate : 3.20g/s (565LPM)
- Rotation speed : 160,000 rpm
- Operation temperature : ~550°C



## ➤ Integrated Heat Exchanger

- 3 heat exchangers integrated in 1 body (HEX100, HEX150, HEX300)
- Primary surface & counter flow type (Reduction of pipe length and hot box volume)



## ➤ EBOP

- Conversion efficiency : 92%
- Input current ripple : 4%
- Output current THD : 3.5%

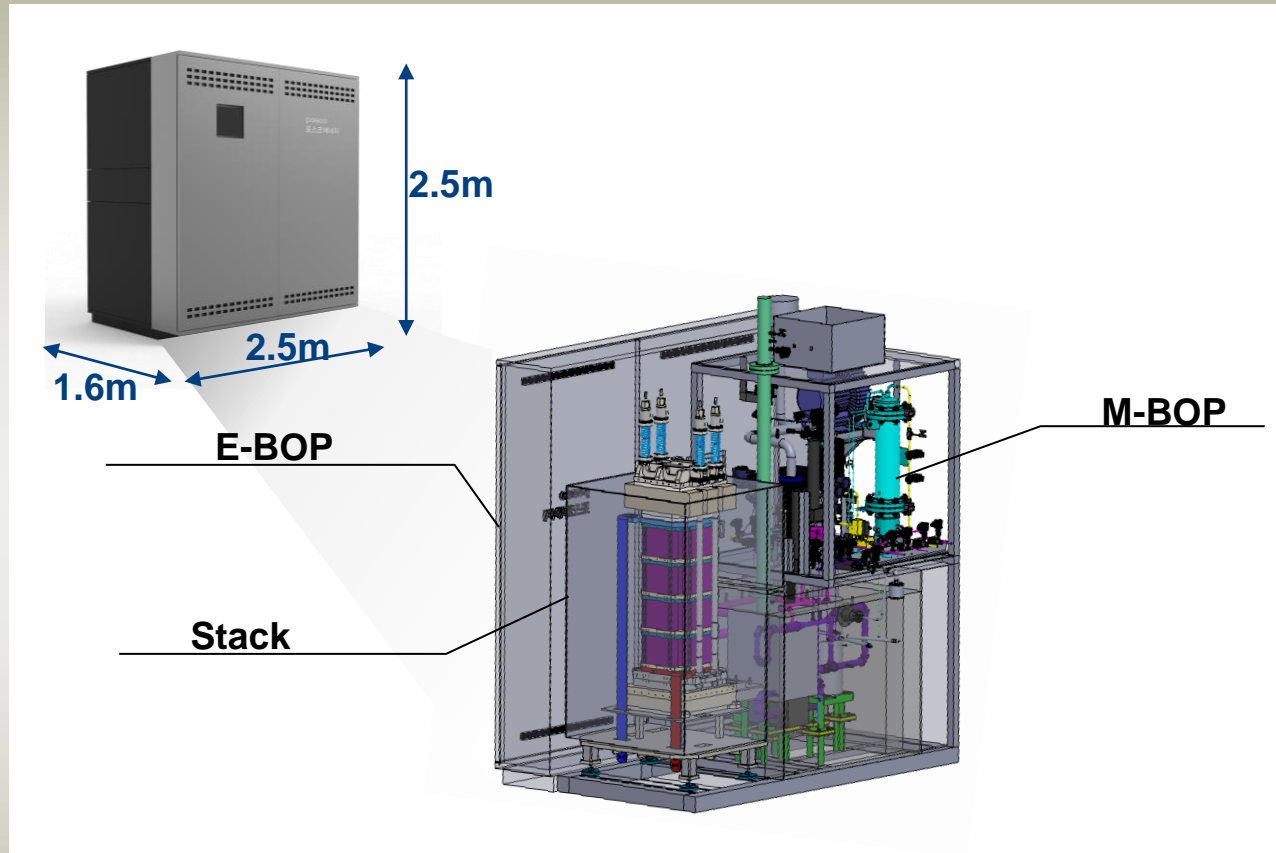
## ➤ Pre-converter (Reformer)

- Heat source : anode exhaust gas
- Reforming ratio : 40%





# 10kW Prototype System



- Recirculation of anode-off gas for enhanced efficiency
- Compact design to meet the requirements for building application
- Unmanned operation and remote control



# Summary

- Based on the governmental subsidies, such as RPS and building regulations, fuel cell market for stationary generation in Korea is expected to grow steadily.
- To accommodate growing market as well as to prepare free market for the future, POSCO Energy put an effort to develop high-efficiency products, while keep improving current MCFC products for lower cost and longer lifetime.
- Recently, large size market for diversified fuels, such as Biogas, COG, SNG, and other H<sub>2</sub>-rich fuel from chemical plants emerges fast, and engineering processes for fuel treatment are also being actively developed.
- 10kW SOFC system for building application in Korean market is almost ready to be demonstrated.
- The quality control and reproducibility as well as the load, thermal, and redox cycle-ability of stack are still open issues for commercialization.
- Research efforts are now being focused on the diagnosis of stack operation, performance degradation studies, and cycle-ability reinforcement.