

Development of Fuel Cell System For Telecommunication Backup Power

HYUNDAI HYSCO

Jeon Yoo Taek

2015.05.29



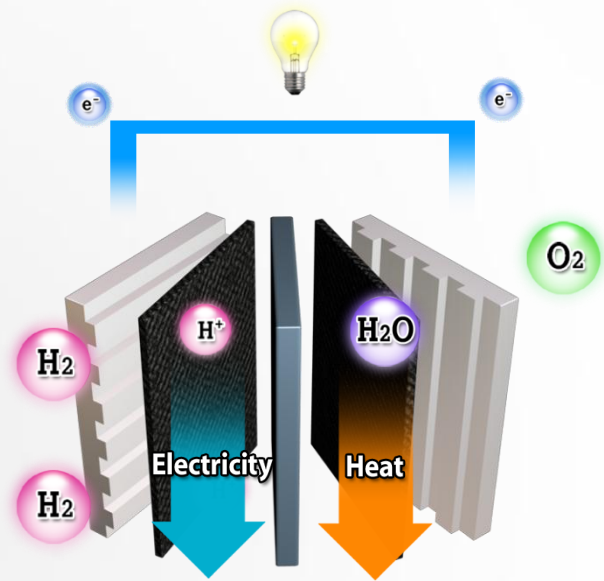
Development of Fuel Cell System For Telecommunication Backup Power

1. Introduction
2. Market analysis
3. Energy issues in Korea
4. Development concept
5. Air-cooled stack
6. FC System technics for Backup Power
7. Future works
8. Conclusions

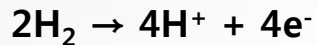


Introduction

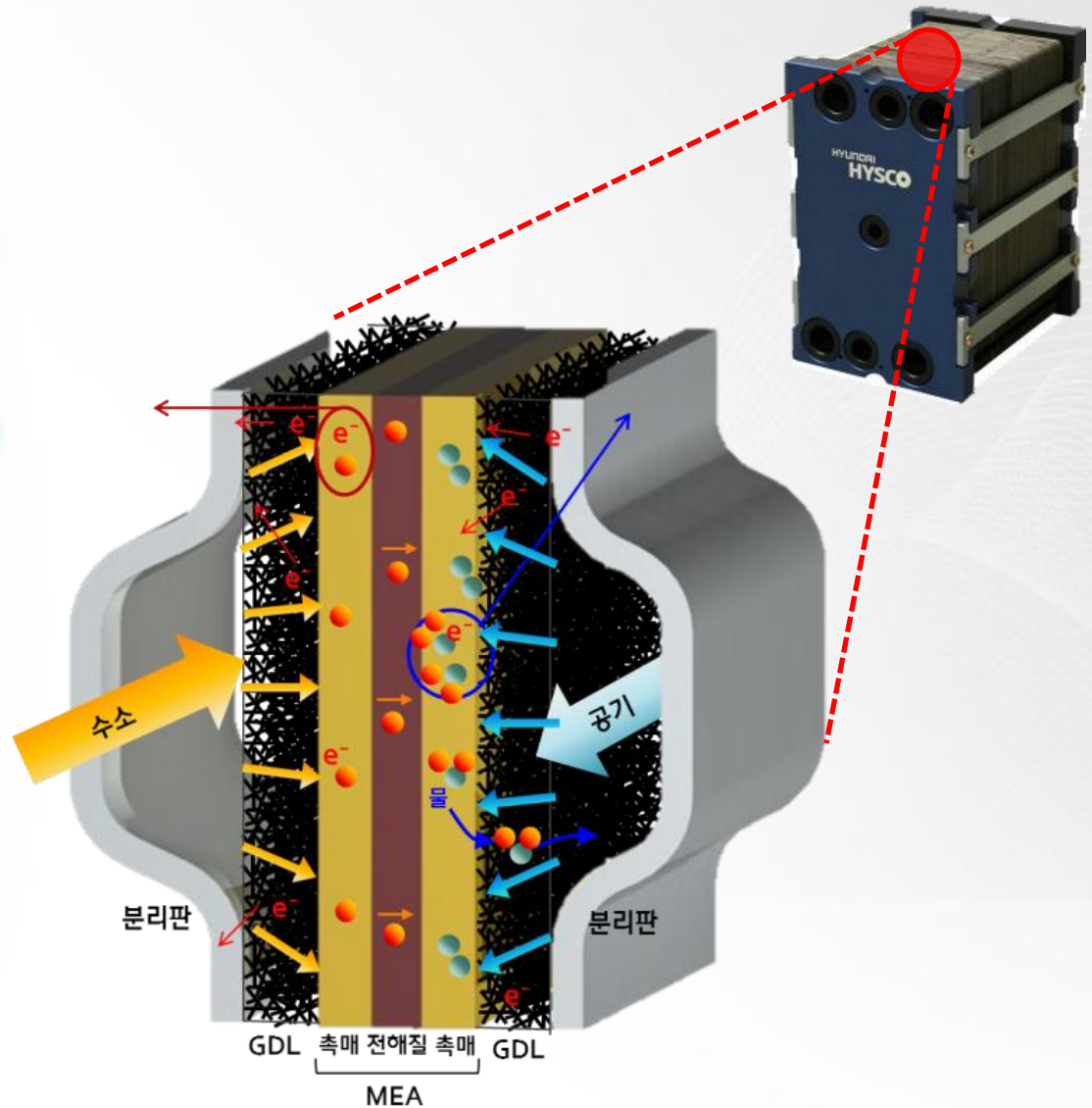
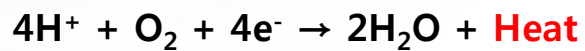
What is H₂ Fuel cell ?



<Anode Reaction>



<Cathode Reaction>



What is Fuel cell for backup power ?

● Restriction of Hazardous substances (RoHS) : July, 2006

- **Lead**, Cadmium, **Mercury**, etc, using these hazardous materials in some specific industries is strictly prohibited
- Reinforced RoHS2 (June, 2011)
- Manufacturers' mandatory compliance with RoHS1, 2

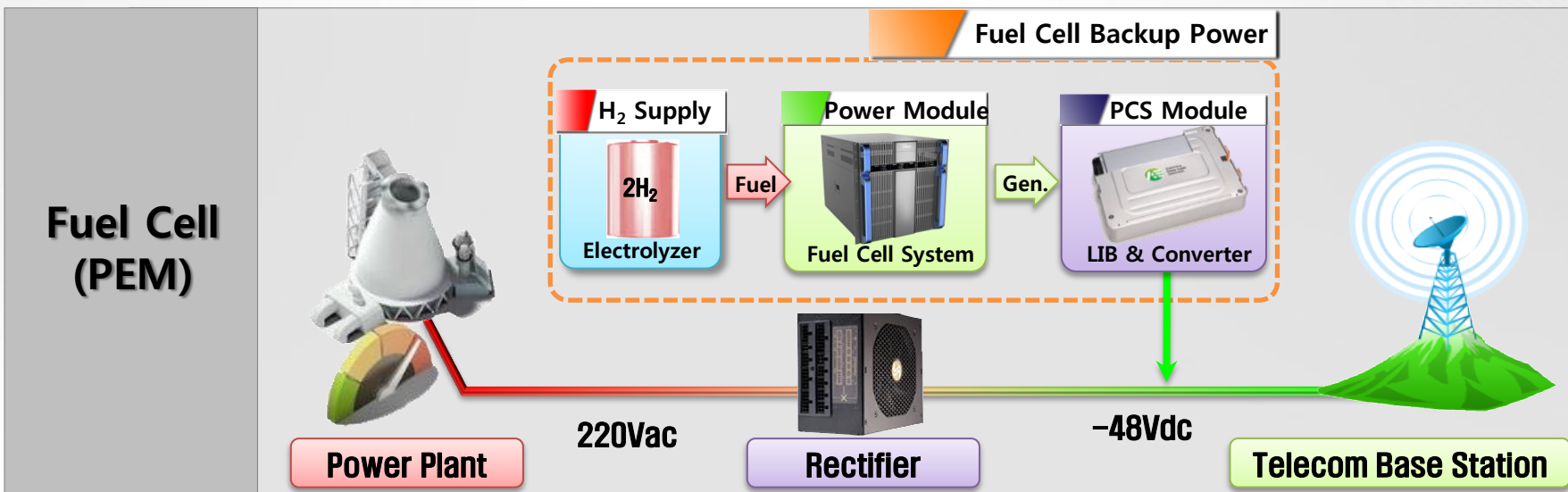
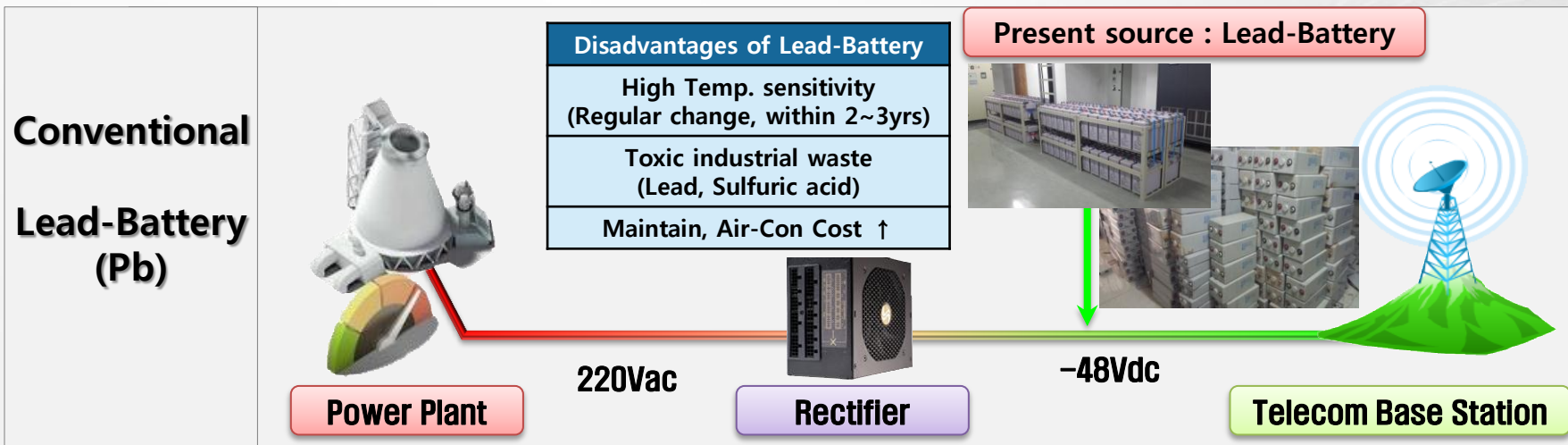
● Demand of renewable energy source

- **Mandatory** installation of backup power : hospital, manufacturing line, etc.
- Recommendation of renewable energy in backup power : **CO₂ reduction**

● Develop technology for low-maintenance cost

- Conventional backup power has low-durability and high maintenance cost
 - Replacement period : Every 2~3yrs (Lead-battery)
 - Air conditioning to maintain system operation of Pb battery
 - : using a lot of electricity ⇒ **Maintenance cost** ↑

Concept of PEM Fuel Cell for Telecommunication Backup power



Failure analysis of Telecom base station

Damage during Blackout

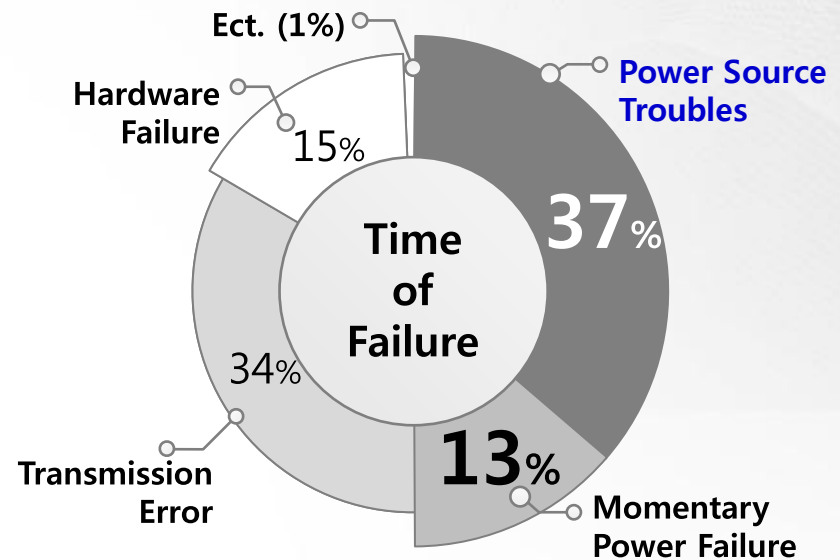
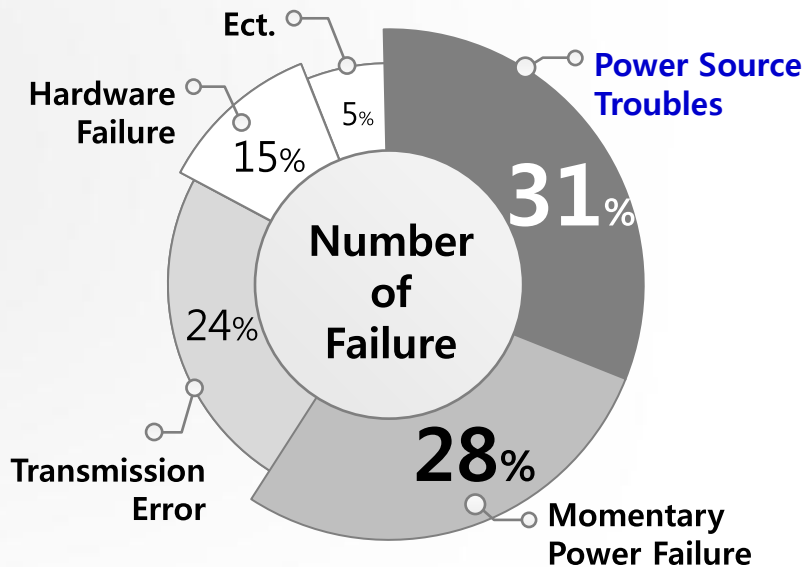
- (Assumption) 1 Telecom. base station/day : Calls 1,350 Erl / Data 12GB

※ 1 Erl = number of calls × average holding time(hr),

※ 1 Erl = Status of call line for 1 hr without interrupt (Erl : 3,600sec, 1Erl = 36HCS)

→ **Damage of service interruption under unstable electricity (1 site/day)**
: about \$ 2,200 per day

- Analysis of Service failure



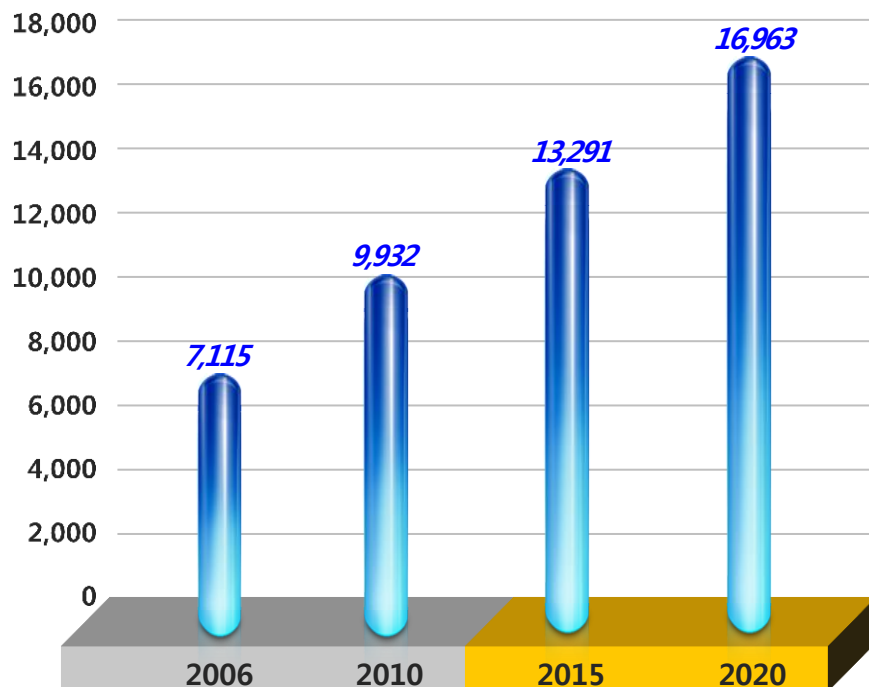
Number of stations	Number of failure	Average shutdown time
1,996 places	168 times/month	2 hrs

UPS (Uninterruptable Power Supply) Market (Global)

- Forming the largest market around the United States and Europe
- Expectation of **rapid market expansion in Asia, especially China and India**
- Estimated Backup power market : about \$ 17 billion in 2020

<Global Market>

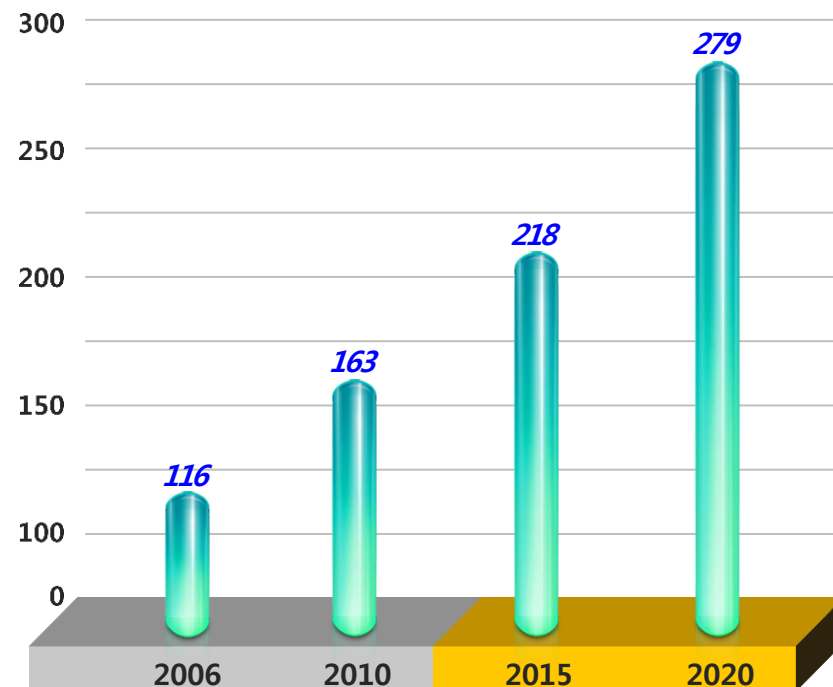
(Units : million \$)



※ Ref. : Frost & Sullivan, Renewable energy market

<Domestic market (KOR)>

(Units : million \$)

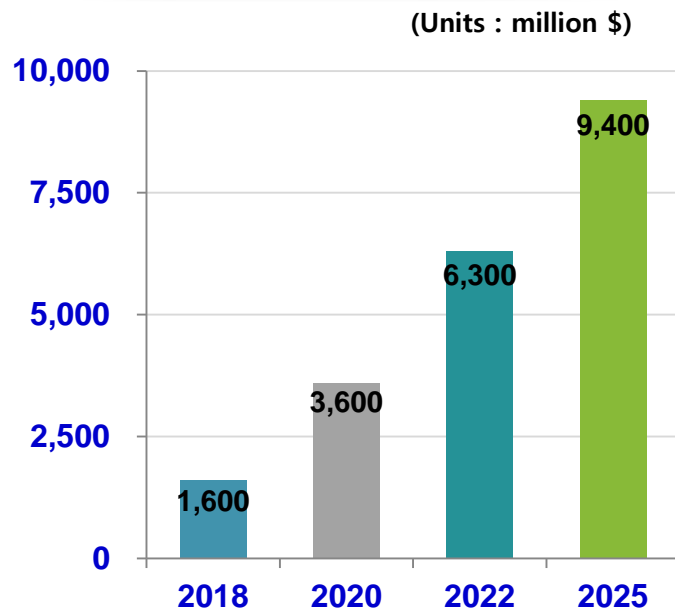


※ Ref. : Ministry of Science, ICT and Future Planning (KOR)
※ Assumption : Base station 50K sites, 1% grow up every year

Market Analysis (Fuel cell)

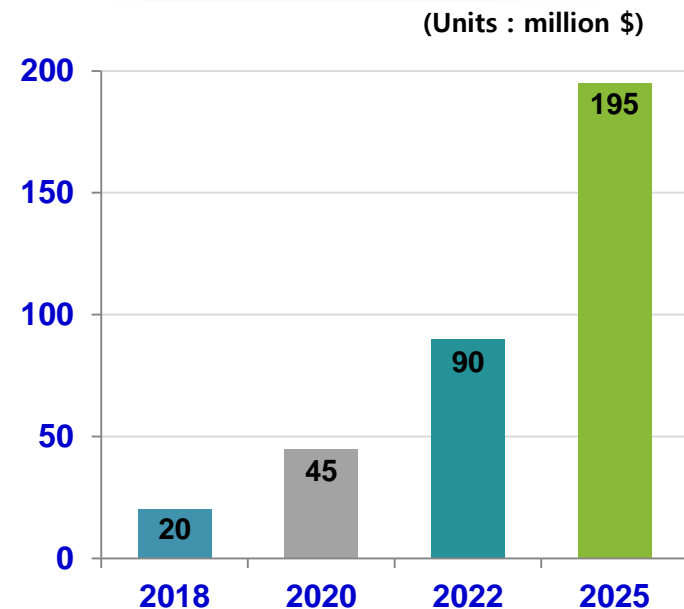
Estimated market of Backup power using Fuel cell

Global Market



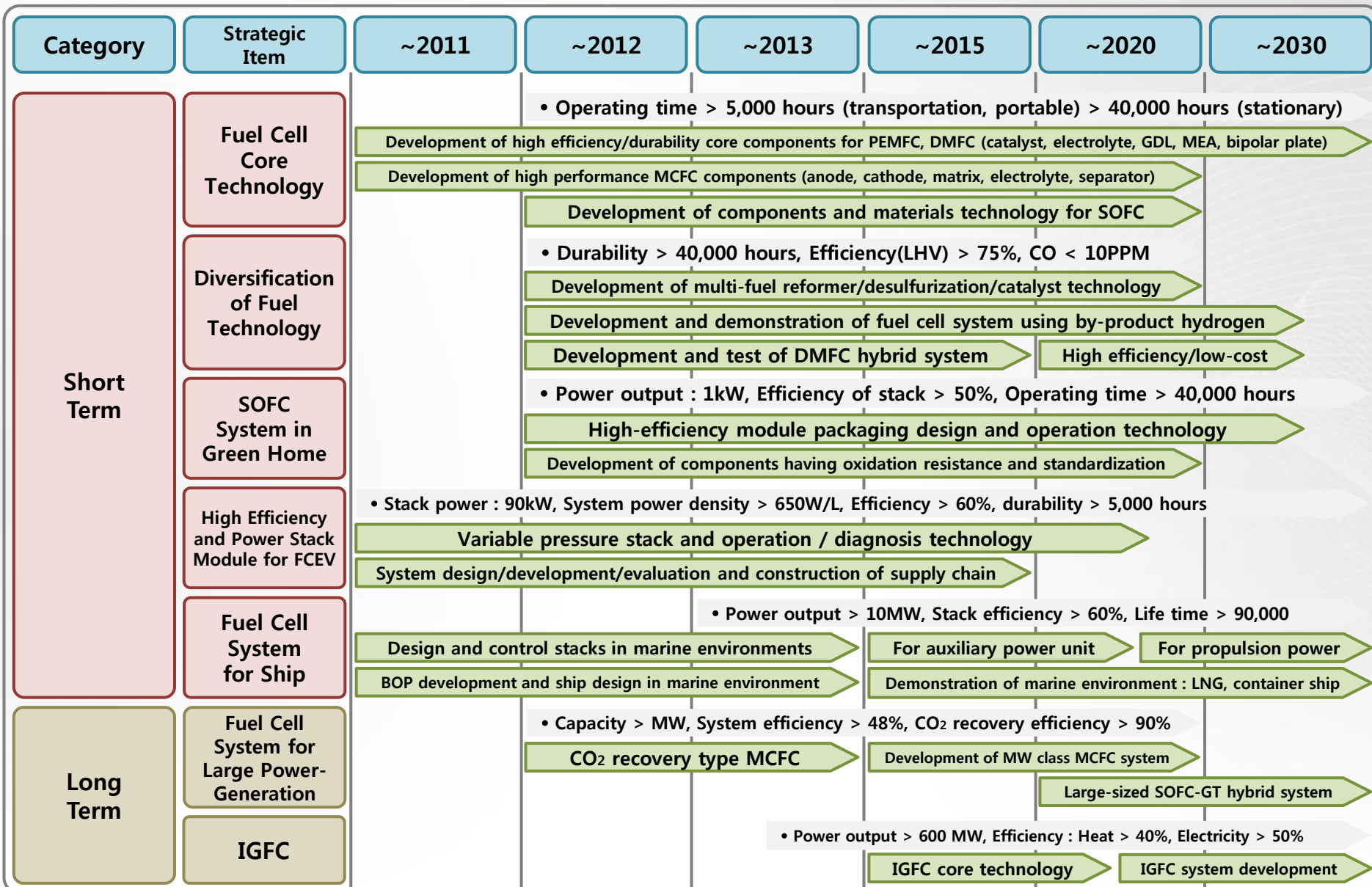
- In 2018, Market share increase up to 10%
- In 2025, about 40% replaced by Fuel Cell
- Market growth \$ 1.6 billion → \$ 9.4 billion

Domestic Market



- In 2025, about 20% market share
- Market growth up to about \$ 0.2 billion

Strategic Road-map for FC in Korea



Project : Backup power for Telecom.

Project (on-going)



LEADING THE WAY INTO A GREEN FUTURE
THROUGH NATIONAL ENERGY TECHNOLOGY INNOVATION



Program	New & Renewable Energy Core Technology Program of the Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Project Title	Development and demonstration of 3kW class fuel cell system having a grid-powered electrolyzer for backup power applications
Funding & Financing	₩ 9 billion KRW / \$ 8.24 million USD from the Ministry of Trade, Industry & Energy, Republic of Korea
Period	2014. 6. 1 ~ 2017. 5. 31 (36 months)
Organization	Hyundai HYSCO, Doosan Fuel cell, CS Enertech, JIT-System, KIER, KIST, KIMS, Ulsan univ.

Objectives

- Achievement of competitiveness of Fuel Cell in comparison with lead-battery
: Price reduction, Low-maintenance cost, High performance
- Expansion of fuel cell system solutions from Telecommunication base station to ICT, hospital, etc.

Core Values

Fuel Cell Module

- Low-cost Air Cooled stack
- Rapid power failure response
- Sufficient operation time (8hrs)

H2 Storage/Supply

- High efficiency electrodes and electrolysis stack
- Good performance and durability

Battery/Converter

- High efficiency power converting module
- Integration of battery and converter

System Demonstration

- System integration and Optimization
- Expandable system module
- Reliability/Durability/Safety

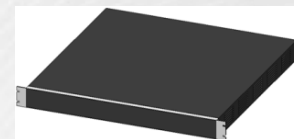
Application for Telecommunication Backup power

<2kW Class Fuel Cell System>



● Built-in Li-ion Battery

- Uninterruptible Operation, High Stability
- Environment-Friendly : Pb free
- Saving of Battery Space



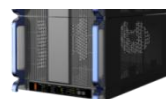
● Water Cooled Stack & Metal Bipolar plate

- High Efficiency : Higher than Air Cooled Stack(50% ↑)
- Fast Start-Up & Response, High Reliability



● Modulation

- Easy to Scale-Up by Parallel Installation
- Modulation : Handy Shipping/Installation & Maintenance
- 19" Rack : Convenient /Easy connection with Other Equip.



2 kW

+



2 kW

→



4 kW



<2kW FC Module for Backup Power>



<Open View (FRT)>



<Outer CASE (FRT)>

Fuel Cell System for Backup Power

Feature	Value	Remarks
Power Output	2 kW	Parallel connection Available. After DC/DC converting.
Voltage Output	48 V DC	-
Size	W440 x D645 xH400 mm	-
Volume	113 L	-
Weight	78 kg	-
Hydrogen Purity	Min. 99.9%	-
Input Pressure	50 kPa (0.5 Bar)	-
Consumption	0.789 Nm ³ /kWh	-
Response Time	2 ms ↓	@ Grid off (Blackout)
Durability	500 cycles ↑	On/Off
Initial Power Source	Li-ion Battery	-

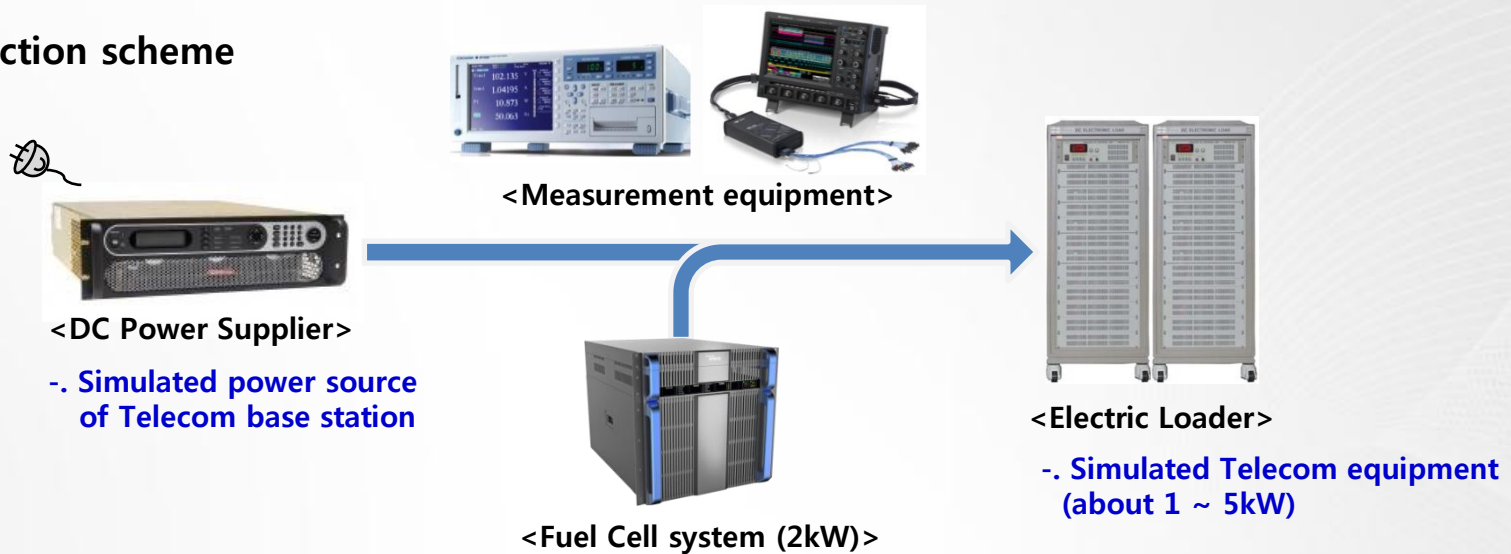
Integrated System with Outdoor Rack

Feature	Value	Remarks
Power Output	4kW (2 FC modules combined)	Additional parallel connection available
Voltage Input	220V AC, 50~60 Hz	For environment controller
Size	W1350 x D110 x H1970 mm	-
Space	38 U	-
Weight	180 kg	-
Ambient Temp.	-20°C ~ 45°C	-
Humidity	5% ~ 90%	-
Communication	RS485, TCP/IP	-

※ IEC 297-1.2.3, IEC 529 standard compliance

Schematic diagram

Connection scheme



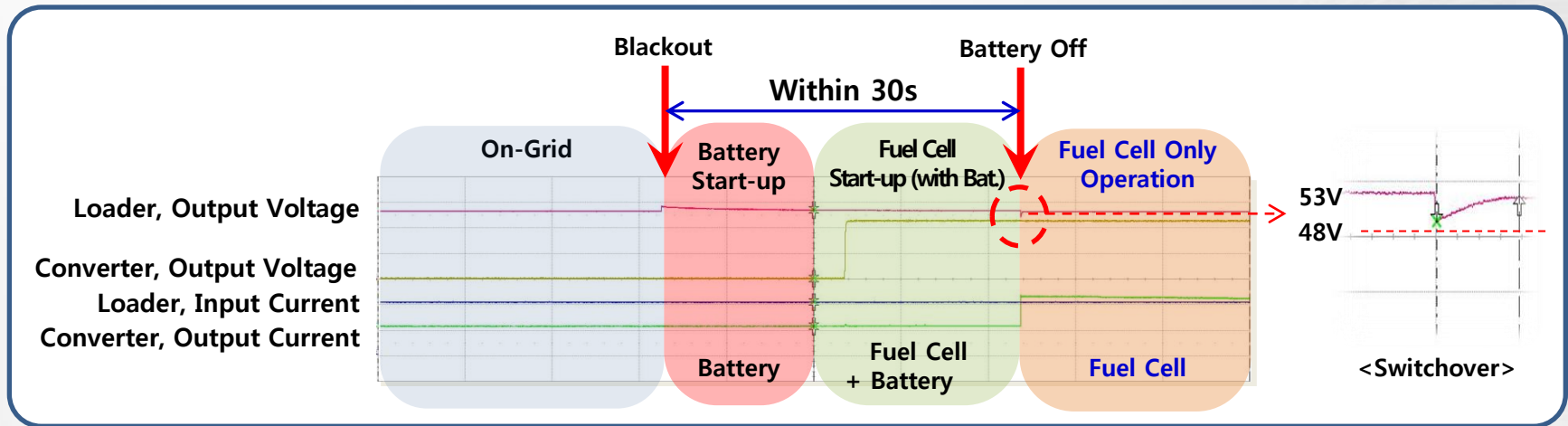
<1 System unit evaluation>



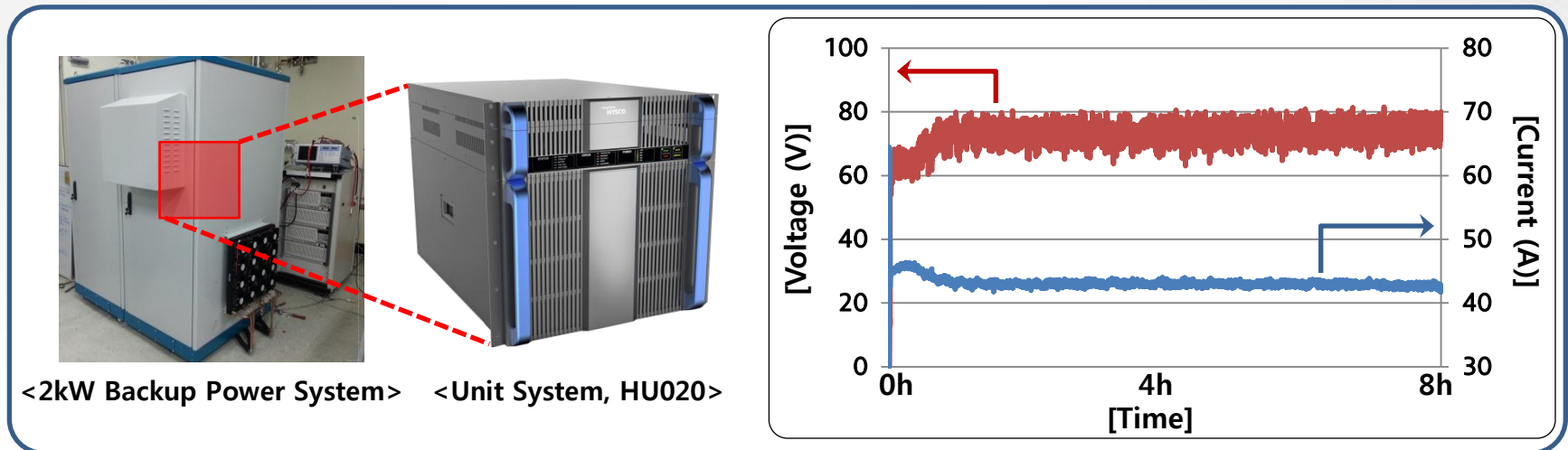
<2 Systems parallel test, with Cabinet>

Performance results

Start-up Test



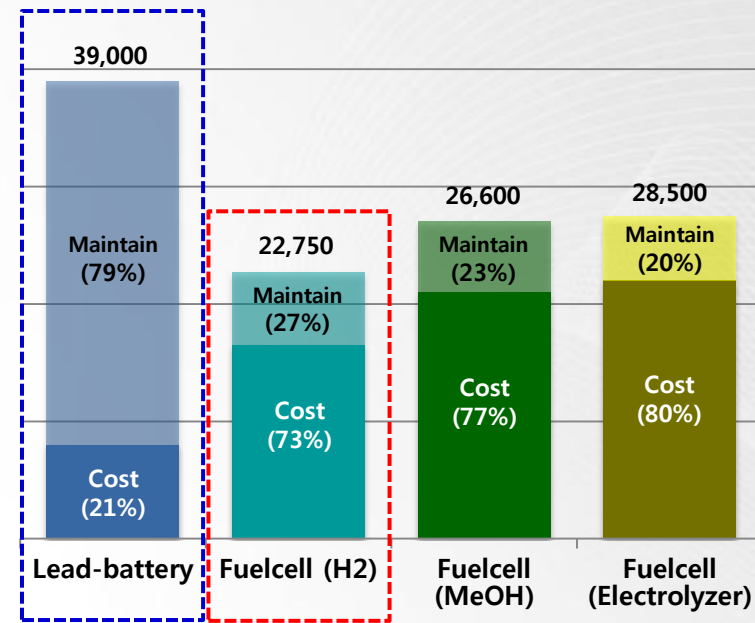
Operation Test



Cost analysis at stable grid

Units : USD (\$)

Content		Lead(Pb) Battery	FuelCell (H2)	FuelCell (MeOH)	FuelCell (Electroly.)
Equipment cost ¹⁾		8,000	16,500	21,000	22,000
Maintain (10 yrs)	Battery Change	16,000	0	0	0
	Electricity cost (air cond. Heat ...)	15,000	5,000	5,000	5,500
	fuel Cost	0	250	100	0
	fuel Delivery	0	1,000	1,000	0
	Sub-total (10yrs)	31,000	6,250	6,100	5,500
TOTAL		39,000	22,750	27,100	27,500



(Assumptions)

- Telecommunication electric load : 2kW
- Operation time : 8 hrs/year, continuous operation (10 years)
- Fuel refill (H₂, MeOH : 1 time/year, Electrolyzer : none)
- Electrolyzer efficiency : 4.5kWh/Nm³
- Electricity fee : Air condition is 3 times larger than normal heating system
- Fuel delivery distance : radius 30km (\$50 / 30km)

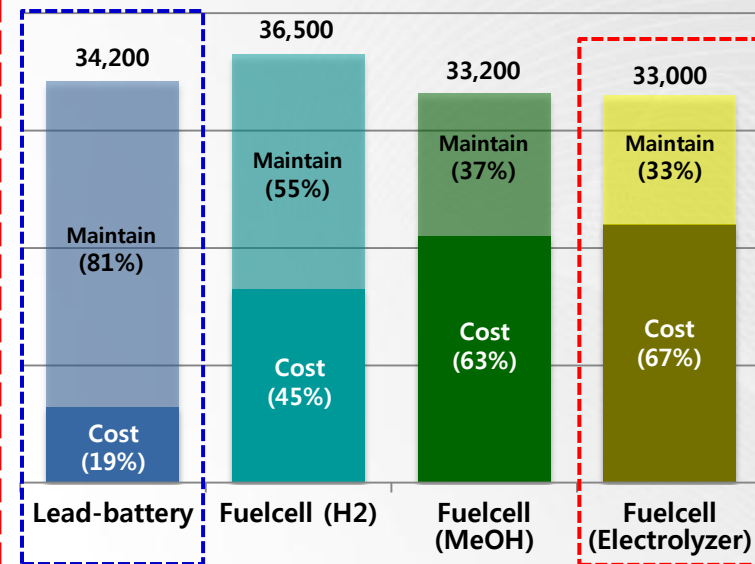
1) Cost of Fuel Cell system : based on 10,000 units capa. per year

*Ref : Market analysis of Fuel Cell Backup Power (2013)

Cost Analysis at Unstable Grid

Units : USD (\$)

Content		Lead(Pb) Battery	FuelCell (H2)	FuelCell (MeOH)	FuelCell (Electroly.)
Equipment cost		6,400	16,500	21,000	22,000
Maintain (10 yrs)	Battery Change	12,800	0	0	0
	Electricity cost (air cond. Heat ...)	15,000	5,000	5,000	11,000
	fuel Cost	0	3,000	1,200	0
	fuel Delivery	0	12,000	6,000	0
	Sub-total (10yrs)	27,800	20,000	12,200	11,000
TOTAL		34,200	36,500	33,200	33,000



(Assumptions)

- Telecommunication electric load : 2kW
- Operation time : 8 hrs/month, continuous operation (10 years)
- Fuel refill (H₂ : 12 times, MeOH : 4 times Electrolyzer : none)
- Electrolyzer efficiency : 4.5kWh/Nm³
- Electricity fee : Air condition is 3 times larger than normal heating system
- Fuel delivery distance : radius 30km (\$50 / 30km)
- Lead-battery cost : local price was reflected

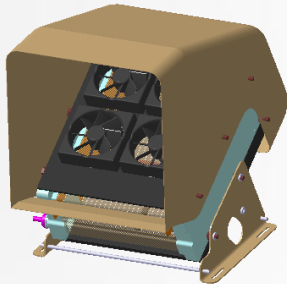
1) Cost of Fuel Cell system : based on 10,000 units capa. per year

*Ref : Market analysis of Fuel Cell Backup Power in CHINA (Sinotrust, 2013)

Cost, Reliability, Efficiency & Safety

**Metallic
Air-Cooled
Stack**

Reduction of BOPs (60% ↑)
Easy Assembly



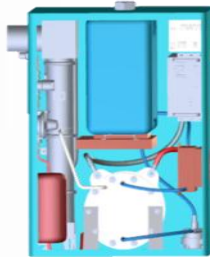
<3kW Air-cooled stack>



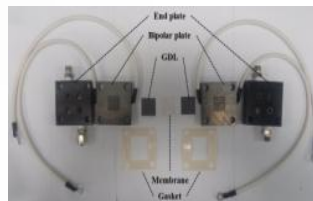
<300W Air-cooled stack>

**Electrolyzer
(AAEM)**

H₂ generation
Maintenance fee ↓



<Electrolyzer>



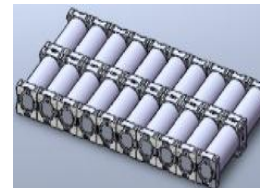
<AAEM Single stack>

**Battery
/ PCS
Modulation**

High efficient Conversion
Non-interruption time



<BMS & Converter Module>



<Li-ion Battery>

**Outdoor
Cabinet**

Reliability, safety
Operation condition

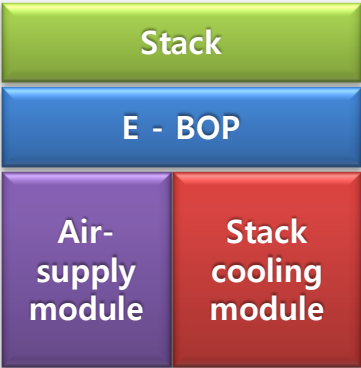
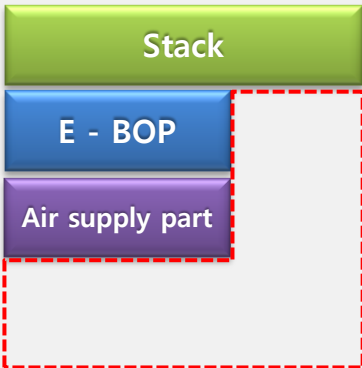


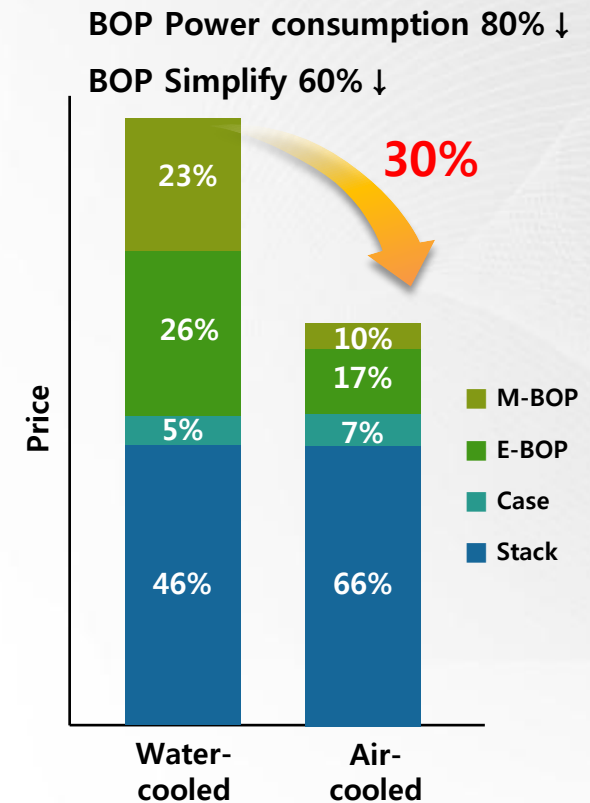
<Outdoor cabinet #1>



<Outdoor cabinet #2>

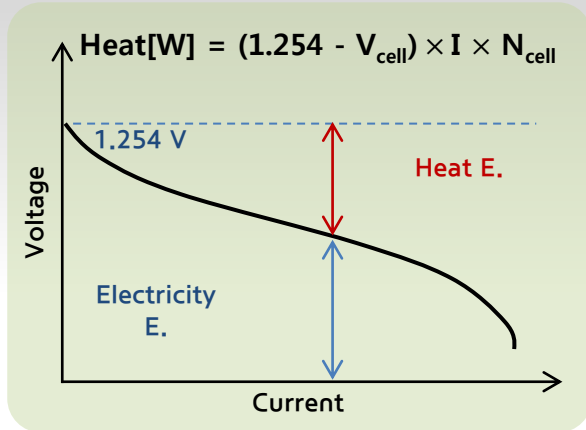
Comparisons (Air cooled vs. Water cooled)

Water-cooled System	Items	Air-cooled System
	Structure	
<ul style="list-style-type: none"> ✓ High performance ✓ Durability ↑ 	Merit	<ul style="list-style-type: none"> ✓ Number of parts ↓ → Price ↓ ✓ Simplified cooling and heating dissipation design
<ul style="list-style-type: none"> ✓ Design complexity ↑ ✓ System size ↑ 	De-merit	<ul style="list-style-type: none"> ✓ Durability ↓ ✓ Susceptible to outside temp



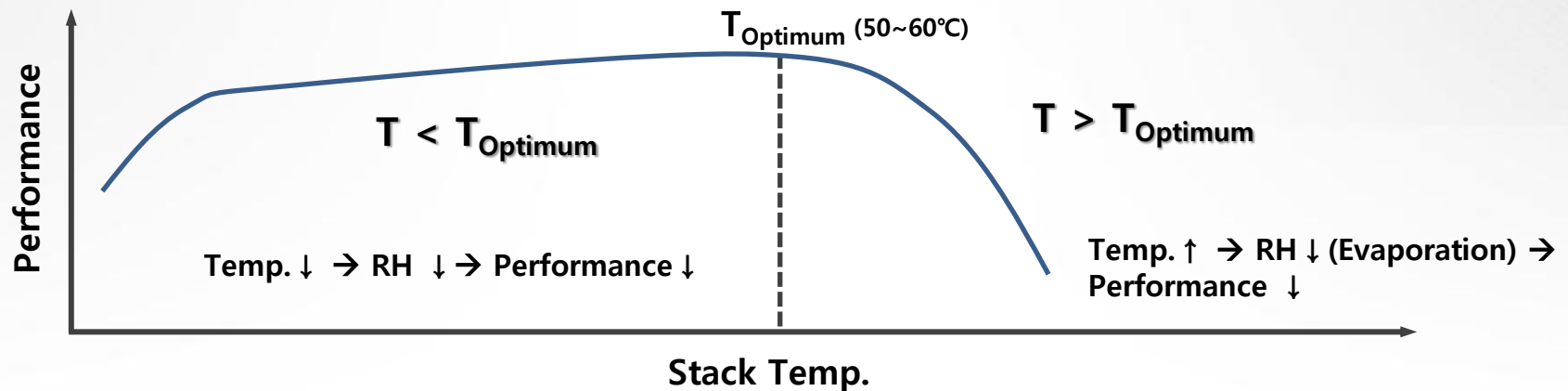
Heat generation

[Ref. J. Hydrogen Energy (2012)]



Air-cooling fuel cell core technology											
AnodeCathode											
Coolant ChannelSeparator LandChannelGas Diffusion LayerCatalyst LayerMembraneCatalyst LayerGas Diffusion LayerChannelSeparator LandCoolant Channel											
Heat Product	Phase Change (Channel)	Ohmic Heating	Ohmic, Reaction Heating	Ohmic Heating	Reaction, Ohmic Heating	Ohmic Heating	Phase Change (Channel)				
Proportion		5%	2	17%	72%	5%					

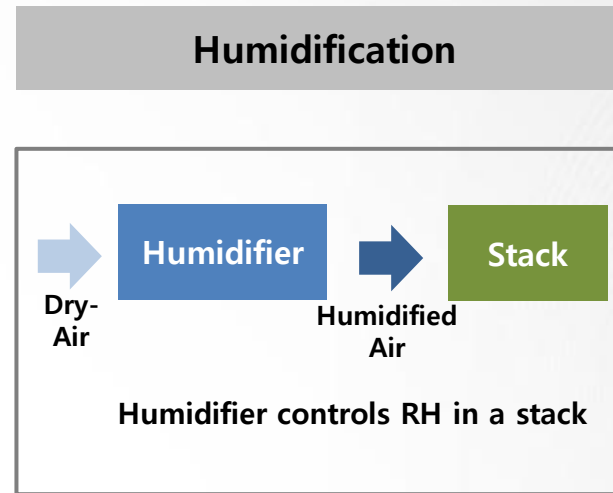
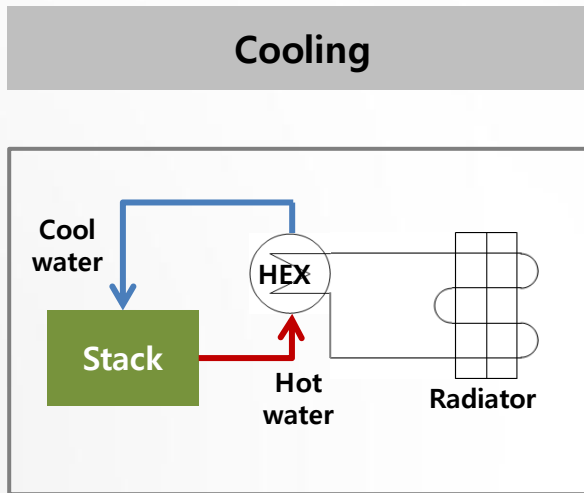
Stack performance with temperature



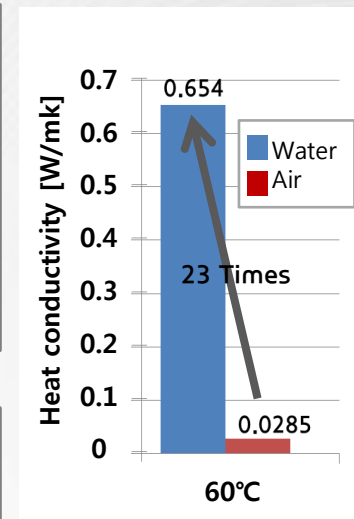
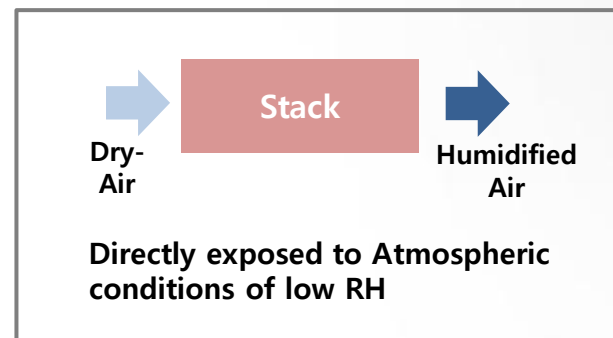
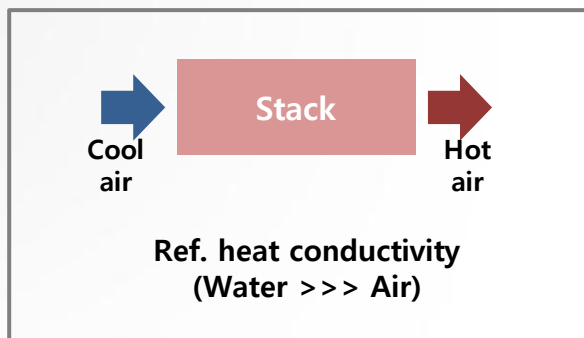
Stack cooling & Humidification

Water-cooled stack vs. Air-cooled stack

Water-cooled

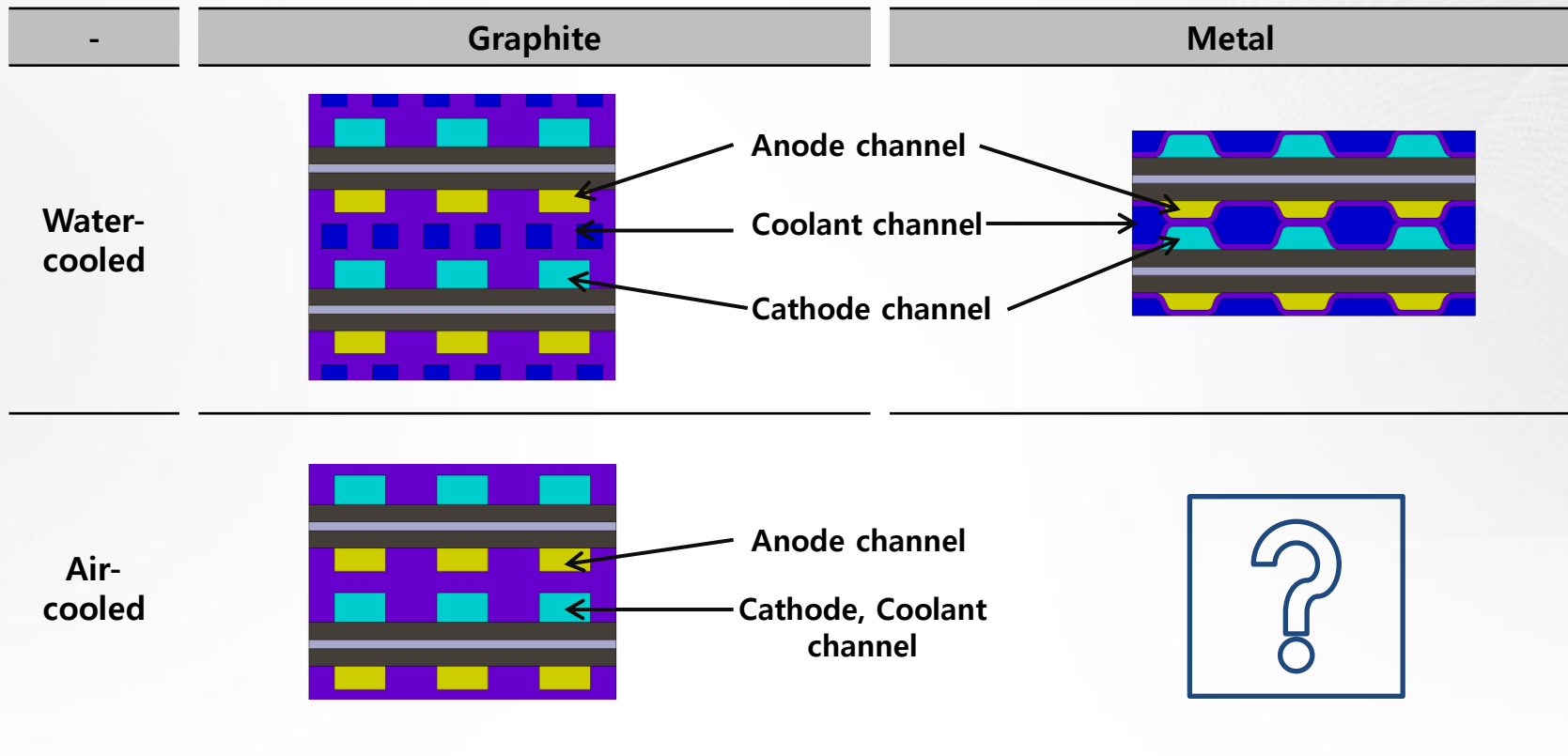


Air-cooled



Graphite vs. Metal

- Water-cooled stack : Separated cooling channel
- Air-cooled stack : Cathode channel has two functions (Cooling & Air supply)

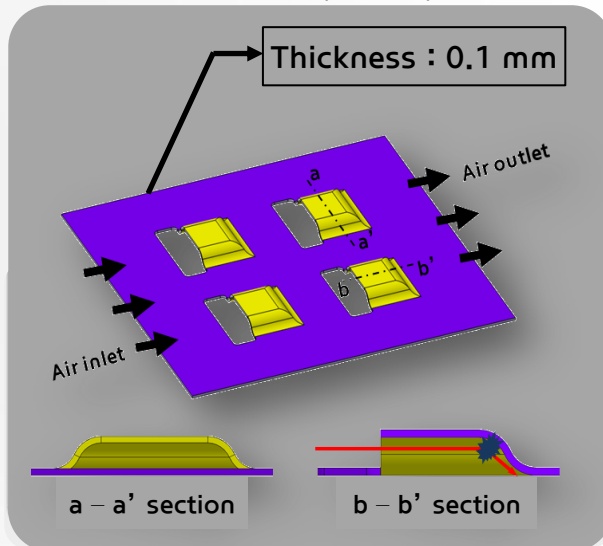


Louver structure

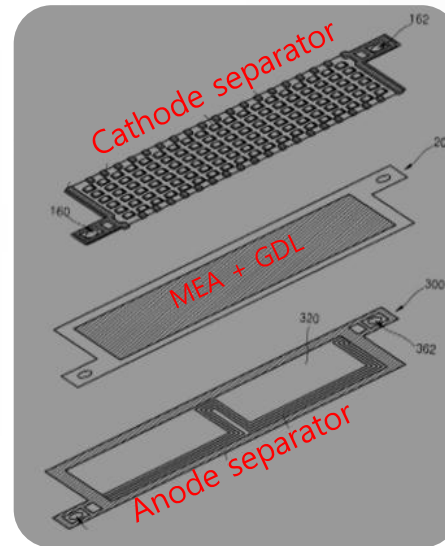


- ✓ Self-humidifying & good cooling performance
- ✓ Graphite separator can not be produced

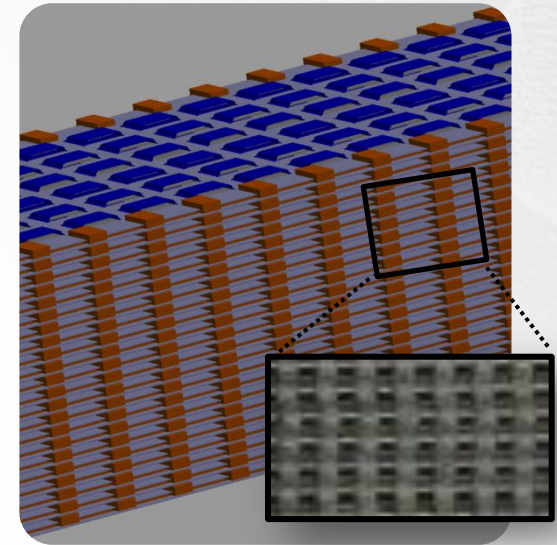
HYSCO Patent : PCT/KR2014/006750



[Structure]



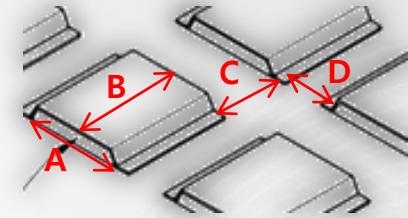
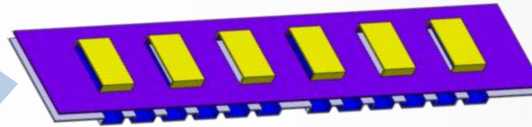
[Single cell assembly]

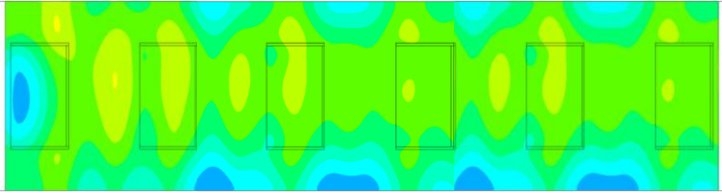
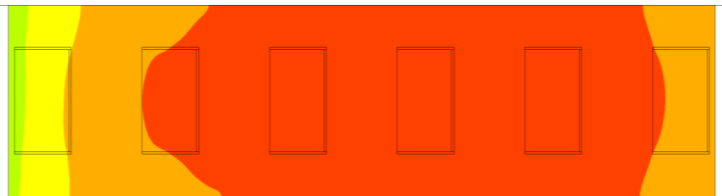
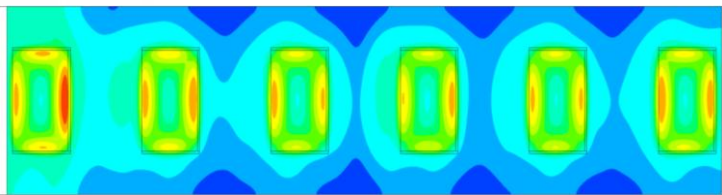


[Stack assembly]

Design optimization

- Temp. : 26°C
- Humidity : 10% RH
- Air Stoi. : 30



Distribution	Results	
Water		Average RH 47.5%
Temp.		Average temp. 50°C
Current		Reaction of near Louver ↑

Mass production of bipolar plate

2011

Mass production
(Capa. 1.2 million eas/yr)



2012

Automated inspection facility
(Capa. 500,000 eas/yr)



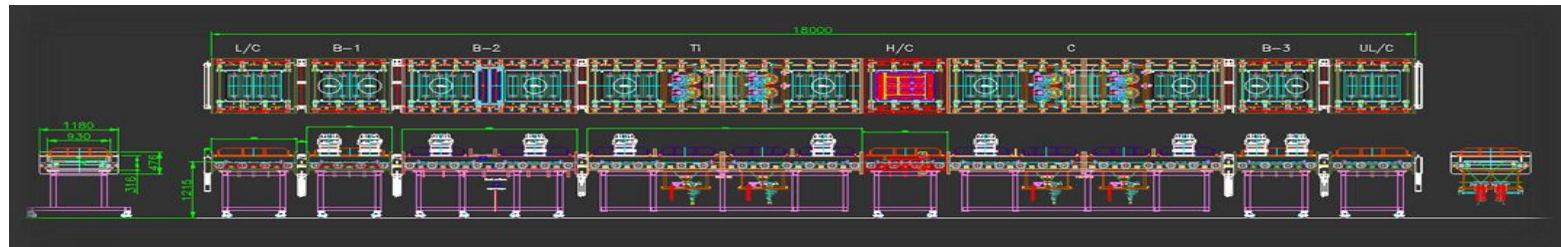
2013

**Mass production of
Fuel Cell Car
(HMC)**



2015 Target

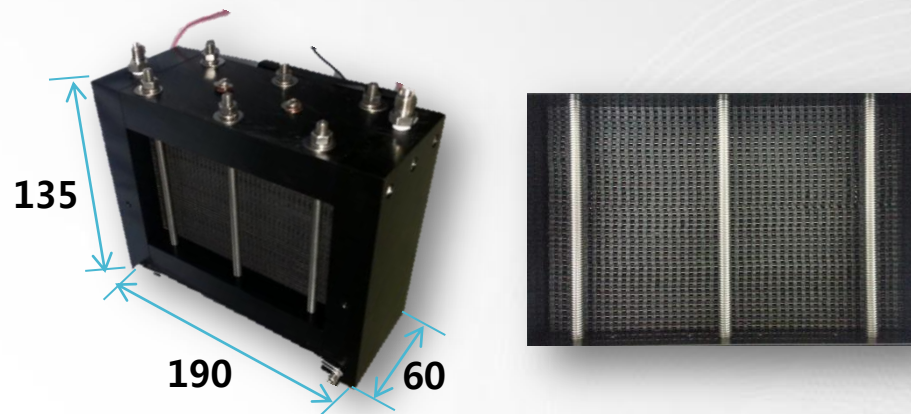
Development of fully automated mass production line
(Capa. 2,500,000 eas/yr)



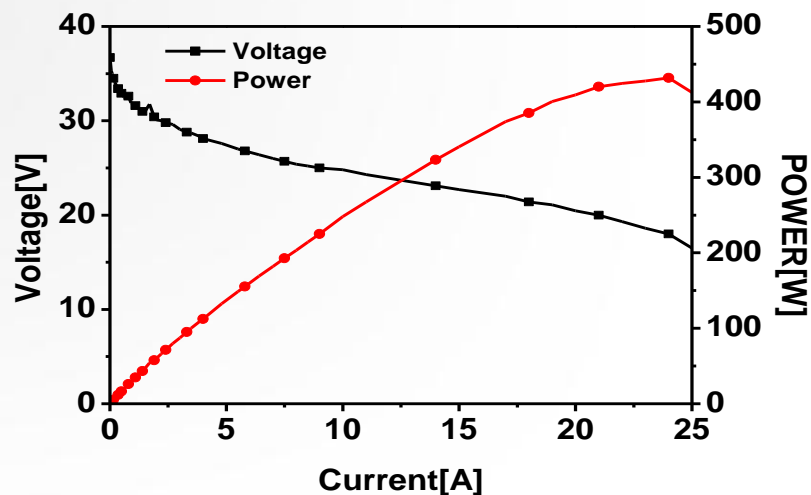
Performance test

Specification

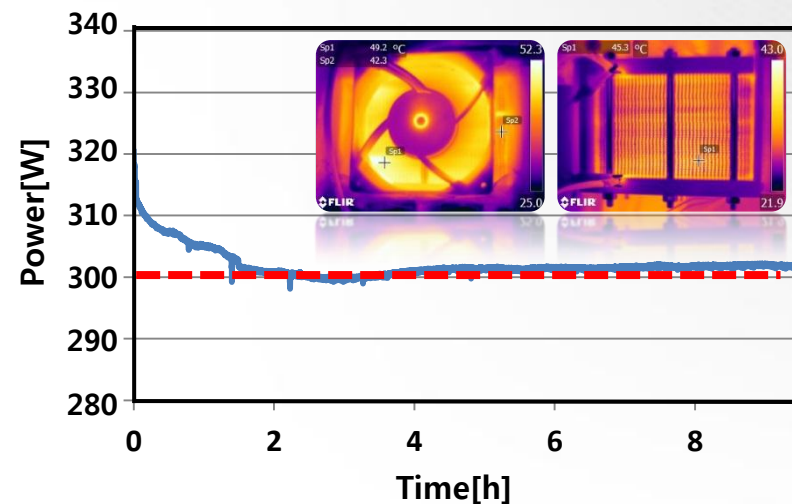
Stack Volume	1.5L (190×60×135)
Max Power	430 W (18V, 24A)
Stack Voltage	20 V
Stack Current	15 A



I-V, P curves

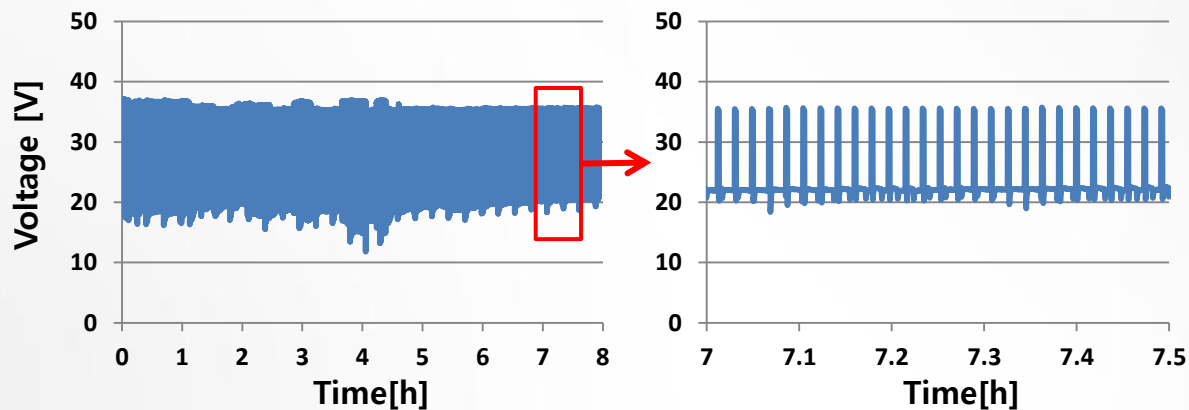


10 hours Operation

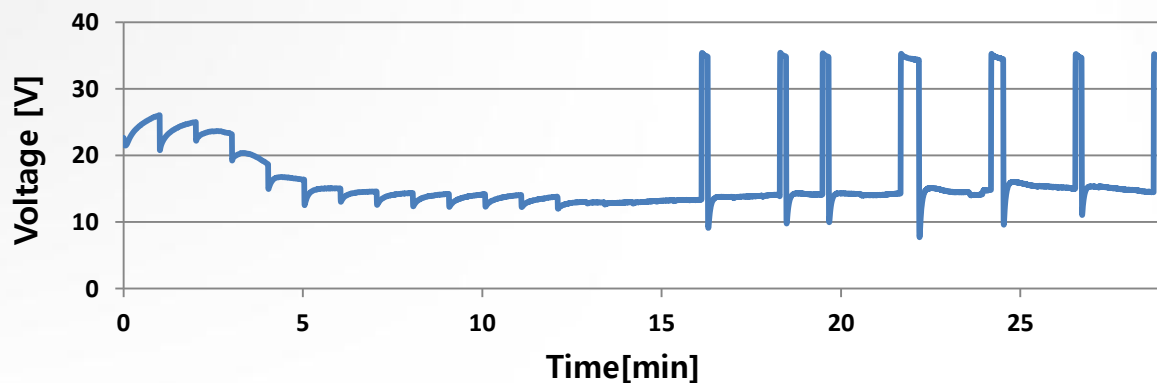


Cycle test

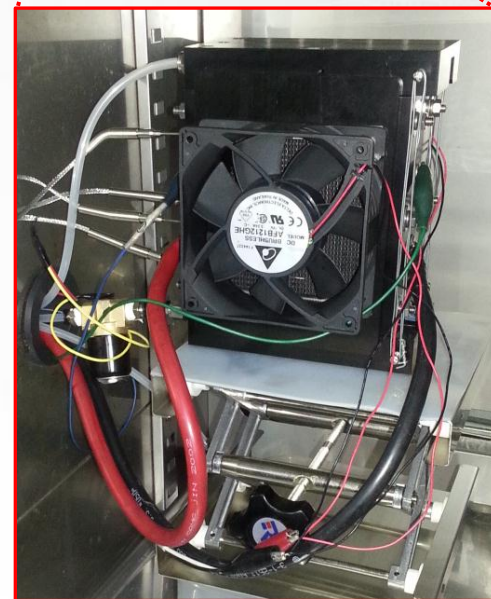
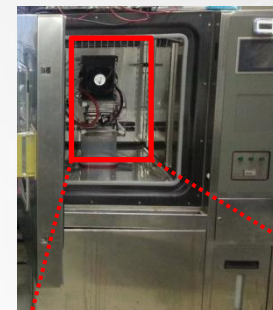
- On/off 400 cycles test @ 50°C air temp.



- On/off cycle test @ -10°C air temp.



[Environmental chamber]

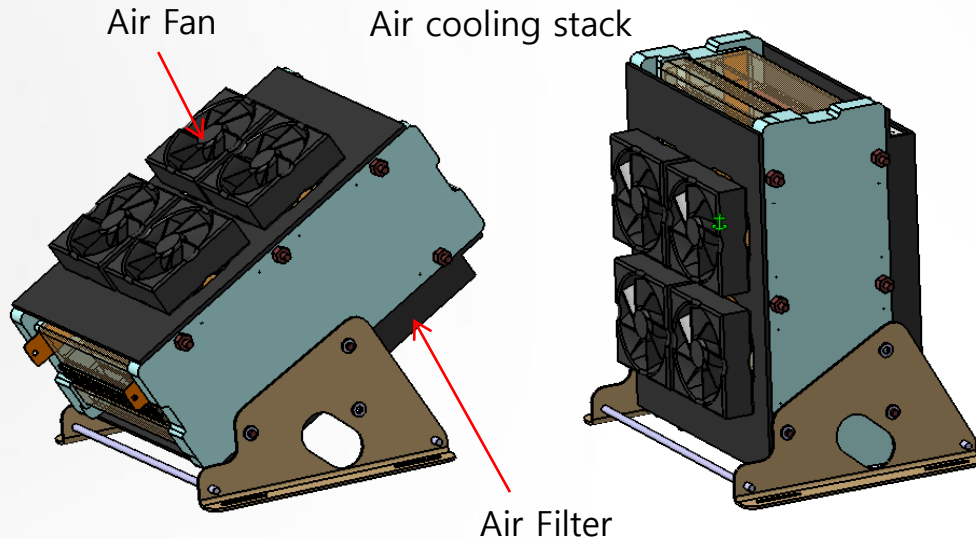


Stack module design(3 kW)

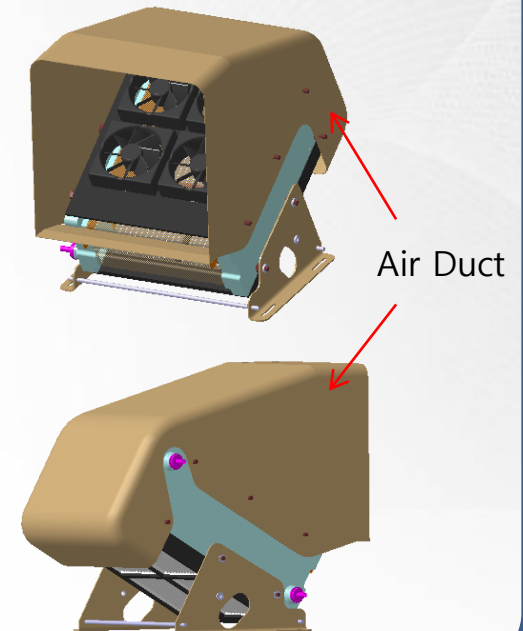
Scale up from 300 W to 3 kW

- Scale up Know-How from 300W stack

Vertical, horizontal applicable design

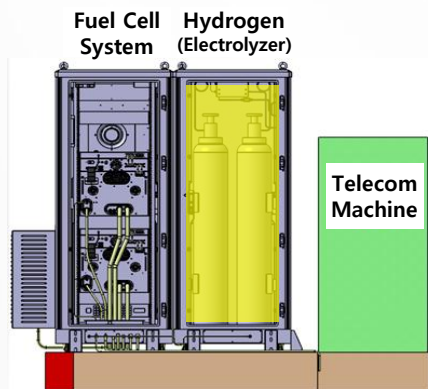


Air Duct design (Air recirculation)



Optimization of operating condition and safety

Concept of product and installation



<2kW System with cabinet> ※ parallel available (4kW)

Environment control

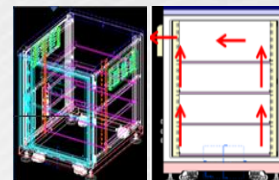
Structural design

- Prevent inflow of dust and moisture
- Insulation, anti-corrosion

Functions

- HVAC (- 20~ 45°C)
- HEX, controller for inner environment
- In/External communication

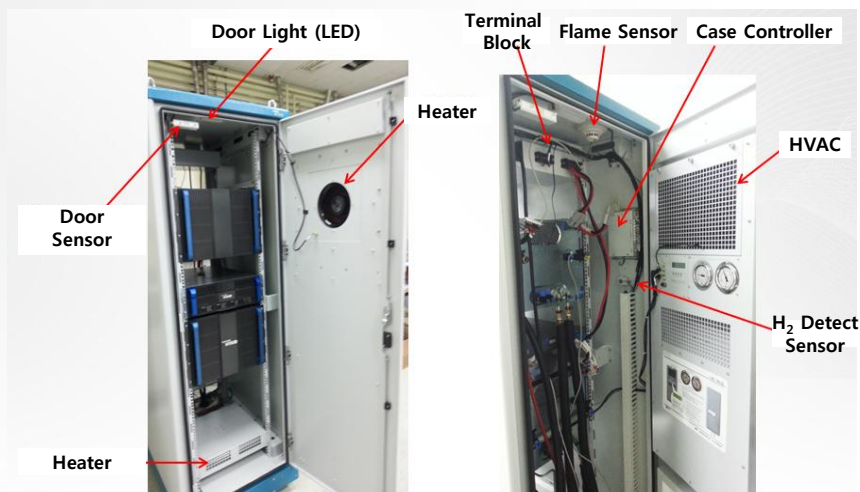
※ HVAC : Heating, Ventilating and Air conditioning



Product safety

Functions

- Gas leak, flame sensors
- Door open alarm
- Inner condition monitoring



<Inner Functional sensors>



Fire Alarm



Flooding sensor



Thermocouple




Door sensor

Development concept

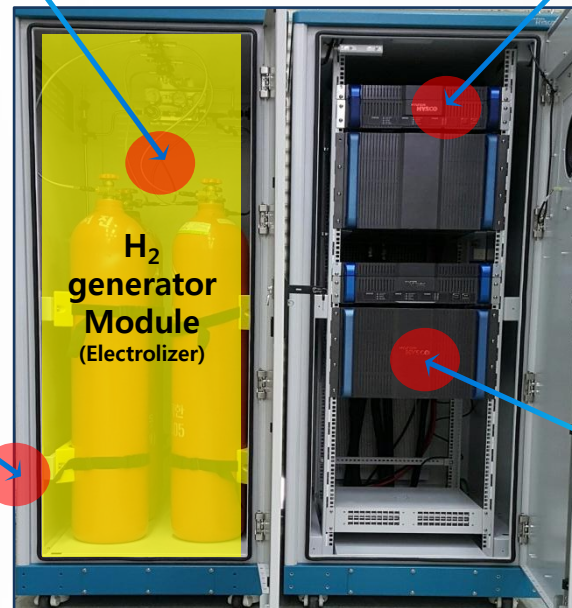
Configurations

Electrolyzer Module (AAEM)

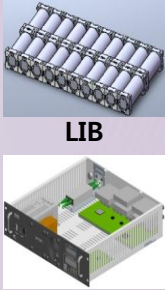


AAEM

	Information
Function	H ₂ Prod./Storage
Component	AAEM Stack Water/Power supply H ₂ Storage
Features	- Anion Exchange - Purity : 99.9% ↑ - 300W




Li-Battery / PCS Module



LIB
Combined Module

	Information
Function	Uninterrupted
Component	Li-ion Battery AC Detector, BMS
Features	- Modulation - Parallel connection - Detecting Blackout

Outdoor Cabinet (IP55)




Cabinet

	Information
Function	Protection of Sys. Control of inner Temp.
Component	Temp. Controller Con. Monitoring
Features	- IP55, Anti-vibration - Ambient : -30~55°C - For only Fuel Cell

<Backup Power Fuel Cell>

Air-Cooled Fuel Cell Module



Air-cooled Stack
Modulation

	Information
Function	3kW Power Generation
Component	Air-cooled stack / Controller
Features	- Metallic Air-cooled Bi-polar plate - Easy Expansion

Expansion to new applications

Mobile Communication Base Station



<Mobile Communication Base Station >

Hospital, Factory and Buildings



<Emergency, Hospital>



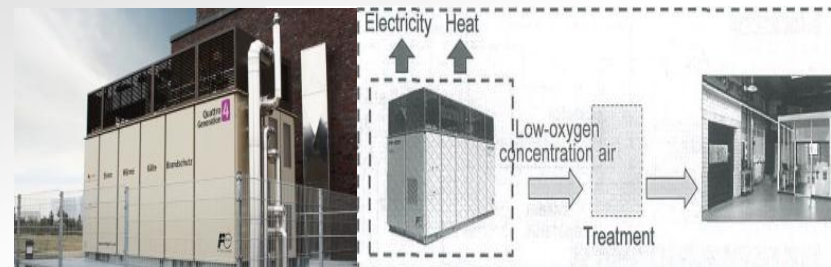
<Manufacturing line>

IDC (Internet Data Center)



<Server and Data Center, IDC>

Fire Prevention Facilities



<Fuji Electronics, N2telligence>

※ Ref. FC EXPO 2014

Thank you for Listening

