MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Mitsubishi Power Sustainable Energy Solutions

Solid Oxide Fuel Cell System

07.07.21

Mitsubishi Power Europe GmbH

MITSUBISHI POWER

Product Concept

- Supply stable and economical electricity
- Reducing green house gases
- Optimize fossil fuel usage
- Lead to sustainable energy supply chain in the future hydrogen society

Advantage of Mitsubishi Power SOFC

Cell Stack Durability

Long Life time of
Cell Stack **7-10** years

Electrical High Efficiency

20 years average
55%(LHV)
***73**%(CHP)

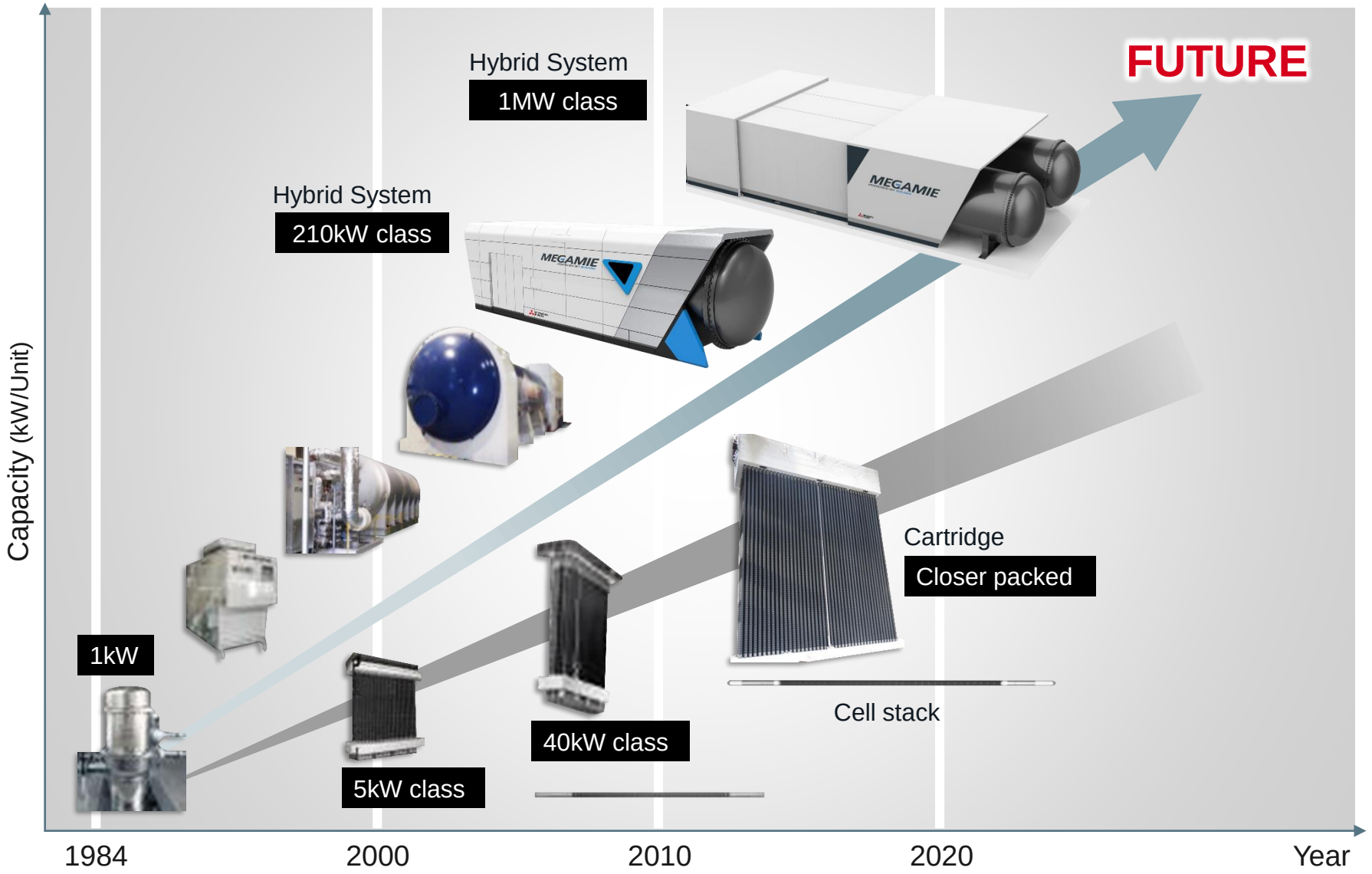
Operation Flexibility

Capable of Partial Load Operation:
50-100%

Fuel Flexibility

Applicable Fuel
LNG
Hydrogen
Bio Gas
Mixed Gas

History of Mitsubishi Power SOFC Development



Mitsubishi Power SOFC System Product Line Up

210kW Class (Commercialized)

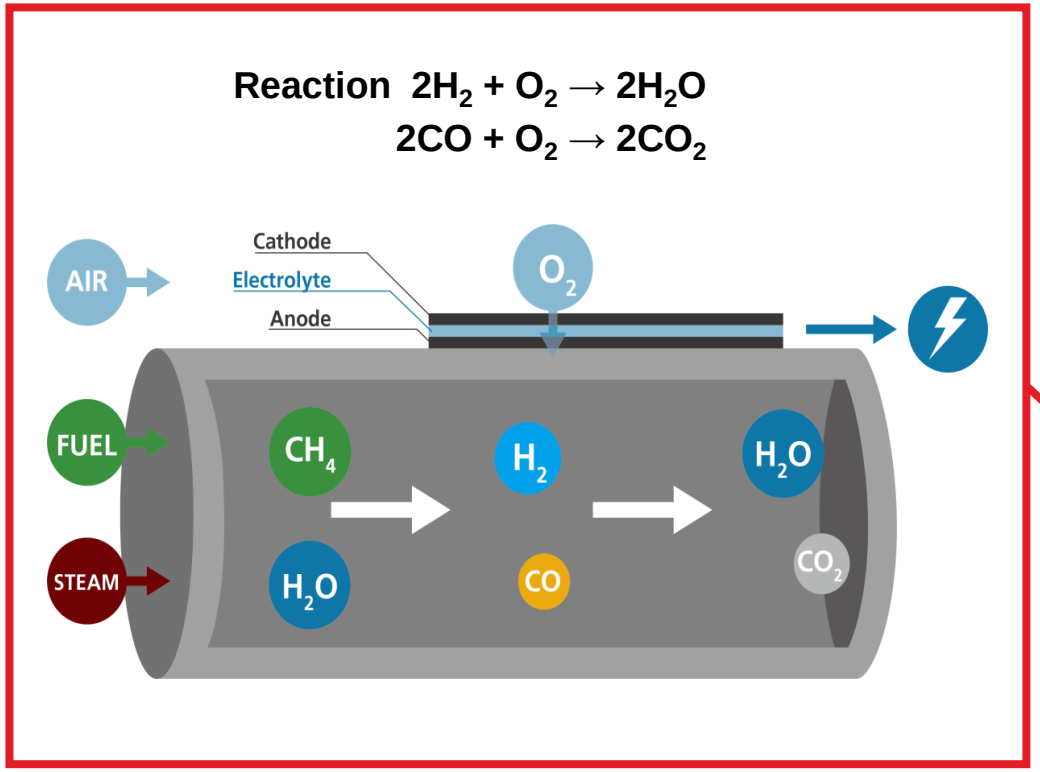
For Commercial & Industry User
(Building, Hospital, Hotel…)

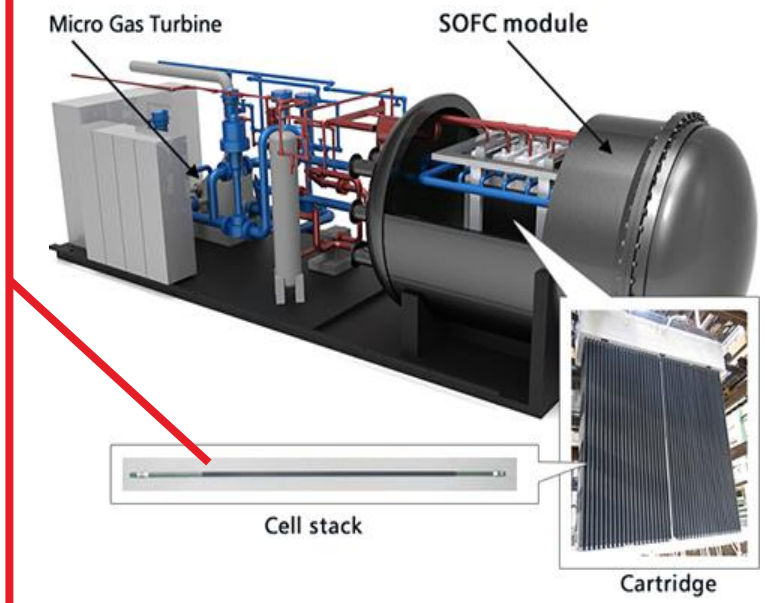
1MW Class (market launch in 2023)

For Utility, Large Industrial Plant &
Micro-grid

Solid Oxide Fuel Cell: How it works

Inside SOFC module, there are a lot of cartridges filled with cell stacks which convert fuel to electricity directly through chemical reaction.





Chemical reaction inside a cell stack

SOFC module components

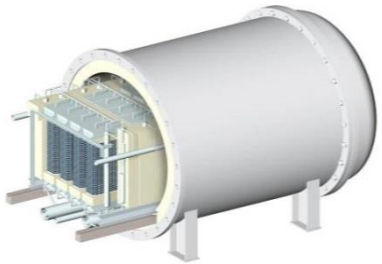
400 Cell Stacks becomes a Cartridge.
8 Cartridges becomes a Sub-module.
Modules were loadded into a pressure vessel to become SOFC module.

Cell-Stack

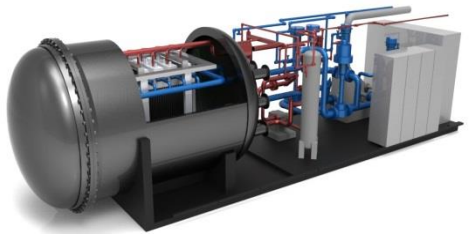
Cartridge

Sub-module

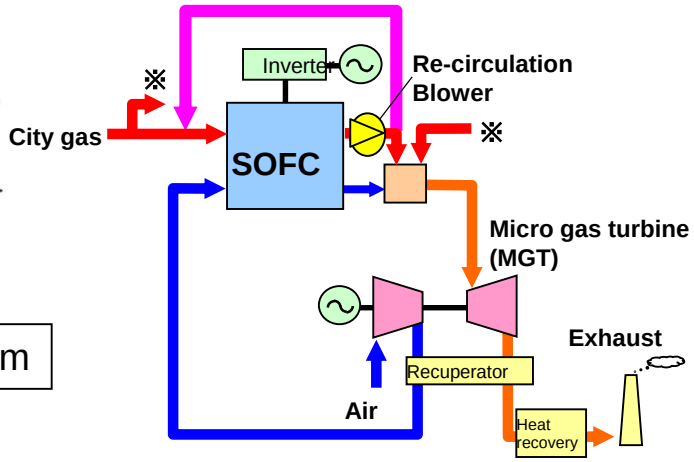
Pressure vessel



SOFC module



Hybrid System



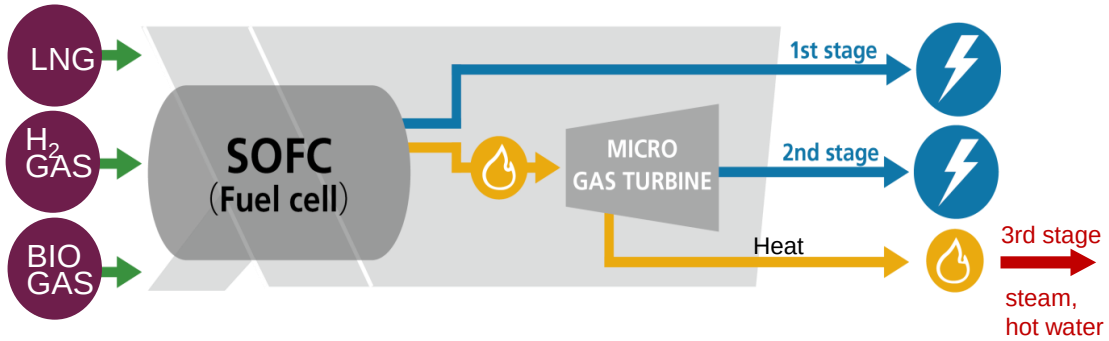
Multi-stage power & heat generation

- Mitsubishi Power-SOFC converts various types of fuel to electricity directly while micro gas turbine utilizes excess fuel from SOFC to generate power.

Electrical Efficiency 55%

Electrical&Thermal Efficiency 73%

(hot water)

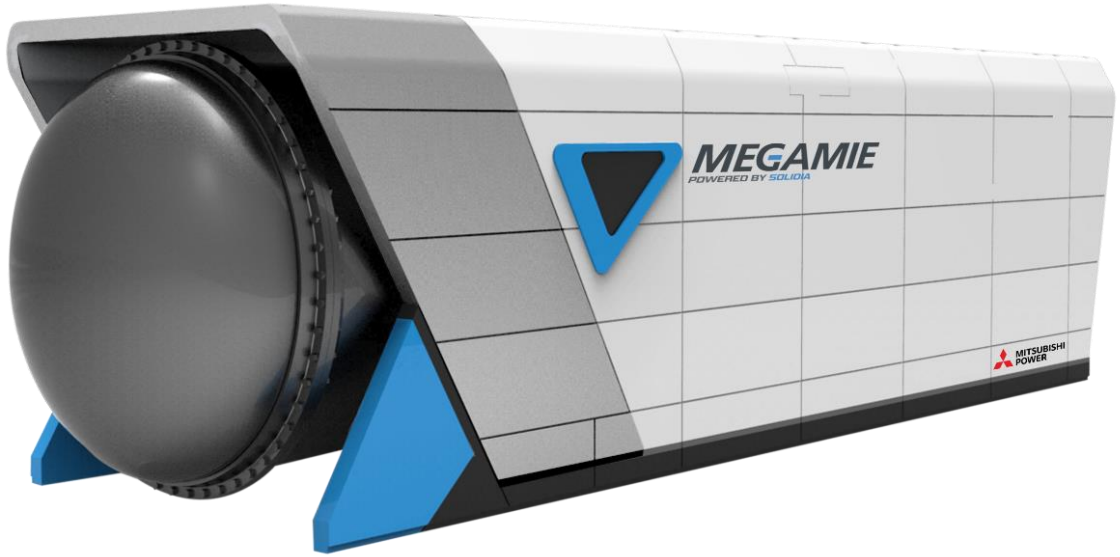


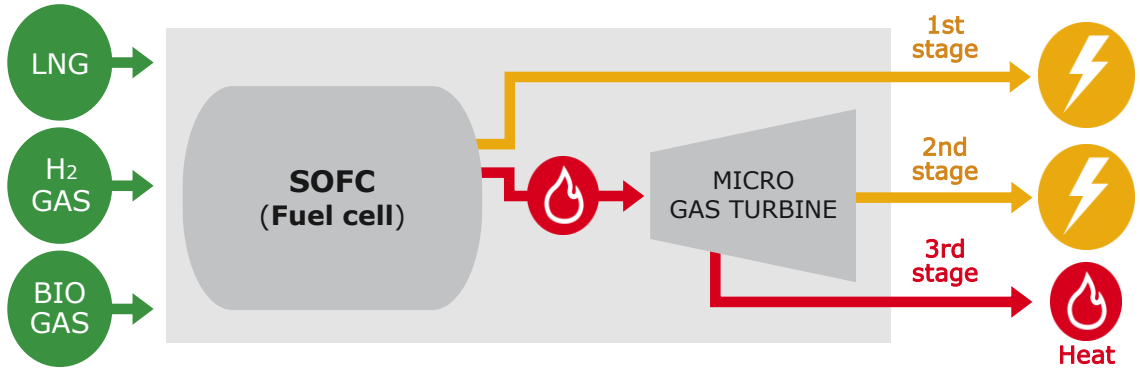
- Due to multi-stage power generation, our SOFC system has proved to have the highest efficiency in all other Distributed Energy Resources at same capacity range

Efficiency Comparison Chart

	PEFC Polymer Electrolyte Fuel Cell	PAFC Phosphoric Acid Fuel Cell	MCFC Molten Carbonate Fuel Cell	Mitsubishi Power-SOFC Solid Oxide Fuel Cell
Temperature(℃)	60～100	150～200	600～650	750～1000
Fuel	Hydrogen	Hydrogen	Natural Gas	Flexible
Efficiency (%LHV)	35～40	38～42	～45	～55

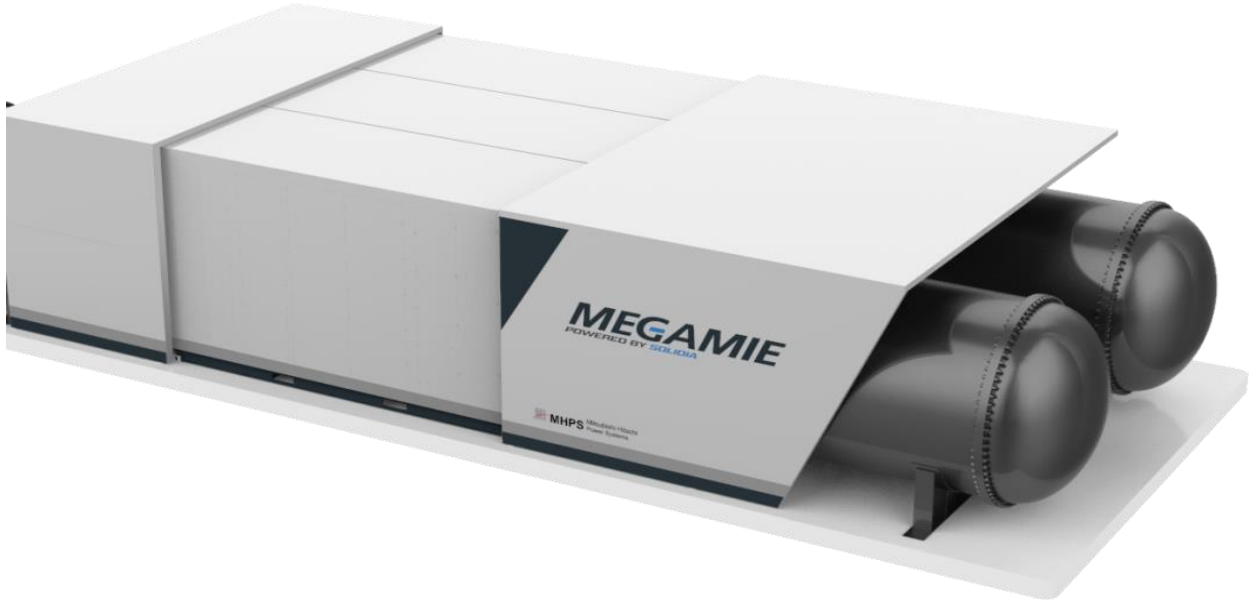
210kW Class SOFC Specification (Commercialized)

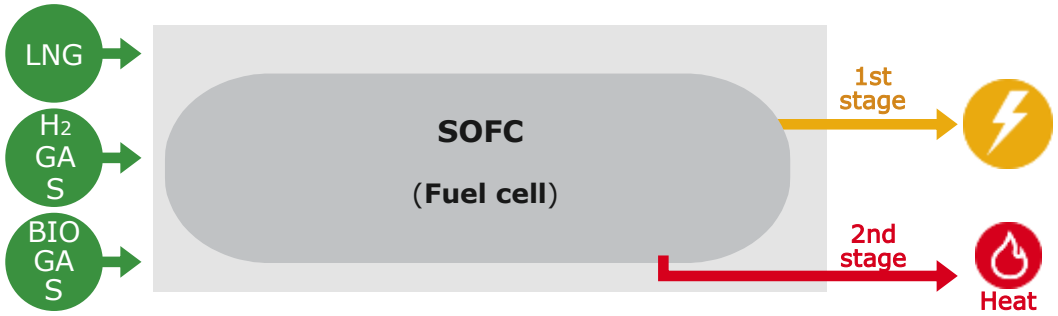




Expected Specification	Mitsubishi Power 210kW Class
Electrical Output (Net)	210kW
Electrical Efficiency (LHV)	53 %
Hot water/ Steam Output	86kW/54kW
Total Efficiency (LHV) Electrical + Thermal	73%/65%
Unit Size	W 3.2m x L 11.4 m x H3.3 m
Weight	33ton
Noise Level (Estimated value)	≦65dBA (at 10m far distance)
NOx (16% O_2)	Low Concentration (Depends on the fuel)
SO_x emission	Low Concentration (Depends on the fuel)
CO2 emission	Low Concentration (Depends on the fuel)

1MW-Class SOFC specification *(Preliminary)*

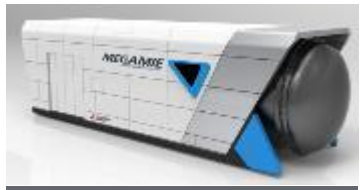




Expected Specification (with Natural Gas)	Mitsubishi Power 1MW Class
Electrical Output (Net)	1,200kW
Electrical Efficiency (LHV)	Approx. 57%
Hot water/ Steam Output	425kW/220kW
Total Efficiency (LHV) Electrical + Thermal	76%/67%
Unit Size	W 8m x L 25m x H 4m
Weight	Approx. 160 ton
Noise Level (Estimated value)	≦65dBA (at 10m far distance)
NOx (16% O_2)	Low Concentration (Depends on the fuel)
SO_x emission	Low Concentration (Depends on the fuel)

Mitsubishi Power SOFC Supply Record

Overseas: 1 Unit



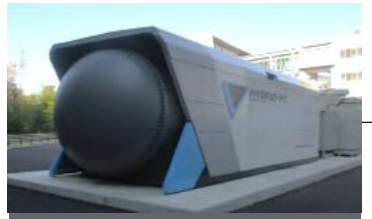
Commercial Operation @2022

Germany / GWI

Co-generation/ Hot water

J Power

Mono-generation



Kyushu Univ.

Mono-generation

1MW demonstration

Mono generation

Japan: 10 Units

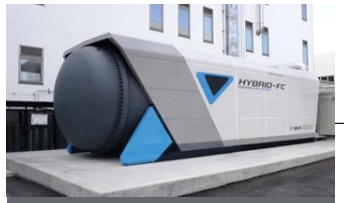
1MW class

210kW class with H2 Rich Fuel

with Biogas Fuel

ASAHI BREWERIES

Co-generation/Steam



TAISEI Corp.

Co-generation/ Hot water

NGK Spark Plug

Co-generation/Steam

Toyota Motor

Co-generation/Steam

Tokyo gas

Co-generation /Hot water

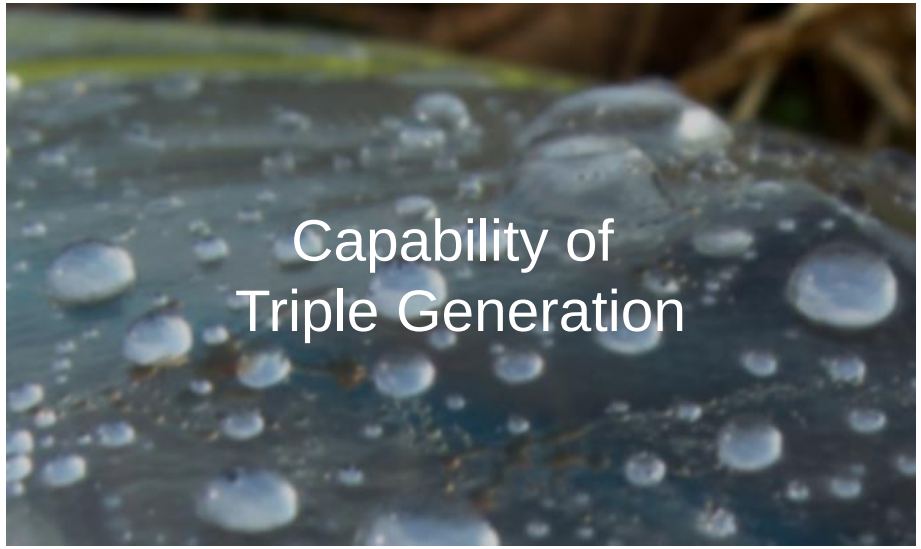
HAZAMA ANDO Corp.

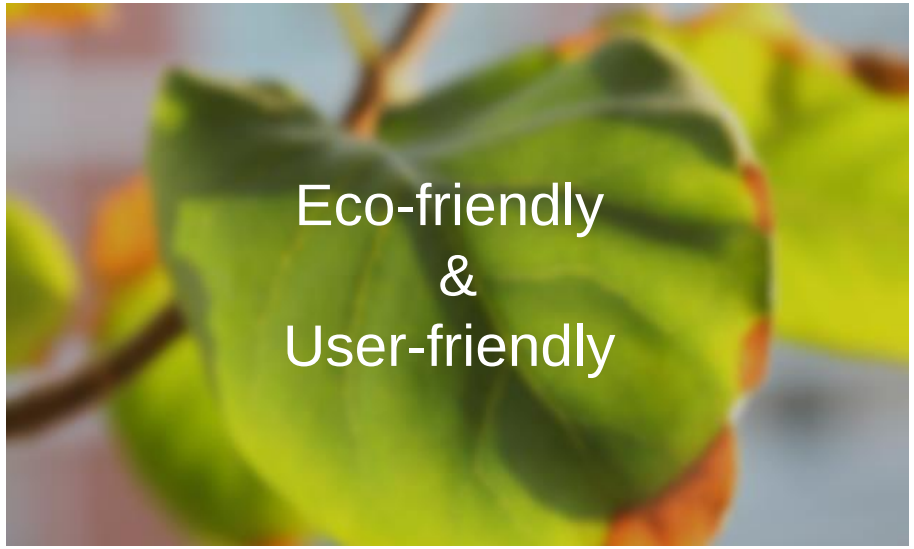
Co-generation /Hot water

MITSUBISHI ESTATE

Co-generation/Steam

Value Proposition of Mitsubishi Power SOFC



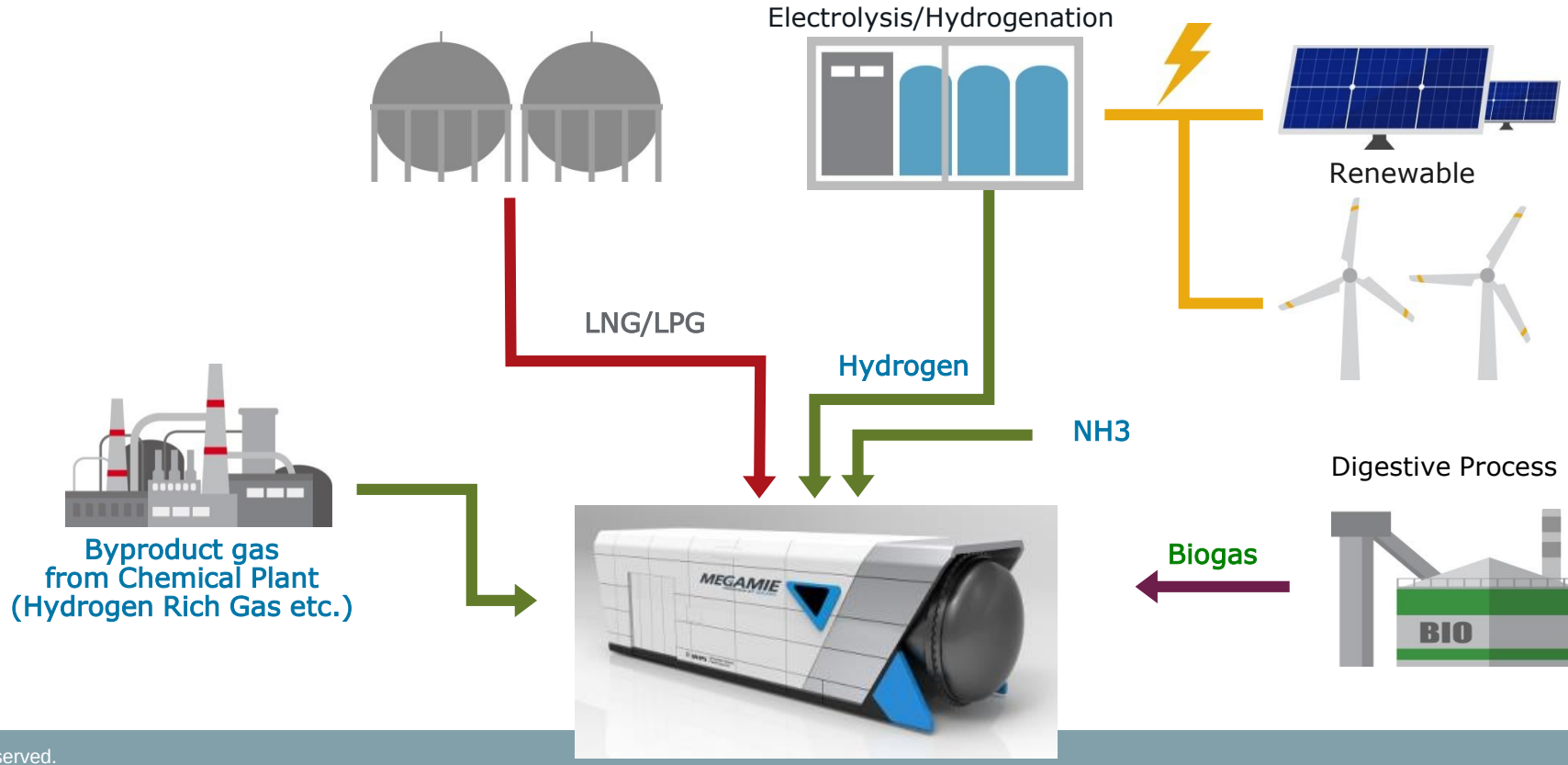


Value Proposition of Mitsubishi Power SOFC

Uses variety of fuel

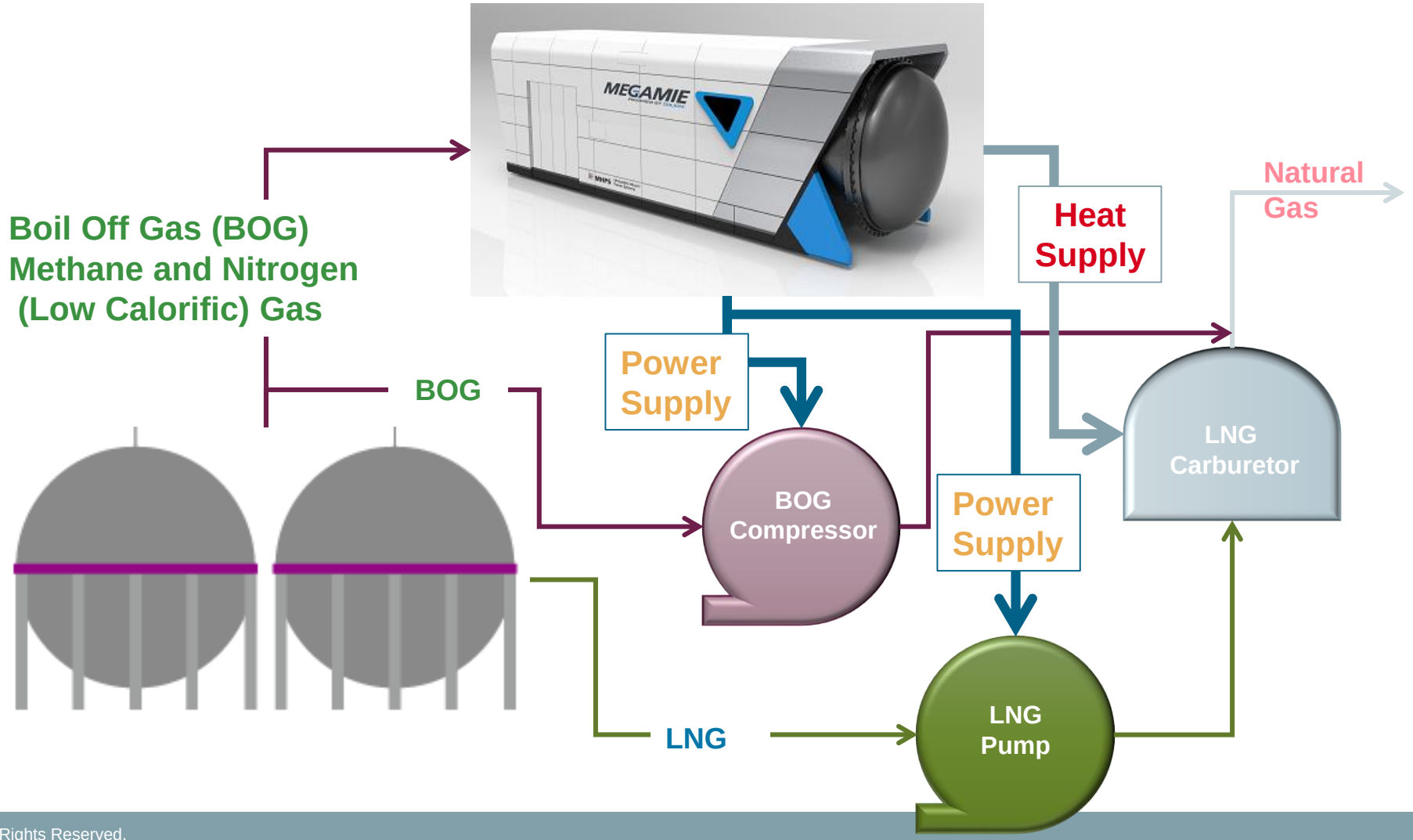
- Bio Gas from Brewery, Water Treatment plant
- Hydrogen from renewable energy and byproduct gas
- 100% city gas/natural gas from the grid, Propane gas
- Byproduct (hydrogen rich) Gas from Chemical Plant

etc…



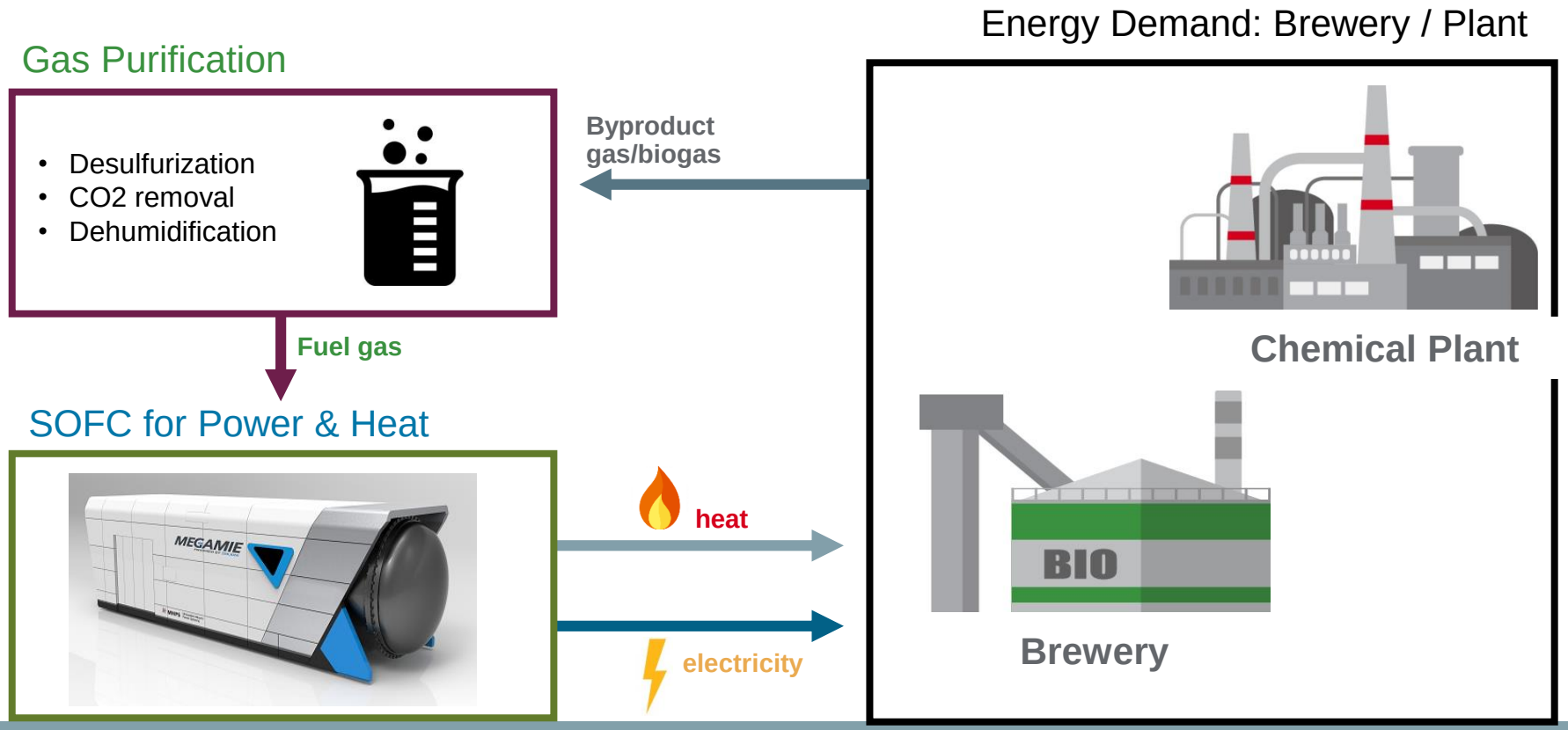
<Application Concept> SOFC for LNG Terminal

Mitsubishi Power SOFC can contribute to LNG Plant Energy Solution as High Efficiency CHP



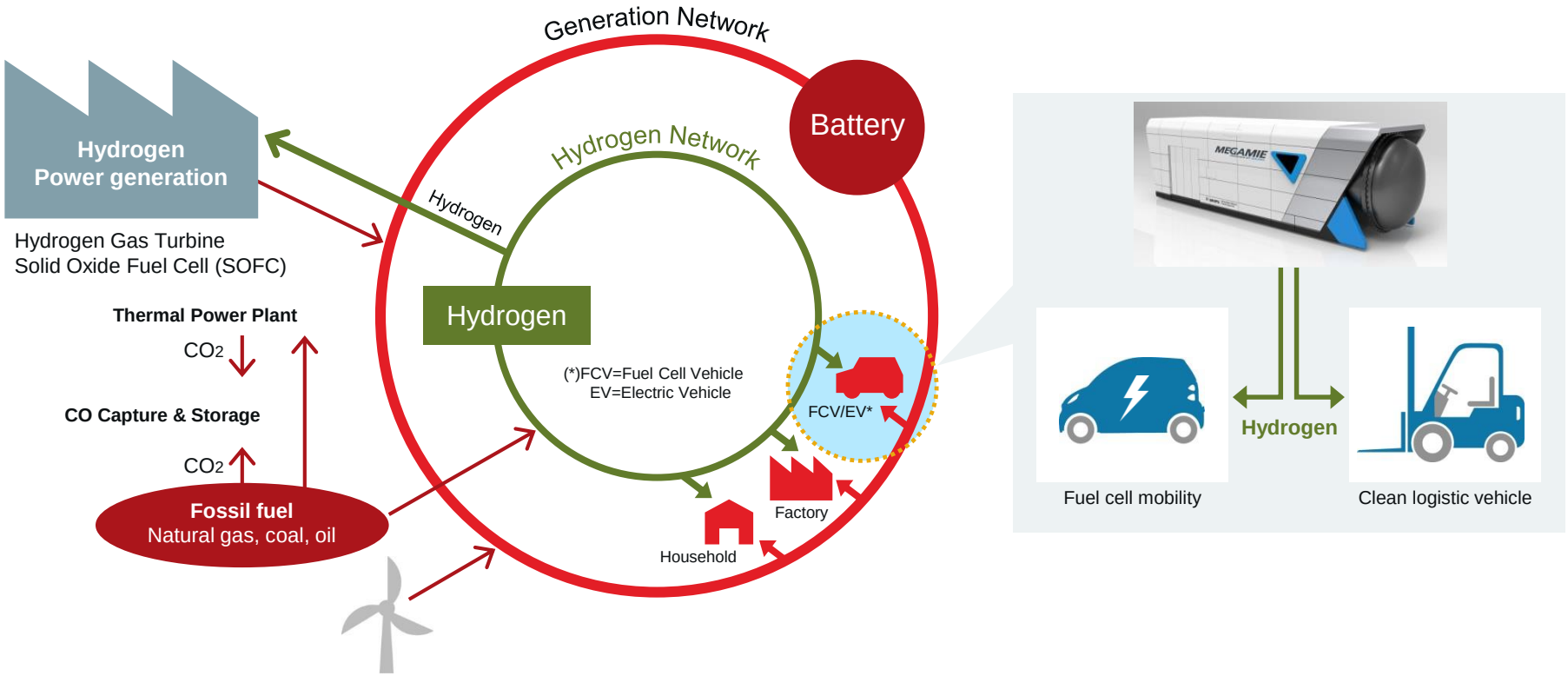
<Application Concept> Utilization of Byproduct Gas for Industrial Users

- SOFC contributes to establish “Sustainable Energy Chain” with Byproduct Gas from factories, such as Chemical & Food Industries.
- SOFC can supply “Power (Electricity)” and “Heat” at the same time.
- Mitsubishi Power can also design Gas Purification process for SOFC system.



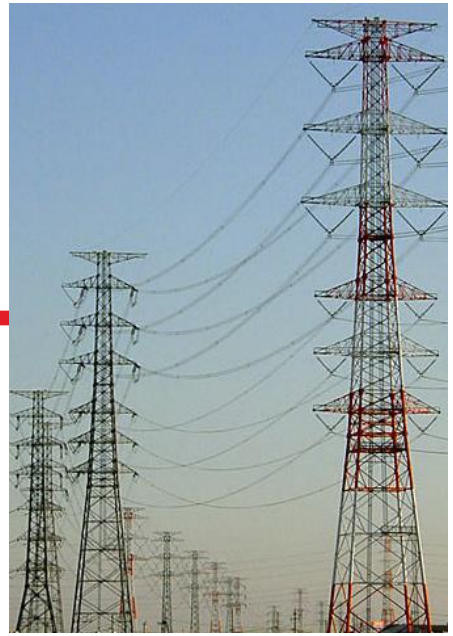
Value Proposition of Mitsubishi Power SOFC

- Triple generation: Electricity, heat and Hydrogen
- Contribution to Hydrogen Supply Chain



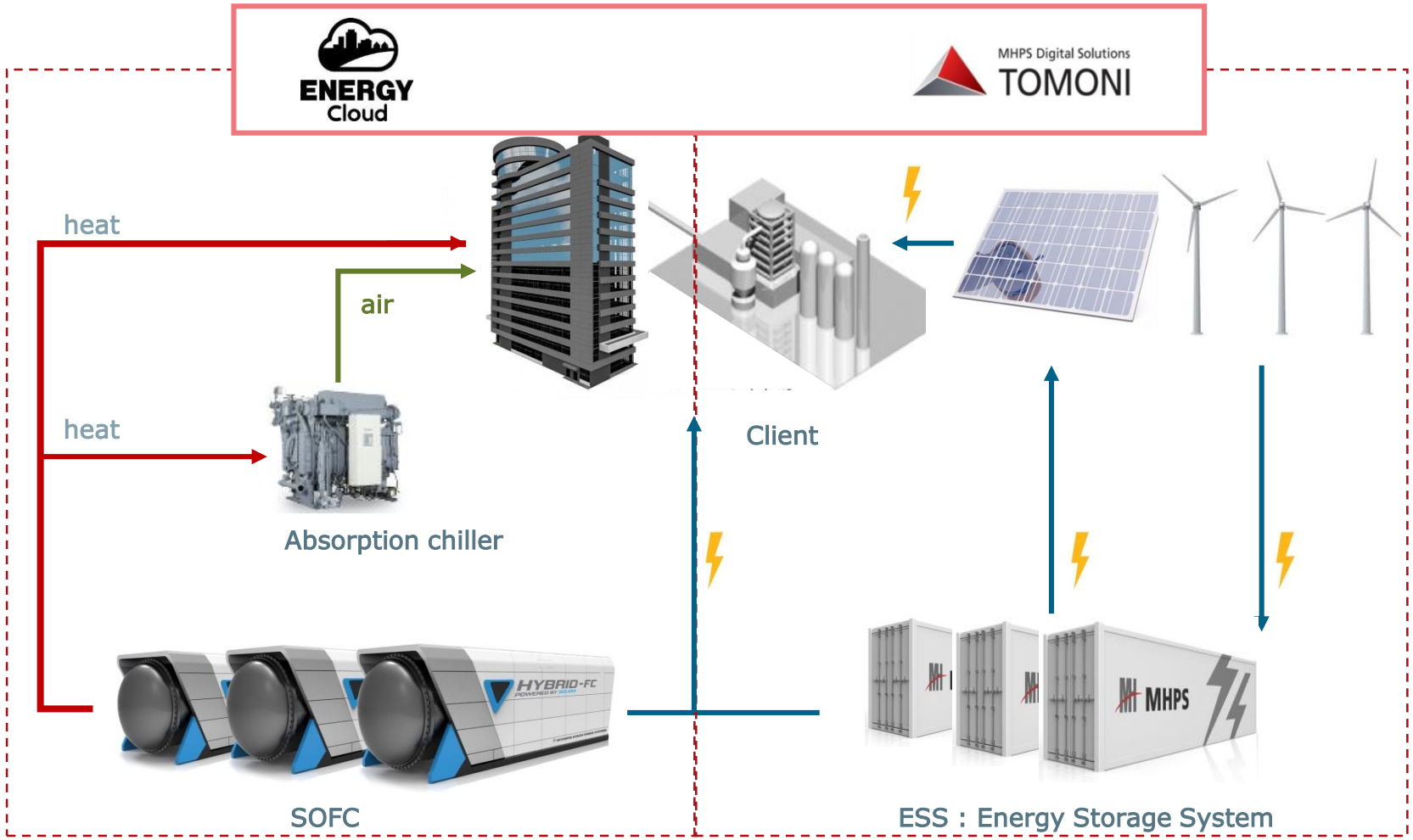
Value Proposition of Mitsubishi Power SOFC

- Reinforcing the lifeline
- reliable Power Supply
- Suitable for Distributed Power Supply



Triple Hybrid Microgrid System Solution with Mitsubishi Power-MEGAMIE (Concept)

- With digital soutions, Mitsubishi Power can integrate a whole sustainable microgrid for commercial and industrial power and heat users

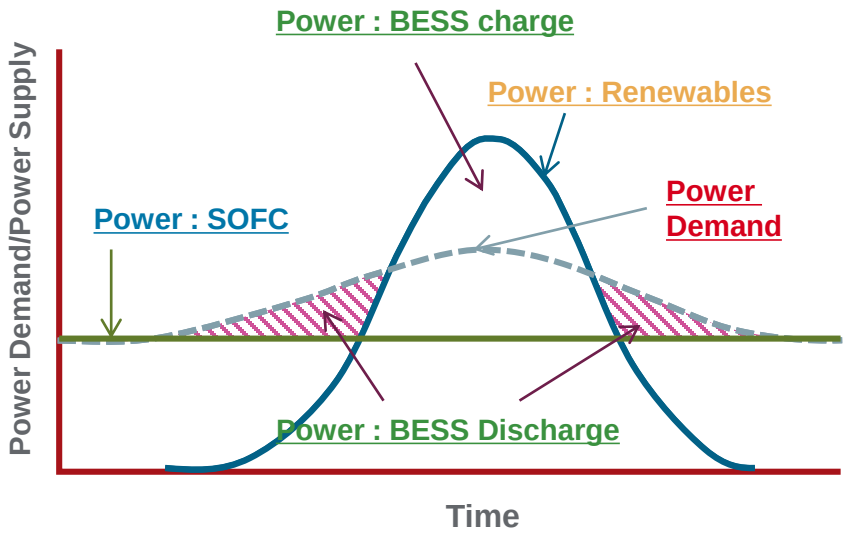


Triple Hybrid Microgrid System Solution with Mitsubishi Power-MEGAMIE (Concept)

- CHP Micro-grid with SOFC:
  - is a Hybrid system consisting of Renewables, Fuel Cells, Battery Storage with Energy Management System, which realizes integrated operation of those.

  - provides stable, reliable and sustainable CHP.

Energy Sources	Value Propositions and Characteristics
Renewables (Variable Energy Resources)	✓ Carbon-free ✓ Dependency on weather (variable)
Fuel Cell (SOFC)	✓ Reliable & Highly Efficient Base-load. ✓ Fuel Flexibility ✓ CHP Application (Hot Water/Steam)
BESS (Battery Energy Storage System)	✓ Quick Response ✓ Grid Stabilization ✓ Energy Balancer ✓ Black Start

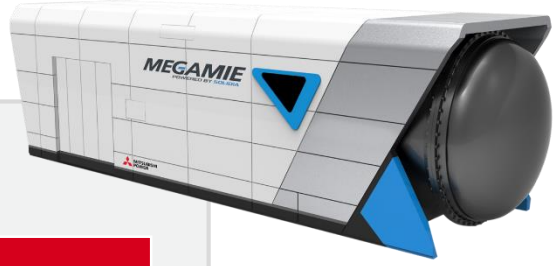



MITSUBISHI
POWER

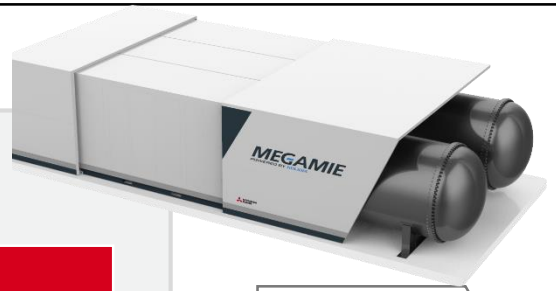
MOVE THE WORLD FORWARD

MITSUBISHI
HEAVY
INDUSTRIES
GROUP

System Interface: 210kW class SOFC



System Interface: 1MW class SOFC



Track Records - Details

Region	Customer	Application	Class	Fuel	No. of Units	Delivery
Japan	Kyushu University	University Campus Microgrid	220 kW	natural gas	1	Oct. 2015
	Taisei Corp.	Office Building CHP	220 kW	natural gas	1	Oct. 2017
	Tokyo Gas Co., Ltd.	Office & Commercial Building CHP	220 kW	natural gas	1	Apr. 2017
	Toyota Motor Corp.	Industrial CHP	220 kW	natural gas	1	Mar. 2017
	NGK Spark Plug Co., Ltd.	Industrial CHP	220 kW	natural gas	1	Mar. 2017
	Electric Power Development Co., Ltd (J-Power)	Mitsubishi Power-SOFC Fuel Flexibility Demonstration	220 kW	natural gas / hydrogen	1	Nov. 2017
	Mitsubishi Estate Co., Ltd	Office & Commercial Building CHP	220 kW	natural gas	1	Early 2019
	HAZAMA ANDO Corp.	Office & Commercial Building CHP	220 kW	natural gas/ hydrogen	1	Mid 2019
	ASAHI BREWERIES	Industrial CHP	220 kW	biogas	1	Oct 2020
Germany	Gas –und Wärme-Institut (GWI)	Office & Commercial Building CHP	220 kW	natural gas/ hydrogen	1	March 2022 (expected)