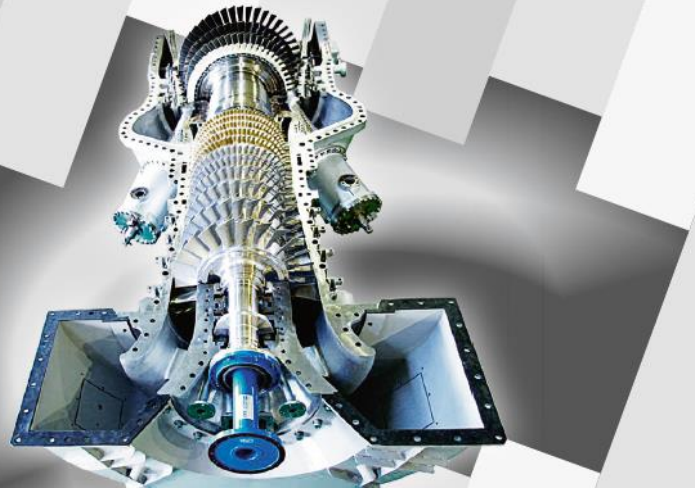
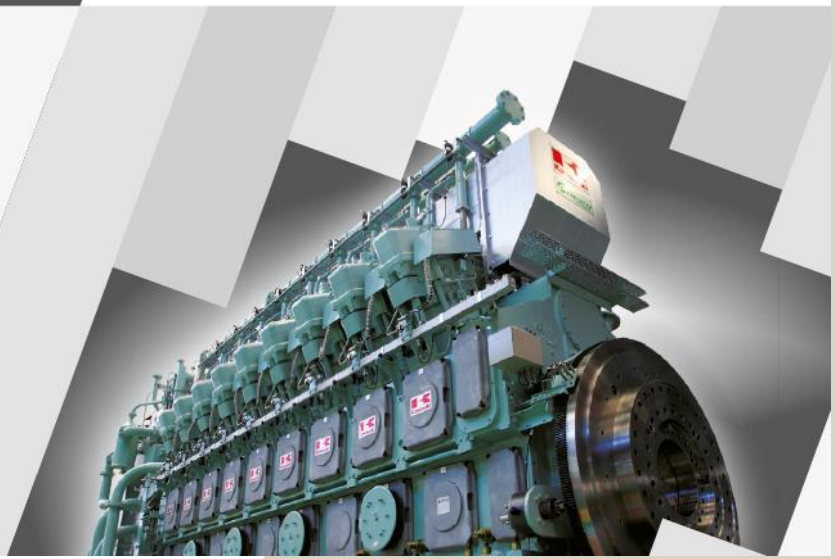
Two Specialists

No Compromise





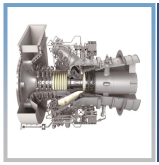
KAWASAKI Gas Turbine Europe GmbH

Energynomics – 26th November 2020,

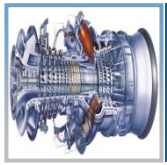
“Decarbozation of the national energy sector – challenges and solutions” conference

Kawasaki
Powering your potential

Agenda



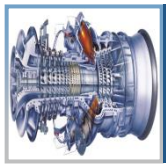
1 Kawasaki Heavy Industries (KHI)



2 Kawasaki Gas Turbine Europe (KGE)

3 KGE / KHI Products & Services

H_2 4 Hydrogen – production, quality and facility



5 Developments for Hydrogen Gas Turbines @ KHI

Kawasaki Heavy Industries – Sections

Kawasaki Heavy Industries, Ltd.

- **Ships & Offshore Structure Company**

- **Rolling Stock Company**

- **Aerospace Company**

- **Energy System & Plant Engineering Company**
- **Motorcycle & Engine Company**

- **Precision Machinery Company**

- **Kawasaki Gas Turbine Europe GmbH**
  - **Germany – Europe headquarter**
  - **Romania – Representative office responsible for South – East Europe**
- **Kawasaki Gas Turbine Asia Sdn. Bhd. (Malaysia)**
- **Kawasaki Gas Turbine Asia Sdn. Bhd. - Jakarta Representative Office**
- **Kawasaki Heavy Industries, LTD - Bangkok Office**

Kawasaki Gas Turbine Europe (KGE) – History

1975 License Agreement with Deutz AG

- *Deutz, Cologne starts the Sales and Service of the M1A Gas Turbine*
- *MWM Diesel & Gastechnik, Mannheim takes over the business from Deutz*

1998 Establishment of KAWASAKI Gas Turbine Europe GmbH

- *Headquarter for the entire European Market*
- *Sales, Packaging and Service of Gas Turbine Generator Sets*
- *10 Employees*

2003 Expansion of Production Facilities

- *Relocation to Bad Homburg (close to Frankfurt City)*
- *Establishment of the Production Site and Service Centre Europe*
- *Start of in-house packaging of GPB17D*
- *25 Employees*

2013 Introduction of the Gas Engines into the product portfolio

- *Start of Promotion and Sales of KG-12/V and KG-18/V*
- *40 Employees*

2018 Establishment of Romanian Office in Bucharest

- *Promotion & Sales Activities started, responsible for South-East Europe*
- *Currently: 67 Employees*

Bundesverband Kraft-Wärme-Kopplung e.V.

KGE's Take

Working as one for the good of the planet!

Highly Focusing on Environmental Protection and Energy Savings

- **Reduction of emissions**
  - Global warming gas CO_2
  - Harmful gas NO_x, SO_x
- **Energy Saving**

→ **Renewable energy**

Distributed Generator System

- **Provide highly efficient energy use**
- **Flexible and reliable**

to complement unstable renewable energy

KGE cogeneration market – request of electricity and steam / hot water

Typical applications:

Pulp and paper

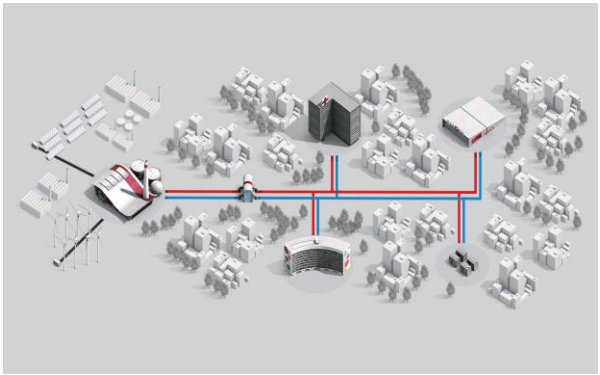
Medicines / cosmetics

Refinery / Chemistry

Food and Beverage

Automotive / Tires

District Heating



Universities

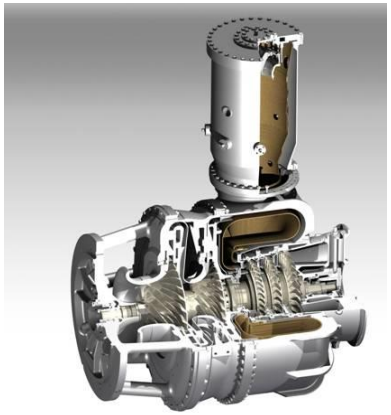
Hospitals

Hotels

Airports

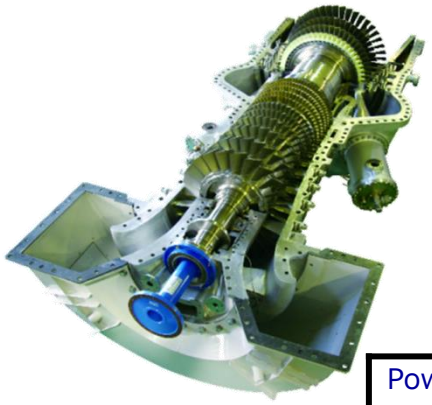
Kawasaki Gas Turbine Generator Sets

M1A-17D



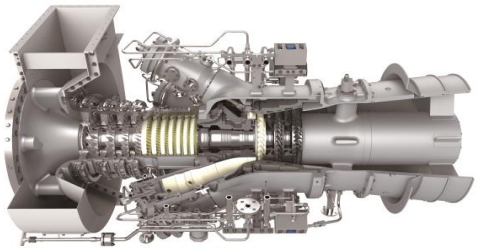
Power Output [kWe]	1,816
Ele. Efficiency [%]	28.1
Sat. steam 8 barg [t/h]	5
Exhaust Gas Temperature [°C]	522
NO_x @ O_2 = 15% [ppm] CO @ O_2 = 15% [ppm]	< 9 50

M7A-03D



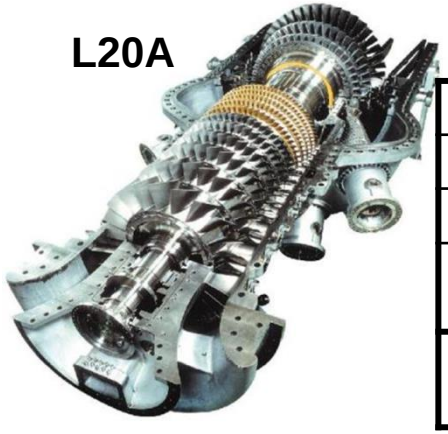
Power Output [kWe]	7,810
Ele. Efficiency [%]	33.6
Sat. steam 8 barg [t/h]	16.4
Exhaust Gas Temperature [°C]	523
NO_x @ O_2 = 15% [ppm] CO @ O_2 = 15% [ppm]	< 9 10

M5A-01D



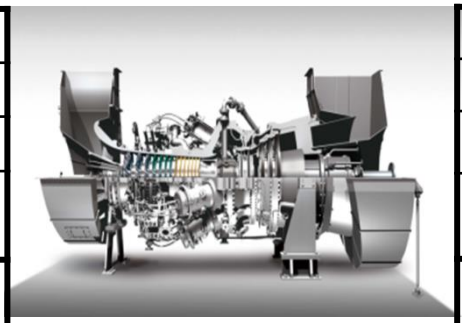
Power Output [kWe]	4,720
Ele. Efficiency [%]	32.6
Sat. steam 8 barg [t/h]	11
Exhaust Gas Temperature [°C]	511
NO_x @ O_2 = 15% [ppm] CO @ O_2 = 15% [ppm]	15 15

L20A



Power Output [kWe]	18,500
Ele. Efficiency [%]	34.3
Sat. steam 8 barg [t/h]	37
Exhaust Gas Temperature [°C]	542
NO_x @ O_2 = 15% [ppm] CO @ O_2 = 15% [ppm]	15 25

L30A



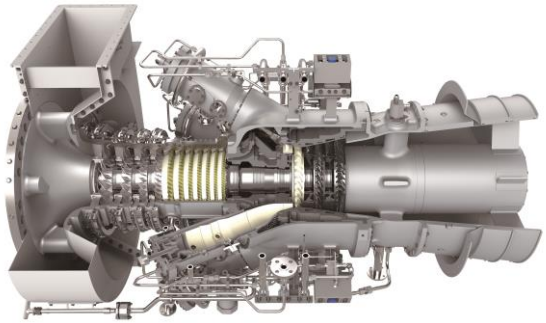
Power Output [kWe]	34,380
Ele. Efficiency [%]	40.3
Sat. steam 8 barg [t/h]	55
Exhaust Gas Temperature [°C]	502
NO_x @ O_2 = 15% [ppm] CO @ O_2 = 15% [ppm]	15 / 9 25

M5A-01D. Highest power generating efficiency in the 5 MW class

On 7th August, 2020 Kawasaki Heavy Industries, Ltd. has received the Best Paper Award for its academic paper, presented at ASME Turbo Expo 2019 organized by the International Gas Turbine Institute (IGTI) of the American Society of Mechanical Engineers (ASME).

Its title is "Development of High Efficiency 5MW Class Gas Turbine the Kawasaki M5A".

M5A-01D

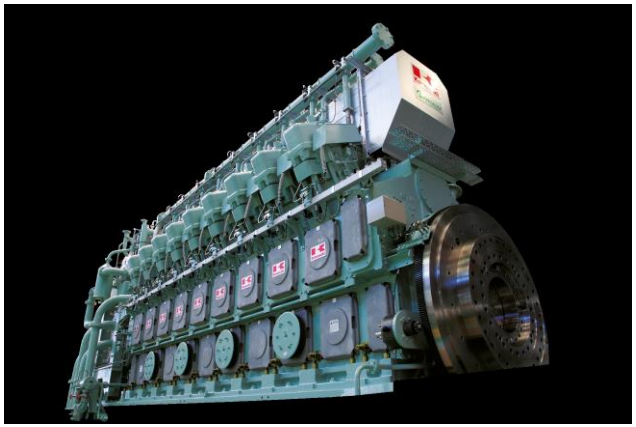


The award-winning paper covers the development of the M5A, a domestically produced gas turbine launched in November 2017, which boasts the world's highest power generating efficiency in the 5 MW class.

- **32.6% generating efficiency, the world's highest among 5 MW models**
- **84.5% combined energy efficiency — the highest in its class.**

Kawasaki Gas Engine Models

KG 18V



Power Output [kWe]	7,800
Ele. Efficiency [%]	49.5
Exhaust Heat [kWth]	4,000
Exhaust Gas Temperature [°C]	320
NOx @ O_2 = 0% [ppm] CO @ O_2 = 0% [ppm]	200 50
Methane number	> 65

KG 12V

Power Output [kWe]	5,200
Ele. Efficiency [%]	49.5
Exhaust Heat [kWth]	2,700
Exhaust Gas Temperature [°C]	320
NOx @ O_2 = 0% [ppm] CO @ O_2 = 0% [ppm]	200 50
Methane number	> 65

KG 18T

Power Output [kWe]	7,800
Ele. Efficiency [%]	51
Exhaust Heat [kWth]	
Exhaust Gas Temperature [°C]	
NOx @ O_2 = 0% [ppm] CO @ O_2 = 0% [ppm]	250
Methane number	> 65

KHI - first in-house-developed 107 MW class CCPP

17th September, 2020 — KHI Ltd. announced the completion for Kashima South Joint Power Corporation (Kamisu City, Ibaraki Prefecture) of 107 MW CCPP.

The plant include a cogeneration facility supplying electricity and steam according to demand from surrounding factories.

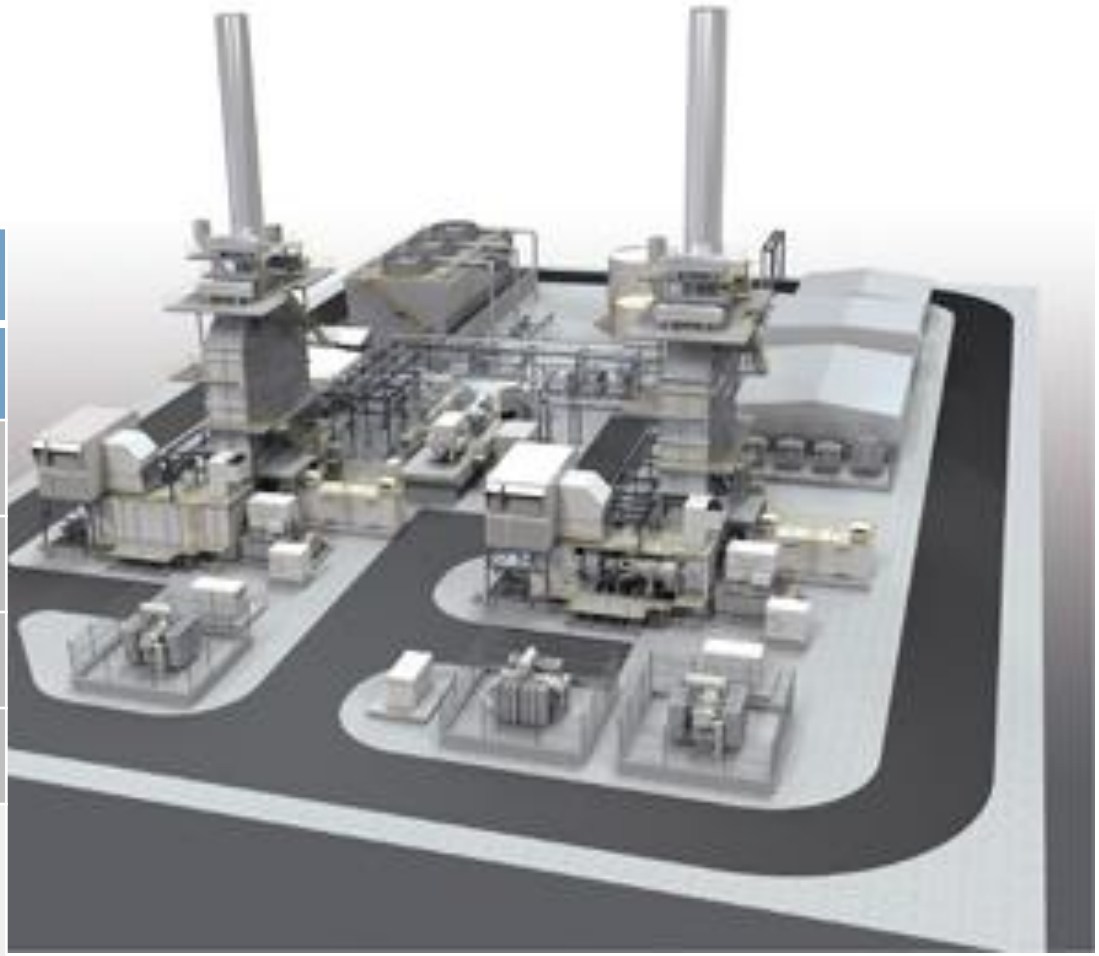
Joetsu Green Power Project for Nihon Techno / J

Model	KG-18-V
Unit Output	7,800kW
No. of Unit	14
Total Output	109.2MW

100 MW CCPP (standard solution)

Combined Cycle Performance Data (Reference)			
	1 on 1	2 on 1	2 on 1 (Reheat)
CC Electric Output [MW]	44.7	89.9	101.5
CC Heat Rate [kJ/kW-hr]	6,650	6,620	6,520
CC Electrical Efficiency [%]	54.1	54.4	55.2
Number of Gas Turbines	1	2	2

Condition:
Inlet Air Temperature: 15 deg-C
Atmospheric Pressure: 101.3 kPa
Fuel Type: Natural Gas (100% CH_4)
LHV of Fuel: 35.9 MJ/Nm³



H_2 - Production

Colors of Hydrogen

	Source	Technology	
Green Hydrogen	Renewable Energy	Electrolyze	Zero CO_2
Turquoise	Natural Gas	Pyrolysis	Solid Carbon
Blue Hydrogen (with CCS)	Natural Gas, Coal, other Fossils	Thermochemical conversion - Steam Metane Reformer - Gasification	+ CO_2
Grey Hydrogen (without CCS)	Natural Gas, Coal, other Fossils	Thermochemical conversion - Steam Reformer - Gasification	+ + + CO_2

H_2 - Quality

H_2 by NG-Steam - Reformer

p=2.5MPa, T=900C

1. $CH_4+H_2O \leftrightarrow CO+3H_2$ (steam injection)

2. $CO+H_2O \leftrightarrow CO_2+H_2$ (shift reaction)

PSA=Pressure swing adsorption

< 20 ppm CO

Quality of H_2: 5.0 (99.999%)

H_2 By-Product

	H_2 Quality:
Chlor-Alkali Elektrolyse ($2NaCl+2H_2O \Rightarrow 2NaOH+Cl_2+H2$)	99,97%
Ethylene	96 - 98%
Cracking	min. 90%

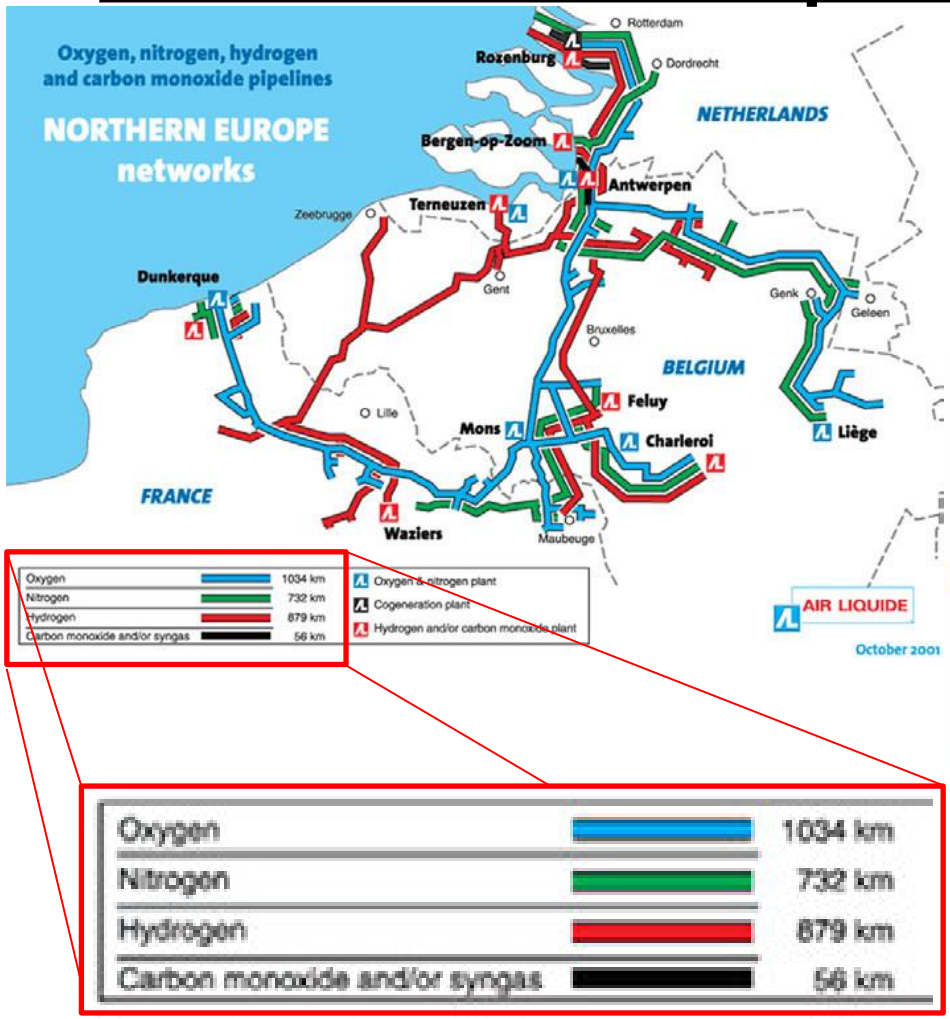
Electrolyzer

Quality of H_2: 5.0 (99.999%)

source: Air Liquide (2009)

H_2 - Facility

worldwide 12 Air Liquide H2-pipelines (1800km)



H_2 - Grid

Overview of worldwide H2-pipelines

source: Shell Study

total: 4542 km

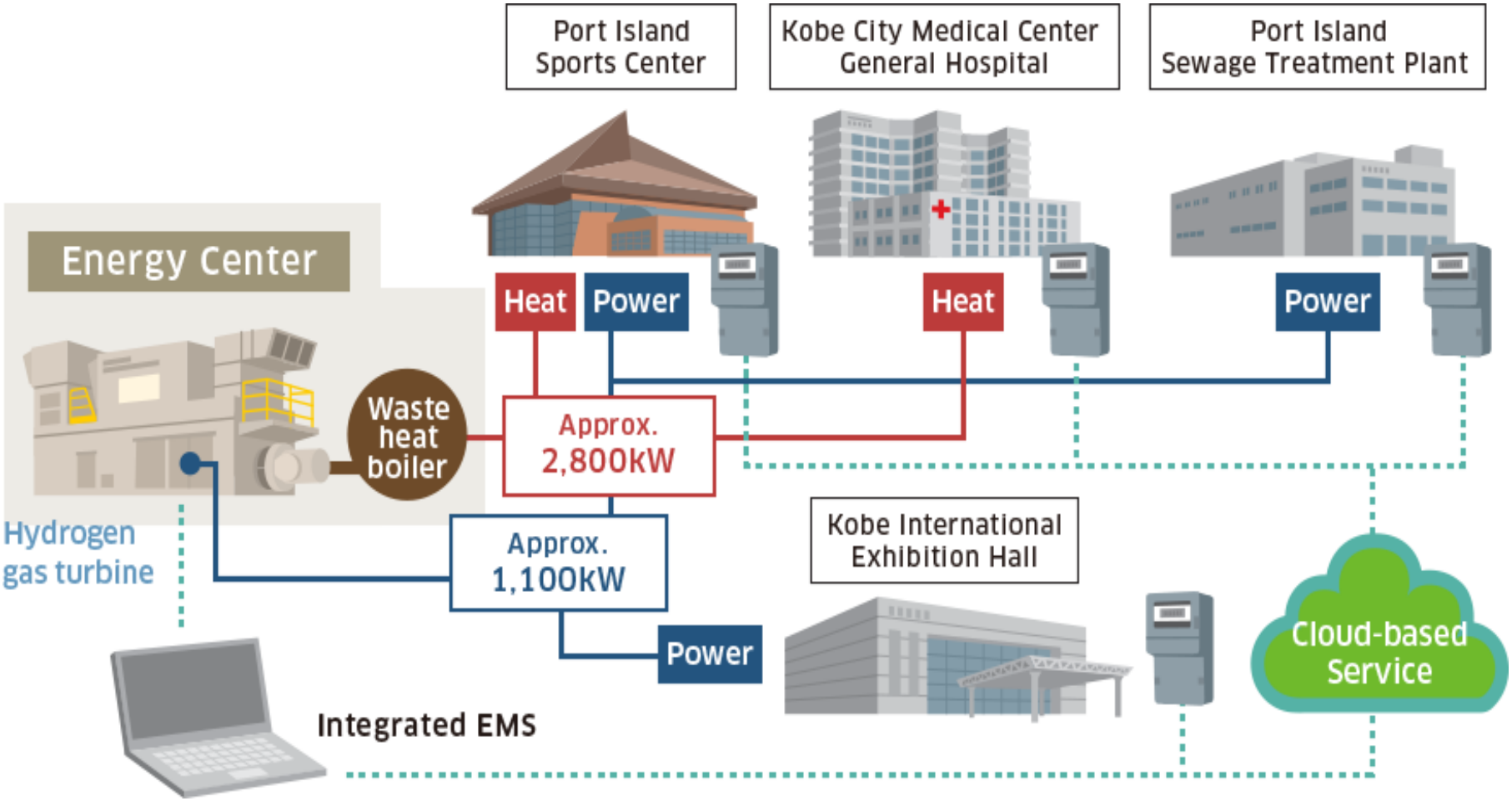
Kawasaki Hydrogen Road Map

KOBE city

Development of Smart Community Technology by Utilization of Cogeneration System with Hydrogen Gas Turbine

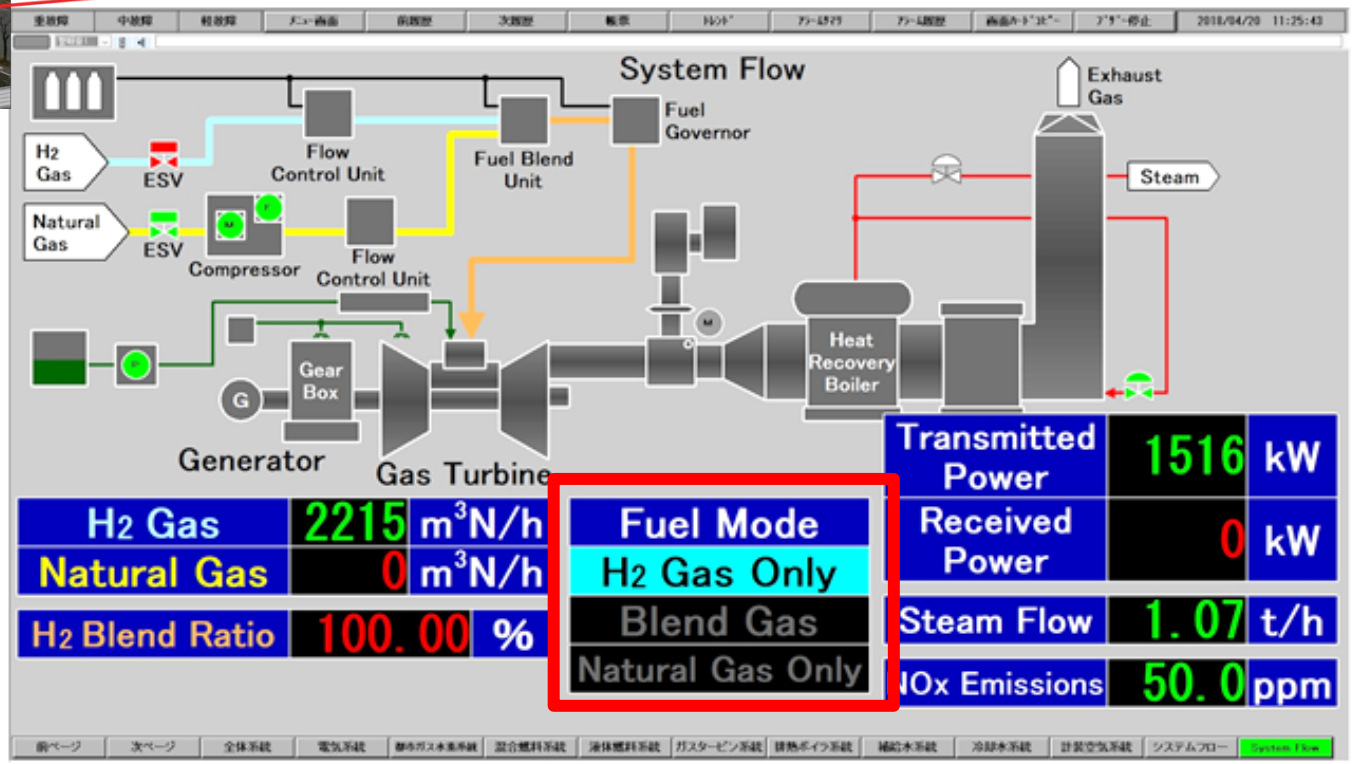
Kawasaki Hydrogen Road Map

The first attempt in the world to supply electric power and heat generated from hydrogen gas turbine to an actual urban area



World‘s First H_2-Cogeneration Plant at Kobe Port

User Control Interface



Kawasaki Hydrogen Road Map

Gas Turbine CHP Plant using 100% Hydrogen as a fuel

Power Generation: 1.7 MWe

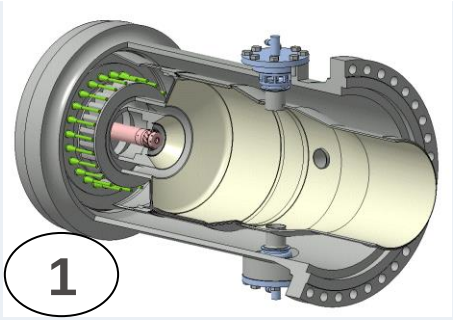
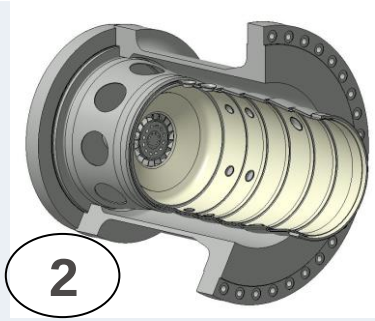
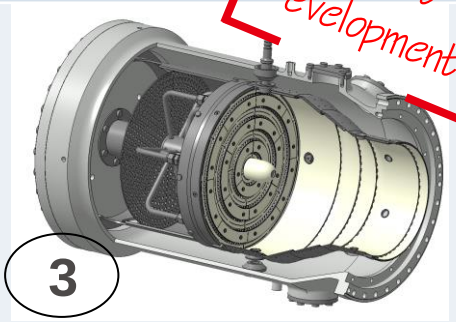
Partners:

- **Obayashi**
- **Kawasaki**
- **Kobe City**
- **KEPCO**
- **Iwatani**
- **Osaka University**

Supported by NEDO

Development of Hydrogen Gas Turbines @ KHI

Overview of Combustor Developments

Combustor Configuration	DLE Combustor for Natural Gas	Diffusion Flame Combustor	DLE Micro-Mix Combustor
NOx Reduction	"Dry"	"Wet" Water/Steam	"Dry"
			
Max. H2 Content	60vol%	100vol%	100vol%
Status	In operation @ Akashi Works 	Final Combustor Test, 2016 Applied to KOBE Demonstration Plant, 2018 	Combustor under development 

Latest Development

Kawasaki Powering your potential

Development of Hydrogen Gas Turbines @ KHI

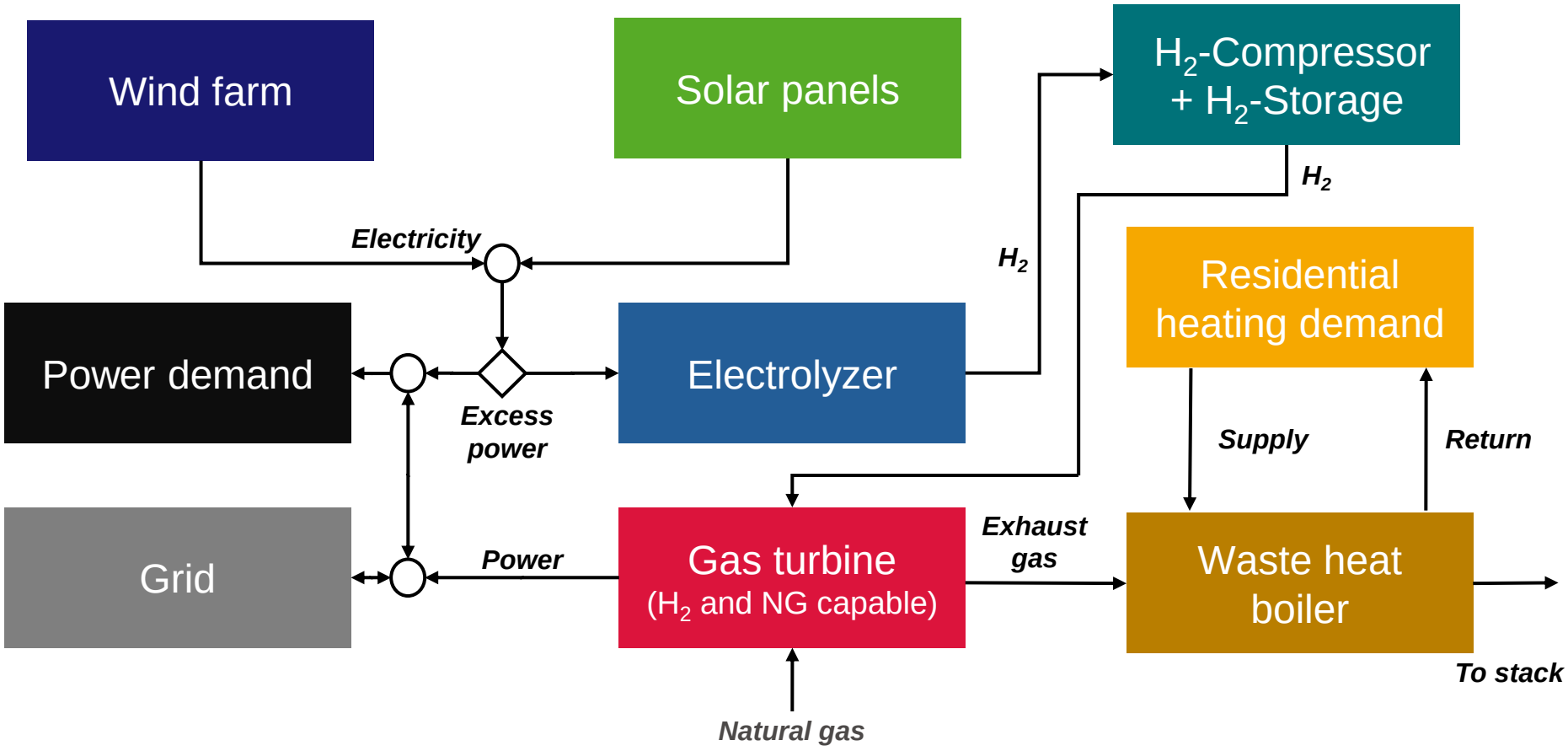
Today situation

- GPB 17D – 100% H2, diffusion mode
- GPB 50D – 10% H2, DLE mode
- GPB 80D – 10% H2, DLE mode
- GPB 180D – 10% H2, DLE mode
- GPB 300D – 10% H2, DLE mode

Short and medium term

- GPB 17D – 100% H2, DLE mode
- GPB 50D – 30% H2, DLE mode
- GPB 80D – 30% H2, DLE mode
- GPB 180D – 30% H2, DLE mode
- GPB 300D – 100% H2, diffusion mode and 30% DLE mode

Future Cogeneration Plants



Kawasaki will pursue "manufacturing that makes the Earth smile."

“Global Kawasaki”

Kawasaki
Powering your potential