

Hydrogen fueled Gas Turbines: CHP Applications, enablers of decarbonization

F. Cervini, M. Baldini

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We are Baker Hughes, an energy technology company. Together, we're making energy safer, cleaner, and more efficient for people and the planet.

Energy for today and tomorrow.

The energy sector is changing, faster than ever before. The energy trilemma – solving for energy security, sustainability, and affordability – is rebalancing our priorities and creating a new path forward for the industry.

We believe we can meet those objectives together. As demand for energy increases, we're demanding more from energy, making it more sustainable, more reliable, more abundant, and more accessible.

We take
energy
forward



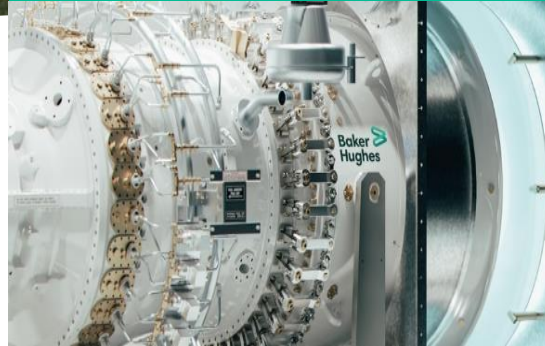
Climate Technology Solutions to support decarbonization Enabled by growth in digital technology offerings

Carbon Capture Utilization & Storage



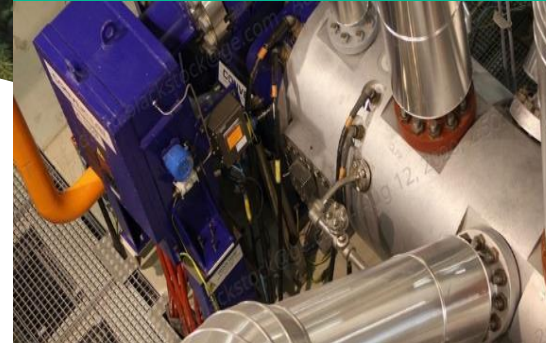
- Consultation & feasibility
- CO₂ capture & liquefaction
- Compression & transportation
- Subsurface storage
- Integrity and monitoring

Hydrogen



- Solutions for production, transportation & storage
- Hydrogen-fueled gas turbines – H₂ blends and 100% H₂
- Wide range of hydrogen compression solutions
- Integration capabilities for optimized design and operations

Clean Power Solutions



- Clean power generation and energy efficient solutions for decentralized and industrial applications
- Digitally augmented low-to no carbon-only portfolio

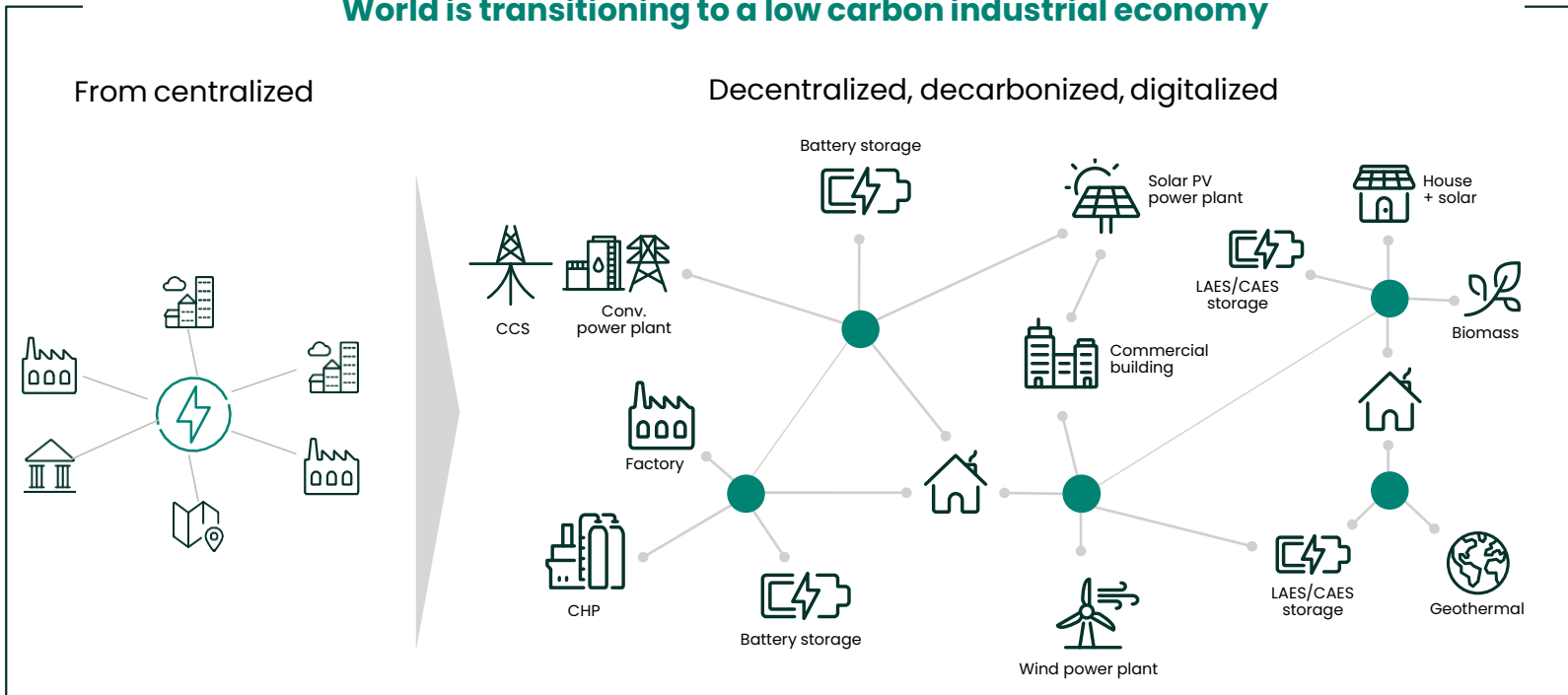
Emissions Management



- Aerial and land-based emissions monitoring
- Real-time analytics
- Equipment upgrades and operational process efficiency

Clean Integrated Power Solutions enabling the future of industrial energy consumption

World is transitioning to a low carbon industrial economy



- Decentralized power led by the adoption of clean energies + higher Project complexity, Smart grid assets integration + digital are driving need to have an integrated approach and evolve business model
- Reliable, affordable and secure electricity supply is vital for future economy
- CHP to join the energy transition path: GTG techs with hydrogen future upgrade potential and RES integration
- Solution deployment to be country/region specific, aligned with local environment and regulations



Decentralized

Power at the vicinity or at the point of use, on or off the grid.



Low to no carbon only

Reduce/neutralize CO₂ footprint through efficiency enhancement and a clean tech portfolio



Digital

Provide connected/augmented, and outcome-based services

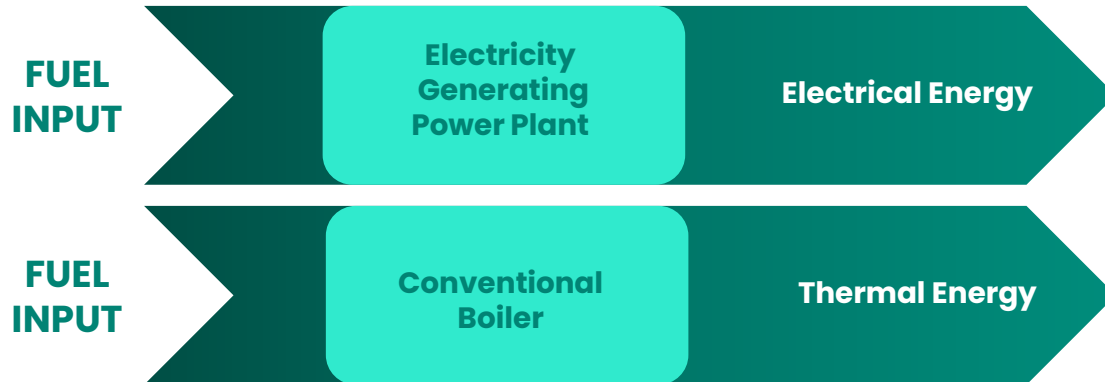


Integrated solutions

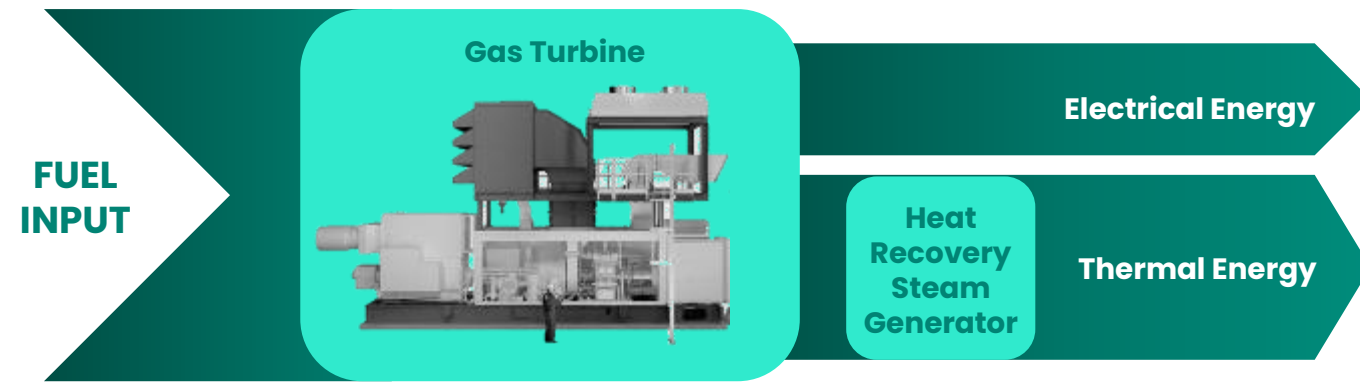
Integrate and connect renewable/battery/energy storage and other solutions

How a Co-generation (CHP) system work

SEPARATE PRODUCTION



COGENERATION SOLUTION



NovaLT™ Fleets in APAC

Customer: Glove Manufacturer Malaysia

COD: 2019

Product: NovaLT™ 16

Application: CHP

Running Hours: > 20,000

Key Features:

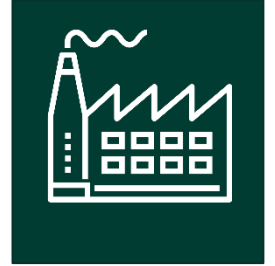
This CHP plant will reduce 54,000 tons/yr of CO₂ ;
equivalent to 2.5 million new trees.

CHP Plant Output:

Elec. =13 MWe and 856t/h of 90°C

Heat= 30 MWth (Suppl.Fired HRSG).

CHP efficiency = 86%



NovaLT™ Fleets in APAC



Customer: Food Manufacturer Malaysia

COD: 2019

Product: NovaLT™ 5

Application: CHP

Running Hours: >20,000

Key Features:

Saving on electricity bill & energy bill. Captive plant to provide both electricity and thermal energy at the same time.

Reliable onsite captive solution providing stable output.



EUROPE

A success story for a cogeneration plant

Client

European multinational leader in the production of tissue, airlaid, and MG paper

Challenge

Increase plant profitability and reduce emissions

Solution

- Introduce a Combined Heat and Power process driven by NovaLT™12 with an output 12 MWe, 24t/h of saturated steam
- Commissioning completed Q4'19

Results

- 80% CHP efficiency
- 34% electrical efficiency
- 7,000 tons/y CO₂ emissions saved vs grid (equivalent 2.800 acres of forest)



**NovaLT™12 installed at the site:
>25,000 continuously running hours (24/7) already accumulated**

150+ years of experience in hydrogen!

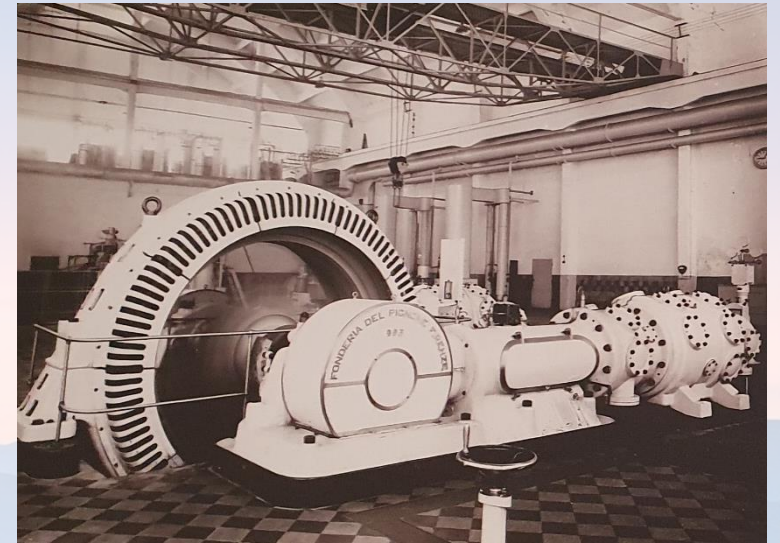


First combustion engine,
running with H₂, **1854**



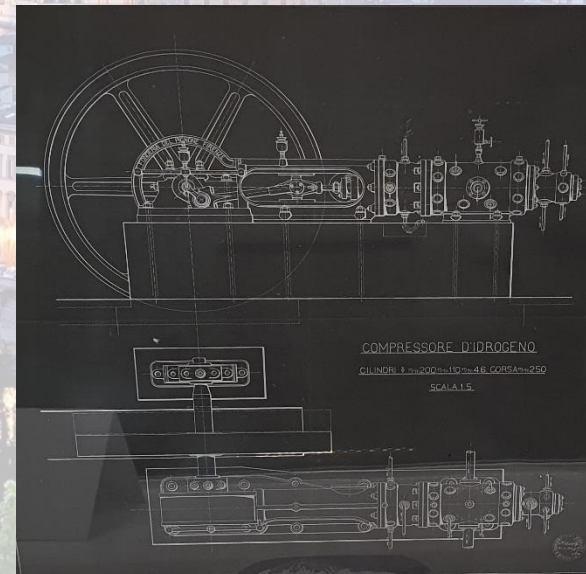
Ammonia compressor **1910**

Compressore frigorifero ad ammoniac
per potenze da 15.000 a 500.000 frigorie all'ora



Ammonia compressor at
860 bar, **1930**

Hydrogen compressor **1915**

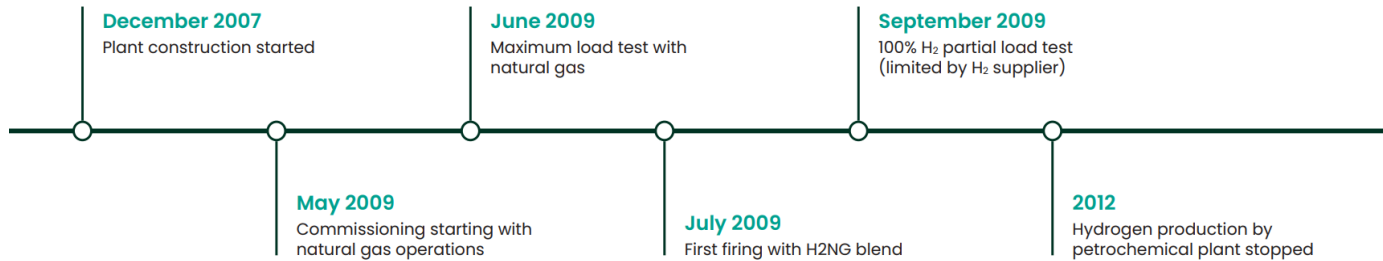


COMPRESSORE D'IDROGENO
CILINDRI 1-1000-110-48-CORSA-250
SCALA 1:15

Full H2 Power Plant in Fusina (IT): 14 years ahead the curve

Zero-emission 16 MWe integrated gasification combined cycle consisting of a hydrogen-fueled gas turbine and a HRSG

- PGT10/1: unique 12MW GT model able to burn up to 100%H2
- Operated since Aug 2009 for a couple of years.
- H2 fuel available as by-product from a nearby petrochemical plants.
- Natural gas used for start-up and back-up fuel.
- NOx abatement by steam injection



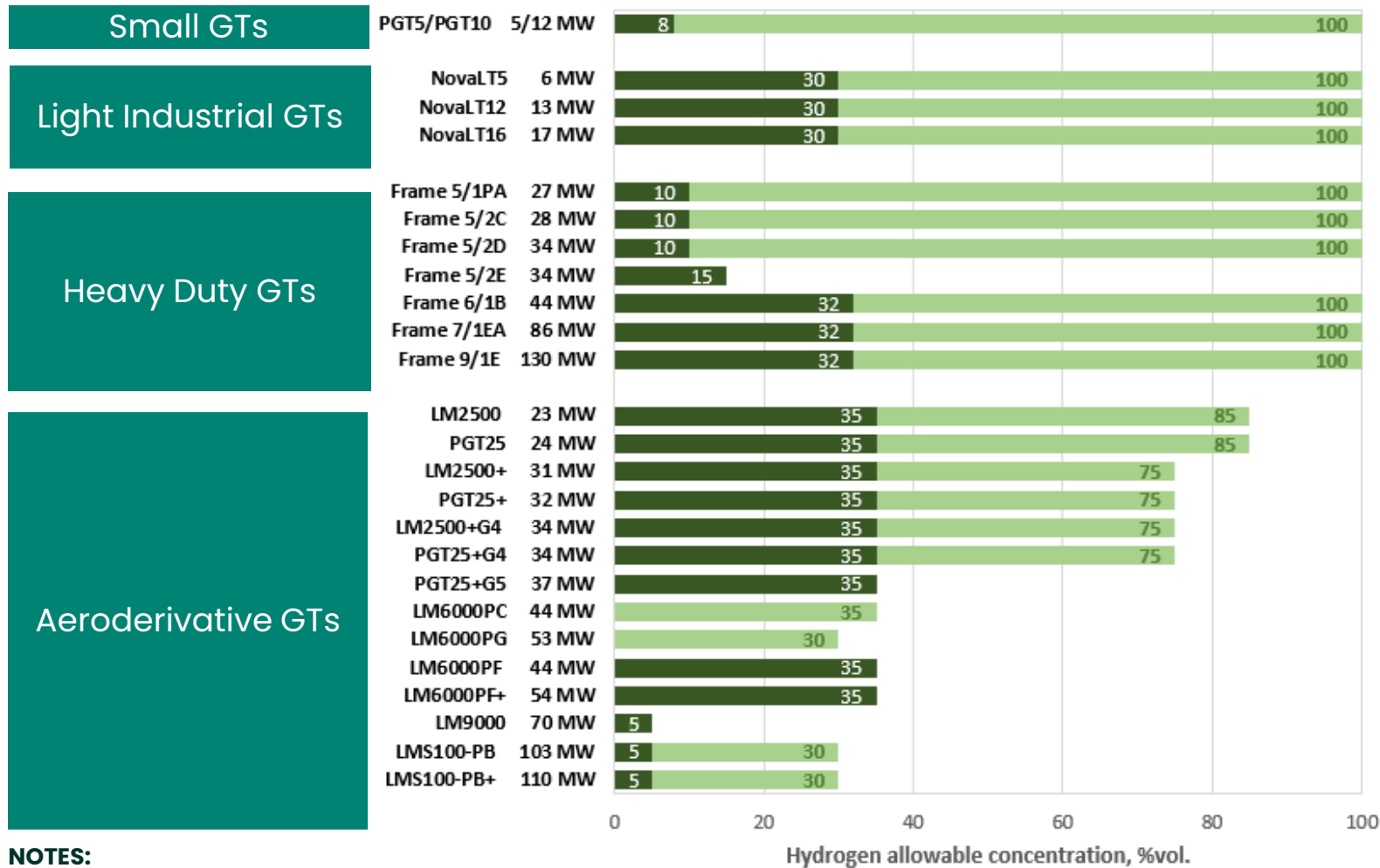
Net electric power in H2 Gas Turbine	11.44 MWe
Net thermal efficiency in the H2 Gas Turbine	31.1%
Net thermal efficiency in combined cycle	41.6%



- | | |
|---|-----------------|
| 1. Dry flue gas stack | 5. Control room |
| 2. Bypass stack | 6. Transformer |
| 3. Heat recovery steam generator (HRSG) | 7. Diverter |
| 4. PGT10 gas turbine | 8. Piping rack |

Baker Hughes H₂ combustion technology capabilities

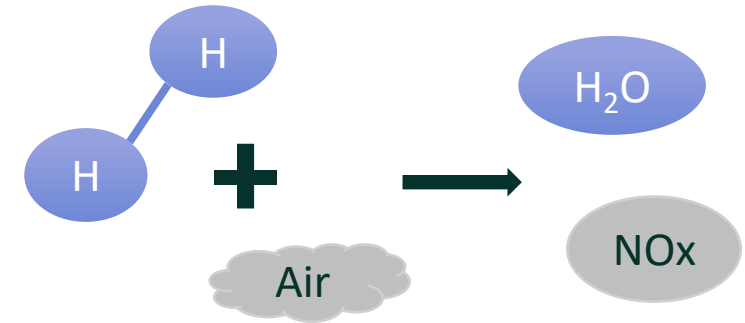
■ DLN/DLE Combustion systems ■ STD/SAC Combustion systems with diluents injection or SCR system for NO_x abatement



NOTES:

1. Shaft Power at ISO conditions
2. The reported limits are intended for preliminary evaluation only. Case-by-case assessment is required for final fuel acceptance. Limitations may apply on guaranteed emission levels, premix turn-down capability (DLN/DLE combustors) and component life (maintenance factor).

Today
 Burning 100% H₂ in a diffusive combustor does not generate CO₂ emissions or other carbon pollution



Next step
 Developing 100% H₂ DLN/DLE combustion systems to avoid diluents injection or SCR system at GT exhaust for NO_x abatement

Hydrogen Utilization in Gas Turbines

Engine and package modifications are needed for hydrogen fuel

Combustion

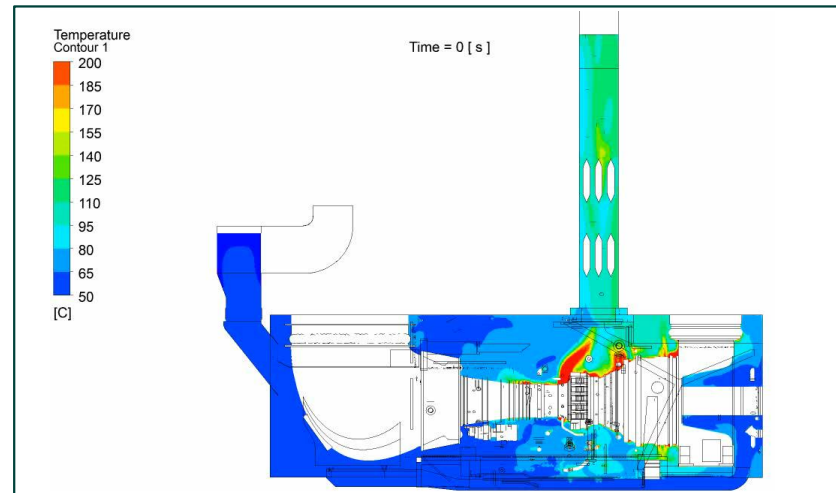
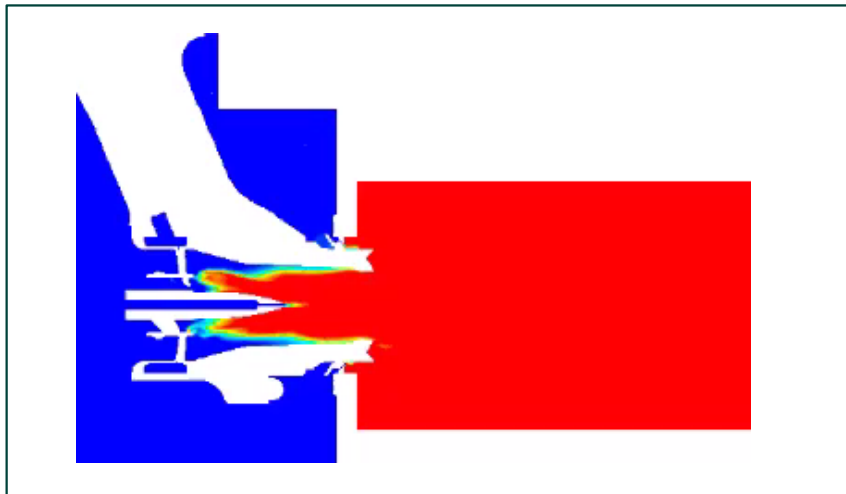
- ❑ High flame speeds
- ❑ Wide flammability limits
- ❑ High flame temperatures
- ❑ Flashback
- ❑ Combustion dynamics

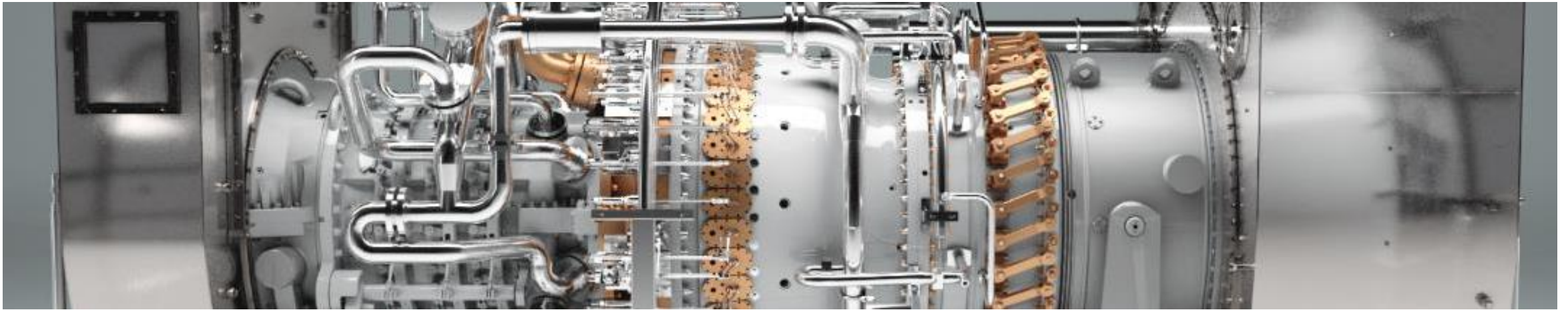
Delivery & Package

- ❑ Storage
- ❑ Sealing
- ❑ Material compatibility
- ❑ Equipment validation & ATEX, NEC certification

Operation

- ❑ Start-up and shut-down procedures
- ❑ Fuel system/engine/package purge requirements
- ❑ Flame detection
- ❑ Gas detection
- ❑ Performance/durability (high % H₂)





Baker Hughes test the world's first hydrogen blend turbine for gas networks

LT16

- NPI Launched in 2013 (16MW space)
- First LT16 Units sold in 2015 for Canada
- LT16 Fleet Leader running smoothly 24/7 since Dec'17
- 15+ units produced with cumulated run hours both in power gen and mech drive applications
- ~100,000 hours in operations

LT12

- NPI launched in 2015 (12MW space)
- First Unit Full Load tested in Nov-2019 for paper mill (ITALY)
- LT12 in commercial operation in IPG (#1 GT running 24/7 since Dec'19)
- ~20,000 hours in operations

LT5

- NPI launched in 2017 (5MW space)
- First LT5-1 in commercial operation in IPG (Malaysia) running 24/7 since Dec'19
- ~36,000 hours in operations

NovaLT™ GT Family Burning 100% Hydrogen

NovaLT™5

POWERGEN SYMPLE CYCLE **5.7 MWe**
 Elect. Efficiency 30.7%

COMBINED CYCLE **7.0 MWe**
 46% Elect. efficiency

COGENERATION (CHP) **15tph Steam output**
 85% CHP Efficiency

MAINTENANCE
 24 khr – 48 khr

No annual stop &
 Fast Engine swap

*Unabated and Water inj. NO_x: available
 DLN, on request*



NovaLT™12

POWERGEN SYMPLE CYCLE **12.5 MWe**
 Elect. Efficiency 35.3%

MECH DRIVE SYMPLE CYCLE **13.0 MW**
 Efficiency 36.8%

COMBINED CYCLE **16.0 MWe**
 47% Elect. efficiency

COGENERATION (CHP) **23tph Steam output**
 80% CHP Efficiency

MAINTENANCE
 35 khr – 70 khr

No annual stop &
 Fast Engine swap

*Unabated and Water inj. NO_x: available
 DLN, on request*



NovaLT™16

POWERGEN SYMPLE CYCLE **16.9 MWe**
 Elect. Efficiency 36.4%

MECH DRIVE SYMPLE CYCLE **17.5 MW**
 Efficiency 37.5%

COMBINED CYCLE **22.0 MWe**
 48% Elect. efficiency

COGENERATION (CHP) **31tph Steam output**
 80% CHP Efficiency

MAINTENANCE
 35 khr – 70 khr

No annual stop &
 Fast Engine swap

*Unabated and Water inj. NO_x: available
 DLN: available in 2025*



Start up with blends up to 100% H₂. Switch from NG to gas blends up to 100% H₂ on the fly

Nova LT™16 Gas Turbine burning 100% Hydrogen

POWERGEN SIMPLE CYCLE

16.9 MWe 36.4% Elect. efficiency

COMBINED CYCLE

22.0 MWe
48% Elect. efficiency

COGENERATION (CHP)

31tph Steam output
80% CHP Efficiency

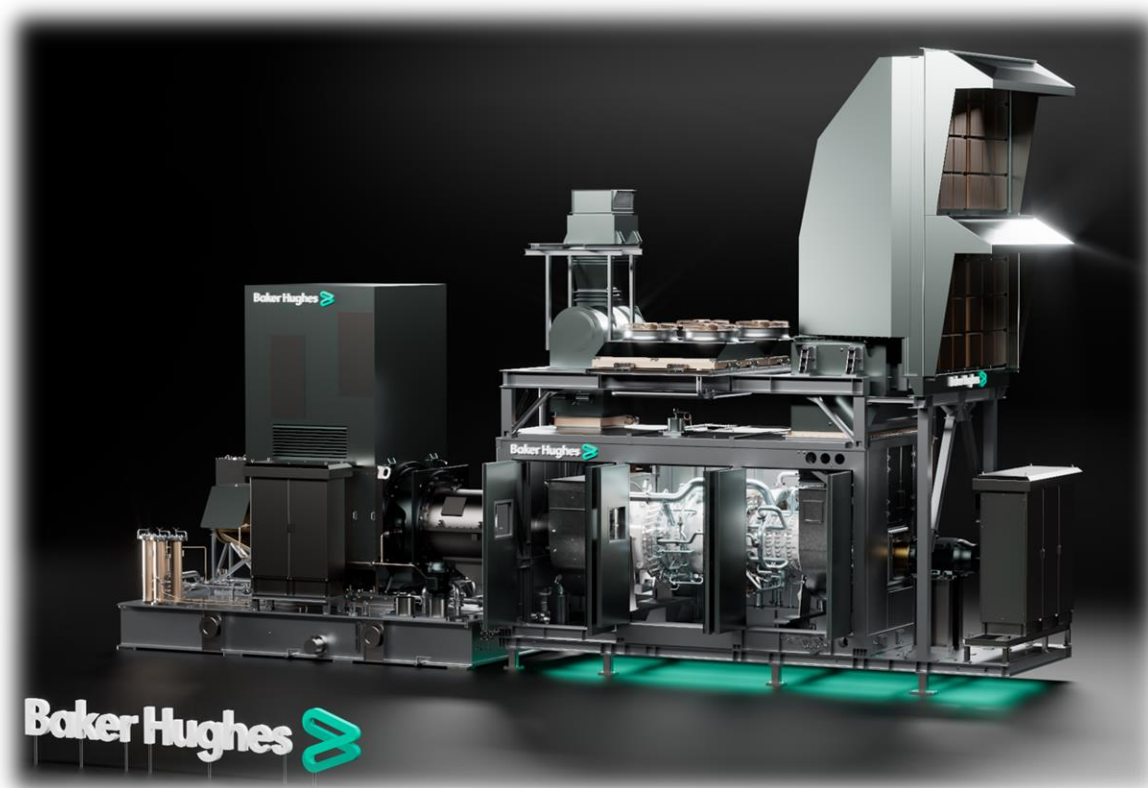
MAINTENANCE

No annual stop &
35 khr – 70 khr (FFH) Fast Engine swap

EMISSIONS

NO_x **15/25 ppm** SCR/WET
15 ppm DLN (from 2026)

CO₂ **NA**



PACKAGE & AUXILIARIES

Main features:

Turbine burners
avoiding flashbacks

Ventilation
enhanced enclosure washing

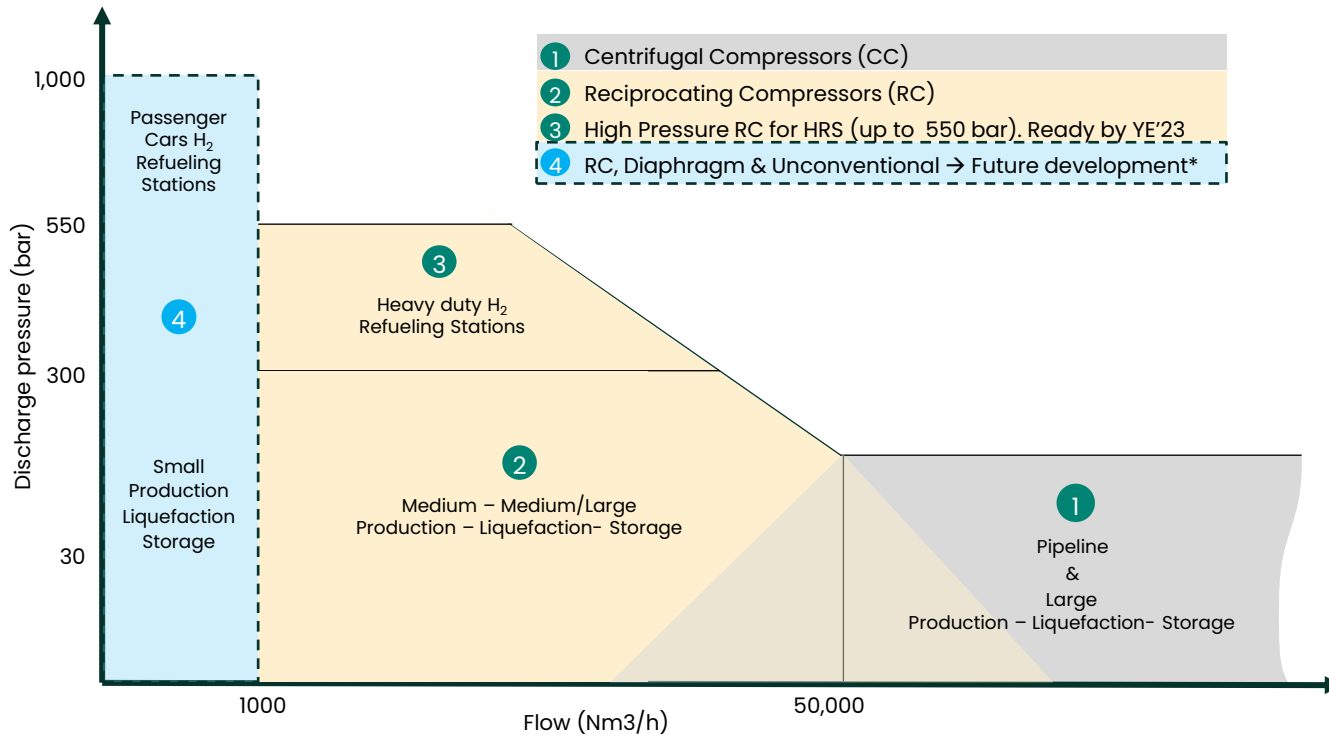
Gas detectors & Fire Fighting Sys
reducing response time

Purge system
safer operation

Blending skid
Included

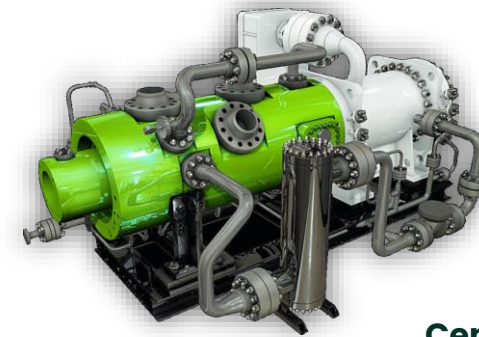
Start up with blends up to 100% H₂. Switch from NG to gas blends up to 100% H₂ on the fly

H₂ Compression | Pressure-Flow Map



Reciprocating Compressors

- H₂ RC SN #1 in 1962: 60y experience w/ H₂ compression
- Largest RC H₂ 20MW - 2020, Refinery



Centrifugal Compressors

- High Pressure Ratio Compression
- Un to 20 MW single unit power
- Large low-pressure horizontally split units
- Zero-Leakage oil-free CC product line

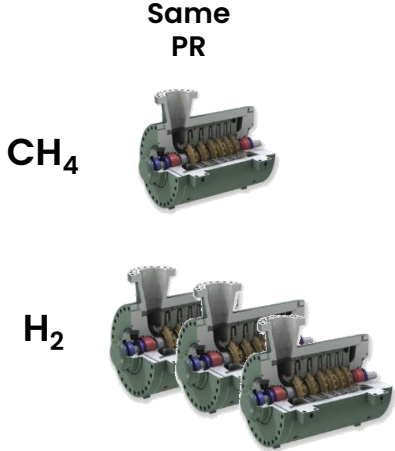
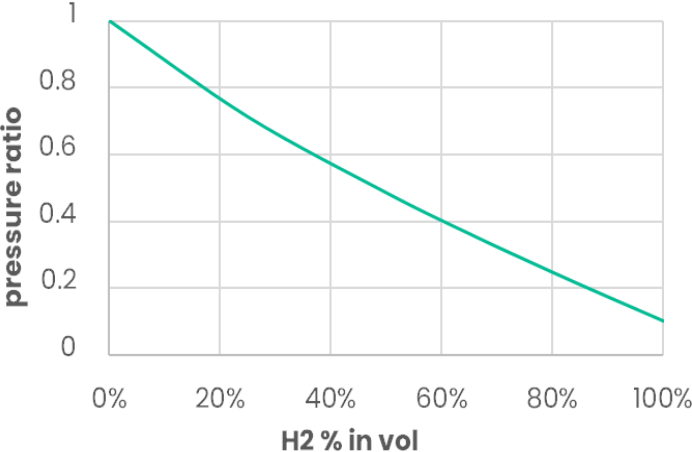
Hydrogen services	Technology	Installed Units	Max Flow (NM ³ /Hr)	Max Power (MW)
+2250 Installed units	Reciprocating	+2000 (+800 with H ₂ >95%)	190.000	20
	Centrifugal	+250	1.200.000	19.4

Centrifugal Compressors: HPRC Technology

HPRC: High Pressure Ratio Compression

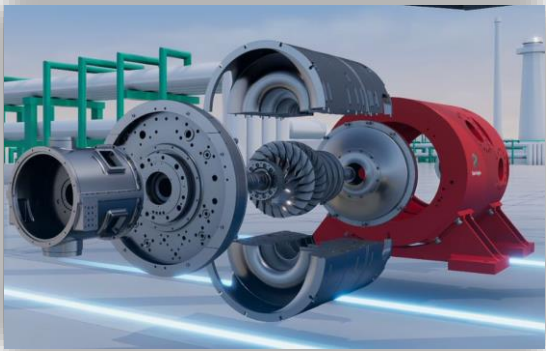
H₂ Effect on Pressure Ratio (PR):

10 times lower vs. pure CH₄*



How to improve compression capability?

- Dedicated Impeller Design
- Running at Higher Speed
- Stacked Rotor configuration
- Advanced Rotodynamic



Game Changer for Capex, Opex and Footprint

* Normalized on 100% CH₄ for same compressor size, impeller family & peripheral speed

Bringing state of the art H2 technologies to market: The role of strategic collaborations

H₂/NG pipeline—Istrana, Italy



Baker Hughes and Snam successfully completed testing of the **world's first hybrid hydrogen turbine** designed for a gas network.

Green H₂—NEOM, Saudi Arabia



Providing **advanced hydrogen compression** technology to Air Products

Blue H₂—Edmonton, Canada



Providing **100% hydrogen fueled NovaLT™16** gas turbine technology to Air Products

Partnering with world hydrogen industry leaders to lower production costs and accelerate adoption of hydrogen as a zero-carbon fuel

Investing for growth today and tomorrow

\$2.1B of strategic acquisitions and investments



Carbon capture, utilization, and storage



Modular Carbon Capture technology
Nov 2020



Exclusive license for mixed-salt capture
Mar 2021



Bio-methanation & synthetic natural gas technology investment
Jun 2021



Next-gen Direct Air Capture technology
Apr 2022



Polaris carbon storage project in Norway
Mar 2021



Industrial process equipment and technologies to eliminate GHG emissions
Feb 2022



CCS hub for Norwegian Industrial Cluster
Jun 2021



Project developer that utilizes CO₂ & H₂ to produce eFuels
March 2023

Hydrogen



Methane pyrolysis technology to produce turquoise H₂
Nov 2021



Hydrogen compression and turbines for multiple projects
Jun 2021



Clean power solutions



Clean integrated power and hydrogen solutions
May 2021



Early-stage hydrogen technologies
Dec 2021



Hydrogen infrastructure investment platform
Anchor Investor
Apr 2021



Technology development & global deployment of zero-emission power plants
Feb 2022

Digital



Reliability and industrial asset management solutions
Feb 2021

Oilfield services & equipment



Well intervention services & downhole technology
Mar 2022



Advanced artificial lift and electrical submersible pumps technology
Jul 2022

Gas & industrial



Inspection solutions for critical infrastructure
Mar 2022



Power Generation

Electrification equipment, generators, and motors
Aug 2022

Geothermal



Closed loop geothermal technology
Mar 2022

Baker Hughes 

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