

# 100% Hydrogen Ready Gas Turbines and Compressors

**Serena Gabriele**

Hydrogen Turbomachinery Platform Manager  
Climate Technology Solutions

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# Baker Hughes is an energy technology company

We are bringing our core technology capabilities to enable a path to net-zero for energy and industry.

## Our ambition

Reach net-zero carbon emissions by 2050

Lead in energy transition and digitalization and be a critical decarbonization partner

Deliver the highest efficiency, and productivity outcomes for broader energy and industry

## Who we are

54,000 employees

120+ countries worldwide

3,066 patents awarded

\$492M R&D development

\$20.5B revenue

204 Perfect HSE Days

## Our credentials

**Signatory**—Methane Guiding Principles, Aiming for Zero Initiative (OGCI)

**Members**— Hydrogen Council, Fuel Cell & Hydrogen Energy Association, International Association of Oil and Gas Producers (IOGP), International Petroleum Industry Environmental Conservation Association (IPIECA), American Petroleum Institute (API)

**Members, EU Initiatives**—European Clean Hydrogen Alliance, European Battery Alliance, Hydrogen Europe, H2IT

15%

reduction in scope 1 and scope 2 emissions versus 2019 baseline

22%

of our electricity comes from renewables and zero-carbon sources

26%

less water use

500+

global facility energy audits and weekend energy walk-throughs

# Sharpening our focus around two key business areas

## OILFIELD SERVICES & EQUIPMENT

- Oilfield Services
- Oilfield Equipment

## SHARED STRENGTHS

- Global customer base
- Global scale & reach
- Mission-critical technology
- Talent
- Culture

## INDUSTRIAL & ENERGY TECHNOLOGY

- Gas & Industrial Technology Solutions
- Industrial Asset Management
- Climate Technology Solutions

Transforming the core, investing for growth, and positioning for new frontiers

# Leading the energy transition

## Baker Hughes solutions

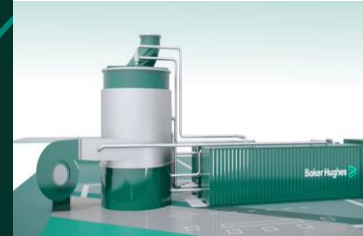
### Hydrogen Space



### Greener Operations



### Carbon Capture



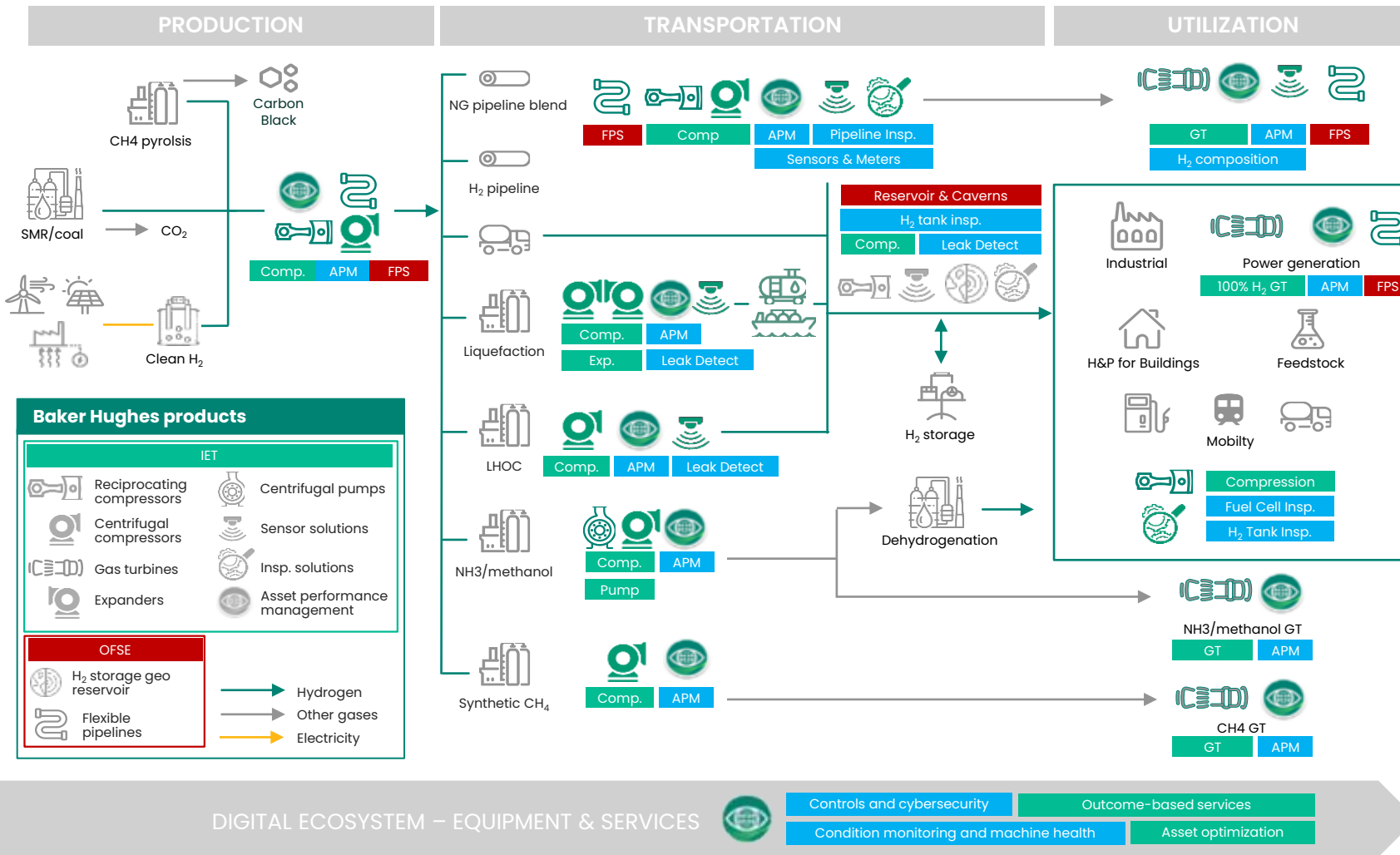
### Clean Power Solutions



**Baker Hughes is committed to achieve net-zero carbon eq. emissions by 2050, and invest in new technologies to help customers reduce their emissions.**

**We take energy forward – making it safer, cleaner and more efficient**

# Baker Hughes portfolio across the H2 value chain



~60 years of experience working with hydrogen

Critical applications across production, transportation, utilization and storage

Ability to work with intermittent energy sources to provide grid support

Digital portfolio of solutions across the whole H<sub>2</sub> value chain

# Hydrogen fueled Gas Turbines

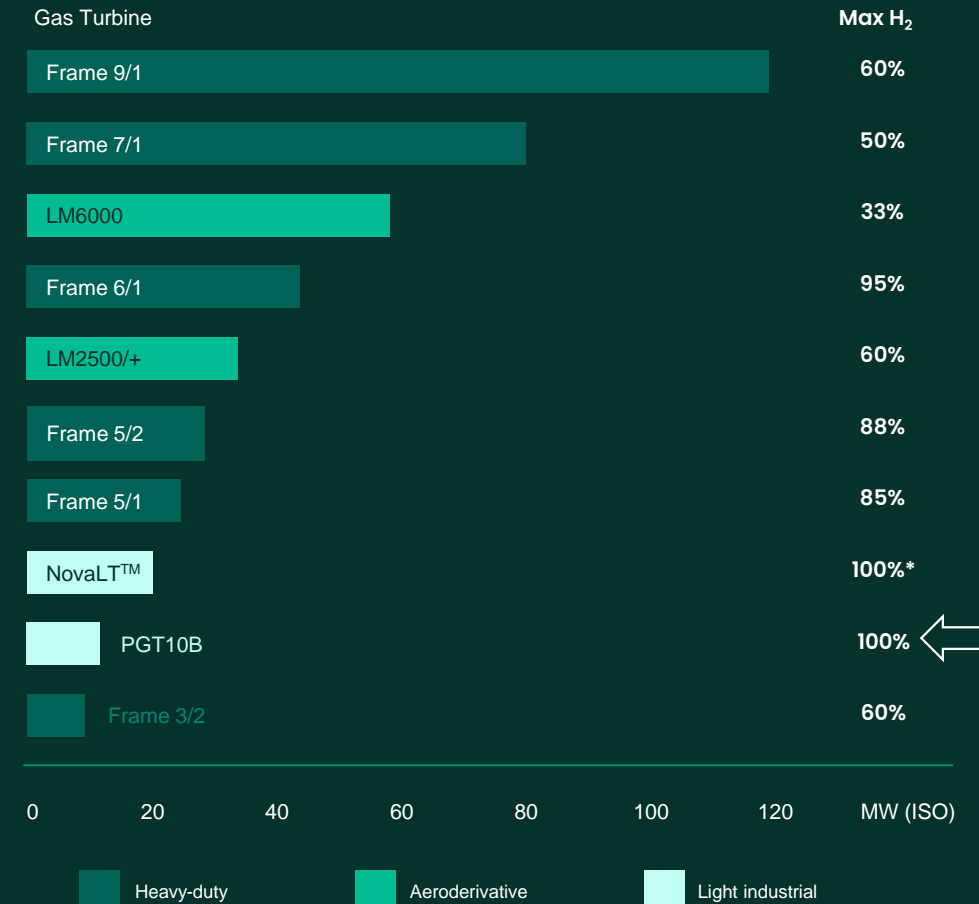
Proven and available today – **up to 100% hydrogen turbine**  
 Fuel gas blends with 10% to 100% hydrogen. Our turbines are ready for integration and adaptation into existing gas infrastructure, specifically designed to facilitate deployment.

## Main achievements

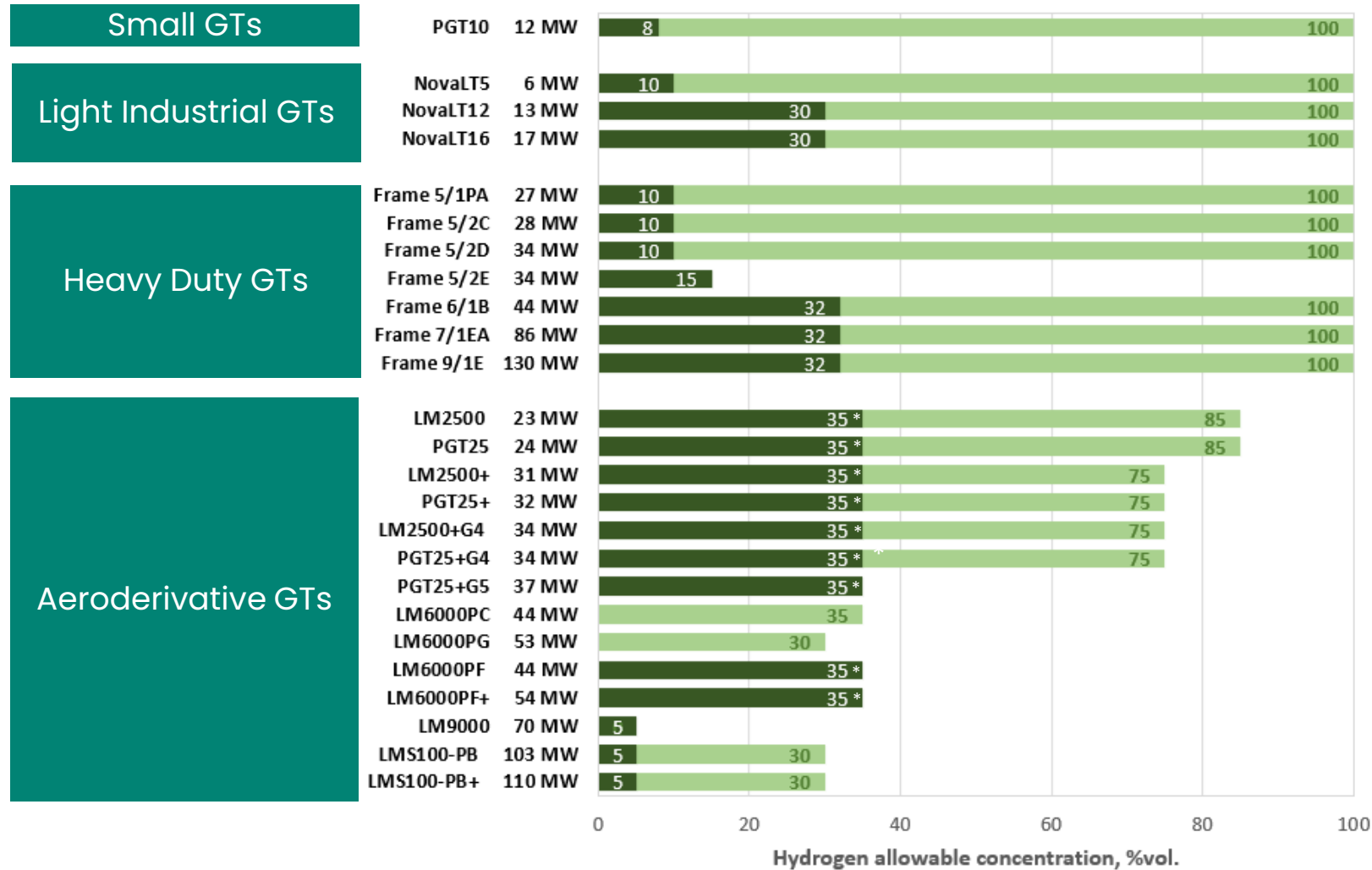
- **70+ units installed** highlighting experience with frame and aeroderivative designs burning H2 rich fuel
- **Complete turbine portfolio** for current and future H2 Market needs. Full scale PGT10 demonstrative plant (100% H2)
- **NovaLT™ turbine technology\***, the H2 Flagship, dedicated LT combustion test @100% H2, able to start and run @ 100% H2



## WIDE RANGE OF EXPERIENCE IN BURNING HYDROGEN



# Baker Hughes H<sub>2</sub> combustion technology capabilities



## Notes:

Shaft Power at ISO conditions

- DLN/DLE Combustion systems
- STD/SAC Combustion systems with diluents injection or SCR system for NO<sub>x</sub> abatement

(\*) up to 35%vol. for service evaluation.

DLE1.5 technology on LM6000PF+ demonstrated on field capability to burn about 10%vol. H<sub>2</sub>

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).

# NovaLT™ GT Family @100%H<sub>2</sub>

## NovaLT™5

POWERGEN SYMPLE CYCLE

5.7 MWe  
30.7% Elect. efficiency

7.0 MWe  
46% Elect. efficiency

15tph Steam output  
85% CHP Efficiency

*Available upon request  
(subject to market dynamics)*




## NovaLT™12

MECHANICAL DRIVE & POWERGEN SYMPLE CYCLE

13.0 MW    12.5 MWe  
36.8%    35.3%  
Efficiency    Elect. efficiency

16.0 MWe  
47% Elect. efficiency

23tph Steam output  
80% CHP Efficiency

 35 khr – 70 khr \*

No annual stop & Fast Engine swap

*\*Maintenance factor 1.5 with water injection for NO<sub>x</sub> abatement(expected)*

*Unabated NO<sub>x</sub>: available  
Water inj. NO<sub>x</sub> abatement: available  
DLN: available upon request*




## NovaLT™16

MECHANICAL DRIVE & POWERGEN SYMPLE CYCLE

17.5 MW    16.9 MWe  
37.5%    36.4%  
Efficiency    Elect. efficiency

22.0 MWe  
48% Elect. efficiency

31tph Steam output  
80% CHP Efficiency

 35 khr – 70 khr \*

No annual stop & Fast Engine swap

*\*Maintenance factor 1.5 with water injection for NO<sub>x</sub> abatement(expected)*

*Unabated NO<sub>x</sub>: available  
Water inj. NO<sub>x</sub> abatement: available  
DLN: available in 2025*



Start up with blends up to 100% H<sub>2</sub>. Switch from NG to gas blends up to 100% H<sub>2</sub>



# NovaLT16 H<sub>2</sub> test 2022

27 Jul '22

28 Aug '22

Test start

Test end

8 test days

45 fired hours

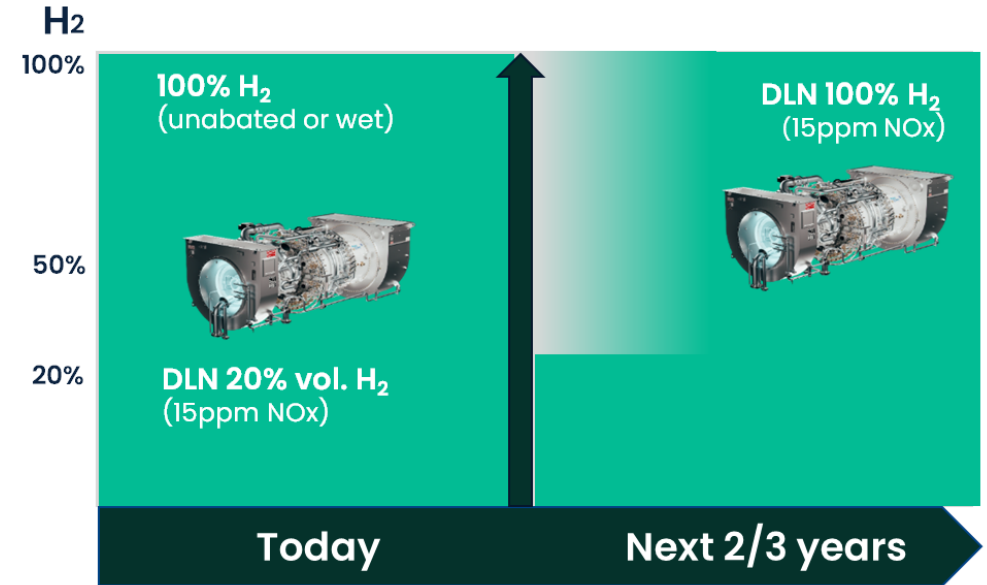
30 start/stop cycles



7.2 tons of burned H<sub>2</sub>

350+ instruments

5 combustor configurations



- Unabated NO<sub>x</sub> emission below 150 ppmvd @15%O<sub>2</sub> ... on the way to meet 100 ppmvd @15%O<sub>2</sub>
- Effective water injection ... down to 25 ppmvd @15%O<sub>2</sub>
- Robust behaviour against flashback / FH limits for 100% H<sub>2</sub> fuel
- No relevant pressure pulsations found during test
- Enhanced burners design ...negligible liners metal temperature differences burning CH<sub>4</sub> or H<sub>2</sub>
- Water injection (maintaining same fuel mass flow) produce a smooth metal temperature reduction
- Parts' life analysis in line with NG maintenance plan

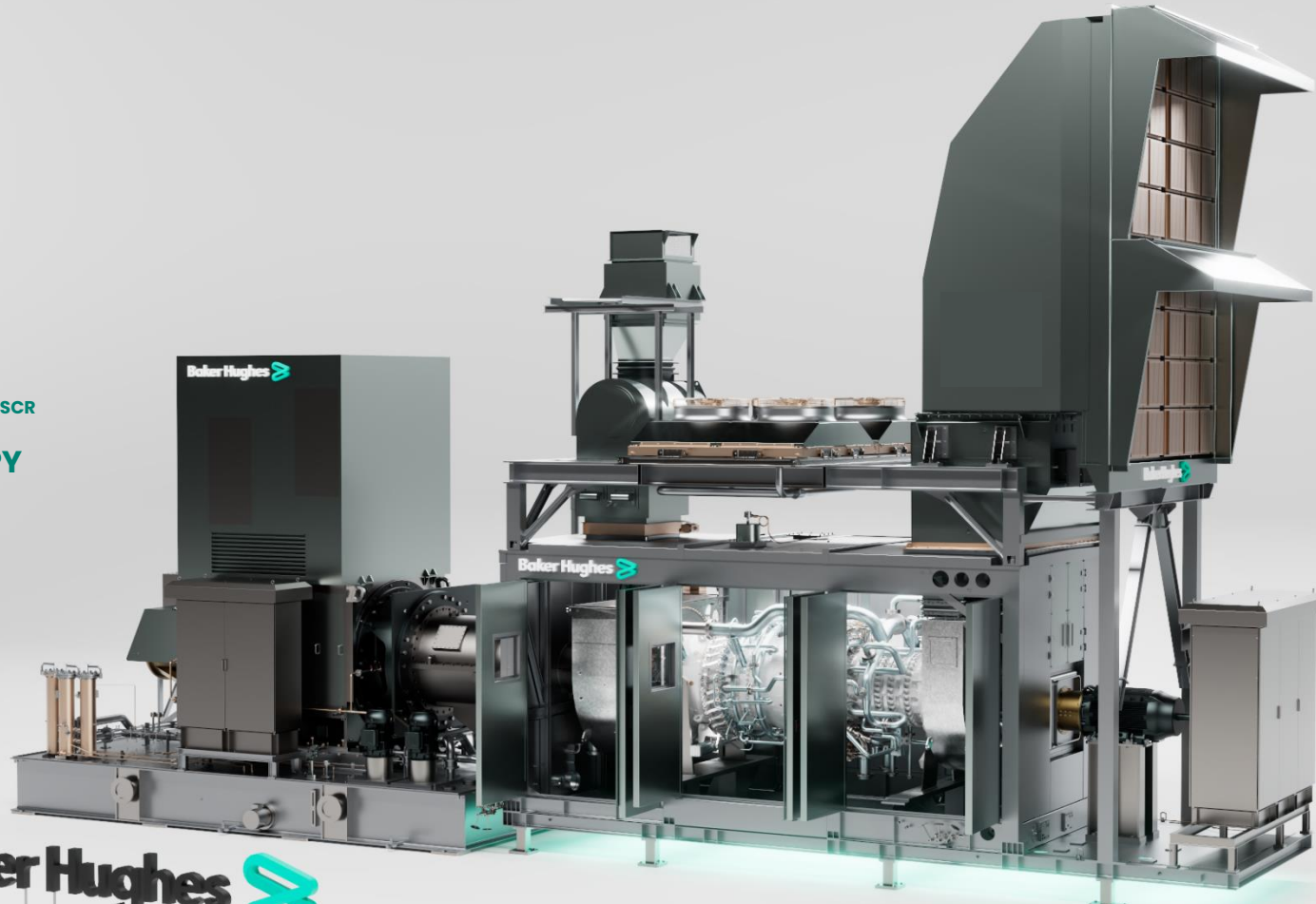
# Powergen package for 100%vol H2 blend

## Emissions

NOx 25 ppm NO SCR

CO2 -80,500 TPY

**Baker Hughes** 



**Ventilation**  
enhanced  
enclosure washing

**Turbine burners**  
avoiding flashbacks

**Gas dect. & Fire Fight**  
reducing response time

**Purge & Firing line**  
safer operation  
startup with 100% H2

**Blending skid**  
Included

# H<sub>2</sub> compression

## Expanding our compression leadership to hydrogen

We are established leaders in compression technology, and our High-Pressure Ratio Compressors (HPRC) provide significant improvements in overall green H<sub>2</sub> plant footprint, reliability, availability, and weight.

### Main achievements

- Long history of handling applications rich in H<sub>2</sub>
- First H<sub>2</sub> application in 1962, a hydrogen compressor
- 2,250+ compressors installed
- Largest compression portfolio tailored to the hydrogen value chain for production, transportation, and distribution.



Hydrogen services	Technology	Installed units	Max Flow (NM <sup>3</sup> /Hr)	Max Power (MW)
+2,250 installed units	Recips	+2,000 (+800 with H <sub>2</sub> >95%)	190.000	20
	Centrifugal	+250	1.200.000	19.4

# HPRC: High Pressure Ratio Compressor

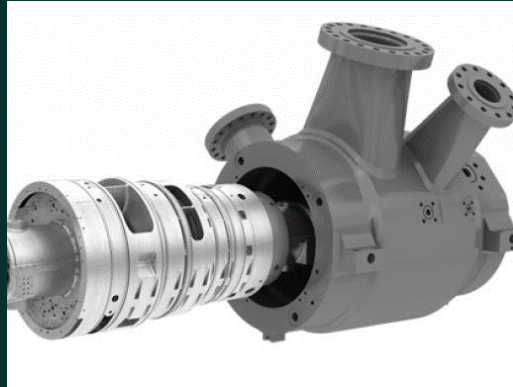
## Standard Compressor



- Casing size:  $\leq 1800$
- Casing PR w/ 100% (dry):  $\leq 1.1$
- Impeller tip speed: +
- Impeller flow coeff. range: ++



## HPRC Compressor



- Casing size:  $\leq 1000$
- Casing PR w/ 100% (dry):  $\leq 2$
- Impeller tip speed: ++
- Impeller flow coeff. range: +



## HPRC Compressor Next Step



- Casing size:  $\leq 1000$
- Casing PR w/ 100% (dry):  $\leq 3$
- Impeller tip speed: +++
- Impeller flow coeff. range: +

High Tip Speed Design – Increased rotating speed – Compact Compressor

# Case study – Pipeline Compression Station

## Case study

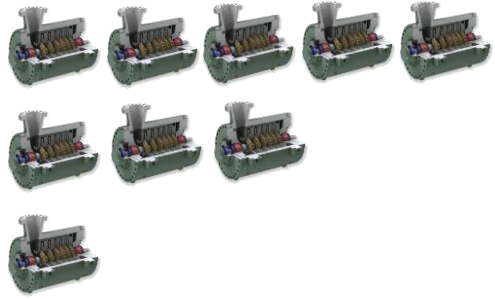
Flow constant: 2000 MMSCFD,

Inlet Pressure: 60 bar

Outlet Pressure: 110 bar

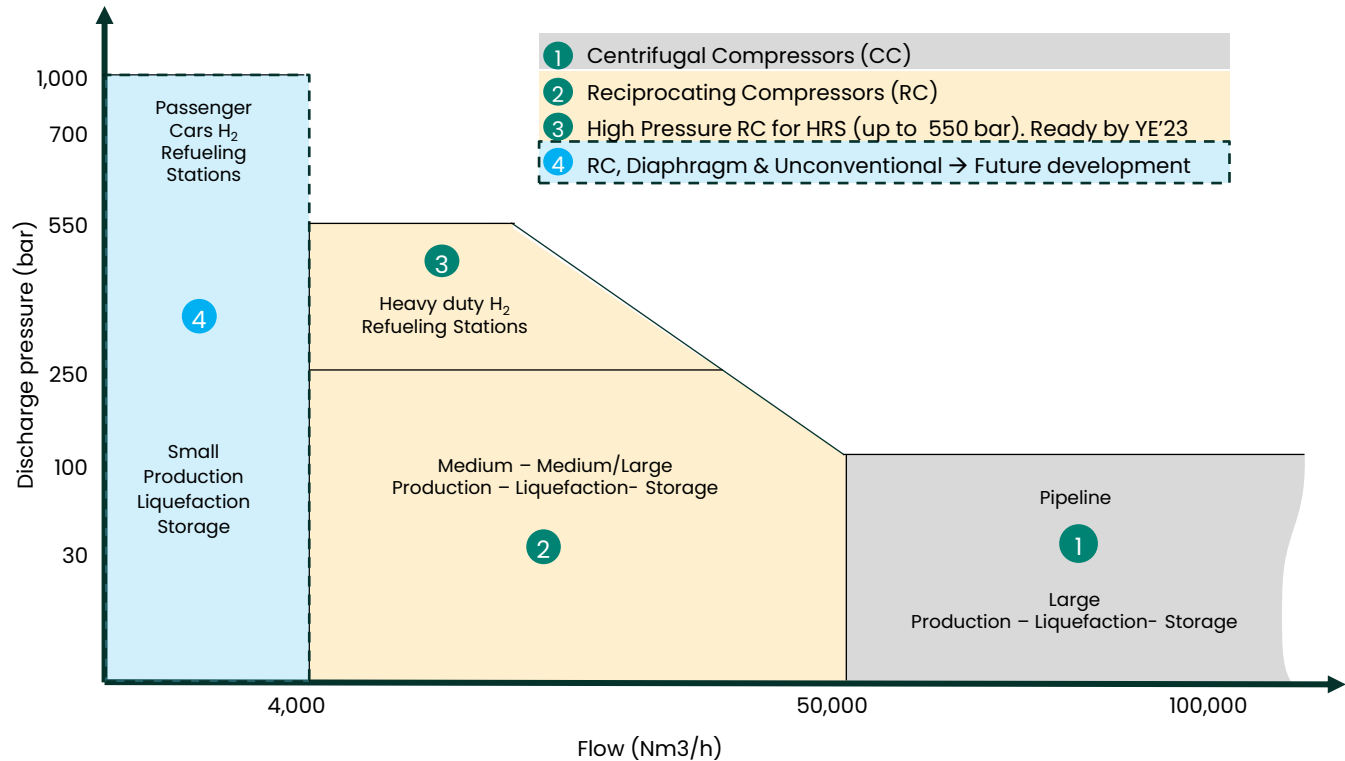
Hydrogen Blend [% vol]	0%	10%	20%	30%	40%	50%	100%
	<b>Number of impeller required</b>						
Standard PCL impellers U2 = 250 m/s	3	4	4	5	5	6	28
High head impellers U2 = 300 m/s	2	3	3	3	4	4	18
HPRC impellers U2=450 m/s	1	2	2	2	2	2	9

<b>100%</b>
28
18
9



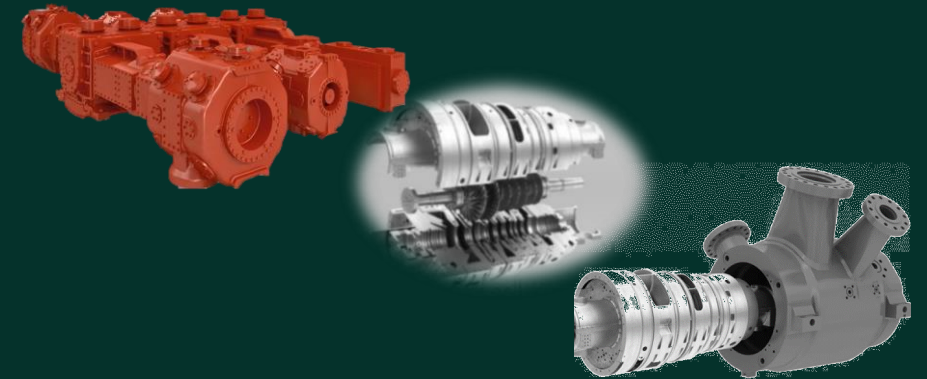
**HPRC solution is a great option when H2 content is predominant**

# H2 Compressors Roadmap



## Baker Hughes H<sub>2</sub> compressors Next Steps

- H<sub>2</sub> RC dry cylinder technology up to 350 bar → Q3 2023
- H<sub>2</sub> RC for heavy duty refueling station 550 bar → Q4 2023
- Centrifugal compressor HPRC enhancement (H<sub>2</sub> materials and impellers) → Q4 2024



Proven Technology Ready for a Wide Range of Hydrogen Applications

# Strategic hydrogen collaborations

## H<sub>2</sub>/NG Pipeline—Istrana, Italy



Baker Hughes and Snam successfully completed testing of the **world's first hydrogen turbine** for pipeline applications.

## Green H<sub>2</sub>—NEOM, Saudi Arabia



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

## Blue H<sub>2</sub>—Edmonton, Canada



Providing **100% hydrogen fueled NovaLT16** gas turbine technology to Air Products

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

# Follow our journey



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