Hydrogen Retrofit Solutions for Existing Gas Turbine Plants

Clean Energy Solutions for Future Generations

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March 21st 2024

Thomassen Energy
a Hanwha company

Gas Turbine Services – Thomassen Energy / PSM

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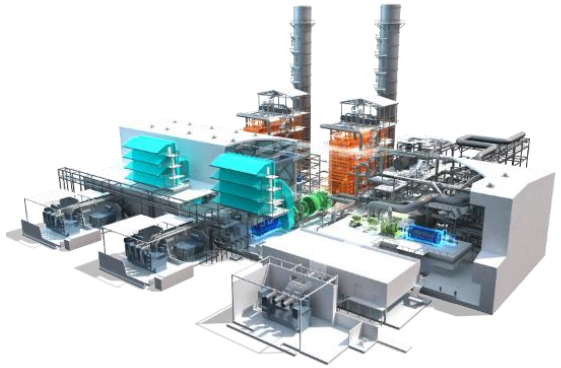
24k, 32k, 40k intervals



Field Service




7F: 170 - 190 MW

7E: 75 - 85 MW

Repair




501F/701F: 175 - 200 MW

Upgraded Components




6B: 35 - 45 MW
Fr5: 20 - 28 MW

Global M&D w/with Digital and Service Engineering




9F: 230 - 245 MW

9E: 120 - 130 MW

Service with Innovation

Our Vision & Mission

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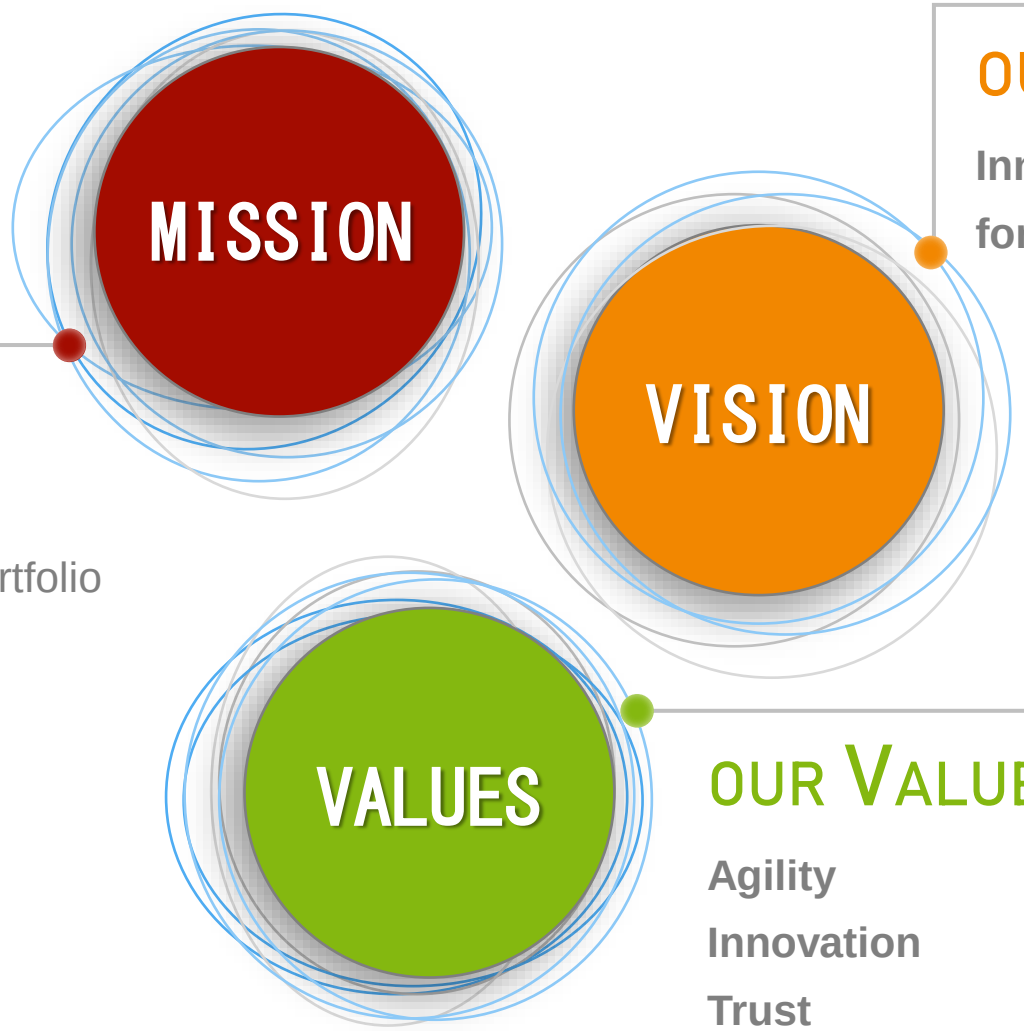

OUR MISSION

Serving customer needs with a **flexible, reliable & efficient** portfolio to improve asset life cycle costs

OUR VISION

Innovative clean energy solutions for future generations

OUR VALUES

Agility

Innovation

Trust

Our Team Culture is Based on **Safety**, **Quality,** and **Respect** for People

Agenda

Thomassen Energy
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01 Thomassen Portfolio

02 GT answering the gap of renewable

03 Thomassen Technology roadmap

04 FlameSheet™ a combustor answering the customer needs

05 Commercial project

06 H2 retrofit solution

Transition to Low Carbon Economy

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Hanwha

Path to Carbon Neutrality

Growth of Renewables + *De*-Carbonization of Conventional Generation

Renewable Power Plants	H2 Infrastructure	Gas Power Plants
Solar panel Supply	Production	Storage	Distribution	Gas Plant Assets	Retrofit/ H2 conversion	Gas Turbine Services
Solar Plant Assets	Green	Others				
ESS						
Retail Services						

Hanwha's current footprint

Current & Future business expansion

PSM Thomassen Gulf a Hanwha company

Portfolio - Upstream to Downstream

Electrolysis	Ammonia	Carrier & FSRU*	Storage	Equipment
Hanwha Chemical	Hanwha Corporation	DSME	Hanwha Cimarron	Hanwha Power Systems

***FSRU –** Floating Storage and Regasification Unit

"Renew, Revitalize, Repurpose and Reset" and *Decarbonize* the Installed Gas Turbine Fleet!

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Gas Turbines Filling The Renewable Gap

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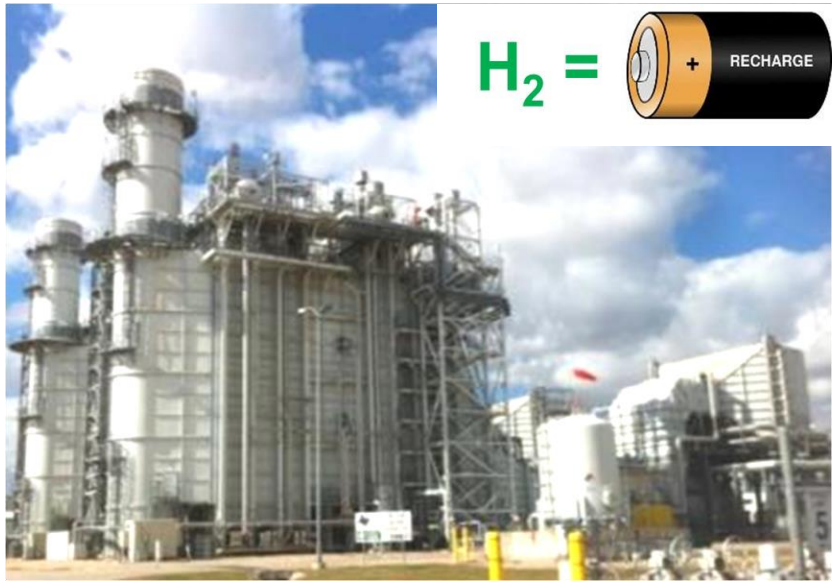
Gas Turbine Advantage :

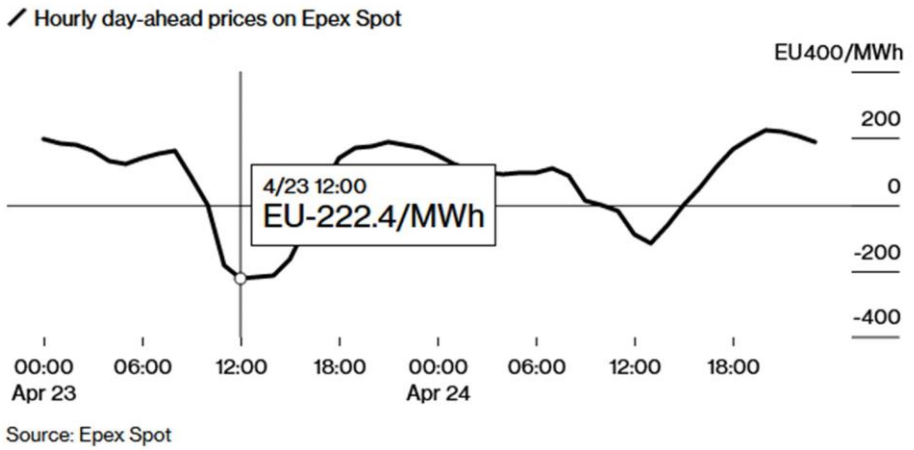
- Flexible fast load coverage
- Cleanest of the fossil fuels
- Ability to run on wide range of fuels, including green fuels such as **hydrogen**



- Excess renewable energy can be harvested, stored and released in gas turbines

- Existing gas turbine power plants available for combustion system retrofit with cost-effective, carbon-free upgrades

- Ability to follow the transition to renewable World at a pace which is flexible and dependent on market drivers



Gas Turbines can Meet the Flexibility Need … and Go Green

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Hydrogen Technology Summary Roadmap

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Technology Enablers Offer Path to Zero Carbon Gas Turbines Using H2

LEC-III™ Platform

6B/7E/9E class

Ultra-Low emissions

Dry lean premix combustion (no diluent)

H_2 blending confirmed in commercially operating units

FlameSheet™ Platform

Wide range of frames

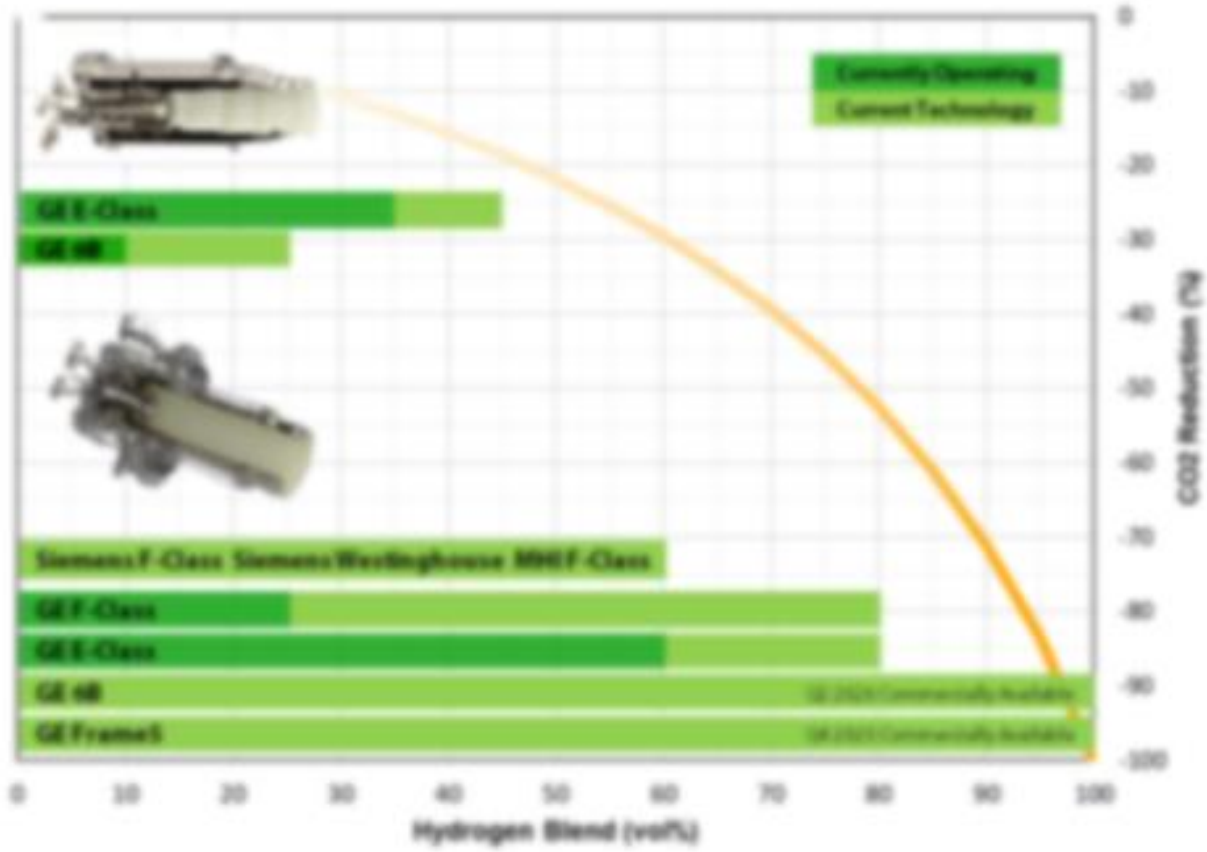
Ultra-Low emissions

Dry lean premix combustion (no diluent)

Fuel flexibility - ROG & Liquid fuel

H_2 blending confirmed in operating commercial units

Variable H2/NG blend over the operational range



As of Jan 2024

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Uniquely versatile and clean combustion system

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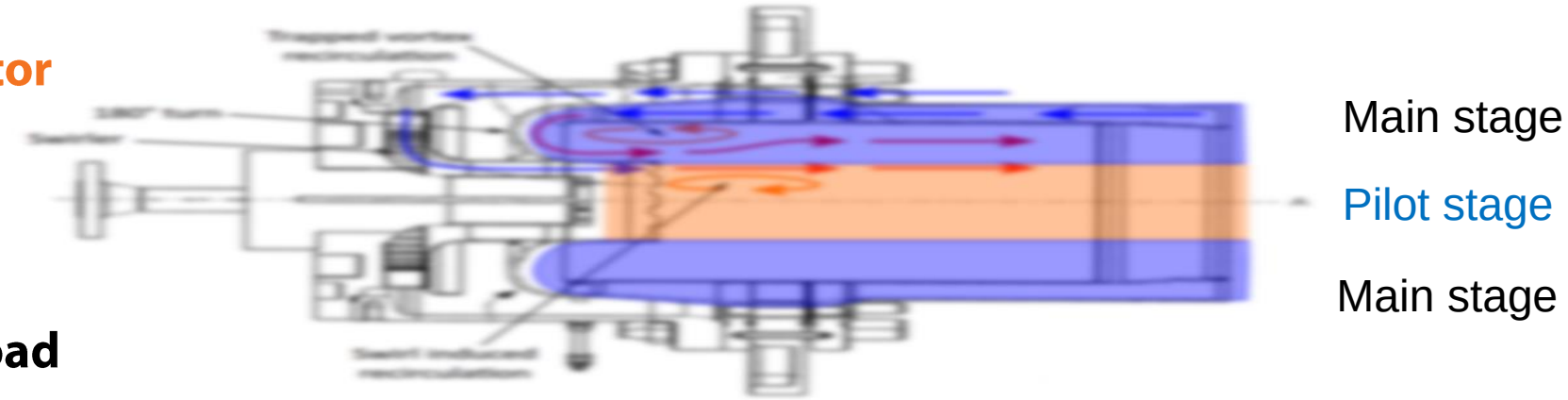
Fr 5,6,7,9, 5/701F Dry Low NOx FlameSheet™

Combustor in combustor

Advanced Flame staging with

- 2 aero stages
- 4 fuel stages

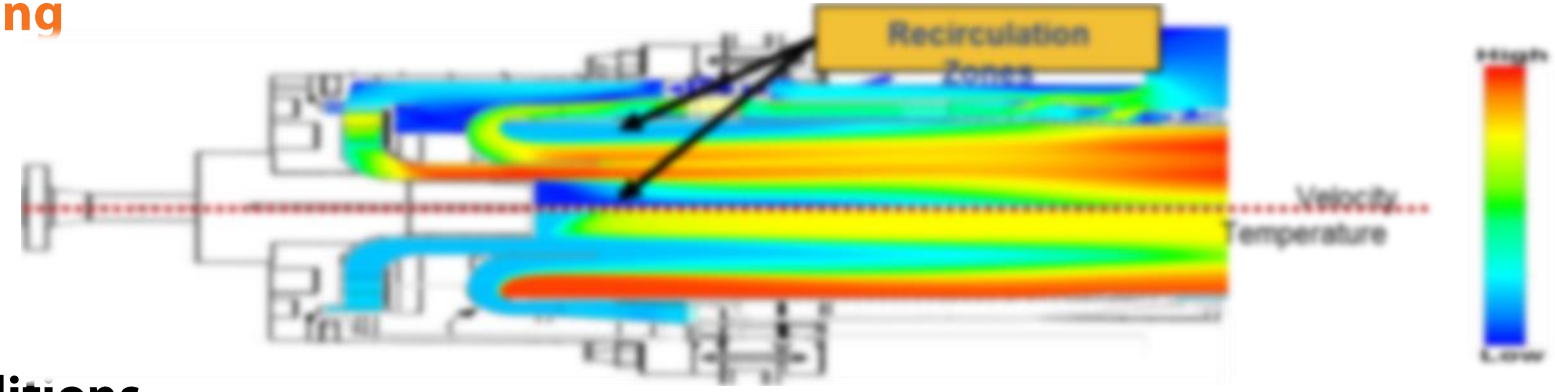
→Ultra flexible from start to baseload



Unique flame stabilization & mixing

Trapped vortex & sheet like flame

High velocity mixing for reactive fuels



Robustness and flexibility

Running a wide variety of fuels and conditions

32k hours / 1250 starts interval

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FlameSheet™ Commercial Machine Experience

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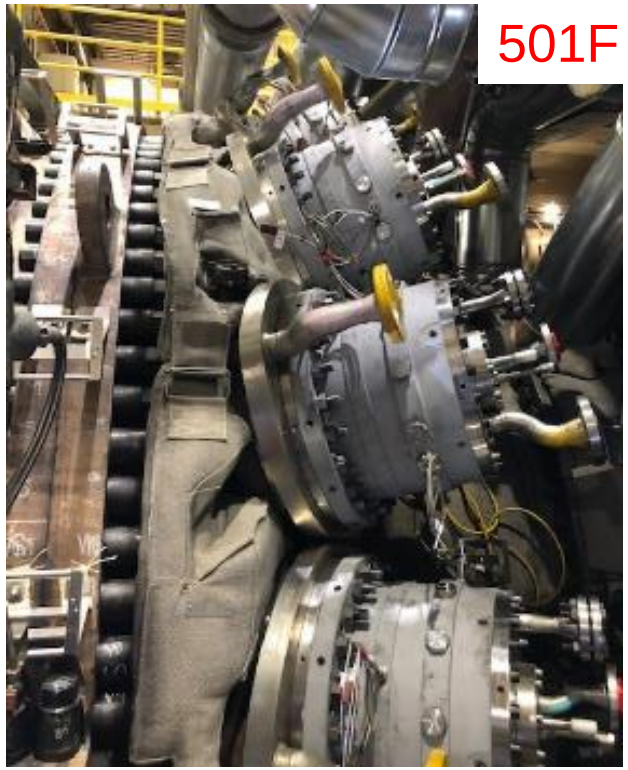
- **30** FlameSheet™ - enabled machines in operation with 8 years of experience
- Up to **20% additional load turndown** and **fuel flex** with **sub 9ppm NOx and CO**
- Hardware in excellent condition after 28,000 hours and 400 starts
- **60% by vol H2** demonstrated on base loaded 80MW Frame gas turbine

7F



501F

7F

501F

FlameSheet™ Retrofit Enhances Operational and Fuel Flexibility

* Higher Hydrocarbon compositions

Commercial adoptions of H2 retrofits

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2023

- ***Frame 7F*** FlameSheet™
- Combustion retrofit solution capable of up to **40% hydrogen** content Refinery Off Gas (ROG) fuel supply
- "JERA Zero CO2 Objective"
- Gas commissioning completed

jera

PHILLIPS 66

- ***Frame 9E*** LEC-III™ **2024**
- Combustion retrofit, new gas supply and lower NOx requirements, targeting blend up to **30% H2**
- Uniper (UK) decarbonization for gas assets
- Installation in **early 2024**

uniper

2024

- ***Frame 5*** FlameSheet™
- Located at Daesan Refinery Facility, lower NOx & CO requirements, initial **7% H2** blend
- Hanwha and Total – strong decarbonization plans for gas assets
- Installation in **Feb 2024**

Hanwha | TOTAL

- ***Frame 7F*** FlameSheet™ DOW **2018**
- FlameSheet™ combustion retrofit in 7FA unit with enhanced turndown **operating since 2018 on 5% H2 ROG** (supply limit)

- ***Frame 9E*** LEC-III™ (DOW) **2018**
- Located at Terneuzen, NL, 3 x Frame 9E
- Combustion retrofit for lower NOx emissions, **operating since 2018 on 25% H2 ROG (validated up to 35%)**

DOW

- ***Frame 7E*** FlameSheet™ **2023**
- Relocate KOWEPO unit, build plant and install in Daesan – Initially **60% H2** completed
- Korea Country Strategy – create a H2 ecosystem by 2040
- **ROG** supplied by Hanwha-Total petrochemical JV plant
- Demonstrated **Apr 2023**

Hanwha

FlameSheet™ H_2 Projects Major Achievements

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Frame 7F Tri-Fuel FlameTop (FlameSheet™ + GTOP)

Commercial Retrofit Project – NJ, USA

- ✓ Mechanical & Electrical Completion
- ✓ Natural Gas: FlameSheet™ with GTOP
- ✓ Natural Gas/ ROG Commissioning in emissions compliance
  - ✓ Up to **12%** H_2 at base load and **25%** at part load (source limited)
  - ✓ Up to **90% ROG** at minimum load
  - ✓ Turndown to ~30% (at 90% ROG)

Frame 7E High Hydrogen FlameSheet™

Power Plant Validation Project – Daesan, South Korea

- ✓ Relocated used 7E unit within Korea
- ✓ Plant construction in under 6 months
- ✓ FlameSheet™ installation
- ✓ Unique 100% H_2 capable fuel skid designs
- ✓ **60% H_2** with single-digit NO_x / CO emissions
- ✓ **100% H_2** demonstrated at FSNL

Frame 5-PA FlameSheet™

Commercial Retrofit Project – Daesan, South Korea

- ✓ First Frame5 FlameSheet™ installation
- Timeline:
  - ✓ Installation completion
  - Hot commissioning Feb 2024
  - Upgrades for higher H_2 in consideration for 2025
- ✓ Scope includes installation of FlameSheet™, mixing, control skids, gas manifolds, and control system adjustment
- ✓ H_2 supplied by waste process gas (7%)

As of Jan 2024

FlameSheet™ Platform

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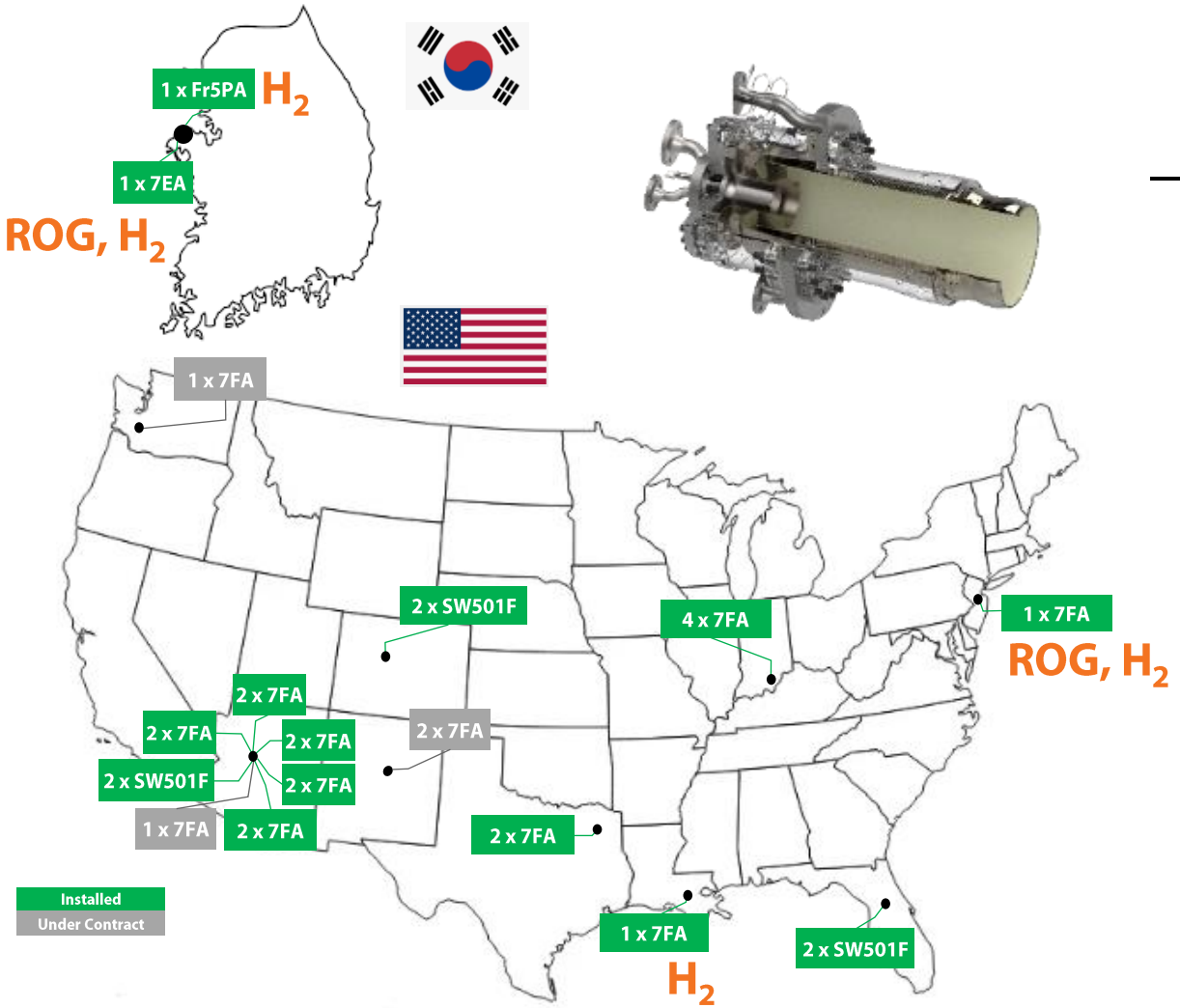

FlameSheet™ Key Metric Highlights

Entire Fleet Operational Hours
Since 2015
>250,000

Fleet Lead Operational Stat.
Hours: **>60,000**
Starts: **>330**

Number of Units
Installed or Under Contract by 2026
30

GE 7FA Units
Installed or Under Contract by 2026
22

Siemens 501F Units
Installed or Under Contract by 2026
6

1st E-Class Commissioning
Korea
2023

1st Frame5 Commissioning
Korea
2024

Number of FlameSheet with H_2
Hydrogen-blend or ROG
4

As of Jan 2024

FlameSheet™ H2 Validation Power Plant

Result & Next steps

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COMMERCIAL OPERATION

Scope: 7E FlameSheet™ H2 Demonstration

- Collaboration across Hanwha business entities
- 50% *minimum* H2 with single digit NOx emissions (contract, guaranteed)

Key Milestones

✓ Completed initial commissioning and testing

✓ ***60% H2 by volume, 6ppm NOx, Baseload***

✓ ***E-Class Conditions (No Derating)***

✓ ***No Diluents (Steam, Water)***

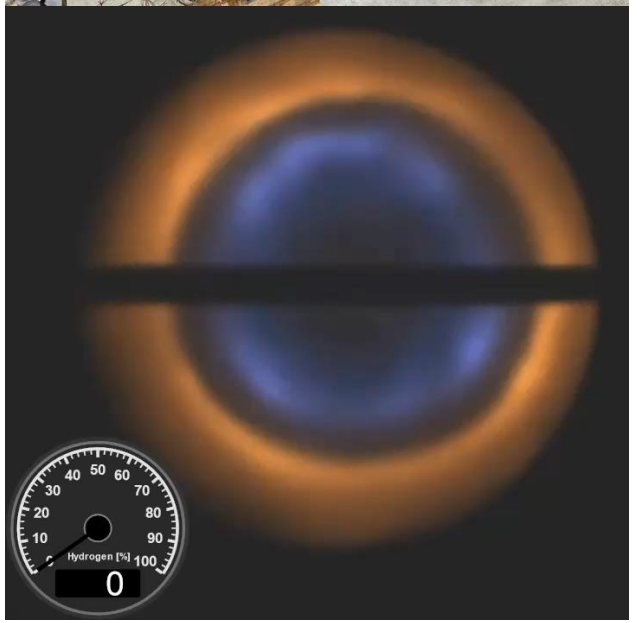
TEST RESULT

Scope: Fr5 FlameSheet™

World 1st rig demonstration of Frame 5 dry low NOx with 0-100% H2 capability, Jan' 2023

Key Milestones

FlameSheet™ Frame 5/6 dry low NOx combustor development for up to 100% hydrogen



Continued FlameSheet™ H2 Development at Facility – Path to 100% H2 Validation

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Turning your Gas Turbine into a Clean Energy Provider

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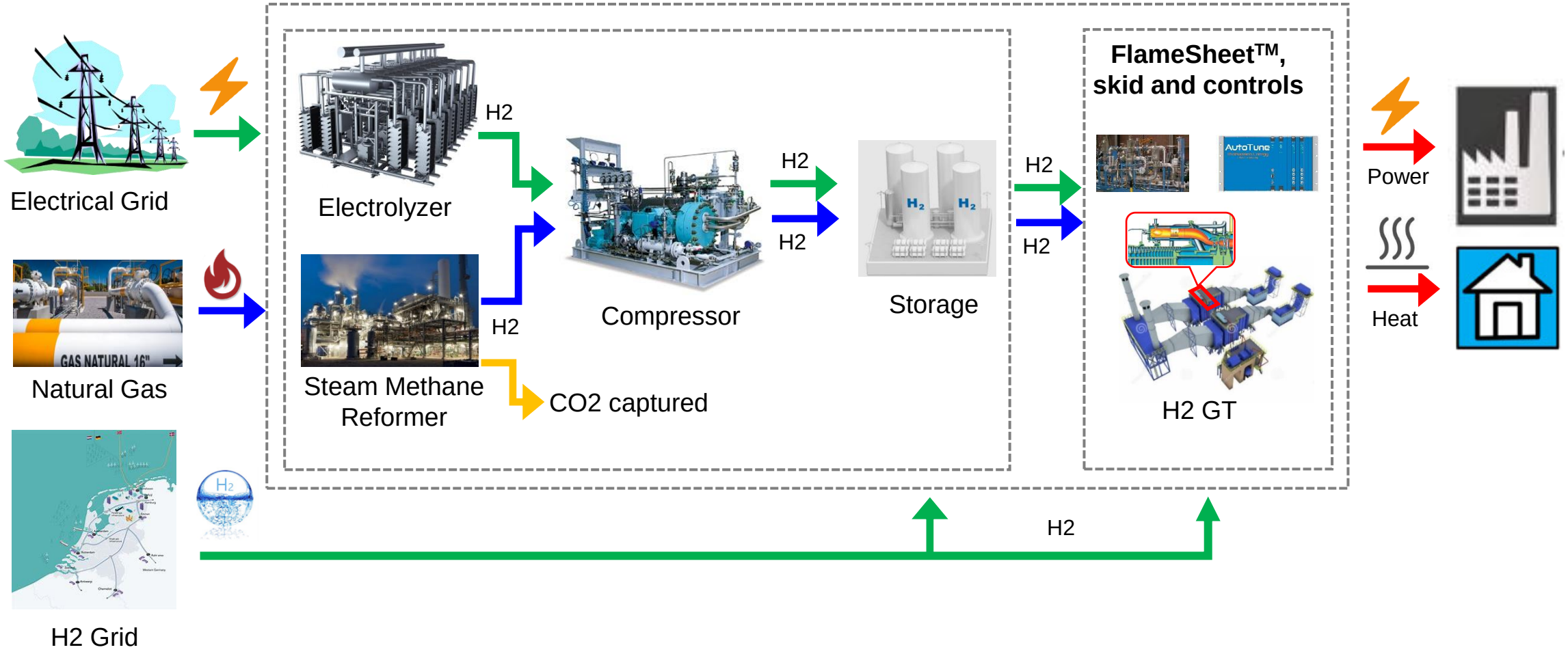
Hydrogen turbine, a reliable utility-scale power source, will play a crucial role in decarbonization and grid balancing by utilizing hydrogen for gas turbine fuel



Low Carbon Flexible hydrogen package solutions TODAY

Turning your Gas Turbine into a Decarbonization of Industrial Facilities

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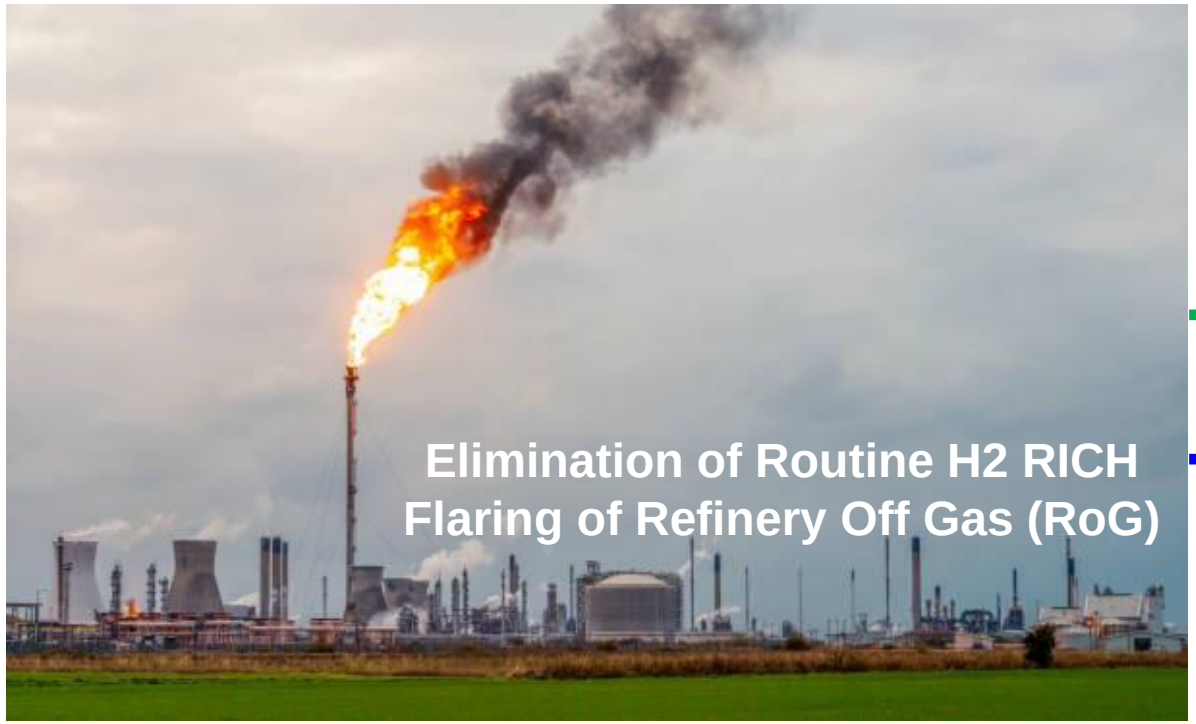
Hydrogen combustion technology can also be effectively applied for refinery and chemical process waste gas

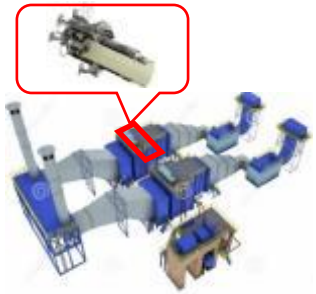
Natural Gas



RoG
H2

NG

FlameSheet™, skid and controls



H2GT

Power

Steam

Substantial decrease in carbon emissions and operating costs when utilizing flared waste gas

TAKE AWAY : Retrofit solutions for decarbonized power generation portfolio

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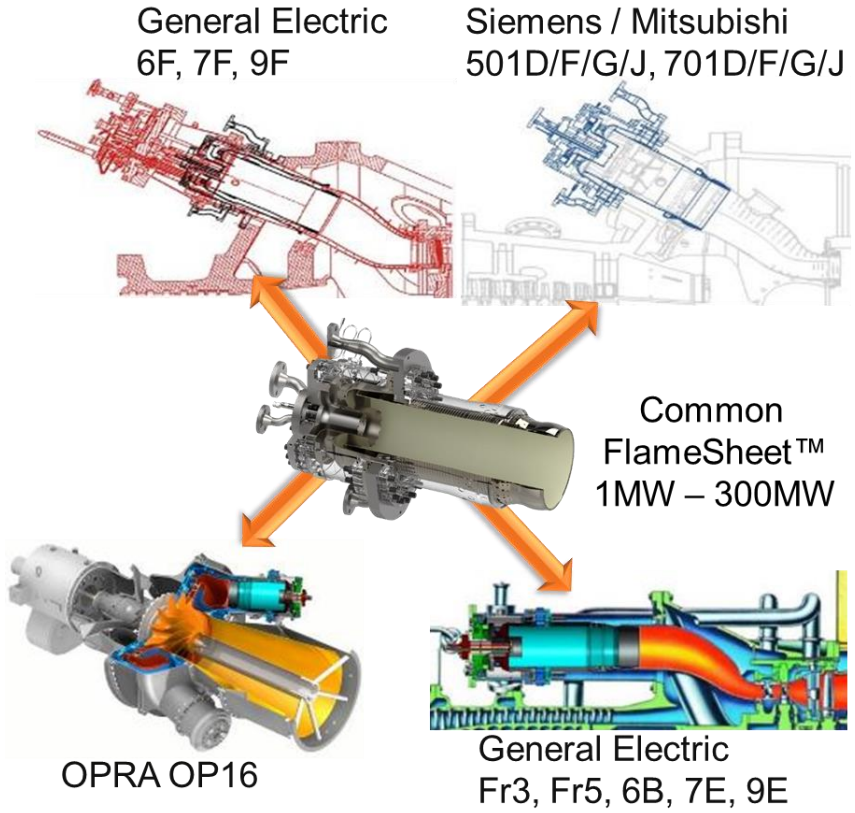
- Demonstrations are leading the way with technology validation for a zero-carbon footprint
- Many hardware/software elements to a successful demonstration:
  - Gas Turbine retrofit
  - Control System
  - Fuel control gas skids
  - Fuel mixing gas skids
  - Fuel delivery to site
  - Safety and systems integration
- Demonstrations already turning into commercial applications



- The FlameSheet™ Retrofit Gas Turbine provides a cost effective, surgical, carbon reducing retrofit without need for a new power plant or new gas turbine

Rapid Growth in High Hydrogen Combustion Retrofits for Carbon Free Power Solutions

Thank You!