



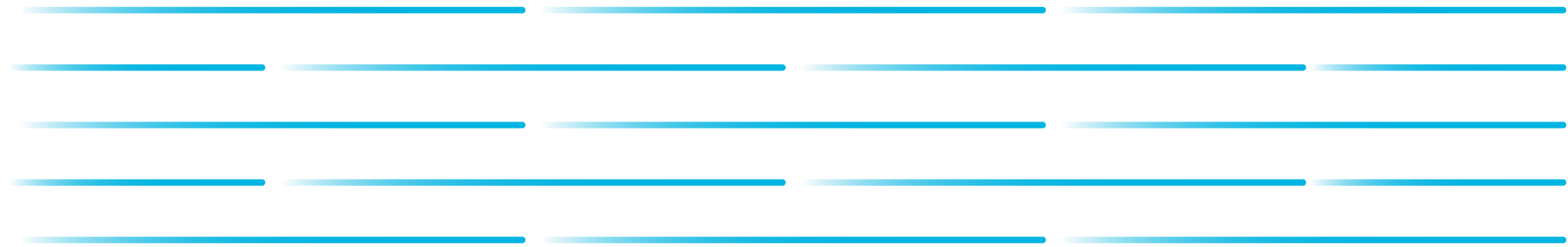
# Gas Turbines: Hydrogen Capability and Experience

*A presentation to the DOE Hydrogen and Fuel Cell Technology Advisory Committee*

**Dr. Jeffrey Goldmeer**

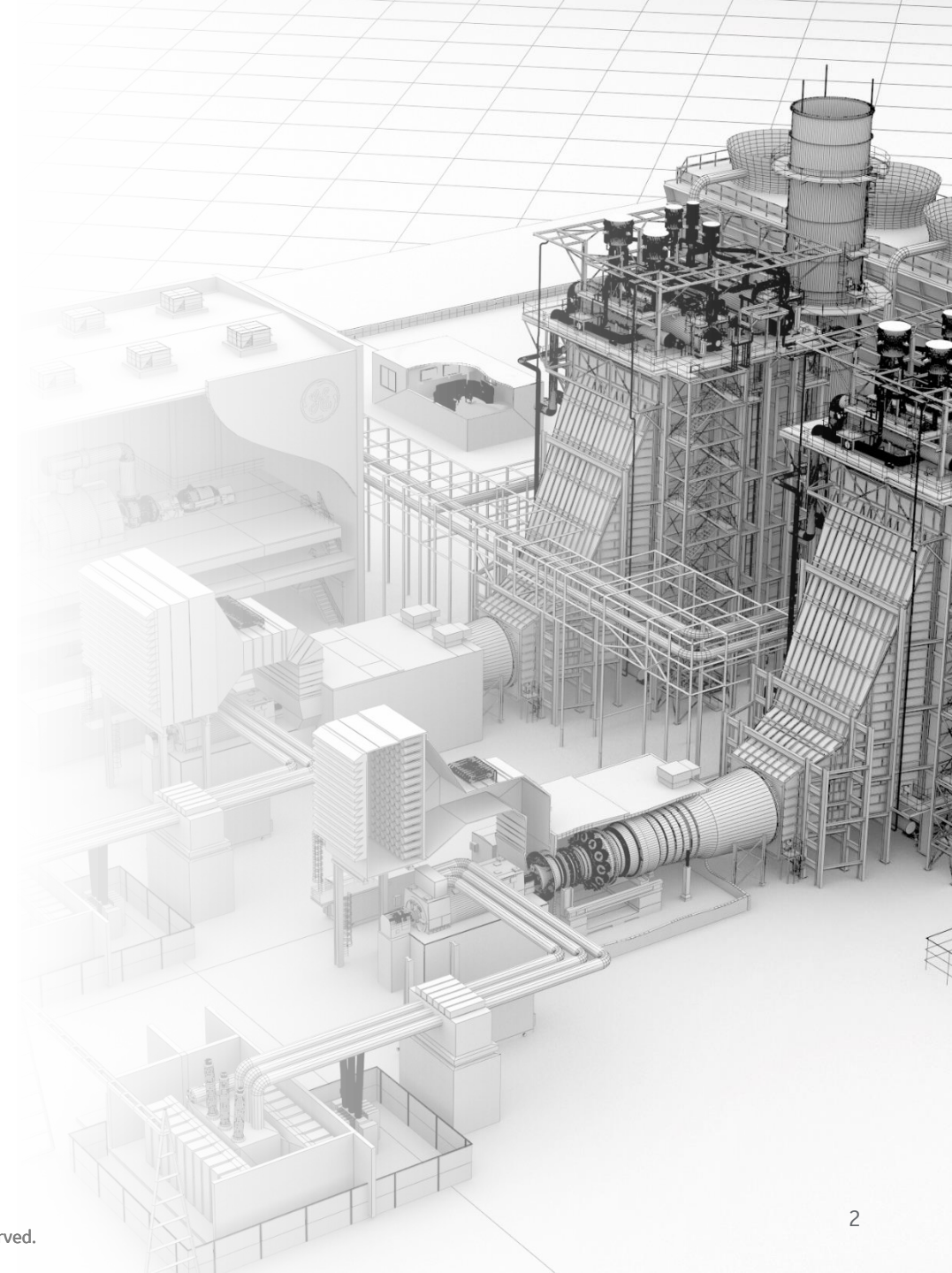
Emergent Technology Director, GE Gas Power

9 March 2020



# Overview

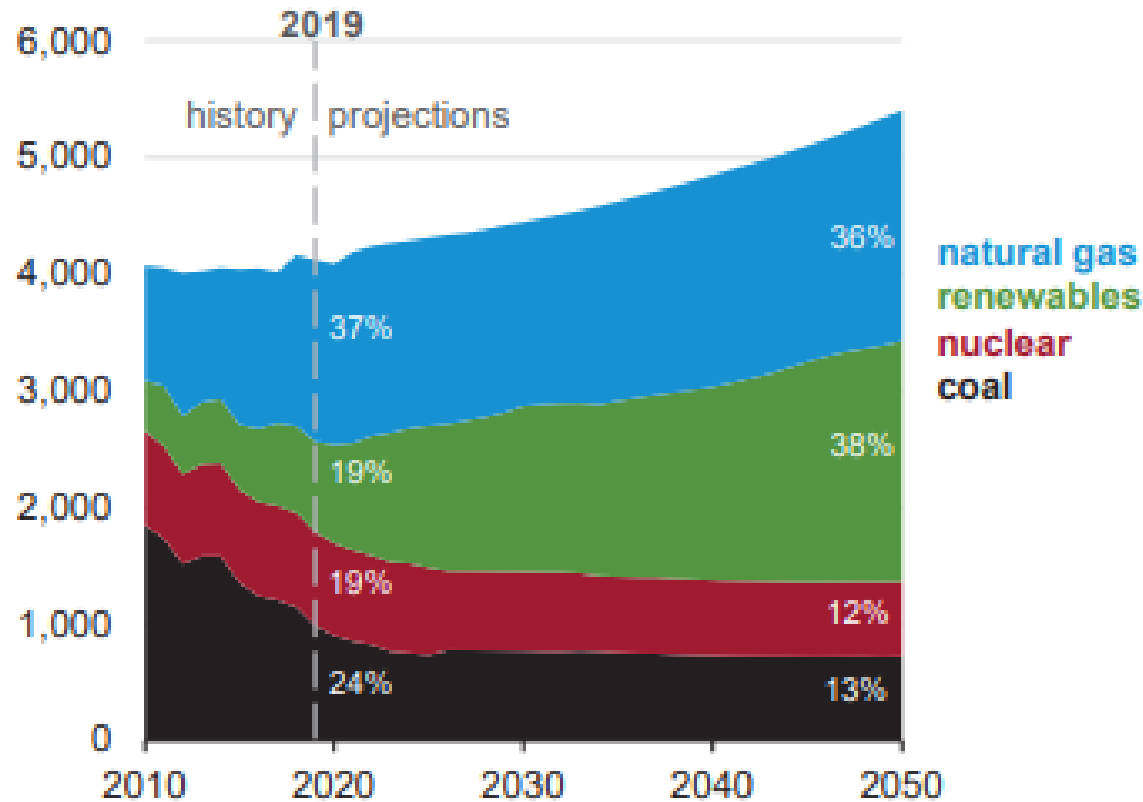
- Gas turbines are capable of operating on a wide variety of fuels, including hydrogen and other low heating value fuels
- Hydrogen and other low heating value fuels have been used to power gas turbines for decades
- Gas turbine based power plants can be configured to operate on these fuels as a new unit, or upgraded at a later date



# The role of gas turbines

## Electricity generation from selected fuels (AEO2020 Reference case)

billion kilowatthours



Source: EIA AEO 2020

- Today, natural gas provides 37% of electricity generated in the US
- The EIA's forecast shows this percentage staying effectively the same for the next three decades
- Therefore as we look at a transition to decarbonized energy ecosystem, we need to include the current gas turbine fleet



# KEY THEMES

1

**Gas turbine intro  
& combustion  
technology**

2

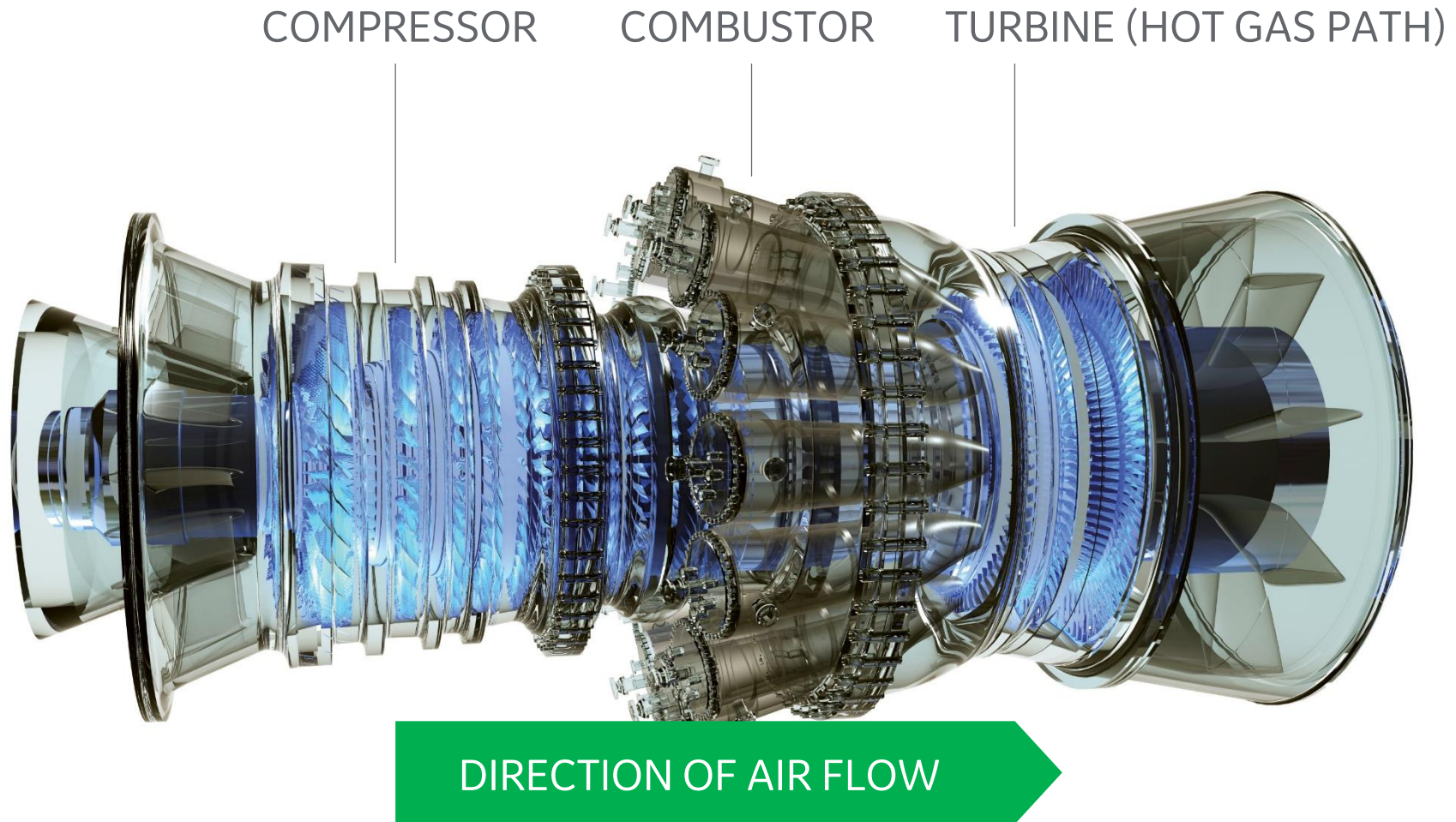
**Gas turbine  
experience &  
capabilities**

3

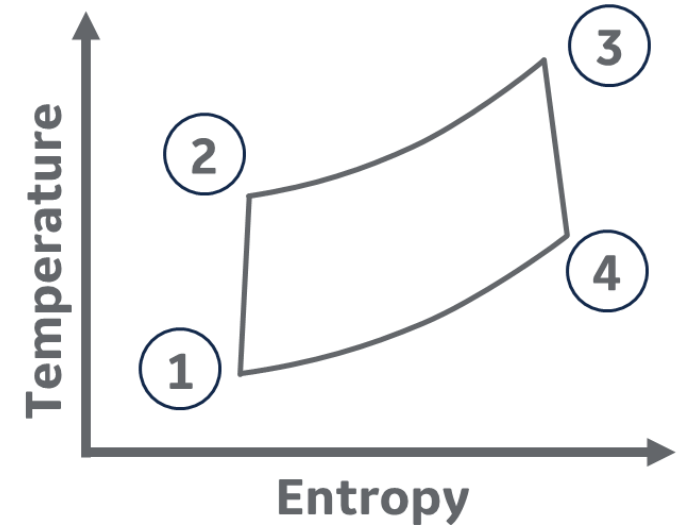
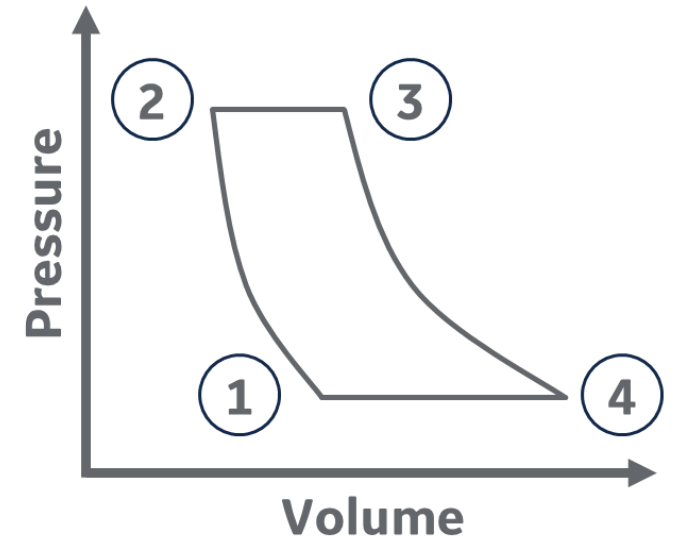
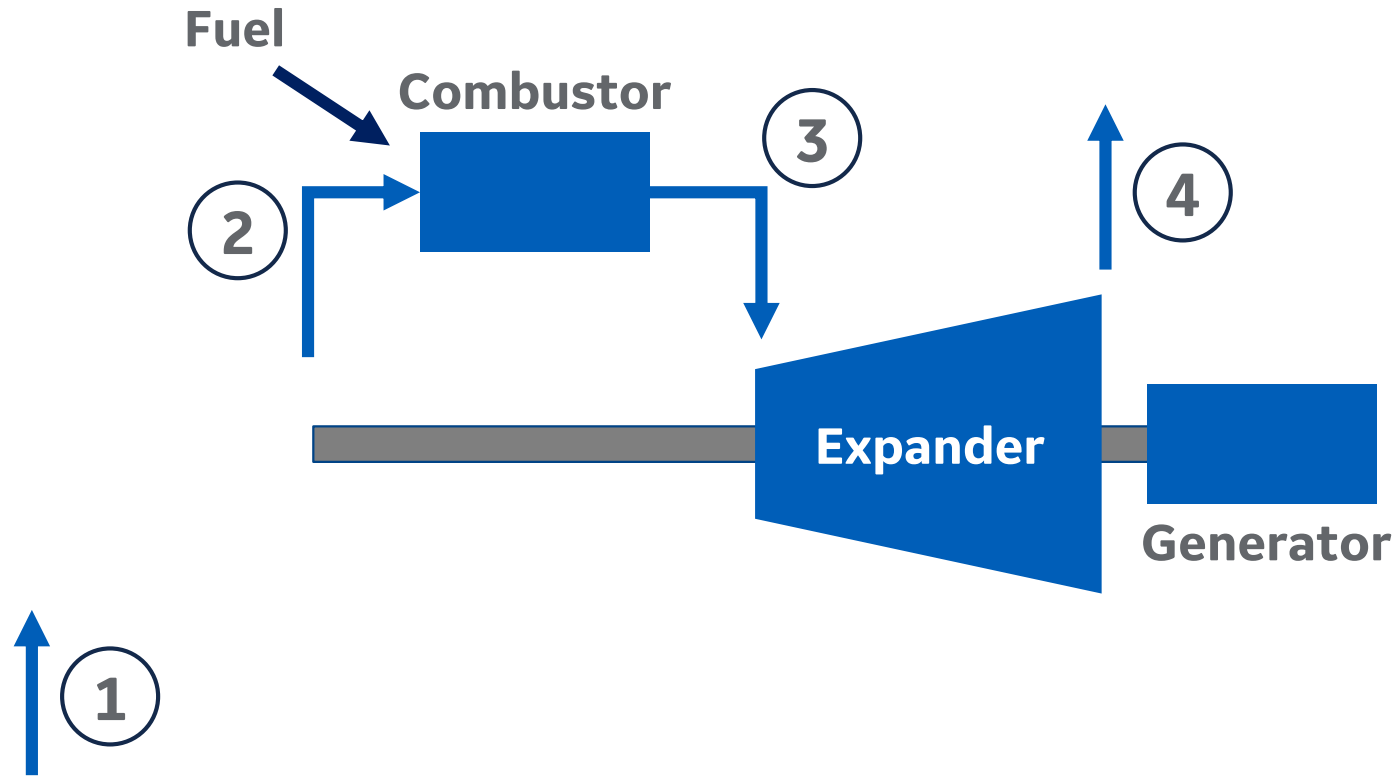
**Implications of  
hydrogen for  
power gen**



# Gas turbine introduction – major systems



# Gas turbine thermodynamics – Brayton Cycle



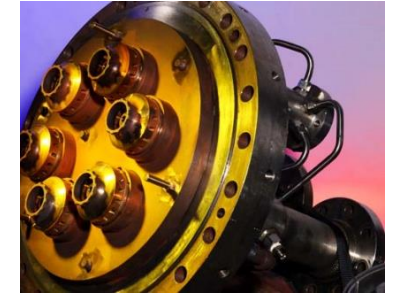
# Combustion science: premixed versus diffusion flames

## Diffusion flame



### Characteristics

- At or near stoichiometric proportion
- Increased flame stability
- High peak flame temperature
- NOx: 200–600 ppm



GE Multi-nozzle quiet combustor

## Premixed flame

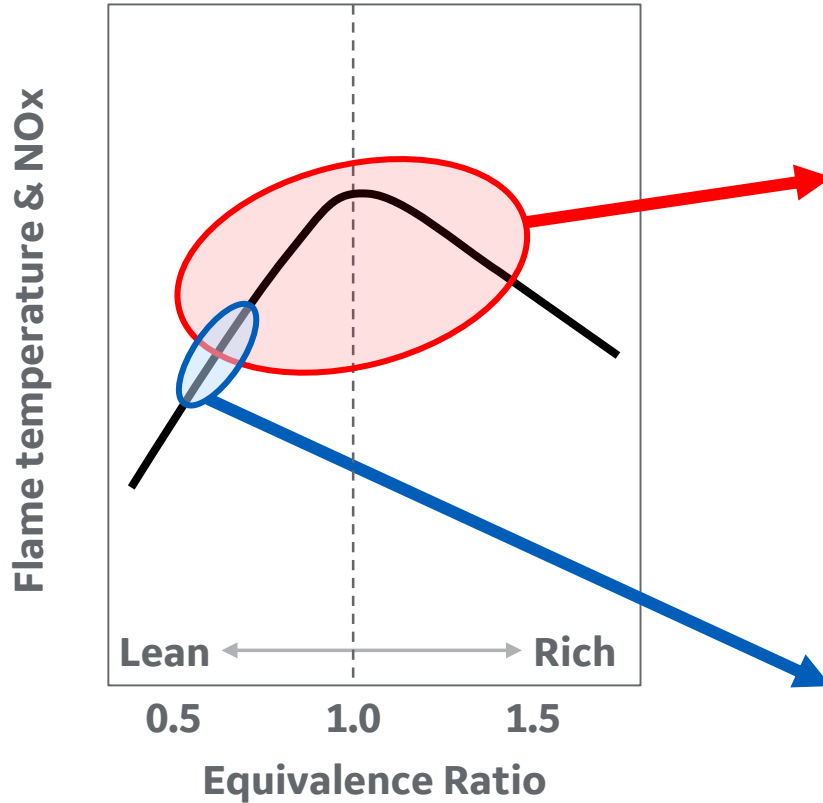


### Characteristics

- Air rich (fuel lean) conditions
- Low NOx without diluent
- More susceptible to combustion dynamics
- NOx: single digit ppm



GE DLN2.6+



Example of stoichiometric reaction



# Advanced premixer technology development

2005



## Swizzle based architectures

Target premixing and flashback tolerance for NG

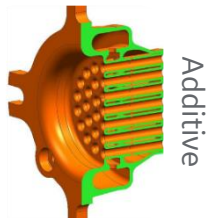
## Hydrogen limits

- DLN 2.6 ~5% (vol)
- DLN 2.6+ ~15-18% (vol)

## DOE High-H<sub>2</sub> program\*

Target premixing and flashback tolerance for H<sub>2</sub>

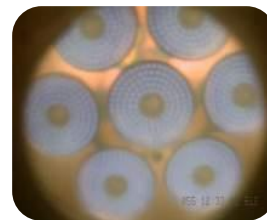
### Small prototype



### Prototype fuel nozzle



### Full head end combustion test



Demonstrated single digit NO<sub>x</sub> emissions at F-class temperatures and pressures

2016



**Demo**  
7HA.01 TS7

2018



**DLN 2.6e**  
**1<sup>st</sup> commercial shipment in 2018**

- This technology can be applied to natural gas or H<sub>2</sub> fuels... decouples flashback, premixing and dynamics
- Demonstrated capability to **50%** (by vol) H<sub>2</sub>

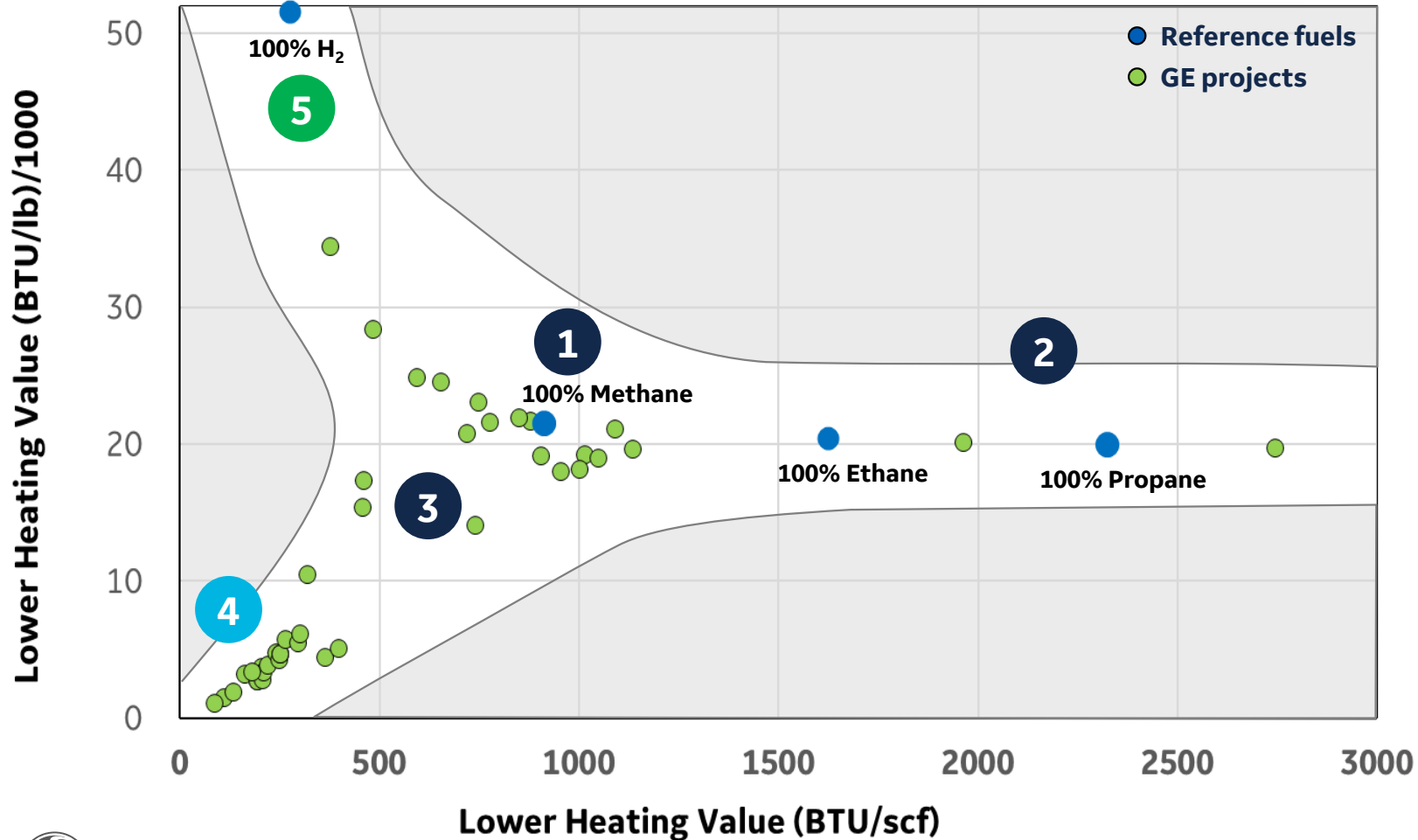




# GE gas turbine experience and capabilities



# Gas turbine fuel flex capabilities: GASEOUS FUELS MAP



- 1** Natural gas, LNG, and shale gas

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- 2** Non-methane hydrocarbons: ethane, propane, LPG, etc.

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- 3** Lean methane fuels

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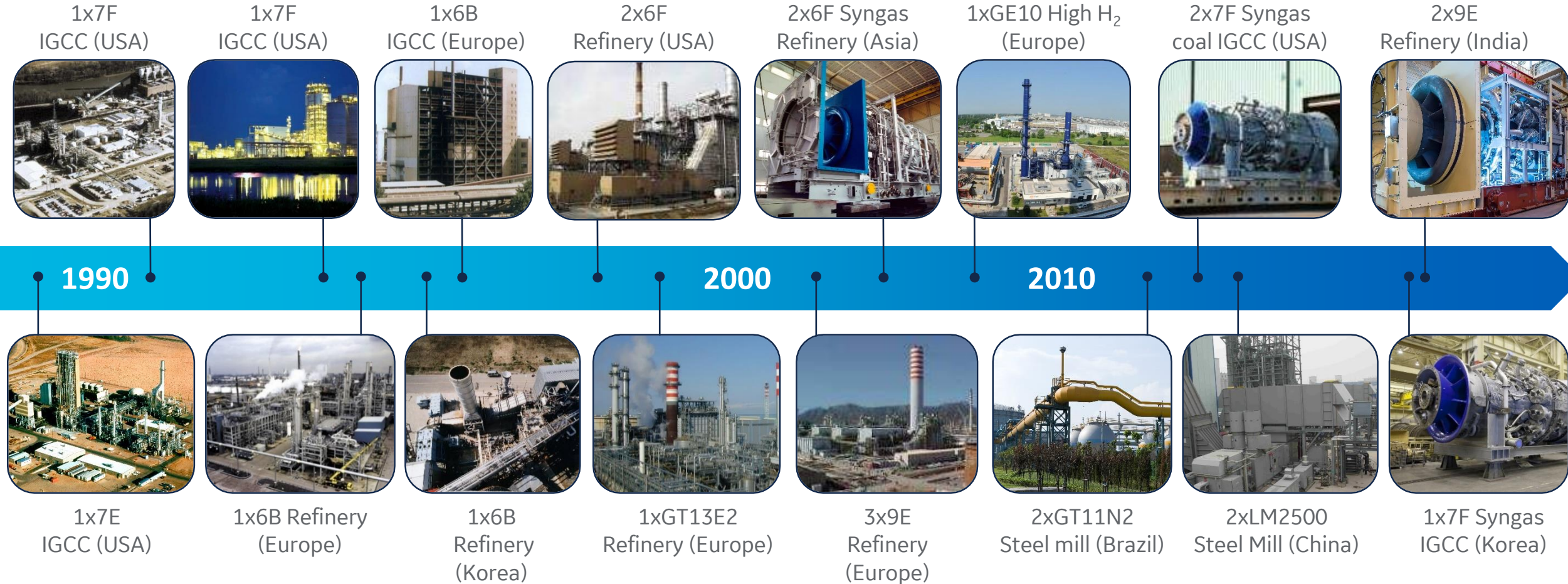
- 4** Low heating value fuels: syngas, steel mill gases

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- 5** High hydrogen (H<sub>2</sub>) fuels



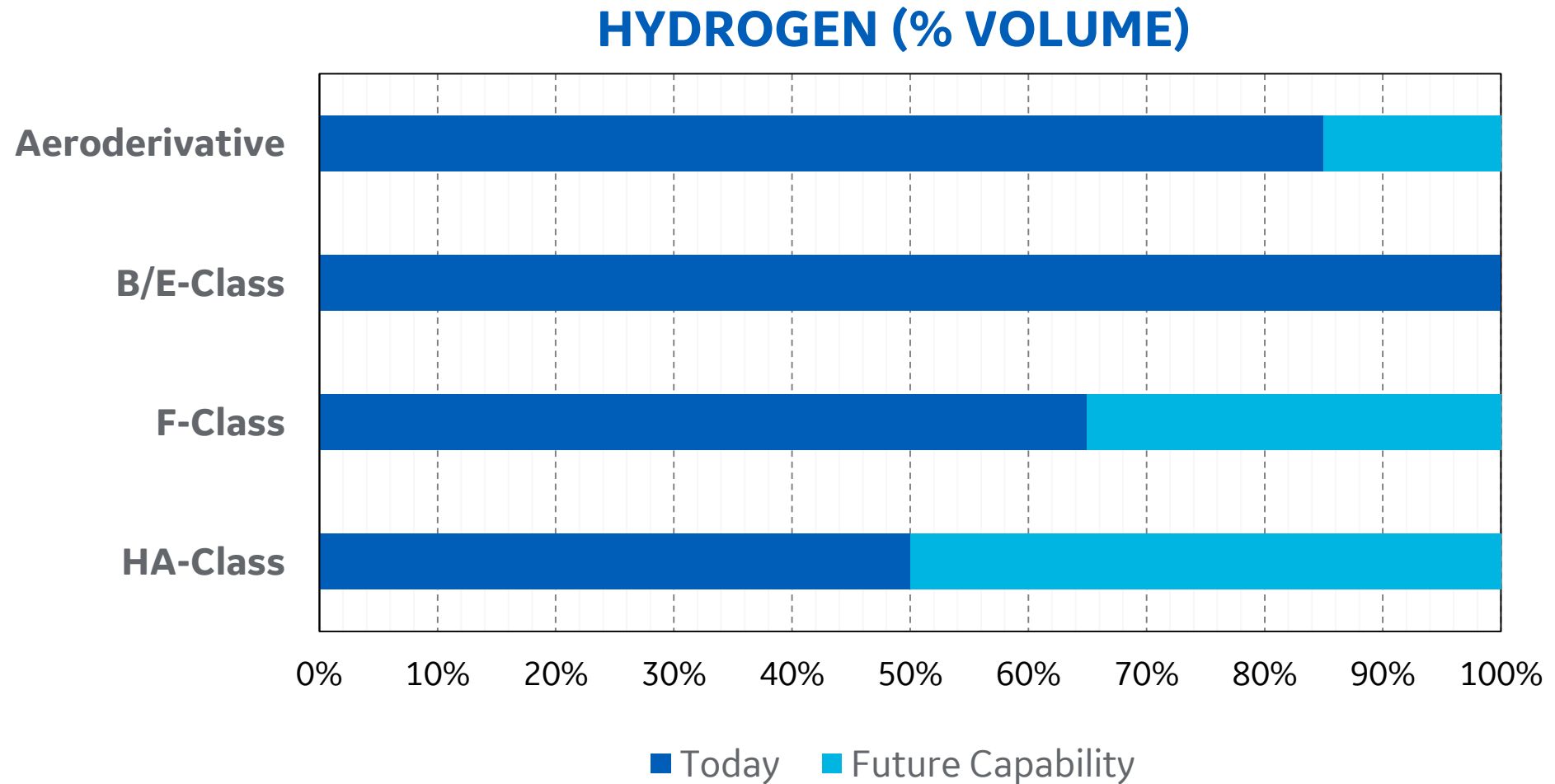
# Timeline of GE experience with H2 and associated fuels



Over **75** gas turbines with more than **5 million hours** on hydrogen and associated low BTU fuels



# GE gas turbine hydrogen capability



# Implications of using hydrogen for power generation



# Impact of hydrogen on power plant systems

SCR

HRSG inlet

Gas turbine  
combustion  
system

Gas turbine controls

**Gas turbine enclosure  
modifications:**

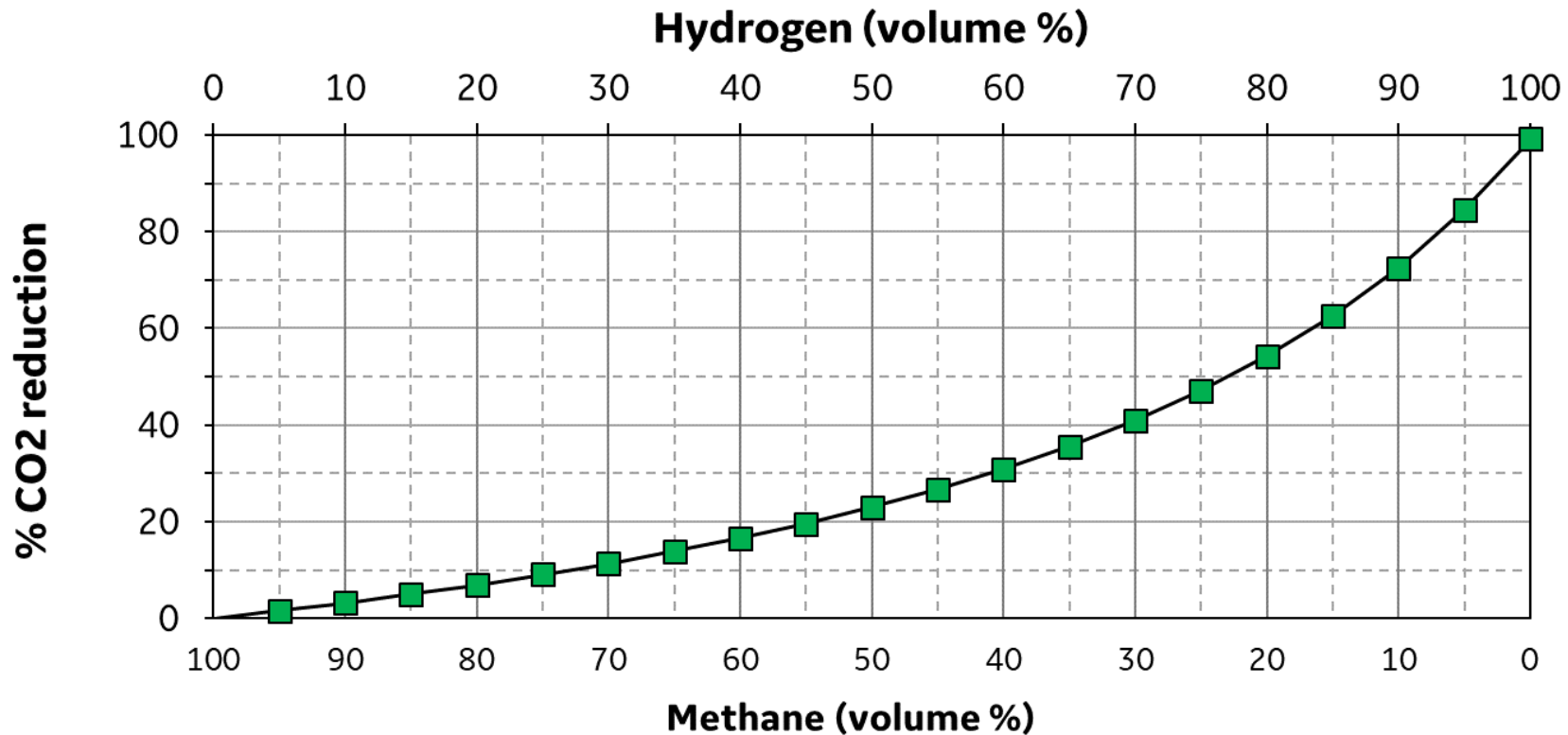
- Ventilation
- Haz gas detection
- Fire protection

**Fuel accessory system:**

Skids, valves, piping,  
purge systems



# CO<sub>2</sub> emissions reduction when operating on H<sub>2</sub>



The use of H<sub>2</sub> as a gas turbine fuel, even if blended with natural gas, can reduce CO<sub>2</sub> emissions



# CO2 emission impact – hydrogen

- To help customers determine the impact of using hydrogen on carbon emissions and the economics of carbon emissions, GE has created a new online tool.
- With a few simple selections (gas turbine model, plant configuration, carbon tax rate, etc.) the tool will calculate infrastructure requirements, carbon emissions reduction, and the avoided cost of carbon emissions.

**HYDROGEN AND CO<sub>2</sub> EMISSIONS CALCULATOR**

### LEARN MORE ABOUT HYDROGEN'S POTENTIAL SAVINGS

With the rise in global interest in the use of hydrogen as a zero-carbon fuel, there are still many questions surrounding the real-world numbers around its implementation. What will you need in terms of infrastructure? How will it impact your CO<sub>2</sub> emissions? We've made it easy for you. GE's Hydrogen and CO<sub>2</sub> Emissions Calculator will help you:

- Understand the fuel flow rate required for a gas turbine to operate on hydrogen
- Discover the water and electricity infrastructure needed to make hydrogen
- Get the numbers around the potential savings you could realize

Want to get started? Give us a few pieces of information to see more information around your potential hydrogen project.

The information presented on or through this website and calculator is made available solely for general informational purposes. GE does not warrant (1) the accuracy, completeness, or timeliness of any results, conclusions, or information provided by this website or calculator, (2) that any specific operating or performance results will occur from any information provided by the website or calculator, or (3) that any other third party will result from the website or calculator. Any reliance you place on such information is strictly at your own risk. GE disclaims all liability and responsibility arising from any reliance placed on the results, conclusions, or information provided by the website or calculator by any person who may be influenced by any of its contents.

**1** What kind of gas turbine do you have?  
7F.05

**2** What are the expected annual operating hours of your gas turbine?  
PEAKER MID MERIT FULL LOAD 8000 HRS

**3** What's the volume percent of hydrogen you want to run through?  
0% 25% 50% 75% 100% 100%

**4** What CO<sub>2</sub> tax rate do you pay today, if any?  
Enter in your rate below. Not sure? Simply select your country using the dropdown menu. Rates are in USD/ton.  
Choose your country/location OR \$ 25.00

**SEE YOUR HYDROGEN POTENTIAL**

Ready to get started? **CONTACT GE TODAY** →

**HYDROGEN AND CO<sub>2</sub> EMISSIONS CALCULATOR**

## YOUR HYDROGEN AND CO<sub>2</sub> EMISSIONS RESULTS

These results are based on your estimate of 8,000 annual operating hours at 100% hydrogen on a 7F.05 turbine and a current CO<sub>2</sub> tax of \$25.00 per ton. **RECALCULATE**

Infrastructure Requirements CO<sub>2</sub> Savings Summary

### HYDROGEN PRODUCTION AND INFRASTRUCTURE REQUIREMENTS

Choose your process: **Electrolysis** Steam methane reforming

**ELECTRICITY REQUIRED**  
Energy per year  
**1,109.7 MW**  
You will need the equivalent of 740 - 1.6 MW wind turbines to create the required energy for your hydrogen infrastructure.

**WATER FLOW REQUIRED**  
Gallons of water per day required  
**1,044,777**  
You will consume the equivalent of 1.68 Olympic-sized pools of water every day as part of your hydrogen infrastructure plan.

**HYDROGEN FLOW REQUIRED**  
Cubic feet per day  
**181.9 million**  
Amount of hydrogen created

Ready to get started? **CONTACT GE TODAY** →

[power.com/h2turbines](https://power.com/h2turbines)





# Closing thoughts



# LOOKING TOWARDS THE FUTURE



The gas turbine industry has **proven experience** operating with H<sub>2</sub> and similar low BTU fuels



**Combustion technology** exists for operating with H<sub>2</sub> blends and high H<sub>2</sub> fuels



Gas turbines are ready for a world with **low-carbon fuels**

