



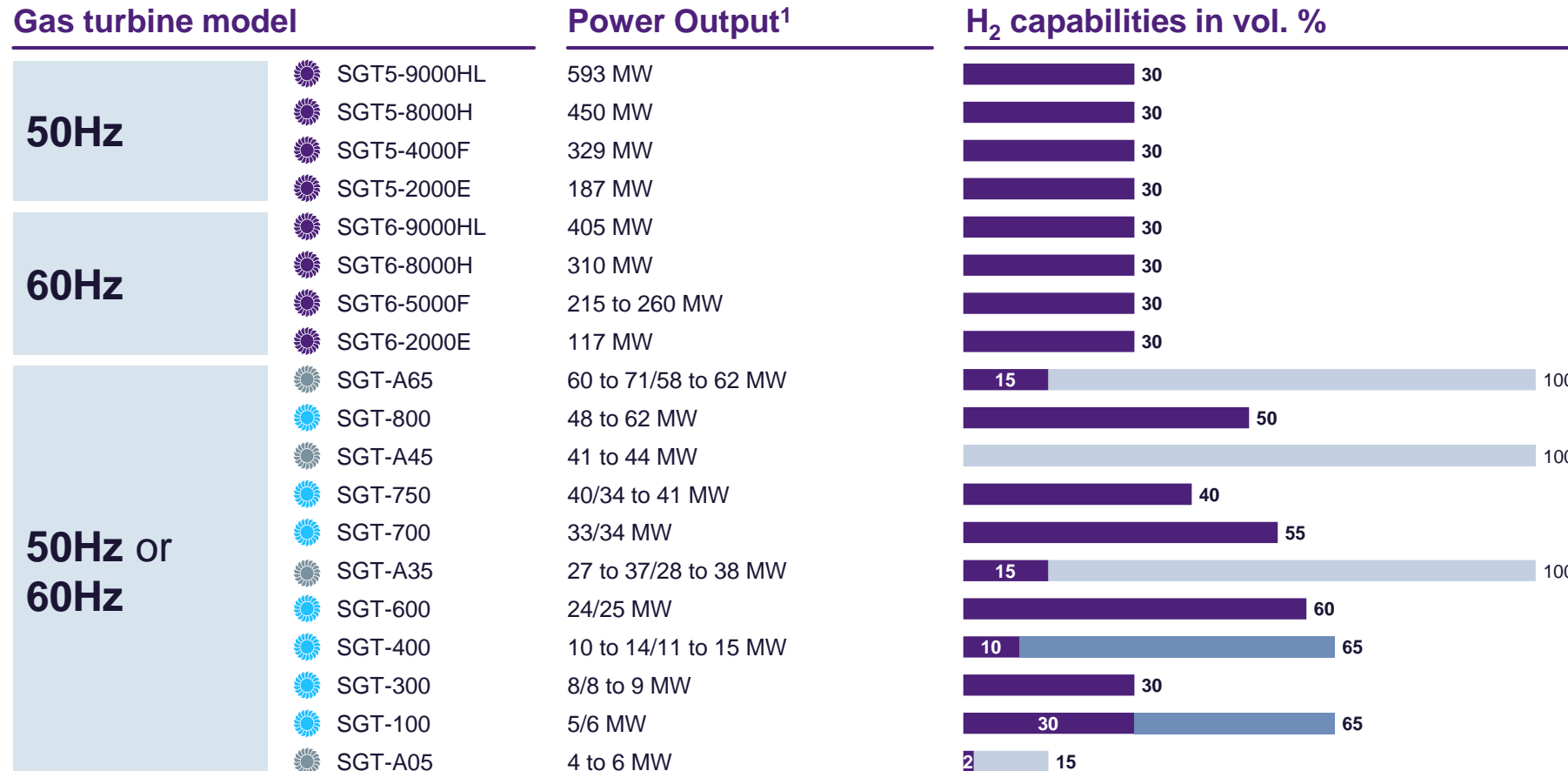
## Hydrogen Combustion in Siemens Gas Turbines

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Manager Product Positioning at Siemens Energy

# Siemens Hydrogen Gas Turbines for our sustainable future

## The mission is to burn 100% hydrogen



Values shown are indicative for new unit applications and depend on local conditions and requirements. Some operating restrictions/special hardware and package modifications may apply.

**Higher H<sub>2</sub> contents to be discussed on a project specific basis**

DLE burner
  WLE burner
  Diffusion burner with unabated NOx emissions

Heavy-duty gas turbines
  Industrial gas turbines
  Aeroderivative gas turbines

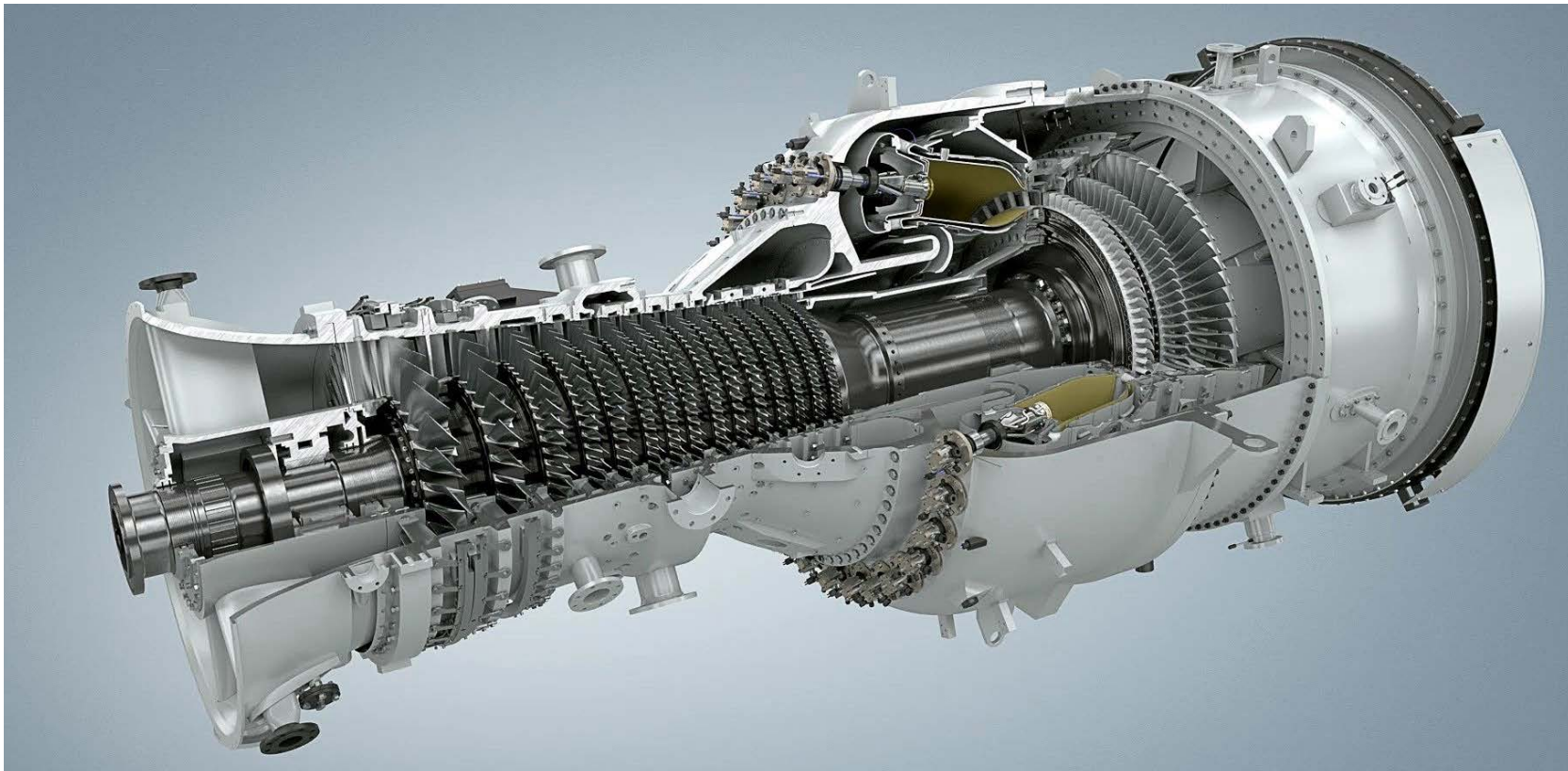
<sup>1</sup> ISO, Base Load, Natural Gas; Version 3.4, July 2020

# Industrial gas turbine

## SGT-800 / 57MW core engine



- 30 DLE burners of so called 3<sup>rd</sup> generation in an annular combustor
- Air entering combustor with about 20 bar and 700K/430°C



Best selling Gas Turbine in Power Range, 48-62MW

- > 350 sold units
- Fleet Reliability: 99.6%
- Fleet Availability: 97.7%

<https://www.youtube.com/watch?v=fr5eDxiYqEs&index=200&list=PUaEE-0s0x3MHg9jzFcHuQQ>

# Hydrogen as fuel in gas turbines

## Hydrogen ignites/ burns fast

- H<sub>2</sub> combustion moves flame closer to injector – avoidance of 'flash-back' by optimizing air and fuel distribution.

## Hydrogen has a wide flammable region

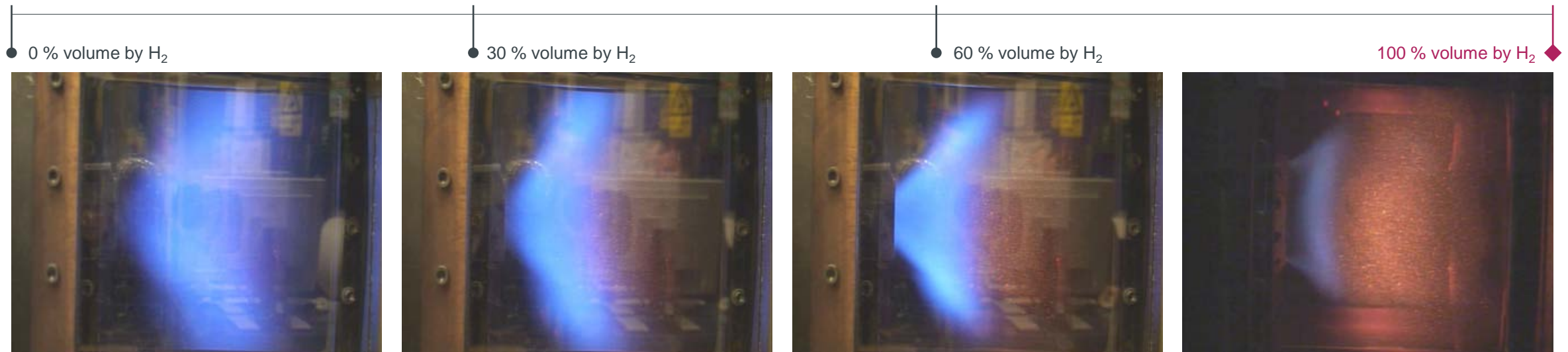
- Much wider range of fuel/ air-ratio to burn compared to natural gas. Adaption of ventilation and gas detection system as well as fuel system.

## Hydrogen has a low ignition energy

- Only a fraction of the ignition energy is needed to get H<sub>2</sub> 'going' compared to methane.

## Hydrogen has lower density...

- ...but fortunately the wobble index remains in natural gas range, i.e. 37 – 49 MJ/nm<sup>3</sup>.



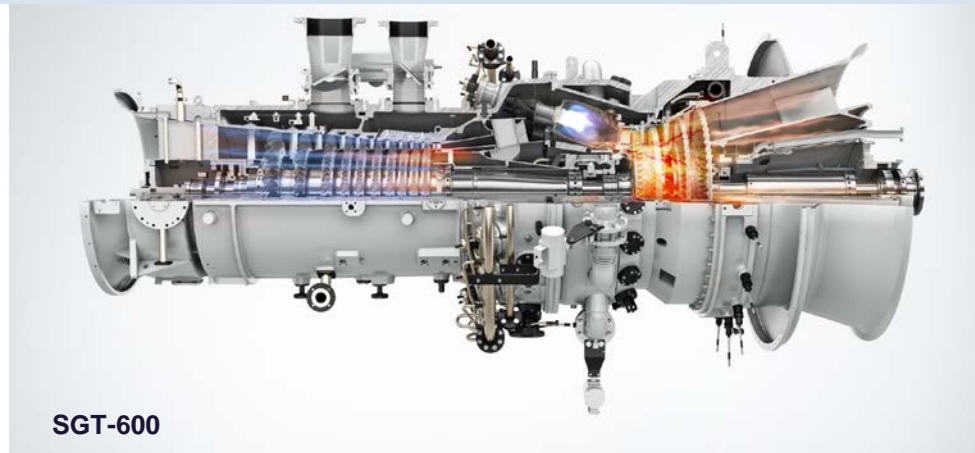
# Evolutionary development of Hydrogen experience

## Built on continuous development experience across the fleet



### Available hydrogen levels for 3<sup>rd</sup> generation DLE at $\leq 25$ ppm NO<sub>x</sub>

- SGT-600 60% H<sub>2</sub>
- SGT-700 55% H<sub>2</sub>
- SGT-800 50% H<sub>2</sub>
- SGT-750<sup>1)</sup> 40% H<sub>2</sub>

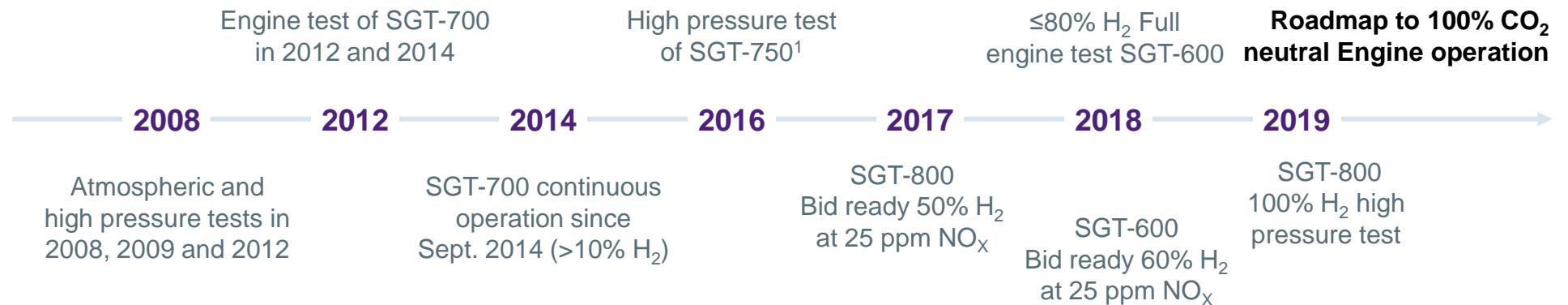


### Burner development enabled through additive manufacturing

- New geometric possible with 3D printed burners
- Agile development
- Rapid prototyping

## Continuous improvement of our DLE design and engine testing steady increase H<sub>2</sub> admixing capabilities

### 3<sup>rd</sup> generation DLE burner



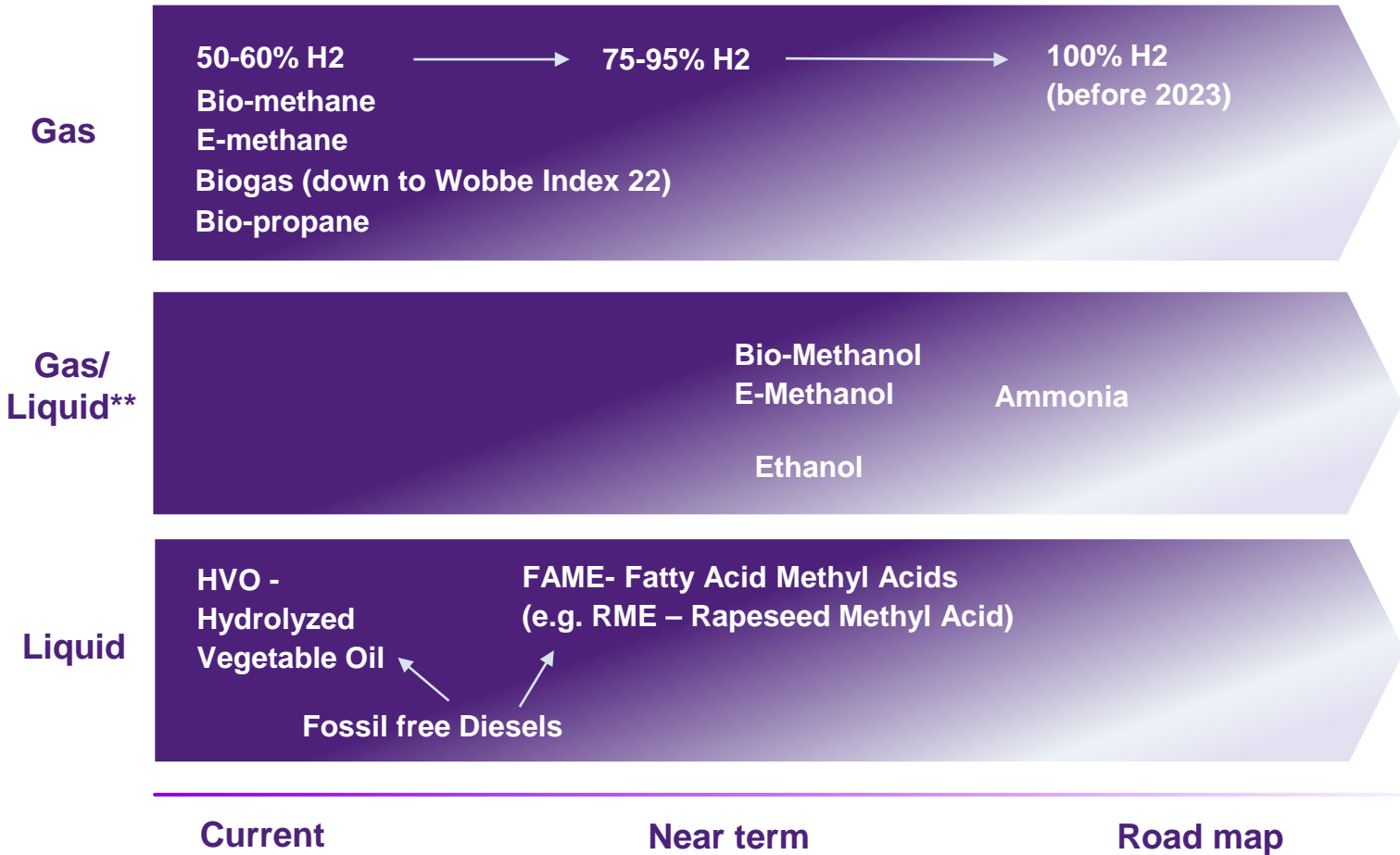
<sup>1</sup> The SGT-750 is already equipped with a 4<sup>th</sup> generation Dry Low Emission burner design

# Green fuel capabilities in Siemens medium gas turbines



## Green fuel capabilities of 3<sup>rd</sup> generation Dry Low Emission system\*

Building on long experience with 3rd generation DLE and accelerated by additive manufacturing



## Development and customer cooperation

- Flexible operation on low carbon fuels (biological, synthetic, off-gas)
  - Different operation modes to adapt to fuel availability and price fluctuations
  - Fuel switch over while operating
  - Operation on fuel mix (liquid and/or gaseous)
- 3D printed burners enables advanced designs to run on new fuels as well as rapid prototyping and agile development

We are looking for **cooperation with customers** that want to operate on high levels of **H2 and/or other green fuels** - *not limited to what is already on the road map*

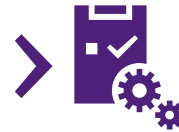


# Gas turbines built for natural gas combustion can be upgraded at later stages to hydrogen when required



## Potential future developments

- **Hydrogen content in gas pipeline likely to increase** in future e.g., due to electrolyzers gaining wider acceptance and discharging hydrogen into the gas grid
- Opportunity to burn **hydrogen, e.g., from nearby refinery** willing to burn surplus hydrogen more efficiently
- Changes in legislation enforcing decarbonization of power sector, leading to a **requirement to co-burn increased content of sustainably-produced hydrogen**



## Upgrade requirement

- Requirement to modify existing gas turbines and combined cycle power plants to burn hydrogen in the future
- Minimization of risk of having future “stranded investments” when deciding today on new GT/CCPP power plant construction projects

## Siemens gas turbines

with ability to burn hydrogen (with full NOx emission compliance!) enabled to be upgraded for future hydrogen combustion as future-proof investment



# Zero Emission Hydrogen Turbine Center

## The future energy system



Develop the gas turbine test facility towards a zero emission demonstrator plant by:

- Utilize power from turbine test runs to produce hydrogen in an electrolyzer
- Installing solar panels for continuously hydrogen production
- Use produced hydrogen as turbine fuel to reduce LNG consumption

Three year project

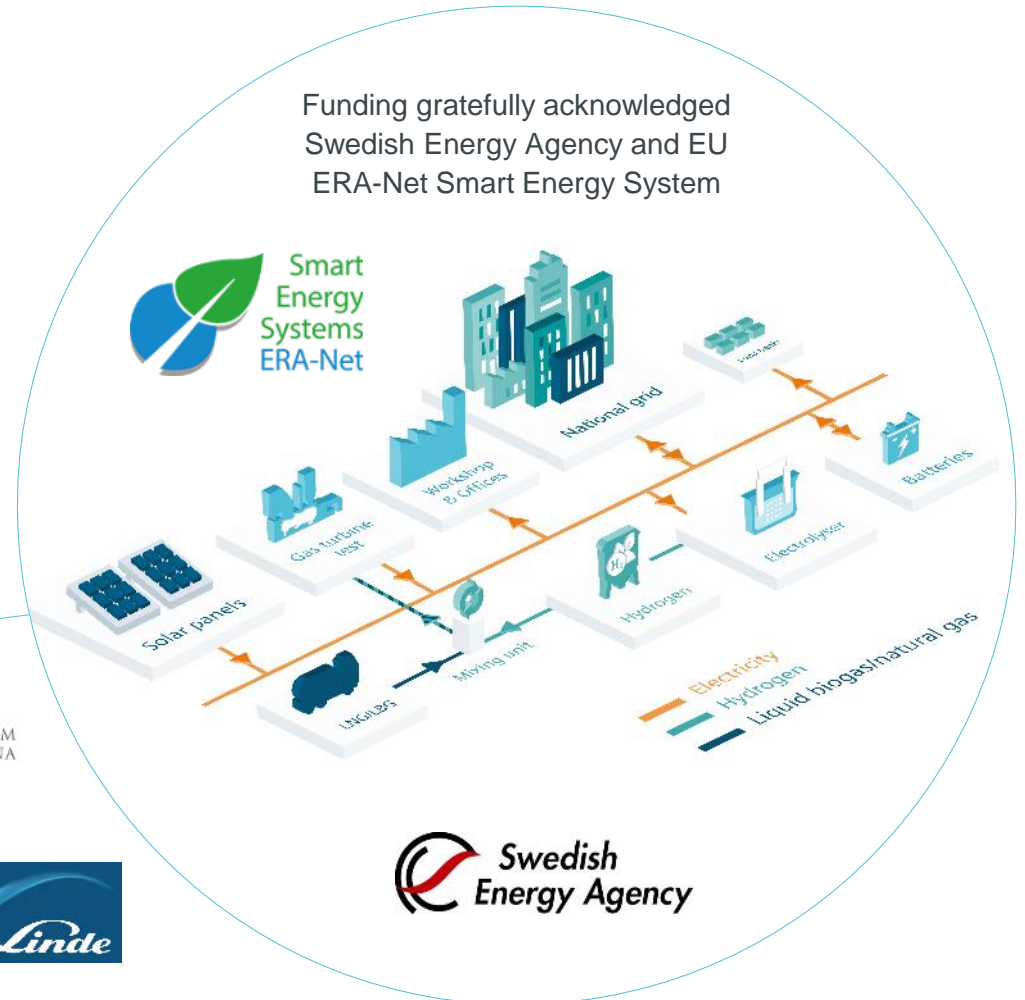
- Operation planned to start in 2021



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# Siemens is the right partner for hydrogen-fueled gas turbines in a sustainable, hydrogen-based energy world



## Hydrogen capabilities in Siemens Gas Turbines

- All newly built Siemens gas turbine types capable to burn different levels of hydrogen in the fuel mix
- Smaller hydrogen contents not requiring any modification compared with standard natural gas turbines (new unit applications)
- Existing gas turbines<sup>1</sup> able to be upgraded to burn hydrogen
- Siemens with a roadmap to burn 100% hydrogen fuel in gas turbines



## Conclusions



Existing assets and future **investments in gas turbines are protected** also in a fully decarbonized world



**Carbon-free power generation** in gas turbines with green hydrogen



Hydrogen-capable gas turbines with **high fuel flexibility** to burn hydrogen and natural gas and other green fuels



Siemens gas turbines **fully compliant with emission limits** when burning hydrogen

<sup>1</sup> Limits to be evaluated

# Thank you



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