Hydrogen Capability
SGT-600, SGT-700 & SGT-800

PIB/SGT-600/21-007, PIB/SGT-700/21-005
PIB/SGT-800/21-005

October 2021

E1B100442295:B

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Hydrogen Capability SGT-600, SGT-700 & SGT-800
Customer value

Siemens Energy increased hydrogen-fuel capabilities enables CO_2 emission reduction in Dry Low Emission burners (DLE)*

A contribution to a sustainable future

A base load, simple cycle operating unit at 75 vol-% H_2 will typically reduce the CO_2 emissions by (compared to natural gas/CH_4 fuel):

- SGT-800 (53MW rating): 110’000 tons per annum or 240 kg/MWh
- SGT-700 (33MW rating): 72’000 tons per annum or 260 kg/MWh
- SGT-600 (25MW rating): 59’000 tons per annum or 280 kg/MWh

Interested in the decarbonization potential for your turbine?

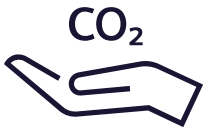
Go to our H_2 decarb calculator

* This presentation is focused on 3rd generation DLE combustion systems used in all SGT-800, SGT-700 and newer SGT-600. SGT-750 has a current release up to 40 vol-% H2. For older DLE or conventional combustion systems, contact Siemens Energy

Hydrogen Capability SGT-600, SGT-700 & SGT-800
Customer value

From the reduction of CO_2

- **Meet current and future market requirements** for sustainable power and heat production – viability of investment and continued license to operate and increased dispatch/effect reserve participation
- **Reduced carbon cost** (expected to increase steeply in line with commitments regarding decarbonization[1])
- **Meet owners' targets, commitments and strategies** regarding decarbonization, sustainability and Corporate Social Responsibility
- **Improved company branding** (product, stock, employer markets as well as standing in the local and global community)
- **Become eligible for incentives programs and grants** for investment in CO_2 reduction



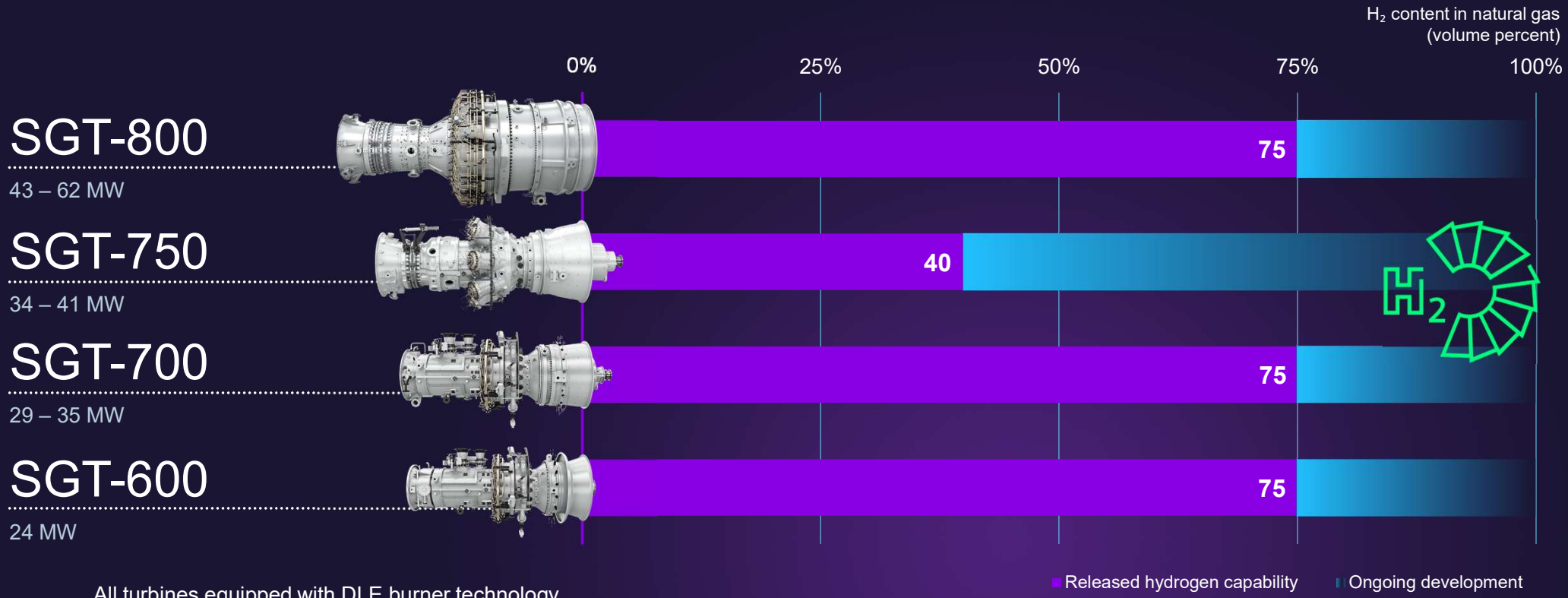
1 https://carbonpricingdashboard.worldbank.org/

Additional values

- Fuel flexibility enables optimization of operation, enabling **utilization of off-gas** as well as **optimized fuel sourcing** based on relative market pricing on green fuels
- Possibility to store surplus energy produced by e.g., renewables as e-fuel **(power-to-X)** and utilize when capacity is needed
- **Low NO_x emissions** through DLE (dry low emission) technology

Which are applicable to your installation?

Hydrogen Capability in Siemens Energy medium size gas turbines



All turbines equipped with DLE burner technology

Power output in MW at ISO ambient conditions and natural gas, includes both new units and existing fleet

Hydrogen Capability SGT-600, SGT-700 & SGT-800

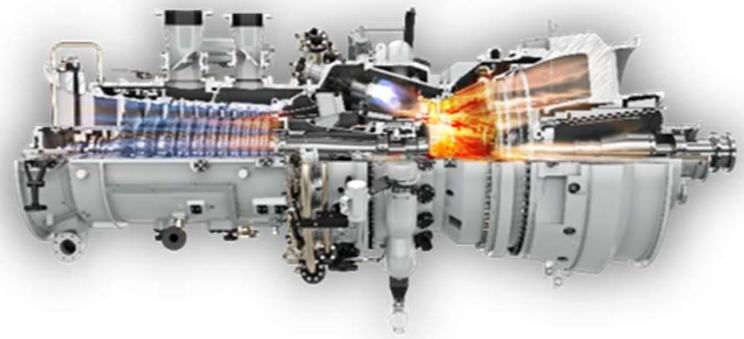
World class leader with Hydrogen

Hydrogen Capabilities

- Currently released:

  SGT-600 → **75 vol-%** H_2
  SGT-700 → **75 vol-%** H_2
  SGT-800 → **75 vol-%** H_2

- **Higher H_2 content** can be evaluated on a project-by-project basis
- Development **towards 100% H_2** on-going and further upgrades will be made available (burners retrofittable)



World Class DLE burners

- **Evolutionary development** of 3rd generation* DLE (Dry Low Emission) burner
  - Experience of DLE systems since 1990
  - Same DLE-burner geometry for SGT-600, SGT-700 & SGT-800
  - Low NO_x emissions
- Optimized burner design **enabled by 3D-printing**
- **Flexible and robust operation** on different fuel mixes with variations over time

Implementation

- Modification package **optimized to customer installation and required level of H_2**, based on OEM knowledge
  - Step-wise scope increase with H_2-level up to 75 vol-%
- **Quick installation** meaning minimal disruption to operation, especially if performed together with an inspection
- **No or only minor additions** to the maintenance program required. EOH (Equivalent Operating Hours) will not be affected.

* used in all SGT-800, SGT-700 and newer SGT-600. More than 500 units sold since introduction in 1998

Hydrogen Capability SGT-600, SGT-700 & SGT-800

Hydrogen as a fuel for gas turbines

Hydrogen ignites/ burns fast

→ H_2 combustion moves flame closer to injector – avoidance of ‘flash-back’ by optimizing air and fuel distribution.

Hydrogen has a wide flammable region

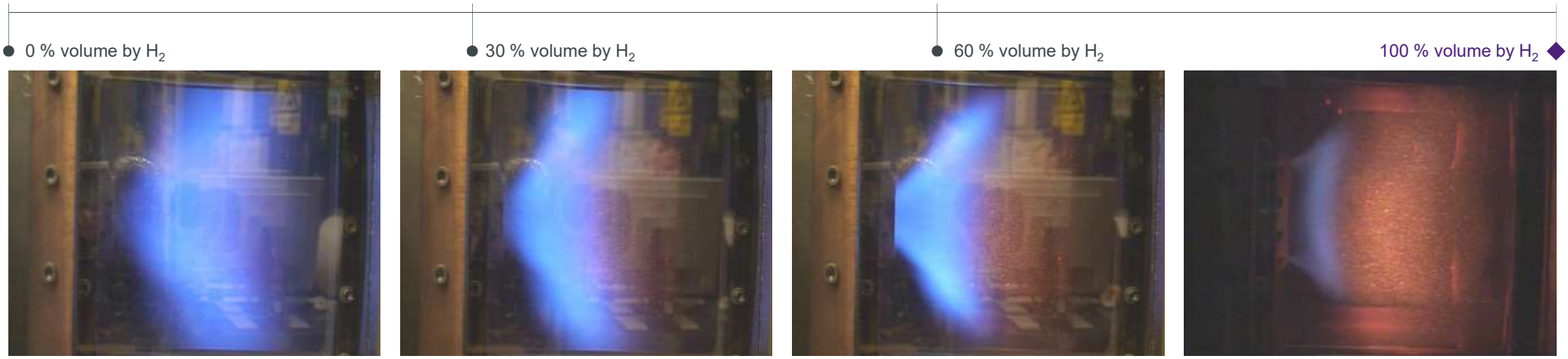
→ Much wider range of fuel/ air-ratio to burn compared to natural gas. Adaption of ventilation and gas detection system as well as fuel system.

Hydrogen has a low ignition energy

→ Only a fraction of the ignition energy is needed to get H2 ‘going’ compared to methane.

Hydrogen has lower density…

→ …but fortunately the wobbe index remains in natural gas range, i.e. 37 – 49 MJ/nm3.



Hydrogen Capability SGT-600, SGT-700 & SGT-800
Continuous development and experience across the fleet

2008
Experience of H_2 combustion in conventional diffusion burners and auxiliary systems since 1980's (~90% H_2)

2008
Atmospheric and high-pressure tests in 2008, 2009 and 2012

2012
Single burner feed in full engine 40/60 vol-% H_2 in 2012 and 2014 (SGT-700)

2014
SGT-700 continuous operation at customer site 10 vol-% H_2

2016
In-house Additive Manufacturing capability – enabling new geometrics and rapid prototyping

2017
SGT-800 full engine test with standard welded burners, bid ready 50 vol-% H_2 at 25 ppm NO_x and derated load

2019
- SGT-600 full engine test, bid ready 60 vol-% H_2 at 25 ppm NO_x
- SGT-700 bid ready 55% vol-% H_2 at 25 ppm NO_x

2019
High pressure single burner test with additive manufactured burners verifying 100 vol-% H_2 capability

SGT-600 customer **engine** delivery test verifying: 60 vol-% H_2 at 25 ppm NO_x and full load, reliable operation with 80 vol-% H_2

2021
SGT-800, SGT-700 and SGT-600 bid ready 75 vol-% H_2

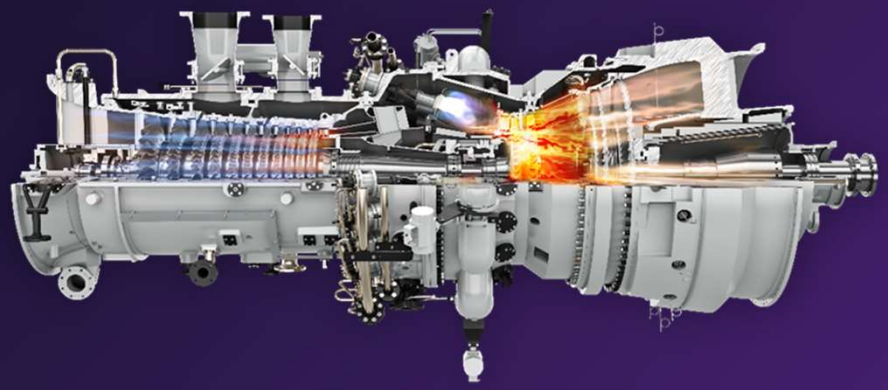
2030
Target 100% H_2 with DLE demonstrated at customer site

3rd generation dry low emissions (DLE) burner used in SGT-600, SGT-700 and SGT-800

Hydrogen test at the Siemens Energy test facility, Finspong Sweden

Hydrogen in gas turbines
Boundary conditions to consider

World class leader in Hydrogen combustion

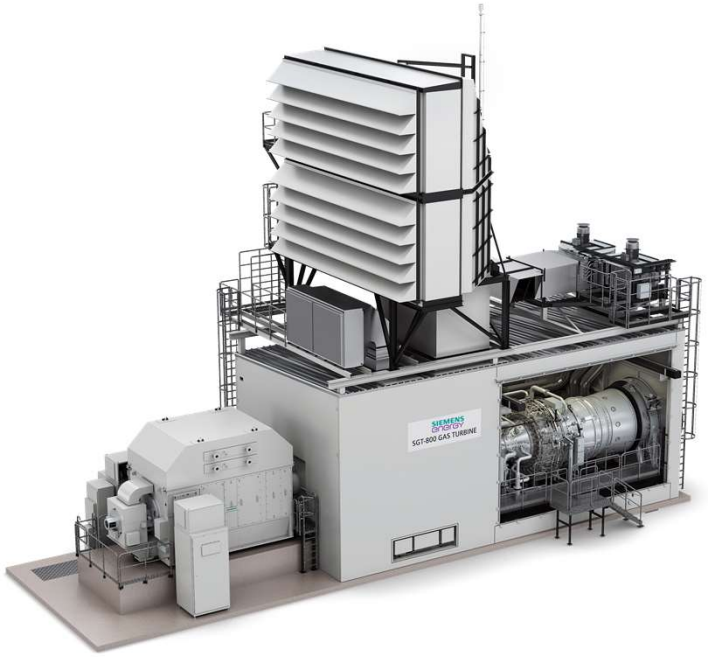


Examples of boundary conditions that need to be clarified are:

- Amount of H_2 desired to be blended with existing fuel (higher amounts will increase the scope)
- Constituents of the fuel to be used together with the H_2-fuel
- Emission regulations that need to be fulfilled
- Estimated operating profile
- Design of existing installation of auxiliary equipment and control system
- Currently installed version of combustion chamber and burners

Hydrogen in gas turbines
Examples of installation adaptions to consider

Examples of installation adaptions to consider	5-15vol-%	15-30vol-%	30-75vol-%
Burner flash-back supervision	✓	✓	✓
Burner flash-back control			✓
Adjusted burner design[1]		✓	✓
Ignition fuel & central gas/purge air system		✓	✓
Enclosure gas detection system	✓	✓	✓
Enclosure fire detection system		✓	✓
ATEX/CFD-considerations & ventilation adjustment	✓	✓	✓
Gas fuel system (material, valves etc.)		✓	✓
Additional monitoring		✓	✓



Logics, procedures & approvals:

- **Operation and control:** Updated settings in the control system and modified start-up sequence. Adjustment of operation including turbine inlet temperature may be required depending on fuel constituents including level of H_2 and emission requirements
- **Additional approvals and certificates** from authorities may be required to get operating permission (customer scope)

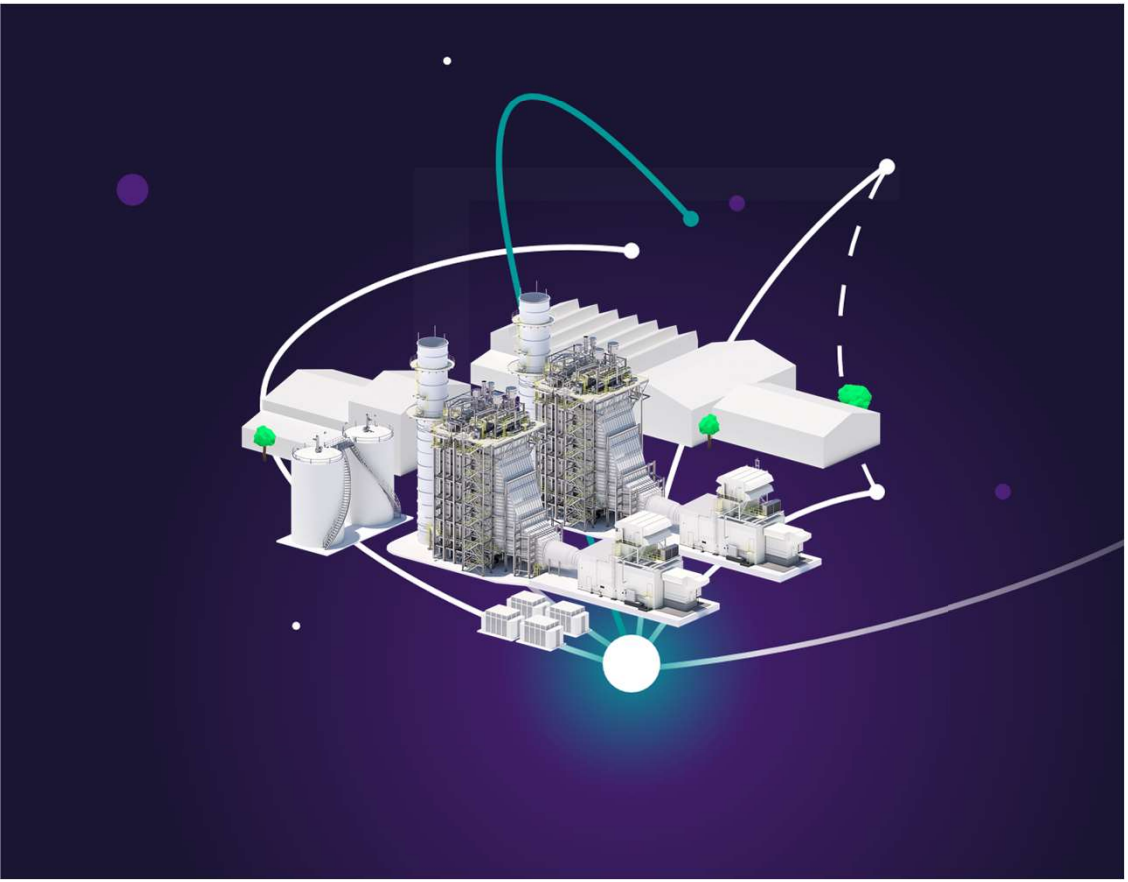
Siemens Energy can provide solutions both for new units and existing fleet

1 For older installed SGT-600/700 units, the combustion chamber might need to be updated

Hydrogen Capability SGT-600, SGT-700 & SGT-800
Conclusions

- Hydrogen capability up to 75 vol-% H_2 in DLE - enables significant CO_2 reduction - low NO_x emissions
- Higher contents can be evaluated
- Roadmap to 100% H_2 accelerated by additive manufacturing
- Modification package optimized to customer installation and required level of H_2
- Siemens Energy can perform a pre-study to define a customized scope of delivery

Contact Information



If you require further information in respect of the hydrogen capabilities, please contact us on

greenfuelgt@siemens-energy.com

siemens-energy.com

Disclaimer

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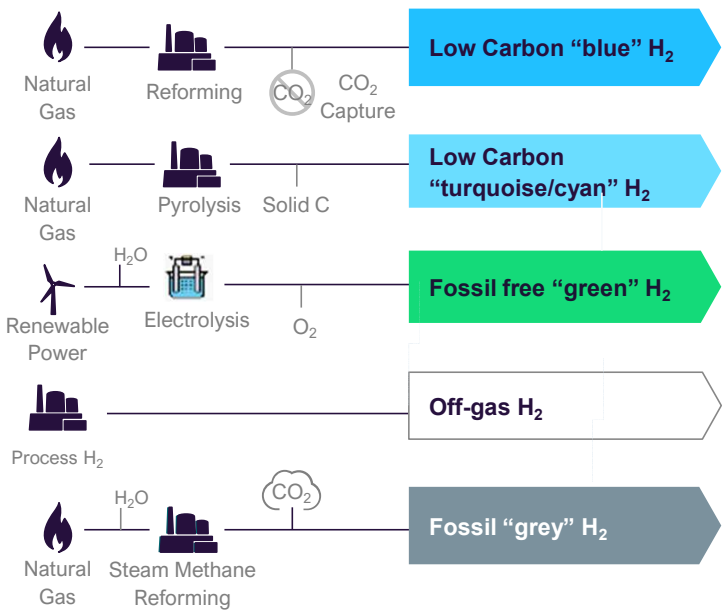
Sources and definitions of H_2



H_2 produced by splitting natural gas/methane (CH_4) into CO_2 and H_2. The process uses heat/steam to perform the split and the CO2 is captured.

H_2 generated using pyrolysis (molecule cracking with heat) process. No CO_2 is generated as the carbon is deposited as a solid. The process is under development.

H_2 produced in an electrolyzer by splitting water (H_2O) into H_2 and O_2 using electricity from renewable sources.

H_2 available as an off-gas (by-product) from a chemical or refinery process. Can be utilized a fuel in a gas turbine instead of e.g. flaring.

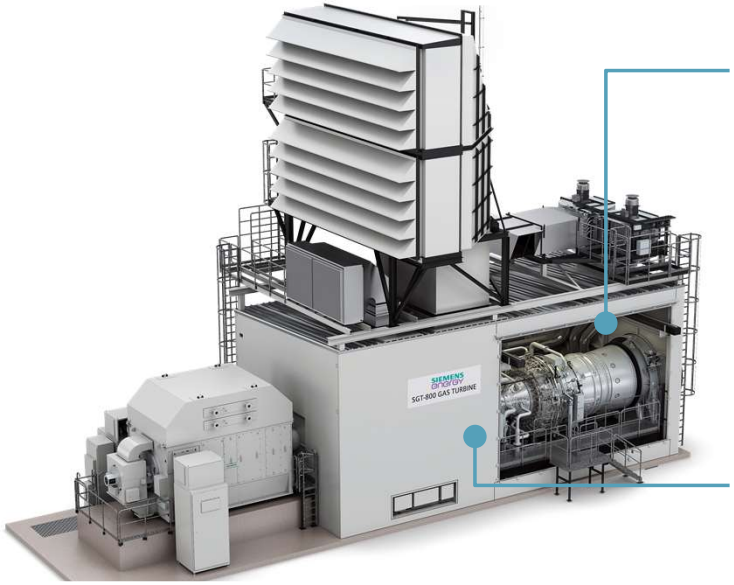
H_2 produced by splitting natural gas/methane (CH_4) into CO_2 and H_2.The process uses heat/steam to perform the split.

This is the most common production pathway today. There are other fossil sources for H_2 such as coal ("brown" or "black" H_2). Fossil hydrogen as a turbine fuel increases the carbon footprint compared to natural gas.

Up to 10 different colors have been used to classify H_2 with inconsistent application of the respective color, however the tendancy is to more and more use definitions such as "clean/renewable H_2" and "low carbon H_2". Please note that "brown" hydrogen sometimes is used for hydrogen produced from coal and sometimes for off-gas hydrogen. Biomass gasification is also a possible source of "green H_2".

Hydrogen Capability SGT-600, SGT-700 & SGT-800
Installation adaptions to consider

Modification package optimized to customer installation and required level of H_2 - step-wise scope increase up to 75 vol-%*



Core engine:

- **DLE burners** optimized for H_2-operation with flashback supervision/control
- **Combustion chamber** may have to be updated to latest design

Package design:

- **Ignition fuel & central gas:** A separate fuel and central gas/purge air system may be needed
- **Gas detection:** Specific design for safe operation
- **Fire detection:** Adaption to detect the different flame appearance
- **ATEX & ventilation:** Hazardous area classification adapted to H_2. Explosion proof (gas group IIC) components may be required in some areas. CFD-analysis and optimization of ventilation flow may be required
- **Gas fuel system:** Modification for H_2 compatibility (component sizing, leakage prevention and material selection)

Logics, procedures & approvals:

- **Operation and control:** Updated settings in the control system and modified start-up sequence. Adjustment of operation including turbine inlet temperature may be required depending on fuel constituents including level of H_2 and emission requirements. Remote connection for additional monitoring.
- **Additional approvals and certificates** from authorities may be required to get operating permission (customer scope)

Siemens Energy can perform a pre-study to define a customized scope of delivery

* Package design available up to 100 vol-%

Reference
Braskem, Brazil

60% Hydrogen at 25ppm NO_x

Customer: Braskem

Country: Brazil

Commercial operation: 2021

Challenge

- Low cost for O&M
- Use of hydrogen as fuel gas to reduce use of natural gas, up to 60% not exceeding 25 ppm NO_x
- Reduced need for external grid supply
- High availability and reliability

Technology

- 2x SGT-600 PG with 3rd generation DLE system for up to 60% H_2 co-firing at 25ppm NO_x

Solution

- Advanced Additive manufactured burners capable for 100% H_2
- Complete plant delivery, Siemens Energy will build, own & operate the CHP, HRSG and gas compressor
- O&M contract based on delivery of steam and power

Benefits

- Fuel cost savings operation on high levels of hydrogen in DLE, no need for water injection
- Lowest emissions using the latest DLE combustion system and control system <25 ppm NO_x
- Predictable operation and maintenance cost
- Tailor made flexible solutions in all important aspects

Reference
HKW Leipzig Süd, Germany

Combined heat and power plant

Customer: Stadtwerke Leipzig GmbH
Country: Germany

Commercial operation: 2022

Challenge

- New gas power plant to substitute existing heat supply from nearby lignite power plant
- Successive conversion from natural gas to hydrogen operation
- The plant is expected to operate with 30 to 50 percent green hydrogen only a few years after start of commercial operation
- The long-term goal is to operate the facility with 100 percent green hydrogen

Technology

- 2 x SGT-800 62 MW gas turbines
- 2 x SGen-100A generators
- SIESTART battery energy storage system
- Long term service contract over a period of 15 years

Solution

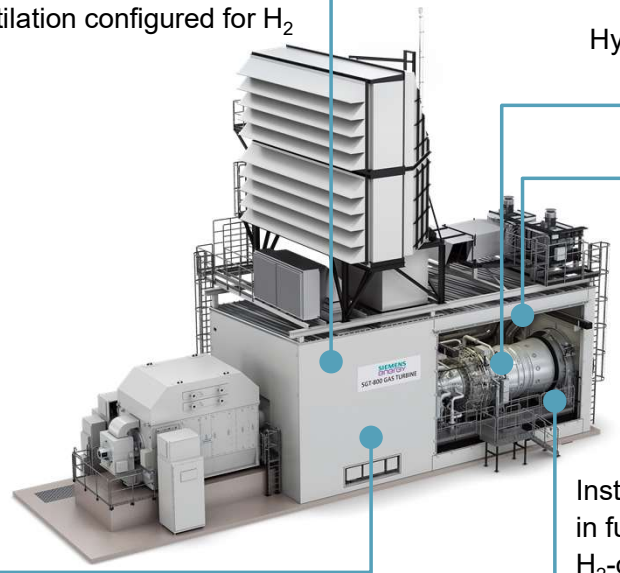
- The new gas power plant, with combined heat and power technology, will produce electricity and district heat for the city
- Successive conversion to hydrogen operation paves the way for Leipzig's decarbonization
- Electrical capacity of ~125 MW and thermal capacity of ~163 MW
- Up to 93% plant fuel efficiency thanks to district heat production (41% electrical efficiency)
- Commissioning scheduled for end of 2022

Benefits

- High electrical and total plant efficiency
- Lowest emissions in its class with outstanding high fuel flexibility
- Competitive lifecycle costs
- Reliable and secure combined heat and power plant with black start capability
- Sustainable and future proof district heating power plant

Modifications for Hydrogen operation – one-pager
SGT-800, SGT-700 & SGT-600 3rd generation DLE

Installation adaptations to consider



- Currently released hydrogen capabilities:
  - SGT-600 → **75 vol-%** H_2
  - SGT-700 → **75 vol-%** H_2
  - SGT-800 → **75 vol-%** H_2
- **Higher H_2 content** can be evaluated on a project-by-project basis

- **Modification package optimized** to customer installation and required level of H_2, based on OEM knowledge
  - Step-wise scope increase with H_2-level up to 75 vol-%
- **Quick installation** meaning minimal disruption to operation, especially if performed together with a major inspection
- **No or minor additions** to the maintenance programme required

Conditions that need to be clarified to determine the scope are e.g.:

- Fuel composition
- Emission regulations
- Estimated operating profile
- Existing installation of auxiliary equipment and control system
- Currently installed version of combustion chamber and burners

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