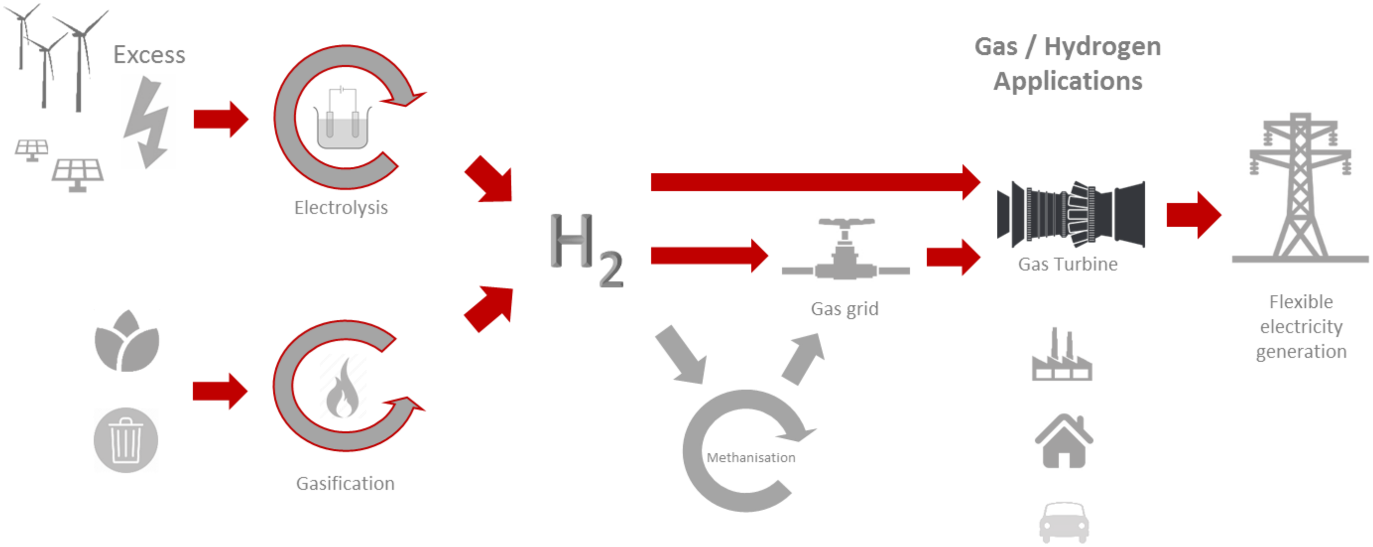
Power-to-Gas & turbines – a perfect combination in the future

R&I priorities for gas turbines

Power-to-Gas will play an important role in the future as part of an energy system that includes an increasing share of intermittent renewable energy sources, such as wind turbines and photovoltaics. Allowing excess energy generated – be it from thermal power plants, or from renewable energy sources – be stored as green fuel to use when needed will contribute to the flexibility that the future energy mix requires.

Gas turbines are very flexible and, in general, can be readily adapted to operate on hydrogen or synthetically derived (syngas) fuels containing hydrogen. Generally, syngas fuel streams can be used with different derivatives of existing combustion systems, based on the characteristics of the different fuels and operating requirements. There are, however, a number of areas that need to be improved and optimised, in order for gas turbines be prepared for this solution in the future.

EUTurbines hereby highlights the flexibility of the gas turbine, identifies where the technology requires further development and outlines how the gas turbine could be used in more novel concepts.



Benefits of power-to-gas & gas turbines

Power-to-Gas enables the use of excess electricity generated at times of low demand, which can be stored and burned, carbon-free, by gas turbines when required. The use of power-to-gas, thus, will be one of the flexibility providers in the future in an energy system with a growing share of intermittent renewable energy sources, ensuring electricity security of supply and contributing to the stability of the grid.

The fact that the existing gas pipeline infrastructure could be used, allows power-to-gas to be a cost-efficient solution, compared to other storage options. Additionally, the utilisation of the existing gas pipeline network enables the transmission of energy, which otherwise would require costly overhead high-voltage lines, which require the building of big infrastructures.

Hydrogen-based fuels

Hydrogen will most likely be available in 3 forms based on what is known today.

Typically generated from water electrolysis using excess power generated from renewable sources, such as photovoltaics or wind turbines, hydrogen can be (1) used as pure hydrogen or (2) mixed in with natural gas, such as in the natural gas pipeline infrastructure for storage and transportation. An additional source of hydrogen is (3) gasified biomass or municipal solid waste – which is typically comprised of CO/H2 mixtures in CO2.

Hydrogen can also be methanised in combination with CO2 and be injected directly into the grid. This option can be readily handled with existing gas turbine combustion systems.

Challenges for the gas turbine technology

The challenges arising from an increased addition of hydrogen natural gas are mainly related to its **combustion**. Often related to combustion issues, the specific areas of **materials** and **health and safety** present as well a number of challenges in this regard. As a result, the performance, lifetime, operation concept, emissions and availability of gas turbines may be impacted.

Hydrogen leads to increased reactivity, which is manifested as increased flame speed and reduced ignition delay time. Both of these two mechanisms affect the combustion performance in general, which results in an increased risk of flashback in lean premixed combustion systems, leading to damaged hardware and elevated NOx emissions.

R&I needs and priorities for gas turbines

R&I efforts are needed now in order to address the challenges mentioned above and to adapt the next generation of gas turbines to the future developments and requirements.

Flexible combustion systems:

The overall purpose is to avoid flashback and auto-ignition while keeping emissions low at high share of hydrogen in fuel. This includes

- Development of a burner for stable combustion of gas mixtures with hydrogen, from current levels to progressively adapting the technology to nearly 100%
- Extension of low emission load range, improving flexible load operation as well
- Improved design of liner to reduce exposure of surfaces to high-temperature gas and radiation
- Development of a safe Hydrogen fuel starting methodology – currently most OEM's require start on a standard fuel, followed by transfer to the hydrogen fuel once on load.

Materials:

The increased reactivity of hydrogen, and related high-temperatures have an impact on the materials that may be used. Improvements in various areas are needed, including in:

- Cooling schemes
- Thermal barrier coatings
- Creep and oxidation resistant materials

Health and safety:

A number of areas also need to be addressed to ensure the safe functioning of the gas turbine under these new circumstances.

- Improved inner and outer gas turbine seals to avoid hydrogen diffusion
- Safety instrumentation and monitoring system in gas turbine enclosures to avoid fire, explosions and other incidents.

Other relevant areas:

Developments in other components can also improve the system, and so, improve the turbine performance as well.

- Heat exchanger technology: Developing a heat exchanger system that can be added into the gas turbine cycle. The design needs to maximise heat transfer effectiveness and minimise pressure loss, while accepting energy from almost any external source.
- Steam injection: Developing a combustion system that can accept high temperature steam intermittently without detriment to emissions or performance.

Gas turbines in novel concepts

Adapting the gas turbine Brayton Cycle

The function of a gas turbine combustion system inside the Brayton cycle is to heat compressed air at near constant pressure. The heating can be accomplished in a number of ways:

- Burn the fuel in the airstream
- Run the compressed air through a heat exchanger, which has been heated by an external heat source (such as direct concentrated solar energy, boiler exhaust)
- High temperature steam injection
- Use the exhaust stream from a fuel cell

To achieve complete fuel flexibility, this would involve moving the combustion section from its traditional location inside the typical compact gas turbine envelope thereby allowing more flexible designs to be integrated.

Combining fuel cells with turbines

Additionally, the combination of turbines and fuel cells (as a substitute for a typical combustor) can play a role due to its potential thermal efficiency gain*, although a better understanding in terms of CAPEX and OPEX, reliability and durability of the fuel cell, gas turbine / fuel cell operability and optimum size determination is needed. A number of specific technological challenges arise for this option:

- Matching flow rates and temperatures within the combined cycle
- Determining how to operate the fuel cell in parallel or series with a DLE (dry low emission) combustor burning hydrogen
- Developing strategies for operation over the complete gas turbine operating range

Thus, there is a need for integrated gas turbines / fuel cell studies, especially looking at the performance, cycle choice and matching sizes and operating temperatures.

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* A 5 MW electrical gas turbine integrated with a fuel cell could have an overall power output of 25MW electrical (Brouwer, J., Hybrid Gas Turbine Fuel Cell Systems, Chapter 4, in “The Gas Turbine Handbook,” Richard A. Dennis, ed., U.S. Department of Energy, DOE/NETL-2006/1230, Morgantown, West Virginia, 2006).

About EUTurbines

EUTurbines is the only association of European gas and steam turbine manufacturers. Its members are Ansaldo Energia, Doosan Skoda Power, GE Power, MAN Diesel and Turbo, Siemens and Solar Turbines.

EUTurbines advocates an economic and legislative environment for European turbine manufacturers to develop and grow R&I and manufacturing in Europe.

EUTurbines promotes the role of the turbine-based power generation in a sustainable, decarbonised European and global energy mix and contributes to the political and regulatory discussions by continuous exchanges with the European institutions and other stakeholders.