**Fuel and operational flexibility of micro Gas Turbines: assessment of combustor performances, emissions, and stability**

Ir. Alessio Pappa

Do we still need combustion in a sustainable future? ﻿Human activities, principally through the emissions of greenhouse gases from the combustion of fossil fuels, have caused what has become the biggest challenge of our generation: global warming. Should combustion therefore disappear considering that, so far, combustion was essential to transport us, fuel our industry, or warm our houses? The urgency of reducing our carbon emissions compels us to consider more sustainable approaches, such as renewable energy technologies, gaining prominence as alternatives to combustion-based energy generation. Nevertheless, the unpredictable nature of renewable energy sources, like solar and wind, leads to fluctuations in the electricity supply. In addition, some sectors related to industry are challenging to electrify. Hence, even in a fully sustainable net-zero carbon economy, combustion will still have a major role, but not by burning fossil fuels. Indeed, to reach clean and sustained energy generation and help the energy transition, **combustion** must become more **flexible**, especially in terms of **fuel and operation**.

In decentralized energy systems in combination with small-scale Combined Heat and Power (CHP) production units, like micro Gas Turbines (mGTs), increased **operational flexibility** can be reached by implementing advanced cycle modifications such as cycle humidification or Exhaust Gas Recirculation (EGR). These cycle improvements involve that the mGT combustion chamber must face unconventional diluted conditions but has still to ensure complete, low-emissions, and stable combustion. In addition, accurate data assessing the impact of such diluted conditions for actual mGT combustor geometries and operating conditions are mandatory to address this need for flexibility.

The increasing share of renewable energies towards decarbonization and the related fluctuating electricity production drive for storing the excess electricity coming from renewable, such as performing Power-to-fuel to convert the excess electricity into Electro-fuels, like Green-hydrogen. However, hydrogen combustion in non-adapted burners is well-known to lead to the risk of flame instabilities, potentially resulting in flashback and irremediable facility damages. Therefore, on behalf of **fuel flexibility**, a single mGT combustor design must be able to work with different fuels such as hydrogen or hydrogen blends.

The objective of this PhD thesis is thus to assess and analyze, using high-fidelity Large Eddy Simulations (LES), the impact of various fuel and fuel blends to meet the need for **fuel flexibility**, and/or unconventional diluted conditions such as water and EGR to meet the need for **operational flexibility**, on the combustion stability, performance, and emissions, especially for mGT combustors.