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Carbon clean and flexible energy production using micro gas turbines: assessment of the performances

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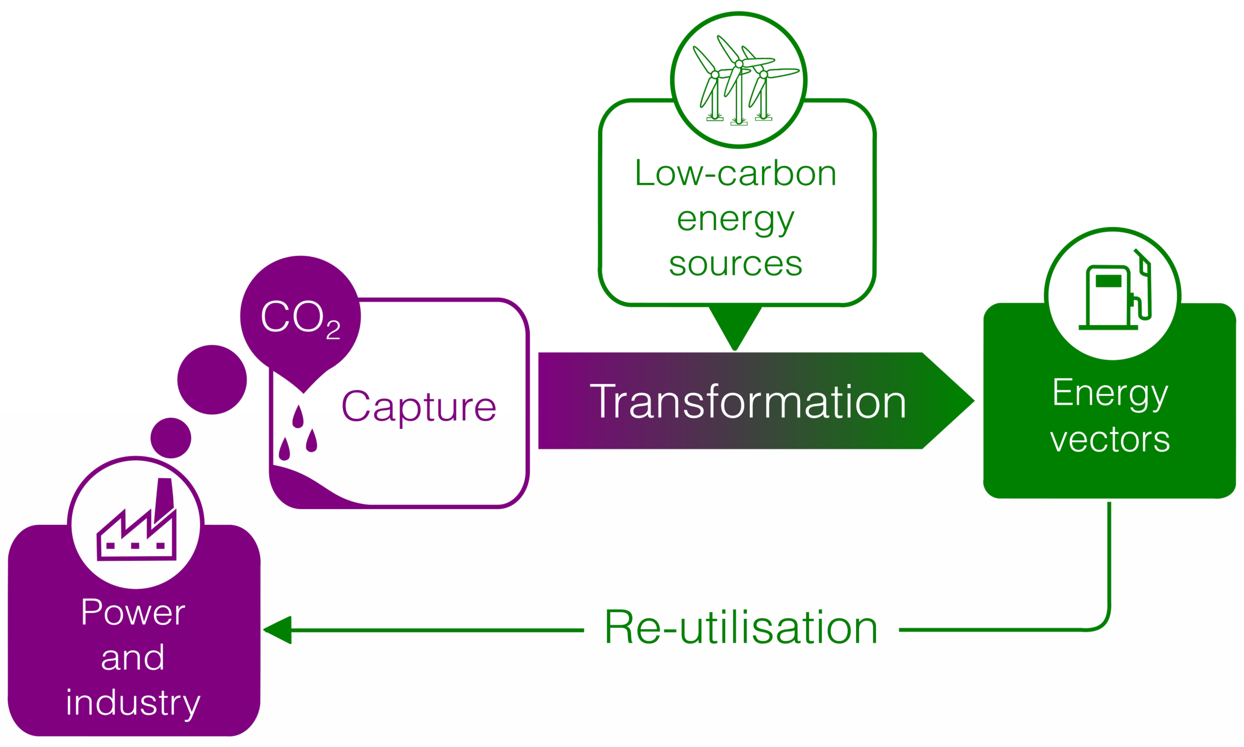
Objective

Designing an optimal humidified gas turbine cycle with Exhaust Gas Recirculation, diluted combustion and Carbon Capture Use and Storage maintaining high efficiency during flexible operation.



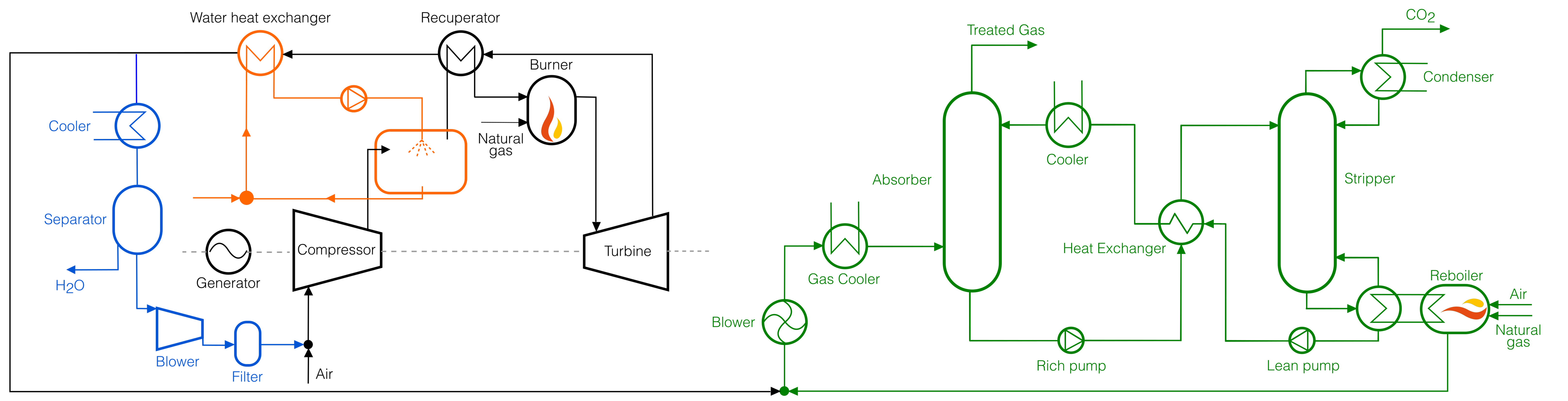
What is the CO_2 utilisation?

In a future in which the carbon dioxide (CO_2) cannot be freely released to the atmosphere, scientific and industrial progress has enabled us to imagine a solution in which CO_2 become an increasingly important carbon resource. A world in which we utilise CO_2 as a building block to create products and not only something to sequestrate.

Carbon Capture Utilisation and Storage (CCUS) will create new opportunities for economic growth, whilst supporting its transition to a circular, low-carbon economy. Once the CO2 has been captured, it can be transformed using the surplus of low-carbon energy sources into energy vectors which can be re-used in our power plants.

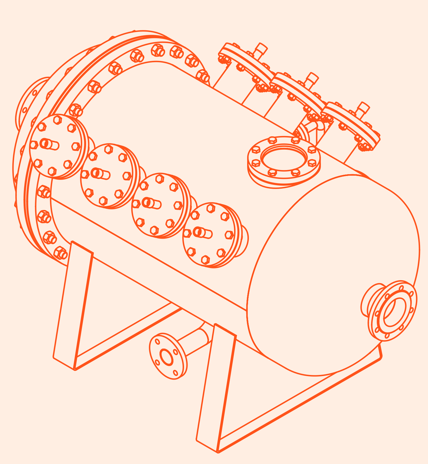
Micro Gas Turbines coupled with a Carbon Capture plant: a numerical study

The large employment of renewable energies will require a flexible, efficient and low-carbon production from fossil fuels. Micro Gas Turbines (mGTs) coupled with a Carbon Capture plant can be a good candidate in this context, but only few numerical and quantitative analyses are available which assess their real potential.



The conversion of the mGT into a carbon capture facility will involve different measures:
conversion in micro Humid Air Turbine (mHAT), application of the Exhaust Gas Recirculation (EGR) and coupling with a Carbon Capture (CC) plant.

Conversion in a micro Humid Air Turbine (mHAT)



Spray saturation tower at VUB lab

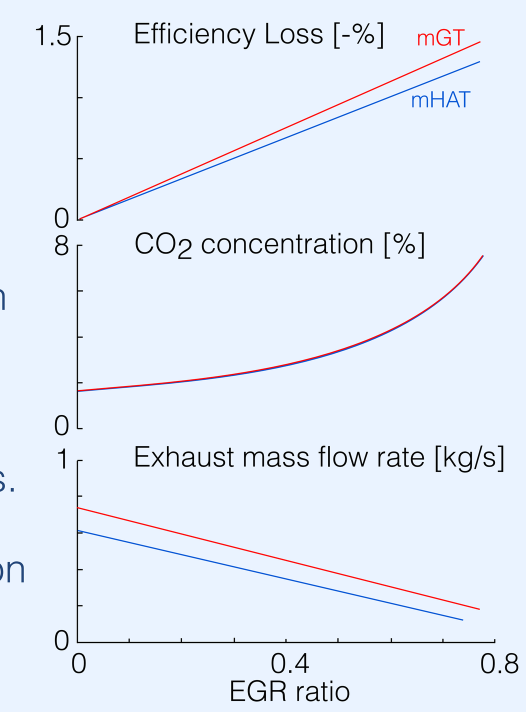
In order to increase the efficiency and the flexibility of the mGT, the waste heat in the exhaust gas, whenever not used for cogeneration, could be used to heat up water, which is then reinjected in the engine, behind the compressor.

The electrical efficiency of the plant shows an increase of 2.2 percentage points.

Exhaust Gas Recirculation (EGR)

Coupling traditional mGTs or mHATs with Carbon Capture plant is not optimal since the concentration of CO_2 is too low for an efficient capture.

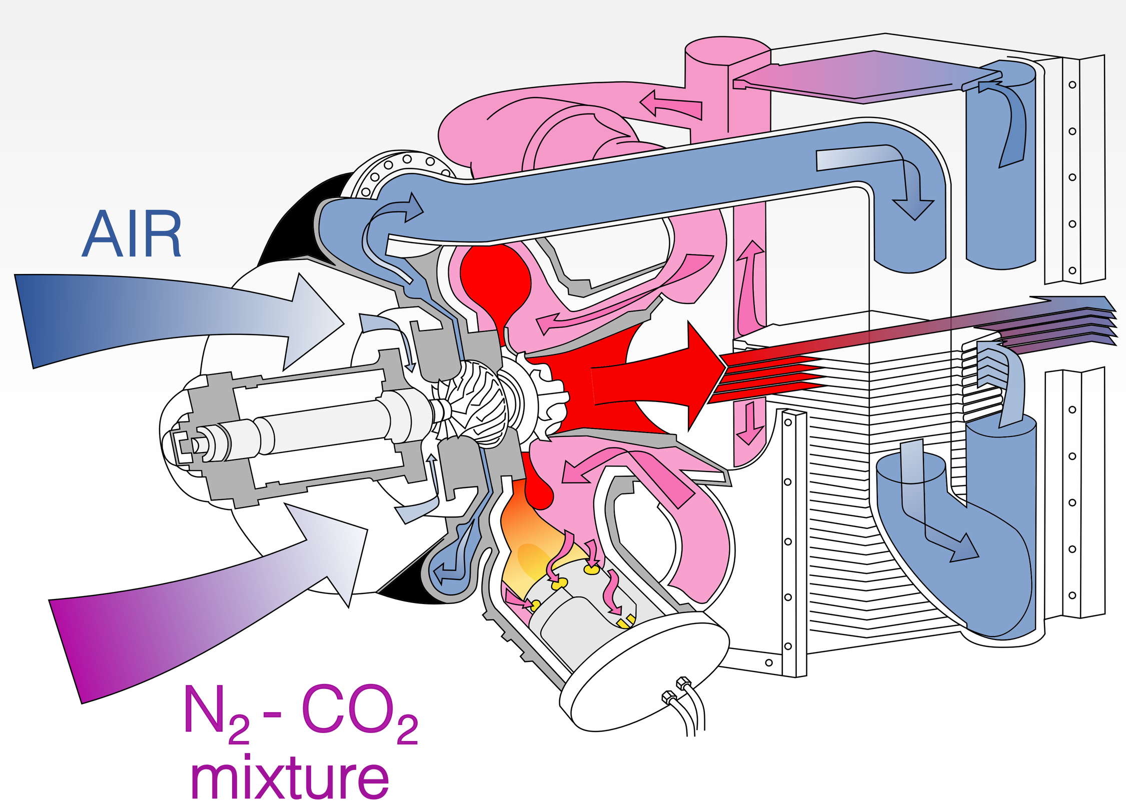
EGR is a smart solution which allows to increase the concentration of CO_2 and at the same time it reduces the mass flow rate of exhaust gas. Recirculating **60%** of the exhaust gas, the concentration of CO_2 increases from 1.5% to **4.3%**.



Carbon Capture (CC) plant

The next step has been adding the carbon capture plant to the previous model to investigate the global energy impact of a CC technology on the mGT or mHAT. A typical capture method is an absorber–stripper system where the absorbent is commonly a 30wt% aqueous MonoEthanolAmine (MEA) solution. The main energy consumption of the CC is the thermal energy to regenerate the solvent.

η_{el}	mGT	mHAT
Traditional plant	29.2%	32.2%
EGR + CC	21.3% (-7.9%)	23.9% (-8.3%)



Experimental campaigns with N_2 and CO_2 injections

The modifications of the mGT will also influence the operational conditions of the plant. For this reason, it is important to understand its behaviour during each operational condition.

Using the mGT installed at Vrije Universiteit Brussel (VUB), we will study experimentally the impact of EGR on the cycle and on the combustion stability. Before implementing the full EGR channel, N2 and CO_2 injections will be performed to assess the operational stability of the turbine.

Future numerical analyses will focus on the energy integration and optimization between the mGT/mHAT and the CC plant, exploiting the thermal energy of the exhaust gas not only for the humidication of the cycle but also to reduce the reboiler heat demand.

Conclusion

The mGT and mHAT models have been modified adding the EGR loop and a CC plant. Preliminary results show a **7.9%** and **8.3%** absolute electrical efficiency decrease respectively compared to the traditional cycles.