UKCCS RESEARCH CENTRE

THE UNIVERSITY of EDINBURGH
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# Integration Options for Low-Carbon Hydrogen and Power Synergies (WP AC4)

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## Project overview

- **Electricity and hydrogen are two key low-carbon vectors** to decarbonise energy used in the transport sector, space heating and industries (CCC, 2018).
- In the UK energy supply systems of the future, both vectors may be **generated** in **in low-carbon CCS industrial clusters, and may benefit from a shared infrastructure** for natural gas supply, electricity grid connection, and transport and geological storage of $CO_2$ (BEIS, 2018).
- This work **investigates the concept of sequential combustion applied to combined cycle gas turbine power plants (CCGT) and steam methane reformers (SMR),** where excess oxygen in the gas turbine flue gas is used as the source of oxygen for combustion in the SMR, for two integrated configurations**.**

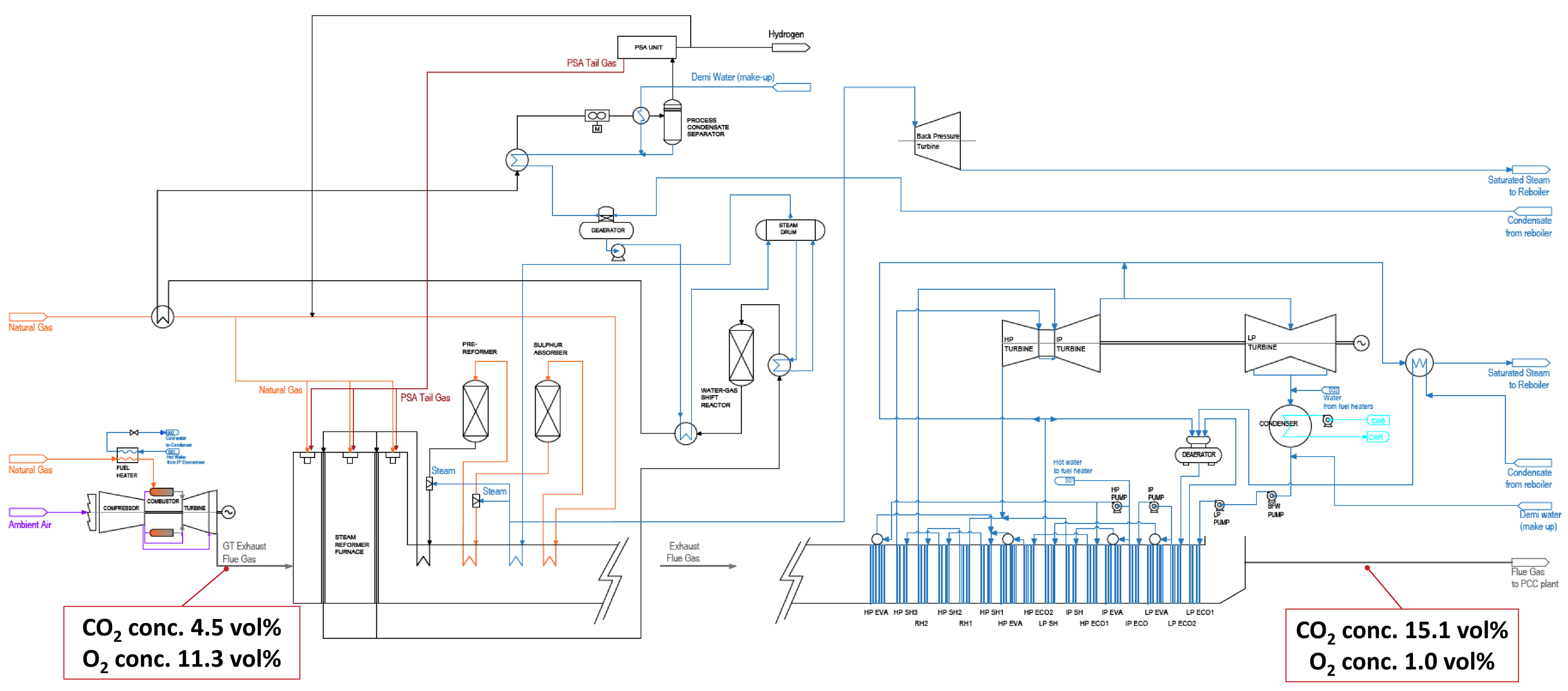
## Key objectives:

- The **objective** is to achieve capital cost reduction of the $CO_2$ capture system, by reducing the flue gas flow rate while maintaining a high $CO_2$ concentration at the inlet of the capture plant, and optimise the thermodynamic integration allowing for flexible generation of low-carbon hydrogen and electricity.

## SMR Hydrogen Plant and CCGT: Integrated Configurations

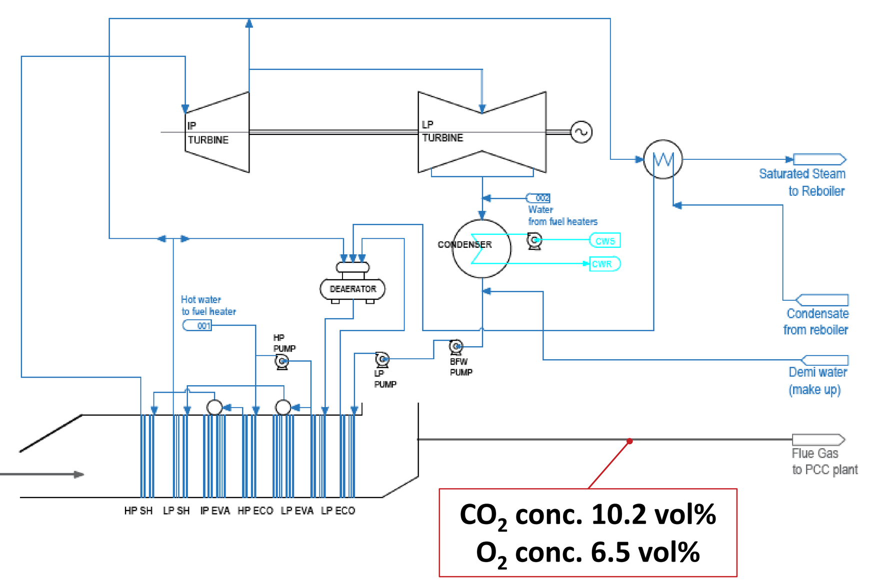
### A) SMR Hydrogen plant downstream of a H-class GT

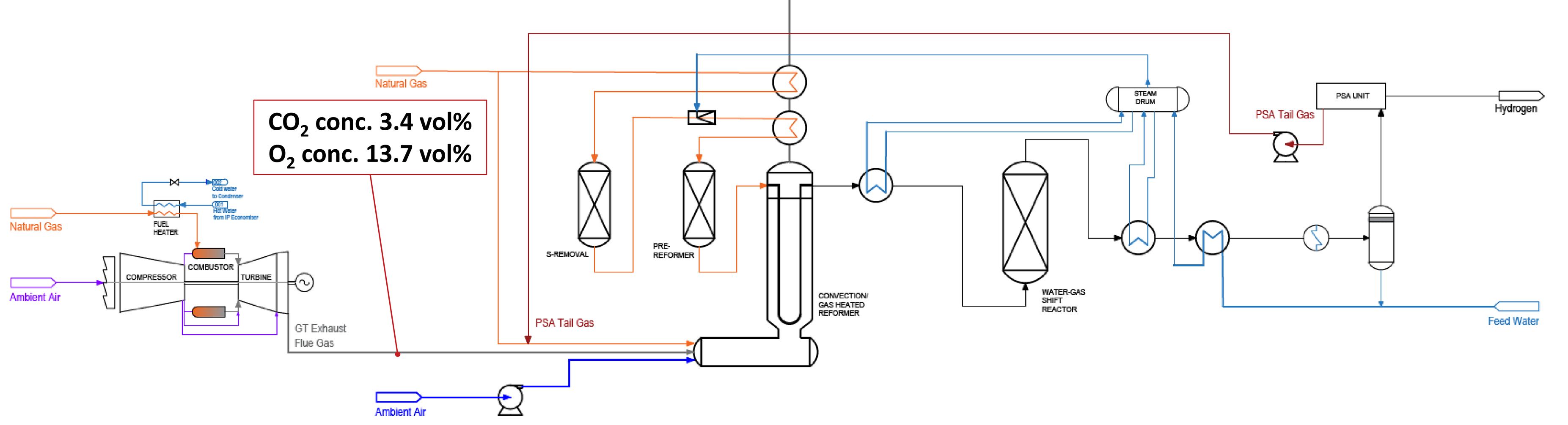
A purpose-built SMR (radiation heat transfer) downstream of an H-class commercially available gas turbine engine.




### B) Gas-heated reformer (GHR) downstream of an aeroderivative GT

A commercially available gas-heated reformer (convection heat transfer) downstream of a commercially available aeroderivative gas turbine engine.




## Research highlights

| Configurations: | | Steam Methane Reformer (SMR) | | | Gas heated reformer (GHR) | | |
|---|---|---|---|---|---|---|---|
| Description | | $H_2$ plant<br>4x SMR | CCGT<br>H-class GT | Integrated<br>H-class GT + SMR | $H_2$ plant<br>1x GHR | CCGT<br>Aero GT | Integrated<br>Aero GT + GHR |
| $H_2$ production | Nm³/h | 762212 | -- | 767250 | 73558 | -- | 73558 |
| Power output [1] | MWe | 27.3 | 584.5 | 679.3 | 0 | 57.3 | 71.5 |
| Thermal input - GT | MWth | 711 | 1033 | 1844 | 10.3 | 133.8 | 133.8 |
| Net thermal eff. [1] | $MWe/MWth_{NG}$ | -- | 56.6 | 65.7 | -- | 42.9 | 53.5 |
| $H_2$ production eff. | $MWth_{H2}/MWth_{NG}$ | 69.0 | -- | 66.6 | 78.9 | -- | 66.7 |
| Capture plant: | | | | | | | |
| Flue gas flow rate | kg/s | 615.9 | 848.9 | 1037 | 70.8 | 147.8 | 161.7 |
| $CO_2$ conc. | %vol | 18.9 | 4.5 | 15.1 | 14.1 | 3.4 | 10.2 |
| Absorber packing vol. | m³ | 11146 | 11690 | 18850 | 751 | 1142 | 1543 |
| Number of absorbers | | 1 | 2 | 2 | 1 | 1 | 1 |

Note [1]: With $CO_2$ capture and $CO_2$ compression
SMR: Steam methane reformer; GHR: Gas heated reformer; GT: Gas Turbine;

## Emerging findings

Compared to the based case configuration where the $H_2$ plant and the CCGT power plant are not integrated, the investigated configurations benefit from:

- **Reduction of ca. 30% of the flue gas flow rate** to the shared capture plant **and increase of $CO_2$ concentration to 15 vol% and 10 vol%** for each configuration, compared to 3.5 to 4.5 vol% at the gas turbine exhaust, respectively.
- The **absorber packing volume** to capture $CO_2$ from both the CCGT and the SMR plants **is reduced by 18%** for each configuration.
- For the same volume of $H_2$ production, the **net power output** increases by 11% and 25%, respectively.
- The **net thermal efficiency**, defined as the net power output divided by the natural gas fuel thermal input in both the GT and the SMR, **increases 9.2 %pt and 10.6 %pt** in the integrated configurations respectively.
- The **$H_2$ production efficiency**, defined here as the hydrogen thermal output divided by the natural gas (fuel and feed) thermal input to the $H_2$ process, **decreases 2.4 %pt and 12.2%pt in each configuration**, due to an increase in the NG fuel to maintain same overall heat transfer rate, and due to an increase in the NG feed to maintain the same $H_2$ production, respectively.

## Next steps

- Evaluation of the capital cost reduction for the integrated configurations
- Assess the feasibility of large scale deployment
- Investigate integration options for flexible generation of low-carbon hydrogen and electricity to cope with variations of both vectors in demand over time.
- Understand/identify key factors with large effect on the short- and long-term variability in demand for both vectors to overcome adverse effects.

**References**

[1] BEIS, 2018. Delivering Clean Growth: CCUS Cost Challenge Taskforce Report.
[2] Committee on Climate Change (CCC), 2018. Hydrogen in a low-carbon economy.
[3] IEAGHG, 2017. Techno - Economic Evaluation of SMR Based Standalone (Merchant) Hydrogen Plant with CCS. Tech. Rev. 2017-02 286.

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