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Gas turbines for carbon capture

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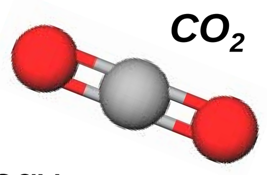
Introduction

MOTIVATION FOR RESEARCH



- **Strict CO_2 emission reduction targets** from stationary combustion sources.
- **Advance commercialisation** of **carbon capture and storage (CCS)** technology.
- **Decarbonisation** of our energy systems whilst providing **flexibility** in the energy mix, meeting **predicted increases in demand** and **development** of the **low carbon economy** today for the future of tomorrow.

RESEARCH AIM

- **Analysis and optimisation** of **selective exhaust gas recirculation (S-EGR)** configurations for application in **combined cycle gas turbine (CCGT)** power plants with **post-combustion CO_2 capture.**
- This will be achieved through **state of the art pilot plant scale experimental** research, **process simulation** and **techno-economic analysis**.

Methodology

EXPERIMENTAL

- **Conduct experimental** research at the **UKCCSRC Pilot-scale Advance Capture Technology (PACT)** facilities located in Sheffield, UK.
- **Design, procurement and installation** of highly-instrumented **micro gas turbine (mGT)** with **CO_2** injection delivery system (Figure 1).

FIGURE 1: HIGHLY INSTRUMENTED MICRO GAS TURBINE.

- **Monoethanolamine (MEA)** is the **benchmark solvent** used for **CO_2 capture** (Fig 2).
- **Perform** experimental test campaigns on the **mGT** and **post-combustion CO_2 capture plant** (Figure 3) to determine how **performance** and **flue gas conditions** are affected under different S-EGR scenarios.

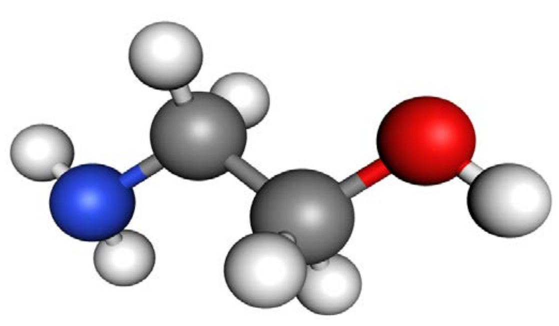


FIGURE 2. MEA ($NH_2CH_2CH_2OH$)

FIG 3: PACT POST-COMBUSTION CO_2 CAPTURE PLANT.

- **Compare** the results to **non-selective EGR scenarios**.
- **Undertake dynamic testing** including **load following, cold mGT start up and shut down** under specific S-EGR conditions, and evaluate how **dynamic scenarios** can offer **flexibility** during electricity generation in CCGT power plants.

PROCESS SIMULATION AND TECHNO-ECONOMICS

- **Design and create** a process model of the PACT facilities using **gPROMS (gCCS)®** process simulation software.
- **Use** the **experimental results** to **validate, verify and optimise** the process model.
- **Complete** a **techno-economic analysis** of **series** and **parallel** S-EGR configurations to determine **commercial scale feasibility**.

Results

EXPECTED TRENDS

- **Higher CO_2** concentrations **~8-12%vol.** in flue gas are observed under **S-EGR conditions**.
- **Parallel** (Figure 4A) and **series** (Figure 4B) S-EGR configurations can be **scaled up** to commercial CCGT power plants.
- **NOx** and **O_2** availability **decreases**, whereas, concentrations of **CO** and **unburnt hydrocarbons (UHC) increase** under S-EGR experimental conditions.
- **Specific reboiler duty decreases** using S-EGR configurations.

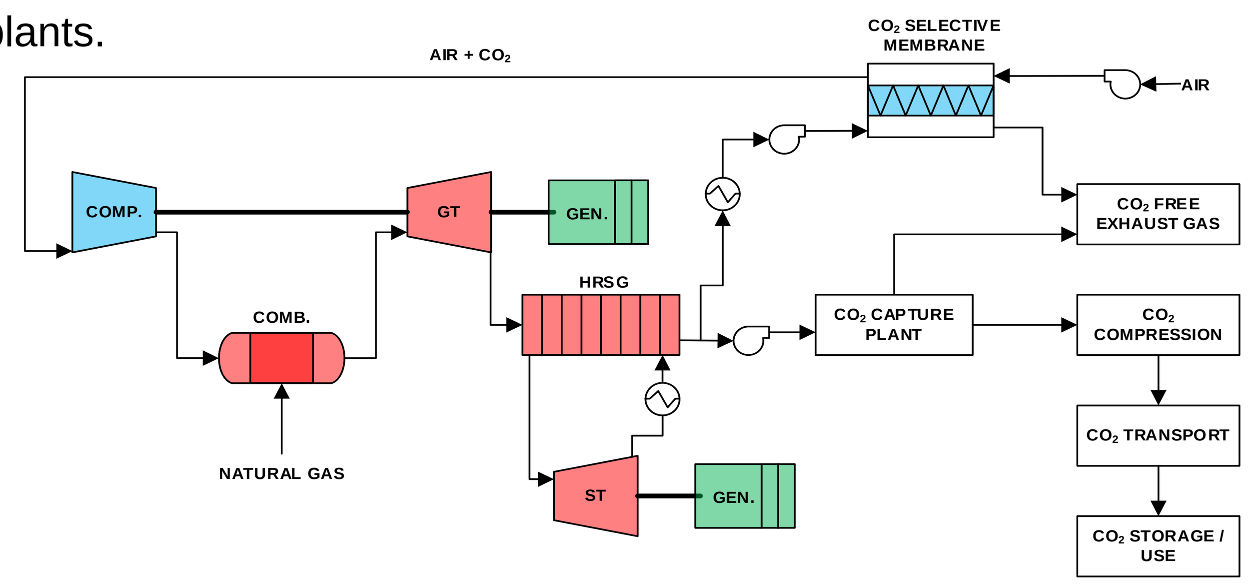


FIGURE 4A: PROCESS SCHEMATIC FOR PARALLEL S-EGR CONFIGURATION.

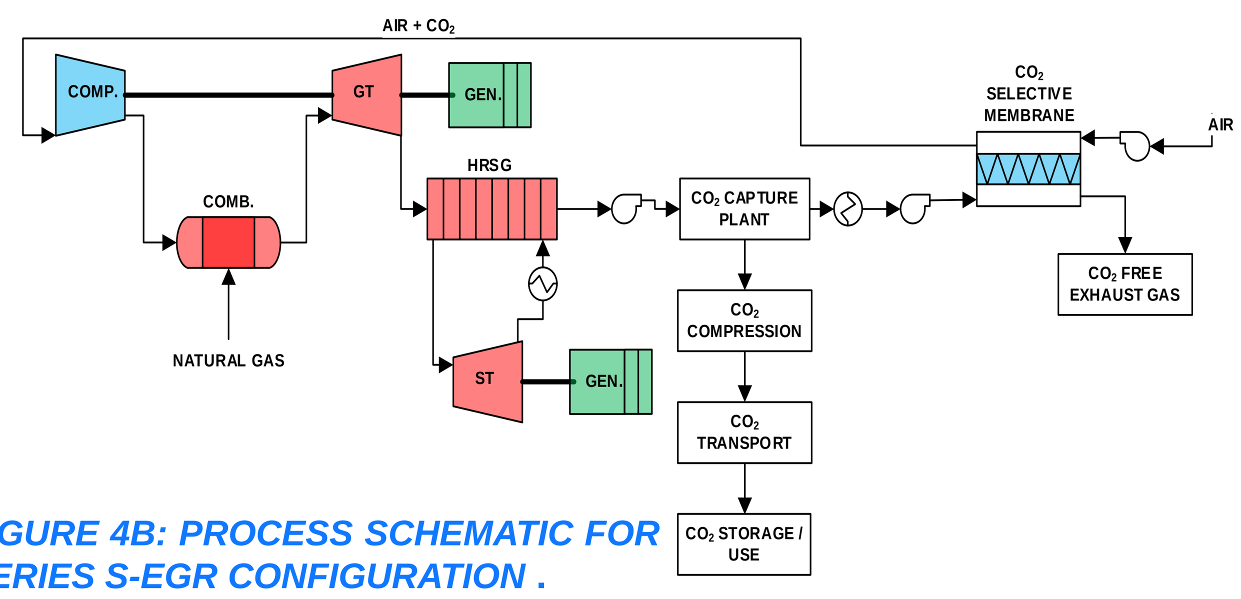


FIGURE 4B: PROCESS SCHEMATIC FOR SERIES S-EGR CONFIGURATION .

- **Dynamic response** of post-combustion CO_2 capture plant shows **flexible operation** with S-EGR is **possible without any major obstacles**.
- **Techno-economic analysis** indicates S-EGR configurations can be **competitive** compared to post-combustion CO_2 capture **with and without EGR**, however, notable **improvements** and **cost reduction** to CO_2 selective membranes is required.

INITIAL RESULTS

- **Preliminary baseline testing completed** without S-EGR or additional instrumentation.
- **Figure 5** illustrates typical **CO_2** and **O_2** concentrations in the **mGT exhaust gas stream** under standard operating conditions without S-EGR.

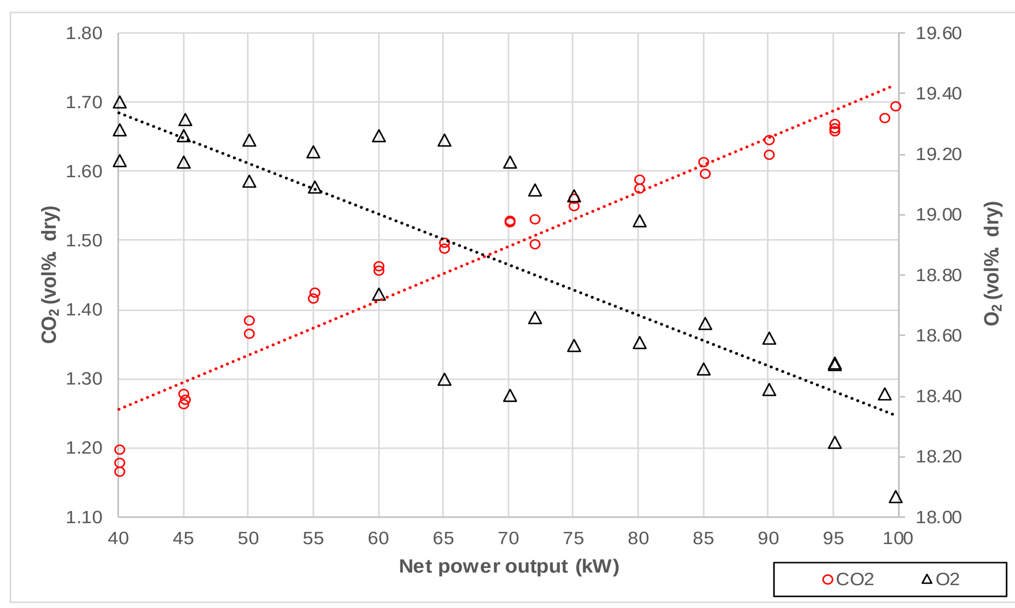


FIGURE 5: CO_2 AND O_2 LEVELS AS VARYING POWER OUTPUT WITHOUT S-EGR.

Research Novelty

- **Pilot scale experimental research** investigating how the **performance** of the **mGT** and **post-combustion CO_2 capture** is affected under **S-EGR conditions.**
- Comprehensive **experimental, process simulation** and **techno-economic data** which contributes towards the **commercialisation of gas-CCS nationally and internationally**.

Publications

- **ASME Turbo Expo 2017 conference paper** accepted and to be presented in Charlotte, North Carolina, USA, this June. *Diego, M. E.; Bellas, J.; Pourkashanian, M. 2017. Process analysis of selective exhaust gas recirculation for CO_2 capture in natural gas combined cycle power plants using amines.*
- **9th Trondheim Conference on Carbon Capture, Transport and Storage** abstract accepted for oral presentation and to be presented in Trondhein, Norway, this June. *Diego, M. E.; Bellas, J.; Pourkashanian, M. 2017. Investigation of CO_2 capture in natural gas combined cycles with selective exhaust gas recirculation.*
- **Greenhouse gases: Science and Technology** journal paper under peer-review. *Diego, M. E.; Akram, M.; Bellas, J.; Finney, K. N.; Pourkashanian, M. 2017. Making gas-CCS a commercial reality: The challenges of scaling up.*

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