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COST OF CO_2 CAPTURE FOR SMALL-SCALE DISPATCHABLE POWER GENERATORS

Authors: Mathew Dennis Wilkes[a], Jude Ejeh[a], Diarmid Roberts[a], Solomon Brown[a]*

[a] Department of Chemical and Biological Engineering, University of Sheffield, Sheffield, S1 3JD, United Kingdom
* s.f.brown@sheffield.ac.uk

Introduction

Open-cycle gas turbines (**OCGT**) are quick starting dispatchable generators that provide system security and flexibility; aiding in the uptake of more renewable and nuclear power generation sources [1]. However, in order to reach Net-Zero by 2050, these peaking plants will require Carbon Capture and Storage **(CCS).** Therefore, this study looks at the cost of incorporating post-combustion capture (**PCC**) on an OCGT power plant. Study objectives:

- Calculate the levelised cost of electricity (**LCOE**) for an OCGT+CCS system.
- Calculate the cost of CO_2 avoidance (**CCA**) for an OCGT+CCS system.
- Compare OCGT+CCS against other low-carbon power sources.

IS DISPATCHABLE GAS-CCS AFFORDABLE?

Process

This study utilises process models developed in our previous studies, and extracts the key operating and design parameters required in the economic model. The OCGT+CCS plant (Figure 1) consists of:

- **Power plant** – 10.4 MWe OCGT with highly transient operation, producing 33.8kg/s flue gas (6.78 wt.% CO_2) [2].
- **CO_2 capture plant** – benchmark 30 wt.% MEA with 92.5% capture rate [2].
- **CO_2 conditioning plant** – 4 stage compression system, producing a CO_2 stream at 111 bar and 50 ppm moisture, ready for pipeline transportation [3].

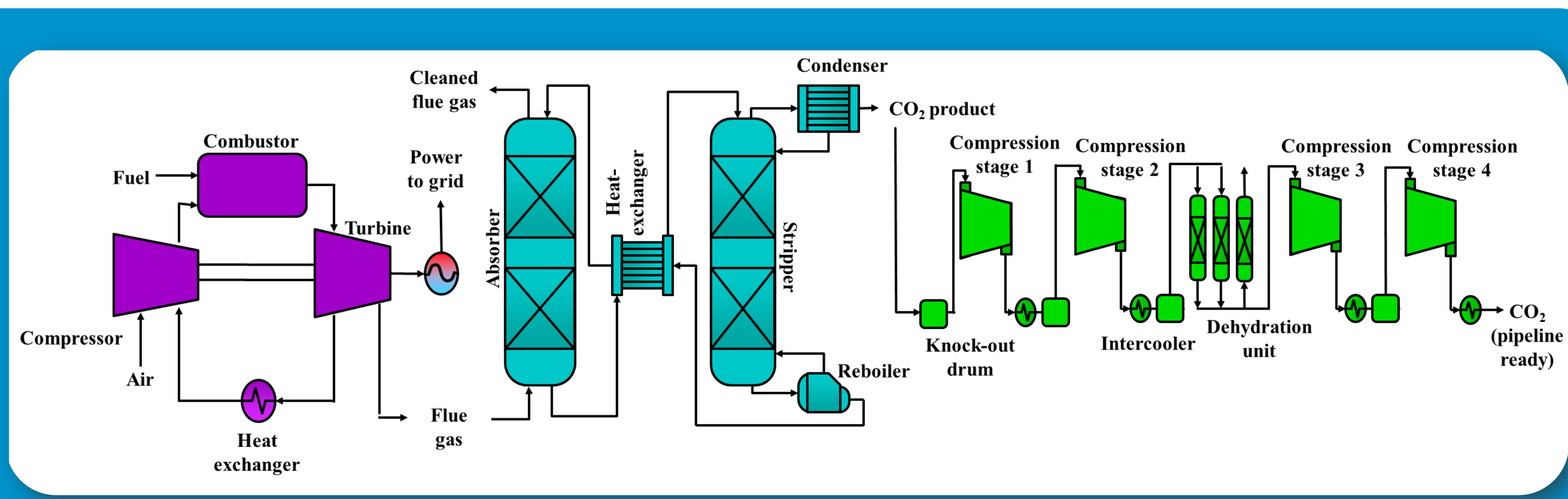

Figure 1: Flowsheet for an OCGT+CCS power plant, highlight the major pieces of equipment

Cost Breakdown

To economically evaluate OCGT+CCS, you need to identify the major pieces of equipment and calculate:

- Purchased equipment cost (**PEC**) – using correlations from Towler & Sinnot [4].
- Total capital cost (**TCC**) – using correlations from Chauvel et al. [5].
- Fixed operating and maintenance (**FOM**).
- Variable operating and maintenance (**VOM**).

FOM and VOM are calculated using data extracted from the process models.

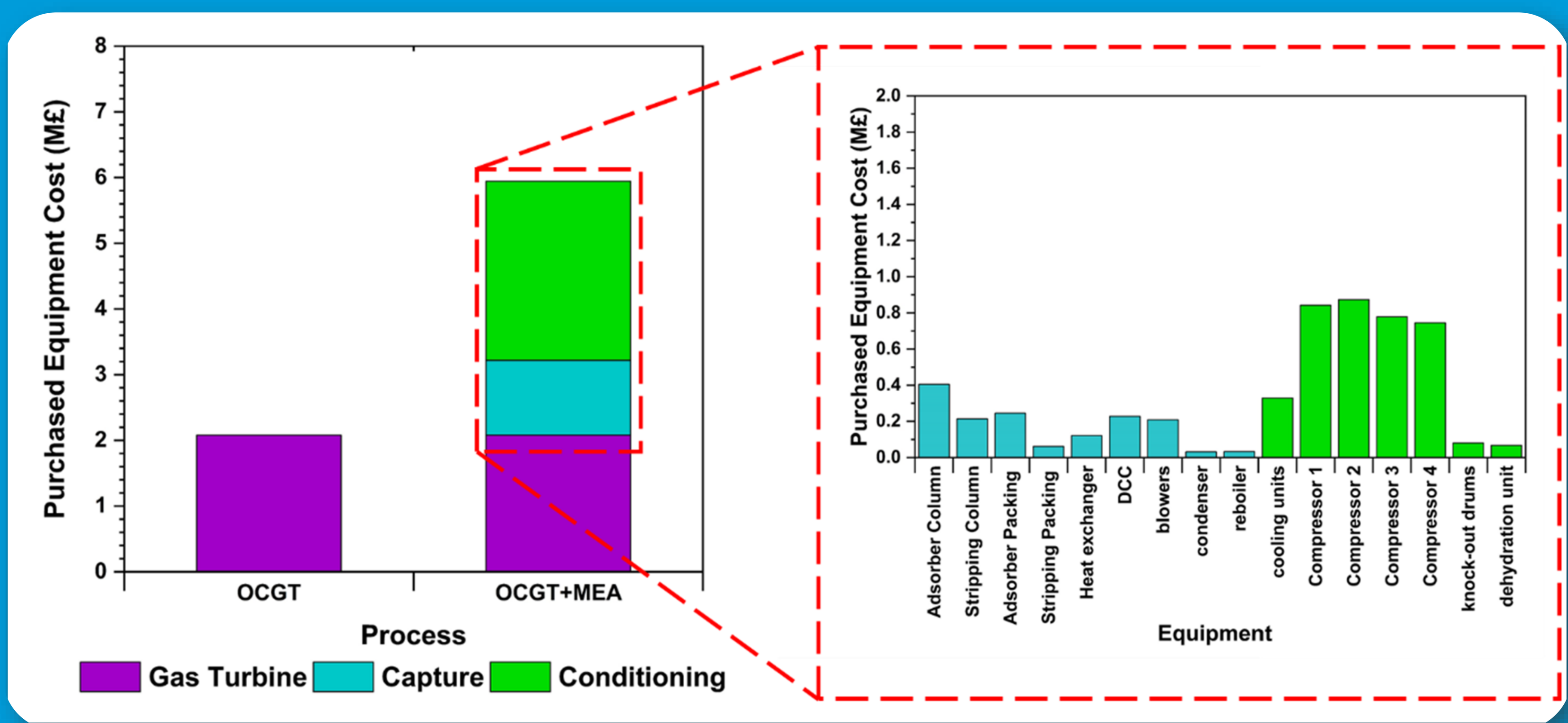

Figure 2: PEC breakdown for an OCGT power plant with and without CO_2 capture and conditioning

The TCC for the OCGT is 6.53 M£ or 628 £/kW, comparable to estimates from industry. The total PEC for the OCGT, MEA, and conditioning plants are 2.08, 1.55 and 2.32 M£, respectively. As shown in Fig. 2, the compressor costs dominate the PEC; indicating, these small-scale emitters would benefit from sharing the conditioning load or incorporating CO_2 utilisation.

LCOE and CCA

The **LCOE** is the sum of the net present value (NPV) of costs divided by the sum of the NPV of electricity generated and sold:

$$LCOE = \frac{NPV_{total\ costs}}{NPV_{generation}} = \frac{\sum\left(\frac{TCC_t}{(1+r)^t} + \frac{FOM_t}{(1+r)^t} + \frac{VOM_t}{(1+r)^t}\right)}{\sum\frac{(net\ electricty\ generated)_t}{(1+r)^t}} \quad [1]$$

Where r is the discount rate, and t is the time period. Once the LCOE is calculated for the reference (ref) case and the OCGT+CCS (CCS) case, you can then calculate the CCA:

$$CCA = \frac{(LCOE)_{ccs} - (LCOE)_{ref}}{\left(\frac{tCO_2}{MWh}\right)_{ref} - \left(\frac{tCO_2}{MWh}\right)_{ccs}} \quad [2]$$

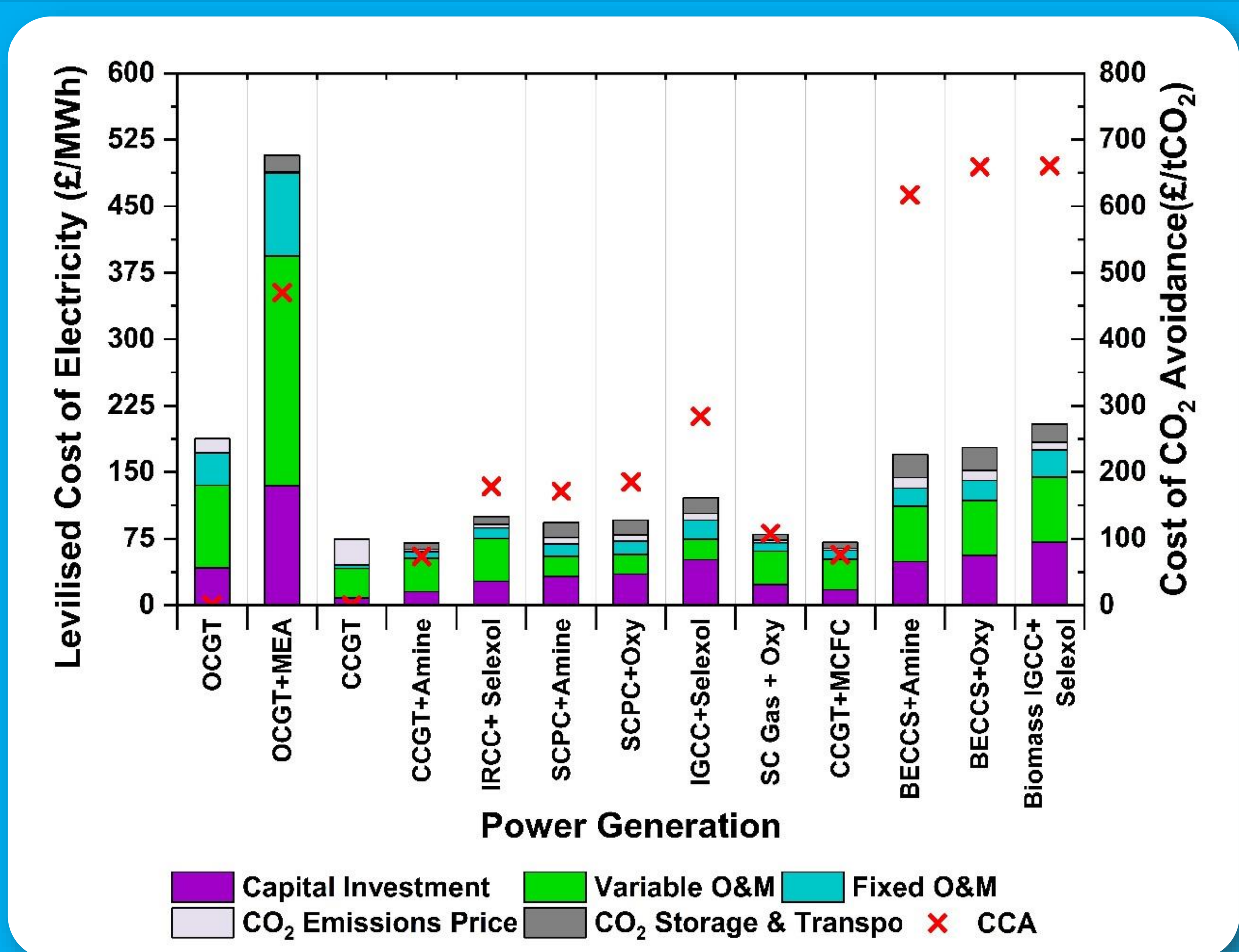

Figure 3: LCOE and CCA comparison between OCGT+CCS and other forms of low-carbon power from BEIS [6]

Table 1 highlights the key performance indicators (KPI) of OCGT+CCS. The significant increase in VOM and FOM (electricity, heat duty, and solvent stock) makes the LCOE of OCGT+CCS much higher than other low-carbon sources (70 -204 £/MWh). However, the CCA for OCGT+CCS is lower than bioenergy with CCS (BECCS) which ranges between 617-661 £/tCO_2.

Table 1: KPIs for OCGT+CCS

KPI	OCGT	OCGT+CCS [a]	OCGT+CCS [b]
Net power output (MWe)	10.4	9.11	9.11
CO_2 emission (tCO_2/yr)	12,400	981	981
LCOE (£/MWh)	172	487	507
CCA (£/tCO_2)	-	470	448

Note: [a] carbon price set to zero, [b] carbon price set to £21.70/tCO_2 BEIS [6]

Conclusion

- Including CCS for dispatchable gas turbines increases the **LCOE** by **183-195%**.
- The CO_2 conditioning plant accounts for **60%** of the additional capital investment.
- In order to achieve **Net-Zero by 2050** cost effectively, future work should investigate:
  - Alternative forms of dispatchable power, e.g. energy storage, H_2 turbines, pumped hydro.
  - Different CO_2 capture and utilisation technologies, e.g. fuel cells or chemical looping.
  - Integration of small-scale utilisation options.

Economic Issues with dispatchable OCGT+CCS:

- **Economies of scale** – the small plant size means the cost per MWh is a lot higher.
- **Low capacity factor** – OCGTs are peaking plants and they operate <1,500 hours annually, significantly less than other power sources.

EPSRC Engineering and Physical Sciences Research Council

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