Opportunities for BECCS in large-scale low carbon hydrogen production

EPSRC Engineering and Physical Sciences Research Council

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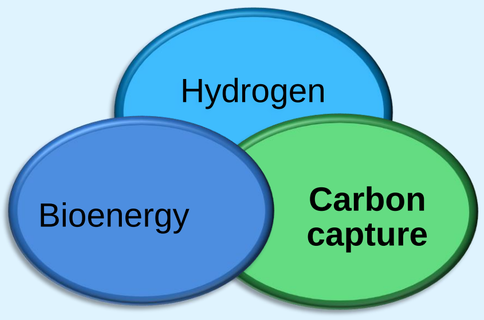
1. Introduction

Hydrogen is a widely used feedstock and it may fuel a future low carbon 'hydrogen economy'.

Most hydrogen is produced via carbon-intensive steam reforming of fossil fuels. The IEA recognises that CCS will play an increasingly important role in reducing the impact of steam reforming[1].

Can we go a step further and combine CCS with the steam reforming of bioenergy feedstocks, such as bio-oil?

This could enable very low or negative emissions in large-scale H_2 production.



4. Conclusions

An initial evaluation of BECCS in bio-oil steam reforming has examined:

- Key stream characteristics of the three potential capture locations
- The role of biogenic and fossil-based emissions.

The use of a novel feedstock presents novel opportunities and challenges for carbon capture in steam reforming:

- The opportunity to capture biogenic emissions.
- Different stream compositions due to feedstock carbon content.
- Different stream properties due to different optimal operating points.

5. Future work

- Development of process models of bio-oil steam reforming with CCS in Aspen Plus.
- Evaluation of process performance.
- Techno-economic analysis.

It is also proposed to consider sorption-enhanced chemical looping steam reforming (SE-CLSR) as an alternative novel reforming route.

2. Bio-oil steam reforming

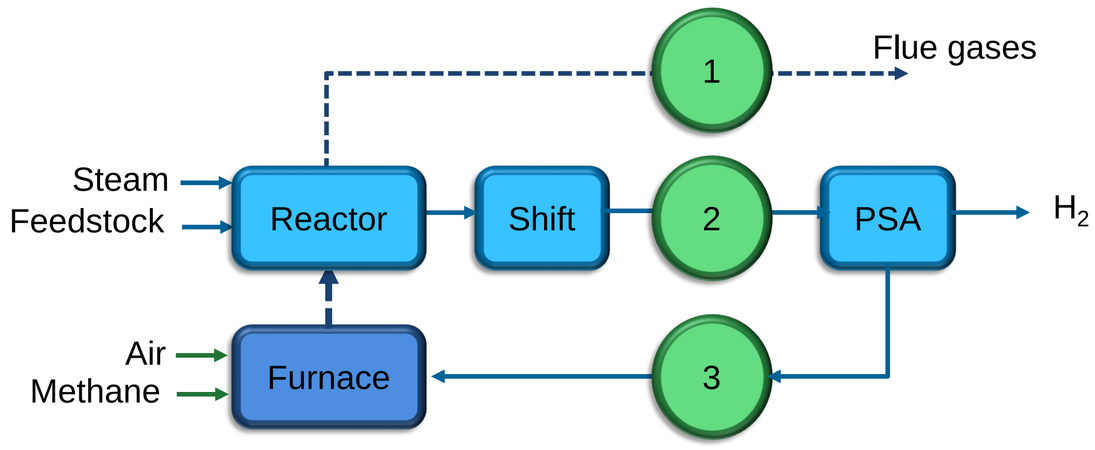


Figure 1 Schematic of bio-oil steam reforming

Circled numbers signify streams which are the main candidates for CO_2 capture[2].

There are two sources of direct CO_2 emissions in the process:

- Combustion of fuel gas, comprised of PSA off-gas and methane top-up.
- The steam reforming reaction:

$$C_nH_mO_k + (2n-k)H_2O \rightarrow (2n+0.5m-k)H_2 + nCO_2 \qquad \textit{(Reaction 1)}$$

In bio-oil steam reforming, the latter would be entirely biogenic.
The former includes biogenic emissions (from the combustion of PSA off-gas), and fossil-based emissions (from the combustion of methane top-up to the furnace).

3. Process evaluation

The process in ***Figure 1*** was simulated in Aspen Plus. Two different feedstocks were used: methane, and acetic acid as a model compound for bio-oil.

Table 1 shows the characteristics of the three streams labelled in ***Figure 1***.

- The acetic acid process has higher concentrations of CO_2, because the feedstock contains more carbon.
- Stream 1 (the flue gas) offers the opportunity for near total carbon capture, but the CO_2 concentration and partial pressure is low.
- Stream 3 (PSA off-gas) has high CO_2 concentration but is at low pressure.

Table 1 Characteristics of CO_2-containing streams in steam reforming (S/C = 3, Reformer at 900ºC and 30 bar

Feedstock	Stream	% of total CO_2	CO_2 concentration (mol%)	CO_2 partial pressure (bar)
Methane	1	100	16.3	0.165
	2	58.5	17.0	4.54
	3	58.5	44.2	0.448
Acetic acid	1	100	22.0	0.223
	2	71.4	32.1	8.57
	3	71.4	67.3	0.682

Acetic acid produces more direct CO_2 emissions than methane (***Figure 2***). However, the CO_2 emissions in acetic acid steam reforming are a mix of biogenic and fossil-based (***Figure 3***).

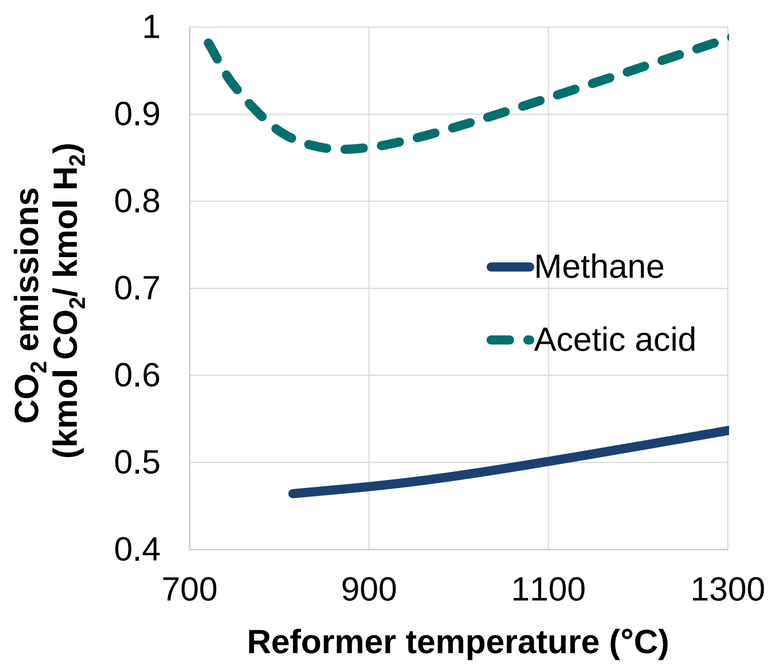


Figure 2 Direct CO_2 emissions in steam reforming of methane or acetic acid (S/C = 3 , P = 30 bar)

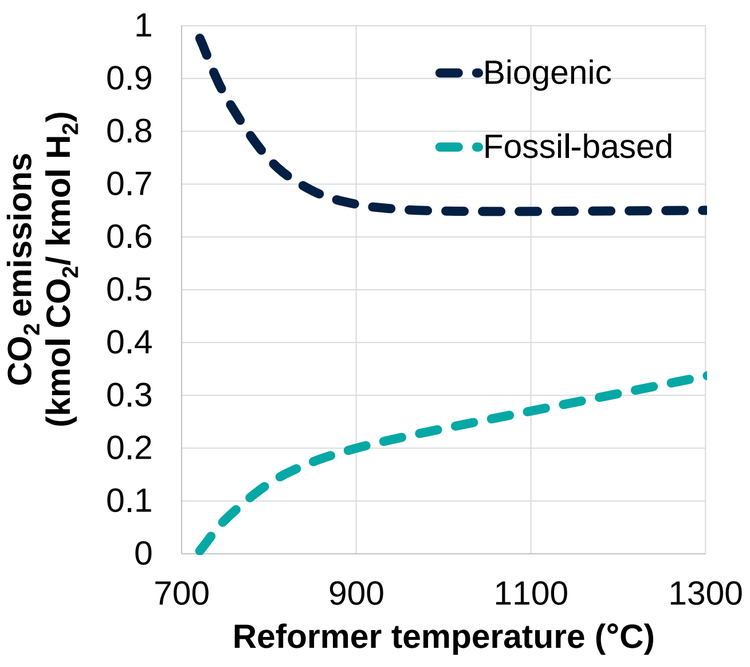


Figure 3 Biogenic and fossil-based emissions in steam reforming of acetic acid (S/C = 3, P = 30 bar)

References

1. IEA, 2015. Technology Roadmap - Hydrogen and Fuel Cells [Online]. Available from: http://www.springerreference.com/index/doi/10.1007/SpringerReference_7300.
2. Soltani, R., Rosen, M.A. and Dincer, I. 2014. Assessment of CO2 capture options from various points in steam methane reforming for hydrogen production. International Journal of Hydrogen Energy. 39(35),pp.20266–20275

Acknowledgments

This project is supported by the EPSRC via the CDT in Bioenergy at the University of Leeds, EP/L014912/1. The authors are also grateful to the UKCCSRC for supporting Miss Spragg's attendance via the ECR Meeting Fund.