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Low-carbon hydrogen economy: exploring potential synergies for electricity and hydrogen production with carbon capture

Laura Herraiz[a,*], Hannah Chalmers[a], Jon Gibbins[b], Mathieu Lucquiaud[a]

[a]*The University of Edinburgh, School of Engineering, The Kings Building, Edinburgh EH9 3JL, United Kingdom*
[b]*Department of Mechanical Engineering, University of Sheffield, Sheffield S1 3JD, United Kingdom*

Abstract

Reducing emissions from power generation has a key role in reaching near full-decarbonisation of the whole energy system, offering the possibility of extending low-carbon electricity to transport, building (heating and cooling) and industry sectors. For the long-term decarbonisation of part of the energy system where electrification is not feasible and/or prohibitively expensive, low-carbon hydrogen has a potentially valuable role. Besides being a raw material to energy intensive industries, hydrogen can replace natural gas for heating in buildings and industrial processes and be used as liquid fuel in heavy transport.

Electricity and hydrogen are therefore two key low-carbon energy vectors. In future energy supply systems, both vectors may be generated in the same location: in low-carbon CCS industrial clusters with a common infrastructure [1]. Future CCS clusters with a shared infrastructure for natural gas supply, electricity grid connection, and transport and geological storage of CO_2 are natural locations for both decarbonized hydrogen production in methane steam reforming facilities and decarbonized gas-fired power generation.

Deploying a hydrogen distribution network requires production of sufficient volumes of low-carbon hydrogen at a competitive price. Renewable-based electrolysis for green hydrogen production is currently expensive and challenging to supply the potential scale of hydrogen demand. Steam methane reforming (SMR) of natural gas or light hydrocarbon is currently the leading technology. Modern SMR facilities have achieved high efficiencies, reducing CO_2 emissions down to nearly 10% above the theoretical minimum, further reduction would only be possible with CCS [2]. SMR with CCS would allow for industrial scale volumes of low-carbon hydrogen, so called blue hydrogen, and lay the foundation for a future hydrogen economy [3].

This work investigates the scope for cost reduction through synergistic design and operation of hydrogen and electricity generation in natural gas combined cycle plants, equipped with CCS. A reduction in the capture plant size and a more efficient heat integration are possible in an integrated system where the excess oxygen in the gas turbine exhaust flue gas is used as the comburent in the SMR furnace, resulting in a single CO_2 emissions point, as illustrated in the block flow diagram in Figure 1. The flue gas stream treated in the post-combustion carbon capture plant will have a reduced flow rate and a relatively high CO_2 concentration of approximately 15 vol%. Relevant modelling work has been undertaken using gPROMS, based on recently developed modelling approaches. Potential benefits include process intensification, shared sub-systems and increased overall net efficiency of the integrated system. Linking hydrogen and power production with CCS also may help to overcome adverse effects of short- and long-term variability in demand for both products, e.g. Leeds H21 Citygate project [4].

Keywords: Hydrogen economy, Low carbon hydrogen, low carbon electricity, Steam Methane Reforming, Natural Gas Combined Cycle, post-combustion carbon capture.

* Corresponding author. Tel.: +44(0)1316507444
E-mail address: l.herraiz@ed.ac.uk

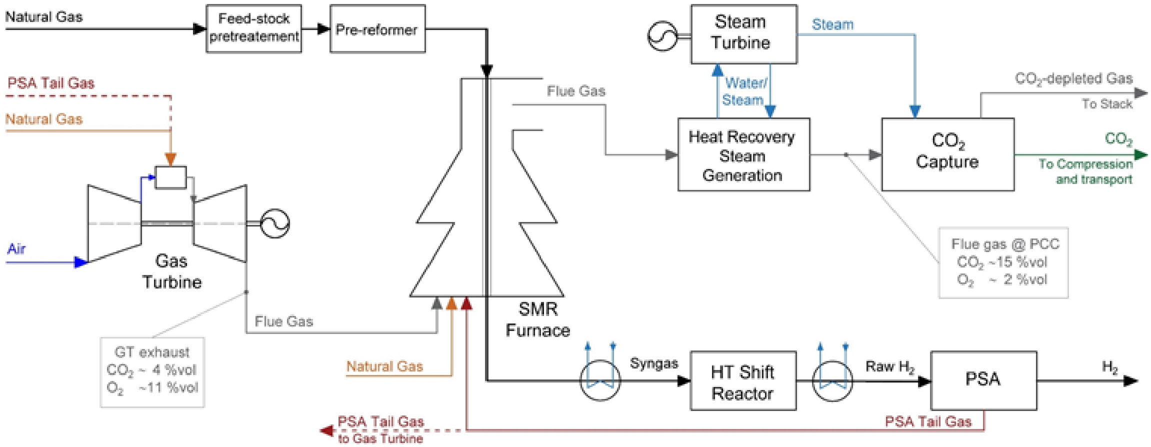

Figure 1. Schematic diagram of a synergistic process design for low carbon hydrogen and electricity production.

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