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Techno-economic analysis of polygeneration systems with carbon capture and storage and CO_2 reuse

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HIGHLIGHTS

- Polygeneration framework provides flexibility in product diversion.
- Economic impacts reduce in order: acetic acid/methanol > hydrogen > electricity.
- Economic potential increases from cogeneration to polygeneration systems.
- Feedstock use efficiency increases from cogeneration to polygeneration systems.
- CO_2 reuse pathways are more sensitive to CO_2 taxation, compared to CCS based systems.

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ABSTRACT

Several decarbonised polygeneration schemes exploiting carbon capture and storage (CCS) or CO_2 reuse technologies for the generation of clean fuels, chemicals, electricity and heat have been systematically analysed for techno-economic feasibility. Process simulation, energy integration and economic analysis were undertaken to analyse the effect of process configurations and operating conditions on the economic potential (*EP*) and risks. CO_2 capture and reuse producing methane using Sabatier's reaction shows less favourable economics compared to the counterpart CCS based scheme, both producing electricity, hydrogen, acetic acid and methanol in common. Post-combustion CO_2 tri-reforming into methanol production in addition to electricity generation shows overall favourable economics compared to the counterpart integrated gasification combined cycle (IGCC) with CCS scheme. Thus, increasing product portfolio from energy products in a cogeneration plant to chemical products evolved from thermodynamic and process integration synergies increases the techno-economic viability. Bio-oil can be processed as an alternative low carbon feedstock. While bio-oil creates environmental incentives, its economic competitiveness can be enhanced by introducing credits on product prices.

1. Introduction

Dwindling global oil reserves, economic and environmental concerns have generated strong research and development focus in clean coal, natural gas and biomass polygeneration technologies, producing transportation fuels, chemicals, heat and electricity. Polygeneration systems incorporating CCS and CO_2 recycling and reuse technologies provide an ability of cascading and recycling CO_2 and flexible switching between a diverse range of feedstocks and products [1–4]. Amongst various fossil resources and technologies, coal with CCS has been recognised to make a significant contribution to the increasing demand for electricity [5]. The ScottishPower has engaged into a demonstration project that uses Scottish coal and biomass co-firing technology integrated with advanced CCS options [6]. A large scale co-processing plant planned in Scotland is an example of UK's energy future goals. However, considering the uncertainty in storing CO_2, its recycling and reuse for chemical production has started to receive high priorities in some regions, US, Denmark, Australia, etc. CO_2 can be reused for enhanced oil recovery in oil extraction process; microalgae production; production of urea, methanol, dimethyl ether, Fischer–Tropsch liquids, methane (Sabatier's reaction), syngas (tri-reforming process) and hydrogen [1,2,7,8]. A recent breakthrough in the area of CO_2 reuse is the launching of the George Olah Plant in Iceland in 2010, for the production of methanol from captured CO_2 from industrial flue gases [9]. In addition, lignocellulosic biomass can be processed for achieving realistic carbon reduction [10–15]. Bio-oil, a higher energy density liquid, from biomass fast pyrolysis processes can be converted to methanol or liquid transportation fuels (diesel and gasoline) [16–18]. Although there have already been a number of papers published in the area of polygeneration,

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