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Life cycle assessment (LCA) of an integrated biomass gasification combined cycle (IBGCC) with CO_2 removal

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Abstract

Based on the results of previous studies, the efficiency of a Brayton/Hirn combined cycle fuelled with a clean syngas produced by means of biomass gasification and equipped with CO_2 removal by chemical absorption reached 33.94%, considering also the separate CO_2 compression process. The specific CO_2 emission of the power plant was 178 kg/MWh. In comparison with values previously found for an integrated coal gasification combined cycle (ICGCC) with upstream CO_2 chemical absorption (38–39% efficiency, 130 kg/MWh specific CO_2 emissions), this configuration seems to be attractive because of the possibility of operating with a simplified scheme and because of the possibility of using biomass in a more efficient way with respect to conventional systems. In this paper, a life cycle assessment (LCA) was conducted with presenting the results on the basis of the Eco-Indicator 95 impact assessment methodology. Further, a comparison with the results previously obtained for the LCA of the ICGCC was performed in order to highlight the environmental impact of biomass production with fossil fuels utilisation. The LCA shows the important environmental advantages of biomass utilisation in terms of reduction of both greenhouse gas emissions and natural resource depletion, although an improved impact assessment methodology may better highlight the advantages due to the biomass utilisation.

Keywords: LCA analysis; Biomass gasification; CO_2 removal; Coal gasification

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1. Introduction

The study of a gasification process producing syngas for a high performance thermodynamic cycle was conducted in two steps:

1. Simulation of the gasification process: gas purification and its utilisation in the energy production cycle performed in a previous study is reported for clarity in the present paper [1].
2. Life cycle assessment of the cycle including biomass production (energy crops) and plant construction/dismantling is presented in this paper.

The schematic of the integrated biomass gasification combined cycle (IBGCC) is shown in Fig. 1 and consists basically in biomass gasification and syngas cleaning before its utilisation in a conventional combined cycle (Brayton/Hirn).

The aim of the process is to obtain a gas with high hydrogen content and low carbon dioxide content suitable for utilisation in a gas turbine. Biomass and air are fed to an atmospheric pressure gasifier. The obtained syngas is first conveyed to a cyclone to remove solid particles and then supplied to a catalytic shift reactor to convert carbon monoxide into hydrogen and carbon dioxide using steam. The goal of this process is to increase the H_2 and CO_2 concentrations before CO_2 removal. Downstream of the shift reaction process, a CO_2 removal is performed in order to reduce the greenhouse gas emissions and to produce a higher LHV fuel. This process consists in chemical absorption by means of an aqueous amine blended solution (diethanolamine, DEA, and methyldiethanolamine, MDEA). In this way, a syngas with high hydrogen content is obtained and then fed to the combustion chamber of the gas turbine. The energy conversion is obtained by means of a conventional combined cycle, integrated with many energy recoveries along the process. Steam is extracted from the steam turbine in order to supply the energy required for both the amine regeneration and shift reaction processes. The simulation was performed by means of a model [2] developed with Aspen Plus 10.1-0 [3].

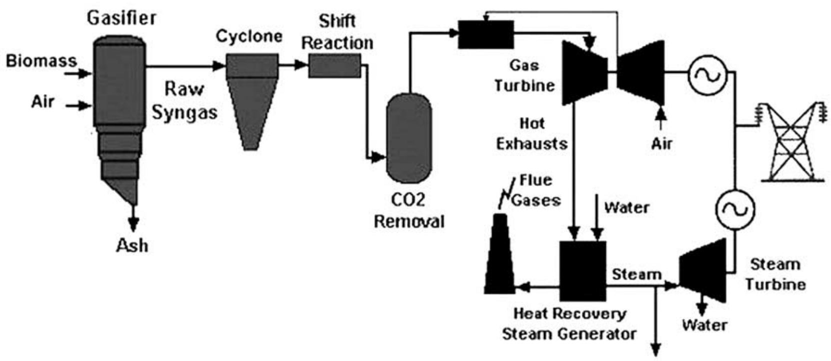

Fig. 1. Schematic of the IBGCC + $DeCO_2$.