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Conceptual design of an integrated hydrothermal liquefaction and biogas plant for sustainable bioenergy production

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HIGHLIGHTS

- ▶ Initial process modelling on a combined biogas and hydrothermal liquefaction plant.
- ▶ The plant produces biofuels from low value biomass feedstock, like cattle manure.
- ▶ Mass and energy balances for two biogas yield scenarios have been done.
- ▶ Aspen Plus and model compounds for biomass and biofuel have been used.
- ▶ 52–63% of the input biomass energy to the plant is recovered in the liquid biofuel.

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ABSTRACT

Initial process studies carried out in Aspen Plus on an integrated thermochemical conversion process are presented herein. In the simulations, a hydrothermal liquefaction (HTL) plant is combined with a biogas plant (BP), such that the digestate from the BP is converted to a biocrude in the HTL process. This biorefinery concept offers a sophisticated and sustainable way of converting organic residuals into a range of high-value biofuel streams in addition to combined heat and power (CHP) production. The primary goal of this study is to provide an initial estimate of the feasibility of such a process. By adding a diesel-quality-fuel output to the process, the product value is increased significantly compared to a conventional BP. An input of 1000 kg h^{-1} manure delivers approximately 30–38 kg h^{-1} fuel and 38–61 kg h^{-1} biogas. The biogas can be used to upgrade the biocrude, to supply the gas grid or for CHP. An estimated 62–84% of the biomass energy can be recovered in the biofuels.

1. Introduction

The need for renewable and sustainable energy sources is high because of a number of factors: the increase in global energy demand, depletion of conventional resources, climate issues and the desire for national/regional energy independence. In 2010, fossil fuels still accounted for 87% of global and 79% of EU primary energy consumption (BP, 2011). Liquid fuels from biomass are essential to meet the imposing challenges of energy and climate (U.S. Energy Information Administration, 2011) due to their carbon neutrality. Marine, aviation and heavy land transport in particular are not likely to become electrified within the next few decades, and for these vehicles, the challenge becomes one of supplying them with suitable drop-in replacement fuels derived from biomass. Because biomass will also be a prime feedstock for a wide range of chemical, nutritional and pharmaceutical products, it will become a limited, high-cost commodity. Therefore, for liquid biofuels to be produced in bulk, it is necessary to identify eligible low-value organic streams such as animal manure, agro-industrial waste and sewage sludge.

For this to occur, the identification of suitable combinations of feedstocks and conversion processes that ensure high process and conversion efficiency and the sustainability of the biomass in the fuel conversion process are critical. The latter is especially important because the energy from fossil fuels used during the biomass conversion process has to be considered in the carbon footprint. The responsible use of resources and minimisation of fossil energy inputs to the process should be targeted. Only an efficient and sustainable process will be commercially compatible and have the capacity to endure. Appropriate process integration and optimisation are the best methods to achieve this.

This work focuses on developing a process design concept for the sustainable production of drop-in biofuels from organic waste streams. In particular, the process design integrates a biochemical (biogas plant – BP) and a thermochemical (hydrothermal

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