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A hybrid optimisation model for the synthesis of sustainable gasification-based integrated biorefinery

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ABSTRACT

Depletion of fossil fuels and increasing public awareness of environmental issues has stimulated the search for alternative energy sources. Biofuels are recognised as one of the most promising alternatives to fossil fuels, as they can be produced from various types of feedstock. The efficiency and sustainability of biomass-based production can be maximised by producing biofuels along with other valuable coproducts in a "biorefinery". This concept was proposed to make the production of biofuels and biochemicals more economically viable by taking advantage of opportunities for process integration and waste recovery. In this work, a novel hybrid optimisation model that combines superstructure-based optimisation approach and insight-based automated targeting for the synthesis of a sustainable integrated biorefinery is presented. In addition, fuzzy optimisation is also adapted to synthesize such integrated facility with the simultaneous consideration of both economic and environmental performance. Note that the proposed approach is a generic synthesis strategy that can be applied even without detailed modelling of individual processes.

Keywords: Automated targeting; Biofuel; Fuzzy optimisation; Integrated biorefinery; Gasification

1. Introduction

The global demand for energy is increasing rapidly due to population growth and concurrent economic development. The total world energy consumption is projected to increase from 5.22×10^{11} GJ in 2007 to about 7.80×10^{11} GJ in 2035 (EIA, 2010). This trend translates approximately to a 50% increment over the projected period of about 30 years. Fossil fuels (i.e., petroleum, natural gas, and coal) are expected to continue contributing a significant proportion of the world energy mix, despite the current high crude oil price of over US$ 90 per barrel (EIA, 2012).

Due to the adverse impact of greenhouse gases on our climate, there is now keen interest to reduce the emissions of greenhouse gases (GHGs), especially CO_2 emissions, from industrial processes. Proposed solutions include changes in government policies to promote sustainable development, and reduction of dependence on fossil fuels by utilising renewable energy sources. In particular, biofuels are now recognised as one of the most promising forms of alternative energy, as they can be produced from using various forms of biomass as feedstock. In recent years, much emphasis has been given on using non-food crops for fuel production. Various types of biofuel are available in the market, such as bioethanol, biodiesel, biogas, biohydrogen, bio-DME, Fischer–Tropsch fuel, biochar, etc. (Biofuel, 2010). Although the current production methods for many of these biofuels are technologically established, they are often not economically feasible without substantial subsidies. Thus, the concept of integrated biorefinery was proposed to improve the overall performance of such processing facilities and allow biomass-based products to be produced in a commercially viable manner. An integrated biorefinery is a facility that integrates conversion processes and equipments to produce fuels, power, and chemicals from biomass (NREL, 2009).

According to Demirbas (2009), there are various technical and non-technical gaps that need to be addressed in the design of a biorefinery. Current technical barriers include the supply and storage of energy crops, the availability of reliable equipment, and the design of process for biomass conversion. Meanwhile, the main non-technical barriers include the issue

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