Comparative assessment of alternative fuel production pathways for sustainable road freight transport

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Abstract

Global challenges of resource depletion and climate change, which are consequences of the escalation of energy demand from industrial and transportation activities, have prompted investigations into the economic and technical feasibilities of utilizing clean fuel alternatives for enhanced environmental outcomes, in recent times. Indeed researchers have consistently emphasised the inevitable need for a paradigm shift from fossil based fuels if imminent environmental catastrophe is to be averted. It is now acknowledged that issues of global warming and fossil resource depletion can be circumvented if renewable fuel alternatives are employed in the transportation industry more so as this industry is highly energy intensive and constitutes a corner stone of all sectors of the global economy. The transportation sector is therefore recognised as a major source of greenhouse gases (i.e. CO_2, NO_x and SO_x) responsible for the aforementioned environmental issues. A consideration of the South African context shows that of all the transportation mode available in the country, roads constitute a crucial component of South Africa's transport system and economy with about 77.3% of freight achieved via land freight of which about road freight accounts for 73.8% of total land freight income[1]. Crucially however, this domination of road for freight transport also leads to an increase in the unfavourable environmental impacts traditionally associated with vehicular transport[2]. Clearly therefore the importance of developing approaches oriented towards sustainable transportation cannot be ignored.

Thus, the present study has investigated the economic and the technical feasibilities of alternative production pathways for the production of 2nd generation (2G) transportation fuels of namely, ethanol, jet fuels and butanol from low grade biomass feedstock such as Lignocellulosic biomass and forestry wastes. These fuels may be utilised directly as transportation fuels or may be blended with fossil fuel to facilitate a net reduction in carbon emissions since such biomass-sourced fuels are recognised as carbon neutral. In this analysis, the initial production of ethanol and its subsequent upgrading to higher value fuels were considered. Firstly therefore, the comparative assessment ethanol production through (i) biomass gasification and syngas fermentation, and (ii) biomass pre-treatment, fermentation and hydrolysis were investigated. These pathways are comparatively assessed because of their associated benefits and limitations such as the anticipated lower capital and energy costs in biomass pre-treatment, fermentation and hydrolysis relative to the higher yields and low operating cost of the syngas fermentation pathway. Thereafter, the assessment of catalytically upgrading the 2G ethanol to either jet fuel or butanol was undertaken.

These alternative upgrading steps of ethanol to butanol and ethanol to jet fuel typically involve the unit operations of carbon-carbon coupling, prior to flash vaporisation then distillation and dehydration, oligomerisation, hydrogenation then distillation processes respectively. These generic unit operations were subsequently employed in modelling the alternative upgrading pathways. The comparative assessment of these upgrading pathway was necessary to elucidate the preferred ethanol upgrading step as a basis for future work in the area since upgrading to butanol and jet fuel are characterised by distinct merits of reduced complexity and enhanced opportunities for heat integration since the processes involved are exothermic, respectively. All data required for assessing these pathways were obtained with flowsheet analysis techniques based on ASPEN plus simulations of process flows and unit operations as specified above from literature. From the simulations, the mass and energy balance data of each process was derived, from which the total capital investment (CAPEX) and operating cost (OPEX) were calculated. These data were subsequently employed in the detrmination of the internal rate of return as the preferred economic performance measure. It is anticipated that at the results of this study will facilitate an improved understanding of biomass conversion pathways and their associated fuels with respect to feasibilites within the South African context for the achievement of the SA government emission targets by the year 2050.

References

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