Bio-gasification of post transesterified microalgae residues: A route to improving overall process renewabilities

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Bio-gasification of post transesterified microalgae residues: A route to improving overall process renewabilities

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Abstract

Using results from experiments and process modelling tools, a renewability assessment was carried out for the use of the conventional and in-situ transesterification processes for a large scale microalgae biodiesel production. In a present day scenario, all the transesterification processes were shown to be non-renewable. The process renewability of biodiesel production from microalgae was found to significantly improve with the use of renewable electricity, reacting alcohols from biomass fermentation and process heating and biomass drying using heat from wood pellet combustion or heat pump technology. The anaerobic digestion of the microalgae residues to generate methane from was further seen to lead to positive renewabilities for the considered microalgae-biodiesel processes.

Keywords: Microalgae, biodiesel, methane, renewability assessment

Introduction

Different approaches to improve the energetic balance of the potential large scale production of biodiesel from oleaginous microalgae have been increasingly investigated. To meet this goal, the application of process modifications to improve the renewability of microalgae biodiesel have been explored (i.e. Ehimen et al., 2010). Further schemes such as the production of methane (CH_4) using the post transesterified residues (otherwise considered as a process waste) have been described experimentally in the literature (Ehimen et al., 2011). Although the potential renewability gains accruable using different transesterification schemes for microalgae biodiesel production have been carried out (Ehimen et al., 2012), no studies on improvements attainable by coupling CH_4 generation from the residues with the biodiesel production process was found in the literature. This poster details renewability improvements achievable via the co-production of CH_4 from the microalgae residues after the biodiesel production process (using *Chlorella* biomass as the process feedstock). The influence of altering other process parameters i.e. choice of process alcohol, process electricity and heat were also considered, with their influence on the microalgae biodiesel renewability determined.

Methods

The oleaginous microalgae biomass (*Chlorella*) with an oil content of 27% (on a dry mass basis) was assumed to be the candidate feedstock for this study. The biomass and conversion reaction conditions assumed for use here were same as have been previously described in Ehimen et al. (2011) and Ehimen et al. (2012). To compare if the choice of transesterification route had a major influence on the eventual process renewability, the biodiesel production was considered to be carried out using two types of transesterification schemes: the conventional (involving a pre-extraction of the oil from the biomass before the biodiesel conversion) and the in-situ (where the oils in the biomass are transesterified directly) processes. The process modelling software (ASPEN plus®) was used to up-scale the experimental results to a theoretical operational basis of 1 t dry microalgae biomass/h and the hypothetical large scale material and energy requirements of were obtained. The microalgae biomass cultivation, biodiesel and methane production processes were then assessed by comparing the minimum work required (Wp) to restore the non-renewable resources degraded in the considered process with the useful work available from the main process products (Wp) as in Berthiaume et al. (2001). The material and energy flows and system boundaries used here are shown in Fig. 1. The process renewability was obtained using Eq. 1:

$$Ir = (Wp - Wr) / Wp \qquad (1)$$

The process renewability can thus be evaluated on the basis of the Ir estimated i.e.:

- Ir = 1, is indicative of a fully renewable system, with Wr = 0
- 0 < Ir < 1, for a partially renewable system.
- Ir = 0, suggests a system in which the work produced by the biofuel and the restoration work required are equal.
- Ir < 0, for a process which consumes more restoration work than it produces. Such processes are considered as non-renewable.

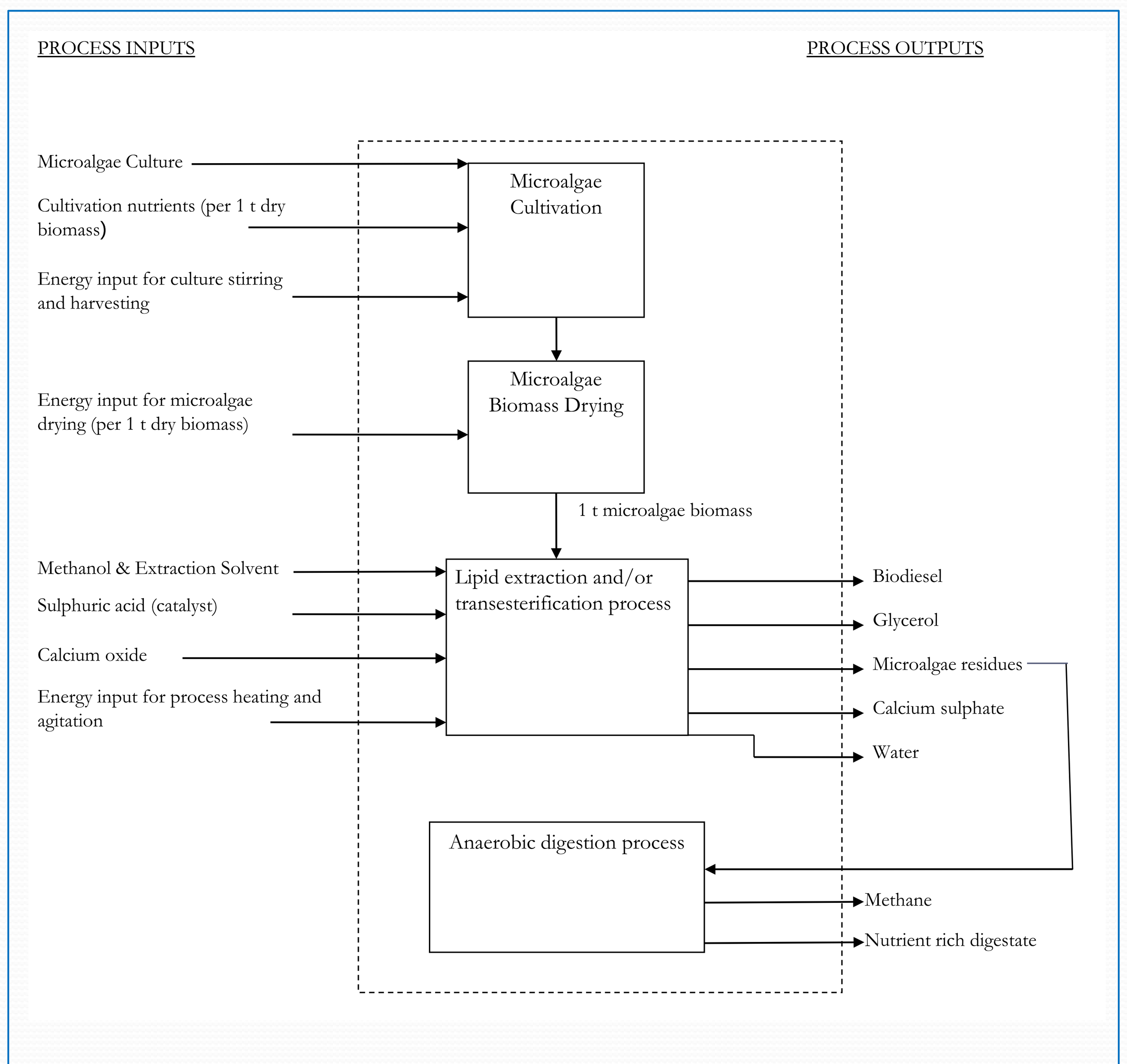

Fig. 1. The system boundary (dashed lines) and material and energy flows considered in this study.

Results and Discussions

The process renewability (Ir) for the singular production of biodiesel production from microalgae (*Chlorella*) biomass in a fossil fuel based-present day scenario can be seen to be largely negative for both the conventional and in-situ transesterification processes considered as shown in Fig. 2. Assuming fermentation alcohols (i.e. ethanol) and renewably sourced electricity (i.e. 100% hydro-electricity) were employed for both transesterification processes, the use of heat pump technologies and wood pellets to meet the process heating requirements was seen to result in positive renewabilities for microalgae biodiesel production (Fig. 3). With CH_4 production from the digestion of the biomass residues integrated with the microalgae biomass transesterification processes, the highest process renewabilities were observed (Fig. 4). The process Wp was seen to be 40-45% higher than when the biodiesel production was conducted alone, with an improvement in the overall process renewability by a factor of ≈2 seen using this scheme compared with the best case scenarios from Fig 3.

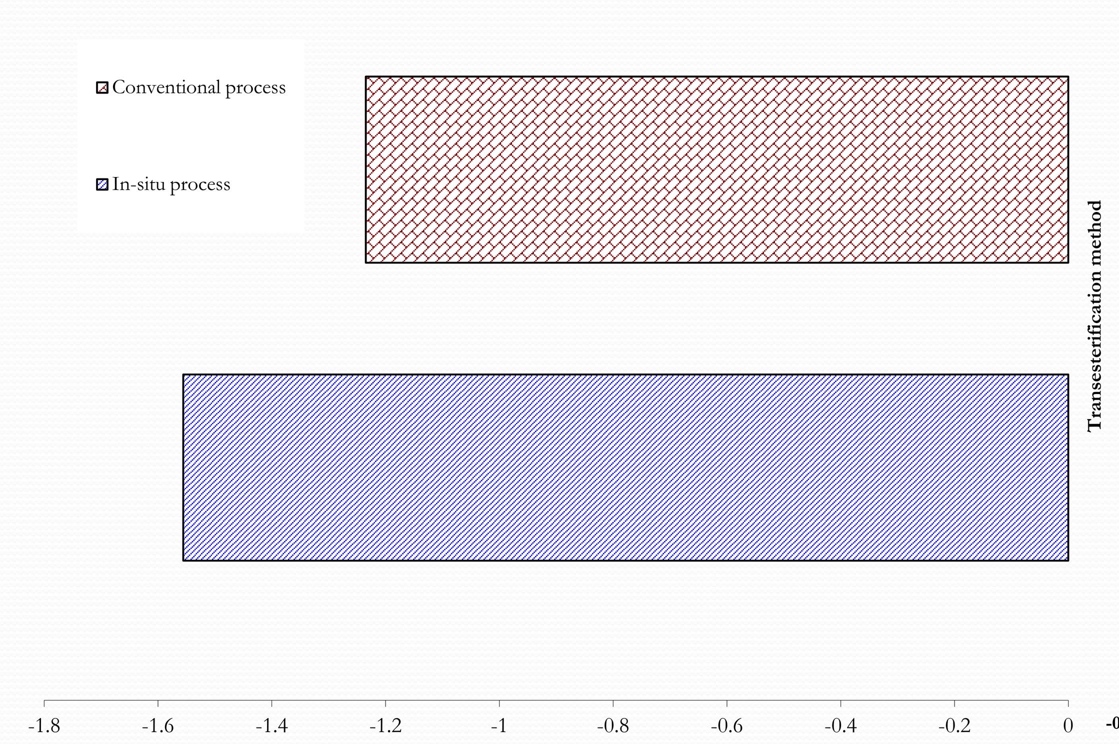

Fig. 2. Renewability indicators for two up-scaled transesterification processes in a fossil fuel based scenario

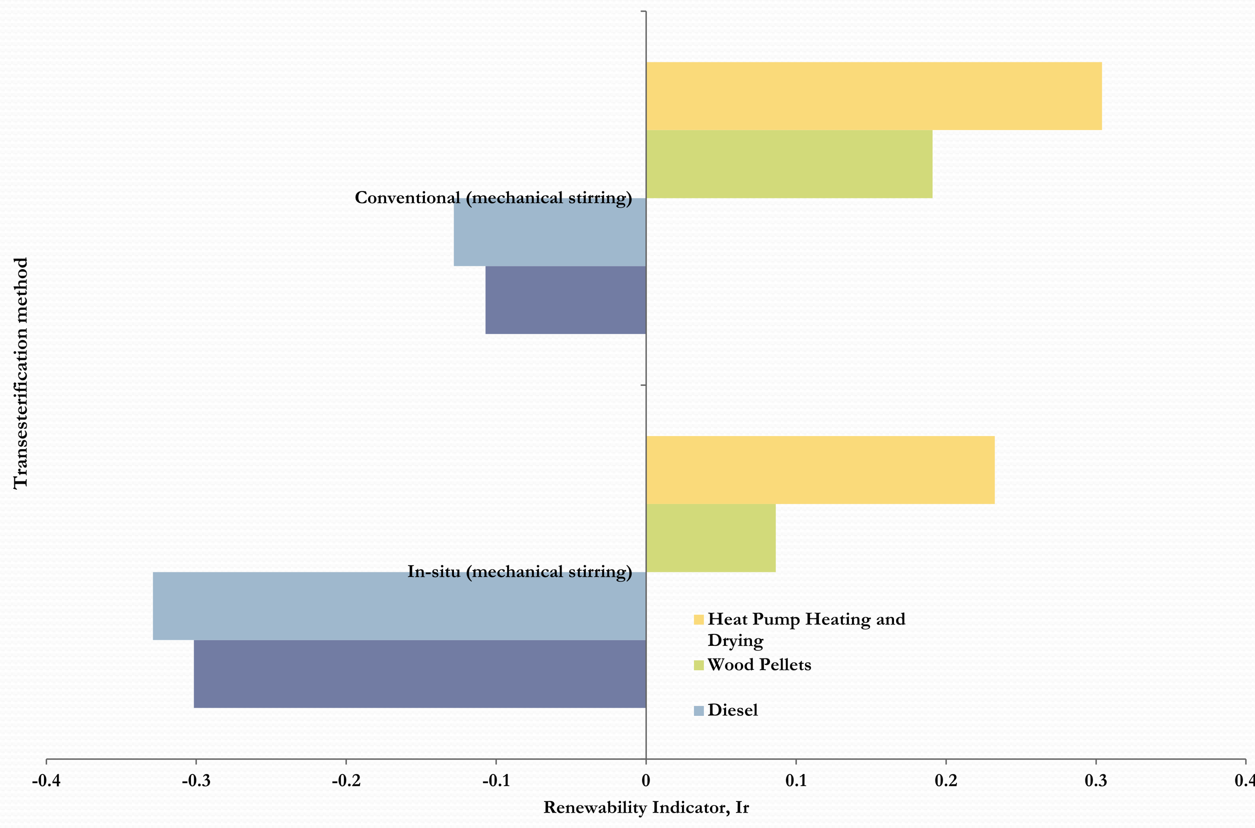

Fig. 3. Influence of choice of heating fuel on the renewability of the different transesterification processes

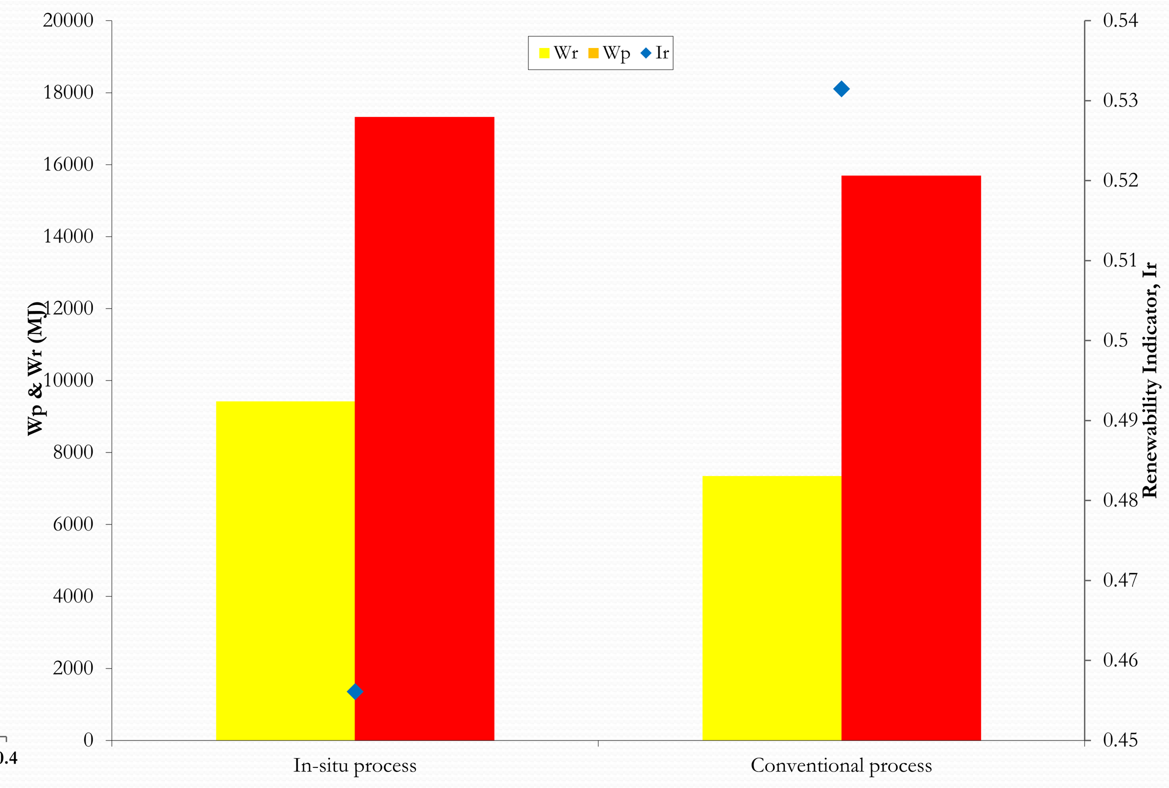

Fig. 4. Comparison of the renewability indicators for biodiesel production integrated with CH_4 recovery from the microalgae residues

Conclusions

The use of fermentation alcohols and renewable electricity coupled with the process heating requirements provided using wood products or efficient heating technologies (i.e. heat pumps) can be applied to ensure that the microalgae biodiesel production is renewable. Furthermore, the production of a secondary energy product - CH_4 via the anaerobic digestion of the microalgae residues was seen to greatly improve the process renewabilities associated with the use of microalgae biomass for biodiesel production.

In addition to this study findings, recycling the nutrient rich digestate after the anaerobic digestion process into the microalgae cultivation unit could be further used to increase the overall renewability of microalgae biodiesel production.

References

Berthiaume R, Bouchard C, Rosen MA.(2001) Exergetic Evaluation of the Renewability of a Biofuel. *Exergy, an International Journal* **1**: 256-268

Ehimen EA, Sun ZF, Carrington CG, Birch EJ, Eaton-Rye JJ (2011) Anaerobic digestion of microalgae residues resulting from the biodiesel production process. *Applied Energy* **88**: 3545-3563.

Ehimen EA, Sun ZF, Carrington CG. (2012) Renewability Analysis of Microalgae Biodiesel Using Different Transesterification Processes. *International Journal of Energy, Environment and Economics* **20**: 135-156

Ehimen EA, Sun ZF, Carrington CG. (2010) Variables Affecting the In Situ Transesterification of Microalgae Lipids. *Fuel* **89**: 677-684.

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