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ENGINEERING MANAGEMENT OF GAS TURBINE POWER PLANT CO2 FOR MICROALGAE BIOFUEL PRODUCTION

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ABSTRACT

Fossil fuel accounts for over 80% of the world`s primary energy, particularly in areas of transportation, manufacturing and domestic heating. However, depletion of fossil reserves, frequent threats to the security of fossil fuel supply, coupled with concerns over emissions of greenhouse gases associated with fossil fuel use has motivated research towards developing renewable and sustainable sources for energy fuels. Consequently, the use of microalgae culture to convert CO2 from power plants flue gases into biomass that are readily converted into biofuel offers a window of opportunities to enhance, compliment or replace fossil- fuel-use. Interest in the use of microalgae biomass for biofuel production is high as it affords the potential for power plant CO2 sequestration – (1kg of dry algae biomass uses about 1.83kg CO2). Similarly, its capacity to utilise nutrients from a variety of wastewater, sets it apart from other biomass resources. These outlined benefits all emphasis the need for extended R&D efforts to advance commercial microalgae biofuel production. The paper is aimed at investigating the environmental performance of the microalgae biofuel production process using LCA.

Keywords: Microalgae biomass, Biofuels, Life Cycle Assessment (LCA).

1 INTRODUCTION

Microalgae biofuel production is an emerging field, which provides a new frame of opportunities as a potential alternative and sustainable energy derivable biomass resource. It has attracted a lot of attention, as a result of its potential to be converted into a variety of liquid and gaseous biofuels derivatives – using current technology & infrastructure. Nonetheless, algae cultivation, incorporation of production system for power plant flue gas use, biomass harvesting, oil extraction and biomass conversion processes have many challenges.

In this paper we present an integrated microalgae biofuel production model based on data available for algae bioprocess benchmarking optimization (Wijffels & Barbosa, 2010). The model (Fig. 1) is aimed at providing an articulate description of a possible wet and dry process route for biofuel production using the entire algae constituent biomass. The research work is distinctive in the sense that it integrates several different technical options of key algae biomass production and conversion pathways, power plant flue gas CO2 use with regards to their Life Cycle Assessment (LCA) impacts. LCA results are cross-compared in order to identify the most significant opportunities for improvement with the final aim of developing a sustainable microalgae biofuel production model.

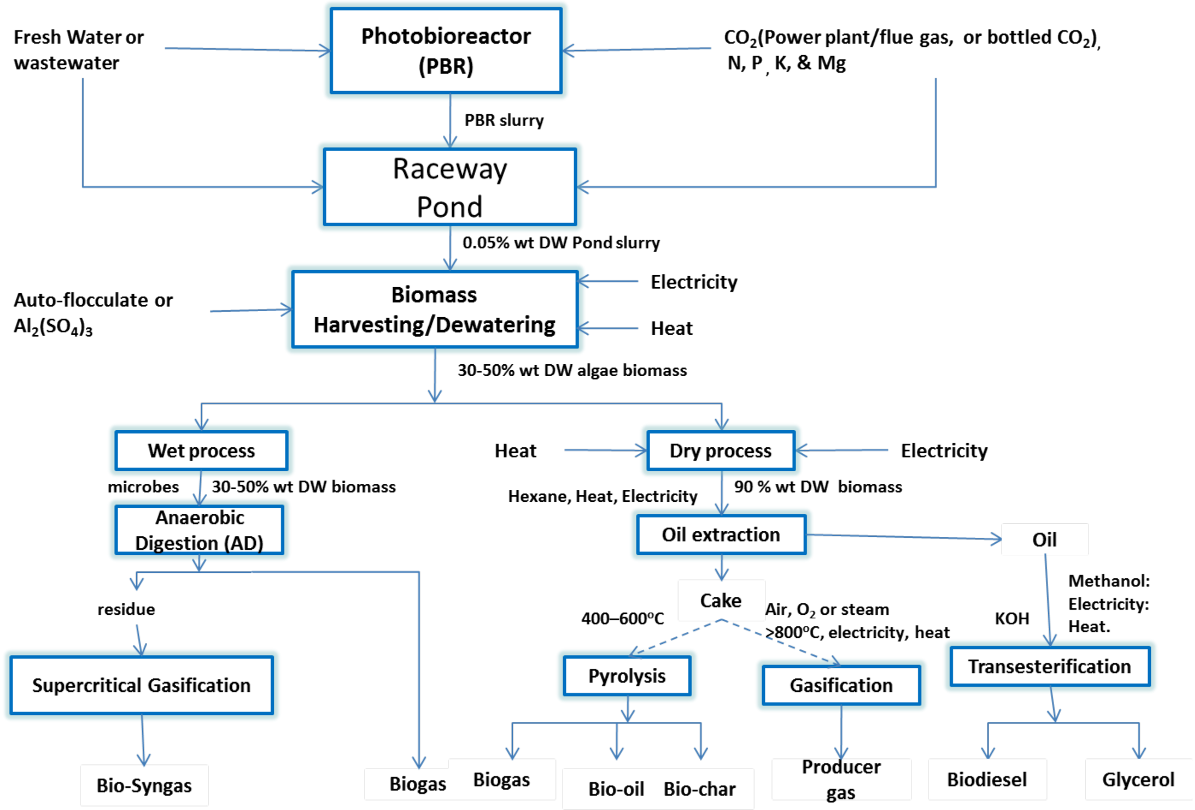

Figure 1: Wet & Dry Microalgae Biofuel Process Flow Diagram

2 METHODOLOGY

In the proposed framework (Figure 2), using LCA methodology entail the modelling of the full Life Cycle Inventory (LCI) and the Life Cycle Impact Assessment (LCIA) for each process unit of; microalgae cultivation, biomass harvesting/dewatering, and biomass oil extraction and conversion into biofuels. The LCI phase requires the computation of quantitative input/output data. While, the LCIA stage entail, determining and establishing the extent of impacts associated with the production process (Figure 2) in terms of; resource use, impact to human health and impact to the environment, using the ISO 14044 & CML 2002 guides respectively (Henrikke, B & Anne-Marie, T 2004).

Furthermore, parameters that affect production such as; Pond evaporation rate (PER), Algae growth rate (AGR) and lipid content (LC), Algae Recovery Rate after Harvest (RRH) and Slurry Content after Harvest (SCH), are factors which also affects the biofuel product composition ratio for each conversion technology, Energy efficiency of each conversion technology and process routes and Environmental emissions associated with each conversion process are analysed to evaluate their interactions, as understanding the burden of these parameters on the production process provides insight for advancing technology and reducing the impact of the overall energy use of future biofuel process (Yang et al., 2011).

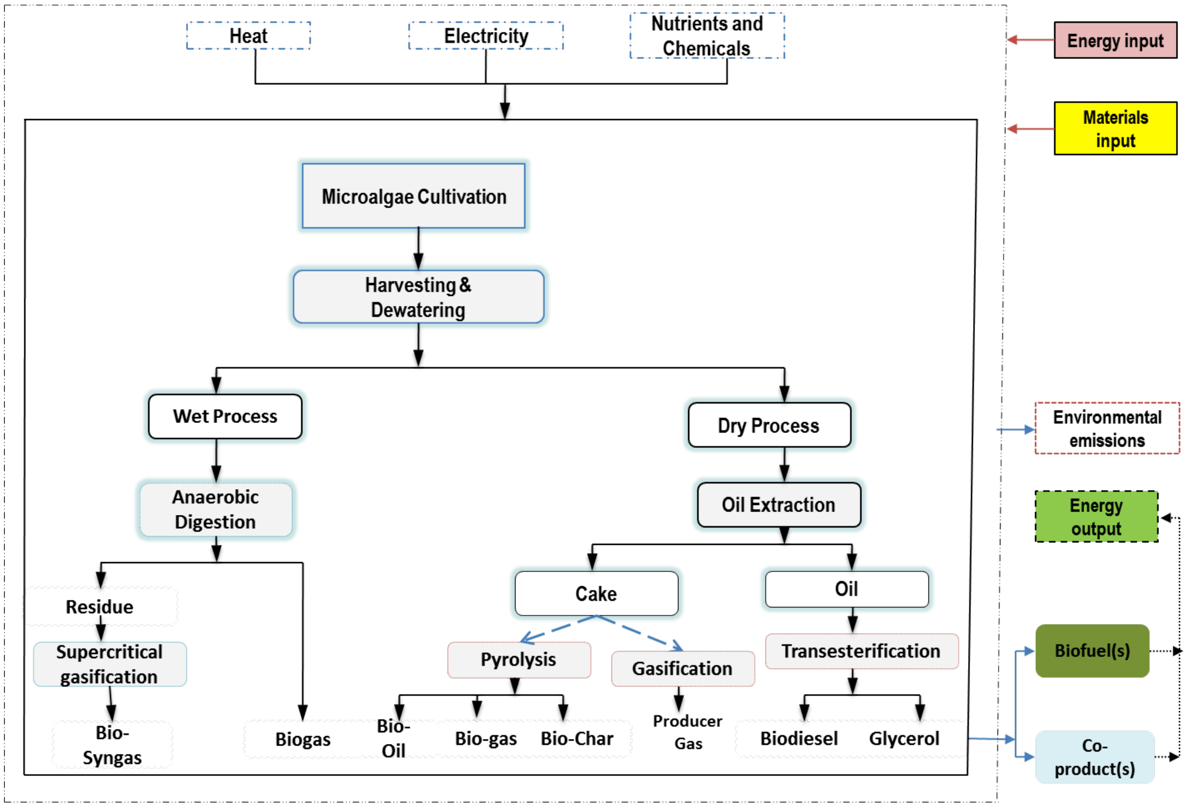

Figure 2: Microalgae biofuel production system boundary

The method proceeds with the interpretation stage, which highlights the significance and the strength of the evidence gotten and processed in previous stages. The interpretation phase entails drawing conclusions and articulating recommendations based on the findings from both the inventory analysis and impact assessment phases in line with the goal and scope of the study – which is to develop an energy/material efficient and environmentally sustainable model of producing biofuel using algae biomass – and in terms of total energy input, total energy output for the resultant biofuels and co-products, material resource use and environmental burden for the entire production process. Other important considerations are the functional unit (1MJ of biofuel), the choice of product/process alternative to be analysed, system boundary, how allocation issues are dealt with, formulation of the reference flow for each alternative process route option and the assumptions/limitations (Finnveden et al., 2009). These considerations help to ensure consistency of the LCA (Henrikke, B & Anne-Marie, T., 2004).

3 PRELIMINARY RESULTS

We found out that energy and CO2 emissions drivers for the transesterification process includes; Energy consumed by Photo Bioreactor (PBR), hydraulic pumps for the open raceway pond, centrifuge, mechanical dryers, heating requirement to increase the biomass to 90% DWB (similar to that of soybean oil), fertilizer requirement, use of chemical flocculants, oil extraction processes and conversion techniques.

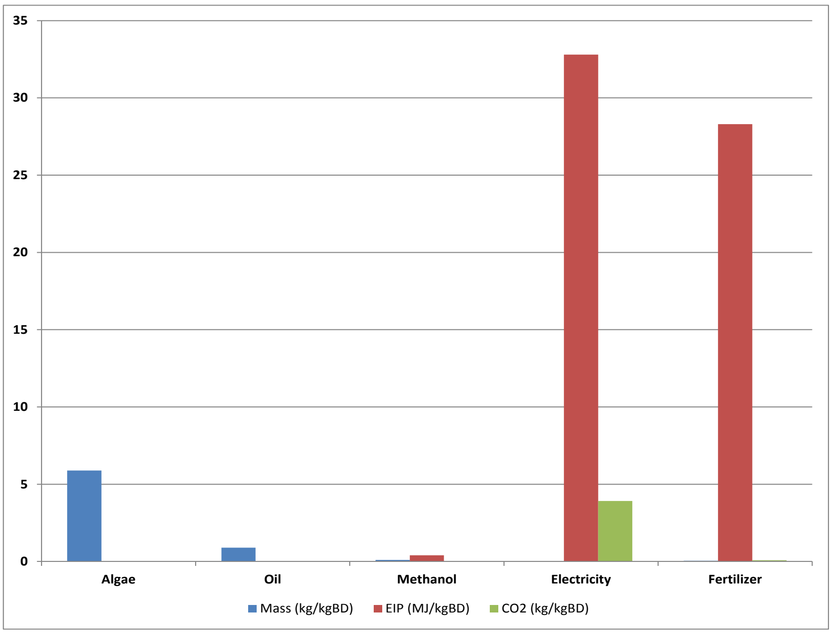

Figure 3: Production of 1Kg Biodiesel (BD): via Transesterification

Similarly, results indicate that heating to increase the biomass to 90% DWB accounts for 64% of total input energy from the transesterification energy input profile, while, electrical energy need and fertilizer requirement representing 19% and 16% respectively.

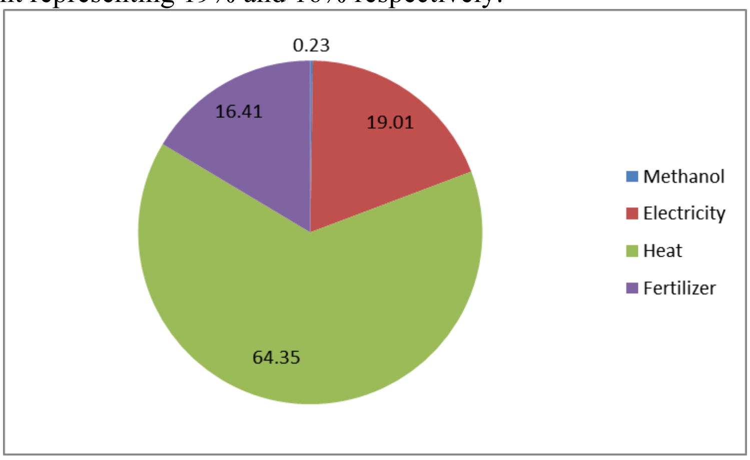

Figure 4: Transesterification Energy Input profile

Also, in our analysis of how the CO_2 gas transfer & mixing operations affects algae growth, we established that most power plants flue gas CO_2 concentration range between 10% - 15% (see Table 1), which are tolerable by most algae. However, when SO_2 levels exceed 400ppm in the flue gas, it lowers the pH – increases acidity. Conversely, there is need to assess and determine the Solubilities of combined flue gas components. As dissolved gases react together, new products are formed which may affect algae growth.

Table 1: Flue gas emission concentrations from different fuels Power Plants (Wang et al., 2008)

Emissions	Natural gas	Fuel oil	Coal
NOx (ppm)	25-160	100-600	150-1000
SOx (ppm)	≤0.5-20	200-2000	200-2000
CO_2 (%)	5-12	12-14	10-15
O_2 (%)	3-18	2-5	3-5
H_2O (%)	8-19	9-12	7-10

4 CONCLUSIONS

The LCA analysis methodology presented has been shown to be useful in providing insights into the economic and environmental performance of the proposed microalgae biofuel production system model. This is because it allows for; evaluating alternative pathways and identifying greater integration opportunities with greater economic advantage and lowering environmental burdens in relationship with existing models. The failure to date of previous models to consider the overall effect of process parameters has resulted in the inability to accurately predict product yields/environmental burdens with variations in operating conditions.

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