Bioresource Technology 262 (2018) 203–211

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Environmental performances of coproducts. Application of Claiming-Based Allocation models to straw and vetiver biorefineries in an Indian context

Edgard Gnansounou*, Jegannathan Kenthorai Raman

Bioenergy and Energy Planning Research Group, EPFL, Switzerland

ARTICLE INFO

Keywords:
Life cycle assessment
Climate change
Biorefinery
Coproducts
Allocation
Claiming-Based model
Vetiver

ABSTRACT

Among the renewables, non-food and wastelands based biofuels are essential for the transport sector to achieve country's climate mitigation targets. With the growing interest in biorefineries, setting policy requirements for other coproducts along with biofuels is necessary to improve the products portfolio of biorefinery, increase the bioproducts perception by the consumers and push the technology forward. Towards this context, Claiming-Based allocation models were used in comparative life cycle assessment of multiple products from wheat straw biorefinery and vetiver biorefinery. Vetiver biorefinery shows promising Greenhouse gas emission savings (181–213%) compared to the common crop based lignocellulose (wheat straw) biorefinery. Assistance of Claiming-Based Allocation models favors to find out the affordable allocation limit (0–80%) among the coproducts in order to achieve the individual prospective policy targets. Such models show promising application in multiproduct life cycle assessment studies where appropriate allocation is challenging to achieve the individual products emission subject to policy targets.

1. Introduction

India, being one of the main signatory in COP21 is keen to mitigate greenhouse gas emissions and is proactive in implementing several schemes. A reduction of emissions up to 30–35% from 2005 level, increasing the non-fossil based power generation capacity by 40% and to create an additional carbon sink of 2.5–3 Gt_{CO2e} have been set as the target for 2030 (Chakrabarty and Chakraborty, 2018). Renewable energy resources such as biomass, solar, wind, and hydro are the major sources to achieve these targets. On the other hand, the wastelands available in India are estimated to be around 467021.16 sq·km in 2009 (Department of Land Resources, 2011) and most of them are in the rural areas. These wastelands could be utilized in an efficient way to create business and employment along with carbon sinks. There is a need of increasing policy supports to utilize these wastelands for biofuel production to avoid feed vs food security conflict (National Policy on Biofuels, 2009).

The role of biomass in complementing the fossil resources is indispensable for transport, energy sectors and chemical industry to mitigate climate change, enhance energy security and foster local economy revitalization. As of now, the widely used first generation bio-resources such as corn and sugarcane could be only short lived due to their eminent role in the food security and land use impacts. Whereas, second generation bio-resources have the potential to partially replace the fossil fuels without affecting the food supply. In addition, they could mitigate the pollution arising due to biomass burning that is practiced in most part of the world. The common lignocellulose biomasses available for second-generation technology are wheat straw, rice straw, bagasse and corn stover (Saini et al., 2015). Several research works and lifecycle assessment studies are available on biofuel and biochemical production from these feedstocks. On the other hand, these biomasses remain as the predominant animal feed supply in the developing countries such as India (Purohit and Dhar, 2015; Sukumaran et al., 2017). Therefore, search for alternative feedstocks are on the way to meet the future biomass demand. In recent years, several alternative biomasses such as, cotton stalks, chilli stalks, bamboo etc. have been proposed in the literature (Singh et al., 2017; Sukumaran et al., 2010). The composition of these biomasses are adequate to consider them for biofuel and bio-chemicals production in a biorefinery that could replace the traditional biomasses. However, as many of these feedstocks would not be solely grown for energy and bio-chemicals purposes, other benefits may be expected such as 1) able to grow in wastelands with minimal nutrients, 2) able to regenerate the wastelands, 3) able to sequestrate carbon in the soil 4) tolerate harsh weather conditions may be expected.

Vetiver is a perennial bunchgrass native to India that belongs to Poaceae family. The shoot and root grow long that are used for various applications such as household, shelter, perfumer, bioremediation etc.

* Corresponding author at: Bioenergy and Energy Planning Research Group, GC, Room A3 424, EPFL IIC ENAC GR-GN, Station 18, CH-1015 Lausanne, Switzerland.
E-mail address: edgard.gnansounou@epfl.ch (E. Gnansounou).

https://doi.org/10.1016/j.biortech.2018.04.090
Received 13 February 2018; Received in revised form 18 April 2018; Accepted 21 April 2018
Available online 24 April 2018
0960-8524/

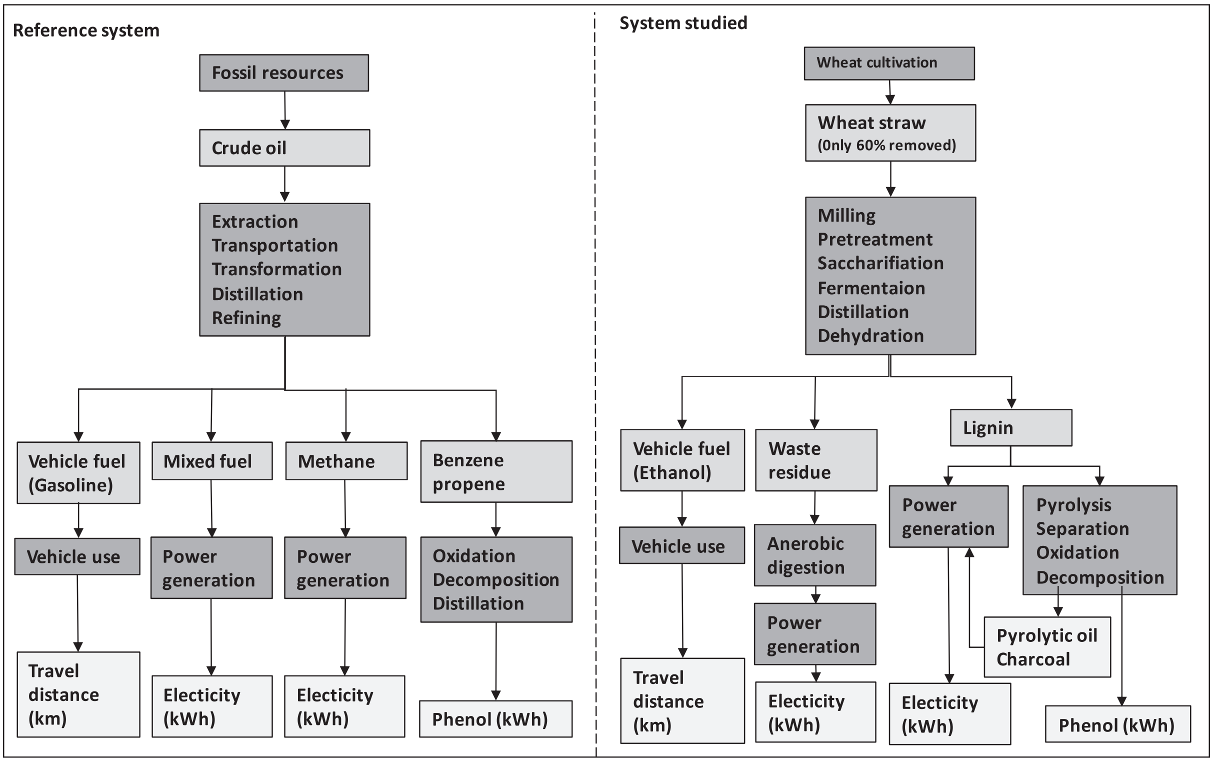

Fig. 1. System boundary for wheat straw biorefinery system.

Vetiver can grow in harsh conditions with minimal or no nutrients requirements and the roots bind to the soil very well avoiding soil erosion and improving the soil qualities along with carbon sequestration. Due to these qualities, vetiver has the potential to be grown in wastelands to provide biomass to the biorefinery industry with positive impact on the environment. Several research studies suggested that vetiver grass could be a promising biomass for the production of several bio-products such as bioethanol, briquettes, furfural, lactic acid, lignin derivatives, building materials accessary (Raman et al., 2018).

In 2003, biofuel mission was launched in India and further a biofuel policy was adopted in 2009. Biodiesel and bioethanol market share target of 20% was fixed to be achieved by 2017 along with reducing the greenhouse gas emissions level of its GDP intensity by 20–25% by 2020, compared to 2005 levels (National Policy on Biofuels, 2009; Press Information Bureau, 2015). However, only 3.3% average blend was achieved by 2016 despite several incentive programs (GAIN Report, 2017). The stipulated targets for 2017 could not be achieved due to various reasons such as inadequate feedstock's supply, insufficient technological development, lower price of fossil oil, lower biomass yield from plantations in wastelands and lack of having a greenhouse gas emission constrains in the policy framework and priorities. However, India's "Intended Nationally Determined Contribution Mitigation Strategy (INDC)" includes the following issues for the period 2011 to 2030 (Pohit et al., 2011; UNFCCC, 2016; Chakrabarty and Chakraborty, 2018): "To reduce CO_2 emission intensity of GDP by 35% of 2005 levels before 2030; to create an additional carbon sink of 2.5–3 billion tons of CO_{2e} through additional forest and tree cover by 2030;;- to build capacities for cutting-edge R&D in this regard."

In order to fulfill these commitments, providing incentives to bio-based products indifferently to their GHG performances that is practiced now should be avoided and performance based incentive should be promoted like in European countries. Furthermore, in a biorefinery with several co-products, claiming performance based incentives depend on the allocation of emissions to the co-products. Envisaging several coproducts from the biorefineries and environmental performance requirements of those products in future, the feasibility of the products in biorefineries to attain the incentives or achieving the policy targets are determined using the Claiming-Based Allocation approach (Gnansounou, 2018). In brief, in this approach the policy targets of the individual products are incorporated while performing the allocation of common emissions to the co-products. In addition, several other biomass feed stocks that grow in wastelands should be considered. Addressing these policy constraints, this study aims to estimate the GHG performance of coproducts from biorefineries for two different Indian contexts namely wheat straw collected in a semi-arid region and vetiver grown in the wastelands of Uttar Pradesh using the Claiming-Based Allocation approach.

2. Materials and methods

2.1. Goal and scope

An LCA study is carried out according to the ISO standard 14,040 series (ISO, 2006). The main goal of this conceptual study is to compare the greenhouse gas (GHG) emissions of each coproduct viz. ethanol, electricity and phenols in both biorefineries, straw vs. vetiver. Fossil based products (gasoline, conventional energy with mixed fuel sources and conventional phenols) remain the reference cases for the coproducts. The geographical scope of this study is India. In the current situation, as the policy reduction target emphasizes on GHG emission, only this impact category is considered in the scope among all other categories.

2.1.1. Functional unit

The options for functional unit selection are based on several aspects such as service basis, energy basis and land use basis. It is very important to choose the appropriate functional unit to collect the relevant data on the process and products. In biorefineries, functional units based on services would be appropriate to compare with the respective conventional product (Gnansounou et al., 2009). Accordingly, a well to wheel (wtw) functional unit based on service of the predominant product that corresponds to the scale of the biorefinery was