Biofuel sustainability through lifecycle GHG emission indicators

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Introduction

The Government of Vietnam has set out a biofuel development strategy with a vision toward 2025, in which blends of E10 for gasoline are utilized in domestic transport after 2015 [3]. Life-cycle energy and GHG balances are commonly used to measure biofuel energy efficiency and effects on GHG emissions. However, GHG emissions of cassava-based ethanol associated with some effects are still missing in the country. In 2013, Loan L.T. partly filled these gaps by investigating the effects of LUC in feedstock plantation [4]. Other effects were merely projected according to ethanol development strategies. In this research, real operation conditions of cassava based ethanol plants and the form of E10 as substitutes for gasoline are investigated. The paper aims to contribute to the existing literature on GHG balances by considering the remaining effects in cassava-based ethanol production and distribution in Vietnam.

Material and Methods

The LCI of bio-energy approach using the common GBEP methodological framework allows identification of how the different steps contribute to the total emissions [2]. As mentioned, the feedstock plantation step has been investigated by another study [4]. In this research, the data collection strategy and methodology is described for the ethanol pathway (biomass processing into ethanol, ethanol transportation, storage and distribution). An aggregate national level indicator value is formed by classifying cassava-based ethanol production and consumption in Viet Nam into categories according to various parameters such as conversion technology, transportation distance and method, end use, etc. and determining a representative lifecycle GHG emissions value per functional unit of energy for each category. CO2, NH4 and N2O are aggregated to CO2 equivalent (CO2eq) using global warming potential factors. The GHG emissions from bio-energy production are calculated using the guidelines from the IPCC and Biograce [1]. Then, the GHG balance compares the GHG emissions from production and utilization of a functional unit of ethanol with that of gasoline for the same functional unit.

In Vietnam, after the harvest, cassava is sliced and dried in the sun before delivery to ethanol plants in the form of dried chips (water content is about 14 %, in average). The conversion ratio of fresh root to dried chips is 2.5 kg/kg, which is derived from the survey and verified by other studies. There are 2 ways of feedstock delivery: 1) Cassava is transported from cultivation areas to the plants; and 2) Cassava is transported from main exporting port to the plants. The transportation occurs by 40 t truck *(full load).*

There are currently only three ethanol companies operational in the country because of the low domestic demand for E100. Two ethanol plants are located in the Middle and the other is in the South. There are four sub-processes to convert dried chips to ethanol: 1) milling, 2) liquefaction, 3) saccharification and fermentation, and 4) distillation and dehydration. Besides ethanol, co-products include biogas used as a supplemental energy, and CO2 collected for sale. The conversion ratio of dried cassava chips to ethanol in average is 2.3 kg/L, which is derived from the survey [5].

The ethanol product is sold to oil companies and delivered to blending stations by 30 m3 trucks. At the blending stations, gasoline and ethanol are blended directly in line before being transferred by truck and ship to the gasoline station.

Results and Conclusions

The technical data provided by three operating ethanol plants are used as inputs in this analysis. Total GHG emission of the ethanol productions resulted in terms of 642.02 g CO2eq/L, of which a main contribution comes from burning solid fuels for steam production (using for slurry preparation, liquefaction, fermentation, distillation and dehydration) in ethanol conversion stage (Table 1). The GHG emissions from the ethanol plants are partly balanced by the amounts of liquid CO2 collected and biogas used for CHP.

**Table 1. GHG emissions from cassava based biofuel product**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *FU = L of ethanol* | Input *(average)* | | Emission factor | CO2eq emission |
|  | *Unit* |  | *g/unit* | *g/L* |
| **(0) - GHG from cassava plantation [4]** |  |  |  | **75.54** |
| **(1) - GHG from dried chips production** |  |  |  | **15.90** |
| How much diesel is used for chipping? | MJ | 0.181 | 87.64 | 15.90 |
| **(2) - GHG from transport of cassava chips** |  |  |  | **45.56** |
| How much diesel is consumed (*two-ways trips)*? | MJ | 0.520 | 87.64 | 45.56 |
| **(3) - GHG from ethanol plants** |  |  |  | **543.12** |
| What amounts of the chemicals are applied? |  |  |  | 26.76 |
| *Sulphuric acid* | *Kg* | *0.0025* | *207.7* | *0.51* |
| *Enzymes* | *Kg* | *0.0015* | *1000.0* | *1.53* |
| *Ammonia* | *Kg* | *0.0045* | *2660.8* | *11.97* |
| *Urea* | *Kg* | *0.0037* | *3167.0* | *11.80* |
| *NaOH* | *Kg* | *0.0020* | *469.3* | *0.95* |
| *DAP* | *Kg* | *0.0027* | *1527.0* | *4.05* |
| How much energy is consumed? |  |  |  | 959.86 |
| *Solid fuel (coal, firewood, cashew nut sell)* | *MJ* | *9.2953* | *111.3* | *1034.38* |
| *Electricity* | *kWh* | *0.1757* | *661.2* | *116.15* |
| *Biogas (in-situ 🡪 electricity)* | *kg CH4* | *-0.0211* | *8363.6* | *- 176.19* |
| Which amounts of CO2 are recovered? | Kg | -0.5000 | 1000.0 | - 499.96 |
| **(4) - GHG from transport of E100 to filling station** |  |  |  | **37.43** |
| How much electricity consumed at filling stations? | Kwh | 0.004 | 661.2 | 2.64 |
| How much diesel do vehicles (2 ways) consume? | MJ | 0.343 | 87.64 | 30.08 |
| Add: from filling station to gas station (2 ways) | MJ | 0.054 | 87.64 | 4.71 |
| **Total GHG from ethanol product (=0+1+2+3+4)** |  |  |  | **642.02** |
| **(5) - GHGs from combustion of biofuel (E10)** |  |  |  | **1105.11** |
| How much heat released from 1 L of biofuel? | MJ | 31.62 | 34.95 | 1105.11 |
| **Total life cycle GHG emissions (=0+1+2+3+4+5)** |  |  |  | **1747.13** |

Taking into account the emissions from using biofuel (E10), total GHG emission of ethanol product resulted of 1822.67 g CO2eq/L, of which about 30% and 61% of the contribution come from the ethanol conversion and the use of the product, respectively (Figure 1). Analysing in detail for each ethanol plants, energy consumption and CO2 collection in Chinese technology based plant is higher and lower, respectively, in comparison to French and Indian technology based plants.

**Figure 1.** Total GHG emissions from cassava-based biofuel product

**Figure 2.** GHG emissions: a comparison between the case study and the BAU

In comparison to gasoline in term of product lifecycle, it shows that total GHG emission from biofuel is about 60% of total GHG emission from gasoline (Figure 2) even fuel consumptions per kilometre of the biofuels and gasoline are similar. This means that the use of E10 as a substitute for gasoline has achieved a GHG emission reduction.

This LCI wishes to engage stakeholders on best practices in biofuel in order to maximize sustainability and contribute to adaptation to climate change in Vietnam. As a result, the further GHG emission saving would be achieved by: 1) improving technology and the ratio of using biogas as an energy supplement in the plants; 2) managing the cassava-chip providing network in order to reduce total distance of material transportation.

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