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Material flow management and cleaner production of cassava processing for future food, feed and fuel in Thailand

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ABSTRACT

This research applied Material Flow Cost Accounting (MFCA) to identify the costs of material and energy loss, as well as the opportunity for technology improvement to increase productivity in starch and ethanol productivity in Thailand. The results showed that ethanol production incurred more loss cost than starch production because it entails several conversion processes. Scenario for technology improvement was evaluated and expanded to the broader scale of the whole country to assess the possibility of increasing cassava feedstock in order to meet the AEDP target. The result shows that the Very High Gravity (VHG) and Simultaneous Saccharification and Fermentation (SSF) processes can increase plant capacity and efficiency. Ethanol production from cassava pulp can also play an important role in meeting the Renewable and Alternative Energy Development Plan (AEDP) and utilizing by-product from starch processing, increasing its value and offsetting loss cost from starch production plant. Those improved options in the scenario can help to reduce cassava feedstock amount required to produce ethanol for the AEDP target. Yield improvement can satisfy feedstock requirement without the need of land for plantation expansion, reduce cassava export and allocation of more molasses for ethanol production.

1. Introduction

Thailand is one of the world's top exporters of cassava products. Yield of cassava production and cassava processing efficiency in Thailand has been improved considerably over the last decade. Cassava is used mainly for food, feed and fuel. The use of cassava can lead to a possibility of feedstock competition. Cassava production in Thailand in 2012 was 26.6 million tons per year (MTPY). The main utilization was starch production at 14.2 MTPY or 54% (domestic use 4.8 MTPY, export 9.4 MTPY). Starch 11.9 MTPY or 44% was used for producing chips and pelleted cassava for animal feed (domestic use 3.4 MTPY, export 8.5 MTPY) and only 2% (0.5 MTPY) was available for ethanol production (OAE, 2013).

The Renewable and Alternative Energy Development Plan (AEDP 2012–2021) aims to expand ethanol production from 1.3 million litres per day (MLPD) (in 2012) to 9.0 MLPD. The plan leads to the challenge in increasing demand of ethanol production feedstocks such as sugarcane and cassava. The proportion between sugarcane (molasses) and cassava to be used in ethanol production depends on many factors including the crop production potential, existing capacity and configuration of available ethanol plants and the new upcoming ethanol plants. Sugarcane production in Thailand has remained stable because the yield is generally lower than other main sugar producing countries. In Thailand, molasses and sugar production are strictly controlled as they must comply with the regulations. The quota of sugar production for domestic and export market is controlled by the Office of the Cane and Sugar Board (OCSB) in order to control supply and demand and for stability of the sugar price (FAO, 2010; Sriroth et al., 2010; Nguyen et al., 2007). Moreover, molasses is used in manufacturing alcoholic beverages and is of high competitive use for both domestic and export spirits and alcohol industry. In 2013, sugarcane production in Thailand was 98 million tons, resulting in molasses production of 4.4 million tons, out of which 1.4 million tons was used in the domestic spirit and alcohol industry, whereas 1 million tons was exported. There were 2 million tons left to be used for ethanol industry (Bank of Thailand, 2014).

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On the other hand, cassava has potential to be used as the feedstock for ethanol production in the future because of several advantages. Firstly, cassava can tolerate all harsh environmental conditions especially drought as also low input requirements in planting and harvesting. Secondly, unlike feedstock from sugar-based industries (molasses) that available seasonally, cassava can grow, and can be harvested all year round. Thirdly, it can be converted into dried chips easily and stored for long periods and is easy to transport. Fourthly, the average yield in Thailand is high compared to the global average and there is technology potential to increase the yield even further in the future. The higher demand of food, feed, and fuel has significant impact on the rising of cassava price. For this reason, the harvested area of cassava tends to expand continuously (FAO, 2010; Sriroth et al., 2010; Nguyen et al., 2007). This makes cost of ethanol production from cassava slightly higher than ethanol produced from molasses. However, feedstock material use efficiency and land utilization of cassava seems to be better than those of sugarcane (molasses) (Silalertruksa and Gheewala, 2009).

At present, even though over half of the ethanol plants in Thailand are configured to use molasses as feedstock, a number of new plants equipped cassava ethanol facilities are under construction. Therefore, The Office of Agricultural Economics (OAE) and the Ministry of Energy (MoE) set the plan for the share of ethanol targets by using either cassava or molasses feedstock. The proportion of molasses:cassava feedstock for ethanol production in Thailand in 2018 would be 20:80 (FAO, 2010). Therefore, ethanol produced from cassava would be 7.2 MLPD or 2160 MLPY (14 MTPY cassava feedstock is required) (DEDE, 2014).

However, cassava feedstock for ethanol production is expected to increase from 2.6 MTPY to over 14 MTPY between 2010 and 2022 (DEDE, 2014; FAO, 2010). If we spare 11.9 MTPY of cassava feedstock for feed and 14.2 MTPY for starch production the same as in 2012, without reduction of export, total requirement of cassava would be 40.1 MTPY. Therefore, cassava production has to be increased considerably. The increase in cassava production can come largely from yield improvements and expansion of the land area (FAO, 2010). Cassava plantation area in Thailand in 2013 is 1.2 million ha. The yield has been targeted to increase from 21 ton/ha to 31 ton/ha. This can increase the cassava production to 37 MTPY (DEDE, 2014). Therefore, yield improvement would not be sufficient to cope with this challenge. Moreover, not only yield improvement depends on a number of factors, but it also requires considerable efforts and is difficult to achieve.

The expansion of the land area is considered as another efficient way to increase production. However, the increase in the harvested area of cassava may result in the reduction of land for other food crops with a consequent reduction in food production. Deforestation may also be increased if agricultural land encroaches directly or indirectly on forests. Development of technologies to improve eco-efficiency and productivity of cassava supply chain (for example: good agricultural practices, water recycling, technology modification for reduction of starch and alcohol lost and material and energy recovery from by-product) can be a positive alternative to assist Thailand in sustainably reaching the AEDP target with minimum burden on the environment (Blottnitz and Curan, 2007; Liewa et al., 2014; Nguyen and Gheewala, 2008).

Material Flow Analysis (MFA) can be used to trace the flow of materials (cassava and sugarcane feedstock and all different cassava and sugarcane products and semi-products, by-products and waste) through all the related processes. It provides a useful conceptual framework to plan for regional sustainable resource and waste management and to evaluate the application of resource management (Birkeland and Schooneveldt, 2003). This research will apply Material Flow Analysis (MFA) model as the main tool and economic analysis will also be covered by Material Flow Cost Accounting (MFCA) model. The loss cost and opportunity for technology improvement in a starch production and ethanol production plant in Thailand will be evaluated. This research will use data collected in 2012 as the base case and will generate scenarios to assess the possibility to meet the Thai AEDP Biofuel target in 2022.

2. Material and methods

This research will apply Material Flow Analysis (MFA) model as a main tool. The economic analysis will also be covered by Material Flow Cost Accounting (MFCA) model in order to evaluate opportunities, effectiveness and potential of technology improvement for cost reduction. METI (2007) has defined Material Flow Cost Accounting (MFCA) as “one of the environmental management accounting methods aimed to reduce both environmental impact and costs at the same time by reducing costs through waste reduction, thereby improving business productivity”.

Material loss in the production refers to non-productive or non-efficient use of materials extracted from nature. MFCA is a tool that can identify the cost of production in each sub-process as well as categorize positive and negative products cost. For example, some company that just applies MFCA found that its positive product is 70 percent whereas negative product can be up to 30 percent. If the company can improve material efficiency or reduce their material loss, their negative cost will reduce (meaning increase in profit). This information can assist the decision making process of the top management of the company on whether is it cost effective to invest in reducing material loss and can help reduce negative product cost.

MFCA tracks and quantifies the flow and stock of “materials”, which include raw materials, parts and components in the manufacturing process using the mass balance principle. Here, part of raw materials that become waste, defective products and emissions associated with material transformation, can be identified as “material loss”.

Four categories of the cost information including material costs, system cost (labor, depreciation etc.), energy cost and waste treatment cost can be compiled as the quantity data based on material flow. The MFCA results allocate product costs into 2 types: “positive product cost” and “negative product cost”. “Positive product costs” are the costs put into process products (positive products) released to the next process. “Negative product costs” or “loss costs” are costs put into wasted or recycled items (negative products). Material loss cost can be simply calculated by multiplying individual quantities (kg) of waste by their material purchased unit price, or by using raw material cost multiplies by percent of material loss by weight. Energy or system loss cost can be calculated by using mass allocation method: cost of energy input multiplied by percent of material loss by weight in each sub-process (out of material input in each sub-process) (METI, 2007).

MFCA considers the main material flows in all processes as well as sub materials, except auxiliary, materials. Main materials, sub materials and auxiliary materials are defined as follows (METI, 2007; Chompu-inwai et al., 2015):

- Main materials: The principal materials in the initial process and the work-in-process from the previous process.
- Sub materials: Materials added to the main materials to form part of the company products in each process
- Auxiliary materials: Materials that are used in each process but do not form part of the company products;