

## Overview of biofuels sustainability and future in ASEAN context

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### **Abstract:**

*This review was motivated by the notion of intergenerational equity, which inherently should contain the concept of sustainability. Six kinds of biofuel feedstock were compared with three different principles of sustainability; social, economical, and environmental. The types were: Palm oil, soybeans, jatropha, cassava, sugarcane, and lignocellulosic biomass. ASEAN region figures were used for comparison when attainable. On all three accounts the best result were gained from lignocellulosic biomass and the two types of feedstock that were chosen to represent the larger class of lignocellulosic biomass; Napier- and switchgrass. They were used to emulate feedstock cultivation for biofuel purposes rather than using agricultural waste. Jatropha's low yield keeps it from being a serious contender. Lastly, the high price of palm oil keeps it from being an economical feedstock, but necessary as a food oil.*

**Keywords:** ASEAN; biofuels; feedstock; lignocellulosic biomass; policy; sustainability

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### **1. Introduction**

Environmental concerns, increasing energy needs, fossil fuel prices, and the fact that countries in the ASEAN region are richly endowed with renewable energy sources have played a role in their rapid expansion (Lidula et al., 2007). Especially the development of biofuels has progressed swiftly in Indonesia, Malaysia, the Philippines and Thailand (Kumar et al., 2013). Rapid development does not always translate into integrated practices and policies. Continuous evaluations are needed to support and provide guidance for the policies and practices, which in turn can assist in sustaining the high levels of development.

Interest in sustainably produced biofuels should continue to increase, for in order to have intergenerational equity it inherently requires the concept of sustainability (IPCC, 2014b). Temperature and precipitation changes, without taking into consideration CO<sub>2</sub>, will contribute to increased global food prices by 2050; increases ranging from 3-84% (IPCC, 2014a). Sustainability criteria are already a part of policies in major biofuel consuming countries, and the criteria are expected to continue to affect the biofuel markets. The Renewable Energy Directive (RED) stipulates that a given biofuel has to attain reductions of at least 35 % in greenhouse gas (GHG), and the threshold will rise to 50 percent in 2017 for existing plants and reach 60 % for new production facilities (OECD, 2011).

### **2. Rationale and objective**

The underlying motivation for this work lays in the supposition that biofuels feedstock, and to a lesser degree processing methods advocated, may be sustainable in the social, economical, and environmental sense. The objective of this study is to compare types of biofuel feedstock in relation to sustainability principles. The sustainability principles in turn can facilitate trade and mitigate fears of bans, such as EU banning biofuel exported from Southeast Asia or World Bank cutting funding (Mekhilefa et al., 2011). For the long term, sustainability assessments play a valuable role in supporting policy makers and other stakeholders in understanding existing and emerging sustainability issues within the biofuel sector. Policy issues are certainly a key factor as the ASEAN regional integration is about to take place as soon as December 2015 called ASEAN Economic Community (AEC) (Aromaki, 2014). Committing to the AEC policies is expected to have advantages which by reducing uncertainty, could lead to expansion of trade and investment in Southeast Asia (Green, 2008).

### 3. Approach and Methodology

For this study a comparative framework was created using the sustainability principles from International Energy Agency (IEA) (2011), and European Biofuels Technology Platform (EBTP, 2014). The sustainability principles are: social, economical, and environmental. Because the study uses data from previous literature it limits the scope and type of answers obtained. The criteria were used to compare types of biofuel feedstock: Palm oil, soybean, jatropha, cassava, sugarcane, and lignocellulosic biomass. Because the lignocellulosic biomass consists of a large group of source materials to emulate feedstock grown specifically for biofuel, production data from switchgrass and Napier grass were used. The criterion for selecting the above mentioned feedstock was their status as established feedstock compared with less established feedstock expected to have high potential. The approach consisted of literature search, a desk study and a case study, followed by an analysis of the methods and assumptions used, and findings obtained to identify detectable differences including sustainability comparisons based on the type of feedstock or on recent developments in processing.

Online search was used to identify papers and reports that have been published between years 2007-2014. The search included published assessments that contained relevant research on at least one of the dimensions of the sustainability criteria. The accepted publications came from peer reviewed journals and respected international institutions such as the International Energy Agency (IEA) and the Food and agriculture Organization (FAO), with two exceptions related to market price. These institutions also provided relevant data to analyze trends that affect biofuels. After reviewing literature the scope of the research was trimmed down to reflect the best available data for comparing biofuel feedstock. The literature in some of the social aspects was relying on anecdotal evidence and in some cases seemed heavily opinionated and as a result the social dimension compares only food vs. fuel subset. In the environmental dimension the GHG was decided to be the defining factor, because of its direct relevance to policies such as the Renewable Energy Directive (RED). From the economic dimension the price and the yield of the feedstock was considered to be the most appropriate, because 60-80 percent of the expense of producing biofuel comes from feedstock (Borugadda and Goud, 2012; Kumar et al., 2013). Energy security and other sustainability concerns are certainly important factors that were not taken into the comparative table, because of limited time, space and other resources.

### 4. Results and discussion

**Table 1** Yields and GHG of Cassava, Oil palm fruit, Soybeans, and Sugar cane, Jatropha

Feedstock	GHG reduction	Yield	Producer Price	Food vs. Fuel
Oil, palm fruit	38-78 % <sup>1,2</sup>	185,564 Hg/Ha	(oil ) 999.33 USD/tonne	Yes
Soybeans	76.4% <sup>4</sup>	14,930 Hg/Ha	598.5- 800.9 USD/tonne	Yes
Sugar cane	63-103 % <sup>1</sup>	681,612 Hg/Ha	30.7-291.3 USD/tonne	Yes
Cassava	25.5%-33.9% <sup>6</sup>	189,452 Hg/Ha	67.2-226.6 USD/tonne	Yes
Napier /Switchgrass	93% <sup>5</sup>	583,000 Hg/Ha <sup>7</sup>	? 10 USD/tonne <sup>9</sup>	No
Jatropha	55-90 % <sup>3</sup>	4,725 Hg/Ha <sup>8</sup>	? 600 USD/tonne <sup>10</sup>	No

Source: FAO, 2012; World Bank, 2012; Smeets, et al., 2009<sup>1</sup>; Yee et al., 2009<sup>2</sup>; Martinez-Hernandez et al., 2014<sup>3</sup>; Pradhan, et al., 2012<sup>4</sup>; Monti et al., 2012<sup>5</sup>; Liu et al., 2013<sup>6</sup>; Rengsirikul et al., 2013<sup>7</sup>; Tikkoo et al., 2013<sup>8</sup>; DEDE, 2013<sup>9</sup>; Alibaba.com, 2014<sup>10</sup>

The environmental portion of sustainability measure used in this review is the GHG reduction compared to fossil fuels. The GHG reduction ranges are presented in Table 1. When applicable the figures comply approximately with the ranges presented in the International Energy Agency roadmap (2011). The table indicates that sugarcane and switchgrass have the highest GHG reduction potential. Lignocellulosic ethanol from other feedstocks might have even higher reduction potential, but using specifically grown feedstock, in this case switchgrass, gives an indication of the potential of specifically grown energy crops. Also it reduces the range that a wider variety of possible agricultural feedstocks may create for GHG results.

From oilseeds oil palm has the highest oil yield producing on average about 4–5 tonnes of oil/ha annually which is about 10 times the yield of soybean oil (Sumathi et al. 2008; FAO, 2012). Table 1 indicates that in ASEAN palm oil is by far superior in terms of yields per hectare among the selected oilseeds. From biomass perspective sugarcane, Napier grass and cassava have higher yield than palm oil.

Feedstock price range for Table 1 comes from the three currently biomass-prominent countries of Indonesia, Malaysia, and Thailand, which for the most part had the best prices of the ASEAN members, and additional price data comes from the world price (World Bank, 2012; FAO, 2012). To get at least some estimate of the price of Napier grass Thailand's promised minimum alternative energy development plan price was converted to dollars with September 3<sup>rd</sup> 2014 conversion rate resulting in a price of 9.36 USD/tonne (DEDE, 2013; XE, 2014). Also jatropha lacks official pricing and the estimate uses an internet trading price (Alibaba.com, 2014). It is safe to assume that there will be some convergence of the feedstock prices when the AEC comes into being, which will have its impact on the feasibility of refining.

In many regards Palm oil is the most prospective biodiesel feedstock compared to other oilseeds. It has higher production yield and low needs for fertilizer, water, and pesticides (Mekhilefa, et al. 2011). It's down side is work intensive and difficult harvesting, price fluctuation is a significant barrier, as are competition with the edible oil market, and problems related to deforestation (Borugadda and Goud, 2012; Mekhilefa, et al., 2011).

Even though Jatropha does not compete with food as can be seen from the table 1 the yields are too low and the market prices too high even though the figures presented in the table were reached with the use of irrigation and fertilizers. Unfortunately so far the conclusion is that Jatropha is not living up to its expectations.

Since the cost of raw materials accounts to about 60–80% of the total cost of biodiesel production, choosing a right feedstock is very important. Table 1 suggests that when counting the yield, GHG reduction and estimated feedstock price. Sugarcane and Napier grass are by far most potential feedstocks for biofuel in general. Napier grass has the additional advantage of not directly competing with food. Naturally in order not to compete with food lignocellulosic biomass should come from agricultural waste, or from feedstock grown on marginal land. Lignocellulosic biomasses are cheap and the most abundant forms of biofuel feedstock attainable today (Nanda et al., 2014).

Growing population and rising consumption increase demand for both biofuels and food, and this naturally leads to a conflict as they depend on the same resources for their production: land, water, and energy (Pimentel et al., 2009). Food prices are expected to rise further because of the global climate change (IPCC, 2014a). Food concerns have important implications for the selection of feedstock, as in the future food vs. fuel will not only be an ethical issue, but an issue of feasibility.

How we process the feedstock matters in all three dimensions of sustainability. The traditional lignocellulosic biomass treatments often called 2<sup>nd</sup> generation (2G) have not been cost competitive because of their high enzymatic costs, high levels of waste and lack of holistic approaches with other value added products that can compensate for low ethanol prices. Newer methods have overcome previous obstacles on feasibility. Pilot case of Chempolis vs. traditional 2G, indicate several improvements: including holistic approach with value added chemical products, yield of glucose from cellulose kg/t biomass 340 vs. 300 traditional 2G, enzyme consumption reduction 10 vs. 20 (comparative figure) traditional 2G, overall product yield kg/t biomass 315 due to value added chemical products vs. 235 traditional 2G (Anttila, 2013).

Because lignocellulosic biomass does not compete with food directly it therefore is more ethical and its price drivers are not directly affected by a growing demand for food. Thus it is a safer option for capital intensive refineries.

## 5. Conclusion

A large diversity of issues governs sustainably produced biofuels and their practicality. In a typical biofuels and investment environment 'Not having all eggs in one basket' appears an effective strategy. ASEAN-wide policy measures such as a common trading platform and data bank could spur investments in the biofuels in general and maybe in the newer technologies that seem to better serve sustainability principles such as lignocellulosic biomass.

Palm oil, cassava and sugarcane still have their places in biofuel production, but their competition with food is an increasingly problematic issue with the growth of population and with climate change. Jatropha holds theoretical promise, but is far from delivering on the expectations laid on it. Lignocellulosic biomass holds potential in answering the rising demand in biofuels in a more sustainable manner than other feedstock compared, but it requires pilot cases in the ASEAN context in order to prove its worth in sustainability and feasibility.

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