Chapter 3

Review of Biofuels Sustainability Assessment and Sustainability Indicators in East Asia Summit Countries

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Chapter 3

Review of Biofuels Sustainability Assessment and Sustainability Indicators in East Asia Summit Countries

1. Introduction

1.1. Background

Energy is important for human survival and all our activities have a related energy demand. Transportation is one such important activity relying largely on fossil-based oil for gasoline and diesel. The two major issues related to the use of gasoline and diesel are the reliance of crude oil, a non-renewable resource, and the emissions of greenhouse gases which contribute to climate change. Biofuels refer to liquid transportation fuels that rely on biomass as the feedstock. This addresses the issue of non-renewability of fossil-based fuels because sustainably produced biomass can be considered as renewable. Also, as the carbon in the biomass is taken from the atmosphere during plant growth, release of carbon dioxide from the combustion of biofuels does not add to the carbon dioxide in the atmosphere. However, from a life cycle perspective, of course this apparent carbon neutrality is far from perfect. Also, there are several other issues of sustainability which cannot be taken for granted for biofuels without a proper and systematic assessment.

Efforts have been made at the regional and international level to identify indicators for assessing sustainability of biofuels. Some of the international efforts include those by the Global Bioenergy Partnership (GBEP) and the Bioenergy and Food Security by the Food and Agriculture Organization of the United Nations (FAO). The GBEP identified 24 indicators, eight each for environment, economy, and society, the three pillars of sustainability, as shown in Table 3.1.

Table 3.1: Global Bioenergy Partnership Sustainability Indicators for Bioenergy

Environmental	Social	Economic
Life cycle GHG emissions	Allocation and tenure of land for new bioenergy production	Productivity
Soil quality	Price and supply of a national food basket	Net energy balance
Harvest levels of wood resources	Change in income	Gross value added
Emissions of non-GHG air pollutants, including air toxics	Jobs in the bioenergy sector	Change in consumption of fossil fuels and traditional use of biomass

Water use and efficiency	Change in unpaid time spent by women and children collecting biomass	Training and requalification of the workforce
Water quality	Bioenergy used to expand access to modern energy services	Energy diversity
Biological diversity in the landscape	Change in mortality and burden of disease attributable to indoor smoke	Infrastructure and logistics for distribution of bioenergy
Land use and land-use change related to bioenergy feedstock production	Incidence of occupational injury, illness and fatalities	Capacity and flexibility of use of bioenergy

GHG = greenhouse gas.

Source: GBEP (2011).

At the time of the development of the GBEP indicators and to some extent preceding it, an expert working group consisting of researchers from various countries in the region was formed by the Economic Research Institute for ASEAN and East Asia (ERIA) in 2007. This working group framed the ‘Asian Biomass Energy Principles,’ which were endorsed in the Energy Ministers’ Meeting during the East Asian Summit held in Bangkok in August 2008. On request from the energy ministers of the region, this working group then developed a region-specific methodology to assess the environmental, economic and social impacts of biomass energy which were subsequently tested via pilot studies in India, Indonesia, Thailand, and the Philippines (Kudoh et al., 2015).

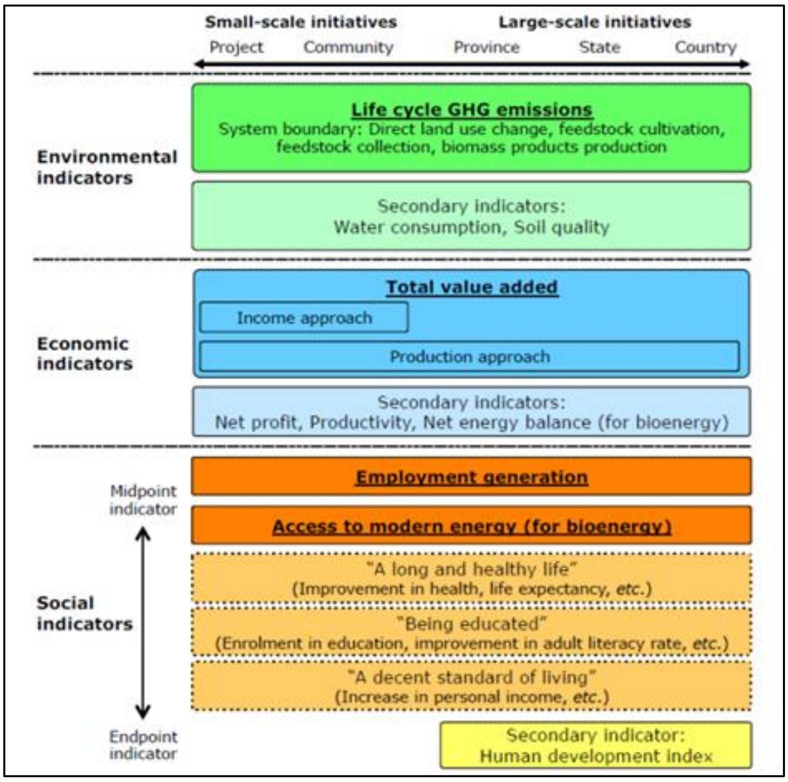
1.2.Objective and Scope

The overall objective of this part of the project is to evaluate the progress of sustainability assessment of biofuels in the East Asia region with examples of some of the participating countries (India, Thailand, Indonesia, Philippines, Malaysia, and Viet Nam) using, if possible, the sustainability indicators proposed by the earlier ERIA project on ‘Sustainable Biomass Utilisation Vision in East Asia’ (Sagisaka, 2008). In the first year, the indicators were introduced to the participating representatives from the different countries and an attempt made to collect existing information. This would lead to information on the current status of sustainability assessment in the East Asia region and needs for collecting further information to fill the gaps in the existing available information or even reconsidering some of the selected indicators, if needed. This would then be supplemented by collecting additional information and/or data for updating research as identified in the first year and conducting additional assessment for updating the research results. In the third year, the research results will be interpreted after scientific validation. Finally, a policy brief will be prepared to address policy concerns and needs vis-à-vis biofuels sustainability in EAS countries.

1.3. Methodology

After extensive deliberation and consultation amongst the working group members, the previous ERIA project (Sagisaka, 2009) suggested three indicators, one each for environmental, economic, and social aspects. This was done with the intention to simplify the evaluation while retaining the important aspects to be considered. Life cycle greenhouse gas (GHG) emissions was chosen as the environmental indicator, total value added as the economic indicator, and the human development index as the social indicator. After field testing of the indicators to check their applicability, slight revisions were made to the list of indicators as indicated in Figure 3.1 (Kudoh et al., 2015).

Figure 3.1: Main and Secondary Indicators of Biofuels Sustainability at Different Levels



GHG = greenhouse gas.
Source: Kudoh et al. (2015).

Based on the recommendations from the previous ERIA working group report, the following six indicators (two each for environmental, economic, and social aspects) were selected to be included as part of the current study. For the assessment of environmental sustainability, life cycle GHG emissions was chosen as the main indicator and water consumption as the secondary indicator. For the assessment of economic sustainability, total value added was chosen as the main indicator and net energy balance as the secondary indicator. For the assessment of social sustainability, employment generation was chosen as the main indicator and access to modern energy as the secondary indicator. The calculation methods for these indicators are described as follows:

1. Life Cycle Greenhouse Gas (GHG) Emissions

The life cycle GHG (or LC-GHG) emissions use the life cycle assessment (LCA) approach to collecting inventory information on GHG emissions throughout the life cycle of a biofuel chain including feedstock cultivation, feedstock processing into biofuels, and the use of biofuels in vehicles. The GHG emissions from intermediate transportation between the different life cycle stages is also included.

$\text{LC-GHG} = \sum_{ij} (\text{GHG}_{ij} \times \text{GWP}_i)$ (1)

Where, i = a greenhouse gas (e.g. carbon dioxide, methane, nitrous oxide)

j = a life cycle stage (e.g. feedstock cultivation, processing, etc.)

LC-GHG = Life cycle GHG emissions ($\text{kgCO}_2\text{e/FU}$)

FU = Functional unit (e.g. MJ of biofuel)

GHGij = GHG 'i' in stage 'j' (kgGHGi/FU)

GWPi = Global warming potential for GHG 'i' ($\text{kgCO}_2\text{e/kgGHGi}$)

2. Water Consumption

Water is required for various activities during the cultivation of biofuel feedstock including land preparation and plant growth. Water is also used in the various processing stages of biomass for producing biofuels. So, like the other environmental indicator, LC-GHG, water consumption also includes the use of freshwater at all the stages of the biofuels life cycle. As a first step, this indicator will only include water use across the biofuel's life cycle.

However, if more information is available from the various countries, then a more sophisticated indicator called 'water scarcity footprint' including water availability and water stress in various regions will also be considered in the future.

3. Total Value Added

Economic assessment of biofuels is often done via indicators such as value addition, job creation, and tax revenue generation. Thus, economic sustainability of biofuels at the project level includes i) total net profit accumulated from biomass conversion or processing; ii) personnel remuneration created by employment in the biofuels industry; iii) tax revenues generated from different entities within the industries; and iv) total value added, which is the sum of all the previous indicators.

The above indicators can be calculated by the following equations:

Total net profit (TNP) = Total returns – Total costs (2)

Where,

Total returns = Sales from primary output + Sales from by-products

Total costs = Amount of material inputs used + Labour costs + Overhead costs

Overhead costs = Taxes and duties + Interest + Depreciation

Personnel remuneration = Total man-days (Employment) × Average wage

per man-day (3)

Where,

Wages = Wage rate × Labour requirement

Tax revenue = Total taxable income × Tax rate (4)

Where,

Total taxable income = Income from main product + Income from by-product

Income from main product = Profit per unit of main product A × Volume of A

Income from by-product = Profit per unit of by-product B × Volume of B

And, finally,

Total value added (TVA) = Total net profit + Personnel remuneration + Tax revenue (5)

A similar approach from the GBEP can be followed for assessing total (or gross) value added at the national level. Here, the indicator shows the size of the contribution of the biofuels sector to the national economy. The indicator also shows the contribution to GDP per unit of biofuels. This allows for more informative comparison with other forms of energy.

Gross value added = Total output value - Intermediate inputs (6)

4. Net Energy Balance

Net energy ratio is described as the ratio of the biofuels (energy) output to total energy inputs for all stages of biofuels production. Another related indicator that is also useful is ‘renewability’, which is defined as the biofuels (energy) output to the life cycle fossil energy input (Gheewala, 2013). Both the ratios should have a value of more than 1 for the biofuel to be 'profitable' in terms of energy. Of course, thermodynamically speaking, output of energy can never be greater than the input; however, a ratio of greater than 1 can be obtained for biofuels because solar energy during the production of biomass that goes into the biofuel is not accounted for.

The net energy balance shows the amount of bioenergy output per unit of total energy input whereas the renewability shows the amount of bioenergy output per unit of fossil energy input. Both the indicators give slightly different, but interesting and important information.

5. Employment Generation

The cultivation of biomass for biofuels is a labour-intensive process creating both direct employment at the farm and supplemental income from the sale of biomass and farm residues. Employment is also generated during biomass processing to produce biofuels. Indirect employment is also created through the production stages of fertilisers, other agrochemicals, farm machinery, and so on. The economy-wide implications of employment generation through the promotion of biofuels could also be included.

6. Access to Modern Energy

This indicator provides an assessment of the contribution of modern bioenergy (biofuels) as an access to modern energy services. It can be assessed as the total amount and percentage of increased access to modern energy services gained through biofuels in terms of energy. It can be measured in terms of megajoules (MJ)/year and percentage.

2. Biofuels Sustainability Assessment and Sustainability Indicators

A. Thailand

a.Environmental Indicators

1.Life cycle GHG emissions

Several extensive LCA studies have been conducted in Thailand covering both palm oil-based biodiesel and ethanol from cassava and sugarcane molasses. Since these studies were designed to support biofuels policy, they also covered several scenarios of land use change, as well as improvement scenarios. Hence, the results were presented as ranges of values. A summary of the results for ethanol (Silalertruksa and Gheewala, 2011) and biodiesel (Silalertruksa and Gheewala, 2012a) are presented in Tables 3.2 and 3.3, respectively.

It is interesting to note here that life cycle GHG emissions of gasoline are 90 gCO_2e/MJ. Thus comparing with the values of ethanol (which would replace gasoline) in Table 3.2 reveals that if there is no land use change during sugarcane or cassava cultivation, then the life cycle GHG emissions of ethanol are generally lower than gasoline, the lowest being when ethanol is produced directly from sugarcane juice. The GHG benefits of ethanol are also possible when grassland is converted to sugarcane or cassava plantations; however, in this case, the benefits are relatively modest and only in the best case for cassava and sugarcane molasses. Ethanol from sugarcane juice still has consistently lower emissions than gasoline in this case. However, if forest land is converted to cassava or sugarcane plantations, then the life cycle GHG emissions from ethanol are substantially higher than that from gasoline for all cases.

Similarly, the life cycle GHG emissions of diesel are 85 gCO_2e/MJ. Thus, comparing the values of biodiesel (which would replace diesel) in Table 3.3 reveals that without land use change, palm biodiesel performs substantially better than diesel. With land use change from rubber, cassava, paddy field, and set-aside land to oil palm, the life cycle GHG emissions are even lower because of the increase in soil organic carbon for oil palm plantations. However, as in the case of ethanol, if forest land is changed to oil palm plantations, then the life cycle GHG emissions of biodiesel are much higher than diesel.

The clear message for both ethanol and biodiesel is that to maintain GHG benefits of the biofuels, it is imperative to avoid conversion of forest land to feedstock agriculture. Also, good practices such as the utilisation of biomass residues and the wastewater generated (by producing biogas) at the processing facilities help to reduce the GHG emissions from the biofuels.

Table 3.2: Life Cycle GHG Emissions from Ethanol in Thailand (gCO_2e/MJ)

Feedstock	Excluding LUC	Forest to Crop	Grassland to Crop
Cassava	27–91	249–313	63–127
Molasses	31–100	295–361	74–140
Sugarcane	23–27	154–157	44–48

g = gram, GHG = greenhouse gas, LUC = land use change, MJ = megajoule.
Source: Silalertruksa and Gheewala (2011).

Table 3.3: Life Cycle GHG Emissions from Palm Biodiesel in Thailand (gCO_2e/MJ)

Excluding LUC	18–38
Rubber to oil palm	5–25
Cassava to oil palm	1–21
Paddy field to oil palm	8–27
Set-aside land to oil palm	9–28
Forest to oil palm	218–248

g = gram, GHG = greenhouse gas, LUC = land use change, MJ = megajoule.
Source: Silalertruksa and Gheewala (2012a).

2.Water Consumption

The freshwater requirement for the life cycle of ethanol and biodiesel production in Thailand has been evaluated. As anticipated, most of the freshwater requirement (more than 95%) for both the biofuels is from the agricultural stage. Part of the freshwater requirement is met by rainfall and partly by irrigation.

The water consumption for ethanol is provided in Table 3.4. The results show that ethanol from cassava has the highest water requirement followed by that from molasses and then sugarcane juice. However, the more critical irrigation water requirement, which affects water scarcity, is maximum for molasses ethanol, followed by sugarcane and cassava. It must also be noted that the irrigation water requirement is a theoretical based on idealised crop water requirement calculations. In fact, crops that are planted outside the irrigation zones may mainly be rainfed. Even crops that are irrigated may not necessarily receive the full theoretical water requirement and may be planted under deficit conditions.

The water consumption for biodiesel is presented in Table 3.5. Oil palm requires a substantial amount of water during cultivation. Also, since the first few years during the growth of the oil palm tree, there is no fruit, the overall water requirement per litre of biodiesel increases partly as a result of that too. However, oil palm is usually planted in the equatorial regions with a lot of rainfall, thus reducing its irrigation water requirement.

Table 3.4: Water Consumption for Ethanol in Thailand (L water/L ethanol)

Feedstock	Total water	Irrigation
Cassava ethanol	2,372–2,838	449–566
Sugarcane ethanol	1,396–2,196	582–859
Molasses ethanol	1,976–3,105	829–1,220

L = litre.
Source: Gheewala et al. (2013).

Table 3.5: Water Consumption for Biodiesel in Thailand (L water/L biodiesel)

Economic Assessment	Life Cycle Stage		Biorefinery complex (THB/year)
	Plantation (THB/year)	Biorefinery (THB/year)	
Total net profit	393,681,432	956,712,601	1,350,394,033
Wages paid	708,125,095	760,810,000	1,468,935,095
Tax revenue	13,625,940	357,494,553	371,120,493
Total Value Added			3,190,449,621

L = litre.
Source: Nilsalab et al. (2017).

b. Economic Indicators

1. Total Value Added

The total value added was calculated for a sugarcane biorefinery complex in the Khon Kaen province of Thailand as part of the pilot studies of the earlier ERIA project. The results are presented in Table 3.6 (Gheewala et al., 2011). The overall biorefinery process yields a total value added of THB3,190,449,621/year (approx. US$116.1 million /year) and is economically viable.

Table 3.6. Total Value Added per year from Sugarcane Cultivation and Biorefinery in Thailand

	Total water	Irrigation
Palm oil biodiesel	2,904–18,704	404–7,504

Source: Gheewala et al. (2011).

2. Net Energy Balance

For evaluating biofuels, one of the first assessments to be done should be a net energy ratio. The biofuels must pass this test before there is even a need to make other assessments. If biofuels do not yield a ratio of more than 1, there seems little reason to pursue them. Several studies have been carried out in Thailand to assess the net energy ratio and renewability of ethanol and biodiesel in Thailand. The results are summarised in Table 3.7. The net energy ratios of ethanol from cassava and molasses are greater than 1, indicating the first step towards their viability (Gheewala, 2013). Of course, they are only marginally greater than 1 indicating that improvements would be in order. The renewability is slightly better indicating that more bioenergy is produced per fossil energy input. The situation with biodiesel is a bit better with both net energy ratio and renewability values more than 2. In fact, with a proper utilisation of residues and biogas from the palm oil mill effluent (wastewater), the values of both the indicators improves substantially indicating the importance of such biomass utilisation (Silalertruksa and Gheewala, 2012b).

Table 3.7. Net Energy Ratio and Renewability of Biofuels in Thailand

Fuel	Net Energy Ratio	Renewability
Cassava ethanol	1.19	1.38
Molasses ethanol	1.12	3.05
Palm biodiesel	2.07 (4.30)	2.12 (4.39)

Source: Gheewala (2013).

c. Social Indicators

1. Employment Generation

One of the major advantages of biofuels is the employment generation, particularly in the agriculture stage. Apart from the agriculture stage itself, the activities induced in related sectors throughout the economy may also have some employment benefits. This is seen in Table 3.8 (Silalertruksa et al., 2012). The employment generation from biofuels is far greater than both gasoline and diesel. For the direct employment, more than 95% was from agriculture for all the biofuels. For the indirect employment, agriculture contributed about 80% for ethanol and about 60% for biodiesel (Silalertruksa et al., 2012).

Table 3.8. Employment Generation (person-years) from Biofuels in Thailand

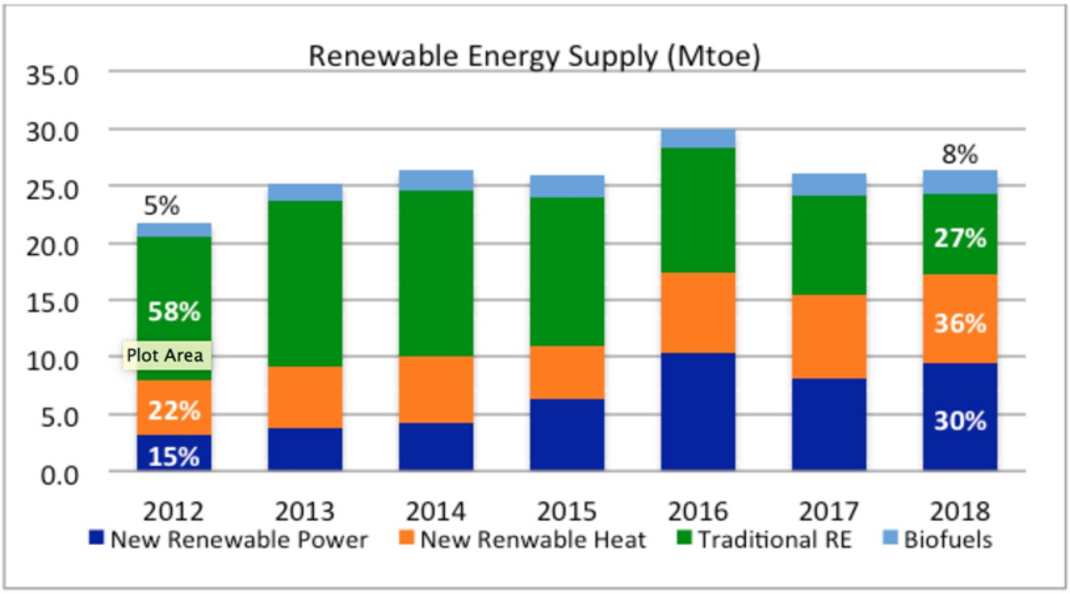
Fuel	Per TJ of Biofuels		
	Direct	Indirect	Total
Cassava ethanol	3.3	2.2	5.5
Molasses ethanol	0.5	4.8	5.3
Sugarcane ethanol	4.0	1.7	5.7
Palm biodiesel	2.0	1.5	3.5
Gasoline	0.0	0.3	0.3
Diesel	0.0	0.3	0.3

TJ = terajoule.
Source: Silalertruksa et al. (2012).

2. Access to Modern Energy

For this particular indicator, data were not available directly for biofuels in the way the indicator has been designed. Some data on the contribution of biofuels to the overall renewable energy was obtained from the Energy Policy and Planning Office as shown in Figure 3.2.

Figure 3.2. New and Traditional Renewable Energy in Thailand



(New Renewable Energy includes: modern use bioenergy for heat and power, solar anc wind, and hydro)

Mtoe = million tons of oil equivalent, RE = renewable energy.
Source: Planning Office, Ministry of Energy, Thailand.

B. Indonesia

The real desires to establish an Indonesian Bioenergy Sustainability Indicators (IBSI) to safeguard the development of bioenergy industry in the country probably aroused after an FAO's funded pilot testing activity in Indonesia of the GBEP Sustainability Indicators for Bioenergy in 2014. Early in 2016, the Indonesia Oil Palm Plantations Fund Management Agency assigned a working team from the Surfactant and the Bioenergy Research Center from Bogor Agriculture University, Bogor, Indonesia, to develop and formulate the IBSI. After reviewing more than 12 bioenergy-related sustainability indicators the team considered that the GBEP Sustainability Indicators for Bioenergy as the indicators that take into account economic, social, and environmental aspects in a balanced manner and therefore chose them as the reference base for developing the IBSI. After extensive desk studies and consultation with stakeholders through various focus group discussions, the team finally established the following 10 IBSI that encompassed environmental, social, as well as economic aspects:

a. Environmental Indicators

1. Lifecycle GHG emissions
2. Waste management and cleaner production:
   - 2.1. Soil quality
   - 2.2. Air quality
   - 2.3. Water use and efficiency

b. Social Aspect Indicators

3. Change in income
4. Job in bioenergy sector
5. Bioenergy used to expand access to modern energy service

c. Economic Aspects Indicators

6. Productivity
7. Net energy balance
8. Gross value added
9. Energy diversity
10. Infrastructure and logistic for bioenergy distribution

The IBSI also require that the plantations producing the bioenergy raw material has fulfilled upstream certification such as Indonesian Sustainable Palm Oil. The IBSI have also been field tested by Papilo et al. (2018) and Aliviar, Arkeman, and Hambali (2019). A book covering the historical development of the IBSI that also contain descriptions and measurement units of all the 10 indicators has been published (Hambali et al., 2019).

During an IBSI workshop in May 2020, stakeholders including the Indonesian Biofuel Producers Association (APROBI) supported the existence of the IBSI and urge their execution.

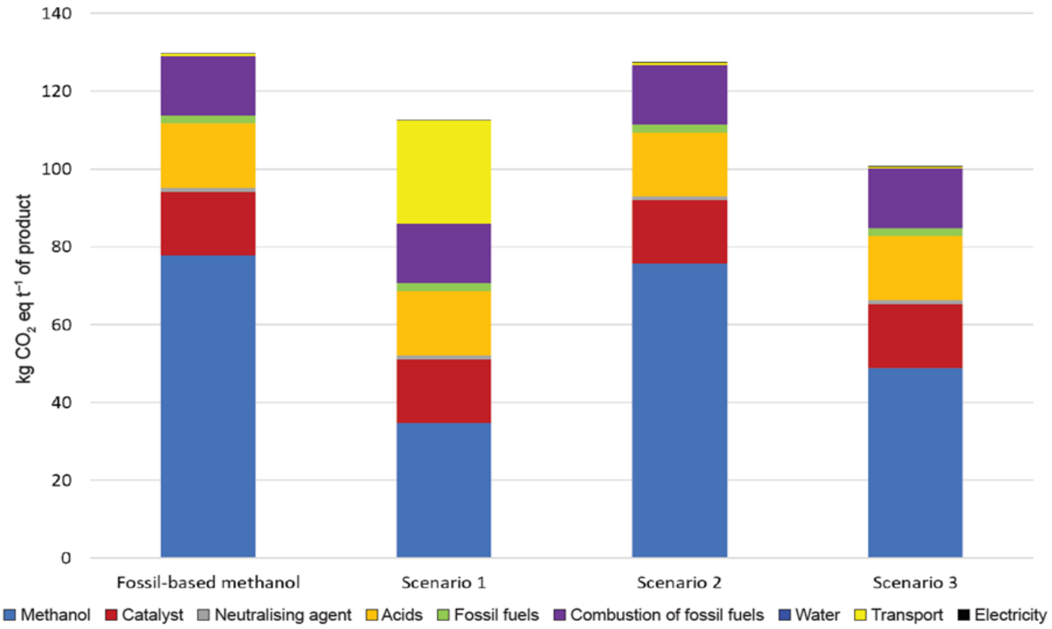
C. Malaysia

Environmental evaluation of palm biodiesel using life cycle assessment (LCA) approach has been conducted by various parties globally for the past decades. These LCA studies are mostly cradle-to-gate or cradle-to-grave type which emphasised mainly on greenhouse gas (GHG) emissions. The production and utilisation of chemical fertilisers in oil palm plantations and biogas (mainly methane) emissions from palm oil mill effluent are identified as the main contributors to the global warming impact inn these studies. Hence, the proposed rectification steps are within the upstream sector of the palm oil industry. There is very little information reported on the activities in the biodiesel production stage. Furthermore, some of the studies were conducted solely based on secondary data, with several assumptions that did not reflect the actual activities of the industry.

A gate-to-gate LCA for the production of palm biodiesel was performed (Yung et al., 2021). The study was carried out based on actual operation data (primary data) obtained from six commercial palm biodiesel plants in Malaysia from 2015–2017. The study was conducted with a specific aim to evaluate the environmental performance of the production of palm biodiesel on various impact categories which focus specifically on the activities in the biodiesel plant. It was also aimed to provide an up-to-date information on the palm biodiesel production in Malaysia.

Based on the LCA conducted for commercial palm biodiesel production, methanol, transesterification catalyst and acids are the main contributors to the environmental impacts. The replacement of fossil-based methanol with biomethanol is able to lower the overall environmental impact (Figure 3.3). However, not all the biomethanol sources would have a positive contribution to the environmental impacts. An impact assessment showed that the replacement of fossil-based methanol with biomethanol produced from biogas is the most preferred option with 22% reduction in global warming impact and saving up to 63% fossil resources. This study also shows that allocation based on mass value does not reflect the actual differences of both products, palm biodiesel and crude glycerol. Since the amount of crude glycerol used as fuel substitute is insignificant, allocation based on energy content was found unsuitable. The study concluded that allocation based on economic value can be more appropriate and relevant as both products are traded commercially in open market at different prices.

Figure 3.3. Life Cycle Assessment of Palm Biodiesel in Malaysia



Note: Scenario 1: Replacement of fossil-based methanol with biomethanol produced from biomass in Switzerland; Scenario 2: Replacement of fossil-based methanol with biomethanol produced from biomass in Malaysia; Scenario 3: Replacement of fossil-based methanol with biomethanol produced from biogas in Malaysia.

Source: Yung et al. (2021).

Viet Nam

In 2018, the FAO carried out a project that aimed to strengthen the capacity of Viet Nam to monitor the environmental, social, and economic impacts of the bioenergy sector, through the implementation of the Global Bioenergy Partnership Sustainability Indicators for Bioenergy and related technical support (FAO, 2018). Two priority bioenergy pathways identified in Viet Nam and chosen for study in the project were cassava-based ethanol and biogas. Regarding cassava-based ethanol, two scenarios were analysed under the various sustainability indicators implemented in Viet Nam: domestic ethanol consumption as of 2016 (assumed to be equal to domestic production, that was 29,500 m^3) and domestic ethanol consumption to meet a hypothetical E5 mandate for RON92 gasoline in 2016 (require about 370,000 m^3 ethanol fuel). For the feedstock production stage, two different cultivation systems were considered: on flat land and on sloping land.

a.Environmental Indicators

1. Life Cycle GHG Emissions

For cassava-based ethanol production, the stages of the value chain included in the LCA were the feedstock production, transformation, and delivery to the ethanol plant; biomass processing into biofuels; and biofuel transportation, storage, and distribution. The three GHGs considered – carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) – were aggregated to the CO_2

equivalent (CO_2e) using the global warming potential (GWP) factors. The GHG emissions of each stage of the value chain and the total GHG emissions were evaluated (Table 3.9). The average of the emissions produced in flat and sloping cassava cultivated areas is 58.36 gCO_2e/MJ fuel.

Table 3.9. GHG Emissions Balance of the Ethanol Product

	GHG Emissions (gCO_2e/MJ ethanol)	
	Ethanol from Cassava – flatland	**Ethanol from Cassava – slopeland**
Land use change	4.56	7.74
Cultivation	18.34	13.42
Transport	3.21	3.21
Processing	32.15	32.15
Use	0.97	0.97
Total	59.23	57.49
Average	58.36	

GHG = greenhouse gas, MJ = megajoule.
Source: FAO (2018).

2. Water Consumption

Based on the report of the Food and Agriculture Organization of the United Nations (FAO, 2018), the total volume of water withdrawn for ethanol feedstock production and processing is calculated and expressed in terms of unit of energy output and as a percentage of Total Actual Renewable Water Resources provided in Table 3.10.

Table 3.10: Water Use for Ethanol Production in Viet Nam

Parameter	Actual Value Based on Ethanol Consumption in 2016	Estimated Value Based on Hypothetical E5 Mandated in 2016
TARWR in Viet Nam	884.1 km^3/year	884.1 km^3/year
Water requirement for cassava cultivation	9,801 m^3/ha/year	9,801 m^3/ha/year
Water requirement for cassava cultivation addressed to ethanol production	0.0849 km^3/year	0.0849 km^3/year

Water requirement for cassava processing into ethanol	0.00066 km^3/year	0.00066 km^3/year
Total water withdrawn for ethanol feedstock production and processing as a percentage of TARWR	0.0097 %	0.0097 %
Water withdrawn for ethanol feedstock production and processing per unit of energy output	0.137 m^3/MJ	0.137^3/MJ

TARWR = total actual renewable water resources.
Source: FAO (2018).

b.Economic Indicators

3. Total Value Added

The report of the FAO (FAO, 2018) evaluated the gross value added per unit of cassava-based ethanol produced and as a percentage of gross domestic product. It shows that the gross value added per unit of ethanol produced is about US$0.07/litre. In 2016, total national consumption of ethanol was 29,500 m^3, the cassava-based ethanol value chain contributed US$2.065 million (or 0.000347%) to the country’s GDP in 2016.

4. Net Energy Balance

The report of the FAO (FAO, 2018) provides the survey data conducted in three ethanol plants (plants A, B, and C) in Viet Nam in which plants A and B use coal to produce heat and electricity for own consumption, whereas plant C uses electricity from the grid and steam that it produced from woodchips and cashew shell as feedstock. The net energy ratio of the entire life cycle of the ethanol pathway varies from 1.53 to 1.71 for the ethanol plants A, B, and C. The average net energy ratio of the cassava-based ethanol pathway in Viet Nam is estimated at 1.61. The fossil energy input accounts for about 62% on average of the ethanol low heating value.

c.Social Indicators

5. Employment Generation

As mentioned in the FAO report (FAO, 2018), cassava-based ethanol production is labour-intensive in Viet Nam, due to the high labour requirements of the stages related to feedstock production. This is due to the low mechanisation level of cassava cultivation and harvest, which contributes to the low productivity of this crop in Viet Nam. Direct jobs associated with the cassava-based ethanol value chain were estimated with the number of 44,200 jobs in 2016. If E5 fuel had been used over the country, this number would have increased to 550,000 jobs.

6. Access to Modern Energy

In the FAO report (FAO, 2018), the number of households using bioenergy was calculated based on the average energy consumption per household and total amount of bioenergy used by households including biomass for improved cookstoves, biogas from household anaerobic digesters and ethanol from E5 gasoline. Considering ethanol fuel, it was estimated that the net useful heat from ethanol in gasoline combustion engine was 3.38 KTOE/year. The report also provided the total number of Vietnamese households (about 22,444,322 households), and the average energy consumption per household that was 3.083 x 10-4 KTOE/year. Therefore, the number of households using bioethanol can be calculated, which is equal to 10,963 households.

D. Philippines

In addition to the identified biofuels sustainability indicators below:

a. Environmental Indicators

1. Life Cycle GHG Emissions

2. Water Consumption

b. Economic Indicators

1. Total Value Added

2. Net Energy Balance

c. Social Indicators

1. Employment Generation

2. Access to Modern Energy

A vital recommendation for consideration may be based on a PDOE-funded project implemented by the University of the Philippines Los Baños (2019) entitled ‘Life Cycle Assessment in Terms of Carbon Debt and Payback Analyses, Carbon Savings and Energetics Studies of Biodiesel Production Coconut in the Philippines’. The project assessed and evaluated the carbon emissions and energy consumption of the components of biodiesel production starting from the feedstock acquisition to product distribution. According to the study, with the current blend at B2 for biodiesel, GHG reduction potential is only estimated at 1.3% which translates to non-fulfilment of the goals of the Biofuels Act which is to mitigate climate change. It was recommended that by increasing the blending rate, GHG reduction potential may also be increased which may result to higher carbon savings. Blending of biofuels with petroleum fuels can significantly reduce GHG emissions from transportation vehicles but biofuel production can also contribute to the emissions of carbon into the environment especially during the land and plant preparation, construction and operations.

The study utilised the following criteria to ensure environment sustainability of biodiesel production in the long run: net carbon emissions, carbon sequestration, carbon savings, carbon payback period, environmental loading ratio, net energy ratio, emergy yield, percentage renewable energy, and value for emergy sustainability indicator. Further, two approaches were identified that can be used as scientific bases for benchmarking in the future construction of biodiesel plants: carbon footprint and energetics studies. The study made use of six scenarios based on the production scale, process and feedstock types, and the most ideal case was found out to be the small-scale production of coco-biodiesel from coconut as it was the most sustainable and renewable compared to the other cases.

Another study that may be considered for sustainability is the 'Life Cycle Greenhouse Gas Emissions from Sugarcane-based Bioethanol in the Philippines: An Analysis based on the Economy of the San Carlos Sugarcane District in Negros Occidental' (Watabe, 2011). The study examined the impact of bioethanol-blended gasoline at E10, E15 and E20 on the net GHG emissions through life cycle analysis starting from the planters' and producer's factors of production and the corresponding reduction in GHG emissions through the consumption of bioethanol.

It was found that as the factors of production and blending rates increased, GHG emissions also increased however, a higher blending rate would also translate to higher mitigation of the net GHG emissions. Consequently, the GHG reduction rates will also increase when sugarcane planters and distilleries' productivity rates increase. One of the identified constraining factors was liming, which is also important to the management of soil, it was seen that for the conduct of liming every 5 years, as the blend rates increases so as the net GHG emissions. It should be noted however, that soil properties are also vital components in emissions studies. The study also mentioned that the use of molasses as feedstock and the inclusion of other distilleries will affect the existing land use patterns and shall be considered for future analysis.

E. India

Environmental Impacts of Use of Ethanol

The use of ethanol blended gasoline decreases the GHG emissions. A summary of emissions benefits with E10 and E20 fuels compared to neat gasoline are presented in Table 3.11.

Table 3.11. Emissions Reduction Potential of Ethanol-gasoline Blends

Emissions	Gasoline	Two-wheelers		Four-wheelers	
		E10*	E20*	E10*	E20
Carbon Monoxide	Baseline	20% lower	50% lower	20% lower	30% lower
Hydrocarbons	Baseline	20% lower	20% lower	20% lower	20% lower
Oxides of nitrogen	Baseline	No significant trend	10% higher	No significant trend	same

Note: *The E10 project was carried out in 2009–2010, the E20 project in 2014–2015. Hence, the test vehicles were not the same. However, the emissions trend is similar.
Source: NITI Aayog, Government of India.

Higher reductions in carbon monoxide emissions were observed with E20 fuel – 50% lower in two-wheelers and 30% lower in four-wheelers. Hydrocarbon emissions reduced by 20% with ethanol blends compared to normal gasoline. Nitrous oxide emissions did not show a significant trend as it depended on the vehicle and/or engine type and engine operating conditions. The unregulated carbonyl emissions, such as acetaldehyde emissions were, however, higher with E10 and E20 compared to normal gasoline, due to the presence of hydroxyl groups in ethanol. However, these emissions were relatively minor (in few micrograms) compared to regulated emissions (which were in grams). Evaporative emissions test results with E20 fuel were similar to E0. Overall, ethanol blending can help decrease emissions from both two-wheelers and four-wheelers (NITI Aayog, Government of India).

Social Indicators

- **Reduce Import Dependency**: One crore litre of E10 saves Rs28 crore of foreign exchange at current rates. The ethanol supply year 2017–18 would have been likely to see a supply of around 150 crore litres of ethanol which will result in savings of over Rs4,000 crore of foreign exchange.
- **Cleaner Environment**: One crore litre of E10 saves around 20,000 tons of CO_2 emissions. For the ethanol supply year 2017–18, there would have been fewer emissions of CO_2 to the tune of 30 lakh ton. By reducing crop burning and conversion of agricultural residues and/or waste to biofuels there will be further reduction in greenhouse gas emissions.
- **Health Benefits**: The prolonged reuse of cooking oil for preparing food, particularly in deep-frying is a potential health hazard and can lead to many diseases. Used cooking oil is a potential feedstock for biodiesel and its use for making biodiesel will prevent diversion of used cooking oil in the food industry.
- **Municipal Solid Waste (MSW) Management**: It is estimated that annually 62 million metric tons of MSW gets generated in India. There are technologies available which can convert waste/plastic and MSW to drop-in fuels. One ton of such waste has the potential to provide around 20% of drop-in fuels.
- **Infrastructure Investment in Rural Areas**: It is estimated that, one 100 kilolitres per day (klpd) bio refinery will require around Rs800 crore capital investment. At present oil marketing companies are in the process of setting up 12 2G bio refineries with an investment of around Rs10,000 crore. Further addition of 2G bio refineries across the country will spur infrastructure investment in the rural areas.
- **Employment Generation**: One 100 klpd 2G bio refinery can contribute 1,200 jobs in plant operations, village level entrepreneurs, and supply chain management.
- **Additional Income to Farmers**: By adopting 2G technologies, agricultural residues and/or waste which otherwise are burnt by the farmers can be converted to ethanol and can fetch a price if a market is developed for the waste. Also, farmers are at a risk of not getting appropriate price for their produce during the surplus production phase. Thus, conversion of surplus grains and agricultural biomass can help in price stabilisation.

3. **Discussion**

Almost 1 decade after the completion of the previous ERIA project on sustainability assessment of bioenergy, this report provides an update on the status of sustainability assessment of biofuels in the East Asia region. Six indicators, two each for environmental, economic, and social assessment, were selected from the suggestions by the previous working group of ERIA. These indicators are also aligned with those provided by the GBEP. The results have been collected based on information existing in the public domain and presented for Thailand, Indonesia, Malaysia, Viet Nam, Philippines, and India. Most of the countries have had some life cycle assessment studies for biofuels which cover at the minimum, greenhouse gas emissions. In general, greenhouse gas emissions reductions have been observed for biofuels as compared to the fossil counterparts, though some studies have cautioned that these reductions could be overturned should forest land be converted to agriculture for cultivating biofuel feedstocks. However, water consumption for the environmental assessment as well as economic and social indicators were not identified in the literature. Only Thailand and Viet Nam have had studies covering most of the indicators. In Thailand, there have been research studies from academia that have provided the information whereas for Viet Nam, it has been from a recent study by the FAO. It is hoped that at the next step, information on all the proposed indicators can be computed at the national level rather than at a case study level by using the approach suggested by the GBEP.

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