Chapter 2

Well-to-Tank CO_2 Emission from Biofuels

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Chapter 2

Well-to-Tank CO_2 Emissions from Biofuels in East Asia Summit Countries

1. Introduction

1.1. Background

Unlike fossil fuels, the upstream part of the life cycle of biofuels, or the so-called 'well-to-tank' is more significant than the downstream part or 'tank-to-wheel', especially for the case of greenhouse gas (GHG) emissions. As biofuels are derived from different agricultural feedstock and through several different processing pathways, these need to be carefully considered to establish the well-to-tank GHG emissions. In addition to the variation in feedstock and production pathways, there may also be additional differences due to country-specific issues.

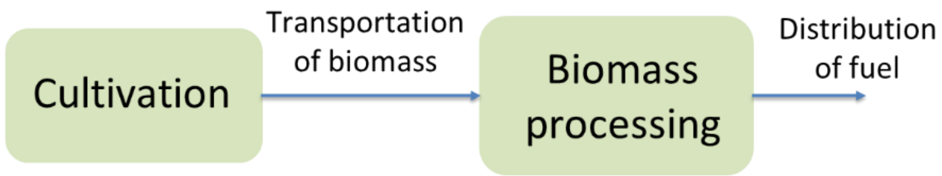
1.2. Objective and Scope

The well-to-tank GHG emissions of various biofuels in the participating East Asia Summit countries are summarised in this chapter. The current utilisation of biofuels and the planned use are also included.

1.3. Methodology

The life cycle approach is used for calculating the well to tank GHG emissions. The generic framework is shown in Figure 2.1. The well-to-tank GHG emissions will include feedstock cultivation, transportation of biomass to the biomass processing facilities, and biofuel production.

Figure 2.1. Generic System Boundary of Biofuel



Source: Authors.

For the current and planned utilisation of biofuels, government data from the various countries have been collated.

2. Well-to-Tank CO_2 Emissions from Biofuels in East Asia Summit Countries

2.1. Malaysia

2.1.1. Biofuels Plan

Malaysia has rolled out numerous energy policies since the 1970s and has gradually changed its policy direction to embrace sustainable development. This is evidenced in the 12th Malaysia Plan (2021–2025) (12 MP) where Theme 3 emphasised 'Advancing Sustainability' through green growth as well as enhancing energy sustainability and transforming the water sector (12th Malaysian Plan, 2021). Under the plan, green growth towards a low carbon nation will be augmented by managing energy in a holistic and sustainable way. The circular economy will be promoted to reduce waste generation, pollution, GHG emissions, and dependency on natural resources to expand the green economy and attain a low carbon future. The government has committed to driving sustainability and inclusivity as outlined in the 12 MP, with a commitment to achieve net-zero GHG emissions by 2050 at the earliest.

In-line with the 12 MP, the National Agricommodity Policy 2021–2030 promotes biofuel as a source of clean energy. Ten indicators and targets were identified to drive development of palm biodiesel over the next 10 years. Seven strategies were prioritised for implementation. The landscape of palm oil-based and oil palm biomass-based renewable energy will cover palm biodiesel, renewable hydrocarbon fuel (hydrotreated vegetable oil and sustainable aviation fuel) and biogas from palm oil mills. The B30 (30% palm biodiesel and 70% diesel) biodiesel programme is planned for implementation by 2030. However, the rollout could start earlier if sufficient technical data have been acquired. Beyond the B30 biodiesel programme, renewable hydrocarbon fuel or hydrotreated vegetable oil could be introduced in the future.

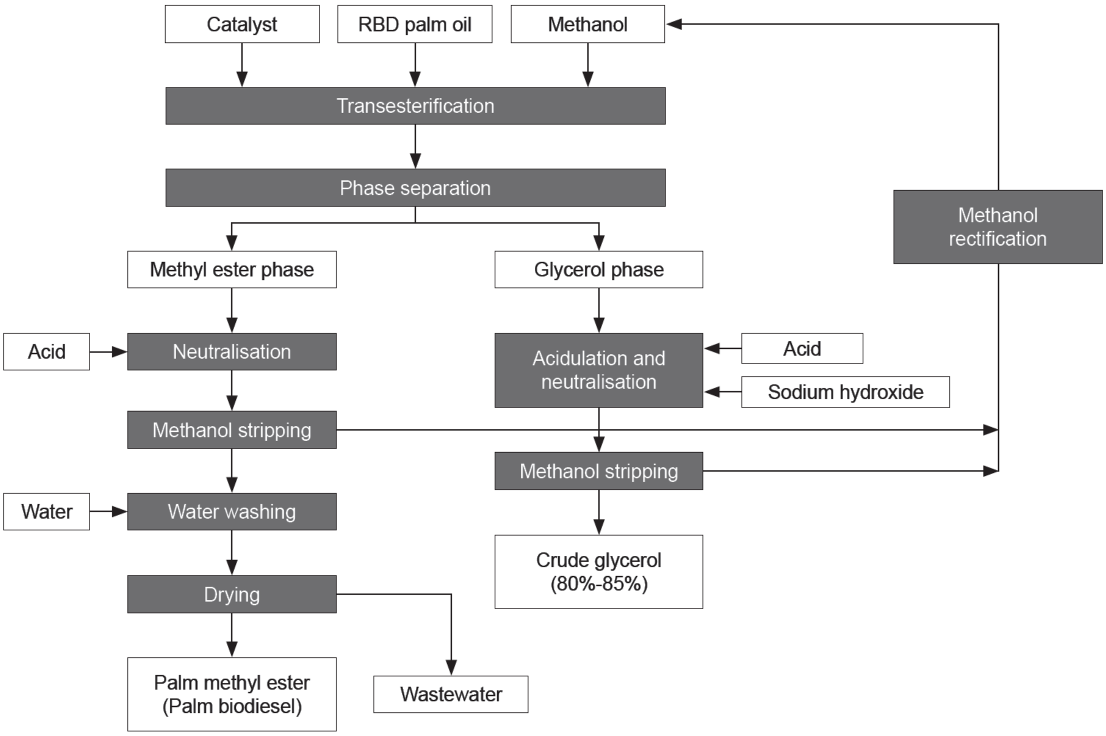
Since the introduction of the National Biofuel Policy 2006, Malaysia implemented the biodiesel programme in 2010. The production of palm biodiesel has increased over the years from 173,000 tonnes in 2010 to 1,423,000 tonnes in 2019. Biodiesel production decreased in 2020 to 906,000 tonnes due to an unfavourable market situation and the COVID-19 pandemic.

The implementation of the biodiesel programme in Malaysia started in 2011 with B5 (5% palm biodiesel and 95% diesel) and the blend ratio was increased to B7 in 2014 and B10 in 2019. The projected demand of biodiesel for the B10 programme is 534,000 tonnes of biodiesel per year. Apart from the automotive sector, B7 also has been mandated for industrial and/or commercial fleet usage starting in 2019 with anticipated demand of 227,000 tonnes of biodiesel per year. The B20 programme for the transport sector was introduced in 2020 by phases and the anticipated delayed rollout due to the COVID-19 pandemic. The nationwide B20 implementation is expected in 2025. The projected demand of palm biodiesel usage for biodiesel mandate in Malaysia is shown in Figure 2.2. The B30 programme is expected to rollout in 2030 with biodiesel usage of 1.6 million tonnes per year.

2.1.2. Well-to-Tank GHG Emissions from Palm Biodiesel in Malaysia

A gate-to-gate life cycle analysis (LCA) for the production of palm biodiesel was performed (Yung, Subramaniam, and Yusoff, 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 that 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. Most of the feedstock used in the production of palm biodiesel for the local mandate is crude palm oil and refined palm oil. Thus, the LCA study was focused on the production of palm biodiesel based on refined palm oil as the primary feedstock. The process flow of the production of palm biodiesel is shown in Figure 2.2.

Figure 2.2. Process Flow Chart for the Production of Palm Biodiesel



RBD = refined, bleached, and deodorised.
Source: Yung, Subramaniam, and Yusoff (2021).

The methodology used for the LCA study was in accordance with ISO 14040 and ISO 14044. The impact assessment was performed using SimaPro software version 8.5.

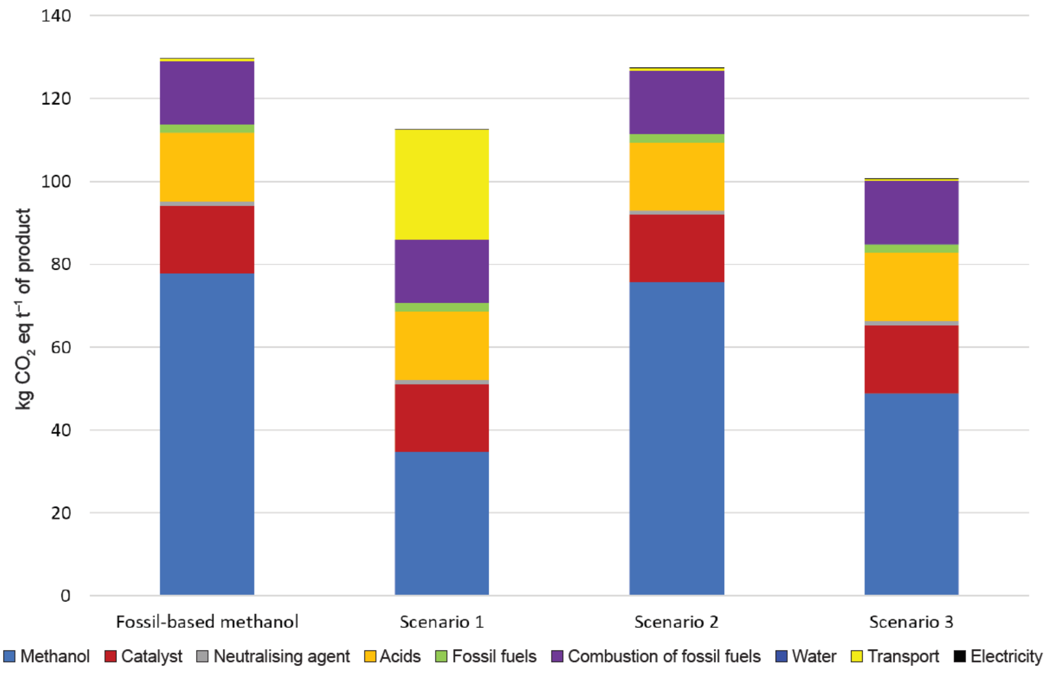
The inventory table was presented as per tonne of palm biodiesel produced as shown in Table 2.1. Based on the LCA conducted for commercial palm biodiesel production, methanol, transesterification catalyst, and acids are the main contributors to the adverse environmental impacts. Replacement of fossil-based methanol with biomethanol can lower the overall adverse environmental impact (Figure 2.3). However, not all the biomethanol sources would have a positive contribution to the environmental impacts. The 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 the open market at different prices.

Table 2.1. Inventory Data of Palm Biodiesel Production

Item	Unit	Amount
Input		
Refined, bleached, and deodorised (RBD) palm oil	tonne	0.9406
RBD palm stearin	tonne	0.0380
Palm fatty acid distillate (PFAD)	tonne	0.0166
Total feed material	tonne	0.9952
Methanol	kilogramme	108.8932
Sodium methoxide 30% (neutralizing agent)	kilogramme	9.4371
Hydrochloric acid	kilogramme	9.5788
Citric acid	kilogramme	0.8725
Acetic acid	kilogramme	0.1396
Sodium hydroxide (neutralising agent)	kilogramme	0.7853
Electricity	kilowatt hour	37.1409
Boiler fuel		
Natural gas	cubic metre	6.0749
Diesel	kilogramme	0.0081
Fuel Oil	kilogramme	0.1348
Water	litre	603.1306
Average distance from palm oil refineries to biodiesel plant	kilometre	9.2864
Transfer of feed oil to biodiesel plant	tonne kilometre	9.2418
Output		
Palm biodiesel	tonne	1.0000
Crude glycerol	kilogramme	127.4327

Note: Weighed average data calculated from five palm biodiesel producers for 2015 to 2017.
RBD = refined, bleached, and deodorised.
Source: Yung, Subramaniam, and Yusoff (2021).

Figure 2.3. Global Warming Effect from the Production of 1 Tonne of Palm Biodiesel



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, Subramaniam, and Yusoff (2021).

The GHG emissions computation in Table 2.2 is based on refined vegetable oils. Generally, the GHG emissions for the production of biodiesel from vegetable oils (palm oil, rapeseed oil, and soybean oil) using the transesterification process are similar as it uses the same amount of energy and chemicals.

Table 2.2. GHG Emissions Computation Based on Refined Palm Oil, Rapeseed Oil, and Soybean Oil

GHG Emissions	Refined Palm Oil (Malaysian Palm Oil Board, 2011)	Refined Rapeseed Oil	Refined Soybean Oil
Tonne CO_2eq/tonne oil	1.11 (without biogas capture) 0.63 (with biogas capture)	1.35	1.70

Sources: Choo et al. (2011); Mortimer et al. (2010).

The GHG emissions data for refined palm oil were published in 2011 using attributional LCA methodology. Palm biodiesel produced from palm oil sourced from mills with and without biogas capture emits 21.20 and 33.19 g CO_2 eq for every megajoule (MJ) of fuel, respectively. Currently, 28% of palm oil produced in Malaysia is with biogas capturing. The summary of the data on GHG emissions of the entire palm oil supply chain (from FFB to palm biodiesel) is shown in Table 2.3.

Table 2.3. GHG Emissions from the Entire Palm Oil Supply Chain (from FFB to palm biodiesel)

Production	GHG Emissions (kg CO_2 equivalent)	
1 tonne fresh fruit bunch (FFB)	119	
	Without biogas capture	**With biogas capture at 85% efficiency**
1 tonne crude palm oil (CPO)	971	506
1 tonne refined palm oil (RPO)	1,113	626
1 MJ of palm biodiesel	**GHG Emissions (g CO_2 equivalent)**	
	33.19	21.20

GHG = greenhouse gas, kg = kilogrammes, g = grammes.
Source: Choo et al. (2011).

By comparing the GHG emissions from utilising 1 MJ of fossil diesel in the transport sector with the GHG emissions from utilising 1 MJ of palm biodiesel, the emissions savings potential was estimated in Table 2.4. Compared to the typical GHG emissions from fossil diesel of 83.8 gCO_2 per MJ of fuel, the emissions savings of palm biodiesel produced from palm oil with and without methane capture are 74.7% and 60.4%, respectively. The GHG emissions savings of palm biodiesel based on national level (28% biogas capturing) would be 64.4%. The high palm biodiesel blending of as much as 30% can provide 18 to 22% more GHG emissions savings when used in automotive diesel applications.

Table 2.4. Estimated GHG Emissions Savings per MJ of Palm Biodiesel Produced

	GHG Emissions (g CO_2 equivalent)	
	Without biogas capture	**With biogas capture at 85% efficiency**
One MJ of palm biodiesel (Choo et al., 2011)	33.19	21.20
One MJ of fossil diesel (ISCC, 2016)	83.8	
	GHG savings potential (%) compared to fossil diesel used in transport sector	
Palm biodiesel (B100)	60.39	74.70
B7	4.22	5.23
B10	6.04	7.47
B20	12.08	14.94
B30	18.12	22.41

GHG = greenhouse gas, MJ = megajoule.
Sources: ISCC (2016); Choo et al. (2011).

2.2. Philippines

As part of the energy sector, the significant contribution of biofuels in the Philippines' energy mix is to develop and utilise indigenous renewable and sustainably sourced clean energy sources, thereby primarily reducing the country's dependence on imported fossil-based fuels.

The National Biofuels Board led the formulation of the Joint Administrative Order (JAO) No. 2008-1, Series of 2008 or the 'Guidelines Governing the Biofuel Feedstocks Production, and Biofuels and Biofuel Blends Production, Distribution and Sale under Republic Act No. 9367' to principally address the increasing unease on 'food versus fuel', which may be encountered in pursuing the progress of the Philippines' biofuels industry.

As defined in the Biofuels Act, feedstock refers to organic sources such as but not limited to the following: molasses, sugarcane, coconut, cassava, jatropha, sweet sorghum, oil palm, and other biomass that can be used to produce biofuels. For bioethanol, molasses and sugarcane are the current feedstock used for production. Out of the 13 accredited bioethanol producers, 10 are using 100% molasses as feedstock, whilst the remaining are using both molasses and sugarcane. Whilst for biodiesel production, coconut oil (CNO) is the currently used feedstock. Ten out of the 13 accredited biodiesel producers use 100% RBD CNO as feedstock with the remaining using both RBD and crude CNO.

The Philippine Sugar Regulatory Administration and the Philippine Coconut Authority are the concerned national government agencies that authorise local bioethanol and biodiesel producers to utilise locally-sourced feedstock in the production of biofuels to be sold to oil company customers for blending with gasoline and diesel, respectively.

For the biodiesel or the coconut methyl ester (CME) production, the raw materials needed are coconut oil (feedstock), alcohol and catalyst (base) which shall undergo transesterification reaction through mixing. Afterwards, the crude CME shall be separated from the glycerol (by-product), formed during the transesterification process. The crude CME shall then be washed with an ample amount of water before it is filtered to remove impurities and excess methanol (for recovery). To obtain the Philippine National Standards (PNS)-grade CME, the washed CME is dried for removal of traces of moisture. Prior to distribution to pump stations, the PNS-grade CME is blended at 2% with diesel fuel.

Whilst for bioethanol production, feedstock such as sugarcane and/or molasses is processed through fermentation producing hydrous ethanol with carbon dioxide and organic sludge water as by-products. Subsequently, to achieve the PNS-grade bioethanol of 99.3%, the produced hydrous ethanol is distilled and dehydrated. Prior to distribution to pump stations, the PNS-grade bioethanol is blended at 10% with gasoline fuel.

2.3. Indonesia

2.3.1. Biofuels Plan

The basic underlying policy of biofuel development in Indonesia is the Government Regulation No. 79/2014 which states that the contribution of new and renewable energy to the national energy mix must reach 23% by 2025. Further, the government has also committed to the Paris Agreement that Indonesia will, by 2030, reduce 29% of its GHG emissions below that of the business-as-usual (BAU) case. As a part of the 23% target, the Ministry of Energy and Mineral Resources (MEMR) has targeted that the contribution of bioenergy (solid biomass, biogas, and liquid biofuels) should reach 8%–9 % by 2025.

Indonesia started to become a net petroleum oil and fuels importing country in 2004 and the production and utilisation of biodiesel and bioethanol started in 2006. Then, through Decree No. 32/2008 of the MEMR, the government mandatorily set that by January 2015, the utilisation of liquid biofuels must reach B5 to B10 (depending on the field of applications) for biodiesel and E5 for bioethanol. However, the implementation of this biofuel programme went up and down due to the lack of a fixed incentive policy. The government took care of the programme only when the increase of international petroleum prices caused a large deficit in the national oil and gas trade balance.

In mid-2015, based on the initial and intensive discussions with the palm oil industry association, the government put a levy of US$50 per ton of exported palm oil and established the Indonesia Oil Palm Plantations Fund Management Agency to collect the levy and use it to subsidise palm oil biodiesel, amongst others. At about the same time, MEMR Decree No. 12/2015 mandatorily set that the utilisation of biodiesel must reach B20 by 2016 and B30 by 2020. The availability of a palm oil biodiesel subsidy from the fund management agency has benefited the biodiesel programme and helped fulfil the targets set by the MEMR Decree. On the other hand, the MEMR Decree No. 12/15 set mandates that the utilisation of bioethanol must reach E2 by 2016 and E5 by 2020, lack of similarly effective incentive policy (and agency) for gasoline-blending biofuel has made, since 2015, practically no bioethanol has entered the automotive fuel market. In turn, this standstill status of the bioethanol fuel programme has been a major cause of practically stagnant development of the Indonesian bioethanol industry. At present, even if the whole domestic bioethanol capacity, regardless of quality, is devoted to blending into gasoline, nation-wide it will not be enough even for an E1 gasohol programme.

In response to the successful development and large-scale trials of technologies to produce bio-hydrocarbon gasoline or bio-gasoline (G100), bio-hydrocarbon or green diesel (D100), as well as jet biofuel (J100) from palm and palm kernel oil, the MEMR has targeted the production of, through co-processing in petroleum refineries as well as a newly built stand-alone plant, 1.4 million cubic metres (m^3) of bio-hydrocarbon diesel and 0.5 million m^3 of bio-hydrocarbon gasoline by 2025 (Bioenergy Directorate, MEMR of Indonesia, 2021).

Recently, the government announced a plan to enforce a carbon tax on fossil fuel. Hopefully, this will provide a new source of funding for incentivising biofuel and other renewable energy development and utilisation programmes.

The target of biofuel implementation in Indonesia is shown in Table 2.5.

Table 2.5. Official Usage Targets of Biofuel (million m^3)

Biofuel	2021	2025	2030	2035
Biodiesel	9.2	9.6	10.5	11.5
Bio-hydrocarbon (green) diesel, D100	-	1.4	1.4	1.4
Bio-hydrocarbon (or bio-) gasoline, G100	-	0.6	2.1	2.1
Total	9.2	11.6	14.0	15.0

Note: As yet no target for bioethanol has been fixed.
Source: Bioenergy Directorate, Indonesian MEMR (2021).

2.3.2. Well-to-Tank GHG Emissions of Biofuels in Indonesia

The well-to-wheel (WTW) GHG emissions of liquid fuels consists of two parts: the well-to-(vehicle fuel)-tank (or WTT) part and the (vehicle fuel) tank-to-wheel (or TTW) part. GHG emissions from fossil fuels are small in the WTT part and large in the TTW part. In contrast, the GHG emissions of biofuels usually are dominantly large in the WTT part and small in the TTW part.

Traction Energy Asia (2019) reported that GHG emissions from plantations are still the largest contributor to emissions from biodiesel in Indonesia, accounting for over 80% of GHG emissions across the biodiesel supply chain. It is reported that the differentiating factor for total GHG emissions produced through land use change lies in the type of land, namely mineral or peat. Palm biodiesel based on mineral land plantations have well-to-gate GHG emissions of 0.7–1.09 kg CO_2 eq/L biodiesel, which is far below the 3.14 kg CO_2 eq/L WTW

GHG emissions of fossil diesel. In contrast, palm biodiesel based on plantations entailing land use change from peat have well-to-gate GHG emissions of 2.54–22.85 kg CO_2 eq/L biodiesel. The report also pointed out that methane capture can halve the emissions from the palm oil mills.

2.4. Viet Nam

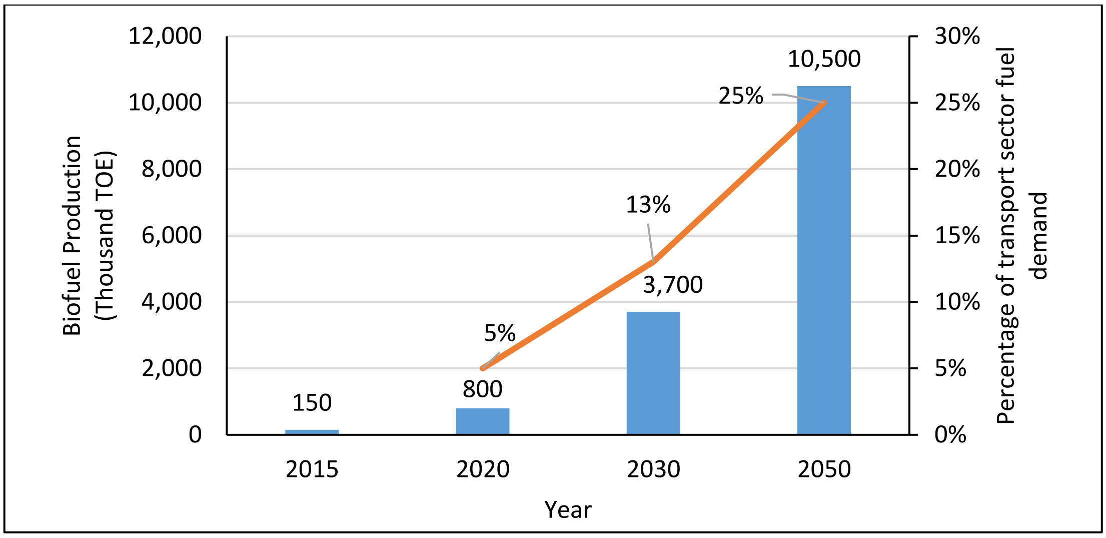
2.4.1. Biofuels Plan

In October 2021, the government issued Decision 1658/QD-TTg approving the National Green Growth Strategy 2021–2030, vision to 2050 (The Prime Minister of Government, 2021). Its overall objective is to contribute to the restructuring of the economy in conjunction with renewing the growth model, to achieve economic prosperity, environmental sustainability, and social equality; strive towards a green and carbon neutral economy; and contribute to the realisation of the goal to reduce global warming. In term of GHG emissions reduction, the specific target is to reduce emissions per gross domestic product (GDP) by at least 15% by 2030 and at least 30% by 2050 compared to 2014. In terms of greenifying economic sectors, the key specific targets until 2030 are to reduce the primary energy consumption per unit of GDP by 1.0%–1.5% annually on average for the 2021–2030 period, to achieve the proportion of 15%–20% of renewable energy in the total primary energy supply; and until 2050 the primary energy consumption per unit of GDP reduces by 1.0% annually on average for each 10-year period; the proportion of renewable energy in the total primary energy supply reaches 25%–30%. In order to promote sustainable transportation, the share of buses that use clean energy is expected to reach at least 15% of total operating buses in special-class cities and 10% of total new buses in class-1 cities by 2030; and the share of clean energy buses in total new buses in special-class cities and class-1 cities is expected to reach 100% and at least 40% respectively by 2050.

The targets for biofuel implementation are mentioned in the following policy documents:

- Decision 177/2007/QD-TTg issued on 20 November 2007 approving the scheme on development of biofuels up to 2015, with a vision to 2025, that states the output of ethanol and vegetable oil will reach 250,000 tons (enough for blending 5 million tons of E5 and B5), satisfying 1% of the whole country's fuel demand by 2015, and reach 1.8 million tons, satisfying about 5% of the whole country's fuel demand by 2025 (The Prime Minister of Government, 2007).
- Decision No. 2068/QĐ-TTg issued on 25 November 2015 approving Viet Nam's Renewable Energy Development Strategy up to 2030 with an outlook to 2050 that expects to produce biofuels from approximately 150,000 tons of oil equivalent (TOE) in 2015 to about 800,000 TOE, i.e. 5% of the transport sector's fuel demand in 2020; 3.7 million TOE, i.e. 13% of transport sector's fuel demand in 2030; and 10.5 million TOE, i.e. 25% of the transport sector's fuel demand in 2050 (Fig 2.4) (The Prime Minister of Government, 2015).

Figure 2.4. Biofuel Production and Consumption Expected, Viet Nam

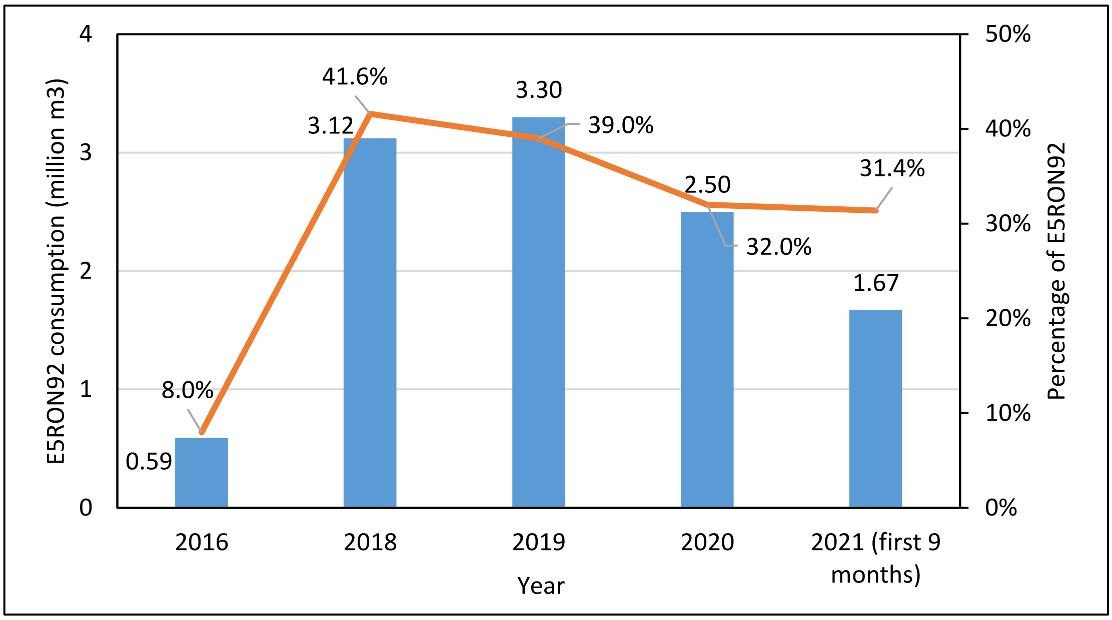


TOE = tons of oil equivalent.
Source: The Prime Minister of Government (2015).

- Decision 53/2012/QD-TTg issued on 22 November 2012 approving the road map to commercialise 5% ethanol blend (E5) in seven big cities (Hanoi, Ho Chi Minh City, Hai Phong, Danang, Can Tho, Quang Ngai, and Ba Ria-Vung Tau) beginning in December 2014 and nationwide from December 2015. This decision also set a target for 10% ethanol blend (E10) commercialisation in the seven cities beginning in December 2016, and nationwide from December 2017 (The Prime Minister of Government, 2012).
- Government Office's Announcement No.255/TB-VPCP dated 6 June 2018 states that as of 1 January 2018 only production of E5RON92 (a blend of 5% of ethanol and 95% of gasoline by volume, octane number (RON) of the blend is 92 minimum) and gasoline RON95 would be allowed (Government Office, 2017). After the release of Announcement No.255/TB-VPCP, E5RON92 consumption increased rapidly in 2018, up to 3.12 million m^3 accounting for 42% of total gasoline consumption.

After the release of Announcement No.255/TB-VPCP, E5RON92 consumption increased up to 3.12 million m^3, accounting for 42% of total gasoline consumption in 2018. In 2019 and 2020, E5RON92 consumption was about 3.3 and 2.5 million m^3, accounting for approximately 39% and 32% of total gasoline consumption, respectively. In the first 9 months of 2021, E5RON92 consumption was about 1.67 million m^3, approximately 31.4% of total gasoline consumption (Figure 2.5) (Vietnamnet, 2019; VOV traffic, 2020; Tuoitre Online, 2021).

Figure 2.5. E5RON92 Consumption, Viet Nam



Sources: Vietnamnet (2019); VOV traffic (2020); Tuoitre Online (2021).

It is seen that E5RON92 fuel consumption in 2020 was 2.5 million m^3, corresponding to 125 thousand m^3 of ethanol consumption or about 0.1 million ton of ethanol, equivalent to about 64.5 thousand TOE. This biofuel consumption achieves just about 8% of the biofuel production and consumption target mentioned in the Decision No. 2068/QĐ-TTg.

So far, there are some suggestions to increase the percentage of ethanol in blend (such as E10), and/or substitute E5 RON95 to gasoline RON95, but the plan has not been announced. Besides, the mandate to biodiesel blend use has not been issued due to the lack of domestic feedstock for biodiesel production.

2.4.2. Well-to-Tank GHG Emissions of Biofuels in Viet Nam

Some main properties of gasoline, diesel, and biofuels are provided in Table 2.6.

Table 2.6. Some Main Properties of Gasoline, Diesel, and Biofuels, Viet Nam

Fuel	Density	Unit	Heating Value	Unit	Tank-to-Wheel	Unit	Well-to-Tank	Unit
Gasoline	0.73 (Reported)	kg/L	43.96 (Energy Conservation Research and Development Center)	MJ/kg	69,300 (2006 IPCC Guidelines)	kg CO_2/TJ fuel	NA	
Diesel	0.85 (Viet Nam Standards, 5689:2018)	kg/L	42.7 (Energy Conservation Research and Development Center)	MJ/kg	74,100 (2006 IPCC Guidelines)	kg CO_2/TJ fuel	NA	
Ethanol	0.79 (Reported)	kg/L	27 (2006 IPCC Guidelines)	MJ/kg		kg CO_2/kg fuel	58.36 (FAO, 2018)	gCO_2/MJ fuel
Biodiesel	0.86–0.90 (Viet Nam Standards, 7717:2007)	kg/L	35.7 (Estimated from Nguyen and Pham, 2015)	MJ/kg	NA		NA	

kg/L = kilogramme per litre, MJ/kg = megajoule per kilogramme, kg CO_2/TJ = kilogramme of carbon dioxide per terajoule, gCO_2/MJ = gramme of carbon dioxide per megajoule, NA = not available.

Source: Various, indicated in the bracket

For biodiesel, there is a study that shows the global warming potential (GWP) of Jatropha biodiesel of 12.3 g CO_2 eq/1 MJ fuel based on the conditions in Viet Nam (Khang, 2019). It means that the GWP of Jatropha biodiesel reduces by 86.56% compared to fossil diesel. The reason for this is the large amount of CO_2 absorbed in biomass growth.

2.5. Thailand

2.5.1. Biofuels Plan

Thailand's Department of Alternative Energy Development and Efficiency (DEDE) has proposed an Alternative Energy Development Plan (AEDP), which provides alternative energy targets for many kinds of alternative energy, including biofuels. The AEDP 2018 target is to increase the share of renewable energy either in the form of electricity, heat, and biofuels to be 30% of final energy consumption in 2037. Biofuels contribute about 3% of the total final energy consumption. The details of the target and actual consumption are presented in Table 2.7.

Table 2.7. Biofuel Targets of AEDP 2018 and Consumption 2019–2021, Thailand

	Unit	AEDP 2018 (2037 target)	2019	2020	2021
1. Ethanol	million litres/day	7.50	4.45	4.10	3.71
2. Biodiesel	million litres/day	8.00	4.90	5.11	4.58

AEDP = Alternative Energy Development Plan.
Sources: DEDE (2018, 2022).

Ethanol is produced from cassava, sugarcane molasses as well as some directly from sugarcane juice. The current installed capacity for ethanol production is 6 million litres per day; the breakdown by feedstock is shown in Table 2.8. Biodiesel, on the other hand, is produced from palm oil. There are 13 factories producing biodiesel in Thailand with a combined capacity of about 8.5 million litres per day, with the capacities varying between 30,000 litres per day to 1,800,000 litres per day (Krungsri Research, 2021b).

Table 2.8. Ethanol Installed Capacity, Thailand (April 2021)

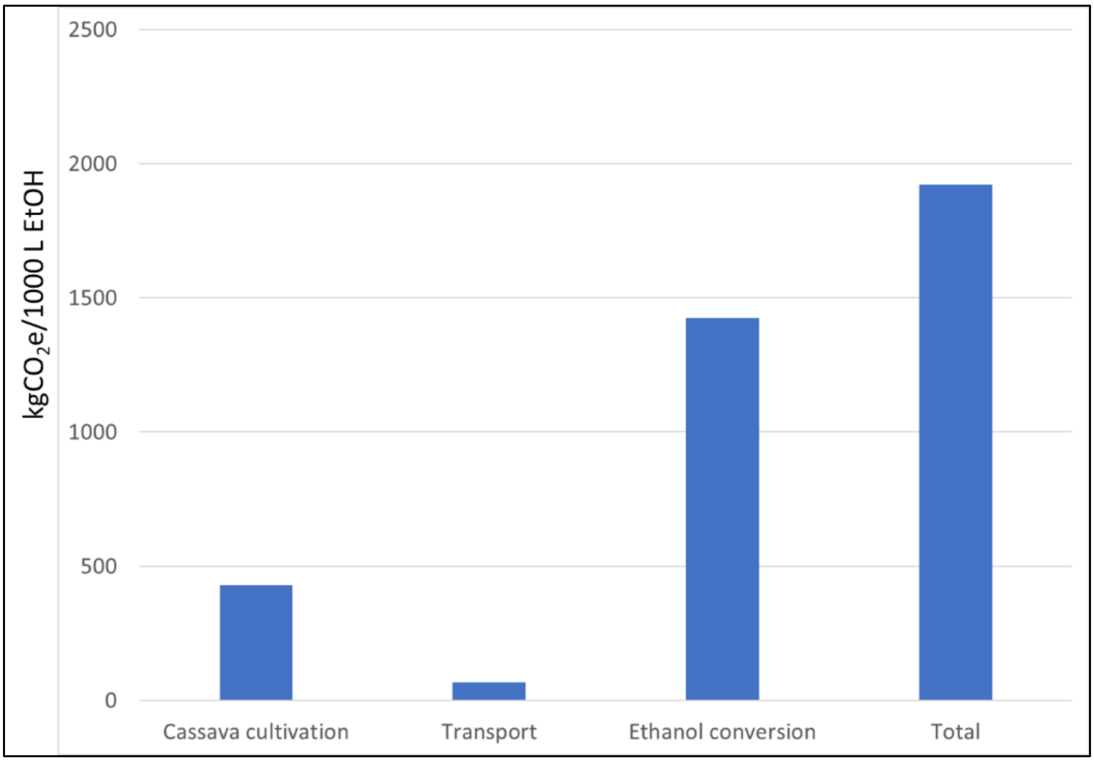
Feedstock	No. of Plants	Installed Capacity (million litres/day)
Molasses	10	2.60
Cassava	10	2.09
Cassava and molasses	5	1.05
Cane juice	1	0.23
Total	**26**	**5.97**

Source: Krungsri Research (2021a).

2.5.2. Well-to-Tank GHG Emissions of Biofuels in Thailand

The well-to-tank stages for ethanol production from cassava includes cassava cultivation, transport, and ethanol conversion (Figure 2.6). Ethanol conversion contributes the biggest share of GHG emissions at 74% followed by cassava cultivation at 22%. The contribution of transportation is relatively modest. The distillation and dehydration process in ethanol conversion requires a substantial amount of energy, which in the case of cassava is largely fossil-fuel based. Cassava cultivation has a large contribution due to the fertilisers and agricultural machinery.

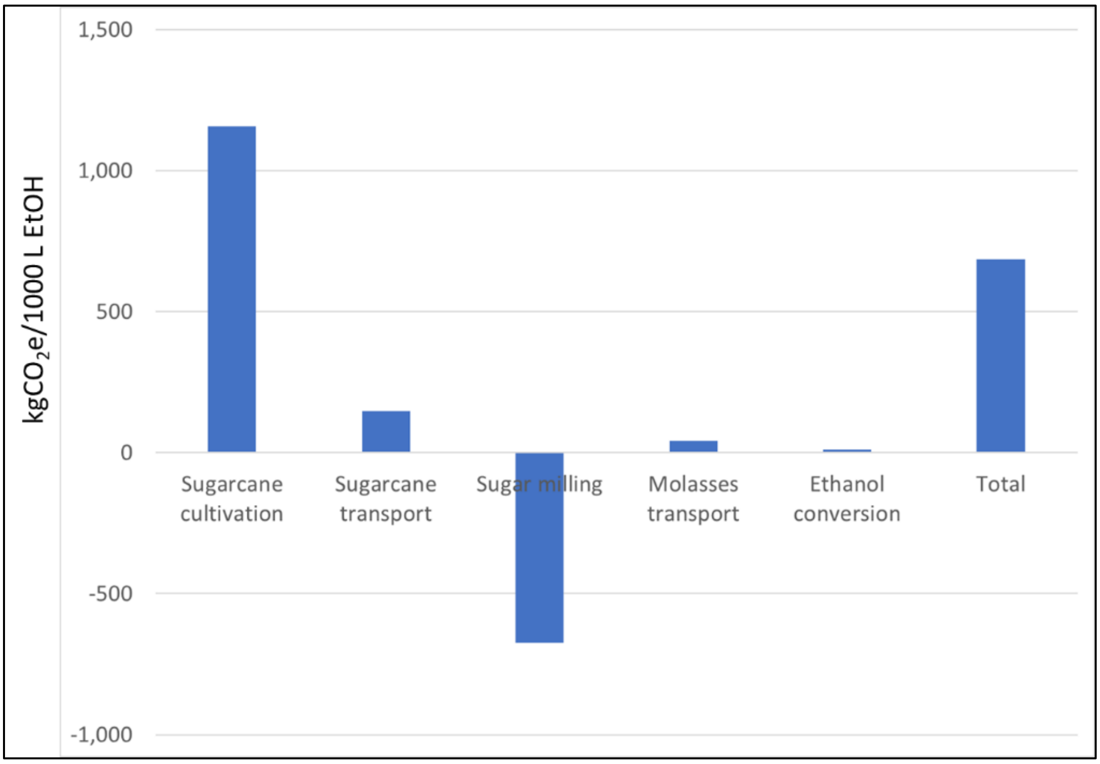
Figure 2.6. GHG Emissions from Production of Cassava Ethanol, Thailand



Source: Silalertruksa and Gheewala (2009).

For the case of ethanol production from sugarcane molasses, the life cycle stages include sugarcane cultivation, sugarcane transport, sugar milling, molasses transport, and ethanol conversion (Figure 2.7). The largest contributor is sugarcane cultivation due to the application of chemical fertilisers and the use of agricultural machinery. Here, unlike the case of cassava ethanol, the contribution of ethanol conversion to the overall GHG emissions is relatively modest despite the high requirement of energy for distillation and dehydration due the use of renewable fuels which are by-products of sugar milling (bagasse) and ethanol production (biogas from wastewater treatment). Sugar milling has a 'negative' contribution because of the production of bagasse which is used for steam and electricity production in excess of the requirement of the sugar mill itself. Transport of both sugarcane and molasses has a modest contribution to GHG emissions.

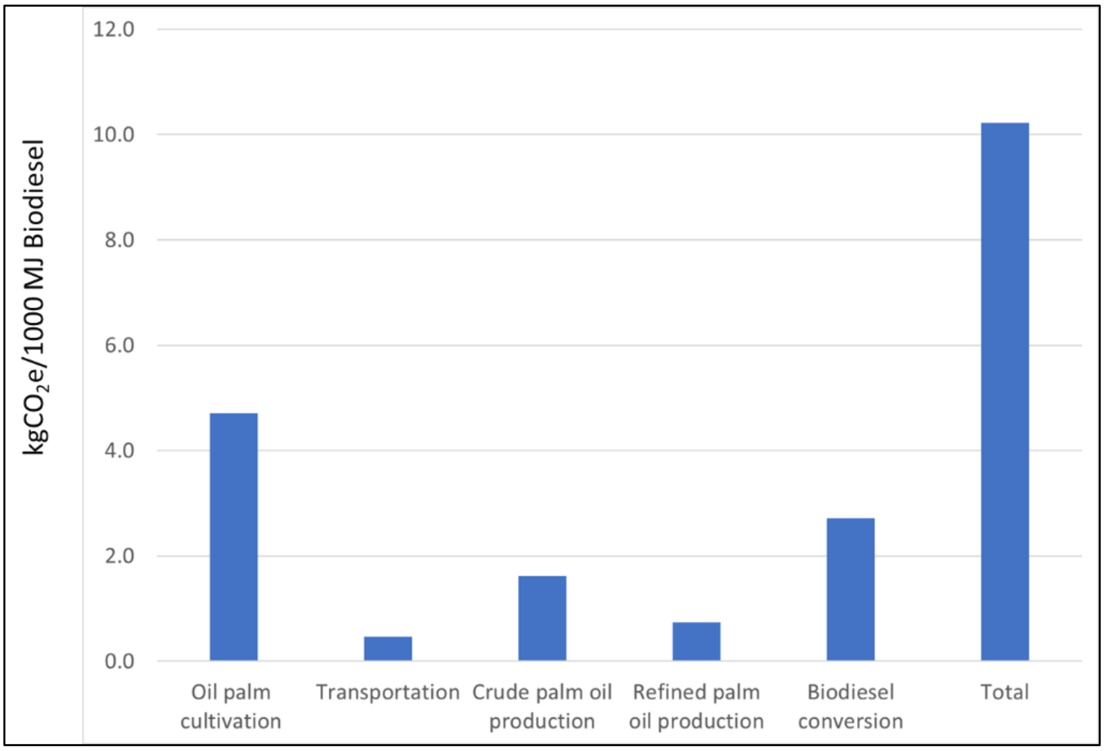
Figure 2.7. GHG Emissions from Production of Molasses Ethanol, Thailand



Source: Silalertruksa and Gheewala (2009).

Biodiesel production from palm oil includes oil palm cultivation, transport, crude palm oil production (palm mill), refining of crude palm oil, and biodiesel production (Figure 2.8). The largest contributor to GHG emissions is oil palm cultivation at about 46%. This is followed by biodiesel production at about 27% and crude palm oil production at 16%. The contribution of transport is nominal.

Figure 2.8. GHG Emissions from Production of Palm Biodiesel, Thailand



Source: Permpool, Ghani, and Gheewala (2020).

3. Discussion

3.1. Biofuel Plans in Selected East Asia Summit Countries

The countries in the region have been promoting biofuels for over a decade via various government regulations. In line with the 12th Malaysia Plan (2021–2025), the National Agricommodity Policy 2021–2030 promotes biofuel as a source of clean energy. Malaysia implemented a biodiesel programme in 2010; the production of palm biodiesel increasing over the years from 173,000 tonnes in 2010 to 1,423,000 tonnes in 2019. Malaysia started in 2011 with B5 and blends, B7 in 2014, and B10 in 2019. By 2025, nationwide implementation of B20 is expected and B30 in 2030. In the Philippines, sugarcane molasses and sugarcane juice are the primary feedstock for bioethanol production and coconut oil for biodiesel. Following the Biofuels Act, ethanol is blended with gasoline at 10% and biodiesel with diesel at 2%. The Ministry of Energy and Mineral Resources in Indonesia targeted to have B5–B10 (depending on the field of applications) for biodiesel and E5 for bioethanol. The target for biodiesel blends was set at B20 by 2016 and B30 by 2020. For bioethanol, the target was E2 by 2016 and E5 by 2020. Viet Nam's Renewable Energy Development Strategy up to 2030 with an outlook to 2050 expects to produce approximately 150,000 TOE biofuels in 2015, about 800,000 TOE, i.e. 5% of the transport sector's fuel demand in 2020; 3.7 million TOE, i.e. 13% of transport sector's fuel demand in 2030; and 10.5 million TOE, i.e. 25% of the transport sector's fuel demand in 2050. The AEDP has a target of 7.5 million litres/day of ethanol from sugarcane molasses, cassava and sugarcane juice, and 8 million litres/day of biodiesel from palm oil.

3.2. Well-to-Tank GHG Emissions from Biofuels

The well-to-tank GHG emissions from biofuels in the various countries in the region are summarised in Table 2.9. Despite some variations in the emissions values from the different feedstock and countries, these are all lower than their fossil fuel counterparts (i.e. 2.92 kg/L gasoline as compared to ethanol and 83.8 gCO_2 eq/MJ diesel as compared to biodiesel).

Table 2.9. Well-to-Tank GHG Emissions from Biofuels

Country	Biofuel	GHG Emissions
Malaysia	Palm biodiesel	33.19 gCO_2 eq/MJ (without biogas capture) 21.20 gCO_2 eq/MJ (with 85% biogas capture)
Indonesia	Palm biodiesel	0.7–1.09 kgCO_2 eq/L
Viet Nam	Bioethanol	58.36 gCO_2 eq/MJ (approx. 1.24 kg kgCO_2 eq/L)
Thailand	Palm biodiesel Cassava ethanol Molasses ethanol	10.2 gCO_2 eq/MJ 1.9 kgCO_2 eq/L 0.685 kgCO_2 eq/L

gCO_2 eq/MJ = grammes of CO_2 equivalent per megajoule of energy, kgCO_2 eq/L = kilogramme of CO_2 equivalent per litre.
Source: Authors.

In the case of palm biodiesel production, the cultivation of oil palm is one of the most significant contributors to GHG emissions followed by biodiesel production (particularly from the production of methanol used in transesterification), and crude palm oil production. Crude palm oil production gains benefits from many by-products such as fibre, shell, empty fruit bunches, and biogas from palm oil mill effluent that can be used for energy. In the case of ethanol, the agriculture stage is once again quite a high contributor for both cassava and sugarcane molasses. However, for the case of cassava, ethanol production particularly distillation and dehydration, has a very high contribution to GHG emissions due to the use of fossil fuels. However, in the case of sugarcane molasses the use of biomass-based by-products such as bagasse and biogas from vinasse as energy sources reduces the contribution of the ethanol production to GHG emissions. Transportation of feedstock and intermediates has a relatively modest contribution for all the biofuels.

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