ERIA Research Project 2021 No. 18

Analysis of Future Mobility Fuel Scenarios Considering the Sustainable Use of Biofuels and Other Alternative Vehicle Fuels in East Asia Summit Countries

Edited by

Shinichirou Morimoto

Shabbir Gheewala

Nuwong Chollacoop

Venkatachalam Anbumozhi

Analysis of Future Mobility Fuel Scenario Considering the Sustainable Use of Biofuels and Other Alternative Vehicle Fuels in East Asia Summit Countries

Economic Research Institute for ASEAN and East Asia (ERIA)

Sentral Senayan II 6th Floor

Jalan Asia Afrika no.8, Gelora Bung Karno

Senayan, Jakarta Pusat 12710

Indonesia

ERIA Research Project Report FY2020 No.18

Published in December 2021

List of Project Members

This report was prepared by the ERIA Research Project Working Group on 'Analysis of EAS Future Mobility Fuel Scenario Considering the Sustainable Use of Biofuels and other Alternative Vehicle Fuels' with results of the studies.

The following are members of the working group and authors of this report (listed in alphabetical order by member country).

Working Group Leader

Dr Shinichirou Morimoto

Team Leader, Environmental and Social Impact Assessment Team, Global Zero Emission Research Center, Department of Energy and Environment, National Institute of Advanced Industrial Science and Technology (AIST), Japan

Working Group Sub-leaders

Dr Shabbir Gheewala

Professor and Head, Life Cycle Sustainability Assessment Lab, Joint Graduate School of Energy and Environment (JGSEE), Thailand

Dr Nuwong Chollacoop

Team Leader, Renewable Energy and Energy Efficiency Research Team, National Energy Technology Center (ENTEC), National Science and Technology Development Agency (NSTDA), Thailand

Working Group Members

Ms Ruby B. De Guzman

Chief Science Research Specialist, Biomass Energy Management Division, Renewable Energy Management Bureau, Department of Energy, Philippines

Dr Bhupendra Kumar Singh

Former Adviser, Energy Security Ministry of External Affairs, India

Dr Tatang Hernas Soerawidjaja

Bandung Institute of Technology (BIT), Indonesia

Dr Harrison Lau Lik Nang

Leader, Biofuel Technology Group, Malaysian Palm Oil Board (MPOB), Malaysia

Dr Adhika Widyaparaga

Assistant Professor, Centre for Energy Studies, Universitas Gadjah Mada (UGM), Indonesia

Dr Pham Huu Tuyen

Director, Research Center for Engines, Hanoi University of Science and Technology (HUST), Viet Nam

Dr Yuki Kudoh

Director, Research Planning Office of Energy and Environment, Department of Energy and Environment, National Institute of Advanced Industrial Science and Technology (AIST), Japan

Contributing Authors

In addition to the ERIA Research Project Working Group members, the following energy experts contributed to this report.

Dr Venkatachalam Anbumozhi

Senior Economist, Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia

Dr Mushtaq Ahmed Memon

Regional Coordinator for Resource Efficiency, United Nations Environment Programme (UNEP), Thailand

Table of Contents

	List of Figures	vi
	List of Tables	viii
	List of Abbreviations and Acronyms	x
	Executive Summary	xiii
Chapter 1	Introduction	1
Chapter 2	Biofuel Policies and Biofuel Implementation in East Asia Summit Countries	4
Chapter 3	Review of Biofuels Sustainability Assessment and Sustainability Indicators in East Asia Summit Countries	75
Chapter 4	Vehicle Electrification and Consumption of Mineral Resources in East Asia Summit Countries	97
Chapter 5	Conclusion as Policy Recommendations	135

List of Figures

Figure 2.1: National Policy on Biofuels 2018 6

Figure 2.2: Industry View of Ethanol Production and Consumption 11

Figure 2.3: Comparative View of India's Gasoline and Diesel Consumption 15

Figure 2.4: Road Map towards Mandatory B30 in 2020 17

Figure 2.5: Historical and Simulated Indonesian Biodiesel Demand 18

Figure 2.6: Inclusion of the Cost of Externalities into the Final Cost of Fuels 27

Figure 2.7: Biofuel Road Map (2018–2040) 33

Figure 2.8: Biofuel Targets in Biofuel Road Map (2018–2040) 33

Figure 2.9: Breakdown of Thailand Alternative Energy Development Plan 38

Figure 2.10: Consumption of Ethanol and Various Grades of Ethanol-blended Gasoline 54

Figure 2.11: Consumption of Biodiesel and Various Grades of Biodiesel-blended Diesel 55

Figure 2.12: Trends for Total Final Energy Consumption, 2007–2017 56

Figure 2.13: Expected Ethanol plus Vegetable Oil Production According to Decision 177/2007/QD-TTg 58

Figure 2.14: Expected Biofuel Production According to Decision No. 2068/QĐ-TTg 60

Figure 2.15: Fuel Consumption in Viet Nam, 2011–2018 61

Figure 2.16: Ethanol Production in Viet Nam 63

Figure 2.17: Share of E5 Fuel in Total Gasoline Consumption 64

Figure 2.18: Comparison of Total CO_2 Equivalent Between Cassava-based Ethanol and Gasoline 69

Figure 3.1: Main and Secondary Indicators of Biofuels Sustainability at Different Levels 77

Figure 3.2: New and Traditional Renewable Energy 85

Figure 3.3: Life Cycle Assessment of Palm Biodiesel in Malaysia 88

Figure 4.1: Relationship Between Growing Rate of Number Vehicles Owned and GDP-PPP/capita 101

Figure 4.2: Thailand Smart Mobility Road Map 30@30 102

Figure 4.3: Target of 100% ZEV Registrations by 2035 for (a) Cars and Pickups, (b) Motorcycles, and (c) Buses and Trucks 106

Figure 4.4: Target of ZEV Production by 2035 107

Figure 4.5: Statistics of Conventional Vehicles and xEV Registrations 109

Figure 4.6: Statistics of EV Charging Stations 110
Figure 4.7: EV Components of the Malaysia National Automotive Policy (2020) 113
Figure 4.8: Iskandar Malaysia Bus Rapid Transit Pilot Test of Hybrid Electric and Biodiesel Buses 115
Figure 4.9: The City e-Bus Service, Kuching, Sarawak 116
Figure 4.10: Number of Newly Registered and In-use Motorcycles 116
Figure 4.11: Number of Newly Registered and In-use Cars 117
Figure 4.12: Share of Automobiles Sold in 2020 Based on Type 118
Figure 4.13: Specific Target of the Strategy for Development of Viet Nam's Automobile Industry 118
Figure 4.14: Number of E-Bikes and E-Motorcycles Produced in 2018–2020 119
Figure 4.15: Neodymium Demand Minimum (left) and Maximum (right) Value 125
Figure 4.16: Cobalt Demand Minimum (left) and Maximum (right) Value 126
Figure 4.17: Neodymium Waste Minimum (left) and Maximum (right) Value 126
Figure 4.18: Cobalt Waste Minimum (left) and Maximum (right) Value 127
Figure 4.19: Neodymium Demand Minimum (left) and Maximum (right) Value 128
Figure 4.20: Cobalt Demand Minimum (left) and Maximum (right) Value 128
Figure 4.21: Neodymium Waste Minimum (left) and Maximum (right) Value 129
Figure 4.22: Cobalt Waste Minimum (left) and Maximum (right) Value 129

List of Tables

Table 2.1: Quantity Supplied (Ethanol) and % Blending Trends 7

Table 2.2: Year-wise and Sector-wise Ethanol Production Projections 9

Table 2.3: Gasoline Demand Projections 10

Table 2.4: Ethanol Demand Projections 10

Table 2.5: Biofuel Consumption in India Since 2011 12

Table 2.6: Gasoline Consumption and Pricing, India 13

Table 2.7: Diesel Consumption and Pricing, India 14

Table 2.8. India: Biodiesel Production from Multiple Feedstocks 15

Table 2.9: Comparison of Current Conditions and Relevant Regulations for the Sources of Biofuels 25

Table 2.10: Biodiesel Implementation Timeline in Malaysia 30

Table 2.11: Projected Demand of Biodiesel in Malaysia 30

Table 2.12: Palm Biodiesel Production (2011–2020) 31

Table 2.13: Bioethanol and Biodiesel Sales 36

Table 2.14: Bioethanol and Biodiesel Sales 37

Table 2.15: Gasoline and Diesel Sales 37

Table 2.16: Specifications for Ethanol Standard 39

Table 2.17: Specifications for Ethanol Blends with Gasoline Standard 40

Table 2.18: Specifications for Biodiesel Standard 46

Table 2.19: Specifications for Biodiesel-blended Diesel Standard 48

Table 2.20: Price Structure of Petroleum Products in Bangkok (28 June 2021) 53

Table 2.21: Specific Targets Mentioned in Current Energy and Climate Policy, Viet Nam 57

Table 2.22: Current Taxes on Ethanol and Gasoline 59

Table 2.23: Ethanol Plants in Viet Nam 62

Table 2.24: Fuel Price 64

Table 2.25: Emissions Reduction Potential of Ethanol-gasoline Blends 65

Table 2.26: GHG Emissions 66

Table 2.27: Summary of the Data on GHG Emissions of Palm Oil Supply Chain 67
Table 2.28: Comparison of GHG Emissions from Diesel and Palm Biodiesel 67
Table 2.29: Well-to-Tank Greenhouse Gas Emissions for Ethanol in Thailand 68
Table 2.30: Well-to-Tank Greenhouse Gas Emissions for Biodiesel in Thailand 69
Table 3.1: Global Bioenergy Partnership Sustainability Indicators for Bioenergy 75
Table 3.2: Life Cycle GHG Emissions from Ethanol in Thailand (gCO_2eq/MJ) 81
Table 3.3: Life Cycle GHG Emissions from Palm Biodiesel in Thailand (gCO_2eq/MJ) 81
Table 3.4: Water Consumption for Ethanol in Thailand (L water/L ethanol) 82
Table 3.5: Water Consumption for Biodiesel in Thailand (L water/L biodiesel) 83
Table 3.6: Total Value Added per year from Sugarcane Cultivation and Biorefinery in Thailand 83
Table 3.7: Net Energy Ratio and Renewability of Biofuels in Thailand 84
Table 3.8: Employment Generation (person-years) from Biofuels in Thailand 84
Table 3.9: GHG Emissions Balance of the Ethanol Product 89
Table 3.10: Water Use for Ethanol Production in Viet Nam 89
Table 3.11: Emissions Reduction Potential of Ethanol-gasoline Blends 92
Table 4.1: Thailand Strategic Vision for Electric Vehicles 103
Table 4.2: Forecast Emissions Factor for National Grid until 2037 105
Table 4-3: Average VKT in Thailand 111
Table 4.4: Average FE in Thailand 111
Table 4.5: Production Targets of Electric Vehicles in Indonesia 112

List of Abbreviations and Acronyms

1G	first generation
2G	second generation
3G	third generation
AEDP	Alternative Energy Development Plan
AFET	alternative fuels and energy technologies
AIST	National Institute of Advanced Industrial Science and Technology
APROBI	Indonesian Biofuel Producers Association
ASEAN	Association of Southeast Asian Nations
BEV	battery electric vehicle
Btu/lb	British thermal unit per pound
CBU	completely built-up
CME	coconut methyl ester
Co	cobalt
CPO	crude palm oil
CREV	Comprehensive Roadmap on EVs
DFPD	Department of Food & Public Distribution
DTI	Department of Trade and Industry
E0	unblended
E10	10% ethanol blend
E20	20% ethanol blend
EAS	East Asia Summit
ERIA	Economic Research Institute for ASEAN and East Asia
ESY	ethanol supply year
EV	electric vehicle
FAME	Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles
FAO	Food and Agriculture Organization of the United Nations
FCEV	fuel cell electric vehicle
FE	fuel economy

GBEP	Global Bioenergy Partnership
GDP	gross domestic product
GHG	greenhouse gas
GWP	global warming potential
HEV	hybrid electric vehicle
IBSI	Indonesian Bioenergy Sustainability Indicators
IPCC	Intergovernmental Panel on Climate Change
L	litre
LC-GHG	life cycle GHG
LCA	life cycle analysis
MITI	Ministry of International Trade and Industry
MJ	megajoule
MPIC	Ministry of Plantation Industries & Commodities
MPOB	Malaysian Palm Oil Board
NAP	National Automotive Policy
NBB	National Biofuel Board
NBP	National Biofuels Program
Nd	neodymium
NGA	national government agency
NRE	new and renewable energy
OMC	oil marketing companies
PDOE	Philippine Department of Energy
PDP	Power Development Plan
PHEV	plug-in hybrid electric vehicle
PNS	Philippine National Standards
PPP	purchasing power parity
PSO	public service obligation
RE	renewable energy
REE	rare earth element
REO	rare earth oxide

RON	research octane number
SCT	special consumption tax
SDGs	Sustainable Development Goals
SUV	sport utility vehicle
TOE	tons of oil equivalent
t/y	ton per year
US	United States
USGS	United States Geological Survey
VKT	vehicle kilometre of travel
xEV	electrified vehicle
ZEV	zero emissions vehicle

Executive Summary

Reducing greenhouse gas (GHG) emissions in the transport sector is now attracting attention worldwide, especially after the Paris Agreement in 2015. To meet this target, East Asia Summit (EAS) countries have been making great efforts to introduce biofuels on a large scale considering the potential of their resources. Meanwhile, the introduction of electrified vehicles (xEVs) is now expanding rapidly, which can be another efficient option to reduce GHG emissions in the transport sector. Therefore, creating a future mobility fuel scenario with the balance of biofuel vehicles and xEVs is necessary.

In this regard, this project aims at analysing the future scenario of EAS mobility, which highly contributes to the Sustainable Development Goals (SDGs) (7, 12, and 13) in consideration of the balance between transport CO_2 reduction, biofuel use, and mineral resources demand. The outcome will contribute to the EAS Energy Research Road Map (Pillar 3: Climate Change Mitigation and Environmental Protection corresponding to the ASEAN Plan of Action for Energy Cooperation 2016–2025, 3.5 Programme Area No.5: Renewable Energy, and 3.6 Programme Area No.6: Regional Energy Policy and Planning).

First, as a follow up to previous ERIA projects, 'Study of Renewable Energy Potential and Its Effective Usage in East Asia Summit Countries' and 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asia Summit Countries', the topic of biofuel policies and implementation, especially from the sustainability aspect, is continuously monitored in the context of mobility transition into electric vehicles across EAS countries.

Existing biofuel policies and implementation plans were updated from selected EAS countries as a foundation to accommodate emerging electric vehicle trends during mobility energy transition. As the result, the following information on biofuel policies and implementation mechanism, as well as potential CO_2 reduction, are collected.

- Past and current national plan for biofuels (ethanol and biodiesel) promotion
- National biofuels (ethanol and biodiesel) standard and their blends with fossil fuel
- Government support and/or incentives for biofuels (ethanol and biodiesel), e.g. subsidies, mandates, targets
- Biofuels (ethanol and biodiesel) blending acceptance by vehicle manufacturer
- Statistics of biofuels (ethanol and biodiesel) and their fossil counterpart landscape
- CO_2-related information (well-to-tank) for biofuels (ethanol and biodiesel) and their fossil counterpart

As seen from the rich content and journey of biofuel policies and implementation schemes in the selected EAS countries of India, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam, each country has its own unique approach and target. In addition, multiple benefits of biofuel implementation not only lie in reduced fossil fuel imports and reduced tank-to-wheel CO_2 emissions, but also value added and demand creation for agricultural products. However, these biofuel policies and implementation schemes must be carefully pursued within the context of sustainability, especially during the transition towards electric mobility in the future.

Second, the progress of sustainability assessment of biofuels in the East Asia region were evaluated with examples of some of the participating countries using the sustainability indicators proposed by the earlier ERIA project on 'Sustainable Biomass Utilisation Vision in East Asia'.

As the result, 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 Global Bioenergy Partnership. 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, GHG emissions. In general, GHG emissions reduction has been observed for biofuels as compared to the fossil fuel counterparts, although some studies have cautioned that these reductions could be overturned should forest land be converted to agriculture for cultivating biofuel feedstock. 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 Food and Agriculture Organisation of the United Nations. 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 Global Bioenergy Partnership.

Third, long-term mineral resource demand associated with automobile electrification was estimated in EAS countries. In addition, the potential for recycling in these countries was assessed by determining the amount of waste of these mineral resources and the effectiveness of introducing a circular economy under these conditions was evaluated.

More particular, the following two methods were adopted for estimation.

Method 1 predicted the number of automobiles that were sold and discarded as described above, and then the number of xEVs sold was calculated by using Deloitte's prediction of automobile electrification and integrating the Nd and Co content.

Method 2 estimated the demand and disposal of neodymium and cobalt by using the target values for vehicle electrification in each country, which were evaluated in this project.

As the conclusion, the demand for neodymium is predicted to be a minimum of 2,996 tons per year (t/y) to a maximum of 4,809 t/y in 2050 based on Method 1 and a minimum of 3,200 t/y to a maximum of 5,295 t/y in 2030 based on Method 2 (including India). If the recycle rate is 100%, secondary resources can cover 47% to 50% of neodymium demand based on Method 1 and 21% to 25% based on Method 2.

Moreover, the total demand for cobalt is predicted to be a minimum of 1,397 t/y to a maximum of 89,762 t/y in 2050 based on Method 1 and a minimum of 1,614 t/y to a maximum of 103,720 t/y in 2030 on Method 2. If the recycle rate is 100%, secondary resources can cover 42% of cobalt demand based on Method 1 and 16% based on Method 2.

However, considering that production of neodymium was 43,200 t/y and cobalt was 140,000 t/y in 2020, it is predicted it will be difficult for world supply to meet the target of EAS mobility electrification regarding the large increase of demand in China, the European Union, and the United States.

For further studies, well-to-wheel CO_2 reduction of biofuel implementation and dynamic material flow analysis of mineral resource will be conducted. The sustainability assessment will then be conducted with more concrete data for each (environmental, social, and economic) indicators using country-level information rather than discrete and specific case studies from the literature that may have been designed for a different purpose. This will bring more uniformity to the overall sustainability assessment of biofuels for the region. Furthermore, the synergies as well as multi-benefits between biofuel implementation and mobility electrification will be more clarified with all sustainability indicators. At last, the sustainable mobility scenarios for EAS countries will be created considering the achievement of the SDGs.

Chapter 1

Introduction

1. Background and Objectives of the Research

Reducing greenhouse gas (GHG) emissions in the transport sector is now attracting attention worldwide, especially after the Paris Agreement in 2015. To meet this target, East Asia Summit (EAS) countries have been making great efforts to introduce biofuels on a large scale considering the potential of their resources. Meanwhile, the introduction of electrified vehicles (xEVs) is now expanding rapidly, which can be another efficient option to reduce GHG emissions in the transport sector. Therefore, creating a future mobility fuel scenario with the balance of biofuel vehicles and xEVs is necessary.

The National Institute of Advanced Industrial Science and Technology (AIST) in Japan has been studying future mobility scenarios of EAS countries since 2014. In this AIST and Economic Research Institute for ASEAN and East Asia (ERIA) project, the scenarios for India, Indonesia, and Thailand were examined considering the potential of biofuels and xEVs and the constitution of power generation. As the result, well-to-wheel CO2 emissions were estimated for several scenarios by creating energy mix models.

However, in the previous project, the sustainability of biofuels and xEVs has not yet been taken into consideration. Diffusion of xEVs can contribute to the reduction of CO2 emissions, but may increase the demand for mineral resources induced by motors and batteries.

In this regard, this project aims at analysing the future scenario of EAS mobility, which highly contributes to the Sustainable Development Goals (SDGs) (7, 12, and 13) in consideration of the balance between transport CO2 reduction, biofuel use, and mineral resources demand. The outcome will contribute to the EAS energy research road map (Pillar 3: Climate Change Mitigation and Environmental Protection corresponding to the ASEAN Plan of Action for Energy Cooperation 2016–2025, 3.5 Programme Area No.5: Renewable Energy, and 3.6 Programme Area No.6: Regional Energy Policy and Planning).

1. Study Method

The topics and method of each study are as follows. The target of EAS countries are India, Thailand, Indonesia, Philippines, Malaysia, and Viet Nam.

(1) Evaluation of the potential for biofuels and its sustainability including fuels from unconventional resources.

1st year	➢ Collate the existing research on biofuels sustainability assessment in EAS countries. ➢ Review the most updated biofuel sustainability standards. ➢ Identify needs for updating research.
2nd year	➢ Collect additional information/data for updating research as identified in the first year. ➢ Collect the existing research which assesses the potential of biofuels from residual waste (and agricultural waste, etc.) ➢ Conduct additional assessment for updating research results.
3rd year	➢ Interpret research results after scientific validation. ➢ Prepare policy brief to address policy concerns and needs vis-à-vis biofuels sustainability in EAS countries.

(2) Assessment of well-to-wheel CO_2 reduction considering the sustainability of biofuels and mineral resources.

1st year	➢ Updating with current biofuel policy of the countries to assess well-to-wheel CO_2 reduction. ➢ Evaluate the relationship between demand of xEVs and consumption of mineral resources (cobalt, nickel, and rare earths) using AIST original database of critical raw materials.
2nd year	➢ Scenario analysis of various biofuel policy in term of CO_2 reduction in connection with Nationally Determined Contribution. ➢ Material flow analysis of mineral resources considering supply chain between ore, alloy, device (batteries and motors) and xEVs. ➢ Forecast the demand of xEVs and mineral resources until 2050 in EAS countries considering the production capacity of mineral resources by using the AIST original reserve database. .
3rd year	➢ Estimate the well-to-wheel CO_2 reduction by biofuels and xEVs in EAS countries.

3. Policy Recommendations

(1) Mobility scenario and strategy of EAS countries.

(2) Reduction of transport energy consumption and CO_2 emissions in EAS countries.

(3) Implementation of sustainable transport energy which highly contributes to SDGs.

4. Timeline/Schedule

Timeline of fiscal year 2020–2021:

October 2020	1st working group meeting
February 2021	2nd working group meeting
June 2021	Submission of report
November 2021	Publication of report

Total timeline of the project: September 2020–June 2023

Chapter 2

Biofuel Policies and Biofuel Implementation in East Asia Summit Countries

1 Introduction

1.1 Background

As a follow up to previous ERIA projects, 'Study of Renewable Energy Potential and Its Effective Usage in East Asia Summit Countries' and 'Evaluation of CO_2 Emissions Reduction by Mobility Electrification and Alternative Biofuel Introduction in East Asia Summit Countries', the topic of biofuel policies and implementation, especially from the sustainability aspect, is continuously monitored in the context of mobility transition into electric vehicles across East Asia Summit (EAS) countries. Balancing between existing biofuel implementation and emerging electric mobility trends towards sustainable future mobility scenario can be harnessed through careful policy directions, which is a focus of this chapter.

1.2 Objective and Scope

The objective of this chapter is to update existing biofuel policies and implementation plans from selected EAS countries as a foundation to accommodate emerging electric vehicle trends during mobility energy transition. Biofuel policies mechanism that already create demand for agriculture surplus to food production must be carefully analysed if part of this demand is replaced by electricity for future mobility. Review of past and existing biofuel polices and regulations in the context of potential EV scenario (to be discussed in Chapter 4) is the scope of this chapter.

1.3 Methodology

In selected EAS countries, the following information on biofuel policies and implementation mechanism, as well as potential CO_2 reduction, are collected.

・Past and current national plan for biofuels (ethanol and biodiesel) promotion

・National biofuels (ethanol and biodiesel) standard and their blends with fossil fuel

・Government support and/or incentives for biofuels (ethanol and biodiesel), e.g. subsidies, mandates, targets

・Biofuels (ethanol and biodiesel) blending acceptance by vehicle manufacturer

・Statistics of biofuels (ethanol and biodiesel) and their fossil counterpart landscape

・CO_2-related information (well-to-tank) for biofuels (ethanol and biodiesel) and their fossil counterpart

2. Biofuel Policies and Biofuel Implementation

A. India

Given continuing uncertainties with regard to supplies, energy security has emerged as a matter of priority concern for India over the last few years. With the sharp escalation in crude oil prices in the past few years, it has been inexorably driven centre-stage, and appears likely to stay that way – at least in the foreseeable future. India's energy security emanates from a continuous supply of energy to cater for sustainable economic and commercial growth. Traditionally India is an oil and gas importer. The growing concern of climate change has forced India to look for alternative green fuel strategies.

The adoption of blending ethanol and the promotion of biofuel are the important strategies that India is following with the objectives of not only reducing the oil import bill but also addressing the climate change concern. It was the first oil crisis of 1973 that compelled India to look for alternative strategies. The genesis of India's biofuel programme went back to 1975 when India began examining the feasibility of blending ethanol with petrol and set up six technical committees and four study groups. After passing through various phases finally India adopted the National Plan of Biofuel in 2018.

National Policy on Biofuel 2018

Salient Features

i. The policy categorises biofuels as 'Basic Biofuels, i.e. first generation (1G) bioethanol & biodiesel and 'Advanced Biofuels' - Second Generation (2G) ethanol, Municipal Solid Waste to drop-in fuels, Third Generation (3G) biofuels, bio-compressed natural gas, etc. to enable extension of appropriate financial and fiscal incentives under each category.

ii. The policy expands the scope of raw material for ethanol production by allowing the use of sugarcane juice, sugar containing materials like sugar beet, sweet sorghum, starch containing materials like corn, cassava, damaged food grains like wheat, broken rice, rotten potatoes, that are unfit for human consumption for ethanol production.

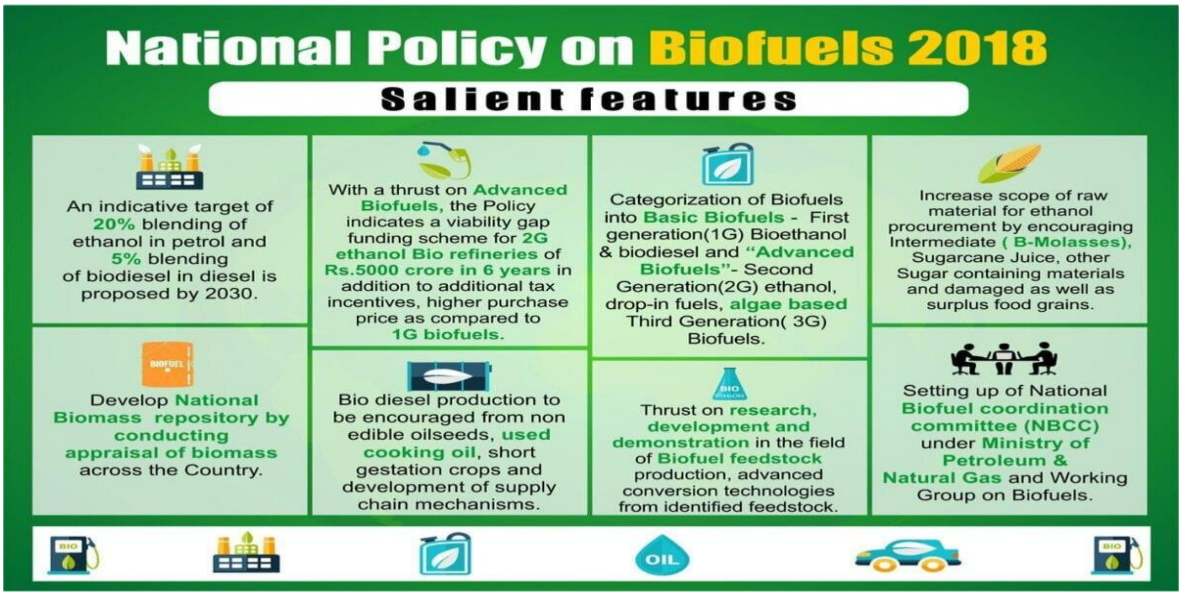
iii. Farmers are at risk of not getting appropriate prices for their produce during the surplus production phase. Taking this into account, the policy allows the use of surplus food grains for the production of ethanol for blending with petrol with the approval of the National Biofuel Coordination Committee.

iv. With a thrust on advanced biofuels, the policy indicates a viability gap funding scheme for 2G ethanol biofuel refineries of Rs5,000 crore in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels.

v. The policy encourages the setting up of supply chain mechanisms for biodiesel production from non-edible oilseeds, used cooking oil, and short gestation crops.[1]

One of the most important salient features of this programme is achieving an indicative target of 20% blending of ethanol in petrol and 5% blending in diesel by 2030. Other important features are shown in Figure 2.1.

Figure 2.1: National Policy on Biofuels 2018



Source: Civilsdaily, 21 Nov 2018. https://www.civilsdaily.com/burning-issue-national-policy-on-biofuels-2018/

National Biofuel (ethanol and biodiesel) Standard and their Blends with Fossil Fuel

Currently petrol with 10% ethanol blend (E10) is being retailed by various oil marketing companies (OMCs) in India. However, due to the scarcity of sufficient ethanol, only around 50% of petrol sold is E10 blended, while the rest is unblended (E0). The current level of average ethanol blending in the country is 5% (ethanol supply year [ESY] 2019–20). Due to several interventions in the supply side of ethanol, the Ministry of Petroleum aims to achieve 10% ethanol blending levels in the ESY 2021–22, i.e. April 2022. The Ministry of Road Transport and Highways has notified BS-VI emissions norms in Central Motor Vehicle Rules 1989, which are applicable to all vehicles after 1 April 2020. Newer vehicles on E20 will have to meet BS-VI norms. The ministry has notified GSR 156(E) on 8 March 2021 for the adoption of E20 fuel as automotive fuel and issued mass emissions standards for it (PPAC 2021).

Currently gasoline vehicles (two-wheelers and four-wheelers) in the country are designed for running on pure gasoline and can be tuned to suit ethanol-blended fuels ranging from E0 to E5 depending on the vehicle type. The government aims to advance the adoption of 20% blending in gasoline in the country by 2025. Surprisingly ethanol blending in India hit over 7.2% in the first 4 months of 2021 (Biofuels-news.com, 2021).

The supply of ethanol under the EBP Programme has increased from 38 crore litres during ESY 2013–14 to 173 crore litres during ESY 2019–20 resulting in an increase in blend percentage from 1.53% to 5.00%, respectively. Further, the allocation for the ongoing ESY (2020–21) has surged to 332 crore litres, which is 91% more in comparison to the ethanol supplies received during preceding ESY (2019–20). The quantity supplied and blending trends are shown in Table 2.1.

Table 2.1: Quantity Supplied (Ethanol) and % Blending Trends

Ethanol Supply Year	Quantity Supplied (crore litre)	Blending % PSU OMCs
2013–14	38.0	1.53%
2014–15	67.4	2.33%
2015–16	111.4	3.51%
2016–17	66.5	2.07%
2017–18	150.5	4.22%
2018–19	188.6	5.00%
2019–20	173.0	5.00%
2020–21	332	8.50%

OMC = oil marketing companies, PSU = public sector undertakings.
Source: Ministry of Petroleum & Natural Gas (2021).

Government Support and Incentives for Biofuel

As per the Union budget 2021–22 of the Government of India, financial assistance will be provided to set up distilleries to produce 1G ethanol from feedstock such as cereals (rice, wheat, barley, corn, and sorghum), sugarcane, and sugar beet.

Assistance will also be provided for the conversion of molasses-based distilleries to dual feedstock. Under the programme, the government would bear interest subvention for 5 years, including a 1-year moratorium against the loan availed by project proponents from banks at 6% per annum or 50% of interest, whichever is lower. The new programme is expected to bring about Rs400 billion (about $5.47 billion) in investments. The programme would facilitate the diversion of excess sugar to ethanol and encourage farmers to diversify their crops from sugarcane and rice to maize and corn, which need less water. About 50 million sugarcane farmers and 500,000 workers associated with sugar mills and other ancillary activities would benefit from the programme.

Loans amounting to about Rs3,600 crore have been sanctioned by banks to 70 sugar mills so far; 31 projects have been completed creating a capacity of 102 crore litres as a result. The capacity of molasses-based distilleries has reached 426 crore litres. Thirty-nine more projects with a capacity of 93 crore litres are likely to be completed by March 2022, which will bring the cumulative capacity to about 519 crore litres.

The Cabinet Committee on Economic Affairs in its meeting dated 30 December 2020 approved a note of the Department of Food & Public Distribution for extending financial assistance for producing 1G ethanol from feedstock such as cereals (rice, wheat, barley, corn & sorghum), sugarcane, sugar beet, etc. The DPFD notified a modified scheme to enhance ethanol distillation capacity in the country for producing 1G ethanol from feedstock such as cereals (rice, wheat, barley, corn & sorghum), sugarcane, sugar beet etc (PIB, 2021). Thereafter, with the approval of the Cabinet Committee on Economic Affairs, the DFPD has notified modified interest subvention scheme on 14.01.2021 for setting up new grain-based distilleries and/or the expansion of existing grain-based distilleries to produce ethanol from other 1G feedstock. About 418 applications received for capacity addition of 1,670 crore litres have been recommended for in-principle approval. It is expected that at least ethanol capacity of about 500 crore litres (molasses and grain-based) would be added from these upcoming projects. Further applications would be invited by the DFPD as and when required.

Thus, it is expected that the capacity of molasses-based distilleries would increase from current levels of 426 crore litres to 730 and 760 crore litres by 2024–25 and 2025–26, respectively. Seventy-five crore litres capacity is being added by existing grain-based distilleries; further oil marketing companies (OMCs) are planning to set up about 10 to 15 new grain-based distilleries thereby adding capacity by 100 to 150 crore litres. Hence, the capacity of grain-based distilleries is expected to reach 350, 450, 700, and 740 crore litres during 2022–23, 2023–24, 2024–25, and 2025–26, respectively from current levels of 258 crore litres.

Under the Pradhan Mantri Jaiv Indhan–Vatavaran Anukool Fasal Awashesh Nivaran (PM–JIVAN) scheme, 12 commercial plants and 10 demonstration plants of 2G biorefineries (using ligno-cellulosic biomass as feedstock) are planned to be set up in areas having sufficient availability of biomass so that ethanol is available for blending throughout the country. Already Rs1,969.50 crore have been earmarked for this scheme. These plants can use feedstock such as rice straw, wheat straw, corn cobs, corn stover, bagasse, bamboo and woody biomass.

Ethanol production projection

Table 2.2 shows the projection of ethanol production. As per the table the current (2020–21) blending rate is 5% which is projected to increase 20% by 2025–26. Commodity wise, sugar molasses would be dominating.

Table 2.2: Year-wise and Sector-wise Ethanol Production Projections

Ethanol Production Projections (crore litres)										
Ethanol Supply Year	For Blending			Blending (in %)	For other uses			Total		
	Grain	Sugar	Total		Grain	Sugar	Total	Grain	Sugar	Total
2019–20	16	157	173	5	150	100	250	166	257	423
2020–21	42	290	332	8.5	150	110	260	192	400	592
2021–22	107	330	437	10	160	110	270	267	440	707
2022–23	123	425	542	12	170	110	280	293	535	828
2023–24	208	490	698	15	180	110	290	388	600	988
2024–25	438	550	988	20	190	110	300	628	660	1,288
2025–26	466	550	1016	20	200	134	334	666	684	1,350

Source: USDA (2021).

Vehicular ethanol demand projection and manufacturers view

The vehicle population in the country is around 22 crore of two- and three-wheelers and around 3.6 crore of four-wheelers (Society of Indian Automobile Manufacturers, 2021). The two-wheelers account for 74% and passenger cars around 12% of the total vehicle population on the road. The two- and three-wheelers consume two-thirds of the gasoline by volume, while four-wheelers consume the balance of one-third by volume. The growth rate of vehicles in this segment is pegged at around 8%–10% per annum. Based on expected vehicle population, the demand projections of gasoline in India is given in Table 2.3.

Table 2.3: Gasoline Demand Projections

Product/Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Motor Gasoline (MMTPA)*	27.7	31	32	33	35	36	37	39	40	41
Motor Gasoline (crore litre)	3,908	4374	4,515	4,656	4,939	5,080	5,221	5,503	5,644	5,785

FY = fiscal year, MMTPA = million metric ton per annum.
Note: Projections as per the 'Report of the Working Group on Enhancing Refining Capacity by FY2040'.
Source: http://www.niti.gov.in/sites/default/files/2021-07/Ethanol-blending-in-India-compressed.pdf

The projected requirement of ethanol based on petrol (gasoline) consumption and estimated average ethanol blending targets for the period ESY 2020–21 to ESY 2025–26 are shown in Table 2.4.

Table 2.4: Ethanol Demand Projections

Ethanol Supply Year	Projected Petrol Sale (MMT)	Projected Petrol Sale (crore litres)	Blending (in %)	Requirement of ethanol for blending in Petrol (crore litres)
A	B	B1 = B * 141.1	C	D = B1* C %
2019–20	24.1 (Actual)	3,413 (Actual)	5	173
2020–21	27.7	3,908	8.5	332
2021–22	31	4,374	10	437
2022–23	32	4,515	12	542
2023–24	33	4,656	15	698
2024–25	35	4,939	20	988
2025–26	36	5,080	20	1,016

MMT = million metric ton.
Source: NITI Aayog (2021).

However, Indian vehicle manufacturers think that some changes in the production line will be necessary to produce compatible vehicles. Engines and components will need to be tested and calibrated with E20 as fuel. Vendors need to be developed for the procurement of additional components compatible with E20. All the components required can be made available in the country. A shift to E20 fuel is a logical, direct progression from E10 rather than going through intermediate steps of E12 and E15. However, two important concerns need to be taken care of.

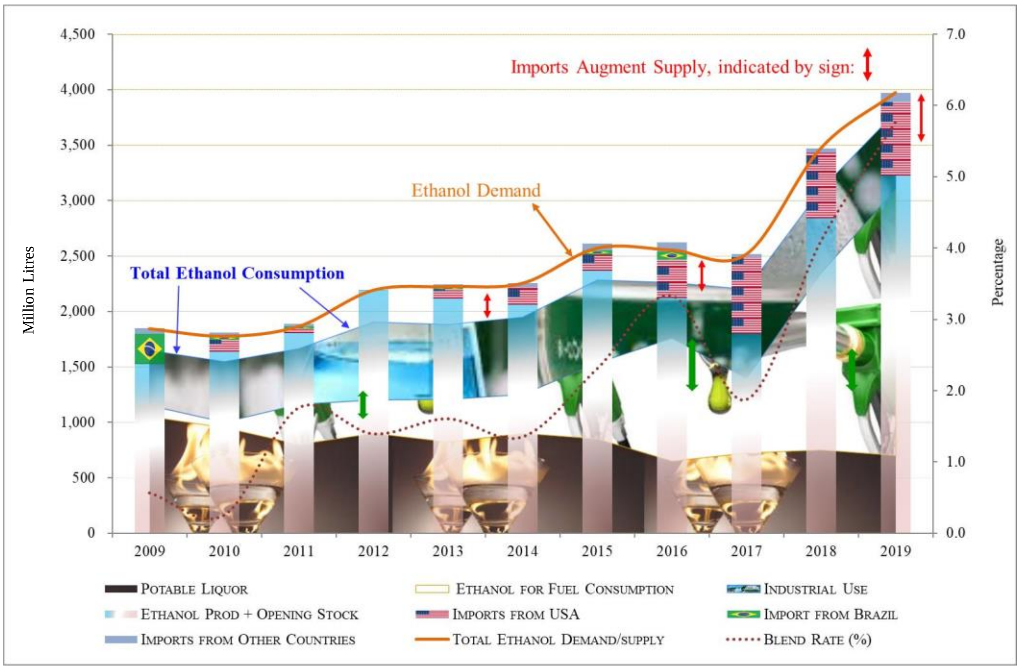
First, E20 should be made available on a pan-India basis. Second, E10 should be made available on a pan-India basis as protection grade fuel for existing pool of vehicles.

The cost of E100 and/or flex fuel vehicles will be higher in comparison to E0/E10 vehicles, which may result in an increase in total cost of ownership for the customer. It has been suggested that only when E100 can be sold at 30% lower cost compared to gasoline and if E100 fuel is available across the country, can flex fuel vehicles be a possible solution.

In the past, OMCs and original equipment manufacturers moved together for implementation of Bharat Stage 6 (BS6) emissions regulations and specification of a single fuel across the country. This needs to continue in future also to ensure portability of vehicles by the customer, especially for vehicles designed for higher blends of ethanol keeping in mind the customer's acceptance and requirements.

Adopting engines with a higher ethanol blend means changes in engine hardware and also engine calibration (tuning). The auto industry is already working on the engine upgradation work for the next level of regulations (BS6.2). Being a huge, unmodifiable task, it is important that fuel changes are also aligned with these regulations to derive complete benefit from all the perspectives, as shown in Figure 2.2.

Figure 2.2: Industry View of Ethanol Production and Consumption



Source: USDA (2019a).

Consumption and Pricing of Biofuel, Gasoline, and Diesel

As Table 2.5 shows there has been an increase of biofuel consumption in India since 2011. In 2011 the total consumption of biofuel in India was 8.24 thousand barrels per day which increased to 44.55 thousand barrel per day in 2019. The changeover is 45.22%. In March 2021, the biofuel price of India was around Rs70 per litre.

Table 2.5: Biofuel Consumption in India Since 2011

Year	Value (thousand barrels per day)
2019	44.55
2018	30.67
2017	14.48
2016	21.18
2015	13.84
2014	7.79
2013	8.79
2012	7.41
2011	8.24

Source: Knoema, 2019. https://knoema.com/atlas/India/topics/Energy/Renewables/Biofuels-consumption about India Total Biofuel Consumption (Access date 25th June 2021)

As far as gasoline is concerned there is a high jump in consumption. Despite conservation measures, the adoption of biofuel and enhancing of energy efficiency of engines, there is an escalating trend of gasoline consumption. In 2011, gasoline consumption in India was 344,000 barrels per day which increased to 646,600 barrels in 2019 as shown in Table 2.6. As far as pricing is concerned there was a steady increase of pricing up to 2019, but afterwards there was a high jump of price and currently (June 2021) the price of gasoline is around Rs96/litre, as shown in Table 2.6.

Table 2.6: Gasoline Consumption and Pricing, India

Year	Consumption (thousand barrels per day)	Price (Rs/litre)
2018–19	646.6	78.43
2017	593.0	65.63
2016	552.0	63.02
2015	492.0	66.29
2014	429.0	71.51
2013	394.0	63.09
2012	363.0	73.18
2011	344.0	63.37

Source: India Gasoline Consumption, https://www.theglobaleconomy.com/download-data.php India Gasoline Consumption about thousand barrels per day) (Access date 25th June 2021)

Table 2.7 shows the consumption and pricing pattern of diesel in India from 2011 to 2019

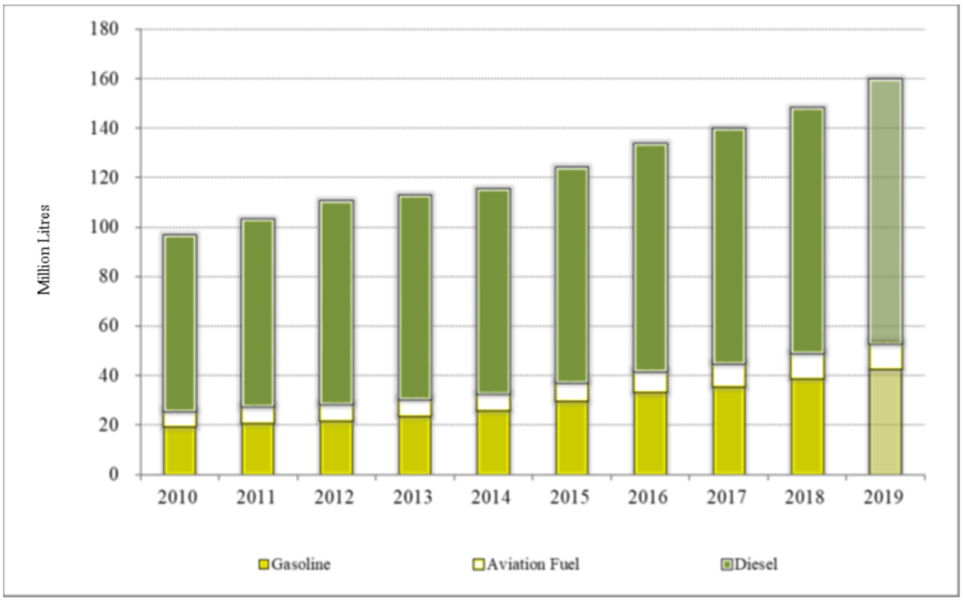
Table 2.7: Diesel Consumption and Pricing, India

Year	**Consumption ('000 million tonnes)**	**Price (Rs/litre)**
2019	82602	66.00
2018	83528	67.80
2017	81073	53.33
2016	76027	54.28
2015	74647	49.71
2014	69416	55.48
2013	68364	48.63
2012	69080	40.91
2011	64750	37.75

Source: Petroleum Planning and Analysis Cell, Ministry of Petroleum and Natural Gas, Government of India.

A comparative view of consumption of gasoline and diesel in India has been depicted in Figure 2.3. Table 2.8 shows the biodiesel production and consumption pattern.

Figure 2.3: Comparative View of India's Gasoline and Diesel Consumption



Source: Petroleum Planning and Analysis Cell (PPAC), Government of India.

Table 2.8. India: Biodiesel Production from Multiple Feedstock

Biodiesel (million litres)										
Calendar Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Beginning Stocks	45	15	13	14	15	11	13	13	18	25
Production	100	111	126	132	138	152	158	170	185	190
Imports	0	0	0	0.3	1.7	0.8	2.7	7.1	25.2	11.5
Exports	0	0	0	3.9	41.5	33.1	41.7	7.6	23.1	19.7
Consumption	131	113	125	128	102	118	119	165	180	185
Ending Stocks	15	13	14	15	11	13	13	18	25	22
Production Capacity (million litres)										
Number of Biorefineries	5	5	5	6	6	6	6	6	6	6
Nameplate Capacity	450	450	460	465	480	500	550	600	650	660

Biodiesel (million litres)										
Calendar Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Capacity Use (%)	22.2	24.7	27.4	28.4	28.8	30.4	28.7	28.3	28.5	28.8
Feedstock Use for Fuel (1,000 metric tons)										
Non-edible Industrial	50	58	65	70	75	85	90	100	110	105
Used Cooking Oil	38	42	48	49	50	55	55	55	60	65
Animal Fats & Tallows	6	6	7	7	6	5	6	6	8	10
	94	106	120	126	131	145	151	161	178	180
Market Penetration (million litres)										
Biodiesel, on-road use	36	31	42	49	32	41	48	72	83	85
Diesel, on-road use	42,625	45,520	49,343	49,354	49,605	52,239	55,179	57,025	61,247	62,284
Blending Rate (%)	0.09	0.07	0.08	0.1	0.06	0.08	0.09	0.13	0.14	0.14
Diesel, total use	71,041	75,866	82,238	82,256	822,674	87,064	91,965	95,041	102,079	103,807

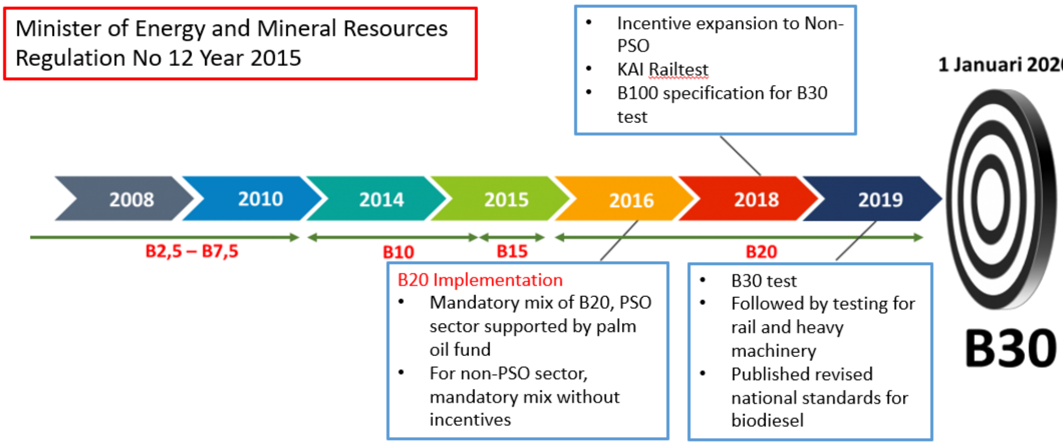
Source: USDA (2019b).

B. Indonesia

Indonesia's mandatory biofuel content within commercial diesel and gasoline fuels was last determined by the Minister of Energy and Mineral Resources Regulation No 12 Year 2015. This regulation defined the targets to be met for both bioethanol and biodiesel-based biofuels for industry, power generation and transportation.

In regard to transportation, the development of bioethanol content has been lagging, however, for biodiesel, the programme has been relatively successful. As according to the regulation, by January 2020, the target biodiesel content is B30, as shown in Figure 2.4 (ESDM, 2019).

Figure 2.4: Road Map Towards Mandatory B30 in 2020

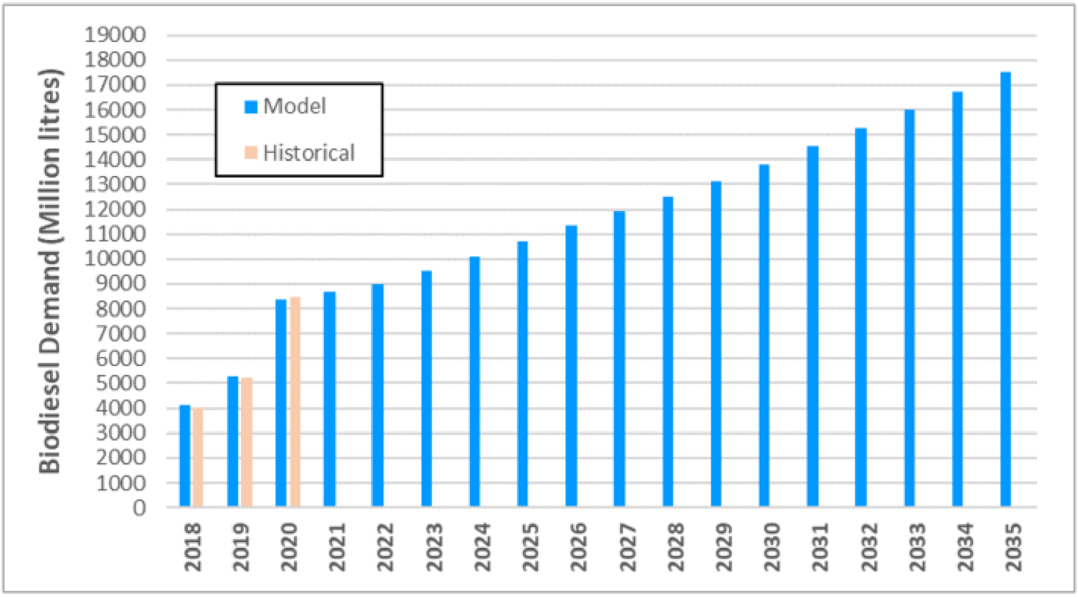


Source: ESDM (2019).

A simulation we have developed to calculate biofuel supply requirements shows that with the current biofuel target, the biodiesel demand will exceed 15 million kilolitres by 2032, as shown in Figure 2.5 (ESDM, 2020; APROBI, 2021). As the sustainability and expansion of the biodiesel programme will further require increased supply, possibilities in regard to unconventional biodiesel sources should be explored.

The success in the development of crude palm oil (CPO) based biodiesel is largely due to the regulatory framework constructed. This framework includes provisions to expand and subsidise CPO based biodiesel. Government Decree 24/2015 concerning Plantation Fund Collection stipulates that funds are collected from entrepreneur fees and levies on exports of strategic plantation commodities which include oil palm, coconut, rubber, coffee, cocoa, sugar cane, and tobacco, as well as other commodities stipulated by the minister. Funds are then allocated amongst others to improve the optimisation of the use of strategic plantations for biofuel. In the case of palm oil, a specific Palm Oil Plantation Fund is defined in Presidential Decree 61/2015 concerning Collection and Use of Palm Oil Plantation Funds. The specific funds are used to subsidise biodiesel as such to cover the shortfall between the market index price for diesel fuel and the market index price for biodiesel fuel.

Figure 2.5: Historical and Simulated Indonesian Biodiesel Demand



Sources: ESDM (2020); APROBI (2021).

One potential source of unconventional biofuels is waste frying oil. Indonesia's palm oil production increased rapidly in 2016 to above 30 million tons and reached 40 million tons in 2019 (BPS, 2018; USDA, 2019b). While the majority goes towards exports, followed by industrial domestic consumption (through production of biodiesel), the human consumption of palm oil for cooking was estimated at more than 5.9 million tons in 2019 with the total estimated domestic consumption being 13.11 million tons in the same year (USDA, 2019b).

As the laws and regulations become the driving force to establish the development of renewable energy, including the development of biodiesel from unconventional sources, it is crucial that a mapping be conducted of the current legal framework pertaining to the use of renewable energy (RE), conventional, and unconventional biofuels. Based on this mapping, regulatory avenues to accelerate inclusion of non-conventional biodiesel sources can be explored. Here, we will focus on the regulatory mapping for use of waste frying oil as a source of unconventional biofuel.

Laws and Government Regulations pertaining to Renewable Energy

The overarching law in regard to the use of renewable energy is the Government Regulation No. 79 of 2014 on The National Energy Policy (PP No 79 Tahun 2014 tentang Kebijakan Energi Nasional) and Law No. 30 of 2007 on Energy (UU No 30 Tahun 2007 tentang Energi).

Government Regulation No. 79 of 2014 on The National Energy Policy

･Specifies the new and renewable energy (NRE) target of 23% NRE in 2025 and 31% NRE in 2050 as long as the economic feasibility is met

･The central and regional governments provide subsidies if the price of NRE is higher than the price of unsubsidised fuel

･The use of NRE from biofuels is carried out while maintaining food security

･Earmarking of fossil energy depletion premiums for NRE development

Law No. 30 of 2007 on Energy

･The provision of RE is prioritised in underdeveloped areas, remote areas, and rural areas

･The central and regional governments provide facilities and/or incentives to business entities, permanent establishments, and individuals who develop RE for a certain period of time until economic feasibility is achieved.

Laws and Government Regulations pertaining to Biofuels for Transportation

In regard to the use of biofuels for transportation, the relevant laws and articles are as follows :

Presidential Decree No. 61 of 2011 concerning the National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK)

･The energy and transportation sector is targeted to contribute to a reduction in emissions of 0.056 gigatons CO_2e, amongst others through increased NRE, use of cleaner fuels (fuel switching), and utilisation of clean technology for transportation facilities.

Presidential Decree No. 191 of 2014 concerning the Provision, Distribution and Retail Price for Oil Based Fuels

･Business entities that are assigned the supplying and distributing certain (subsidised) fuels are required to blend biofuel.

･The market index price for fuel oil and the market index price for biofuel which are mixed into certain types of fuel and special assigned fuel types are determined by the minister.

･The market index price for fuel oil and the market index price for biofuel which is mixed into the general fuel type shall be determined by the business entity and reported to the minister.

Minister of Energy and Mineral Resources (MEMR) Regulation No 12 Year 2015 on the Third Revision of MEMR Regulation No.32 of 2008 on the Provision, Usage and Commercialization of Biofuels as Alternative Fuels

・Setting the blending target up to 2025 in the form of phasing the minimum obligation to use biodiesel (B100) as a mixture of fuel for public service obligation (PSO) and non-PSO transportation by 30% of total demand

・The phasing of the minimum obligation to use bioethanol (E100) as a fuel mixture for PSO transportation is 5% in January 2020 and 20% in January 2025 of total demand

・The minimum obligation to use bioethanol (E100) as a mixture of fuel for non-PSO transportation is 10% in January 2020 and 20% in January 2025 of total demand

Laws and Government Regulations pertaining to CPO based Biodiesel for Transportation

・To devise a recommendation to promote the development and supply of biodiesel from unconventional sources, it is important to recognise the regulations supporting the existing provision of biodiesel from CPO.

Minister of Energy and Mineral Resources Regulation No. 45 of 2018 on the Amendment of Minister of Energy and Mineral Resources Regulation Number 41 of 2018 Concerning Provision and Utilization of Biofuel of the Biodiesel Type in the Context of Financing by the Oil Palm Plantation Fund Management

・The government provides biodiesel financing funds originating from oil palm plantation funds that are collected, administered, managed, stored, and distributed by the Fund Management Agency to cover the deficiency between the market index price for diesel fuel oil and the market index price for biodiesel fuel.

Government Regulation No. 24 of 2015 concerning Plantation Fund Collection

・Establishment of a Plantation Fund that is collected by the Fund Management Agency which comes from entrepreneur fees and levies on exports of strategic plantation commodities which include oil palm, coconut, rubber, coffee, cocoa, sugar cane, and tobacco, as well as other commodities stipulated by the minister.

・Funds are allocated amongst others to improve the optimisation of the use of strategic plantations for biofuel.

Government Regulation No. 61 of 2015 concerning Palm Plantation Fund Collection and Usage

・Establishment of the Palm Oil Plantation Fund which is collected from fees and export levies from palm oil plantation products or derivatives.

・Funds are allocated for the provision and utilisation of biofuel from the type of biodiesel originating from oil palm plantations.

Government Regulation No. 66 of 2018 on the Second Amendment of Government Regulation No. 61 of 2015 concerning Palm Plantation Fund Collection and Usage

・The utilisation of the funds support the purpose of provision, distribution, and usage of biodiesel fuels of which in this regard is to cover the shortfall between the market index price for diesel fuel and the market index price for biodiesel fuel.

・These funds are paid to business entities supplying biodiesel fuels after verification by the Ministry of Energy and Mineral Resources

Minister of Finance Regulation No. 113/PMK.01 of 2015 on the Organization and Working Procedure of the Plantation Fund Management Agency

・Defines the organisation and functions and tasks of the of divisions of the Plantation Fund Management Agency

・The Division of Biodiesel Development is tasked with the planning of allocation and disbursement of funds, management of funding collaborations, research, and data management regarding biodiesel development.

Laws and Government Regulations pertaining to Biofuel from Waste and Unconventional Sources

There are existing regulations in place that provide an avenue towards the collection of waste and feedstock for the production of biodiesel from unconventional sources. Regulations from the Ministry of Villages, Development of Disadvantaged Areas and Transmigration particularly mention the funding of biodiesel production from cooking oil waste.

Law No. 32 of 2009 on the Environment

・Parties that produce Hazardous and Toxic Waste (LB3) are required to manage the LB3 they produce, either independently or submitted to other parties. Management includes reduction, storage, collection, transportation, utilisation and/or processing, including hoarding.

Minister of Villages, Development of Disadvantaged Areas and Transmigration Regulation No. 11 of 2019 concerning Priority for the Use of Village Funds in 2020

・One of the list of priority activities in the Village Development Sector is the development of renewable energy, which includes:

1) processing livestock waste for biogas energy,

2) making bioethanol from cassava,

3) processing used cooking oil into biodiesel,

4) management of wind power plants,

5) management of solar energy,

6) training in utilising solar energy, and

7) development of other renewable energy in accordance with the authority of the Village and decided in Village deliberations.

Minister of Villages, Development of Disadvantaged Areas and Transmigration Regulation (MVDT) No. 14 of 2020 on the Third Amendment of MVDT Regulation No. 11 of 2019 concerning Priority for the Use of Village Funds in 202018

・The use of Village Funds is prioritised for climate change mitigation and adaptation activities, including construction of RE infrastructure such as cooking oil waste treatment equipment for biodiesel.

・Utilisation of Village Funds for village owned companies that are engaged in the business of managing waste and used cooking oil waste from households into biodiesel

Regional and local governments have initiated regulations that support the development of renewable energy. These include regulations there are also regulations that support the collection and processing of waste cooking oil to biodiesel.

Bogor City Regulation No. 1 of 2014 on Environmental Protection and Management

・Produced waste cooking oil can be handed over by the producer to the regional or city government

・Any agency whose business activities produce used cooking oil as a result of its business activities is obliged to submit used cooking oil to the regional government.

・Used cooking oil is processed into biodiesel, which is used as an environmentally friendly alternative fuel.

DKI Jakarta Governor Regulation No. 167 of 2016 on the Management of Frying Oil Waste

・Promotes the use of frying oil waste as an alternative biodiesel fuel for transportation and local industries

・Producers of frying oil waste must manage the waste and/or collaborate with waste collection parties and/or users

・It is prohibited to reuse frying oil waste for human consumption or for food processing

・Frying oil waste can be utilised directly as a combustible fuel or converted into biodiesel

・The chain of frying oil waste management may include:

- Producers, which include restaurant businesses, hotels, food industries, and other cooking oil user businesses, are required to prepare a cooking oil waste management plan document as part of the environmental document in the application for a business license to the Badan Pelayanan Terpadu Satu Pintu (a one Stop Integrated Service Agency). Producers are required to store waste cooking oil produced in storage places that meet technical safety standards, for further use alone (except for human and animal consumption) and/or in collaboration with collectors.
- Collector: a party that carries out business activities to collect and distribute cooking oil waste based on a cooking oil waste collection permit from the Badan Pelayanan Terpadu Satu Pintu.
- Utiliser: parties who directly utilise cooking oil waste to add fuel diesel oil and/or process it into biodiesel or for other permitted purposes.

・Penalties for parties who violate the provisions on cooking oil waste management in the form of temporary suspension of business activities or revocation of business licenses.

Aceh Qanun 4/2019 concerning the General Plan for Aceh Energy

・Building supply and demand by :

- Formulating and implementing incentive policies for the use of NRE
- Limit the amount of fossil fuels at service posts, and on the other hand, improve the quality and quantity of biofuels
- Providing incentives for entrepreneurs in the form of:

✓Relax the timing for implementing licenses

✓Assisting soft loans in development and production operations

✓Ensuring good quality production results will be purchased by the Government of Aceh

✓Prioritising marketing access

- Giving incentives to mass transportation entrepreneurs who use alternative energy:

  ✓Investment incentives take the form of investment facilitation and tax breaks

  ✓Priority in the business area

  ✓Subsidies and assistance by the Government of Aceh

- Acceleration of biofuel supply for transportation and industry through:

  ✓Mapping of potential areas for raw material production through surveys and feasibility studies

  ✓Determination of production areas for biomass raw materials into Aceh Qanun

✓Development of processing plants in the form of ethanol plants in the eastern and western regions and biodiesel plants in the central and northern regions

North Kalimantan Provincial Regulation 3/2019 concerning General Regional Plan for Energy

・Encourage and strengthen the development of the energy industry in the regions through:

・Facilitation (public–private partnership scheme) of the development of manufacturing industries that support the energy and energy services industries

・Development of industrial equipment for production and utilisation of RE

・Prepare local regulations on RE investment from local sources specifically in remote and border areas

・The use of biofuel in the land transport sector, especially urban and urban public transport, sea transportation including fishing boats, and air transportation until 2025

・Establish a special provincial government enterprise in the energy sector that is tasked with producing and buying biofuel

・Encourage increased use of environmentally friendly energy technology based on the 3Rs (reuse, reduce, and recycle) principle for waste

・Implement a one-stop permit policy and simplifying licensing in order to increase investment in the energy sector

・Develop the biodiesel industry in 2025 as a mixture of fuel for the utilisation of the transportation, industrial and power generation sectors

・Provide facilitation and incentives in fiscal and non-fiscal forms in order to accommodate the development of the bioethanol industry to meet bioethanol needs in North Kalimantan and its surrounding areas

Recommendations for the acceleration of unconventional biofuels from waste:

Table 2.9 (Widyaparaga, 2021) shows the comparison of current conditions and relevant regulations for the sources of biofuels. It is clear that the current regulatory framework, although supportive in some aspects, still requires development if it is intended to support the development of biofuels from unconventional sources.

Table 2.9: Comparison of Current Conditions and Relevant Regulations for the Sources of Biofuels

Biofuel Source	Current Condition	Relevant Government Branches/Body and Regulations
Biofuel from strategic plantation commodities	o Palm oil is the most sustainable to develop today o There is relatively well-established funding support from the Oil Palm Plantation Fund o The management scheme and institutions have been established o Political support exists and is strong	Ministry of Energy and Mineral Resources, Ministry of Agriculture; Ministry of State Owned Enterprises (SOE); Local Governments o Energy sector regulation o Agriculture-plantation sector regulation o The compensation policy from the Minister of SOE o Local/regional regulations
Biofuel from non-strategic plantation commodities	o Plants such as jatropha, tamanu (nyamplung) and reutalis (kemiri sunan) have the potential to be developed (DEN, 2020), but are not yet sustainable to be developed at this time o There is no definite funding support yet o Supply–demand has not yet been developed	Ministry of Energy and Mineral Resources; Ministry of Agriculture; Ministry of State Owned Enterprises; Local Government o Energy sector regulation o Agriculture-plantation sector regulation o The compensation policy from the Minister of SOE o Local/regional regulations
Unconventional biofuel from waste	o Potential to be developed at the regional level	Ministry of Energy and Mineral Resources; Ministry of Environment and Forestry; Ministry of Home

Biofuel Source	Current Condition	Relevant Government Branches/Body and Regulations
	o Requires large community participation o There is no definite institutional and financial support; possible funding via Village funds o Requires the role of regional government/village owned enterprises (BUMD/BUMDes) as a driving vehicle o National and local regulations are needed that are able to build sustainable supply–demand	Affairs; Ministry of Health, Development of Disadvantaged Areas and Transmigration; Local Governments o Energy sector regulation o Environment sector regulations o Health sector regulations o Supervisory policy from the Minister of Home Affairs o Local/Regional Regulations

Source: Widyaparaga (2021).

To accelerate the inclusion and development of unconventional sources of biofuel, the following is recommended:

Formulation of strict regulations regarding the energy transition in the transportation sector in regard to unconventional biofuels

oBinding and applicable regulations that create supply–demand for unconventional biofuels (e.g. waste oil collection and processing)

o The obstacle in developing unconventional biofuels in general is that the price of unconventional biofuels is higher than fossil fuels. This is a barrier from the national oil company (Pertamina) side as end-user supplier.

o Designated state owned enterprises such as Pertamina will require government support in the form of compensation and/or incentives. There is a legal basis in Article 66 paragraph (4) of the State Owned Enterprises Law which has been amended in the Law No. 11 of 2020 concerning Job Creation, which reads: ‘If the assignment is financially impractical, the Central Government must provide compensation for all costs incurred by the SOE, including margins expected as long as it is within the level of reasonableness in accordance with the assignment given’.

o Guarantee demand and feasible prices for producers of unconventional biofuels oEstablish a funding mechanism for unconventional biofuels. This can adopt the scheme that has been established for CPO based biodiesel.

Include cost of externalities in the cost of fossil fuels thus increasing attractiveness of biofuels, as shown in Figure 2.6

o Currently, Indonesia has not considered the cost of externalities of non-RE fuel usage.

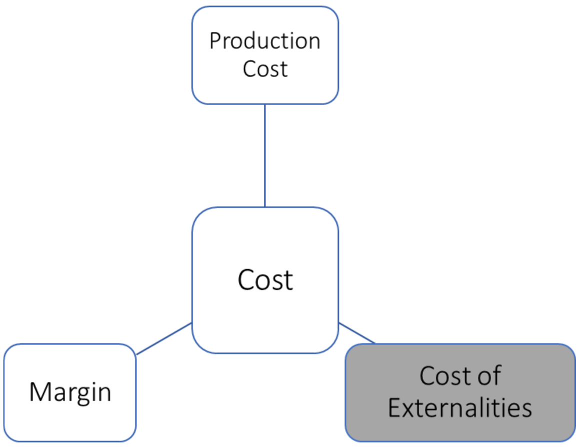
o Including the cost of externalities in non-RE fuel can level the playing field between RE and non-RE fuels by reducing the attractiveness of non-RE fuels (Fig. 2.6)

o Cost of externalities can be compensated via a carbon tax mechanism

o Carbon tax as: (1) disincentive for fossil fuel users (2) regulatory function of tax, where carbon tax is aimed to reduced fossil fuel usage and create demand for biofuels

o Regulatory basis for carbon tax is present in Law No 32 of 2009 article 43 point (3) introducing tax as an economical instrument for environment protection

Figure 2.6: Inclusion of the Cost of Externalities into the Final Cost of Fuels



Source: Widyaparaga (2021).

C. Malaysia

Any legitimate implementation of fuel mandates requires the proper framework in the form of government policies to spearhead it. The Malaysian government had rolled out policies from different ministries that were able to streamline with each other to achieve increased usage of biofuels in the country as follows.

National Biofuel Policy 2006

This policy (MPIC, 2006) was published on 21 March 2006 by the Ministry of Plantation Industries & Commodities (MPIC) together with the Malaysian Palm Oil Board (MPOB) to serve as the framework for biofuel industry development in Malaysia. The policy looks to achieve the following objectives.

・To expand the use of downstream palm oil products and become an initiative to increase the income of oil palm smallholders through palm oil market price control mechanisms

・To help reduce the country's dependence on fossil fuels as one of the energy security initiatives

・To reduce the greenhouse gas (GHG) emissions rate in line with the country's aspiration towards achieving the GHG emissions reduction target of 45% of GDP by 2030

The National Biofuel Policy 2006 contains five thrusts that are geared towards pushing the development of the biodiesel industry. The thrusts are: Thrust 1: Biofuel for Transport; Thrust 2: Biofuel for Industry; Thrust 3: Biofuel Technologies; Thrust 4: Biofuel for Export and Thrust 5: Biofuel for Cleaner Environment.

Malaysian Biofuel Industry Act 2007 (Act 666)

The Biofuel Industry Act of Malaysia (Commissioner of Law Revision, 2007) was followed shortly by the establishment of National Biofuel Policy of Malaysia in 2006. The Biofuel Industry Act was introduced to further regulate and facilitate biofuel sectors development.

With the introduction of this Act, companies that are interested to venture into biofuel only need to apply for one license and therefore the Act reduced administrative barriers by streamlining the licensing process. The activities licensed under the Act include (a) production of biofuel (b) trading of biofuel, and (c) biofuel services.

As for future policy and regulation related to biofuel in Malaysia, related policies are as follows.

National Energy Policy 2021–2040

The National Energy Policy was started in 1979 to become the framework for the direction of energy in Malaysia. The newest iteration of this policy is due to be unveiled in the second half of 2021 by the Malaysian Economic Planning Unit (EPU, 2021). In its efforts to transform Malaysian energy sector into a cleaner and more sustainable industry, initiatives such electrification and renewable fuels utilisation are to be introduced.

In the biofuels front, biogas and biodiesel initiatives are being touted as possible steps to be taken. Biogas can be a clean alternative for power generation whereas B20 (20% palm biodiesel blended with 80% petroleum diesel) implementation in the transportation sector can reduce vehicle emissions.

National Automotive Policy 2020

The National Automotive Policy was first introduced in 2006 under the Third Malaysia Plan to spearhead Malaysia's automotive industry as a prime contributor to the economy. The latest iteration of the policy was published in 2020 by the Ministry of International Trade and Industry (MITI, 2020) which highlights policies to introduce supply chain integration, investment promotion, green and sustainable improvements, and connected mobility.

Under the green and sustainability policy, the implementation of biodiesel blends is seen as one of the programmes that can help achieve this vision. The following are some of the strategies outlined.

- Coordinate R&D between industry and academia.
- Comprehensive validation system by government and industry on biodiesel approved vehicles
- Review biodiesel vehicles ecosystem to inculcate promotion of higher biodiesel grade.
- Empower research activities on application of biodiesel.

Malaysian Standards on Automotive Diesel and Biodiesel

The Department of Standards Malaysia has published multiple standards regarding the use of diesel and biodiesel in automotive engines. The latest biodiesel standard, MS 2008:2014 was further enhanced with new limits for oxidation stability (10 hours minimum @ 110^{o}C) and monoglycerides content (0.7 weight % maximum). The latest diesel standards which are MS 123-4:2020 (Euro 2M) and MS 123-5:2020 (Euro 5) allows for the blending of 7.1% to 20% palm biodiesel in petroleum diesel. These standards have allowed for the implementation of biodiesel blends up to B20 as quality requirements have been met.

Government Instruction on Specifications of Imported Vehicles

MITI is the governing authority on imported vehicles coming into Malaysia. Through cooperation between MPIC and MITI, an instruction was made to all vehicle manufacturers that starting from 1 January 2020 all diesel vehicles in the Malaysian market must be compatible with B20 and above usage.

The implementation of biodiesel usage in Malaysia had started in 2011 with the usage of B5 (5% palm biodiesel blended with 95% petroleum diesel). It then expanded to B7 in 2014, B10 in 2019, and B20 starting 2020 (MPOB, 2021). As shown in Table 2.10, the implementation had covered various sectors that utilise diesel and ensures that there is constantly a mix of renewable fuels and fossil fuels in the country.

Table 2.10: Biodiesel Implementation Timeline in Malaysia

Date of Implementation	Sector	Programme	Region
November 2011	Transport	B5	Central region, Peninsula Malaysia
July 2013		B5	Southern region, Peninsular Malaysia
February 2014		B5	Northern region, Peninsular Malaysia
March 2014		B5	Eastern region, Peninsular Malaysia
November 2014		B7	Whole Peninsular Malaysia
December 2014		B7	East Malaysia
February 2019		B10	Nationwide
July 2019	Industrial	B7	Nationwide
January 2020	Transport	B20	Langkawi and Labuan Islands
September 2020			Sarawak

Source: MPOB (2021).

Biodiesel usage in Malaysia has been steadily increasing from 2011 until 2020 with every implementation of the biodiesel blending programmes, as shown in Table 2.11 (MPOB, 2021). Currently the B20 implementation is being done in phases to accommodate for blending facilities upgrading at petroleum terminal. Once the upgrades have been completed, the blending facilities can cater up to B30 blending. It is projected that the B30 programme for the transport sector with B10 programme for industrial sector to be in place until 2030.

Table 2.11: Projected Demand of Biodiesel in Malaysia

Mandate	Implementation Period	Biodiesel Demand (tons/year)
B5 Transport	2011–2014	267,000
B7 Transport	2014–2018	374,000
B10 Transport B7 Industry	2019–2020	761,000
B20 Transport B7 Industry	2020–2024	1,294,000
B30 Transport B10 Industry	2025–2030	1,926,000

Source: MPOB (2021).

In 2020, there were a total of 19 licensed biodiesel plants that were operating with a total production capacity of 2.32 million tons per year, as shown in Table 2.12 (MPOB, 2021). The palm biodiesel produced in 2020 only accounts for about 39.2% of the total production capacity of the operating biodiesel plants. This indicates that there is room for the biodiesel industry to grow with initiatives and policies to increase domestic consumption and new markets to export are introduced.

Table 2.12: Palm Biodiesel Production (2011–2020)

Duration	Palm Biodiesel Production (million tons)
2011	0.17
2012	0.24
2013	0.47
2014	0.60
2015	0.67
2016	0.50
2017	0.72
2018	1.09
2019	1.42
2020	0.91

Source: MPOB (2021).

Initial implementation of the B5 programme for the transport sector was met with anxiety by most diesel vehicle manufacturers as most OEM are wary of new fuels coming into the market. MPOB together with MPIC had conducted trials on engines and vehicles prior to the implementation to provide proof that biodiesel blends can be used in diesel engines.

With the development of Malaysian standards for diesel and biodiesel, OEM and users of diesel vehicles concerns on fuel quality were allayed. The current implementation of B20 has been accepted by most vehicle manufacturers especially brands from Japan that constitute a majority of diesel vehicles in the market.

D. Philippines

National Plan for Biofuel (ethanol and biodiesel) Promotion

Republic Act (R.A.) No. 9367 otherwise known as the Biofuels Act of 2006, signed into law on 12 January 2007, is a landmark law which directed the use of biofuels as well as establishing the National Biofuels Program (NBP). The Biofuels Act was aimed to increase the contribution of biofuels in the country's energy mix by developing and utilising indigenous renewable and sustainably sourced clean energy sources, thereby reducing the country's dependence on imported fossil-based fuels, enhance the quality of the environment, and create opportunities for countryside socio-economic development.

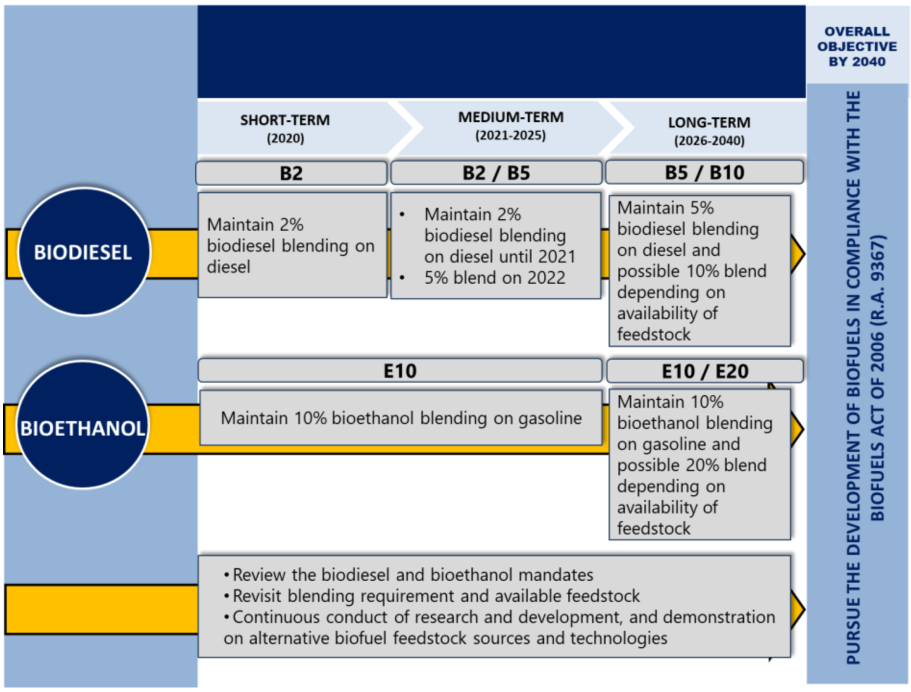
The Act also created the National Biofuel Board (NBB), an inter-agency policy recommendatory body, whose main functions are to monitor the implementation of the NBP including the supply and utilisation of biofuel and biofuel-blends, review and recommend to the Department of Energy the adjustment in the mandated biofuel blends subject to the availability of locally sourced biofuels, amongst others.

To address the growing concern on 'food versus fuel' being raised in the development and utilisation of biofuels in the country, the NBB has initiated the formulation of the Joint Administrative Order (JAO) No. 2008-1, Series of 2008, which provides the guidelines governing the biofuel feedstocks production, biofuels and biofuel blends production, distribution, and sale under the RA 9367. The guidelines were adopted by the NBB for the information, guidance, and compliance of all concerned stakeholders.

The Philippine Department of Energy (PDOE) is continuously embarking on research, development, and demonstration and deployment activities geared towards identifying viable and alternative feedstock for biofuel production in partnership with academic and research institutions and other industry stakeholders. There are other alternative biofuel feedstock sources that can be tapped and harnessed to address the issue on supply sustainability. Implementation of higher blend may also be hastened through the development of indigenous biofuel feedstock. In the case of biodiesel, feedstock sources include (a) jatropha, (b) waste cooking oil, (c) microalgae, and (d) rubber seed oil. While for bioethanol sources include (a) sweet sorghum, (b) cassava, (c) microalgae, (d) nipa sap, and (e) cellulosic materials, amongst others.

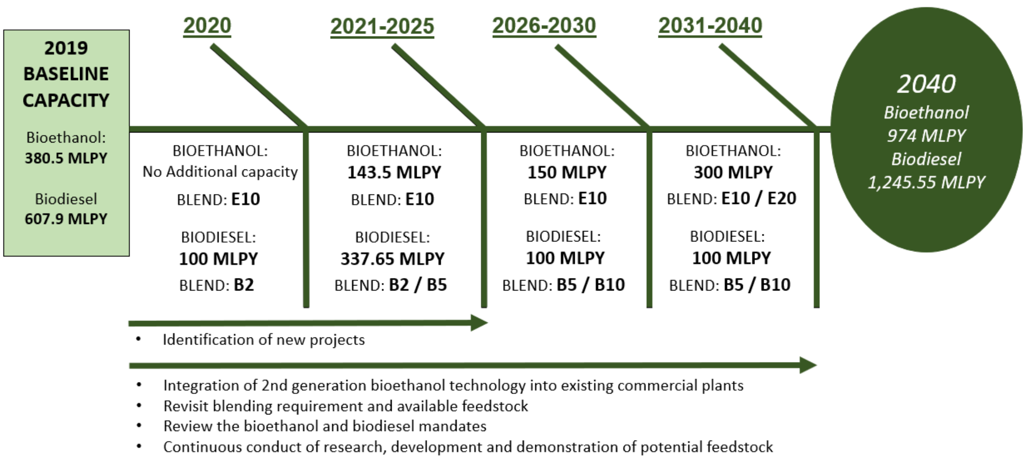
Several developmental issues encountered by the industry have contributed to the delays in the biofuel sector's road map, as shown in Figure 2.7 and Figure 2.8 (PDOE, 2021). It has always been a continuing challenge for the industry to sustain the level of production and supply to meet the growing demand, particularly in increasing the mandated biofuels' blend rates. The rise in demand of biofuels is always paralleled with the rise in demand for feedstock. The sustainability of feedstock, such as sugarcane and coconut oil for bioethanol and biodiesel production, respectively, poses a challenge for the industry specifically on the issue of food security and pricing. While pricing is also considered as a major factor that challenges the stability of the domestic biofuel industry with relatively higher per litre price of local biodiesel and bioethanol than gasoline and diesel. Thus, this affects the pump price of the transport fuel, which further makes higher blends more expensive. The PDOE and NBB deemed it necessary to address these issues through a holistic analysis as the basis in finalising a decision to increase biofuel blend mandates.

Figure 2.7: Biofuel Road Map (2020–2040)



Source: PDOE (2021).

Figure 2.8: Biofuel Targets in Biofuel Road Map (2020–2040)



MLPY = million litres per year.
Source: PDOE (2021).

National Biofuel (ethanol and biodiesel) Standard and their Blends with Fossil Fuel

The 2% biodiesel (B2) and 10% bioethanol (E10) blend mandates were implemented starting 6 February 2011 and 5 February 2009, respectively, through the issuance of the Department Circular No. 2011-02-0001 also known as the Mandatory Use of Biofuel Blend pursuant to the Biofuels Act. Pursuant to Section 9.C of RA 9367 to wit:

The National Biofuel Board shall review and recommend to DOE the adjustment in the minimum mandated biofuels-blends subject to the availability of locally-sourced biofuel: Provided, That the minimum blend may be decreased only within the first four years from the effectivity of this Act. Thereafter, the minimum blends of 5% and 2% for bioethanol and biodiesel, respectively, shall not be decreased.

The Philippine National Standards (PNS) for Anhydrous Bioethanol and Bioethanol Fuel (PNS/DOE QS 007:2014) – E100 were formulated to address the technical requirements for biofuel grade ethanol in pure form and denatured use as blending component of automotive gasoline suitable for various types of automotive spark ignition engine and other similar types of engines. While the PNS for Coconut Methyl Ester (CME) – B100 was formulated to address the technical requirements for CME (B100) suitable for blending with diesel fuel for use in various types of compression ignition engines and other similar types of engines. The PDOE issued DC Nos. DC2015-07-0012 and DC2016-05-0006 to effectively implement the PNS for E100 and B100, respectively.

Further, in preparation for the increase in the biodiesel blend mandate from B2 to B5, the PNS was promulgated to address technical requirements for high FAME-blended diesel oils (B5) suitable for various types of diesel engines and other similar types of engines. The standard specification is not yet implemented since there is no mandate for B5 and shall support future energy policies towards the integration of higher biofuels blends in the petroleum sector.

Meanwhile, the PDOE, through its Oil Industry Management Bureau, is soliciting comments and inputs on the draft PNS for CME-blended automotive and industrial diesel Oils covering the biodiesel blends of 3% (B3) and 4% (B4) on or before 30 June 2021. The draft PNS was formulated in anticipation of a proposed gradual or calibrated increase in the biodiesel blend mandate, as initially recommended by the biodiesel industry stakeholders.

The PNS for higher bioethanol blends such as E15 and E20 are still to be developed . The PDOE through its Technical Committee on Petroleum Products and Additives shall formulate said specification to be used as standard for ethanol-blended gasoline fuel suitable for various types of gasoline engines.

Government Support and Incentives for Biofuel (ethanol and biodiesel)

Consistent with the objectives of the Biofuels Act, the PDOE encourages investments and provides fiscal incentives to entities engaged in the production of biofuels and biofuels feedstock. Under R.A. 9513 or the Renewable Energy Act of 2008, the Biofuels Act and its corresponding implementing rules and regulations, registered and/or accredited biofuel producers shall be entitled to the privilege of availing various fiscal incentives as provided for in both Acts and the implementing rules and regulations, including but not limited to income tax holiday, zero-rated value added tax transactions, tax and duty-free importation of components, parts and materials, amongst others, subject to the biofuel producers' compliance to its obligations under the registration/accreditation with the PDOE and concerned national government agencies (NGAs).

In accordance with Section 17 of the Biofuels Act, the Social Amelioration Welfare Program has been institutionalised to provide the following services to qualified biofuel workers: (a) training and education, (b) livelihood assistance, (c) emergency assistance, and (d) social protection and welfare benefits. The Social Amelioration Welfare Program fund is sourced from the lien or the levy collected from PDOE-accredited biodiesel and bioethanol producers, and planters who are supplying sugarcane for bioethanol production. Lien from the biodiesel sector is equivalent to Php0.05 for every litre of coco methyl ester (biodiesel) produced and sold. While for the bioethanol sector which utilises sugarcane as feedstock, lien is equivalent to Php13.43 for every ton of sugarcane used as feedstock for bioethanol production, while Php0.07 per litre of molasses-based bioethanol produced and sold is the equivalent lien for bioethanol sector which utilises molasses as feedstock.

Biofuel Targets

Based on the PDOE's Biofuels Road Map, the biodiesel mandate shall be maintained at B2 until 2021 amidst developmental challenges and targeted to increase to B5 by 2022, with possible implementation until 2025 to cover the medium term. From 2026 to 2040, the target biodiesel blend rate will be at B10. With continued research and development, and resource assessment, an additional 200 million litres is targeted for the long-term period depending on the availability of feedstock.

On the other hand, the bioethanol mandate shall be maintained at E10 until 2025–2030 and possibly increased to higher blends such as E15 or E20 for the period of 2031–2040, depending on feedstock supply availability. Additional capacities are foreseen until 2025 as existing bioethanol producers are undertaking progressive optimisation of production and additional feedstock supply. For the period 2030–2040, possible capacity increase may reach 450 million litres per year, derived from non-food based and second generation feedstock and technologies. While maintaining the current blend mandates at B2 and E10 as well as utilising coconut and sugarcane and/or molasses as feedstock, respectively, the PDOE along with the NBB and other stakeholders shall revisit the biofuel blend requirements and available feedstock.

Biofuel (ethanol and biodiesel) Blending Acceptance by Vehicle Manufacturer

One of the identified developmental issues encountered in the biodiesel sector is the potential impact of higher biofuels blend to current vehicle fleets (both in-use and new) in terms of suitability to existing specifications. However, based on the PDOE-implemented actual on-road testing using B5, initial results of the covered 17,000-kilometres distance showed a kilometre increase of about 10% for B5 as compared to B2.

Statistics of Biofuel (ethanol and biodiesel) Landscape

For bioethanol, the PDOE has 13 accredited local producers with a total rated production capacity of 425.5-MLPY as of June 2021, which is equivalent to about 52% of the volume requirement for the E10 mandate. While for biodiesel, PDOE has 13 accredited local producers as of June 2021, with a total rated production capacity amounting to 707.9-MLPY, about three-fold of the volume requirement for the B2 mandate. Thus, the biofuel industry situation in the Philippines shows a big gap in local ethanol supply where the deficit is filled in by importation sourced from the US, Brazil, Thailand, amongst others, while for biodiesel, there is excess capacity that are not fully utilised.

Further, total sales of local bioethanol for 2020 reached 276.74-ML or an increase of 63.87% as compared to the 2015 level. For biodiesel during the same period, local sales amounted to 160.42ML or a decrease of 20.02% in comparison to the 2015 level, as shown in Table 2.13 (PDOE, 2021). As a result of the pandemic which caused the drop in demand for gasoline and diesel, local sales for both bioethanol and biodiesel have registered a decrease of 22.17% and 26.25% from the 2019 levels, respectively.

Table 2.13: Bioethanol and Biodiesel Sales

Year	Bioethanol Sales (in million litres)	Biodiesel Sales (in million litres)
2015	168.88	200.57
2016	226.88	217.70
2017	234.61	203.53
2018	303.73	205.24
2019	355.55	217.52
2020	276.74	160.42

Source: PDOE (2021).

In terms of pricing, bioethanol producers refer to the Bioethanol Reference Price Index as circulated by the NBB, while biodiesel producers use current market price as basis in supply contract negotiations. Bioethanol price in 2015 ranging from PhP41.00–61.14/litre has slightly increased to about PhP48.00–66.00/litre as of end 2020. While biodiesel price in 2015 of around PhP43.00–72.00/litre has significantly fluctuated to about PhP 35.00–75.01/litre in 2020, as shown in Table 2.14 (PDOE, 2021), with fossil fuel price counterpart shown in Table 2.15 (PDOE, 2021).

Table 2.14: Bioethanol and Biodiesel Sales

Year	Biodiesel Price Range (PhP)	Bioethanol Price Range (PhP)
2015	43.00 – 72.00	41.00 – 61.14
2016	42.50 – 85.00	49.00 – 63.10
2017	45.00 – 95.00	40.00 – 63.00
2018	40.00 – 90.75	38.00 – 58.15
2019	35.00 – 70.00	47.98 – 65.00
2020	35.00 – 75.01	48.00 – 66.00

Source: PDOE (2021).

Table 2.15: Gasoline and Diesel Sales

Year	**Sales /Actual Consumption/Demand (in million litres)**		**Average Price (PhP)**	
	Gasoline	Diesel	Gasoline	Diesel
2015	5,221	9,336	42.23	27.54
2016	5,741	10,321	39.80	25.36
2017	6,253	10,860	45.89	32.14
2018	6,441	11,207	54.41	43.02
2019	6,973	11,534	53.11	42.44
2020	5,936	9,786	48.25	35.12

Source: PDOE (2021).

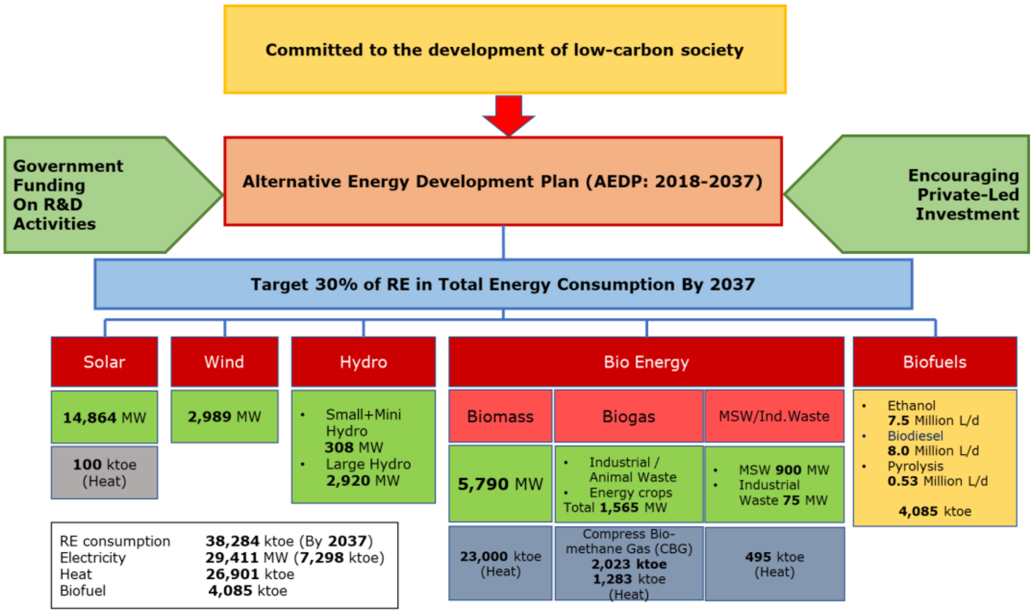
As of end 2020, the PDOE has 17 accredited oil industry participants, all of which are mandated to blend at B2 and E10 as per the Biofuels Act. Actual consumption of gasoline for 2020 reached 5,936 million litres or an increase of 13.69% as compared to the 2015 level. While for diesel during the same period, actual consumption amounted to 9,786 million litres or an increase of 4.82% as compared to the 2015 level. Due to the pandemic which heavily affected the transportation sector, demand for gasoline and diesel both registered a decrease of 14.87% and 15.16% from the 2019 levels, respectively.

As regard to average prices, gasoline was sold at around PhP42.23/litre in 2015 and has increased to PhP48.25/litre as of end 2020. While for diesel, the 2015 average price of PhP27.54/litre and has increased to about PhP35.12/litre in 2020.

E. Thailand

The first policy on renewable energy, with targets on biofuel for transportation, has dated back since 2008 under the Renewable Energy Development Plan (2008–2022), which was then revised with a name change to the Alternative Energy Development Plan (AEDP: 2012–2021). AEDP2012 was again revised as AEDP: 2015–2036 to align under the same 2015–2036 periods with other national energy plans, such as the Power Development Plan (PDP), the Energy Efficient Plan, the Gas Plan, and the Oil Plan. With recent trends in energy transition to digitalisation, where the consumer becomes the prosumer and electric vehicles have penetrated conventional vehicles, the current AEDP: 2018–2037 was launched with the same overall 30% renewable energy target in 2037 but decreasing biofuel target and increasing renewable electricity and heat targets, as shown in Figure 2.9 (DEDE, 2019).

Figure 2.9: Breakdown of Thailand Alternative Energy Development Plan



ktoe = kilotons of oil equivalent, L/d = litres per day, MW = megawatt, R&D = research and development, RE = renewable energy,

Source: AEDP (2018–2037).

The 2037 targets for bioethanol and biodiesel consumptions are 7.5 and 8.0 million litres/day, respectively, where 2019 average consumptions of bioethanol and biodiesel are 4.45 and 4.90 million litres/day, respectively (DEDE, 2019). Commercially available blends for bioethanol into gasoline are 0% (ULG), 10% (E10), 20% (E20), and 85% (E85); whereas biodiesel blends into diesel are 7% (B7), 10% (B10 or main diesel grade), and 20% (B20). Tables 2.16 and Table 2.17 show specifications for ethanol (DOEB, 2005) and their blends (DOEB, 2019a; DOEB, 2019b) with gasoline; whereas Table 2.18 and Table 2.19 show those for biodiesel (DOEB, 2019c) and their blends (DOEB, 2020) with diesel, respectively.

Table 2.16: Specifications for Ethanol Standard

No.	Items	Unit	Value		Test method
1	Ethanol plus higher saturated alcohols,	% vol.	≥	99	EN 2870 Appendix 2 Method B
2	Higher saturated (C_3-C_5) mono alcohols,	% vol.	≤	2	EN 2870 Method lll
3	Methanol,	% vol.	≤	0.5	EN 2870 Method lll
4	Solvent Washed Gum,	mg/100mL	≤	5	ASTM D 381
5	Water,	% vol.	≤	0.3	ASTM E 203
6	Inorganic chloride,	mg/L	≤	20	ASTM D 512
7	Copper	mg/kg	≤	0.07	ASTM D 1688
8	Acidity as acetic acid,	mg/L	≤	30	ASTM D 1613
9	pHe		≥	6.5	ASTM D 6423
			and		
			≤	9	
11	Electrical conductivity,	µS/m	≤	500	ASTM D 1125
11	Appearance		Clear, No separation/colloid		Visual inspection
12	Additive		Approval by Director General		

Source: DOEB (2005).

Table 2.17: Specifications for Ethanol Blends with Gasoline Standard

No.	Items for E0 (ULG)	Unit	Value		Test method
1	Octane number				
	1.1 Research octane number; RON				ASTM D 2699
	(1) Producer		≥	95	
	(2) Dealer		≥	94.6	
	1.2 Motor octane number; MON				ASTM D 2700
	(1) Producer		≥	94	
	(2) Dealer		≥	83.6	
2	Lead	g/L	≤	0.005	ASTM D 5059
3	Sulphur	% wt.	≤	0.005	ASTM D 2622
4	Phosphorus	g/L	≤	0.0013	ASTM D 3231
5	Silver strip corrosion		≤	Number 1	ASTM D 7671
6	Oxidation stability	minutes	≥	360	ASTM D 525
7	Solvent washed gum	mg/100 mL	≤	4	ASTM D 381
8	Distillation	°C			ASTM D 86
	8.1 Temperature				
	(1) 10% Evaporated		≤	70	
	(2) 50% Evaporated		≥	70	
			and		
			≤	110	
	(3) 90% Evaporated		≤	170	
	(4) End point		≤	200	
	8.2 Residue	% vol.	≤	2	
9	Vapour pressure at 37.8°C	kPa	≤	62	ASTM D 5191
10	Benzene	% vol.	≤	1	ASTM D 5580

No.	Items for E0 (ULG)	Unit	Value		Test method
11	Aromatics	% vol.	≤	35	ASTM D 5580
12	Olefins	% vol.	≤	18	ASTM D 6839
13	Colour				
	13.1 Hue			Yellow	
	13.2 Intensity		≥	0.5	ASTM D 1500
			and		
			≤	1.5	
14	Water	% wt.	≤	0.7	ASTM E 204
15	Oxygenate	% vol.	≥ and ≤	5.5	ASTM D 4815
	MTBE (Methyl tertiary butyl ether) or other oxygenates that are approved by the Department of Energy Business				
				11	
16	Appearance		Clear, No separation/colloid		Visual inspection
17	Detergent additive				
	17.1 Port fuel injector		Approval by Director General		
	17.2 Intake valve		Approval by Director General		
18	Other additives, if any		Approval by Director General		

No.	Items for E10-E20	Unit		Gasohol E10		Gasohol E20	Test method
				Octane 91	Octane 95		
1	Octane number						
	1.1 Research octane number; RON						ASTM D 2699
	(1) Producer		≥	91	95	95	
	(2) Dealer		≥	90.6	94.6	94.6	
	1.2 Motor octane number; MON						ASTM D 2700
	(1) Producer		≥	80	84	84	
	(2) Dealer		≥	79.6	83.6	83.6	
2	Lead	g/L	≤	0.005	0.005	0.005	ASTM D 5059
3	Sulphur	% wt.	≤	0.005	0.005	0.005	ASTM D 2622
4	Phosphorus	g/L	≤	0.0013	0.0013	0.0013	ASTM D 3231
5	Silver strip corrosion		≤	Number 1	Number 2	Number 3	ASTM D 7671
6	Oxidation stability	minutes	≥	360	360	360	ASTM D 525
7	Solvent washed gum	mg/100 mL	≤	4	4	4	ASTM D 381
8	Distillation	°C					ASTM D 86
	8.1 Temperature						
	(1) 10% Evaporated		≤	70	70	65	
	2) 50% Evaporated		≥	70	70	65	
			and				
			≤	110	110	110	

No.	Items for E10-E20	Unit		Gasohol E10		Gasohol E20	Test method
				Octane 91	Octane 95		
	(3) 90% Evaporated		≤	170	170	170	
	(4) End point		≤	200	200	200	
	8.2 Residue	% vol.	≤	2	2	2	
9	Vapour pressure at 37.8°C	kPa	≤	62	62	64	ASTM D 5191
10	Benzene	% vol.	≤	1	1	1	ASTM D 5580
11	Aromatics	% vol.	≤	35	35	35	ASTM D 5580
12	Olefins	% vol.	≤	18	18	18	ASTM D 6839
13	Colour						ASTM D 1500 or
	13.1 Hue			Green	Orange	Brown	ASTM D 2392
	13.2 Dye	mg/L	≥	4	10.0	20.0	
14	Water	% wt.	≤	0.7	0.7	0.7	ASTM E 203
15	Denatured ethanol	% vol.	≥	9	9	19	ASTM D 4815
			and				
			≤	10	10	20	
16	Oxygenates		Approval by Director General				ASTM D 4815
17	Appearance		Clear, No separation/colloid				Visual inspection
18	Detergent additive						
	18.1 Port fuel injector		Approval by Director General				
	18.2 Intake valve		Approval by Director General				
19	Other additives, if any		Approval by Director General				

No.	Items for E85	Unit		Gasohol E85	Test method
1	Octane number				
	1.1 Research octane number; RON				ASTM D 2699
	(1) Producer		≥	95	
	(2) Dealer		≥	94.6	
	1.2 Motor octane number; MON				ASTM D 2700
	(1) Producer		≥	95	
	(2) Dealer		≥	84.6	
2	Lead	g/L	≤	0.005	ASTM D 5059
3	Sulphur	% wt.	≤	0.005	ASTM D 2622
4	Phosphorus	g/L	≤	0.0013	ASTM D 3231
5	Silver strip corrosion		≤	Number 1	ASTM D 7671
6	Oxidation stability	minutes	≥	360	ASTM D 525
7	Solvent washed gum	mg/100 mL	≤	5	ASTM D 381
8	Distillation	°C			ASTM D 86
	8.1 End point		≤	200	
	8.2 Residue	% vol.	≤	2	
9	Vapour pressure at 37.8°C	kPa	≥	35	ASTM D 5191
			and		
			≤	70	
10	Benzene	% vol.	≤	1	ASTM D 5580
11	Aromatics	% vol.	≤	35	ASTM D 5580
12	Olefins	% vol.	≤	18	ASTM D 6839
13	Colour				ASTM D 1500
	13.1 Hue			Purple	or
	13.2 Dye		≥	20	ASTM D 2392
14	Water	% wt.	≤	0.7	ASTM E 203

No.	Items for E85	Unit		Gasohol E85	Test method
15	Denatured ethanol	% vol.	≥	75	ASTM D 5501
16	Hydrocarbon/aliphatic ether	% vol.	≥	14	[(100-(water + alcohol)]
			and		
			≤	25	
17	Methanol	% vol.	≤	0.5	ASTM D 5501
18	Higher	% vol.	≤	2	ASTM D 4815
19	Acidity calculated as acetic acid	mg/L	≤	30	ASTM D 1613
20	Inorganic chloride	mg/L	≤	1	ISO 6227
21	pHe		≥	6.5	ASTM D 6423
			and		
			≤	9	
22	Copper	mg/kg	≤	0.07	ASTM D 1688
23	Appearance		Clear, No separation/colloid		Inspection by eyes
24	Detergent additive				
	24.1 Port fuel injector		Approval by Director General		
	24.2 Intake valve		Approval by Director General		
25	Other additives, if any		Approval by Director General		

Source: DOEB (2019a, 2019b).

Table 2.18: Specifications for Biodiesel Standard

No.	Items for B100	Unit	Value		Method
1	Methyl esters	% wt	≥	96.5	EN 14103
2	Density at 15°C	kg/m^3	≥	860	ASTM D 1298
			and		
			≤	900	
3	Viscosity at 40°C	cSt	≥	3.5	ASTM D 445
			and		
			≤	5	
4	Flash point	°C	≥	120	ASTM D 93
5	Sulphur	% wt.	≤	0.001	ASTM D 2622
6	Carbon residue on 10% distillation residue	% wt.	≤	0.3	ASTM D 4530
7	Cetane number		≥	51	ASTM D 613
8	Sulphated ash	% wt.	≤	0.02	ASTM D 874
9	Sulphated ash	% wt.	≤	500	EN ISO 12937
10	Total contamination	mg/kg	≤	25	EN 12662
11	Copper strip corrosion		≤	No.1	ASTM D 130
12	Oxidation stability at 110°C	hours	≥	10	EN 15751
13	Acid value	mg KOH/g	≤	0.5	ASTM D 664
14	Iodine value	g Iodine/100g	≤	120	EN 14111
15	Linolenic acid methyl ester	% wt.	≤	12	EN 14103
16	Methanol	% wt.	≤	0.2	EN 14110
17	Monoglyceride	% wt.	≤	0.4	EN 14105
18	Diglyceride	% wt.	≤	0.2	EN 14105
19	Triglyceride	% wt.	≤	0.2	EN 14105
20	Free glycerine	% wt.	≤	0.02	EN 14105

No.	Items for B100	Unit	Value		Method
21	Total glycerine	% wt.	≤	0.25	EN 14105
22	Group I metals; Na + K	mg/kg	≤	5	EN 14538
	Group II metals; Ca + Mg	mg/kg		5	EN 14538
23	Phosphorus	% wt.	≤	0.001	EN 14107
24	Cloud point	°C	report		
25	Cloud flow plugging point	°C	report		
26	Additives, if any		Approval by Director General		

Source: DOEB (2019c).

Table 2.19: Specifications for Biodiesel-blended Diesel Standard

No.	Items	Unit		Diesel				Method
				High speed			Low	
				Normal	B7	B20	speed	
1	Specific gravity at 15.6/15.6	°C	≥	0.81	0.81	0.81	-	ASTM D1298
			and					
			≤	0.87	0.87	0.87	0.92	
2	Cetane number		≥	50	50	50	0.92	ASTM D613
	or Calculated cetane index							ASTM D976
3	Viscosity	cSt						
	3.1 at 40°C		≥	1.8	1.8	1.8	-	
			and					
			≤	4.1	4.1	4.1	8	
	3.2 at 50°C		≤	-	-	-	7	
4	Pour point	°C	≤	10	10	10	16	ASTM D97
5	Sulphur							ASTM D2622

No.	Items	Unit		Diesel				Method
				High speed			Low speed	
				Normal	B7	B20		
	Before 1 Jan 2024	mg/kg	≤	50	50	50	-	
		% wt	≤	-	-	-	1.5	
	From 1 Jan 2024 onwards	mg/kg	≤	10	10	10	-	
		% wt	≤	-	-	-	1.5	
6	Copper strip corrosion		≤	No.1	No.1	No.1	-	ASTM D 130
7	Oxidation stability	g/m^3	≤	25	25	25	-	ASTM D2274
		hours	≤	35	35	35	-	EN 15751
8	Carbon residue on 10% distillation	% wt	≤	0.3	0.3	0.3	-	ASTM D4530
9	Water and sediment	% vol.	≤	-	-	-	0.3	ASTM D2709
10	Water	% vol.	≤	200	300	300	-	EN ISO 12937

No.	Items	Unit		Diesel				Method
				High speed			Low speed	
				Normal	B7	B20		
11	Total contamination	mg/kg	≤	24	24	24	-	EN 12662
12	Ash	% wt.	≤	0.01	0.01	0.01	0.02	ASTM D 482
13	Flash point	°C	≤	52	52	52	52	ASTM D 93
14	Distillation	°C						ASTM D 86
	90% Recovered	°C	≤	35.7	35.7	35.7	-	
15	Polycyclic aromatic hydrocarbon	% wt.						
	Before 1 Jan 2021		≤	11	11	11	-	
	From 1 Jan 2021 onwards		≤	8	8	8	-	

No.	Items	Unit		Diesel				Method
				High speed			Low speed	
				Normal	B7	B20		
16	Colour							
	16.1 Hue			Purple	Yellow	Red	Brown	ASTM D1500 ASTM D2392
	16.2 Intensity		≥	equivalent standard color	-	equivalent standard color	4.5	
			and					
			≤		4		7.5	
17	Methyl ester of fatty acids	% vol.	≥	9	6.6	19	-	EN 14078
			and					
			≤	10	7	20	-	
18	Lubricity wear scar	micrometer	≤	460	460	460	-	CEC F-06-96
19	Additive, if any			Approval by Director General				

Source: DOEB (2020).

As biofuels (both bioethanol and biodiesel) are often more expensive than fossil fuel, the Thai Ministry of Energy has a cross-subsidy mechanism though the Oil Fund, which is levied from non and/or low-biofuel blend to subsidise high-biofuel blend, without interfering with the national budget. Another fund, the Energy Conservation Fund, collects all commercial fuel grades for usage in research and development to promote renewable energy. The levies and subsidies are periodically adjusted by the Committee on Energy Policy Administration chaired by the Minister of Energy to ensure that the Oil Fund is stable enough for future subsidy of biofuel. As shown in Table 2.20 (EPPO, 2021), the price structure of various fuels is composed of ex-refinery price (Ex-Refin) as a starting point with excise tax and municipal tax levied on the fossil portion only prior to Oil Fund and Energy Conservation Fund levied before the wholesale price can be determined. A marketing margin is allowable ceiling for fuel retailers.

Table 2.20: Price Structure of Petroleum Products in Bangkok (28 June 2021)

Unit: baht/litre	Ex-Refinery (Average)	Tax baht/Litre	Municipal Tax baht/litre	Oil Fund	Energy Conservation Fund	Wholesale Price	VAT	WS & VAT	Marketing Margin	VAT	Retail
ULG	17.1621	6.5000	0.6500	6.5800	0.1000	30.9921	2.1694	33.1615	3.0827	0.2158	36.46
GASOHOL95 E10	17.8204	5.8500	0.5850	0.6200	0.1000	24.9754	1.7483	26.7236	2.1742	0.1522	29.05
GASOHOL91	17.4255	5.8500	0.5850	0.6200	0.1000	24.5805	1.7206	26.3011	2.3167	0.1622	28.78
GASOHOL95 E20	18.3502	5.2000	0.5200	-2.2800	0.1000	21.8902	1.5323	23.4225	3.8481	0.2694	27.54
GASOHOL95 E85	23.5283	0.9750	0.0975	-7.1300	0.1000	17.5708	1.2300	18.8008	3.5413	0.2479	22.59
H-DIESEL B7	17.3927	5.9900	0.5990	1.0000	0.1000	25.0817	1.7557	26.8374	2.0118	0.1408	28.99
H-DIESEL	17.8315	5.8000	0.5800	-2.5000	0.1000	21.8115	1.5268	23.3383	2.4783	0.1735	25.99
H-DIESEL B20	19.6599	5.1530	0.5153	-4.1600	0.1000	21.2682	1.4888	22.7570	2.7879	0.1952	25.74

Exchange Rate	=	31.9591	Baht/$
Ethanol Reference Price	=	25.84	Baht/Litre
Biodiesel (B100) Reference Price	=	34.47	Baht/Litre

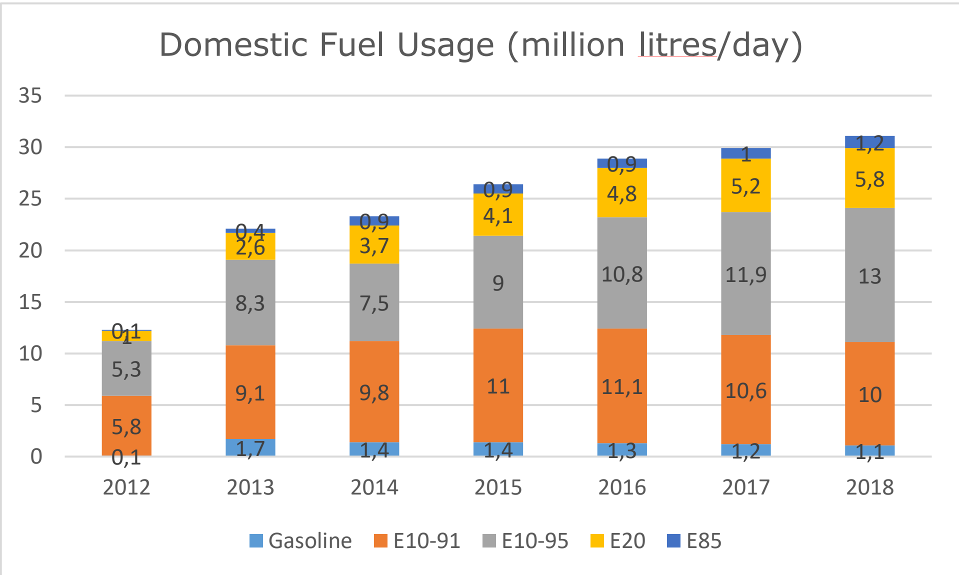
ULG = unleaded gasoline, VAT = value added tax, WS = wholesale.
Source: EPPO (2021).

As shown in Figure 2.9, 2037 targets for bioethanol and biodiesel consumption are 7.5 and 8.0 million litres/day, respectively, where approximately 60% of targets were achieved in 2019 from the average consumption of bioethanol and biodiesel of 4.45 and 4.90 million litres/day, respectively (DEDE, 2019). There are no official periodic targets along the way to 2037.

As for biofuel blending acceptance by vehicle manufacturers, most gasoline vehicles accept E10 with those models after 2008 compatible with E20 due to government incentives to reduce 5% excise tax for E20-compatible vehicles; whereas pure gasoline (ULG or E0) is commercially available for old vehicles that cannot accept ethanol blending. As for biodiesel blending, mandatory blending was enforced since May 2011, so vehicles have been compatible with blending of biodiesel. The blending level was increased to 7% in January 2014 and optional B20 launched in July 2018, followed by optional B10 in May 2019. Since October 2020, the main diesel grade is B10 with optional B7 and B20 available. Official diesel vehicle acceptance for B10 and B20 is shown with biodiesel-blended diesel standard (DOEB, 2020).

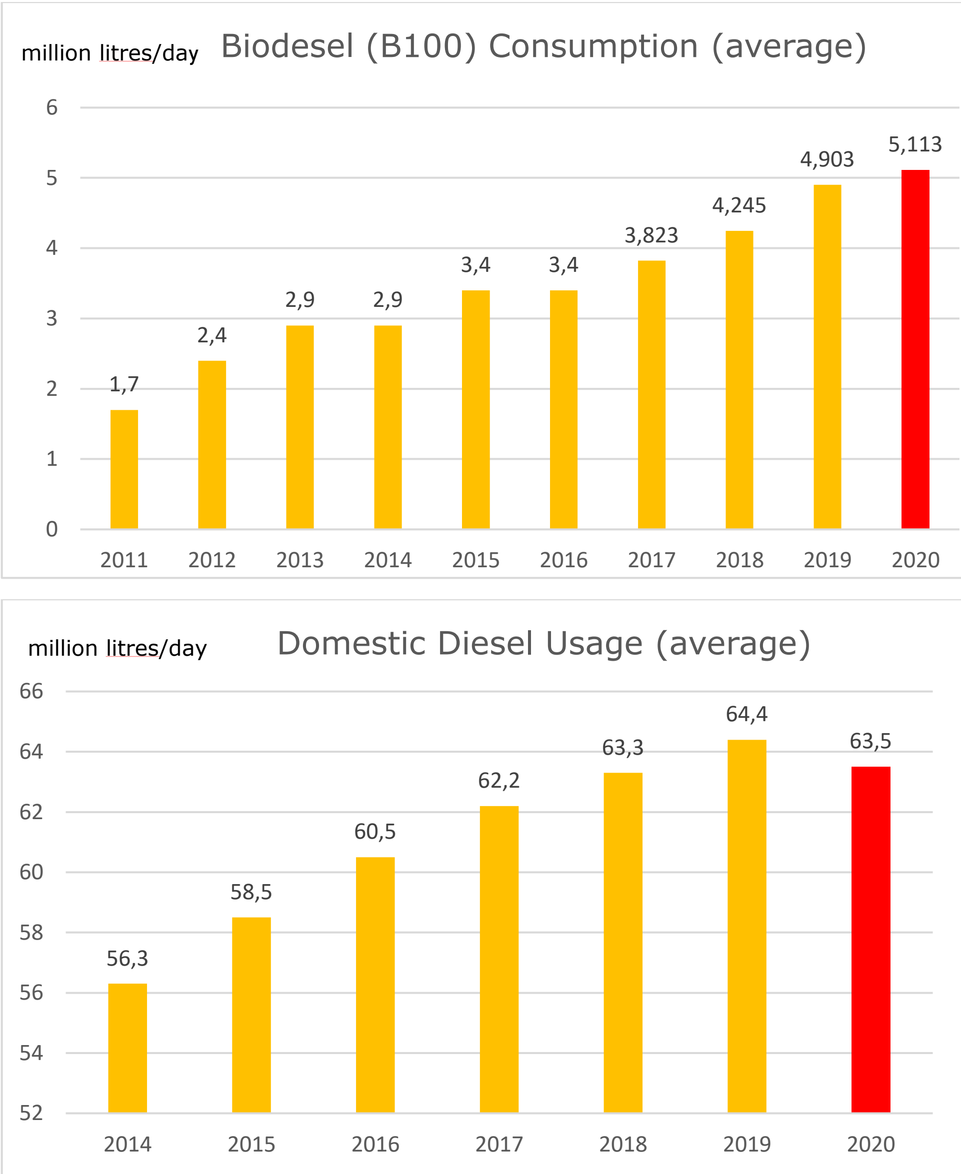
As for biofuel statistics, Figure 2.10 shows consumption of ethanol and various grades of ethanol-blended gasoline (DOEB, 2021); whereas Figure 2.11 shows consumption of diesel and various grades of biodiesel-blended diesel (DOEB, 2021).

Figure 2.10: Consumption of Ethanol and Various Grades of Ethanol-blended Gasoline



Source: DOEB (2021).

Figure 2.11: Consumption of Biodiesel and Various Grades of Biodiesel-blended Diesel

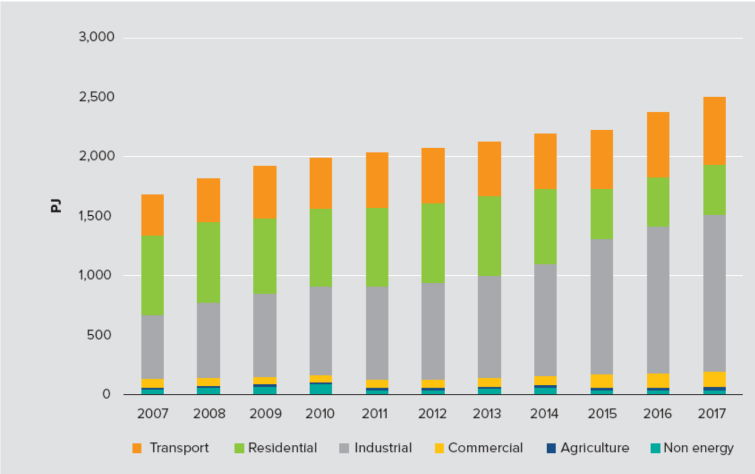


Source: DOEB (2021).

F.Viet Nam

Viet Nam is a country with a population of 96.48 million in 2019 and an area of 331,236 square kilometres (General Statistics Office of Vietnam, 2019). For decades Viet Nam has been one of the fastest growing economies in the region and in the world. From 2011 to 2019, the average gross domestic product (GDP) growth was 6.3% per annum, reaching 7.0% in 2019 (World Bank, 2021). In 2020, despite COVID-19, Viet Nam's economy has remained resilient, expanding by 2.9% in 2020—one of the highest growth rates in the world (IMF, 2021). The economic growth resulted in an increase in energy consumption. During 2007–2017, the total final energy consumption increased from 1,691 petajoules in 2007 to 2,500 petajoules in 2017, with a growth rate of 4.0% per annum (EREA and DEA, 2019). As shown in Figure 2.12, the industrial sector shows the largest average annual growth during the period (9.3%), followed by the commercial and transport sectors with 6.4% and 5.2% per annum, respectively.

Figure 2.12: Trends for Total Final Energy Consumption, 2007–2017



PJ = petajoule.
Source: EREA and DEA (2019).

Economic development has been the key to improvements in the quality of life and has resulted in a dramatic drop in the poverty rate. While economic growth is high priority for the government, government strategies emphasise that the fast development needs to uphold sustainability at the same time.

The Government of Viet Nam has several key policies for sustainable energy development with four main pillars: energy efficiency, renewable energy, energy market, and climate change. The current main policy targets for renewable energy, energy efficiency, and greenhouse gas emissions are listed in Table 2.21 (EREA and DEA, 2019).

Table 2.21: Specific Targets in Current Energy and Climate Policy, Viet Nam

Target	2020	2025	2030	2050
Renewable energy				
RE share in primary energy supply	31%		32%	44%
RE share in total electricity generation	38%* 4% excl. hydro		32%* 15% excl. hydro	43%* 33% excl. hydro
Energy efficiency as compared to business-as-usual				
Final energy demand saving		5-7%	8-10%	
GHG emissions reduction as compared to business-as-usual				
Green growth strategy	10–20%		20-30%	
Intended Nationally Determined Contributions			8% (unconditional) 25% (conditional)	
Energy sector	5%		25%	45%

* Including small and large hydro power, wind power, solar power, biomass, biogas, and geothermal energy.
GHG = greenhouse gas, RE = renewable energy.
Source: EREA and DEA (2019).

Viet Nam, assisted by the World Bank, published its renewable energy action plan in 2002, which aimed to develop renewable energy that included renewable energy policy and institutional development and other technical and business support from government and international assistance (World Bank, 2002).

With the domestic potential of biomass feedstock and renewable energy sources, in 2007 the government approved the Decision 1855/QD-TTg on National Energy Development Strategy to 2020, with a vision to 2050. This strategy plans to develop new and renewable energies and set the target for new and renewable energy shares to 5% of primary commercial energy in 2020, and 11% by 2050, respectively.

For biofuel development and utilisation, in 2007 the government issued Decision 177/2007/QD-TTg approving the scheme on development of biofuels up to 2015, with a vision to 2025 that aims to promote biofuel for use as an alternative to partially replace conventional fossil fuels, contributing to assuring energy security and environmental protection. The main tasks of the scheme comprise:

· Conducting scientific research and technological development, deploying trial production of products to serve biofuel development.

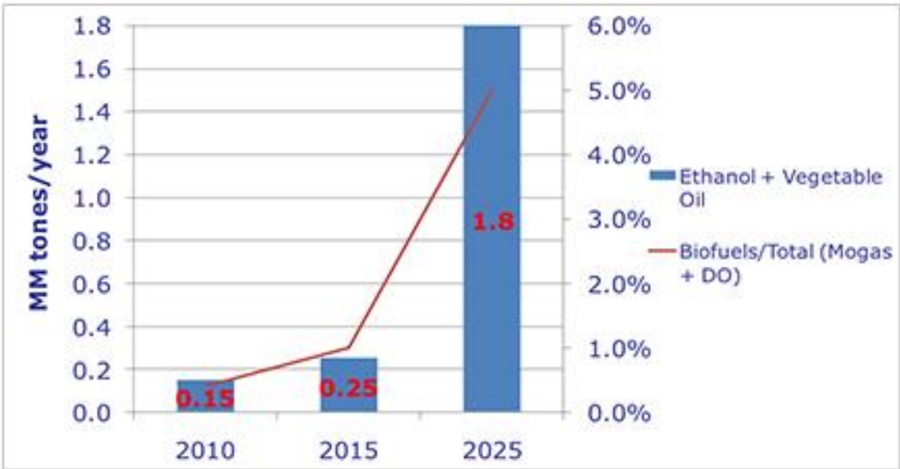
· Founding and developing the biofuel production industry

· Building biofuel development potential

· International cooperation in research and development, technology transfer, and application for biofuel production and utilisation

The scheme states that 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, as shown in Figure 2.13. The Ministry of Industry and Trade, in coordination with concerned ministries, is responsible for the development and implementation of the government's policy for biofuels, while the Ministry of Planning and Investment and the Ministry of Finance are responsible for policies on tax and investment incentives.

Figure 2.13: Expected Ethanol and Vegetable Oil Production According to Decision 177/2007/QD-TTg



MM = metric million.
Source: The Prime Minister of Vietnam (2007).

To boost the consumption of biofuel, especially bioethanol, Decision 53/2012/QD-TTg on the road map for application of ratios for blending biofuels with traditional fuels was issued in 2012. This decision laid out a road map to commercialise 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 E10 commercialisation in the above seven cities beginning in December 2016, and nationwide from December 2017.

In 2015, the government issued Directive No. 23/CT-TTg on enhancement of the use, blending, and distribution of ethanol-gasoline blends in order to implement Decision 53/2012/QD-TTg. It is noted that biodiesel has not been mentioned in the decision due to it still not being commercially available on the market. In order to encourage the use of E5 (and E10 in the future), according to Law No. 70/2014/QH13 issued in 2014 amending and supplementing the Law on Special Consumption Tax (SCT), the SCT for E5 is 8% and E10 is 7%, while the SCT for gasoline is 10%. Also, the Environment Protection Tax on E5 is 5% lower than that for gasoline. Moreover, to protect domestic ethanol production, the tax imposed on imported ethanol was high at 20% in 2014, but has been reduced to 15% since October 2020 based on Decree 57/2020/ND-CP. Table 2.22 shows various taxes on ethanol and gasoline.

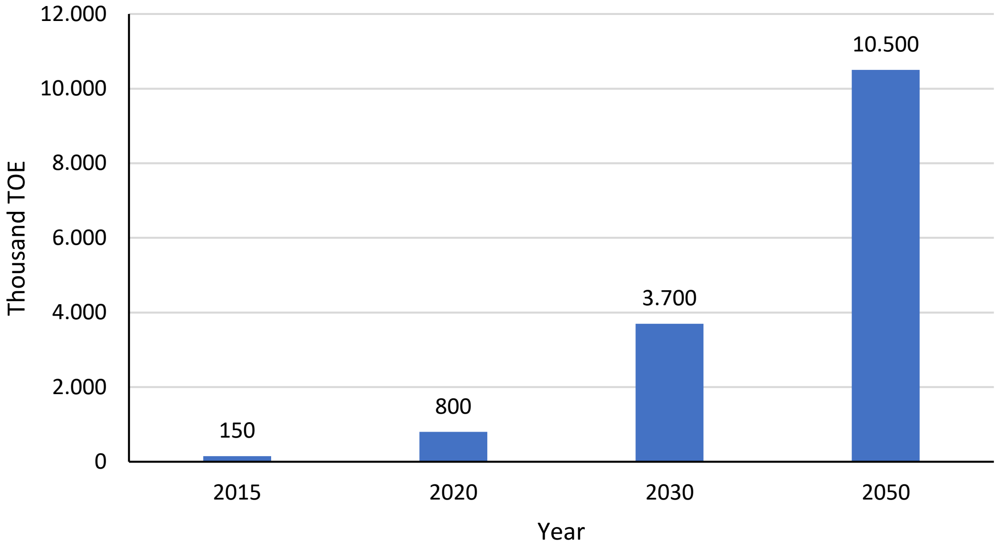
Table 2.22: Current Taxes on Ethanol and Gasoline

Tax	**E5 RON92**			**Gasoline RON95**
		Ethanol	**Gasoline RON92**	
Import tax	Most Favoured Nation (MFN)	15%	20%	20%
	Vietnam–Korea Free Trade Agreement (VKFTA)	0%	10%	10%
	ASEAN Trade in Goods Agreement (ATIGA)	0%	20%	20%
Value Added Tax (VAT)	10%			10%
Special Consumption Tax (SCT)	8%			10%
Environmental Protection Tax (EPT)	D3,800/litre			D4,000/litre

Source: USDA (2020).

In 2015 the government also issued Decision No. 2068/QĐ-TTg, a further plan – the Viet Nam's Renewable Energy Development Strategy up to 2030 with an outlook to 2050. As part of this strategy biofuels are expected to be produced 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, as shown in Figure 2.14.

Figure 2.14: Expected Biofuel Production According to Decision No. 2068/QĐ-TTg



TOE = tons of oil equivalent.
Source: Decision of The Prime Minister of Vietnam (2015). About Development Strategy of Renewable Energy of Vietnam by 2030 with a Vision to 2050. https://policy.asiapacificenergy.org/node/3447

In order to control and monitor biofuel quality, the government has issued and implemented several national standards and national regulation technical regulations on ethanol, biodiesel, and their blends with fossil fuel:

・TCVN 7716:2011 – Denatured fuel ethanol for blending with gasolines for use as automotive spark-ignition engine fuel – specification and test methods

・TCVN 7717:2007 – Biodiesel fuel blend stock (B100) – specification

・TCVN 10625:2014 – Undenatured fuel ethanol for blending with gasolines for use as automotive spark-ignition engine fuel – specification and test methods

・TCVN 8063:2015 – 5% ethanol unleaded gasoline blends – specification and test methods

・TCVN 8064:2015 – 5% fatty acid methyl esters blended diesel fuel oils –specification and test method

・TCVN 8401:2015 – 10% ethanol unleaded gasoline blends – specification and test methods

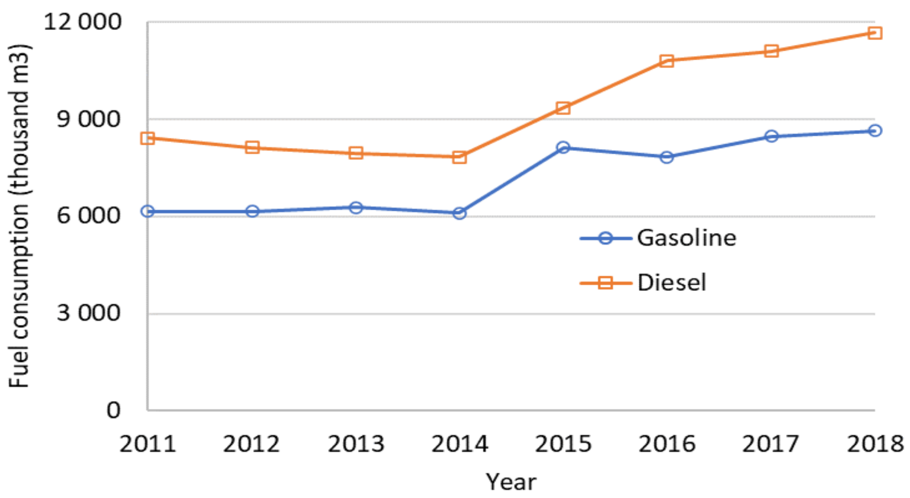
・QCVN 01:2015/BKHCN and amending 1:2017 QCVN 01:2015/BKHCN – National technical regulation on gasolines, diesel fuel oils, and biofuels

・QCVN 02: 2014/BCT – National technical regulation on equipment, auxiliaries for storing and dispensing ethanol blended gasoline – gasohol E10 at filling station

The government also issued Decision No.49/2011/QD-TTg providing a road map for the application of exhaust emissions standards to manufactured, assembled, and imported new cars and motorbikes. According to this road map, newly manufactured, assembled, and imported cars shall meet Euro 4 norms from 1 January 2017, then Euro 5 norms from 1 January 2022 onwards. Newly manufactured, assembled, and imported motorbikes shall meet Euro 3 norms from 1 January 2017 onwards to be eligible for registration in Viet Nam. To meet the requirement of the road map for vehicle emissions standards, the national fuel standards and regulations have been updated and supplemented.

The economic growth leads to the growth in fuel consumption. In recent years, Viet Nam has consumed about 20 million cubic metres (m^3) of gasoline and diesel fuels annually in which gasoline contributes to about 42% of the total, as shown in Figure 2.15 (EIA, 2021).

Figure 2.15: Fuel Consumption in Viet Nam, 2011–2018



m^3 = cubic metre.
Source: EIA (2021).

Concerning biofuel, in Viet Nam the main feedstock for ethanol production is cassava. The cassava growing area nationwide is about 550,000 hectares (ha), the average yield in 2016 is about 20 tons/ha, with many regions having achieved high yields of over 50 tons/ha.

Cassava production reached 10.7 million tons in 2015, 10.1 million tons in 2019 and the target is 16.5 million tons in 2030 for starch processing, export, and biofuel production serving food needs (domestic and export) as well as feedstock for ethanol production (General Statistics Office of Vietnam, 2019; Vietnam Economic News, 2017).

In order to provide sufficient ethanol for E5 and E10 blending that should follow the road map, Viet Nam has built seven ethanol plants as listed in Table 2.23 (General Statistics Office of Vietnam, 2019), with a total design capacity of about 600,000 m^3 per year. However, five plants have halted production due to inefficiencies and financial losses.

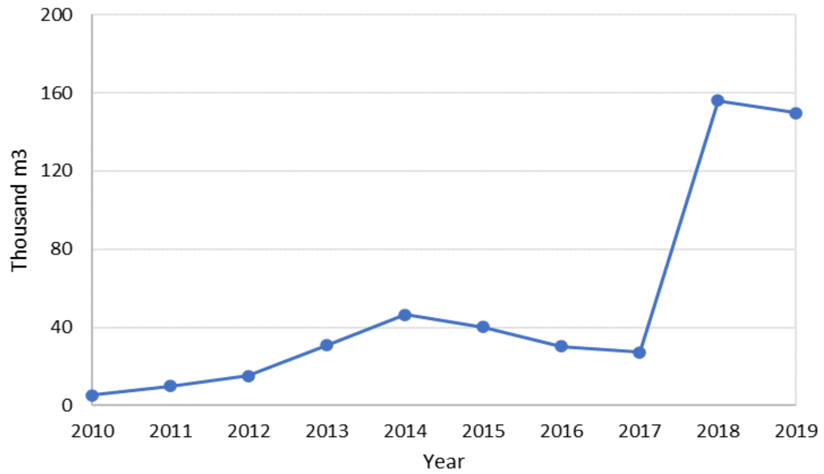
Table 2.23: Ethanol Plants in Viet Nam

No.	**Name of Plant**	**Province**	**Capacity ($1,000m^3/y$)**	**Status**
1	Tam Nong Bioethanol plant	Phu Tho	100	In construction
2	Dai Tan Bioethanol plant	Quang Nam	120	In operation
3	Dung Quat Bioethanol plant	Quang Ngai	100	Not in operation
4	Binh Phuoc Bioethanol plant	Binh Phuoc	100	Not in operation
5	Dak To Bioethanol	Kon Tum	65	Not in operation
6	Dai Viet Bioethanol plant	Dak Nong	60	Not in operation
7	Tung Lam Co.	Dong Nai	75	In operation

m^3 = cubic metre.
Source: General Statistics Office of Vietnam (2019).

Even though the road map for application of ethanol-gasoline blends was issued and there are several policies to promote the utilisation of the blends, in some localities, customers still ignored E5 fuel, due to weak dissemination on the new energy, the lack of retail stations, and difficult production and distribution. Actually, it was not until January 2018 that gasoline research octane number (RON)92 was banned, and only E5 RON92 and gasoline RON95 have been produced and available for purchase so far, following Notification No. 255/TB-VPCP issued by the government in 2017. Ethanol production, therefore, increased significantly in 2018, as shown in Figure 2.16 (Adapted from World Data Atlas, 2019).

Figure 2.16: Ethanol Production in Viet Nam

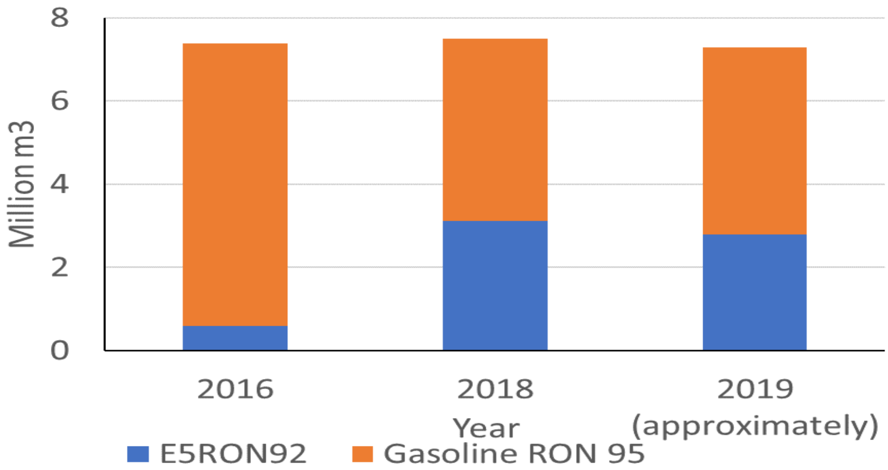


Source: Adapted from World Data Atlas (2019).

In 2016, total gasoline consumption in Viet Nam reached about 7.4 million m^3, of which, E5 RON92 was about 0.590 million m^3, accounting for 8% of the total amount of gasoline consumed in the market; and gasoline was about 6.81 million m^3, accounting for about 92%. In the composition of gasoline, gasoline RON95 accounted for about 2.043 million m^3, equivalent to 30% of the total amount of gasoline, and gasoline RON92 accounted for about 4.767 million m^3, equivalent to 70% of the total amount of gasoline. Total ethanol fuel consumed in 2016 was about 29 500 m^3 (MOIT, 2017).

When gasoline RON92 was banned in 2018, E5 RON92 consumption increased up to 3.12 million m^3, accounting for 42% of total gasoline consumption. In 2019, however, E5 consumption tended to decrease slightly, accounting for approximately 38% of total gasoline consumption, and in 2020 it still decreased, leading to a low demand for bioethanol, as shown in Figure 2.17 (Vietnamnet, 2019).

Figure 2.17: Share of E5 Fuel in Total Gasoline Consumption



M^3 = cubic metre, RON = research octane number.
Source: Vietnamnet (2019).

The decline in sales of E5 RON92 was attributed to a narrow gap between conventional gasoline and E5 prices, making E5 less attractive to price sensitive consumers. Currently, the E5 RON 92 and RON95-III price gap is D1,110 ($0.049) per litre as shown in Table 2.24, which is not sufficient to shift consumers' buying patterns (Petrolimex, 2021).

Table 2.24: Fuel Prices

Fuel	Price in D/litre	Price in US$/litre*
Gasoline RON95-IV	19,630	0.859
Gasoline RON95-III	19,530	0.855
E5 RON92	18,420	0.806
Diesel 0.001S	15,790	0.691
Diesel 0.05S	15,444	0.676

Note: *exchange rate Vietcombank at 8 am, 15 June 2021: US$1 = D 22,850.
D = Vietnamese dong; US$ = United States dollar; RON = research octane number.
Source: Petrolimex (2021).

Another reason is that consumers still have concerns about the quality of E5. Regardless of the government efforts to educate consumers on the environmental benefits and that E5 is not harmful to vehicle engines, changing consumer consumption habits remains a challenge.

Not aligned with bioethanol, the implementation for biodiesel still faces difficulties, that mainly come from the shortage of feedstock. Biodiesel is produced from vegetable oil and animal fat, while their production is still low they are often prioritised for food rather than for biodiesel production. There was a scheme on the research, development, and utilisation of Jatropha curcas (a species of flowering plant) in Viet Nam in 2008 to 2015, with a vision to 2025. However, this scheme had an unexpected result and just stayed in the research phase. As a consequence, so far in Viet Nam, biodiesel has been produced on a pilot scale, not on a commercial scale.

3.Evaluation of Well-to-Wheel CO_2 Reduction

This section focuses on the primary potential benefit for biofuel in term of CO_2 reduction for further discussion on sustainability in Chapter 3.

A. India

Environmental Impacts of Usage of Ethanol

The use of ethanol-blended gasoline decreases GHG emissions. A summary of emissions benefits with E10 and E20 fuels compared to neat gasoline are presented in Table 2.25.

Table 2.25: 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 (2021).

Higher reductions in CO_2 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 they 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 a 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, 2021).

B. Malaysia

Palm biodiesel is a green and sustainable alternative fuel for petroleum diesel. Although the Malaysian fuel mix in the automotive sector is dominated by gasoline, the use of diesel has an image of trucks spewing out black smoke from their exhausts. Further advances in diesel exhaust aftertreatment systems have reduced the polluting emissions in most diesel vehicles. The addition of biodiesel into diesel can also reduce the polluting factor from older models of diesel vehicles that do not have up to date exhaust aftertreatment systems.

The GHG emissions computation in Table 2.26 (Choo et al., 2011; Mortimer, 2010) is based on refined vegetable oils. Generally, the GHG emissions for the production of biodiesel from vegetable oils (palm, rapeseed, and soybean) using the transesterification process are similar as it uses the same amount of energy and chemicals.

Table 2.26: GHG Emissions

GHG Emissions	**Refined Palm Oil**	**Refined Rapeseed Oil**	**Refined Soybean Oil**
Ton CO_2eq/ton oil	1.11 (without biogas capture) 0.63 (with biogas capture)	1.35	1.70

GHG = greenhouse gas.
Sources: Choo et al. (2011); Mortimer (2010).

The GHG emissions data for refined palm oil was published in 2011 using attributional life cycle analysis (LCA) methodology. The summary of the data on GHG emissions of the entire palm oil supply chain (from fresh fruit bunch to palm biodiesel) are shown in Table 2.27 (Choo et al., 2011; Mortimer, 2010).

Table 2.27: Summary of the Data on GHG Emissions of Palm Oil Supply Chain

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

g = gram, GHG = greenhouse gas, kg = kilogram, MJ = megajoule.
Sources: Choo et al. (2011); Mortimer (2010).

By comparing the GHG emissions from utilising one megajoule (MJ) of fossil diesel in the transport sector with the GHG emissions from utilising one MJ of palm biodiesel, the emissions savings potential is shown in Table 2.28 (ISCC, 2016). The higher palm biodiesel blending of as much as 30% can provide 18% more emissions savings when used in automotive diesel applications.

Table 2.28: Comparison of GHG Emissions from Diesel and Palm Biodiesel

	GHG Emissions (g CO_2 equivalent)	
	Without biogas capture	**With biogas capture at 85% efficiency**
One MJ of palm biodiesel	33.19	21.20
One MJ of fossil diesel	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

g = gram, GHG = greenhouse gas, MJ = megajoule.
Source: ISCC (2016).

C. Philippines

Fuel information was gathered from the PNS, PDOE's Energy Research and Testing Laboratory Services and 2019 Energy Balance Table. For gasoline, density is set at 0.783 kg/litre at a maximum temperature of 15°C, while its heating value is estimated at 19,000 British thermal unit per pound (Btu/lb) and well-to-tank was computed at around 13.59 metric tons of CO_2 equivalent ($MTCO_2e$) (University of the Philippines Los Baños, 2019; Watabe, 2011). In the case of diesel, density is set at 0.82–0.86 kg/litre at a maximum temperature of 15°C, with an estimated heating value of 19,500 Btu/lb and well-to-tank data of about 19.31 $MTCO_2e$. Also based on the existing quality standards, density of bioethanol and biodiesel are required to be 0.7915 kg/litre and 0.86-0.90 kg/litre at a maximum temperature of 20°C, respectively.

D. Thailand

Regarding well-to-wheel CO_2 emissions, the Thai government uses national life cycle inventory data from survey for well-to-tank portion while referring to Intergovernmental Panel on Climate Change (IPCC) Tier 2 default emissions factor (MTEC, 2021) (Table 2.29 and Table 2.30).

Table 2.29: Well-to-Tank Greenhouse Gas Emissions for Ethanol in Thailand

Fuel Type	**Supply Fraction (%)**	**WTT GHG Emissions Factor ($kgCO_{2,eq}$/GJ)**	**Notes**
Ethanol from molasses	67.46	18.1920	Silalertruksa, 2015
Ethanol from sugarcane juice	5.09	30.1474	Garcia et al., 2011
Ethanol from cassava	27.45	65.3046	Papong and Malakul, 2010
Average ethanol		31.7315	
E0 (pure gasoline)		13.7262	
E10 with E100 for Thai ethanol mix		14.9927	
E20 with E100 for Thai ethanol mix		16.3456	
E85 with E100 for Thai ethanol mix		28.0259	

GHG = greenhouse gas, GJ = gigajoule, kg = kilogram, WTT = well-to-tank.
Source: MTEC (2021).

Table 2.30: Well-to-Tank Greenhouse Gas Emissions for Biodiesel in Thailand

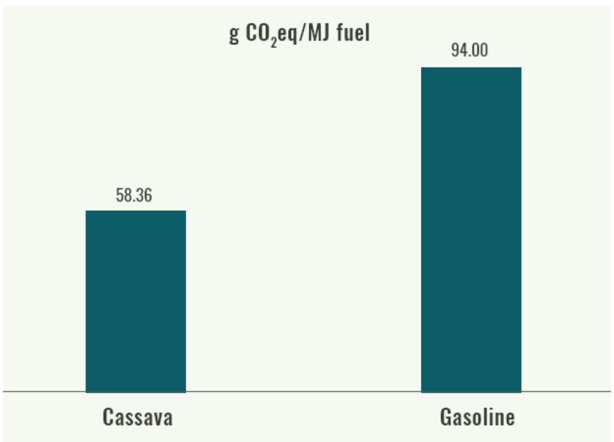
Fuel Type	GHG Emissions (kg $CO_{2,\,eq}$/GJ)	Notes
Biodiesel from palm	53.5748	MTEC, 2021
B0 (pure diesel)	7.4382	
B7 with B100 from FAME	10.2939	
B10 with B100 from FAME	11.5325	
B20 with B100 from FAME	15.7295	

FAME = Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles, GHG = greenhouse gas, GJ = gigajoule, kg = kilogram.
Source: MTEC (2021).

E. Viet Nam

According to the report of the Food and Agriculture Organization of the United Nations (FAO, 2018) for cassava-based ethanol production, the stages of the value chain included in the LCA were feedstock production, transformation, and delivery to the ethanol plant; biomass processing into biofuels; and biofuel transportation, storage and distribution. The amount of CO_2 equivalent from all steps of cassava-based ethanol production in Viet Nam was evaluated and compared with those of gasoline, as shown in Figure 2.18 (FAO, 2018). It shows that ethanol production and use (for transportation) result in average total GHG emissions of 58.36 gCO_2eq/MJ of product, which is a 37%–39% (depending on where cassava is cultivated) GHG emissions saving in comparison to gasoline.

Figure 2.18: Comparison of Total CO_2 Equivalent between Cassava-based Ethanol and Gasoline



G = gram, MJ = megajoule.
Source: FAO (2018).

For biodiesel, a study shows that Jatropha-based biodiesel production and use based on the conditions in Viet Nam result in 12.3 gCO_2eq/MJ that can be reduced by 86.56% compared to fossil diesel (Khang, 2019). In calculation CO_2 emissions of gasoline and diesel use on stationary and mobile sources, the emissions factors can be referred to the IPCC Guidelines (IPCC, 2006).

4. Discussion

As seen from the rich content and journey of biofuel policies and implementation schemes in the selected EAS countries of India, Indonesia, Malaysia, Philippines, Thailand, and Viet Nam, each country has its own unique approach and target. For instance, India has focused more on bioethanol than biodiesel due to its large sugarcane industry, even with second generation cellulosic ethanol under the PM-JIVAN scheme. While 10% bioethanol blend (E10) is sold by various retailers, only 50% of gasoline sold in the market is E10. For Indonesia and Malaysia, biodiesel is more focused than bioethanol due to the large oil palm industry with higher blending ratio (B30) in Indonesia. Effective biodiesel promotion mechanism in Indonesia comes from the Palm Plantation Fund, which is collected from fees and export levies from palm oil plantation products or derivatives for biodiesel subsidy to gain market price attractiveness. For Malaysia, the effective role of the Ministry of Plantation Industries & Commodities (MPIC), together with the Malaysian Palm Oil Board (MPOB), has served as a framework for biodiesel industry development in Malaysia. For the Philippines, both bioethanol and biodiesel are being mandated as E10 and B2 by the Philippine Department of Energy (PDOE) with unique feedstock for biodiesel from coconut. For Thailand, both bioethanol and biodiesel are being promoted as commercial fuels with various blends (E10, E20, E85 and B7, B10, B20) under the cross-subsidy schemes levied from less biofuel blending to subsidising high blending ratios so that retail prices of higher biofuel blending are more attractive. For Viet Nam, bioethanol is more focused with nation-wide blending and especially the ban of RON92 gasoline (but RON95 gasoline still available) in 2018, which significantly boosted bioethanol consumption.

In addition, multiple benefits of biofuel implementation not only lie in reduced fossil fuel imports and reduced tank-to-wheel CO_2 emissions, but also value added and demand creation for agriculture products. However, these biofuel policies and implementation schemes must be carefully pursued within the context of sustainability, especially during the transition towards electric mobility in the future.

References

APROBI (2021), Tok! Biodiesel Domestik Dipatok 9,2 Juta KL di 2021. https://aprobi.or.id/2020/12/28/tok-biodiesel-domestik-dipatok-92-juta-kl-di-2021/ (in Bahasa Indonesian)

Biofuels International (2021), 'India Blends Record Levels of Ethanol in First Four Months of 2021', 6 April. https://biofuels-news.com/news/india-blends-record-levels-of-ethanol-in-first-four-months-of-2021/

BPS (2018), Distribusi Perdagangan Komoditas Badan Pusat Statistik Minyak Goreng Indonesia Tahun 2018. (in Bahasa Indonesia)

Choo, Y.M., H. Muhamad, Z. Hashim, V. Subramaniam, C.W. Puah, and Y.A. Tan (2011), 'Determination of GHG Contribution by Subsystems in the Oil Palm Supply Chain using the LCA Approach', *International Journal of Life Cycle Assessment.* DOI10.1007/s11367-011-0303-9

Decision of The Prime Minister of Vietnam (2015). About Development Strategy of Renewable Energy of Vietnam by 2030 with a Vision to 2050. https://policy.asiapacificenergy.org/node/3447

Department of Alternative Energy Development and Efficiency (DEDE) (2019), *Thailand Alternative Energy Situation 2019.* Bangkok, DEDE. https://www.dede.go.th/download/stat63/Thailand_Alternative_Energy_Situation_2019.pdf

Department of Energy Business (DOEB) (2005), Denature Ethanol Fuel Specification. http://elaw.doeb.go.th/document_doeb/85_0001.pdf

DOEB (2019a), Gasoline Fuel Specification. http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/087/T_0021.PDF, http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/314/T_0011.PDF

DOEB (2019b), Ethanol-blended Gasoline Fuel Specification. http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/087/T_0025.PDF, http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/314/T_0013.PDF

DOEB (2019c), Biodiesel Fuel Specification. http://www.ratchakitcha.soc.go.th/DATA/PDF/2562/E/264/T_0004.PDF

DOEB (2020), Biodiesel-blended Diesel Fuel Specification. http://www.ratchakitcha.soc.go.th/DATA/PDF/2563/E/135/T_0011.PDF

DOEB (2021), Fuel Statistics. https://www.doeb.go.th/2017/#/article/statistic

Energy Information Administration (IEA) (2021), International Data, Petroleum and other Liquids.

Energy Policy and Planning Office (EPPO) (2021), Fuel Price Structure. http://www.eppo.go.th/index.php/th/petroleum/price/structure-oil-price

Economic Planning Unit (EPU) (2021), 'EPU in Final Stage of Formulating National Energy Policy', 23 March. https://www.theedgemarkets.com/article/epu-final-stage-formulating-national-energy-policy (accessed 16 June 2021).

Electricity and Renewable Energy Authority and Danish Energy Agency (EREA and DEA) (2019), *Vietnam Energy Outlook Report 2019.* Ha Noi: EREA and DEA.

ESDM [Ministry of Energy and Mineral Resources Indonesia] (2019), FAQ : Program Mandatori Biodiesel 30% (B30). https://ebtke.esdm.go.id/post/2019/12/19/2434/faq.program.mandatori.biodiesel.30.b30 (in Bahasa Indonesia)

ESDM [Ministry of Energy and Mineral Resources Indonesia] (2020), Handbook of Energy and Economic Statistics of Indonesia 2019. Ministry of Energy and Mineral Resources.

Food and Agriculture Organization of the United Nations (FAO) (2018), 'Sustainability of Biogas and Cassava-based Ethanol Value Chains in Vietnam', *FAO Working Paper 69.*

Garcia, C.A., A. Fuentes, A. Hennecke, E. Riegelhaupt, F. Manzini, and O. Masera (2011), 'Life-cycle Greenhouse Gas Emissions and Energy Balances of Sugarcane Ethanol Production in Mexico', *Applied Energy*, 88(6), pp.2088–97.

General Statistics Office of Vietnam (2019), Statistics of Vietnam.

India Gasoline Consumption, https://www.theglobaleconomy.com /download-data.php India Gasoline Consumption about India Gasoline Consumption, thousand barrels per day) (Access date 25th June 2021)

International Monetary Fund (IMF) (2021), 'Vietnam: 2020 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for Vietnam', *Country Report No. 2021/042.*

Intergovernmental Panel on Climate Change (IPCC) (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

International Sustainability & Carbon Certification (ISCC) (2016), 'Greenhouse Gas Emissions', Version 3, 2016.

Khang, D.S. (2019), 'Environmental Impacts Assessment of Biodiesel Production from Jatropha and WCO', *Vietnam Journal of Science and Technology,* 57(5), pp. 606–616. Doi:10.15625/2525-2518/57/5/13371.

Knoema (2019), 'India – Total Biofuels Consumption', World Data Atlas. https://knoema.com/atlas/India/topics/Energy/Renewables/Biofuels-consumption

Malaysia Commissioner of Law Revision (2007), Malaysian Biofuel Industry Act 2007 (Act 666). (as of 1 November 2012).

Ministry of Petroleum & Natural Gas (2021), Press Information Bureau, Government of India. https://mopng.gov.in/en

Ministry of International Trade and Industries (MITI) (2020), National Automotive Policy 2020.

Ministry of Industry and Trade (MOIT) (2017), The supply of E5 gasoline is completely met when replacing RON 92 gasoline from January 1, 2018 https://moit.gov.vn/tin-tuc/thi-truong-nuoc-ngoai/nguon-cung-xang-e5-hoan-toan-dap-ung-khi-thay-the-xang-ron-9.html. (in Vietnamese)

Mortimer, N.D., A.K.F. Evans, O. Mwabonie, and C.L. Whittaker (2010), Comparison of the GHG Benefits Resulting from Use of Vegetable Oils for Electricity, Heat, Transport and Industrial Purposes. North Energy Associates Ltd.

Ministry of Plantation Industries & Commodities (MPIC) (2006), *National Biofuel Policy 2006*.

Malaysian Palm Oil Board (MPOB) (2021), 'Biodiesel Factsheet'.

Metal and Materials Technology Center (MTEC) (2021) 'Thai National Life Cycle Inventory Database, The Country Database of Life Cycle Analysis of Base Materials and Energy'.

NITI Aayog (2021), Government of India. https://www.niti.gov.in/sites/default/files/2021-06/EthanolBlendingInIndia_compressed.pdf

Petroleum Planning and Analysis Cell, Ministry of Petroleum and Natural Gas, Government of India (PPAC) (2021), 'Snapshot Of India's Oil And Gas Data', January. https://www.ppac.gov.in/WriteReadData/Reports/202102190444572101992SnapshotofIndia'sOilGasdata,January2021.pdf

Petrolimex (2021), https://www.petrolimex.com.vn / (accessed 15 June 2021).

Philippine Department of Energy. Philippine Energy Plan 2018–2040. https://www.doe.gov.ph/sites/default/files/pdf/pep/pep-2018-2040_20210323.pdf

Philippines (2007), Republic Act No. 9367, An Act to Direct the Use of Biofuels, Establishing for this Purpose the Biofuel Program, Appropriating Funds therefore, and for Other Purposes. 12 January. https://www.doe.gov.ph/sites/default/files/pdf/issuances/ra_9367.pdf

Philippines (2008), Joint Administrative Order No. 2008-1, Series of 2008, Guidelines Governing the Biofuel Feedstocks Production, and Biofuels and Biofuel Blends Production, Distribution and Sale under Republic Act No. 9367. 08 October. https://www.doe.gov.ph/sites/default/files/pdf/issuances/jao-no-2008-1.pdf

PIB (2021), 'Department of Food & Public Distribution Notified Modified Scheme to Enhance Ethanol Distillation Capacity in the Country for Producing 1st Generation (1G) Ethanol from Feed Stocks such as Cereals (rice, wheat, barley, corn & sorghum), Sugarcane, Sugar Beet etc.', PIB Press Release. https://pib.gov.in/PressReleasePage.aspx?PRID=1688616

Prime Minister of Viet Nam (2007), Decision No. 177/2007/QD-TTg, Approving the Scheme on Development of Biofuels up to 2015, with a Vision to 2025.

Seksan P. and P. Malakul (2010), 'Life-cycle Energy and Environmental Analysis of Bioethanol Production from Cassava in Thailand', *Bioresource Technology*, 101, pp. S112–S118.

Society of Indian Automobile Manufacturers (2021), New Delhi. https://siam.in

Silalertruksa, T., H. Shabbir, S.H. Gheewala, and P. Pongpat (2015), 'Sustainability Assessment of Sugarcane Biorefinery and Molasses Ethanol Production in Thailand Using Eco-efficiency Indicator', *Applied Energy,* 160(C), pp. 603–609.

The Prime Minister of Government (2007). Decision No. 177/2007/QD-TTg, Approving the scheme on development of biofuels up to 2015, with a vision to 2025. https://www.ecolex.org/details/legislation/decision-no-1772007qd-ttg-approving-the-scheme-on-development-of-biofuels-up-to-2015-with-a-vision-to-2025-lex-faoc079326/

University of the Philippines Los Baños. (2019), 'Life Cycle Assessment in Terms of Carbon Debt and Payback Analyses, Carbon Savings and Energetics Studies of Biodiesel Production from Coconut in the Philippines'.

United States Department of Agriculture (USDA) (2019a), *India Biofuels Annual.* https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Biofuels%20Annual_New%20Delhi_India_8-9-2019.pdf

USDA (2019b*), Indonesia Oilseeds and Products Annual 2019*. http://gain.fas.usda.gov/Recent GAIN Publications/Oilseeds and Products Annual_Jakarta_Indonesia_3-20-2015.pdf

USDA (2020), Report Number: VM2020-0080, Vietnam Ethanol Background Report. https://www.fas.usda.gov/data/vietnam-vietnam-ethanol-background-report

USDA (2021), 'India – Grain and Feed Update'. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=India%20-%20Grain%20and%20Feed%20Update%20-%20February%202021_New%20Delhi_India_02-02-2021

Vietnam Economic News (2017), 'Ethanol Production: Feedstock Diversification'. https://congthuong.vn/san-xuat-ethanol-da-dang-hoa-nguon-nguyen-lieu-94175.html&link=1 (in Vietnamese)

Vietnamnet (2019), 'Concern of the Deputy Minister for the Utilization of E5 Gasoline'. https://vietnamnet.vn/vn/kinh-doanh/thi-truong/thu-truong-cong-thuong-tieu-thu-xang-e5-giam-528758.htm l (in Vietnamese)

Watabe, A. (2011), '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'.

World Bank (2002), 'Vietnam - Renewable Energy Action Plan', *ESMAP Technical Paper.*

World Bank (2021), World Development Indicators. http://databank.worldbank.org/data/ (accessed 18 June 2021).

World Data Atlas (2019), Viet Nam – Fuel Ethanol Production. https://knoema.com/atlas/Viet-Nam/topics/Energy/Renewables/Fuel-ethanol-production

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).

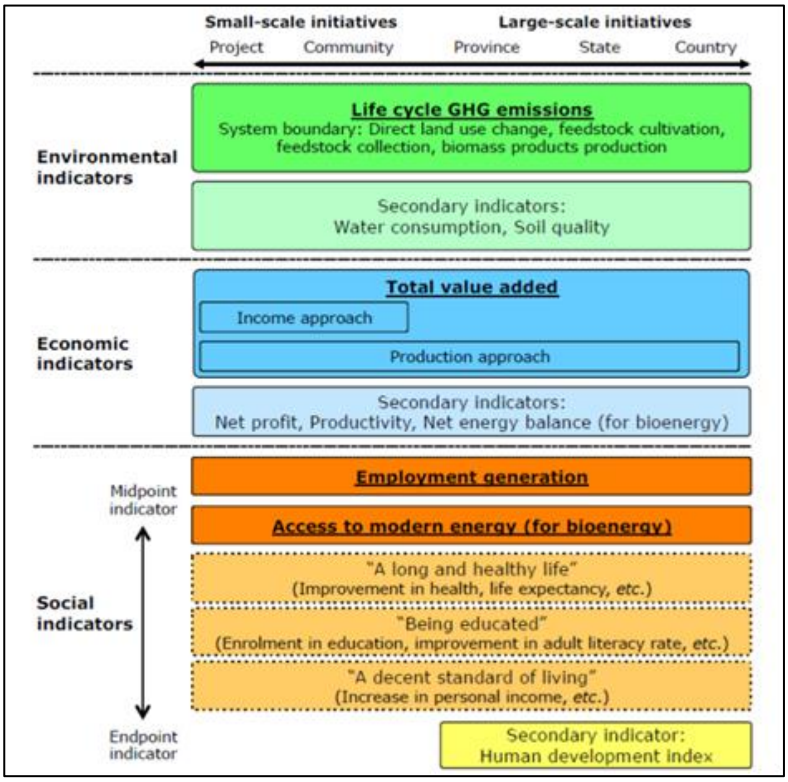
1.2.Objective and Scope

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.

LC-GHG = $\sum ij$ (GHGij × GWPi) (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 (kgCO_2e/FU)

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

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

GWPi = Global warming potential for GHG ‘i' (kgCO_2e/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

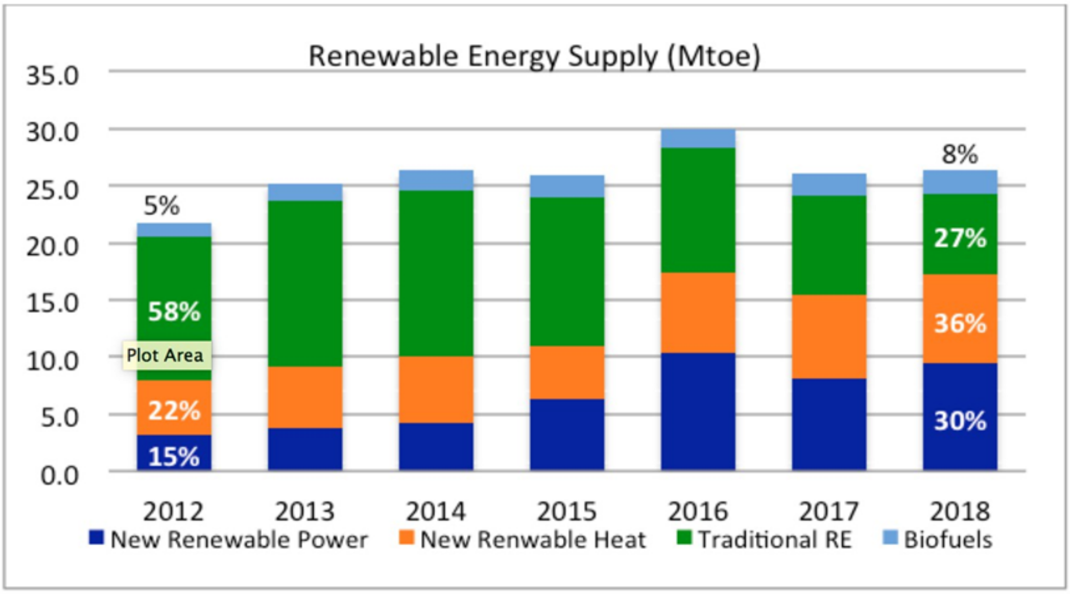
Fuel	Per TJ of Biofuels		
	Direct	Indirect	Total
Cassava ethanol	3.3	2.2	5.5
Molasses ethanol	0.5	4.8	5.3
Sugarcane ethanol	4.0	1.7	5.7
Palm biodiesel	2.0	1.5	3.5
Gasoline	0.0	0.3	0.3
Diesel	0.0	0.3	0.3

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.

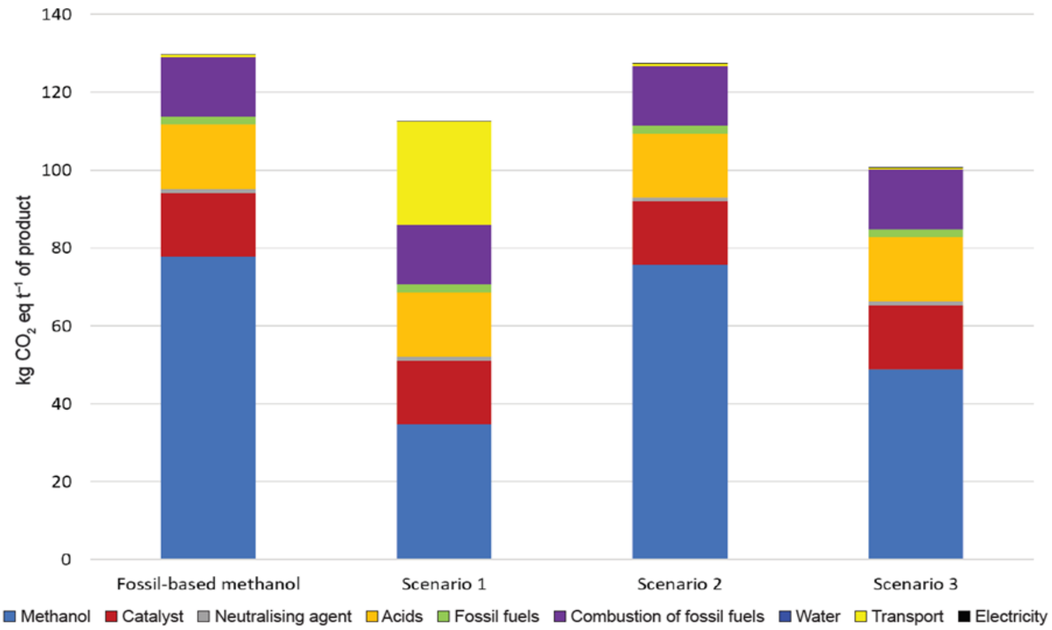
C. Malaysia

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.

References

Aliviar, R., Y. Arkeman, and E. Hambali (2019), 'Indonesia's Oil Palm Bioenergy Sustainability Assessment System Using Indonesian Bioenergy Sustainability Indicators (IBSI)', *International Journal of Engineering and Management Research* 9. https://doi.org/10.31033/ijemr.9.1.16

Food and Agriculture Organization of the United Nations (FAO) (2018), 'Sustainability of Biogas and Cassava-based Ethanol Value Chains in Vietnam', *FAO Working Paper 69.*

Gheewala, S.H. (2013), 'Environmental Sustainability Assessment of Ethanol from Cassava and Sugarcane Molasses in a Life Cycle Perspective', In A. Singh, S.L. Olsen, and D. Pant, (eds.), *Life Cycle Assessment of Renewable Energy Sources.* Springer, pp. 131–143.

Gheewala, S.H., T. Silalertruksa, P. Nilsalab, R. Mungkung, S.R. Perret, and N. Chaiyawannakarn (2013), 'Implications of the Biofuels Policy Mandate in Thailand on Water: the Case of Bioethanol', *Bioresource Technology*, 150, pp.457–65.

Gheewala, S.H., S. Bonnet, K. Prueksakorn, and P. Nilsalab (2011), 'Sustainability Assessment of a Biorefinery Complex in Thailand', *Sustainability*, 3, pp.518–30.

Global Bioenergy Partnership (GBEP) (2011), *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy* (First Edition). Rome: Food and Agriculture Organization. http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf (accessed 16 May 2021).

Hambali, E., P. Papilo, Y. Arkeman, and R.A. Rizkyanti (2019), 'Indikator Keberlanjutan Bioenergi Indonesia (Indonesian Bioenergy Sustainability Indicators, IBSI)'. Bogor, Indonesia: IPB Press.

Kudoh, Y. et al. (2015), 'A Region-specific Methodology for Assessing the Sustainability of Biomass Utilisation in East Asia', *Sustainability,* 7, pp. 16237–16259

Nilsalab, P., S.H. Gheewala, R. Mungkung, S.R. Perret, T. Silalertruksa, and S. Bonnet, (2017), 'Water Demand and Stress from Oil Palm Based Biodiesel Production in Thailand', *International Journal of Life Cycle Assessment*, 22(11), pp.1666–77.

Papilo, P., E. Marimin. E. Hambali, and I.S. Sitanggang (2018), 'Sustainability Index Assessment of Palm Oil-based Bioenergy in Indonesia'*, Journal of Cleaner Production,* 196, pp. 808–820.

Sagisaka, M. (2008), 'Sustainable Biomass Utilisation Vision in East Asia', *ERIA Research Project Report 2007, No.6-3.* Jakarta: ERIA. https://eria-development.website/eria/Publications/Detail/sustainable-biomass-utilisation-vision-in-east-asia

Sagisaka, M. (2009), 'Guidelines to Assess Sustainability of Biomass Utilisation in East Asia', *ERIA Research Project Report 2008 No.8-2.* Jakarta: ERIA. https://eria-development.website/eria/Publications/Detail/guidelines-to-assess-sustainability-of-biomass-utilisation-in-east-asia

Silalertruksa T., and S.H. Gheewala (2011), 'Long-term Bio-ethanol System and its Implications on GHG Emissions: A Case Study of Thailand', *Environmental Science and Technology*, 39, pp.834–43.

Silalertruksa, T., and S.H. Gheewala (2012a), 'Food, Fuel and Climate Change: Is Palm-based Biodiesel a Sustainable Option for Thailand?' *Journal of Industrial Ecology,* 16(4), pp.541–51.

Silalertruksa, T., and S.H. Gheewala (2012b), 'Environmental Sustainability Assessment of Palm Biodiesel Production in Thailand', *Energy,* 43(1), pp.306–14.

Silalertruksa, T., S.H. Gheewala, K. Hünecke, and U.R. Fritsche (2012), 'Biofuels and Employment Effects: Implications for Socio-economic Development in Thailand', *Biomass and Bioenergy,* 46, pp.409–18.

University of the Philippines Los Baños (2019), 'Life Cycle Assessment in Terms of Carbon Debt and Payback Analyses, Carbon Savings and Energetics Studies of Biodiesel Production from Coconut in the Philippines'.

Watabe, A. (2011), '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'.

Yung, C.L., S. Vijaya and Y. Sumiani (2021), Life Cycle Assessment for the Production of Palm Biodiesel, *Journal of Oil Palm Research*, 33(1), pp.145–50.

Chapter 4

Vehicle Electrification and Consumption of Mineral Resources in East Asia Summit Countries

1. Introduction

The introduction of hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), electric vehicles (BEVs), and fuel cell vehicles (FCVs), hereinafter described as 'xEVs') and biofuels in East Asia Summit (EAS) countries is advancing rapidly. For instance, the Indian automobile market has registered over 638,000 electric vehicle (EV) units since 2011–2012. There were more than 1,000 electric cars registered in Viet Nam at the end of 2020, which consist of 99% HEV+PHEV and 1% BEV. There were 32,264 HEV/PHEVs and 2,999 BEVs registered in Thailand in 2020.

The electrification of automobiles will greatly contribute to CO_2 reduction and complement the introduction of renewable energy programmes. This suggests that EAS countries will continue to promote the electrification of automobiles in order to achieve the ambitious targets set out in the Paris Agreement (UN, 2015).

However, the electrification of cars requires significant increases in battery requirements, including the development of high-efficiency motors and lithium ion batteries. High-efficiency motors use neodymium magnets, which are high-performance permanent magnets designed to maintain their efficacy; however, they require several rare earth elements including neodymium (Nd) and dysprosium (Dy), which preserve the thermotolerance of these magnets. This implies that it is becoming increasingly necessary to secure long-term access to these rare-earth elements (Morimoto et al., 2019). Similarly, critical raw materials such as lithium, nickel, and cobalt (Co) are also all required for lithium-ion batteries (Chan, 2021). Therefore, the electrification of automobiles relies on the sustainability of these mineral resources and promotes the idea of creating a circular economy that recycles these resources.

Circular economies are designed to improve resource efficiency and minimise the amount of resources needed and their waste by improving both the production system and product design of these items. This prolongs the lifespan of these products and promotes their reuse, remanufacture, repair, and recycling. Currently, EAS countries only consume 'cradle-to-grave' products, i.e. those that are produced, designed, and discarded. Therefore, there is a need to shift the consumption of mineral resources to a 'cradle-to-cradle' model rather than the cradle-to-grave model mentioned above (ERIA, 2020).

This study estimates the long-term mineral resource demand associated with automobile electrification in EAS countries. In addition, the study aims to assess the potential for recycling in these countries by determining the amount of waste of these mineral resources and evaluate the effectiveness of introducing a circular economy under these conditions.

1.1. Background

At present, the electrification of vehicles and the introduction of biofuels is being promoted in EAS countries to reduce CO_2 emissions from the transport sector.

The details are described in Section 2. The current status of motor vehicle motorisation in various EAS countries is as follows:

Indonesia

In Indonesia there were 219 4-wheeled electric vehicles and 5,000 2-wheeled vehicles registered in 2020. The target of mobility electrification in Indonesia for 4-wheelers is 400,000 units by 2025, 600,000 units by 2030, and 1,000,000 units by 2035. The target of 2-wheeler electric vehicles is 1,760,000 units by 2025, 2,450,000 units by 2030, and 3,225,000 units by 2035.

Malaysia

The government is targeting 10% of new additions to the fleet being battery electric vehicles (BEVs) by 2022, with the percentage increasing to 20% from 2023 to 2025. From 2026 to 2030, 50% of the new additions to government and government-link company fleets are targeted to be locally manufactured BEVs.

Philippines

Registered EVs (includes e-trikes, e-motorcycles, e-jeepneys, e-cars, e-SUVs, e-trucks, e-trucks, and e-buses) with the Land Transportation Office (LTO) for 2010–2020 were reported at 12,965 units (EVAP, 2021). The market projection for additional EVs in 2021 are 1,930 units (PDOE, 2021). According to the Department of Trade and Industry (DTI) and the Electric Vehicle Association of the Philippines EV Comprehensive Road Map, the industry is targeting about 21% EV utilisation by 2030 out of the total vehicle population, specifically focusing on public transportation. By 2040, industry target is set at 50% EVs of the total vehicles being utilised in the country for the said period (Cahiles-Magkilat, 2020).

Thailand

The number of xEVs registered in Thailand is explained below:

2017: 11,945 units hybrid electric vehicles/plug-in hybrid electric vehicles (HEV/PHEV) and 165 units BEV

2018: 20,344 units HEV/PHEV and 325 units BEV

2019: 30,676 units HEV/PHEV and 1,572 units BEV

2020: 32,264 units HEV/PHEV and 2,999 units BEV

2021 (until March): 14,248 units HEV/PHEV and 1,253 units BEV

The target of mobility electrification in Thailand for four-wheelers is 243,000 units in 2025, 473,000 units in 2030, and 1,237,000 units in 2035. For two-wheelers the target of electric vehicles is 360,000 units in 2025, 650,000 units in 2030, and 1,800,000 units in 2035.

Viet Nam

Registered electric cars in Viet Nam until 2020 are more than 1,000 units, which consists of 99% HEV+PHEV and 1% BEV. For electric two-wheelers, the numbers of registered vehicles in Viet Nam are listed below:

2018: 46,370 units of e-bikes and 212,920 units of e-motorcycles

2019: 52,940 units of e-bikes and 237,740 units of e-motorcycles

2020: 21,320 units of e-bikes and 152,710 units of e-motorcycles

India

The Indian automobile market has registered over 638,000 EVs since 2011–2012. India's 2030 EV ambition signalled by NITI Aayog, states that 70% of all commercial cars, 30% of private cars, 40% of buses, and 80% of the two- and three-wheeler sales in 2030 would be electric.

However, advancing these electrification efforts will lead to a substantial increase in demand for mineral resources such as Nd, Dy, Li, Ni, and Co. For example, the United States (US) Geological Survey (USGS, 2021) Minerals Commodity Summary for 2021 reports that the global rare earth elements (REE) production was approximately 220,000 tons/year in 2019, with China accounting for the highest share of global production (60%), followed by the US (13%) and Myanmar (11%). The global REE production increased to 240,000 rare earth oxides (REO) tons/year in 2020. Notably, China's share of the global production declined from 60% in 2019 to 58% in 2020, while production outside China, such as in the US, Burma (Myanmar), and Madagascar increased during the same period.

Furthermore, with neodymium making up approximately 18% of all REE produced, the production of neodymium increased from 39,600 REO tons/year in 2019 to 43,200 REO tons/year in 2020.

Based on the same data from the USGS, the global cobalt production was approximately 144,000 tons/year in 2019 and decreased to 140,000 tons/year in 2020. Congo boasts the highest share of global cobalt production, followed by Russia, Australia, and the Philippines. Congo's share of global production declined from 70% in 2019 to 68% in 2020, with the production outside Congo mostly decreasing over this same period.

When promoting automobile electrification in EAS countries, a circular economy should be introduced efficiently by taking into account the productive limitations of these mineral resources. For example, the Association of Southeast Asian Nations (ASEAN) is currently concerned about the environmental disruption resulting from natural resource mining, and more efforts are being made to develop sustainable industries. This was taken into account at the ASEAN Summit 2021 (27 October 2021), which focused on strategies to strengthen the resilience of ASEAN economies by making them more sustainable and less vulnerable to future disturbances via stabilisation of manufacturing, thereby promoting complementarities in the regional supply chain through technology exchange and formalising these ideas in the ASEAN Community Vision 2025, the ASEAN Integrated Food Security Framework, the ASEAN Network for Combating Illegal, Unreported, Unregulated Fishing, and the ASEAN Framework of Action on Marine Debris (ASEAN Storage, 2020).

1.2 Objective and Scope

This project analyses future scenarios for EAS mobility, which may strongly contribute to the regional SDGs (7, 12, and 13) and provide a balance between transport CO_2 reduction, biofuel use, and the demands on mineral resources. In this chapter, the demand for Nd and Co were forecast and the amount of waste resulting from the promotion of automobile electrification in EAS countries were also estimated. The possibility of a future supply–demand gap is also examined and the recycling potential for these items are evaluated.

1.3 Methodology

This section describes a method for predicting the demands for Nd and Co and estimating the amount of waste after the promotion of electrified automobiles in EAS countries.

Several EAS countries were selected for evaluation and the relationship of the number of vehicles owned as per the International Organization of Motor Vehicle Manufacturers (OICA, 2020) with the growth rate and gross domestic product purchasing power parity (GDP-PPP)/capita (international dollars/year) between 2005 and 2015 (IMF, 2020) was analysed. The results are shown in Figure 4.1.

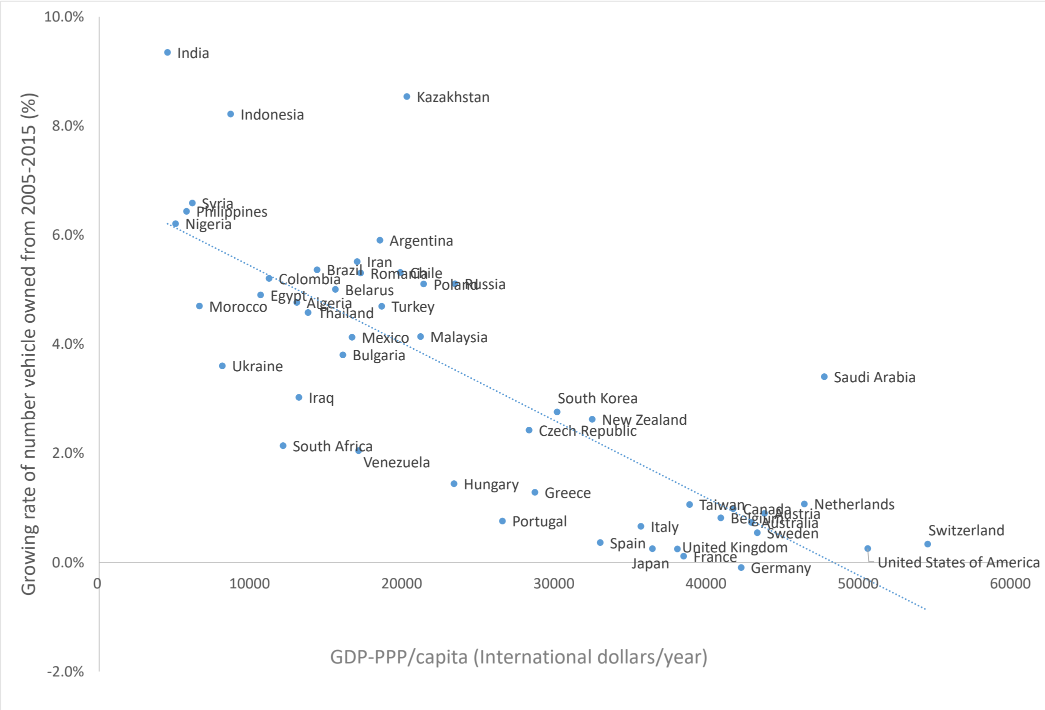
As shown in Figure 4.1, a higher GDP-PPP/capita due to economic growth causes a linear decrease in the growth rate of the number of cars held. This study then predicted the number of cars in each country using the projected future national GDP values published by the International Monetary Fund. This data were also used to predict the number of vehicles in the market and the number of discarded vehicles for each country. The number of discarded vehicles was estimated using the Weibull distribution, when assuming a car's life span to be 14.4 years (Morimoto et al., 2020).

Finally, the demand and disposal of Nd and Co were calculated by integrating the data on the amount (contained rate) of Nd and Co in these automobiles with the number of automobiles that were sold and disposed of during these projections.

The demand and disposal of Nd and Co were determined using two methods. **Method 1** predicted the number of automobiles that were sold and discarded as described above, and then the number of xEVs sold was calculated by using Deloitte's prediction (Deloitte, 2020) of automobile electrification and integrating the Nd and Co contents.

Method 2 estimated the demand and disposal of Nd and Co by using the target values for vehicle electrification in each country, which were evaluated in this project.

Figure 4.1. Relationship Between Growing Rate of Number of Vehicles Owned and GDP-PPP/capita



Deloitte's projection describes five different enablers that are crucial to realise electrification in ASEAN. In that study, the level of maturity for each enabler was assessed and used to calculate the total weighted average score. Subsequently, the average percentage for each enabler was calculated and the final value was determined (Deloitte, 2020).

2. Vehicle Electrification Policies

At present, each EAS country has its own goal for the electrification of automobiles. This chapter describes the electrification targets in each of these countries.

A. Thailand

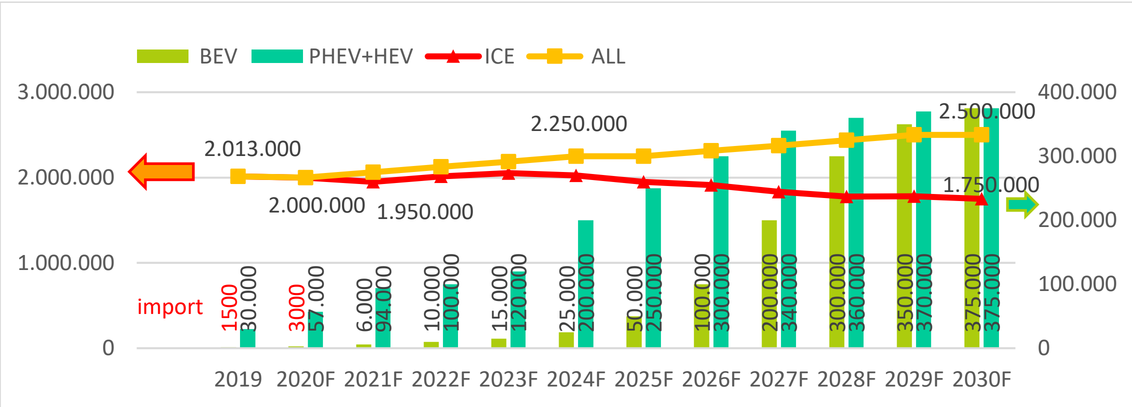
Like many other countries around the word, Thailand has been preparing to cope with disruptive technology like electric vehicles to enter the domestic market, where Thailand has been a hub of conventional automotive production. After 1-ton pickup trucks and eco cars, Thailand aims to push EVs as the next project champion for the Thai automotive industry.

National Plan for xEVs (HEV, PHEV, BEV, FCEV) Promotion (existing and developing)

The national plan with targets for EVs had not been formulated until early 2020, when the Prime Minister established the National Electric Vehicle Policy Committee on 7 February 2020, chaired by the Deputy Prime Minister on Economics with 18 members from related ministries (Ministry of Industry, Ministry of Transport, Ministry of Energy, Ministry of Finance, and Office of Prime Minister), industrial sectors (Federation of Thai Industries, Board of Trade of Thailand, Thai Automotive Industry Association) and national experts. This national committee has a task to identify the direction and target of EVs in alignment with the 20-Year National Strategy: 2018–2037 (OESDB, 2018).

This National EV Policy Committee had its first meeting on 11 March 2020 with the proposed Thailand Smart Mobility 30@30 to target 30% of domestic automotive production in 2030 from xEVs (15% from BEVs and 15% from HEVs and PHEVs). As shown in Figure 4.2 (Thailand National EV Policy Committee, 2020), 2030 domestic automotive production is forecast at 3 million vehicles so 750,000 vehicles would be xEVs from 375,000 BEVs and 375,000 HEVs and PHEVs.

Figure 4.2: Thailand Smart Mobility Road Map 30@30



BEV = battery electric vehicle, F = forecast, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle.
Source: Thailand National EV Policy Committee (2020).

Since the first meeting of the National EV Policy Committee, there have been subsequent supporting mechanisms from the Board of Investment (BOI) in order to reach 30@30 target. The second meeting of the National EV Policy Committee on 24 March 2021 accelerated the EV target to be 100% newly registered zero emissions vehicles (ZEV = BEV + FCEV) by 2035 across three vehicle classifications: cars and pickups, motorcycles, and buses and trucks under strategic vision in Table 4.1 (Thailand National EV Policy Committee, 2021).

Table 4.1: Thailand Strategic Vision for Electric Vehicles

<table>
<tr><td>Key Drivers</td><td colspan="12">Air pollution reduction (PM2.5, NOx, Sox)
Greenhouse gas reduction
New industry foundation</td></tr>
<tr><td>Key Strength</td><td colspan="3">High demand for vehicle</td><td colspan="3">Strong automotive industry</td><td colspan="3">Stable electricity infrastructure with high potential for renewable energy</td><td colspan="3">Strategic location for export</td></tr>
<tr><td>Thailand's Vision</td><td colspan="12">Global EV and parts production hub</td></tr>
<tr><td>Key Objective</td><td colspan="4">EV production and export
EV production becomes main products in industry</td><td colspan="4">Usage and infrastructure
EV usage becomes widespread with supporting infrastructure</td><td colspan="4">Sustainability
Sustainability in financial and environmental aspects</td></tr>
<tr><td>Key Initiatives</td><td colspan="4">–Establish incentives for domestic EV part and battery productions
–Establish EV standards</td><td colspan="4">–Establish EV demonstration projects
–Prepare electricity infrastructure with enough charging stations under standard, incentive, and compulsory mechanism
–Regulate suitable electricity price</td><td colspan="4">–Establish protocol to manage waste from EVs and battery
–Balance government income</td></tr>
<tr><td>Key Support</td><td colspan="12">Supporting measures in finance, regulation, R&D, HRD, and information management</td></tr>
</table>

EV = electric vehicle, R&D = research and development, HRD = human resource development.
Source: Thailand National EV Policy Committee (2021).

Urgent and short-term measures include:

Urgent measures

- ✓ Provide incentives to boost the use of two-wheeled, three-wheeled, and four-wheeled EV.
- ✓ Provide national standards, battery testing centres, energy plans, and charging stations for electric vehicles and electric motorbikes.
- ✓ Set up an electric bus rental project that should implement the use of 2,511 electric buses.

Short-term measures (within next 1–5 years)

- ✓ Restructure the taxation system, e.g. update the excise tax for new vehicles from 2026 onwards, and annual vehicle taxes calculated based on the age of the vehicle, i.e. the older the vehicle, the more expensive the tax.
- ✓ Set up facilities to manage and treat used vehicles, batteries, and solar PV.

- ✓ Build ecosystem and infrastructure to support the use of ZEV.
- ✓ Develop human resource and capacity to support the use of ZEV.

Government Support and Incentives for xEVs (HEV, PHEV, BEV, FCEV), e.g. subsidy, mandate

Thus far, Thailand has been launching mostly supply-side incentives for EVs through the BOI. For instance, the BOI has already approved 24 projects for vehicle manufacturers to domestically produce HEVs, PHEVs, and BEVs with a combined capacity of over half a million units per year and charging stations of over 4,000 per year (Thailand BOI, 2020a). The approved projects include:

- ✓ Mitsubishi Motors (Thailand): investment to upgrade the company's existing car production line at Laem Chabang Industrial Estate to allow the annual production from 2023 of a total of 39,000 vehicles, consisting of 9,500 BEVs and 29,500 HEVs.
- ✓ Sammitr Group: investment for the production in Phetchaburi Province of 30,000 BEVs. Similar to the Mitsubishi Motors (Thailand) project, the Sammitr Group project, like most others, will be aimed at the local market and exports, mainly to other ASEAN countries.
- ✓ BMW: production of PHEVs and partnership with the DRÄXLMAIER Group for the production of high-voltage batteries and battery modules.
- ✓ FOMM: a new Japanese EV brand (FOMM = First One Mile Mobility) with compact BEVs production at a plant in Chonburi province.
- ✓ Nissan Motors: investment in hybrid car production in Thailand with and received approval recently for a new BEV production project.

In November 2020 (Thailand BOI, 2020b), the BOI has rolled out a new package for EVs to replace its first EV package that expired in 2018. The new approved projects with THB35.7 billion (US$1.1 billion) worth of investment covering a comprehensive range of electrical vehicles including passenger cars, buses, trucks, motorcycles, tricycles, and ships can be summarised as follows:

- ✓ Four-wheelers:
    - ➢ For qualified projects with total investment package worth at least THB5 billion: PHEVs receives 3-year tax holidays while BEVs receive 8-year corporate income tax exemption period with extendable option in the case of R&D investment and/or expenditures.
    - ➢ For qualified projects with total investment worth less than THB5 billion: PHEVs and BEVs both receive 3-year tax holidays with extendable tax holidays period for BEVs under special requirements, such as production commencement by 2022, additional part production, minimum production of 10,000 units within 3 years, and R&D investment and/or expenditures.
- ✓ Motorcycles, three-wheelers, buses, and trucks: qualified projects will receive 3-year corporate income tax exemption, extendable if meeting additional requirements.

- ✓ Electric-powered ships: qualified projects for vessels with less than 500 gross tonnage will be eligible for 8 years of corporate income tax exemption.
- ✓ Critical EV parts, such as high voltage harness, reduction gear, battery cooling systems, and regenerative braking systems, will receive 8-years corporate tax exemptions.
- ✓ Battery modules and battery cells for the local market will receive a 90% reduction of import duties for 2 years on raw or essential materials not available locally.

CO_2-related Information (well-to-tank) for Electricity

The Ministry of Energy has regularly published Power Development Plans (PDP) for electricity infrastructure development. In preparation for upcoming EV usage in the country, the current PDP version 2018 revision 1 (EPPO, 2020) has been updated to include regional load forecast including EV load. In addition, emissions factors for the entire grid have been updated, as shown in Table 4.2 (EPPO, 2020).

Table 4.2: Forecast Emissions Factors for National Grid until 2037

Year	PDP2018		PDP2018 Revision 1	
	Annual ($kgCO_2/kWh$)	Annual (kton)	Annual ($kgCO_2/kWh$)	Annual (kton)
2018	0.413	83,975	0.413	83,976
2019	0.395	83,607	0.395	83,668
2020	0.386	84,825	0.381	83,698
2021	0.384	87,576	0.374	85,359
2022	0.368	86,947	0.359	84,841
2023	0.365	89,406	0.354	86,686
2024	0.362	91,536	0.351	88,799
2025	0.337	88,021	0.329	85,947
2026	0.333	89,689	0.322	86,744
2027	0.339	97,007	0.323	89,458
2028	0.332	94,885	0.319	91,041
2029	0.329	97,006	0.318	93,783
2030	0.326	98,743	0.315	95,472
2031	0.320	99,765	0.310	96,675
2032	0.291	93,357	0.281	90,228
2033	0.292	96,509	0.282	93,026

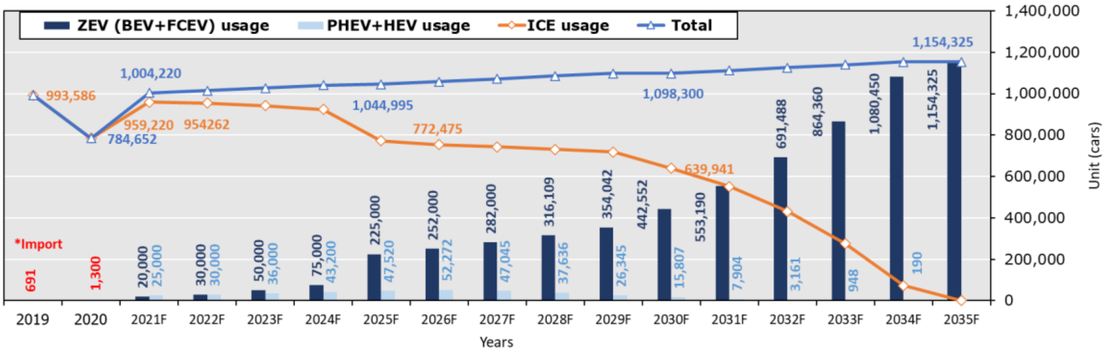
Year	PDP2018		PDP2018 Revision 1	
	Annual ($kgCO_2/kWh$)	Annual (kton)	Annual ($kgCO_2/kWh$)	Annual (kton)
2034	0.302	102,319	0.291	98,797
2035	0.295	102,717	0.284	98,871
2036	0.289	103,248	0.277	99,184
2037	0.283	103,845	0.271	99,712

kg = kilogram, kton = kiloton. PDP = Power Development Plan.
Source: EPPO (2020).

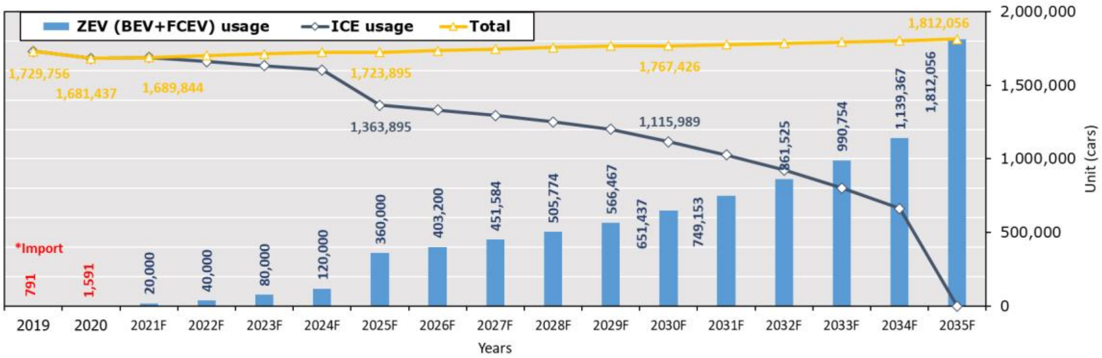
Official xEV Targets (at least up to 2030)

From the second meeting of the National EV Policy Committee on 24 March 2021, the detailed target for 100% ZEV registration is shown in Figure 4.3, as well as ZEV production target in Figure 4.4.

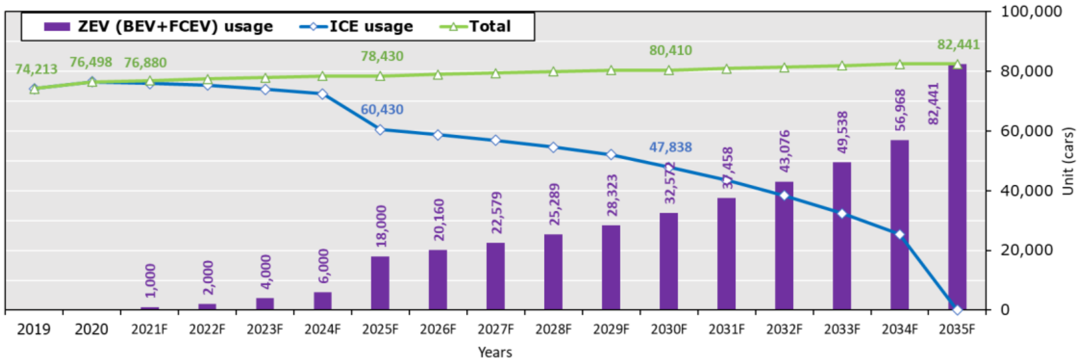
Figure. 4.3: Target of 100% ZEV Registration by 2035 for (a) Cars and Pickups, (b) Motorcycles, and (c) Buses and Trucks



(a)



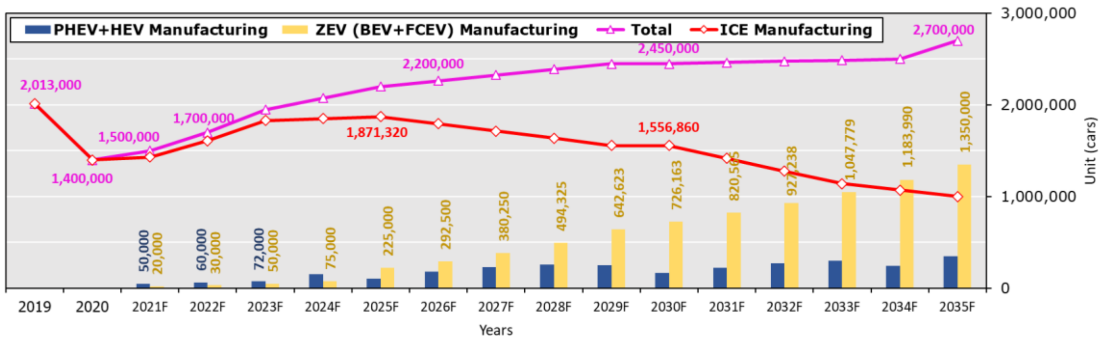
(b)



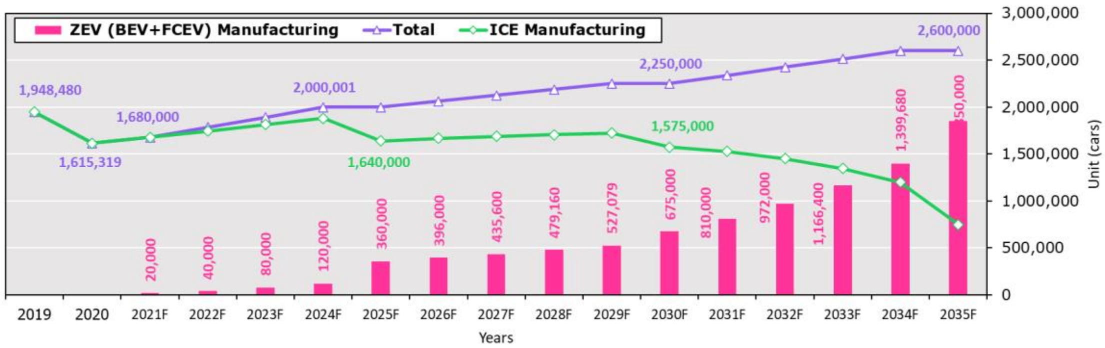
(c)

BEV= battery electric vehicle, FCEV = fuel cell electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, ZEV = zero emissions vehicle.
Source: Thailand National EV Policy Committee (2021).

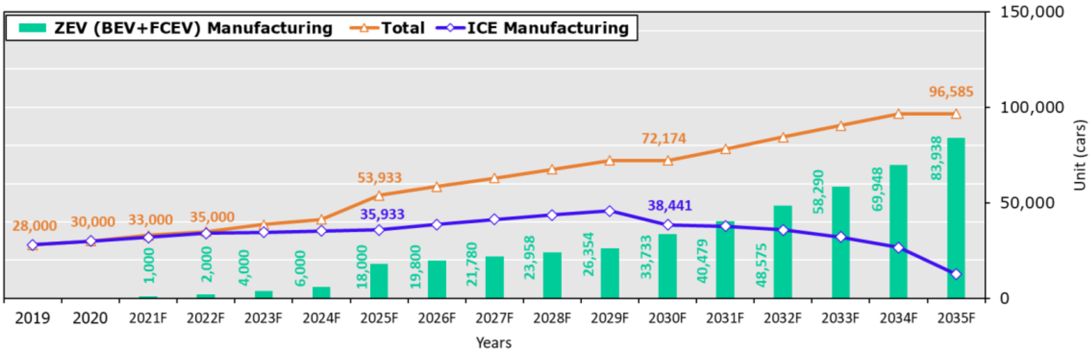
Figure 4.4: Target of ZEV Production by 2035



(a)



(b)



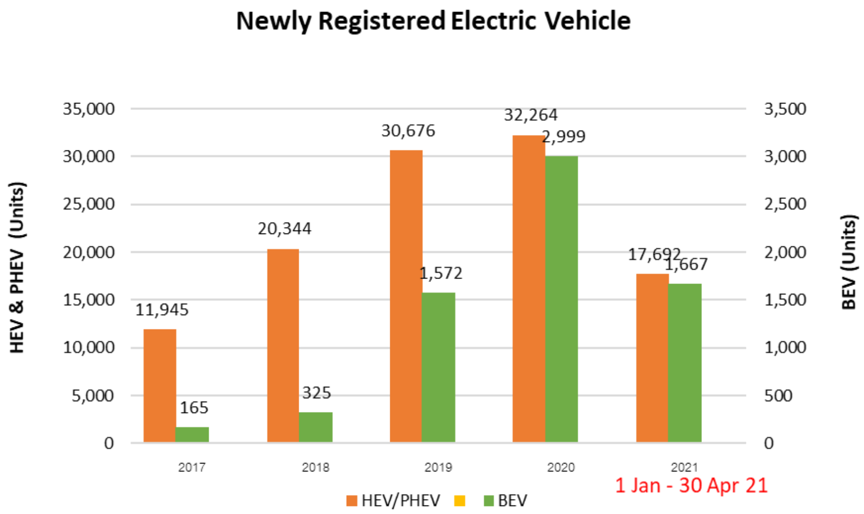
(c)

BEV= battery electric vehicle, FCEV = fuel cell electric vehicle, HEV = hybrid electric vehicle, ICE = internal combustion engine, PHEV = plug-in hybrid electric vehicle, ZEV = zero emissions vehicle.
Source: Thailand National EV Policy Committee (2021).

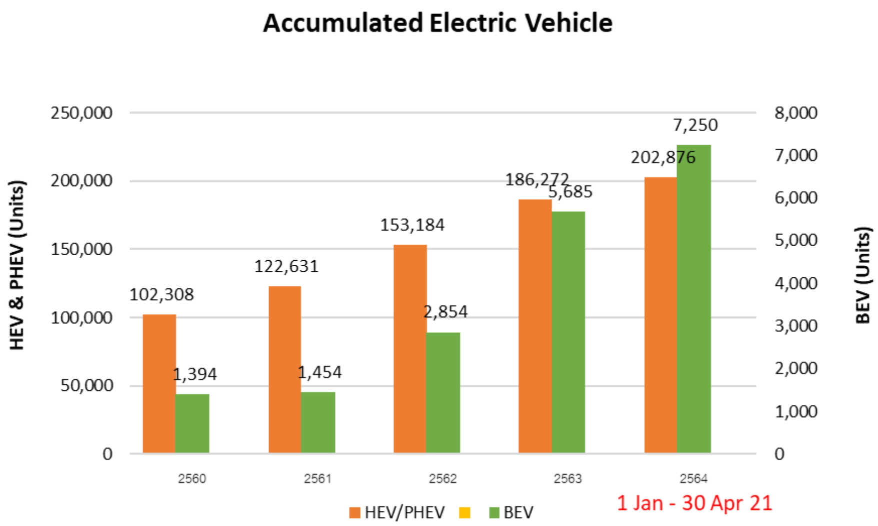
Statistics of Vehicle (gasoline and diesel type) and xEV (HEV, PHEV, BEV, FCEV) Registrations since 2011

Thailand has seen increasing interest in EV usage trends with more than 30,000 new HEVs/PHEVs and more than 1,200 battery electric cars and motorcycles registered in 2019, with approximately 750 charging outlets were setup in some 500 locations, as shown in Figure 4.5 (DLT, 2021) and Figure 4.6 (EVAT, 2021), respectively.

Figure 4.5: Statistics of Conventional Vehicles and xEV Registrations



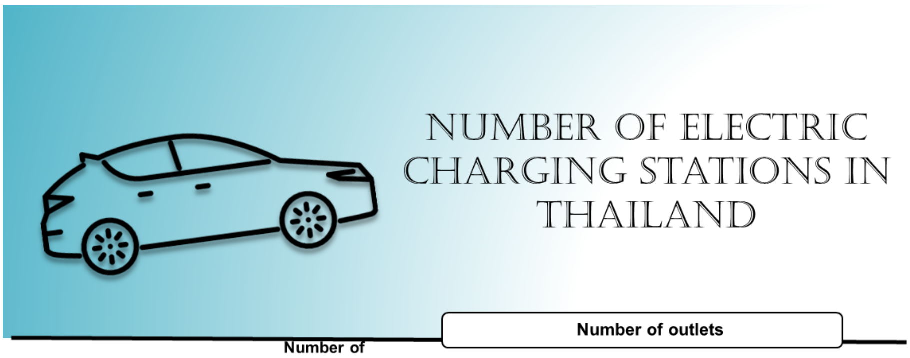
(a)



(b)

BEV= battery electric vehicle, HEV = hybrid electric vehicle, PHEV = plug-in hybrid electric vehicle, xEV = electrified vehicle.
Source: DLT (2021).

Figure 4.6: Statistics of EV Charging Stations



Service Providers	Number of Locations	Number of outlets		
		AC Normal Chargers	DC Fast Chargers	All Total Chargers
EA ANYWHERE	417	1,062	571	1,633
CHARGING STATION	68	42	32	80
EVOLT	49	79	23	102
PEA EV	32	36	111	147
pttstation	30	38	10	48
ChargeNow	18	62	1	63
EleX by EGAT	14	16	21	37
SHARGE	14	65	0	65
MEA EV	10	11	5	16
PUMP CHARGE	6	18	0	18
EVen	4	7	0	7
on ion	2	8	0	8
TOTAL	664	1,459	771	2,224

Source: EVAT (2021).

Vehicle Assumption, e.g. Average Vehicle Kilometre of Travel, Average Vehicle Fuel Economy (gasoline and diesel)

To analyse future mobility fuel scenarios, vehicle assumptions, such as average vehicle kilometre of travel (VKT), average vehicle fuel economy (FE) are necessary. Although these kind of data are preferably to be record periodically, only project-based data are available in Thailand. EPPO has been conducting surveys every 5 years with latest data on VKT and FE collected in 2019 (EPPO, 2019). Together with efforts from the Ministry of Transport (OTP, 2016) and the Ministry of Industry (OIE, 2021), more data have been collected resulting in Table 4.3 and Table 4.4.

Table 4.3: Average VKT in Thailand

Vehicle Classification	VKT (km/year)
Car	20,230
Van	24,742
Pickup	24,270
Motorcycle	13,960
3-wheeler	30,285
Taxi	86,297
Bus Fixed Route	77,258
Bus_Non-Fixed Route	55,601
Truck	61,048

VKT = vehicle kilometre of travel.
Sources: EPPO (2019); OTP (2016); OIE (2021).

Table 4.4: Average FE in Thailand

Vehicle Classification	FE (litres of gasoline equivalent/100 km)
1: Eco car	4.76
2: City car, subcompact : Sedan and Hatchback	5.83
3: Compact car C-segment : Sedan and Hatchback Coupe Roadster	6.13
4 : D-segment full size sedan	6.71
5 : mini-MPV and B-SUV	5.79
6 : SUV and MPV	7.37
7 : PPV	8.13

8 : Single cab pickup	7.42
9 : Extra cab pickup	7.47
10 : 4 doors pickup	7.83

FE = fuel economy.
Sources: EPPO (2019); OTP (2016); OIE (2021).

Indonesia

Indonesia is in the very early stage of electric vehicle development. The majority of people support vehicle electrification and many people do not care where the electricity come from. There are currently about 220 electric cars and 5,000 electric motorbikes in the country.

On 8 August 2019, through Presidential Regulation no. 55/2019 on the Acceleration Program for Battery-powered Electric Vehicles for Road Transportation, Indonesia promulgated the country's first regulation on electric vehicles. Within 37 articles, the decree sets the legal framework for the future of the production of electric vehicles in Indonesia. However, the follow up of this presidential regulation is not so clear. For example, the present National Energy General Plan states that the target for electric vehicles is 2,200 cars and 2.1 million motorbikes by 2025. On the other hand, the Ministry of Industry has an even more ambitious targets as shown in Table 4.5.

Table 4.5: Production Targets of Electric Vehicles in Indonesia

Vehicle Type	**2025**		**2030**		**2035**	
	Number of units	**% of total production**	**Number of units**	**% of total production**	**Number of units**	**% of total production**
Four-wheeler	400,000	20	600,000	20	1,000,000	20
Two-wheeler	1,760,000	20	2,450,000	25	3,225,000	30

Source: Indonesian Minister of Industry Decree no. 27/2020.

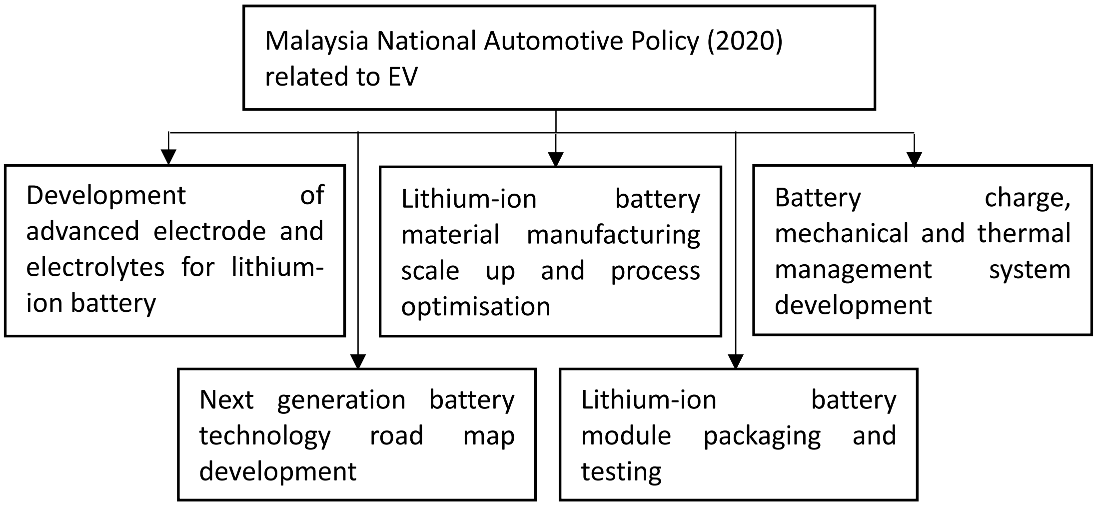
Considering that currently the electric vehicle production ecosystem in Indonesia still needs a lot of development, the targets shown in Table 4.5, especially those for 2025, are considered ambitious.

Malaysia

The government of Malaysia has formulated a series of policies in the last decade to encourage the use of alternative vehicles such as battery electric vehicles (BEVs). One such recent policy is the National Automotive Policy (NAP) (2020) (Ministry of International Trade and Industry Malaysia, 2020; Iskandar and Araffin, 2019; Rahim et al. 2019). Based on the government's

National Automotive Policy (2020), depicted in Figure 4.7, several technology developments project has been mapped out to improve the ease of owning EVs in Malaysia.

Figure 4.7: EV Components of the Malaysia National Automotive Policy (2020)



EV = electric vehicle.
Source: Ministry of International Trade and Industry Malaysia (2020).

The Ministry of International Trade and Industry Malaysia and the Malaysia Automotive, Robotics and IoT Institute (MARii) are finalising the last phase of the new policy on EVs as part of the upcoming revision of the NAP 2020. The policy would contain revisions that would jump start the road to electrification in Malaysia and enable the country to attract investment in the particular field. The policy proposes incentives for EVs including allowance for foreign automakers to bring in a number of completely built-up (CBU) units with the absence of tariffs, zero excise and import duties, full sales tax exemption, and zero road tax.

Coinciding with the NAP 2020, a draft of the Low Carbon Mobility Blueprint 2021–2030 under the Ministry of Environment and Water Malaysia and the Malaysian Green Technology and Climate Change Centre is being finalised by Cabinet, aimed at driving increased use of electric vehicles and low-carbon transportation in the public and private sectors to lower Malaysia's carbon emissions output. The transport sector contributes around 20% of the country's total emissions levels (Ghadimzadeh et al., 2015). The blueprint covers four key areas: vehicle energy efficiency improvement, EV adoption and related tax exemptions, alternative fuel adoption, and greenhouse gas (GHG) emissions and energy reduction.

Among the notable plans in the blueprint are the requirement of exhaust emissions testing for all new cars with the introduction of new GHG standards for new vehicles and a national average target, and full tax exemptions for government fleets, taxis, and ride-hailing vehicles, as well as excise duty and import tax exception for up to 10,000 individual CBU battery EVs until the end of 2022. From 2023 to 2025, CBU EV units will be given a 50% import and excise duty exemption until locally assembled BEVs become available on the market.

Plug-in hybrid (PHEV) specific incentives also will also be introduced. These include tax exemption for qualified complete knocked-down models, with 100% exemption being given until 2022, 75% exemption from 2023 to 2025, and 50% exemption from 2026 to 2030. To ensure penetration, a sufficient EV charging infrastructure is needed, and the plan calls for the establishment of a national target of having 7,000 AC public charging points and 500 DC charging points. A public tender for a national fast charging network is planned with providing tax incentives under Green Income Tax Exemption for such services until 2030. In areas not serviced by private operators, the installation of a fast charger for every 100 kilometres and at every R&R stop along major highways, commencing from next year until 2025. Elsewhere, the new requirement guidelines for installing EV charging facilities proposes to be incorporated in planning permission for all new buildings, and a tariff revision for public EV charging services to be studied before the specific rates are implemented.

The government-led initiatives include plans to push EV (presumably both BEV and PHEV) adoption for taxi use as part of the modernisation process for such services. Incentives for the purchase of EVs and income tax exemption until 2030 are being proposed to offset the higher capital cost of EVs. The blueprint also lays out the adoption of BEVs for use in government and GLC fleets as a means to encourage wider adoption. For use in government targets for 10% of new additions to the fleet being BEVs by next year, with the percentage increasing to 20% from 2023 to 2025 while GLC fleets, with tax incentives being provided until 2030. From 2026 to 2030, 50% of the new additions to government and GLC fleets are targeted to be locally manufactured BEVs.

Buses and motorcycles are also set to feature in the move towards electrification, with plans to establish an e-bus central procurement agency, offering subscriptions of these to ministries and state governments. As for electric motorcycles, support will also be provided to local manufacturers, by giving tax incentives to operators purchasing these for use as delivery service vehicles. There is also a plan to develop a battery swapping standard for e-bikes and have it in place by 2023.

The electrification action plan aims to grow localisation through providing R&D grants and support for local manufacturers of electric vehicles. Presently, there are no dedicated tax incentives for investment in ‘green’ production and distribution activities, and the idea is to introduce a tax incentive scheme for industries in the production, distribution, and services related to low-carbon transpiration.

The blueprint is targeted to reduce GHG emissions by 165 million tons of CO_2, save fuel expenditure of RM150 billion over 10 years, and increase the use of electric vehicles and low-carbon transportation.

To support the government's efforts on EV policy plans, the Iskandar Malaysia Bus Rapid Transit together with the Iskandar Regional Development Authority started pilot testing of hybrid electric and biodiesel buses (Figure 4.8) from nine local and international suppliers on 8 April

2021 in line with Johor's modernisation of its public transport system. The project is said to have identified feeder, direct, and main routes that reach 2,043 kilometres or around 90% of Iskandar Malaysia's populated areas. Once fully implemented, the Iskandar Malaysia Bus Rapid Transit will be able to connect 55 feeder routes and 44 direct routes with the main route and its 33 stations. In addition, the Sarawak Tourism, Arts and Culture Ministry launched the first public bus running on electric power (e-Bus) in Malaysia, in line with the state government's policy to focus on sustainable development. The city e-Bus service that started in February 2019 on a trial basis with a single bus has been well received by visitors and locals, who commended the free, innovative, green energy bus services (Figure 4.9).

Figure 4.8: Iskandar Malaysia Bus Rapid Transit Pilot Test of Hybrid Electric and Biodiesel Buses

Source: Scania Malaysia (2021).

Figure 4.9: The City e-Bus Service, Kuching, Sarawak

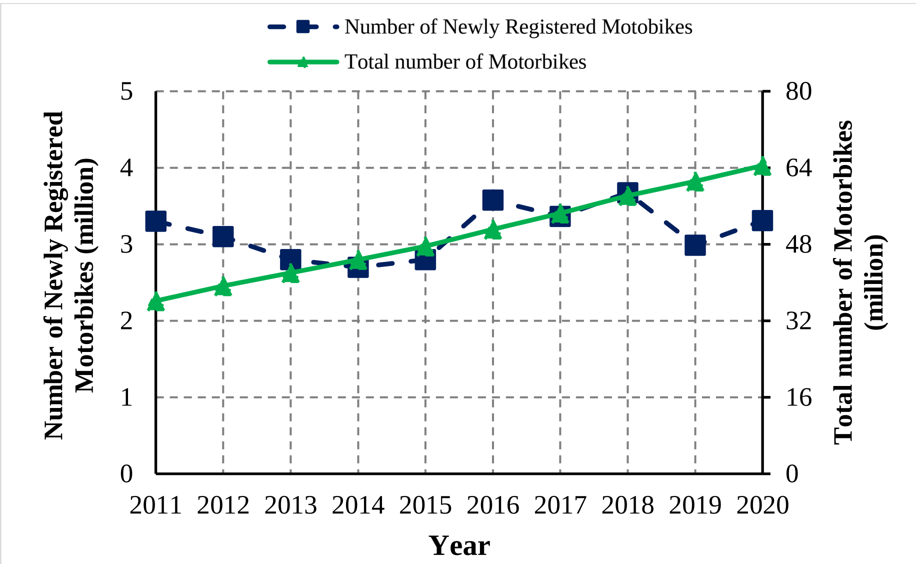
Source: Sarawak Tourism (2021).

B. Viet Nam

Motorbikes are the most popular transport means in Viet Nam, with the average number of motorbikes sold annually of about 3 million units, due to their low cost and flexibility (Figure 4.10). In 2019, Viet Nam had about 60 million motorbikes and was the fourth-highest country in the world for the number of motorbikes, and in 2020 the number of motorbikes incr

eased to about 64 million units (Vietnamnet, 2016; VAMM, 2021; Vietnam Register, 2021a).

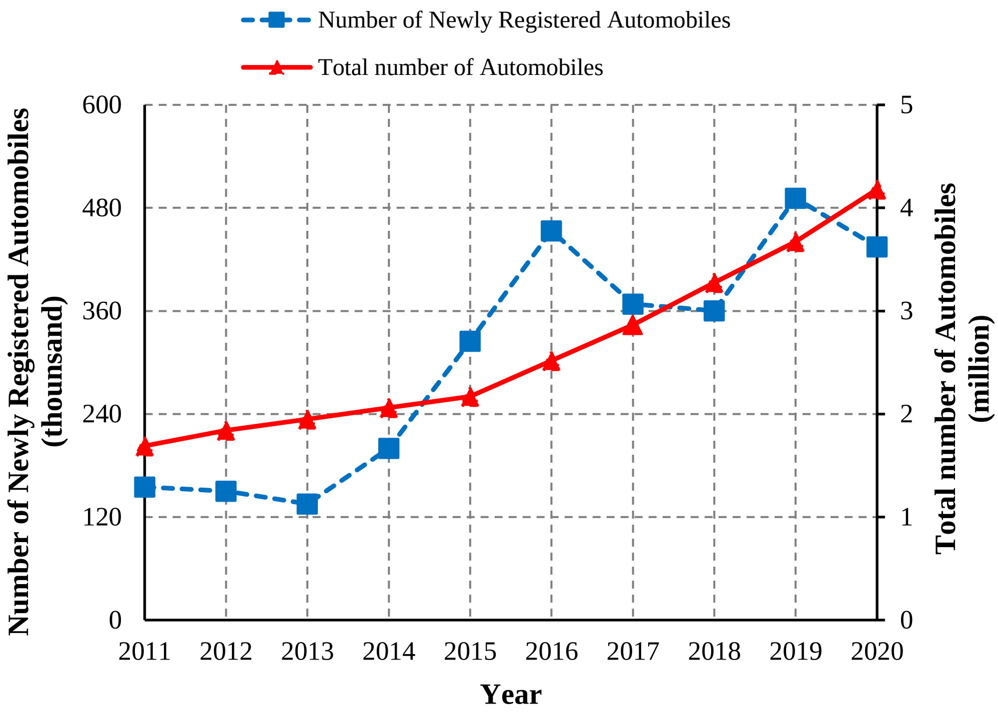
Figure 4.10: Number of Newly Registered and In-use Motorbikes



Sources: Vietnamnet (2016); VAMM (2021); Vietnam Register (2021a).

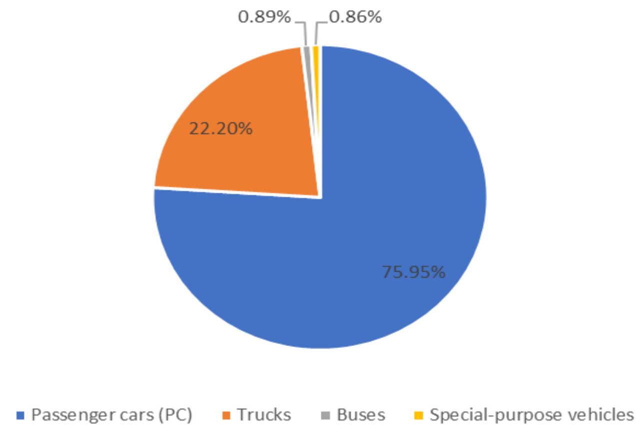
Viet Nam's automotive industry is also growing rapidly and has been doing so continuously during recent years. On average, the growth of the automobile market has been 20% to 30% annually. The total number of registered automobiles until 2020 was about 4.2 million units, as shown in Figure 4.11 (CEIC, 2015; Vietnam Register, 2021a). In 2020, the number of domestically assembled and imported automobiles are about 324,000 and 110,000 units, respectively (Vietnam Register, 2021a). The sales report of the Vietnam Automobile Manufacturer's Association in 2020 shows that passenger cars contribute to 76%, commercial vehicles contribute to 23% of total automobiles sold, as shown in Figure 4.12 (VAMA, 2021). From the passenger car's fuel consumption list based on the compound driving cycles (Vietnam Register, 2021b), it is estimated that the average fuel consumption is about 8.02 litre/100km for gasoline cars, and 7.52 litre/100km for diesel cars.

Figure 4.11: Number of Newly Registered and In-use Automobiles



Source: CEIC (2015); Vietnam Register (2021a).

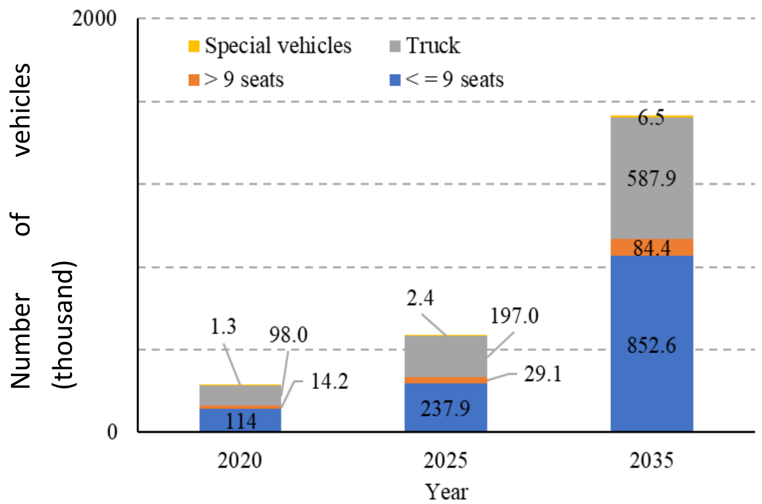
Figure 4.12: Share of Automobiles Sold in 2020 Based on Type



Source: VAMA (2021).

In 2014, the Viet Nam government issued Decision No 1168/QD-TTg approving the strategy for development of Viet Nam's automobile industry up to 2025, with a vision to 2035. The decision also set target numbers for domestically assembled cars (Figure 4.13).

Figure 4.13: Specific Target of the Strategy for Development of Viet Nam's Automobile Industry

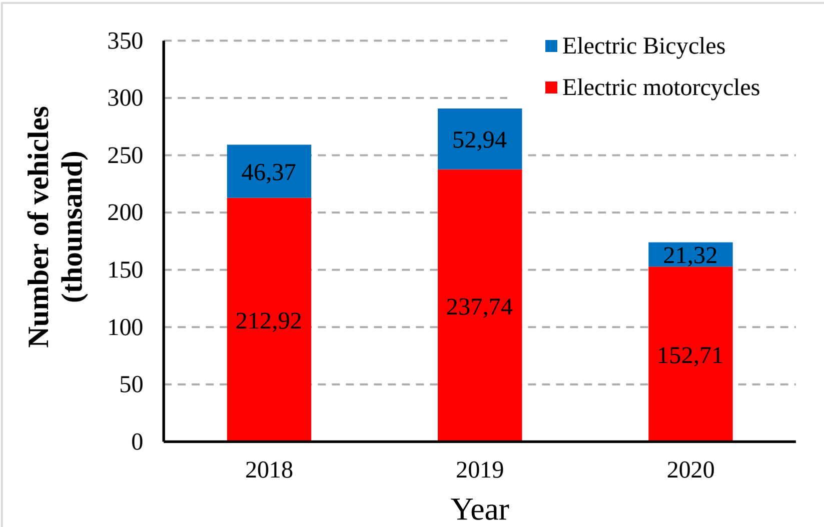


Source: Decision of The Prime Minister of Vietnam Government (2014). About approval for strategy to develop automotive industry in VietNam by 2025, orientation towards 2035. https://vanbanphapluat.co/decision-no-1168-qd-ttg-dated-2014-strategy-to-develop-automotive-industry-in-vietnam-by-2025

The Decision also encourages the manufacture of environment friendly vehicles (fuel efficient vehicles, hybrid, biofuel-powered, and electric vehicles, etc.) to meet the requirements on emissions standards.

Currently, the electric vehicle market is dominated by electric bikes and electric motorcycles. In 2018, there were 14 e-bike and 39 e-motorcycle manufacturers that produced 46,373 units of e-bikes and 212,924 units of e-motorcycles. These numbers have seen some changes in 2019 and 2020, as shown in Figure 4.14 (ICT News, 2020). In the first quarter of the year 2021, about 76,184 units of e-bikes and e-motorcycles were sold (Tienphong, 2021).

Figure 4.14: Number of E-Bikes and E-Motorcycles Produced in 2018–2020



Source: ICT News (2020).

In contrast, the electrified car market in Viet Nam, especially electric cars, is still in its early stage. Some projects on the development of electric cars have been carried out. In 2012, Siemens Vietnam and Vinamotor signed a contract to jointly produce a prototype bus with ELFA hybrid technology. This hybrid bus was officially introduced in 2013 and also approved by Vietnam Register in accordance with the operating conditions of our country's urban areas. However, this bus had a huge cost and still lacks support from the government (Automation Today, 2015; Tuan, 2019).

In 2016, the Mai Linh Group, one of the biggest taxi companies in Viet Nam, signed a memorandum of understanding with the genuine distributor of French carmaker Renault to import electric motor cars for use as taxis. However, this plan failed because there were no charging stations for electric taxis, and the long charging times are unsuitable for taxis (Vietnamnet, 2021). In 2017, VinFast, a part of Vingroup which is Viet Nam’s biggest private enterprise, was established with the aim to be a leading automobile and motorcycle manufacturer in Southeast Asia. Initially targeting the domestic vehicle market, VinFast fabricates electric motorbikes, electric buses, and (electric) cars. In its first phase, VinFast aims to produce 100,000–200,000 vehicles per year, including five-seat sedans, seven-seat sport utility vehicles (SUVs), and electric motorbikes. In 2018, Vinfast's first two prototypes, a sedan and an SUV, were introduced at the Paris Motor Show and a small car model called Fadil was also unveiled in Ha Noi. Vinfast's e-scooter factory has first-phase capacity of 250,000 scooters each year and the capacity designed for the second phase is 500,000 scooters each year and could reach 1 million (Vietnamplus, 2018). Its electric scooter models under the brand Klara have already been available on the market since November 2018 (now some other electric scooter models of Vinfast are also available including Feliz, Theon, and Ludo). Recently Vinfast has just also introduced a model of electric buses (Vinbus) and electric cars (VF E34) (but are not on the road yet).

Based on the report of Toyota Vietnam, the current hybrid and EV sales are very low with no more than 1,000 units (up to end 2020), adding about 600 units in the first quarter of the 2021, in which EVs contribute just about 1% (Toyota Vietnam, 2021; MOIT, 2021). These numbers do not include electric vehicles that are mostly less than 16 seats and without doors, sold to tourism companies, hotels, and households engaged in tourism services.

The obstacles of electric car development in Viet Nam include low income per capita, a lack of charging infrastructure, a lack of government incentives, and a lack of a comprehensive e-vehicle development strategy.

Furthermore, electricity generation source in Viet Nam is dominated by coal. As planned in Decision No 428/QD-TTg approval of the Revised National Power Development Master Plan for the 2011–2020 Period with the Vision to 2030, coal-fired thermal power contributes to 42.7% in 2020, 49.3% in 2025, and 42.6% in 2030 of the total capacity of power plants. In the Notification 263/BDKH-TTBVTOD of the Ministry of Natural Resources and Environment, the emissions factor of the electric grid in Viet Nam was calculated at 0.913 tCO_2/MWh.

C. Philippines

National Plan for xEVs (HEV, PHEV, BEV, FCEV) Promotion (existing and developing)

The Philippine Department of Energy (PDOE) is continuously embarking in prioritising plans and programmes regarding the promotion of alternative fuels and energy technologies (AFETs) as it is deemed necessary to address the issue on the increasing demand of the transport sector and the high dependency on imported conventional fuels. This is in partnership with other national government agencies (NGA) and the private sector to craft viable mechanisms and build-up local capacities. The use of AFETs in the energy mix for supply security and reduction of GHG emissions result in enhanced quality of air by providing options for gradual replacement of fossil-based fuels. In relation thereto, this shall serve as one of the key strategies in meeting the country's Nationally Determined Contribution to the Paris Agreement.

Following are the PDOE's medium and long-term objectives covering 2019 to 2040: (1) review, update, and formulate energy-related policies, guidelines, and standards; (2) scale-up the use of AFET; (3) pursue the use of sustainable energy efficient technologies; (4) collaboration with stakeholders; (5) alternative fuel vehicle mainstreamed in the transport sector; (6) continuing government initiatives; (7) priority AFETs; (8) assessment of non-transport energy technologies will be pursued; and (9) infrastructure support, the promotion, and deployment of EVs may come to fruition.

In May 2021, Senate Bill No. 1382 otherwise known as the Electric Vehicles and Charging Stations Act was approved to primarily promote EVs and aid in the country's emissions reduction objectives. One of the main highlights of the Act is the formulation of the Comprehensive Road Map on EVs (CREV) as well as the crafting of the guidelines specifically for the 'manufacturing, importation, utilisation, and regulation of EVs and hybrids as well as parts, components, and batteries' and mechanisms for charging stations across the country (Laurel, 2021).

Consistent with the Electric Vehicles and Charging Stations Act and the plans for increasing EV utilisation in the country, the Philippines is also aiming to be an auto-manufacturing hub, particularly to place third in the Southeast Asian region, through its 'low cost transportation and commercial vehicles' by banking on the country's significant contribution to exports of machinery and transport equipment (Cahiles-Magkilat, 2020).

Government Support and Incentives for xEVs (HEV, PHEV, BEV, FCEV), e.g. Subsidy, Mandate

Through the Electric Vehicles and Charging Stations Act, fiscal incentives are to be availed by entities engaged in the activities concerning manufacturing, importation and utilisation through several NGAs such as the Department of Trade and Industry (DTI), the Land Transportation Office, and the Metropolitan Manila Development Authority. The fiscal incentives include the income tax holiday, import exemption from excise taxes, duties and value-added tax, and discounts from payment of motor vehicle user's charges, registration, and inspection fees, amongst others. Also, the DTI through its Board of Investments shall formulate and carry out an EV incentive strategy in line with the CREV.

While non-fiscal incentives can also be granted for EV activities related to the expedition of applications and registrations with NGAs and local government units, exemption from some existing mechanisms for conventional vehicles fleets is imposed by the Metropolitan Manila Development Authority. Other support initiatives are to be provided by institutions through financial assistance in accordance with the Act.

CO_2-related Information (well-to-tank) for Electricity

In line with the PDOE's objectives, a technology demonstration was conducted for the validation and pilot testing of AFETs with potential for commercialisation. Among those included in the said activity were EVs, hybrid vehicles, and plug-in hybrids. EVs involved in the demonstration were described as 'powered by electricity through battery packs' and were identified with 51km/litre equivalent efficiency and no tailpipe emissions as compared to gasoline with 29.23 km/litre equivalent efficiency and 101 g CO_2/km emissions.

Official xEV Target by Year (at least up to 2030)

According to the DTI and the Electric Vehicle Association of the Philippines' EV Comprehensive Road Map, the industry is targeting about 21% EV utilisation by 2030 out of the total vehicle population specifically focusing on public transportation. By 2040, the industry target is set at 50% EVs of the total vehicles being utilised in the country for the said period (Cahiles-Magkilat, 2020).

Further, based on the Electric Vehicles and Charging Stations Act and its corresponding CREV, it is mandated that around 5% EV utilisation shall be realised through a gradual increase involving the vehicle fleets of those belonging to the government and corporate sectors.

Statistics of Vehicle (gasoline and diesel type) Registration

According to the LTO (2021), registered motor vehicles using gasoline and diesel fuel as of end 2020 reached 11.85 million or a decrease of 6.87% as compared to the 2019 level which was around 12.73 million. The decrease was attributed to the absence of transactions relating to registrations during the month of April 2020 due to the quarantine classifications imposed across all regions in the Philippines during the pandemic.

Statistics of xEV (HEV, PHEV, BEV, FCEV) Registration

The number of registered EVs through the LTO as of 2019 was recorded at 5,002 units encompassing e-trikes, e-quads, e-jeeps, e-motorcycles, e-trucks and e-buses including the 3,000 units of e-trikes from the PDOE E-trike Project. While market projections for 2020 and 2021 are set at 1,750 and 1,930 additional units, additional registered EVs for 2020–2021 are seen to be greatly affected by the ongoing pandemic and recovery in the EV market is targeted to come in the second semester of 2021.

Vehicle Assumption, e.g. Average Vehicle Kilometre of Travel, Average Vehicle Fuel Economy (gasoline and diesel)

Based on the PDOE's 2016 Fuel Economy Run at 280-kilometre distance consisting of various vehicle types and models, the average fuel consumption at Euro 4 is at 12.894 litres for gasoline and 13.205 litres for diesel.

D. India

To ensure a cleaner and sustainable energy security and to establish a net zero emissions regime, the Government of India is promoting deployment of electricity vehicles at the larger scale. The major initiative towards this direction started in 2013 when the National Electric Mobility Mission Plan was launched. Under this plan an outlay Rs14,000 crore (1 crore is 10,000,000) were envisaged up to 2020. The focus of this plan was to promote demand incentives, manufacturing, charging infrastructure development, and R&D. Since then, various plans have been launched. The important plans are:

FAME 1: In 2015 The Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME 1) was launched. The salient features of this plan are:

- Budget outlay: Rs895 crore
- Focus: market Development of EVs focusing on demand incentives, technology development, pilot project, and charging infrastructure
- Outcome: 2.78 lakh (1 lakh is 100,000) XEVs and 465 buses received subsidy

National Mission on Transformative Mobility and Storage (Policy Statement) was launched in 2017. The important features of this plan are:

•Policy with a mission to coordinate with key stakeholders in ministries, departments, and the states for integrated actions.

•Focus: Road Map for Battery Manufacturing (Phased Manufacturing Plans), Support sustainable mobility ecosystem. Progressive support across regulations. charging technologies, manufacturing, recreational vehicle (RV) integration.

FAME 2 was launched in 2019. The salient features are:

•Total outlay of Rs10,000 crore for a period of 3 years

•Focus: Electrification of public and shared transportation (7,000 e-buses, 5 lakh electric 3W, 55,000 electric 4W, and 10 lakhs electric 2W).

State Policies: While the above polices have been launched by the Central Government of India, except for five states, most states have yet to come out with EV policies. The following depicts the state policies (NITI Aayog, Government of India):

Delhi: Targets 25% EV sales by 2024. State-level incentives over and above central incentives. Purchase incentives for all categories of private and commercial EVs. Waiver in fees, allowance to sell EVs without batteries (battery as a service concept), scrappage incentives, subsidy for private charging points, special tariffs, introduction of feebates (fee collection from polluting vehicles), tax waivers.

Andhra Pradesh: Targets 1 million EVs by 2024 and 100% e-buses by 2029. Focus: Support for setting up manufacturing through in-kind support, fee waivers, and reimbursement.

Karnataka: Focus: R&D, production, services, and customer support with indirect incentives for R&D units, manufacturing and charging networks, and start-up ecosystems.

Kerala: Targets 1 million EVs on the road by 2022. Focus: R&D, production, services, and customer support with indirect incentives for R&D units, manufacturing and charging networks.

Uttar Pradesh: Targets 1 million EVs and 70% electrification of public transport by 2030. 2 lakh charging points by 2024. Focus on manufacturing.

Current Status and Indicators of EVs

The indicators of EV progress and current status are:

- India's 2030 EV ambition, signalled by NITI Aayog, states that 70% of all commercial cars, 30% of private cars, 40% of buses, and 80% of two- and three-wheeler sales in 2030 would be electric.
- At the end of March 2020, the total number of registered electric vehicles in India stood at only half a million.
- The EV sector registered nearly 1.35 lakh EVs in FY21. Three-wheeler EVs made up 65% of all EV registrations in FY21, having comprised 83% of the market in the year
- The Indian automobile market has registered over 6.38 lakh EVs in 2020–21 since 2011–12.
- According to the Council of Energy, Environment and Water-Centre for Energy Finance study, the cumulative EV sales in all vehicle segments could cross over 100 million units by FY2030 which is 200 times its current market size.
- India's EV ambition would require an estimated annual battery capacity of 158 GWh by FY2030.
- India would also need a network of over 2.9 million public charging points by FY2030, beyond the in-home charging points. Currently, there are just 1,800 public charging points across the country.
- It will require a cumulative investment of up to $2.9 billion (Rs20,600 crore) until 2030.

Challenges

Although India has an ambitious plan to deploy electrical vehicles at the larger scale covering about 70% to 80% of transportation vehicles by 2030, there are some challenges which need to be addressed.

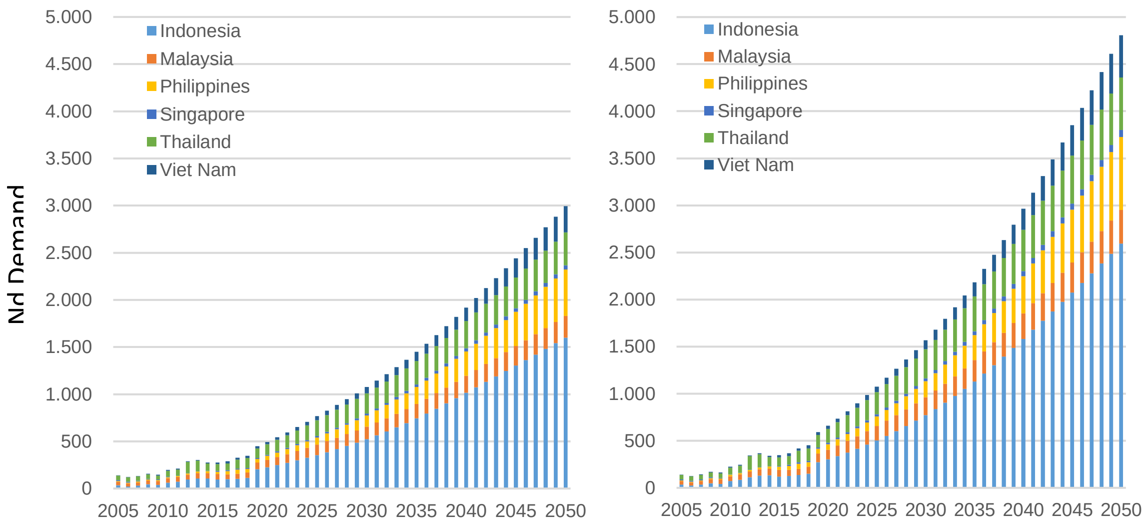
- Demand incentives absent for private EVs (except for Delhi): FAME 2 slow to pick up – 1.4% utilisation of incentives as of July 2020.
- Significant challenges in scaling-up manufacturing value chains, especially for batteries, mainly on account of raw material and technology constraints.
- Limited support and capability in innovation and technology development and R&D.
- Weak and highly-loaded distribution grid infrastructure posing potential challenges to implementation of charging infrastructure, especially high-power charging infrastructure
- Lack of coordination between the central and state governments to implement EV policies.

3. Evaluation of Mineral Resource Consumption Regarding Vehicle Electrification

This study describes the results of our predictions for the demand and waste of Nd and Co in response to the electrification of automobiles in each country, as predicted by each of the two evaluation methods described in Section 2.

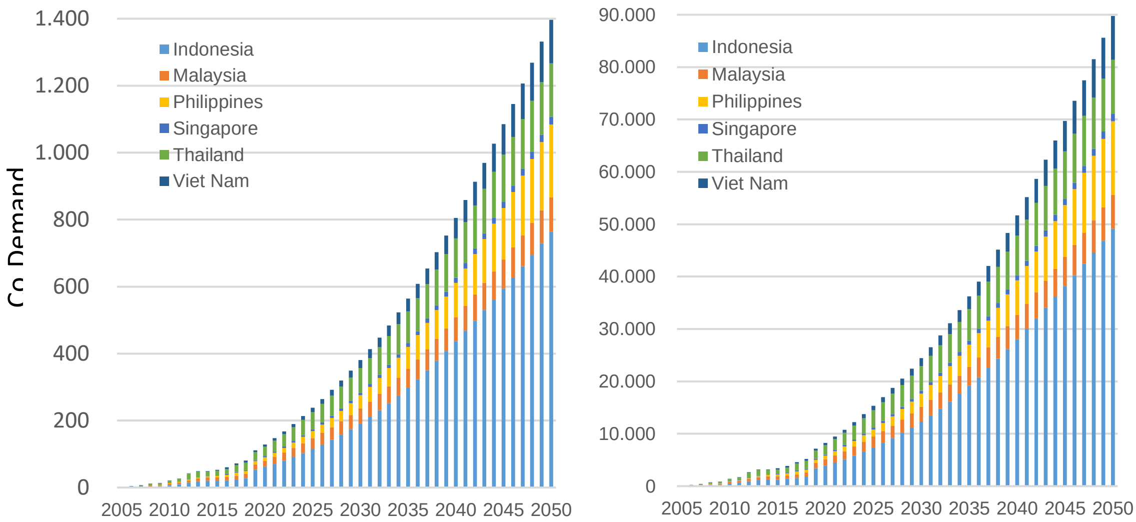
Figures 4.15 to 4.18 show the results of these estimations by first calculating the number of vehicles that were sold and the number of vehicles that were discarded; these values were then compared to the calculated values in Method 1.

Figure 4.15: Neodymium Demand Minimum (left) and Maximum (right) Value



Nd = neodymium, t/y = ton/year.
Source: Authors

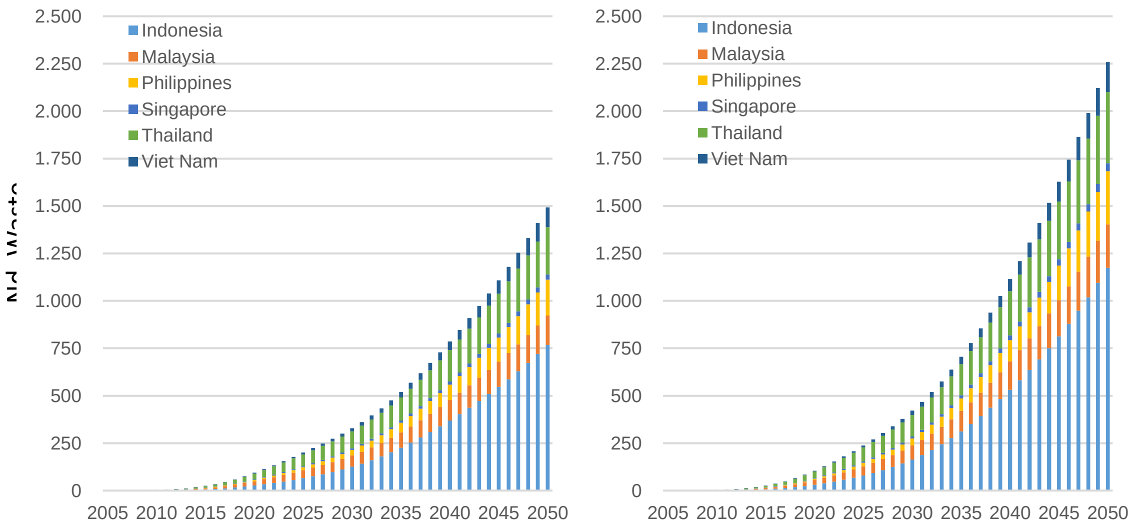
Figure 4.16: Cobalt Demand Minimum (left) and Maximum (right) Value



Co = cobalt, t/y = ton/year.
Source: Author.

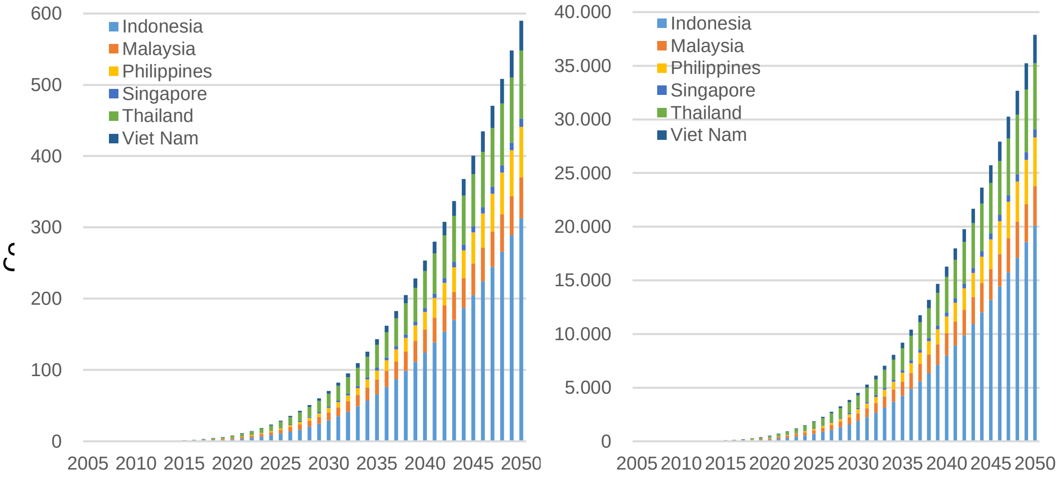
From the result of Figures 4.15 and 4.16, the total demand of neodymium is predicted to be a minimum of 2,996 t/y to a maximum of 4,809 t/y in 2050 based on Method 1. Moreover, the total demand of cobalt is predicted to be a minimum of 1,397 t/y to a maximum of 89,762 t/y in 2050.

Figure 4.17: Neodymium Waste Minimum (left) and Maximum (right) Value



Nd = neodymium, t/y = ton/year.
Source: Morimoto (2021).

Figure 4.18: Cobalt Waste Minimum (left) and Maximum (right) Value

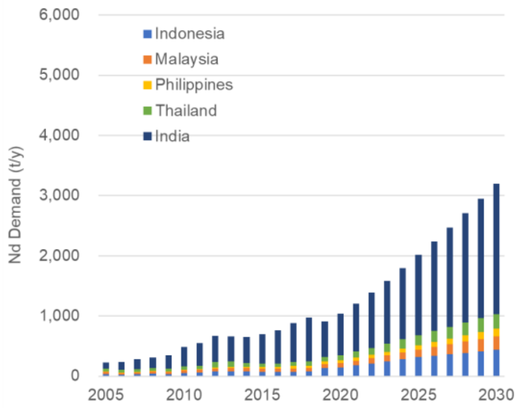


Co = cobalt, t/y = ton/year.
Source: Morimoto (2021).

From the result of Figures 4.17 and 4.18, the total waste of neodymium is predicted to be a minimum of 1,494 t/y to a maximum of 2,260 t/y in 2050. Moreover, the total waste of cobalt is predicted to be a minimum 590 t/y to a maximum 37,896 t/y in 2050. Therefore, based on Method 1, secondary resource can cover 47% to 50% of neodymium demand and 42% of cobalt demand if the recycle rate is 100%.

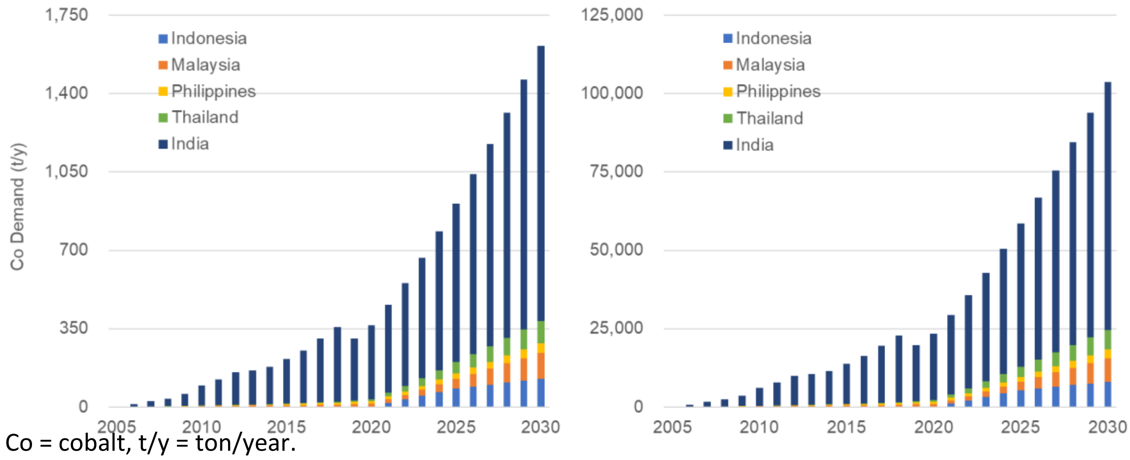
Figures 4.19 to 4.22 show the results of these estimations by first calculating the number of vehicles that were sold and the number of vehicles that were discarded; these values were then compared to the calculated values in Method 2. However, countries that included in the estimation is deferent between Method 1 and Method 2. This is due to the difference in source data that Deloitte's data did not include India, but original data was collected from projected member in Method 2.

Figure 4.19: Neodymium Demand Minimum (left) and Maximum (right) Value



Nd = neodymium, t/y = ton/year.
Source: Morimoto (2021).

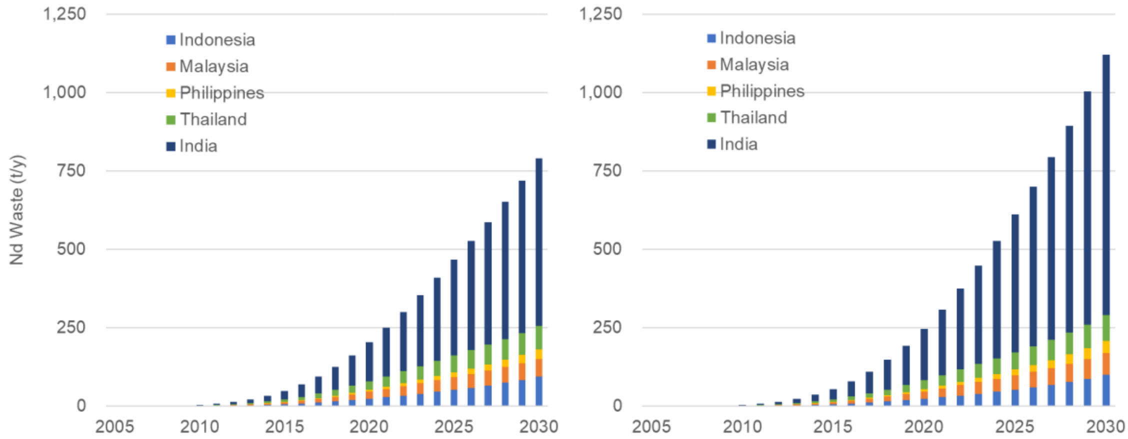
Figure 4.20: Cobalt Demand Minimum (left) and Maximum (right) Value



Co = cobalt, t/y = ton/year.
Source: Morimoto (2021).

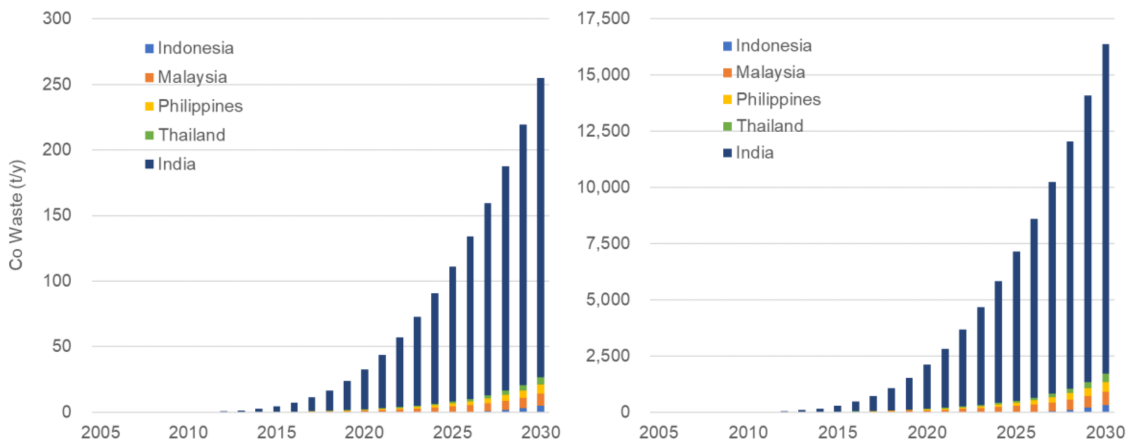
From the results of Figures 4.19 and 4.20, the total demand of neodymium is predicted to be a minimum of 3,200 t/y to a maximum of 5,295 t/y in 2030 based on Method 2 (including India). Moreover, the total demand of cobalt is predicted to be a minimum of 1,614 t/y to a maximum of 103,720 t/y in 2030.

Figure 4.21: Neodymium Waste Minimum (left) and Maximum (right) Value



Nd = neodymium, t/y = ton/year.
Source: Morimoto (2021).

Figure 4.22: Cobalt Waste Minimum (left) and Maximum (right) Value



Co = cobalt, t/y = ton/year.
Source: Morimoto (2021).

From the results of Figures 4.21 and 4.22, the total waste of neodymium is predicted to be a minimum of 791 t/y to a maximum of 1,121 t/y in 2030. Moreover, the total waste of cobalt is predicted to be a minimum t/y 255 to a maximum of 16,374 t/y in 2030. Therefore, based on Method 2, secondary resource can cover 21% to 25% of neodymium demand and 16% of cobalt demand if the recycle rate is 100%.

4. **Discussion**

This chapter described the results of the estimation for the long-term mineral resource demand associated with automobile electrification in EAS countries. In addition, this chapter described the results of the assessment of the potential for recycling in these countries by determining the amount of waste of these mineral resources.

As the conclusion, the demand for neodymium is predicted to be a minimum of 2,996 t/y to a maximum of 4,809 t/y in 2050 based on Method 1 and a minimum of 3,200 t/y to a maximum of 5,295 t/y in 2030 based on Method 2 (including India). If the recycle rate is 100%, secondary resources can cover 47% to 50% of neodymium demand based on Method 1 and 21% to 25% based on Method 2.

Moreover, the total demand for cobalt is predicted to be a minimum of 1,397 t/y to a maximum of 89,762 t/y in 2050 based on Method 1 and a minimum of 1,614 t/y to a maximum of 103,720 t/y in 2030 on Method 2. If the recycle rate is 100%, secondary resources can cover 42% of cobalt demand based on Method 1 and 16% based on Method 2.

However, considering that production of neodymium was 43,200 REO tons/year and cobalt was 140,000 tons/year in 2020, it is predicted to be difficult that world supply will meet the target of EAS mobility electrification regarding the large increase of demand in China, the European Union, and United States.

Therefore, it is necessary to consider the balance between biofuels and mobility electrification based on the potential of secondary resources and circular economy.

References

ASEAN Storage (2020), 'ASEAN Leaders' Vision Statement on a Cohesive and Responsive ASEAN'.

Automation Today (2015), 'SIEMENS ELFA Technology for City Bus and Technology Transfer to Vietnam', http://automation.net.vn/Cong-nghe-Ung-dung/Cong-nghe-truyen-dong-dien-keo-SIEMENS-ELFA-cho-xe-Buyt-do-thi-va-viec-chuyen-giao-ve-Viet-Nam.html (in Vietnamese)

Cahiles-Magkilat, B. (2020), 'PH Eyes 21% EVs of all Vehicles by 2030', *Manila Bulletin*, 28 September. https://mb.com.ph/2020/09/28/ph-eyes-21-evs-of-all-vehicles-by-2030/

Chan, K. H., J. Anawati, M. Malik, and G. Azimi (2021), 'Closed-Loop Recycling of Lithium, Cobalt, Nickel, and Manganese from Waste Lithium-Ion Batteries of Electric Vehicles', ACS *Sustainable Chem. Eng*. 2021, 9(12), pp.4398–410. https://doi.org/10.1021/acssuschemeng.0c06869

CEIC (2015), Vietnam Registered Motor Vehicles. https://www.ceicdata.com/en/indicator/vietnam/motor-vehicle-registered (accessed 10 June 2021).

Decision of The Prime Minister of Vietnam Government (2014). About approval for strategy to develop automotive industry in VietNam by 2025, orientation towards 2035. https://vanbanphapluat.co/decision-no-1168-qd-ttg-dated-2014-strategy-to-develop-automotive-industry-in-vietnam-by-202

Deloitte (2021), 'Full Speed Ahead Supercharging Electric Mobility in Southeast Asia', March.

Economic Research Institute for ASEAN and East Asia (ERIA) (2020), *Assessing the Readiness for Industry 4.0 and the Circular Economy*. Jakarta: ERIA.

Electric Vehicle Association of the Philippines (EVAP) (2021), 'Statistics of Registered Electric Vehicles in the Philippines'. *9th Virtual Philippine Electric Vehicles Summit 2021*, 23–24 September.

Electric Vehicle Association of Thailand (EVAT) (2021), www.evat.or.th (accessed 30 June 2021).

Energy Policy and Planning Office (EPPO) (2019), Energy Policy and Planning Office, Study and Survey of Energy Usage in Transport Sector.

EPPO (2020), 'Power Development Plan 2018rev1'. http://www.eppo.go.th/images/Infromation_service/public_relations/PDP2018/PDP2018Rev1.pdf

Ghadimzadeh, A., A.A. Makmom, M.K. Hosea, N. Asgari, R. Shamsipour, A. Askari, and T.S. Narany (2015), 'Review on CO_2 Emission from Transportation Sector in Malaysia', *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 9(5), pp.61–70.

ICT News (2020), 'E-bikes and E-motorcycle Market'. https://ictnews.vietnamnet.vn/kham-pha/thi-truong-xe-dien-sut-giam-manh-nhieu-doanh-nghiep-dung-san-xuat-267243.html (in Vietnamese) (accessed 10 June 2021).

International Monetary Fund (IMF) (2020), https://www.imf.org/en/Data

International Organization of Motor Vehicle Manufacturers (2020), https://www.oica.net/category/vehicles-in-use/

Iskandar, M.L., and A.S. Ariffin (2019), 'Relationship between National Automotive Policy (NAP), Innovation and Automotive Vendors' Performance in Malaysia', *Manag. Sci. Lett*. 2019(9), pp.1181–98.

Laurel, D. (2021), 'EV and Charging Stations Act Passes PH Senate in Third Reading', *Top Gear Philippines.* https://www.topgear.com.ph/news/motoring-news/ev-and-charging-stations-act-senate-a962-20210531

Malaysia Ministry of International Trade and Industry (2020), National Automotive Policy 2020 (NAP), pp.1–68. https://www.miti.gov.my/index.php/pages/view/nap2020 (accessed 15 June 2021).

Mercado, N.A. (2021), 'House Panel OK Regulatory Framework for Use of Electric Vehicles', *Inquirer*, 12 May. https://newsinfo.inquirer.net/1430705/house-panels-ok-regulatory-framework-for-use-of-electric-vehicles

MOIT (2021), 'Electric cars in Vietnam are still very modest'. https://moit.gov.vn/tin-tuc/phat-trien-cong-nghiep/o-to-dien-o-viet-nam-van-con-rat-khiem-ton-.html (in Vietnamese), (accessed 2 November 2021).

Morimoto, S., K. Sanematsu, K. Ozaki, A. Ozawa, and Y. Seo (2019), 'Methodological Study of Evaluating the Traceability of Neodymium Based on the Global Substance Flow Analysis and Monte Carlo Simulation', *Resource Policy,* 63, 101448. DOI: 10.1016/j.resourpol.2019.101448

Morimoto, S., Y. Cheng, N. Mizukoshi, and K. Tahara (2020), 'Methodological Study of Evaluating Future Lightweight Vehicle Scenarios and CO_2 Reduction Based on Life Cycle Assessment', *Sustainability,* 12(14), p.5713. DOI:10.3390/su12145713

Office of the Economic and Social Development Board (OESDB) (2018*), National Strategy 2019–2037.* https://oia.coj.go.th/th/file/get/file/201901317934e3f549573c6542707b1fb9680e48104421.pdf

Office of Industrial Economics (OIE) (2021), Office of Industrial Economics Eco Sticker. http://www.car.go.th and http://www.motorcycle.go.th

Office of Transport and Traffic Policy and Planning (OTP) (2016), 'Study of an Approach to Tracking of Energy Consumption Reduction from the Transport Sector Measures'. https://www.otp.go.th/edureport/view?id=139

Philippines (2008), Joint Administrative Order No. 2008-1, Series of 2008, Guidelines Governing the Biofuel Feedstocks Production, and Biofuels and Biofuel Blends Production, Distribution and Sale under Republic Act No. 9367. 8 October. https://www.doe.gov.ph/sites/default/files/pdf/issuances/jao-no-2008-1.pdf

Philippines (2020). Senate Bill No. 1382, An Act Providing the National Energy Policy and Regulatory Framework for the Use of Electric Vehicles and the Establishment of Electric Charging Stations. http://legacy.senate.gov.ph/lisdata/3242729284!.pdf

Philippine Department of Energy (2007), Republic Act No. 9367. An Act to Direct the Use of Biofuels, Establishing for this Purpose the Biofuel Program, Appropriating Funds therefore, and for Other Purposes. 12 January. https://www.doe.gov.ph/sites/default/files/pdf/issuances/ra_9367.pdf

Philippine Department of Energy (PDOE). *Philippine Energy Plan 2018–2040*. https://www.doe.gov.ph/sites/default/files/pdf/pep/pep-2018-2040_20210323.pdf

Philippines Land Transportation Office (2021), *Annual Report 2020* as of December 2020. https://lto.gov.ph/transparency-seal/annual-reports/file/1167-annual-report-2020-as-of-december-2020.html

The Prime Minister of Vietnam Government (2014). About approval for strategy to develop automotive industry in VietNam by 2025, orientation towards 2035.

https://vanbanphapluat.co/decision-no-1168-qd-ttg-dated-2014-strategy-to-develop-automotive-industry-in-vietnam-by-2025

The Prime Minister of Vietnam (2015). About Development Strategy of Renewable Energy of Vietnam by 2030 with a Vision to 2050. https://policy.asiapacificenergy.org/node/3447

Rahim, N.A., H.S. Che, M. Hasanuzzaman, and A. Habib (2019), 'Toward Cleaner Cities: Renewable Energy Initiatives in Malaysia', In H. Farzaneh (ed.) *Devising a Clean Energy Strategy for Asian Cities.* Singapore: Springer Singapore, pp.165–85.

Tienphong (2021), 'The Vietnamese Market is Waiting for a Boom from Electric Motorbikes'. https://tienphong.vn/thi-truong-viet-nam-cho-doi-bung-no-tu-xe-may-dien-post1350838.tpo (in Vietnamese) (accessed 2 November /2021).

Tuan L.A. (2019), 'Status of Electric Vehicle Development in Vietnam', *Vietnam EV Forum*, 29 March.

Thailand Board of Investment (BOI) (2020a), 'Thailand Car Makers Ramp Up Electric Vehicle Capacity in Thailand, Investment Board Says', Press Release, 30 June. https://www.boi.go.th/index.php?page=press_releases_detail&topic_id=125377

Thailand BOI (2020b), 'Thailand BOI Approves New EV Package, and Over 35 Billion Baht in Large Investment Projects', 4 November. https://www.boi.go.th/upload/content/no.141_2563.pdf

Thailand Department of Land Transport (DLT) (2021), www.dlt.go.th (accessed 30 June 2021).

Thailand National EV Policy Committee (2020), Meeting Minutes on 11 March 2020.

Thailand National EV Policy Committee (2021), Meeting Minutes on 24 March 2021.

Toyota Vietnam (2021) Status of Electrified Vehicle Development in Vietnam. Workshop on Efficiency Evaluation of Hybrid Technology in Vietnam, Ha Noi, 3/2021.

Vietnam Automobile Manufacturers' Association (VAMA) (2021), 'VAMA Sales Report'. http://vama.org.vn/Data/upload/files/2020/Thang12-2020/Cover%20Letter%20Sales%20report%20-%20December%202020%20-%20VIE.pdf (in Vietnamese)

VAMM (2021), 'Sales Report'. https://vamm.vn/bao-cao-ban-hang/ (in Vietnamese)

Vietnamnet (2016), 'Motorcycles in Vietnam'. https://vietnamnet.vn/vn/oto-xe-may/xe-may-tai-viet-nam-nhung-con-so-giat-minh-327440.html (in Vietnamese) (accessed date 10 June 2021).

Vietnamnet (2021), 'Battery Technology will Determine Race for Electric Cars', 13 April. https://vietnamnet.vn/en/feature/battery-technology-will-determine-race-for-electric-cars-726943.html

Vietnamplus (2018), 'Vinfast Launches New E-scooter', 5 November. https://en.vietnamplus.vn/vinfast-launches-new-escooter/141303.vnp

Vietnam Register (2021a), 'Vehicle Number Statistics'. http://www.vr.org.vn/thong-ke/Pages/tong-hop-so-lieu-phuong-tien-giao-thong-trong-ca-nuoc.aspx (in Vietnamese) (accessed 4 June 2021).

Vietnam Register (2021b), 'Passenger Car's Fuel Consumption List'. http://203.162.20.156/vaq/Tieuthu_Nlieu/List_Tieuthu_nlieu.asp (in Vietnamese) (accessed 10 June 2021).

United Nations (2015), Paris Agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf (accessed 5 August 2016).

United States Geological Survey (USGS) (2021), *Mineral Commodity Summaries 2021.* https://doi.org/10.3133/mcs2021

Chapter 5

Conclusion as Policy Recommendations

1. Introduction

The National Institute of Advanced Industrial Science and Technology (AIST) has been studying future mobility scenarios of East Asia Summit (EAS) countries since 2014. In the past AIST–ERIA project, the scenarios for India, Indonesia, and Thailand were examined considering the potential of biofuels and electrified vehicles (xEVs). As the result, well-to-wheel CO_2 emissions were estimated for several scenarios by creating energy mix model.

However, in the previous project, the sustainability of biofuels and xEVs has not yet been taken into consideration. Diffusion of xEVs can contribute to CO_2 reduction, but mfay affect mineral resource demand induced by motors and batteries. Therefore, the aim of this project is to analyse future scenarios of EAS mobility which highly contribute to the Sustainable Development Goals (SDGs) (7, 12, and 13) in consideration of the balance between transport CO_2 reduction, biofuel use, and mineral resources demand. The outcome will contribute to the EAS Energy Research Road Map (Pillar 3: Climate Change Mitigation and Environmental Protection corresponding to ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025 3.5 Programme Area No.5: Renewable Energy and 3.6 Programme Area No.6: Regional Energy Policy and Planning).

In fiscal year 2020, the first phase of this project was conducted. The working group meetings were conducted in November 2020 and May 2021. As the result, biofuel policies and strategies, as well as existing research on biofuels sustainability were assessed for the EAS countries (India, Thailand, Malaysia, Viet Nam, Indonesia, and Philippines). Moreover, a database was created to evaluate well-to-wheel CO_2 reduction and mineral resource demand based on the biofuel implementation and mobility electrification. This chapter describes the conclusion and progress of each study (chapters).

2. Biofuel Policies and Biofuel Implementation in East Asia Summit Countries

In chapter 2, existing biofuel policies and implementation plan from selected EAS countries were assessed as a foundation to accommodate emerging electric vehicle trends during mobility energy transition. Biofuel policies mechanism was analysed and past and existing biofuel polices and regulations in the context of potential EV scenario (discussed in Chapter 4) were reviewed.

As the conclusion, multi-benefits of biofuel implementation does not only lie upon reduced fossil fuel import and reduced tank-to-wheel CO_2 emissions, but also by added value and demand creation for agriculture product. However, this biofuel policies and implementation schemes must be carefully pursued within the context of sustainability, especially during transition toward electric mobility in the future.

3. Review of Biofuels Sustainability Assessment and Sustainability Indicators in EAS Countries

The progress of sustainability assessment of biofuels in the East Asia region was evaluated with examples of some of the participating countries (India, Thailand, Indonesia, Philippines, Malaysia, and Viet Nam) using 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 was anticipated to 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.

As the conclusion, this report provided 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 (Kudoh et al., 2015). These indicators are also aligned with those provided by the Global Bioenergy Partnership (GBEP, 2011). 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, although some studies have cautioned that these reductions could be overturned should forest land be converted to agriculture for cultivating biofuel feedstock. 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 several research studies from academia that have provided the information (e.g. Gheewala, 2013; Gheewala et al., 2011; Silalertruksa and Gheewala, 2011, 2012a, 2012b). On the other hand, for Viet Nam, the information has come from a recent study by the Food and Agriculture Organization of the United Nations (FAO, 2018). It is hoped that at the next step of the project, 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.

4. Vehicle Electrification and Consumption of Mineral Resources in East Asia Summit Countries

The long-term mineral resource demand associated with automobile electrification in EAS countries was estimated and the potential for recycling in these countries were assessed by determining the amount of waste of these mineral resources. Furthermore, effectiveness of introducing a circular economy in EAS countries was evaluated.

As the conclusion, the demand of neodymium is predicted to be a minimum of 2,996 ton/year (t/y) to a maximum of 4,809 t/y in 2050 based on Method 1 and a minimum of 3,200 to a maximum of 5,295 t/y in 2030 based on Method 2 (including India). If the recycle rate is 100%, secondary resources can cover 4%7 to 50% of neodymium demand based on Method 1 and 21 to 25% based on Method 2.

Moreover, the total demand of cobalt is predicted to be a minimum of 1,397 t/y to a maximum of 89,762 t/y in 2050 based on Method 1 and a minimum of 1,614 t/y to a maximum of 103,720 t/y in 2030 on Method 2. If the recycle rate is 100%, secondary resource can cover 42% of cobalt demand based on Method 1 and 16% based on Method 2.

However, considering that production of neodymium was 43,200 rare earth oxide t/y and cobalt was 140,000 t/y in 2020 (USGS, 2021), it is predicted to be difficult that world supply will meet the target of EAS mobility electrification due to the large increase of demand in China, the European Union, and the United States. Therefore, the need of considering the balance between biofuels and mobility electrification was revealed based on the potential of secondary resources and circular economy.

5. Conclusion and Future Aspects

This study assessed the policies and strategies for biofuels and mobility electrification, as well as existing research on biofuels sustainability for the EAS countries (India, Thailand, Malaysia, Viet Nam, Indonesia, and Philippines). Despite the data insufficiency, several databases were created to evaluate well-to-wheel CO_2 reduction of biofuel implementation and mineral resource (neodymium and cobalt) demand based on the mobility electrification.

As the conclusion, the synergies between biofuel implementation and mobility electrification were clarified, which highly contribute to the SDGs. Biofuel implementation will add extra value by demand creation for agriculture products and therefore, creating a circular economy will lead to an improvement on collecting waste agriculture products. This perspective is also similar for recycling mineral resources since secondary resources can covers 21% to 50% of neodymium demand and 16% to 42% of cobalt demand in mobility electrification. As the conclusion, creating a circular economy will bring multi-benefits for both agriculture and mineral resources sustainability and therefore, sustainability assessment from environmental, social, and economic indicators will be necessary.

For further studies, well-to-wheel CO_2 reduction of biofuel implementation and dynamic material flow analysis of mineral resource will be conducted. The sustainability assessment will then be conducted with more concrete data for each (environmental, social, and economic) indicators using country-level information rather than discrete and specific case studies from the literature that may have been designed for a different purpose. This will bring more uniformity to the overall sustainability assessment of biofuels for the region. Furthermore, the synergies as well as multi-benefits between biofuel implementation and mobility electrification will be more clarified with all sustainability indicators. At last, the sustainable mobility scenarios for EAS countries will be created considering the achievement of the SDGs.

References

Food and Agriculture Organization of the United Nations (FAO) (2018), 'Sustainability of Biogas and Cassava-based Ethanol Value Chains in Vietnam', *FAO Working Paper 69.*

Gheewala, S.H. (2013), 'Environmental Sustainability Assessment of Ethanol from Cassava and Sugarcane Molasses in a Life Cycle Perspective', In A. Singh, S.L. Olsen, and D. Pant (eds.) *Life Cycle Assessment of Renewable Energy Sources*, Springer, pp.131–43.

Gheewala, S.H., T. Silalertruksa, P. Nilsalab, R. Mungkung, S.R. Perret, and N. Chaiyawannakarn (2013), 'Implications of the Biofuels Policy Mandate in Thailand on Water: The Case of Bioethanol', *Bioresource Technology,* 150, pp.457–65.

Gheewala, S.H., S. Bonnet, K. Prueksakorn, and P. Nilsalab (2011), 'Sustainability Assessment of a Biorefinery Complex in Thailand', *Sustainability*, 3, pp.518–30.

Global Bioenergy Partnership (GBEP) (2011), *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy* (First Edition). http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf (accessed 16 May 2021).

Kudoh, Y. et al. (2015), 'A Region-specific Methodology for Assessing the Sustainability of Biomass Utilisation in East Asia', *Sustainability*, 7, pp. 16237–16259.

Sagisaka, M. (2008), 'Sustainable Biomass Utilisation Vision in East Asia', *ERIA Research Project Report 2007, No. 6–3*. Jakarta: ERIA. https://eria-development.website/eria/Publications/Detail/sustainable-biomass-utilisation-vision-in-east-asia

Silalertruksa T. and S.H. Gheewala (2011), 'Long-term Bio-ethanol System and its Implications on GHG Emissions: A Case Study of Thailand', *Environmental Science and Technology*, 39, pp.834–43.

Silalertruksa, T., and S.H. Gheewala (2012a), 'Food, Fuel and Climate Change: Is Palm-based Biodiesel a Sustainable Option for Thailand? *Journal of Industrial Ecology*, 16(4), pp.541–51.

Silalertruksa, T. and S.H. Gheewala (2012b), Environmental Sustainability Assessment of Palm Biodiesel Production in Thailand', *Energy*, 43(1), pp.306–14.

United States Geology Survey (USGS) (2021), *Mineral Commodity Summaries 2021.* https://doi.org/10.3133/mcs2021