Promoting the Production of Sustainable Aviation Fuels from Agricultural Waste in the ASEAN Region

→ Techno-Economic Assessment Report

April 2025

Project Lead: GHD
Project Sponsor: CTIF
Beneficiary: ASEAN Secretariat
Knowledge Partner: Boeing

Contents

Abbreviations

AD	Anaerobic Digestion
AEP	Agro-Eco Philippines
AJCEP	ASEAN-Japan Comprehensive Economic Partnership
AKFTA	ASEAN-Korea Free Trade Agreement
ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
ATJ	Alcohol to Jet
BAFS	Bangkok Aviation Fuel Services
BBGI	Bio-Based Gasoline and Jet Fuel Initiative
bpd	Barrels per Day
bpsd	Barrel per Stream Day
BSGF	Bio-Synthetic Gasoline and Fuel
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CCO	Crude Coconut Oil
CEPT	Common Effective Preferential Tariff
CESDR	Center for Engineering and Sustainable Development Research
CI	Carbon Intensity
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
C-SAF	Canadian Council for Sustainable Aviation Fuels
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTC	Sugarcane Technology Centre
CTIF	Canadian Trade and Investment Facility for Development
DENR	Department of Environment and Natural Resources
DHL	Deutsche Post DHL Group
DOE	Department of Energy
DTI	Department of Trade and Industry
E&S	Environmental and Social
EA	Energy Absolute Plc

Abbreviations

EFB	Empty Fruit Brunches
EIA	Environmental Impact Assessment
Est	Estimated
ETS	Emissions Trading System
EU	European Union
EU ETS	European Union Emissions Trading System
FAA	Federal Aviation Administration
FAME	Fatty Acid Methyl Esters
FAOSTAT	Food and Agriculture Organisation Statistics
FAST	Fueling Aviation's Sustainable Transition
FGV	Federal Land Development Authority (Malaysia)
FPIC	Free, prior, and informed consent
FT	Fischer-Tropsch
FTA	Free Trade Agreements
FT-SPK	Fischer-Tropsch Synthetic Paraffinic Kerosene
FT-SPK/A	Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics
GAC	Global Affairs Canada
GAP	Good Agricultural Practices
GEWE	Gender Equality and Women's Empowerment
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
GoO	Guarantee of Origin
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Technologies
GWP	Global Warming Potential
HEFA	Hydro-processed Esters and Fatty Acids
HTL	Hydrothermal liquefaction
HVO	Hydrotreated vegetable oils
ICAO	International Civil Aviation Organization
ICC	International Coconut Community
IEA	International Energy Agency

Abbreviations

ILUC	Indirect Land Use Change
IMO	International Maritime Organisation
IPAC	Institute of Public Administrators of Canada
IPCC	Intergovernmental Panel on Climate Change
IPRA	Indigenous Peoples' Rights Act
IRA	Inflation Reduction Act
IRR	Internal Rate of Return
IRRI	International Rice Research Institute
ISCC	International Sustainability & Carbon Certification
ISO	International Organisation for Standardisation
ISPO	Indonesian Sustainable Palm Oil Standard
kg	Kilograms
km	Kilometre
KLIA	Kuala Lumpur International Airport
Lao PDR	Lao People's Democratic Republic
LCA	Life Cycle Assessment
LCEF	Low Carbon Energy Fund
LCO	Levelised Cost
LCOE	Levelised Cost of Electricity
LPG	Liquefied Petroleum Gas
m	Meter
MAG	Modernization of Agricultural Growth
MCA	Multiple Criteria Analysis
MH	MH Bio-Energy
MJ	Megajoule
ML	Mililitre
MOU	Memorandum of Understanding
MSW	Municipal Solid Waste
MT	Megatonne
MY	My Renewable

Abbreviations

NP	Net Profit
NRC	National Research Council Canada
NRCan	Natural Resources Canada
OPEX	Operating expenditure
PAP	Phnom Penh Autonomous Port
PCA	Philippine Coconut Authority
PCAARRD	Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
PCSD	Palawan Council for Sustainable Development
PDR	People's Democratic Republic
PFAD	Palm Fatty Acid Distillate
PIPC	Philippine Institute of Pure and Applied Chemistry
PKS	Palm Kernel Shell
POME	Palm Oil Mill Effluent
PPSA	Philippines Partnership for Sustainable Agriculture
PTT	Petroleum Authority of Thailand
RBDPO	Refined Bleached Deodorised Palm Oil
RD	Research and Development
RED	Renewable Energy Directive
RFS	US Renewable Fuel Standard Program
RGC	Renewable Gas Certification
RSB	Roundtable on Sustainable Biomaterials
RSPO	Roundtable on Sustainable Palm Oil
RU	Refinery Unit
SAF	Sustainable Aviation Fuels
SAFs	Sustainable Aviation Fuels
SANRM	Sustainable Agriculture and Natural Resources Management
SAWP	Social Amelioration and Welfare Program
SD	SD Guthrie Berhad
SE Asia	Southeast Asia

Abbreviations

SEP	Strategic Environmental Plan
SIN	Singapore
SOP	Standard Operating Procedure
SPC	Sustainable Palm Certification
SPK	Synthetic Paraffinic Kerosene
SRA	Sugar Regulatory Administration
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TRL	Technology Readiness Level
UCO	Used Cooking Oil
UK	United Kingdom
US	United States
USD	United States Dollar
USDA	United States Department of Agriculture

GHD Advisory

Executive Summary

1. Introduction & Background

Acknowledgement

GHD acknowledges and extends our gratitude towards all stakeholders for their invaluable support in the development and completion of this Techno-Economic Assessment Report including the Project Sponsor Canadian Trade and Investment Facility for Development (CTIF) implemented by Cowater International (Cowater) in association with the Institute of Public Administrators of Canada (IPAC) under Global Affairs Canada (GAC).

We express our sincere thanks to the ASEAN Secretariat, our Beneficiary, for their continued collaboration and trust.

We also express our appreciation to Boeing as our Knowledge Partner for their expertise and insights that have further enhanced the delivery and content of the Techno-Economic Assessment Report.

Countries

The scope of the Techno-economic Report is a desktop review and assessment. The countries covered includes Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Philippines, Thailand and Vietnam as per Figure ES1 below.

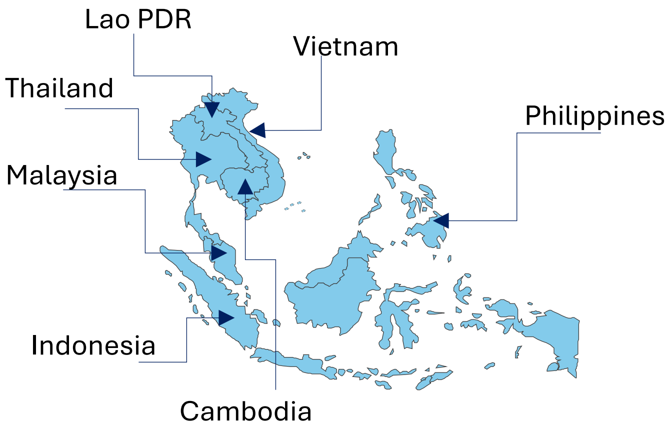


Figure ES1: ASEAN Member States to be covered for the Mandate

Methodology

GHD's mandate focuses on agricultural and forestry waste feedstock sources, excluding municipal solid waste. GHD has endeavoured to follow the agricultural and forestry feedstock categories as provided by ICAO.

In this Techno-economic Assessment Report, the findings are focused on the following workstreams to develop a comprehensive understanding of SAFs within the target countries:

- **Feedstock Assessment** – Evaluates availability, location, consumption, and potential production increase of feedstock volumes, detailing quantities, seasonality, storage limitations, and specifications, while estimating agricultural and forestry waste availability.
- **Technology Selection** – Presents ASTM-approved and other viable technology pathways, considering plant capacities, yields, co-products, utility needs, workforce skills, job creation, regulatory requirements, SWOT analysis, and cost rankings.
- **Carbon Intensity** – Assesses typical CORSIA default and GHD-calculated life cycle emissions for identified feedstocks. Ranks SAF products by carbon intensity and emissions savings, with recommendations for CORSIA eligibility.
- **Feedstock and Product Logistics** – Identifies key supply chain locations and infrastructure, associated costs, logistics, regulatory requirements, and potential SAF regional supply chain that include South Korea and Japan.
- **Environmental and Social Aspects** – Identifies key environmental and social risks and opportunities in the SAF value chain, with a high-level stakeholder analysis and potential research opportunities.
- **Institutional Frameworks** – Identifies government and private sector activities and enabling policies for SAF adoption, ranking countries based on development indexes.
- **Financial Assessment** – Assesses scale, CAPEX, OPEX, and LCOE of SAF for likely technology pathways.

2. Feedstock Assessment

For the feedstock assessment the following pertinent feedstock parameters and properties were studied for each country: Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam.

1. Feedstock Types and Locations

Evaluation of the potential agricultural (plant-based) and forestry waste for Sustainable Aviation Fuel (SAF) production in Southeast Asia including waste volumes generated per region and per country, high and low potential feedstocks identification, waste to product conversion and calculations and waste hotspots identification.

2. Feedstock Growth Potential

Taking into consideration key feedstocks with each country, assessment of business-as-usual activities, practically available feedstock and potential to increase production of selected feedstocks.

3. Feedstock Seasonality

Assessment of the planting and growth, as well as harvesting season for each of the key feedstocks identified.

4. Feedstock Storage

Assessment of typical feedstock storage periods for each feedstock.

5. Feedstock Composition

Assessment of typical feedstock compositions including moisture content, carbon content, ash content and bulk density.

6. Additional Land Assessment

High level overview of the utilised and available land for agricultural and forestry expansion.

7. Feedstock Costs

Additional considerations required for assessment of the feedstock costs.

8. Large-scale Biomass Management Advantages

Identification of large-scale farming, harvesting and transport advantages, particularly from an efficiency, productivity and cost perspective.

2. Feedstock Assessment

Key Findings

1. Feedstock types and Locations

For five countries - Cambodia, Indonesia, Lao PDR, Philippines and Vietnam, the types of agricultural waste biomass with apparent higher potential are generated in the production of **cassava, rice and corn.** Thailand is similar, where the types of agricultural waste biomass with apparent higher potential are generated in the production of **cassava, rice and oil palm fruit.** In Malaysia, **oil palm** cultivation dominates agricultural production, followed by rice and a smaller extent of coconut farming. Indonesia and Philippines also produces significant volumes of coconut, yielding waste biomass in the form of coconut husk and non-standard coconut.

While sugarcane is produced in significant quantities in most countries, much of the waste feedstock generated is used for electricity and steam generation for sugar mill operation, and unlikely to be available for fuels production without significant and deliberate changes to the way the mills operate.

Forestry waste generation potential was most prevalent in Indonesia followed by Thailand. In most cases, forestry wastes generated by sawmills could be a good supplementary feedstock for SAF production, since it will already be aggregated at the mills and is typically not bound by seasonality.

Indonesia and Thailand have been assessed to hold the greatest volumes of plant-based agricultural wastes and potential converted product volumes, while **Lao PDR has been assessed to hold the least** as per Figure ES2. There are multiple agriculture and forestry waste "hot spots", where more than one type of agricultural waste is produced in sufficient quantities for SAF production, as per Figure ES3.

Feedstock properties such as **moisture content** and **bulk density** require consideration. **Moisture content is generally high** for these feedstocks and drying may be required prior to thermal conversion, although some conversion technologies are more forgiving than others. Moisture in the feedstock also adds to the transport cost on a $/litre of produced fuel basis. Most agricultural waste feedstocks have low bulk densities in the order of 70-100 kg/m^3, resulting in high transport cost. **Forestry wastes have higher densities** in the order of 120-520 kg/m^3 for logging residues and 320-520 kg/m^3 for wood processing residues.

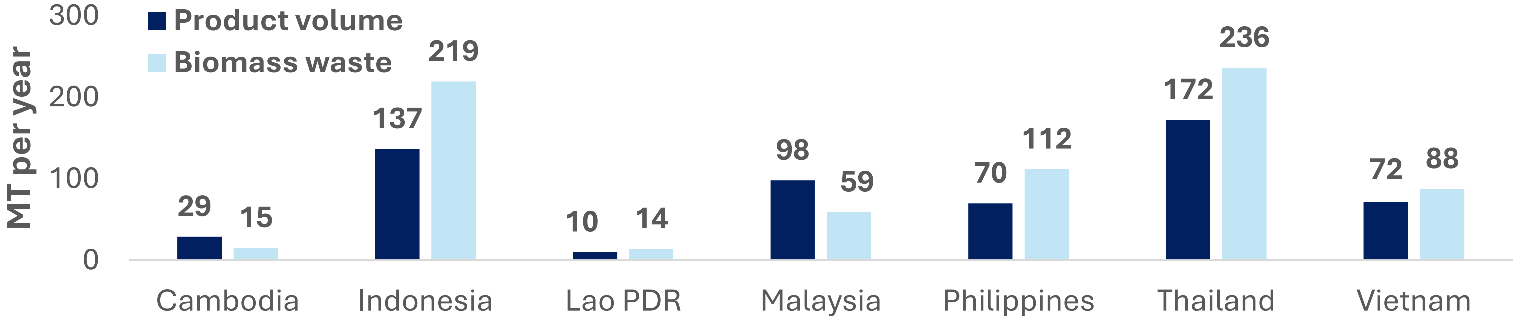


Figure ES2: Product Volume and Biomass Waste per Country[4]

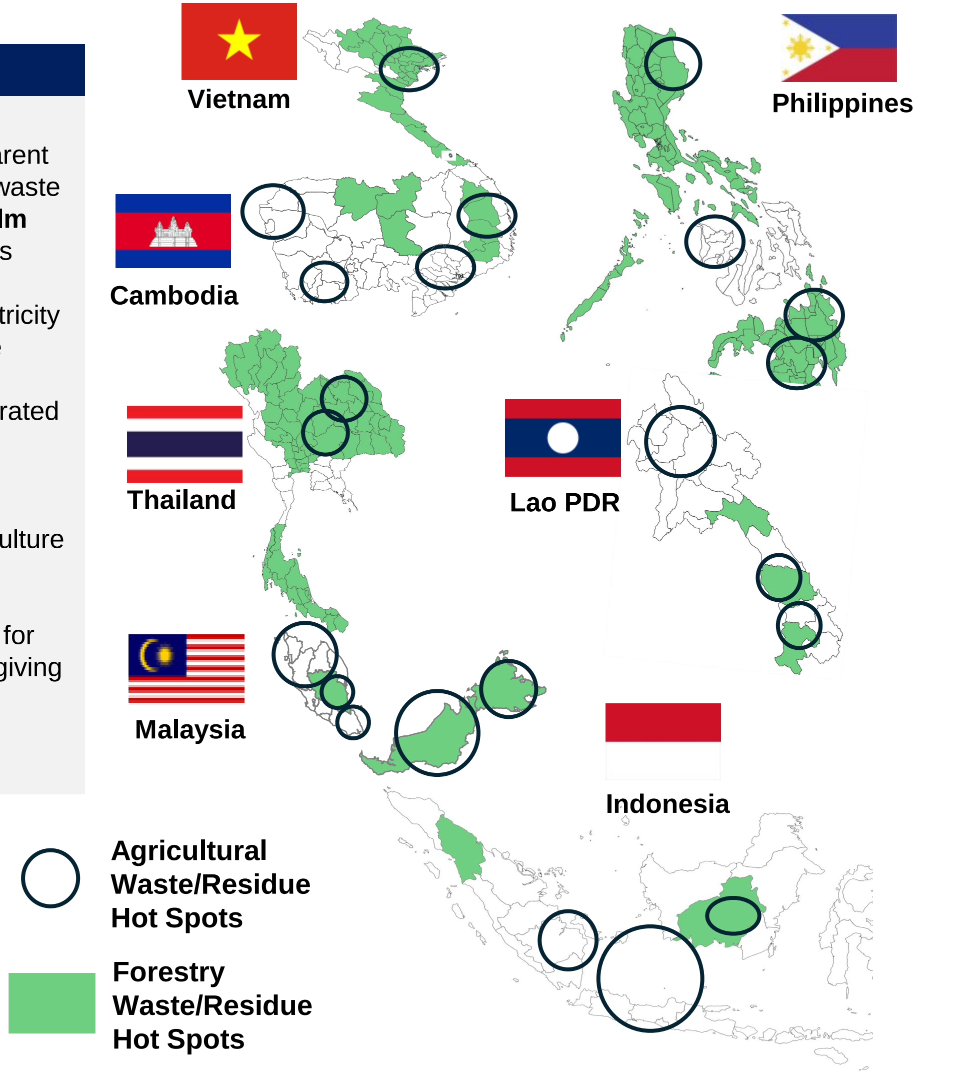


Figure ES3: Overview of Agriculture and Forestry Waste/Residue Hot Spots in each Country

*Sugarcane is not included in this chart because while sugarcane is typically the most prevalent crop, it is unlikely that sugarcane bagasse would be available for SAF production as it is used for energy generation

2. Feedstock Assessment

Key Findings

2. Feedstock Growth Potential
While there appears to be significant volumes of agricultural wastes available from rice, corn and sugarcane cropping, access to these wastes may be difficult. In all of the assessed countries, the largest portion of these crops are grown by smallholder farmers, so that contracting and aggregation of the wastes may be difficult to orchestrate. In many cases, the wastes are left on the field or burnt, and in order to access these feedstocks, farming practices will have to change. This is only possible with government and private industry support to educate farmers and make equipment available to make collection of these wastes cheaper. Incentives could also assist to encourage farmers to collect some of these wastes. It is important to understand how much of each of these wastes could be removed from the fields without negatively impacting soil quality and the natural insulation and weed protection that many of these feedstocks offer when left in the field.

In some cases, waste feedstocks are already aggregated at mills, such as EFB at palm oil mills and sugarcane bagasse at sugar mills. SAF production facilities could take advantage of such aggregated feedstocks.

All of the assessed countries already utilise large percentages of land for agricultural purposes, so that it is difficult to imagine that feedstock growth will be the result of expanded agricultural land being made available. Therefore, increased crop and biomass wastes yield will be the result of better farming practices and educating farmers on these practices, increased irrigation, research and development into new and improved species of specific crops and better access for farmers to machinery to mechanise planting and harvesting.

3. Feedstock Seasonality
All of the assessed countries have relatively constant temperature profiles throughout the year, with a notable “wet” and “dry” season only. As a result, many crops can be grown all year round, with planting typically preferred at the beginning of the wet season for many crops. There are fast-growing crops like rice and corn where more than one harvest can be achieved per year. Therefore, relatively fresh feedstocks should be available for SAF production all year round, particularly if more than one type of feedstock is utilised for a SAF facility. The temperate climate with the ability to grow crops all year provides SE Asia with an advantage over many other regions such as Europe and North America for biofuels production.

4. Feedstock Storage
Most of the feedstocks that have been identified for SAF production in the assessed countries can be stored for up to a year, provided that it is stored correctly, in some cases dried, and covered to protect it from rain and wind. In most cases, feedstocks can be stored in baled form or loose, and either stored under a roof or under tarps. Feedstock availability and storage costs should be weighted against each other to determine how much feedstock can be practically stored at the production site. Safety and the fire hazard that the stored feedstock poses should also be considered, particularly when the feedstock is dried prior to storage or stored for prolonged periods of time (becoming dryer over time).

Given that most of the feedstock providers are smallholder farmers, it is unlikely that storage facilities will be available at the farms.

5. Feedstock Composition
Most of the assessed feedstocks, including cassava, corn, coconuts, sugarcane, and forestry wastes have moisture contents between 30-85 mass%, with the exception of rice straws, EFB and cassava peels (once dried in the sun), which all have moisture contents of less than 20 mass%. The moisture content influences how much energy is required to dry the feedstock prior to some of the primary processing steps (such as gasification) and therefore influences the overall energy efficiency of the process, or influences how much effluent is produced from the process that requires treatment (HTL technology pathway). It also influences transport cost, as the moisture is transported with the rest of the biomass to site but does not contribute to fuels production, and therefore increasing the unit transport cost per litre of SAF produced.

2. Feedstock Assessment

Key Findings

5. Feedstock Composition

Most of the assessed feedstocks have less than 5 mass% ash content (dry basis), so that little solid residue remains for disposal following SAF production. The exceptions are rice straw and husks and sugarcane bagasse, with ash content of around 18-20 mass%. In the case of rice straw and husks, the ash consists mainly of silica and could be utilised as cement filler for example.

The calorific value of the feedstocks that were assessed were all in the range of 14-18 MJ/kg on a dry basis.

The bulk density directly influences the volume of feedstock that can be transported per for example truck load and therefore directly influences feedstock transport costs. Bulk densities for feedstocks such as straws, cassava peels, sugarcane trash and coconut husks are in the order of 50-80 kg/m^3, while sugarcane bagasse has a bulk density of 80-120 kg/m^3 and wood wastes have the highest bulk density at 235-280 kg/m^3. The bulk density of wood wastes are highly dependent on how these are chipped. The bulk densities of these feedstocks can be increased through mechanical treatment such as crushing, tamping and baling at additional expense at farming sites. This should be weighed against the cost of transport feedstocks with lower bulk densities.

6. Additional Land Assessment

The assessed countries all utilise a large portion of land for agricultural purposes, and most of the rest of the land is classified as forested land and protected areas. Agricultural land in some of the assessed countries such as Vietnam is being acquisitioned for urbanisation as the population grows and socio-economic demands change. It is therefore difficult to foresee that additional land would be made available to agriculture; rather, land that is already used for agricultural activities could be repurposed for specific feedstocks as required.

The types of soil that is available in each country for crops and the types of soil that specific feedstocks thrive in or can tolerate should be considered when land is being repurposed for specific crops For countries with low-lying regions, these regions are mainly suitable for rice cropping during wet seasons. Crops like sugarcane is not sensitive and can be grown in almost all types of soil, from sandy to clay loams and acidic volcanic to calcareous sedimentary deposits. Cassava is resilient and can tolerate low soil fertility and droughts but not water-logged or saline soils. Corn can grow in various soil types but do best in loamy rich soils. Palm oil trees grows well in loamy or alluvial soils but does not do well in soils prone to water-logging, saline or alkaline soils. Crops that can tolerate poor soils or water-logged conditions should be considered for areas where such conditions could occur, while richer soils should be reserved for those crops that will not do well in any other conditions. This should be considered while keeping biodiversity of specific areas in mind.

7. Feedstock Costs

As most of the agricultural waste feedstocks that have been identified currently have no use or value attached to them, there are no formal markets or pricing for these feedstocks. A number of parameters have to be taken into account to attach value to each type of feedstock, including cost involved to aggregate a particular feedstock, logistics cost to transport the feedstock from farm to processing site, and properties of the feedstock such as bulk density, moisture content and calorific value. Higher calorific feedstocks, feedstocks with lower moisture content and higher bulk density feedstocks are typically preferred and would have a higher value attached to them than others.

8. Large-Scale Biomass Management Advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include lower overheads as a percentage of revenue, access to advanced farming techniques and easier mechanisation, less complex and cheaper aggregation of feedstocks and less complex contracting for feedstocks.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

3. Technology Selection

This section presents an overview of the technology selection assessment including the technology pathways, job creation, regulatory requirements, SWOT Analysis and a Multi Criteria Analysis (MCA).

Technology Pathways

Currently, drop-in biofuels are primarily produced via **Hydro-processed Esters and Fatty Acids (HEFA) from Hydrotreated Vegetable Oils (HVO)** or animal fats, but due to limited and expensive feedstocks, alternative pathways using more abundant and low-value feedstocks are being explored, despite higher investment costs.

Alternative Pathways:

- **Fischer-Tropsch (FT-SPK & FT-SPK/A):** Uses lignocellulosic feedstocks, requires drying and gasification.
- **Alcohol to Jet (AtJ-SPK):** Converts ethanol to jet fuel, involves biomass pre-treatment.
- **Hydrothermal Liquefaction (HTL):** No feedstock drying needed, high biocrude yield.
- **Gasification & Methanol Synthesis:** Produces methanol, which can be upgraded to jet fuel.

Job Creation

Biorefinery facilities, regardless of technology, will create similar jobs in biomass aggregation, storage, conversion, and upgrading, with significant potential for direct and indirect job creation in SE Asia, as evidenced by biofuels industry developments in the US, Singapore, and Australia.

Regulatory Requirements

A biorefinery requires rigorous regulatory and environmental approvals similar to other chemical facilities, with specific considerations for feedstock transport and storage, and must demonstrate tangible sustainability benefits verified by third-party certification to meet international standards. This includes adherence to standards such as **EU RED II, ISO 13065:2015, and ICAO CORSIA.**

SWOT Analysis

- **HEFA:** Most technically and commercially mature pathway for SAF production, with the ability to produce 100% SAF blend. However, it requires large amounts of hydrogen, which can increase costs and carbon intensity if derived from non-renewable sources.

- **HTL:** Does not require feedstock drying and yielding high biocrude, but faces challenges such as high complexity, CAPEX, and unproven water treatment; offers flexibility in feedstock and by-products, with threats including variability in biocrude properties affecting ASTM approval.

- **ATJ:** ASTM-approved and capable of producing saleable interim products like bio-ethanol or bio-butanol, but faces challenges such as high complexity and CAPEX; offers flexibility in feedstock and by-products, with potential for a hub and spoke model for feedstock processing.

- **Gasification/FT:** ASTM-approved and can be self-sustaining, but faces challenges such as high complexity, CAPEX, and water consumption; offers flexibility in feedstock and by-products, with threats including past failures in similar technologies impacting confidence.

- **Gasification/Methanol Synthesis:** Can be self-sustaining with saleable methanol as an interim product, but faces challenges such as high process complexity and CAPEX; offers flexibility in feedstock and by-products, with threats including the lack of ASTM approval for the final SAF product.

Multi Criteria Analysis

The MCA, using the following criteria: Financial indicators (33%), Environmental/Efficiency indicators (30%), Technical indicators (27%), and Experience indicators (10%), has determined that **HEFA ranks the highest overall**, followed by ATJ, HTL, Gasification/Fischer-Tropsch, and Gasification/Methanol. However, it should be noted that HEFA requires oils and fats as feedstocks, which limits its applicability to many other agricultural and forestry feedstock wastes, in which case the ATJ pathway would rank the highest for these feedstocks.

4. Carbon Intensity

This section provides an overview of the carbon intensity assessment. Life Cycle Assessment (LCA) is commonly used to estimate GHG emissions from SAF in comparison to fossil derived jet fuel. To be certified as “sustainable” fuel, SAF products will have to meet a specific carbon intensity reduction threshold (compared to crude-derived jet fuel).

The International Civil Aviation Organisation (ICAO) has published the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), to measure, report and verify emissions from the aviation sector for each of its member states. While the methodology may still be modified, it is currently the most likely to be widely adopted for SAF carbon intensity calculations and accreditation. CORSIA allows the use of SAF to reduce airlines carbon offsetting requirements. Under CORSIA, emissions reductions from using SAF are calculated using an LCA approach, as set out in ISO 14040 and 14044[61].

L_{CEF} (life cycle emissions value for a CORSIA eligible fuel in gCO_2e/MJ) = Core LCA value + ILUC – Emission credits

Where:

- Core LCA value = Case C SAF, residue according to Section 4, calculated using methodologies from Sections 4.2 and 4.4, or approved by CORSIA (Default Life Cycle Emissions, June 2022.
- ILUC = 0, Case 1 based on residue as feedstock.
- Emissions credits = 0.
- 100-year GWP and Fifth Assessment report of the IPCC (CH_4 = 28, N_2O = 265).

Figure ES4 shows an overview of the typical CORSIA SAF System Boundary scenarios for both non-by-product and by-product SAF production scenarios. System boundary for SAF derived from waste has been used to estimate high level carbon intensities of various waste feedstocks into SAF for this project, in accordance with the ICAO document, CORSIA Methodology for Calculating Actual Life Cycle Emissions Values, March 2024. The approach typically follows a well-to-wake approach, which focuses on the emissions of aviation fuels from fuel production (well) to its final use during flight (wake).

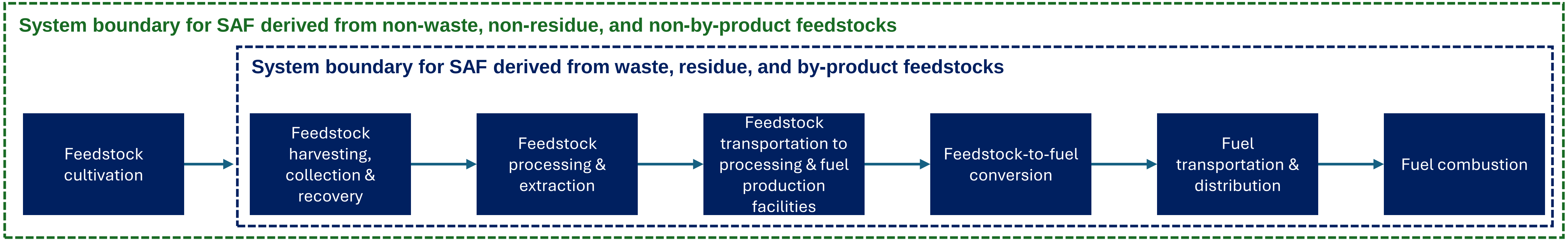
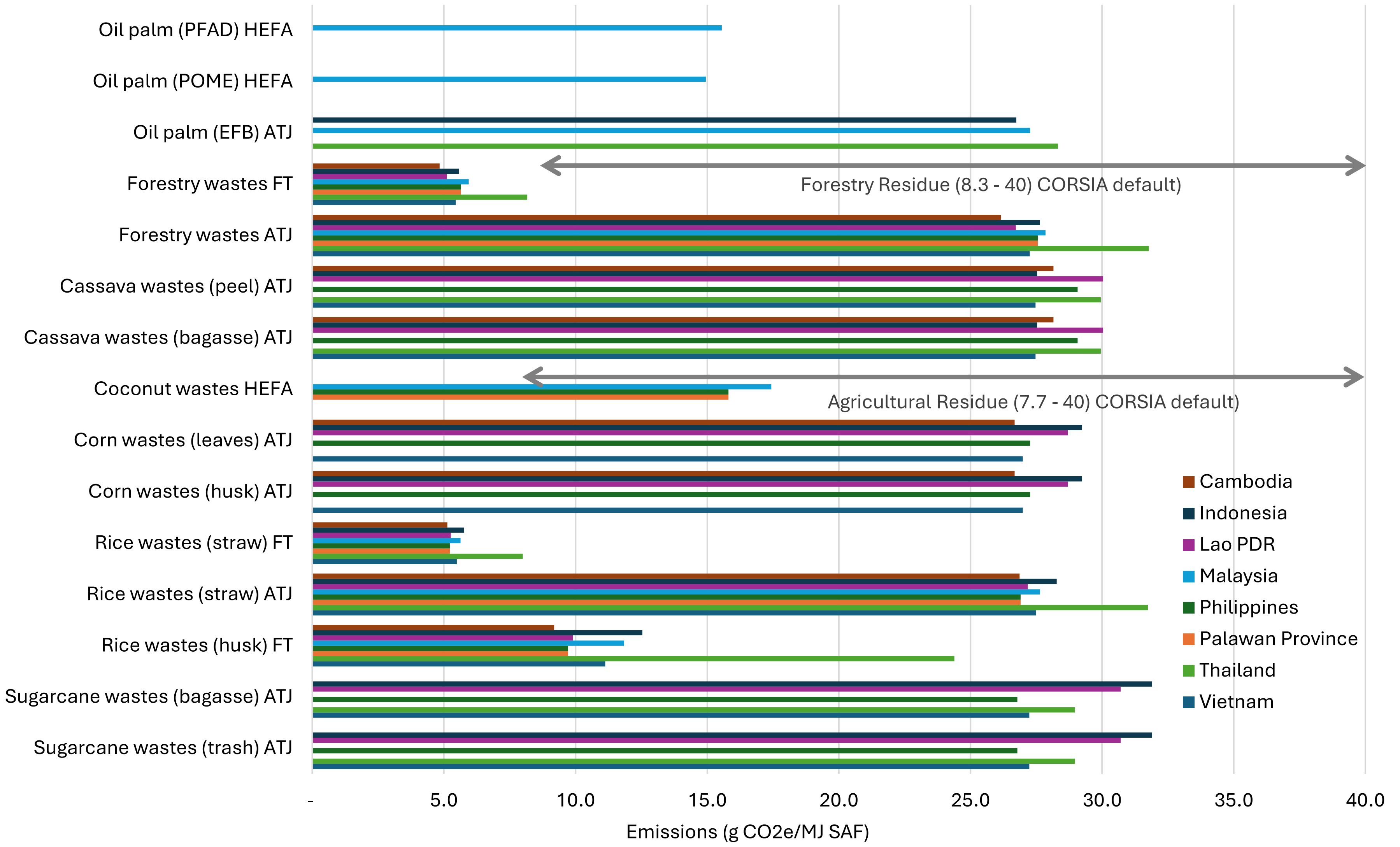
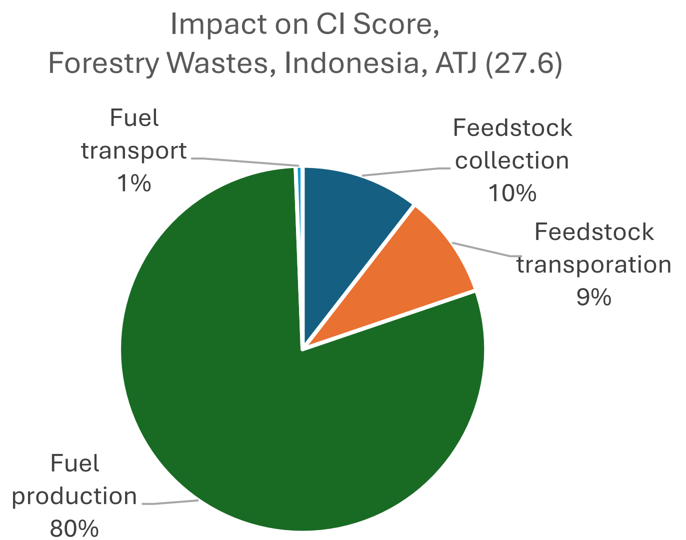


Figure ES4: CORSIA SAF System Boundary Scenarios [62]

4. Carbon Intensity

Figure ES5 shows an overview of the estimated carbon intensities for the selected wastes per country.





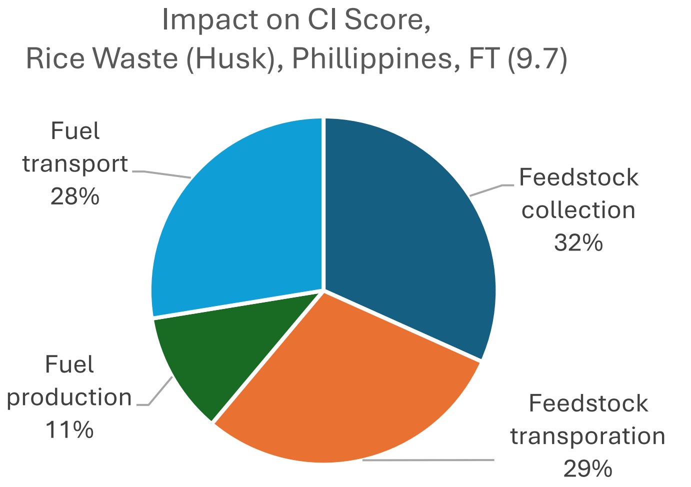


Figure ES5: Estimated Carbon Intensities for Select Agriculture and Forestry Wastes

4. Carbon Intensity

CORSIA and Carbon Intensity Estimation Key Findings

CORSIA

- ICAO published the CORSIA scheme to measure, report and verify emissions from the aviation sector for each member state, still in pilot phase.
- CORSIA default life cycle emissions are available for ATJ and FT using agricultural residues and forestry residues. There are no HEFA default core LCA values for agricultural or forestry residues.
- ICAO-GREET version can be used to estimate and verify default core LCA values of the CORSIA-approved SAF pathways (only includes wheat straw and corn stover as agricultural residues).
- Sufficient data on the conversion process, feedstock and region of interest is required to be evaluated for CORSIA default LCA emissions values.

CORSIA certification uncertainties

- Rice husks and rice straw (FT), sugarcane bagasse, tops and leaves (ATJ) and corn cob, husks, stover and straw (FT) display minimal to no certification risk under RSB CORSIA.
- Forest and wood residues (FT) and palm oil residues (PKS, EFB, old trunk) (FT) display certification risks under RSB CORSIA, due to potential sustainability risks.
- Uncertainties for other residue feedstocks studied in this project are unknown.

Carbon Intensity Estimates for the Study

- The fuel production stage has the greatest carbon intensity for ATJ, followed by HEFA and then FT.
- The FT technology pathway has significantly lower total emissions compared to ATJ due to the fuel production stage.
    - More research is needed to confirm FT conversion process gives a lower CI value when compared with other conversion processes. There is limited available information for agricultural residue other than sugarcane and corn stover.[9]
    - The FT method produces syngas which is used as a fuel in the process. Electricity is generated from excess steam from gasification and FT synthesis. The CI for FT generally is lower than ATJ due to the self-sufficiency of the process and excess electricity production. ATJ requires hydrogen and if hydrogen can be sourced from renewable sources rather than through steam methane reforming using fossil-based energy sources, the CI for the SAF will improve.[10]
- There are many considerations when it comes to estimating the CI for SAF from the agricultural and forestry residues. These include determining the most suitable technology for the feedstock, identifying the source of hydrogen if Alcohol-to-Jet (ATJ) technology is used, and assessing the emission intensity of the local electrical grid or whether the electricity is sourced from renewable energy.
- Indonesia, Lao PDR and Thailand generally have higher CI scores for most feedstocks due to high feedstock transport distances.
- Rice husk has a high CI score due to low fuel yield.
- Thailand rice husk has a significantly higher CI score due to the fuel transport distance of 660 km compared to <120 km for other feedstocks.
- Detailed analysis of collection and process will improve accuracy of estimates.

GHG Intensity Summary by Country for Top Feedstocks (gCO_2e/MJ fuel)

- **Indonesia**: Rice wastes (straw) (5.8, FT) has the lowest CI, rice waste (husks) (12.5, FT) has a moderate CI, and palm oil (EFB; ATJ), cassava waste (bagasse and peel, ATJ) and corn waste (husks and leaves; ATJ) have the highest CIs (26.7 - 29.2).
- **Malaysia**: Palm oil pathways show varying carbon intensities—EFB (27.3, ATJ), POME (14.9, HEFA), and PFAD (15.6, HEFA). Rice waste (straw) (5.6, FT) has the lowest CI, while rice waste (husks) (11.8, FT) and coconut wastes (17.4, HEFA) have moderate CIs, and rice wastes (straw; ATJ) has the highest CI (27.6).
- **Philippines**: Rice waste (straw) (5.2, FT) has the lowest CI, while rice waste (husks) (9.7, FT) and coconut wastes (15.8, HEFA) have moderate CIs, and corn wastes (leaves and husks; ATJ), rice wastes (straw; ATJ) and cassava wastes (bagasse and peel; ATJ) have the highest CIs (26.9 - 29.1).
- **Thailand**: Rice wastes (straw) (8.0, FT) has the lowest CI, while rice waste (husks; FT), rice waste (straw; ATJ), palm oil (EFB; ATJ), and cassava waste (bagasse and peel, ATJ) have the highest CIs (24.4 - 31.7).
- **Vietnam**: Rice wastes (straw) (5.5, FT) has the lowest CI, rice waste (husks; FT) has a moderate CI (11.1, FT), while rice waste (straw; ATJ), corn wastes (leaves and husks, ATJ) and cassava waste (bagasse and peel, ATJ) have the highest CIs (27.0 - 27.5).

5. Feedstock and Product Logistics

This section provides an overview of the feedstock and product logistics, in which three key locations were considered and linked for each country as per Figure ES6 below.

Major Feedstock Location

Feedstock locations as per the feedstock assessment conducted (Refer Section 2).

SAF Biorefinery Facilities

Existing facilities within each country that, with upgrades, may be used for conversion of biomass product to SAF.

Blending SAF Facilities / Port

Considered to be within 50 km of airport locations within each country. This may include existing or new facilities.
The unblended SAF may also be shipped out for an export for both domestic and international usage via the identified key ports in respective countries.

Figure ES6: Key Locations considered for the Feedstock and Product Logistics Assessment

Key Findings

Out of the seven countries covered in this report, the Philippines had the most number of biorefineries in reasonable proximity to the identified feedstock locations as per Section 2. Based on the estimated SAF potential, it is envisaged that a significant additional infrastructure (or proportional to SAF potential capacity) such as pre-processing facilities, SAF biorefinery, and truck fleet operation, will likely be required in these countries.

In Indonesia, existing biorefineries are primarily owned by PT Pertamina, in which the locations are sparse given the archipelagic nature of the country. In Thailand, the biomass feedstock sources are located within the North and Northeast regions of Thailand, however, there are limited biorefineries observed within these regions (with only two identified). Malaysia has biorefineries that spread across the Malaysian Peninsular Malaysia and West Malaysia. However, there are fewer biorefineries observed within East Malaysia as compared to Peninsular Malaysia, despite the feedstock potential in this region is identified to be greater. Similarly, in Lao PDR and Vietnam, there are only two biorefineries for each country, and there is only one biorefineries in Cambodia, which can be considered SAF biorefinery facilities.
Palawan province, despite being identified to have SAF potential from Non-Standard Coconut, the region does not have any biorefineries facilities, and the feedstock would likely need to be transported to CCO refineries located across Albay, Davao and Quezon or alternatively, crude coconut oil factory can be established to process the feedstock locally

Airports in each country identified can serve as both domestic market and international markets within ASEAN. Major ports in Cambodia, Indonesia, Malaysia, Philippines, Thailand and Vietnam appear to be equipped with oil/petroleum product import/export facilities that can be upgraded to be capitalised for SAF distribution domestically and internationally.
For Lao PDR, being a landlocked country, SAF produced in Laos can be transported via the Mekong River to Vietnam, which serves as a key re-export hub. Vietnam facilitates the onward shipping of SAF to international markets, effectively acting as a transit point for Lao PDR's SAF exports.

Cost of road transport across the seven countries has been found to vary from a range of approximately US$ 0.06 to 0.50 per ton-km, where the sea freight varies from a range of approximately US$ 0.001 to 0.007 per ton-km.

Refer to Sections 5.2 to 5.9 for further details.

5. Feedstock and Product Logistics

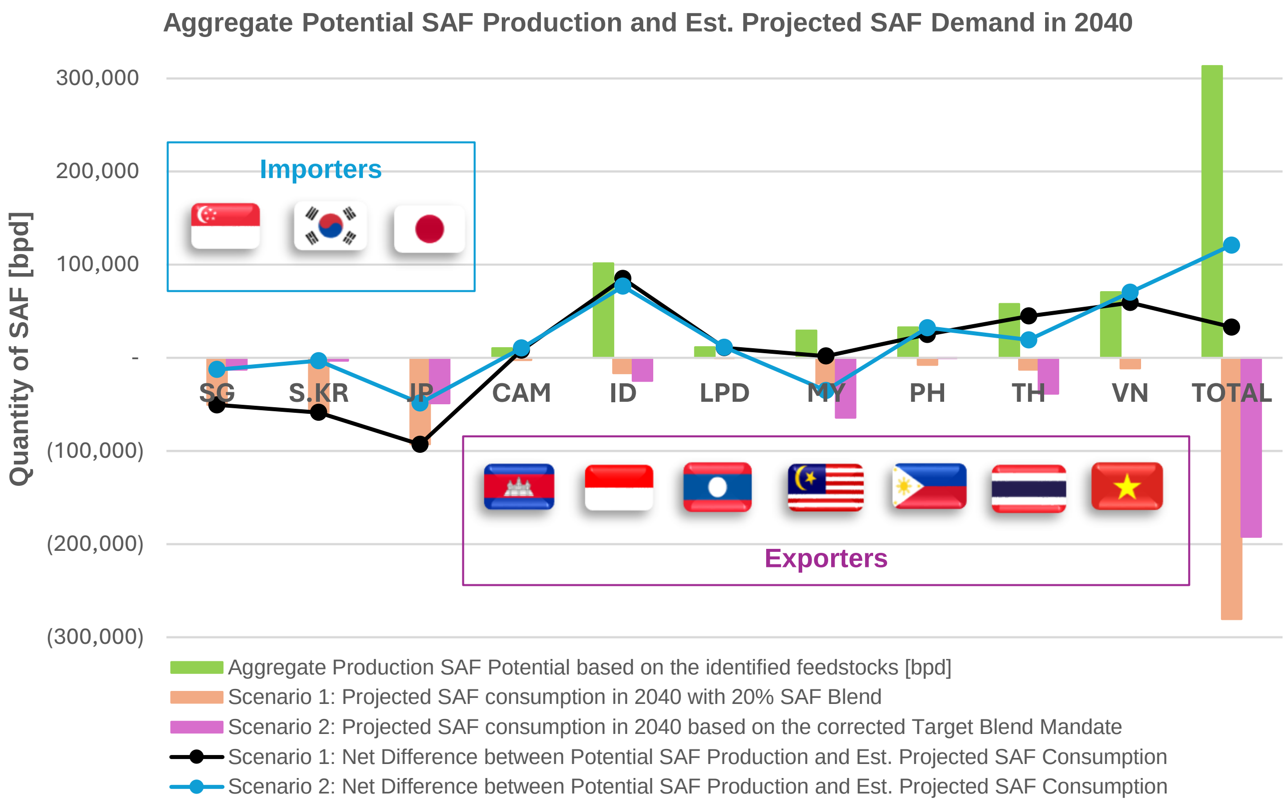


Figure ES7: SAF Regional Supply – Demand Distribution

As part of the study, a SAF Demand-Supply Analysis was conducted using the projected Sustainable Aviation Fuel (SAF) consumption and production potential in Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Philippines, Singapore, South Korea, Thailand, and Vietnam by 2040 under two different scenarios:

Scenario 1

This scenario assumes that all countries (Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Philippines, Singapore, South Korea, Thailand, and Vietnam) are progressing towards achieving a 20% SAF blend by 2040.

The 20% SAF blend target is derived from the average Target Blend Mandate set by countries that have committed to SAF adoption goals.

Scenario 2

Est. Projected SAF Consumption in 2040 is corrected for different target years of the Target Blend Mandate stated independently by Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, and Thailand. In this scenario, the projected domestic SAF consumption of Cambodia, Lao PDR and Vietnam are assumed to be zero, as there is no SAF Mandate by these nations to date.

Key Assumptions

- The feedstock quantities and potential SAF production outlined in Section 5.2 to 5.8 are assumed to be fully operational by 2040. SAF biorefineries are expected to be developed progressively to align with and maximise the potential SAF production derived from the respective feedstock by 2040.
- Figure ES7 indicates the supply and demand for SAF in the region, expressed in potential SAF production and est. projected SAF demand in 2040. Acknowledging that Japan, Singapore and South Korea may have their own SAF refineries or future plans for development of SAF refineries for SAF, this has not been accounted for in Figure ES7.
- Japan, Singapore and South Korea are assumed to be SAF feedstock and/or SAF importers, relying on their neighbouring countries to meet their SAF production and/or SAF demand.

Summary Assessment

- In both Scenarios, there is a possibility of a surplus of Sustainable Aviation Fuel (SAF) within ASEAN, excess supply could potentially be distributed, in region, to other countries, including Australia and New Zealand, Melanesia, Micronesia, and Polynesia or be sold as diesel in regional markets.
- Countries like Cambodia, Indonesia, Lao PDR, Philippines, Thailand, and Vietnam could potentially be SAF exporters due to their excess in SAF after their domestic SAF consumption is considered. Based on the feedstock quantity from the most prominent region within each country (Sections 2 and 5.2 to 5.8), all countries have the potential to be a net SAF exporter. In particular, this includes Indonesia, Malaysia, Philippines, Thailand, and Vietnam. Lao PDR and Cambodia also have a potential of being a net SAF exporter, however as per Sections 2, 5.2 to 5.8, the feedstock availability is relatively low compared to the other assessed countries.
- Under Scenario 1, Malaysia is projected to likely have a surplus of SAF as the country progresses toward achieving a 20% SAF blend by 2040. However, in Scenario 2, Malaysia is anticipated to face a potential SAF deficit, necessitating imports from other member states to meet its domestic SAF consumption requirements.

5. Feedstock and Product Logistics

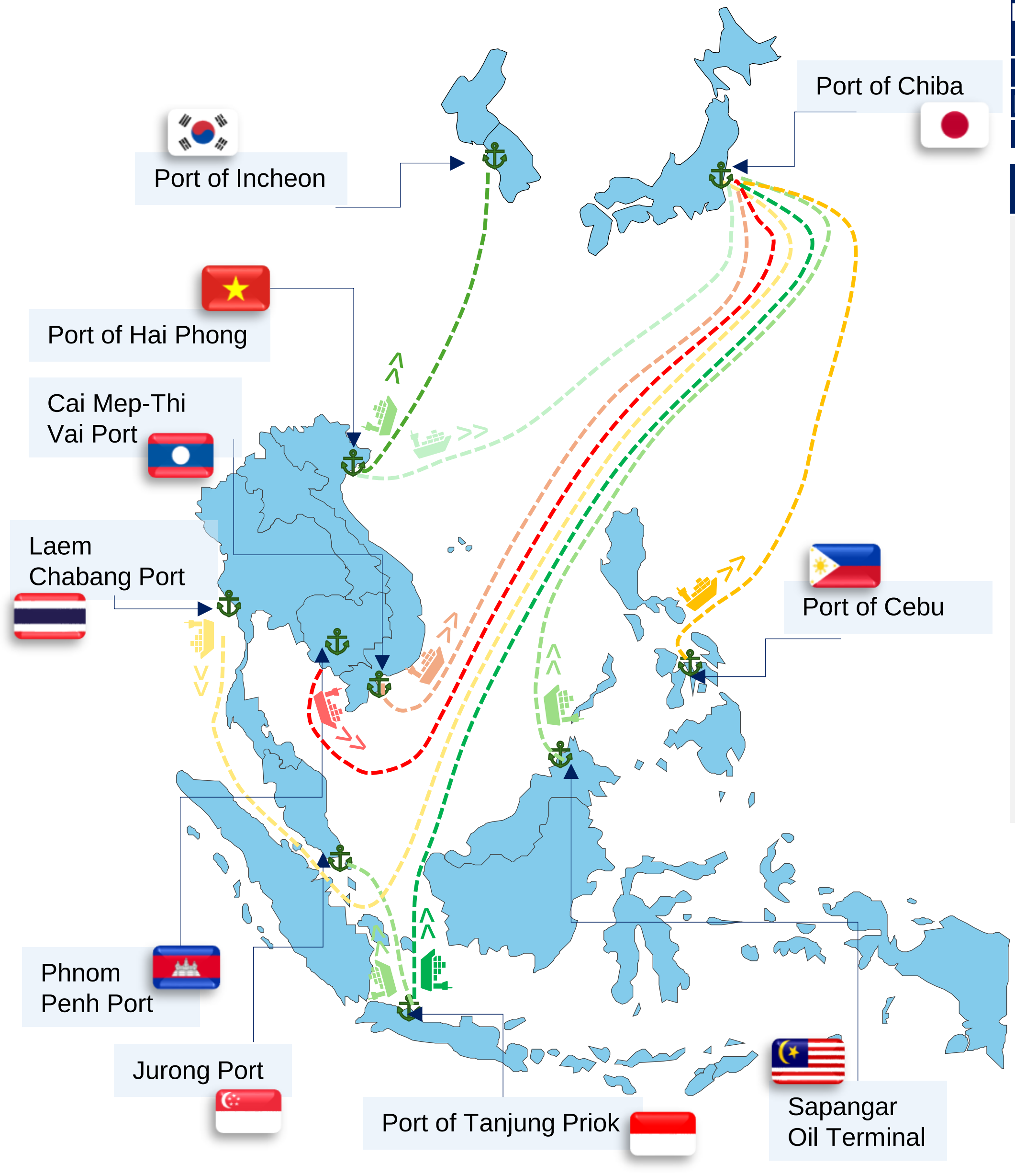


Figure ES8: Potential SAF Regional Distribution Supply Chain – Scenario 1

Table ES1: Relative Est. Cost Comparison of SAF Logistics from Refinery to Japan, Singapore and South Korea

Demand\Supply Port	Phnom Penh Port	Port of Tanjung Priok	Cai Mep-Thi Vai Port	Sapangar Oil terminal	Port of Cebu	Laem Chabang Port	Port of Hai Phong
Jurong Port	6	2	5	1	7	3	4
Port of Incheon	6	3	5	1	7	4	2
Port of Chiba	6	3	5	1	7	4	2

Summary Assessment

Considering the cost-distance of SAF produced from the ASEAN Members, it appears the most cost-effective supply chain to distribute SAF to Japan, Singapore and South Korea is from Malaysia, Vietnam and Indonesia respectively. Despite its strategic location, the Philippines is noted to have higher road freight costs than other member states, potentially reducing its competitiveness as a SAF distributor. However, further review and investigation of its road conditions and improvement measures may improve the Philippine's competitiveness as an exporter to the import countries mentioned.

Scenario 1 – Projected 20% SAF Blend in 2040 for all jurisdictions

Considering the surplus SAF and the relative logistics costs (from **cheapest (#1)** to **most expensive (#7)**), the likely SAF supply chain routes for Japan, Singapore and South Korea are as follows:

- Japan (Port of China): import from Indonesia# (Port of Tanjung Priok), Malaysia (Sapangar Oil Terminal), Vietnam # (Port of Hai Phong), Thailand (Laem Chabang Port), Lao PDR (Cai Mep-Thi Vai Port), Cambodia (Phnom Penh Port) and the Philippines (Port of Cebu)
- Singapore (Jurong Port): import from Indonesia (Port of Tanjung Priok)
- South Korea (Port of Incheon): import from Vietnam (Port of Hai Phong)

This study scenario requires selecting a specific point or localised port within the country. The chosen port is selected based on the highest surplus of SAF available after meeting the domestic consumption needs of the nearest major airport. Key feedstocks contributing to the SAF supply chain at these distribution ports have been identified based on their availability in the surrounding areas, and they are:

Country	Feedstock Type	Country	Feedstock Type	Country	Feedstock Type

Note:

- Rankings 1 to 7 indicate cost-effectiveness, with 1 being the most cost-effective supply chain route and 7 being the least across the Demand Ports
- # Indonesia and Vietnam excess SAF surplus after distributing to Singapore and South Korea respectively

5. Feedstock and Product Logistics

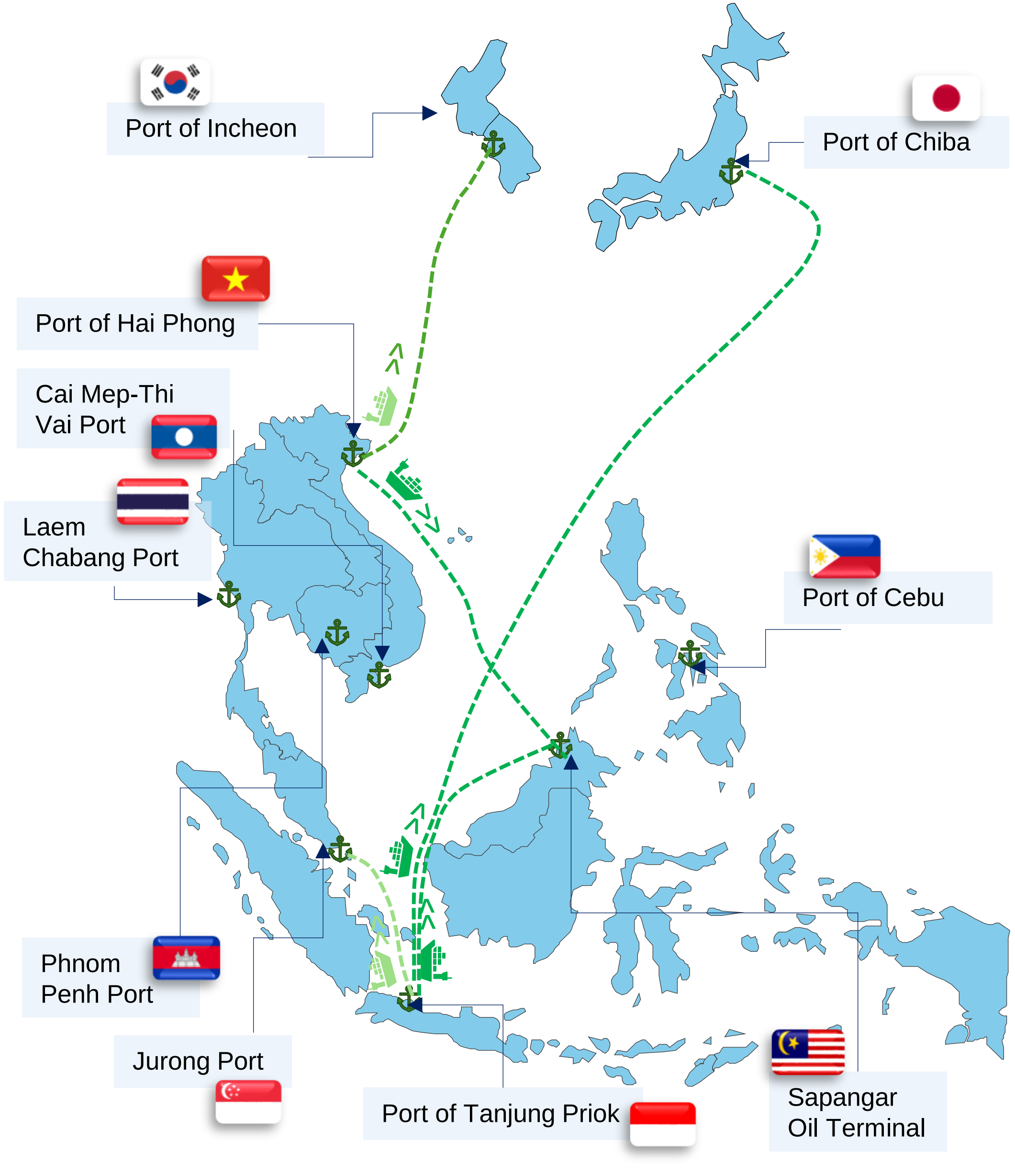


Figure ES9: Potential SAF Regional Distribution Supply Chain – Scenario 2

Table ES2: Relative Est. Cost Comparison of SAF Logistics from Refinery to Japan, Singapore and South Korea

Demand\Supply Port	Phnom Penh Port	Port of Tanjung Priok	Cai Mep-Thi Vai Port	Sapangar Oil terminal	Port of Cebu	Laem Chabang Port	Port of Hai Phong
Jurong Port	6	2	5	1	7	3	4
Port of Incheon	6	3	5	1	7	4	2
Port of Chiba	6	3	5	1	7	4	2
Sapangar Oil Terminal	3	1	4		5	2	1

Summary Assessment

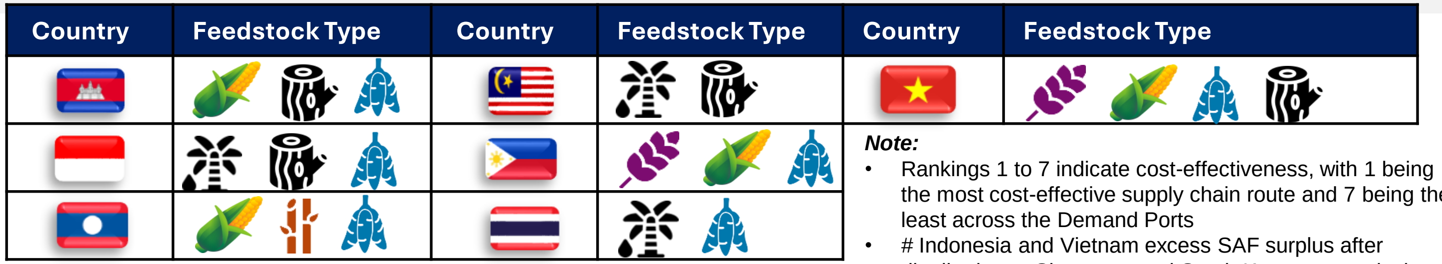
Considering the cost-distance of SAF produced from the ASEAN Members, likewise, it appears the most cost-effective supply chain to distribute SAF to Japan, Singapore and South Korea is from Malaysia, Vietnam and Indonesia respectively. Similarly, despite its strategic location, the Philippines is noted to have higher road freight costs than other member states, potentially reducing its competitiveness as a SAF distributor. However, further review and investigation of its road conditions and improvement measures may improve the Philippine's competitiveness as an exporter to the import countries mentioned. In this scenario, Malaysia is likely to face the SAF deficit for its own domestic consumption and possibly would have to import SAF from either Indonesia (Port of Tanjung Priok) or Vietnam (Port of Hai Phong) since the cost-distance for sea freight is computed to be approximately similar.

Scenario 2 – Est. % SAF Blend based on Corrected Mandate Target Year

Considering the surplus SAF and the relative logistics costs (from **cheapest (#1)** to **most expensive (#7)**), the likely SAF supply chain routes for Japan, Singapore and South Korea are as follows:

- Singapore (Jurong Port): import from Indonesia (Port of Tanjung Priok)
- South Korea (Port of Incheon): import from Vietnam (Port of Hai Phong)
- Japan (Port of China): import from Indonesia# (Port of Tanjung Priok) and Vietnam# (Port of Hai Phong)

This study scenario requires selecting a specific point or localised port within the country. The chosen port is selected based on the highest surplus of SAF available after meeting the domestic consumption needs of the nearest major airport. Key feedstocks contributing to the SAF supply chain at these distribution ports have been identified based on their availability in the surrounding areas, and they are:



Note:

- Rankings 1 to 7 indicate cost-effectiveness, with 1 being the most cost-effective supply chain route and 7 being the least across the Demand Ports
- # Indonesia and Vietnam excess SAF surplus after distributing to Singapore and South Korea respectively

5. Feedstock and Product Logistics

Key Findings

Domestic transportation of both biomass feedstock and SAF is likely governed and limited by the Transportation Regulation such as on the size, weight, height, speed limit of the fleets and also domestic infrastructure. International transportation of biomass feedstock may be subjected to phytosanitary regulations. Furthermore, in-country regulations on the import and export of oil, and petrochemical products are also likely to apply to SAF regional or international trading.

While biomass stockpiling is not necessarily regulated, however, it is important to consider the degradation and loss of energy content over time when storing the biomass feedstock. Prolonged storage without proper infrastructure can potentially lead to issues like feedstock wastage, moisture buildup, decomposition, and safety hazards such as fire risks and the release of toxic gases. Hence, storage infrastructure may need to be in compliance with the in-countries regulations and standards on as fire-fighting systems, ventilation, health & safety, and drainage.

Within ASEAN, the Common Effective Preferential Tariff (CEPT) scheme aims to gradually reduce and eliminate intra-regional tariffs based on product sensitivity to domestic industries. The ASEAN-Korea Free Trade Agreement (AKFTA) and ASEAN-Japan Comprehensive Economic Partnership (AJCEP) facilitate trade between ASEAN, Japan, and Korea. While SAF is not explicitly listed, it could potentially be included.

A review of regional supply chains suggests that Indonesia and Vietnam might consider Free Trade Agreements (FTAs) with Japan and South Korea for SAF distribution due to market demand, supply chain efficiency, and cost competitiveness.

The establishment of a Green Trade Lane or Green Corridor in Southeast Asia may potentially be feasible, aligning with the International Maritime Organization’s (IMO) GHG Emission Goals and existing sustainable shipping initiatives. Key ports like Port of Tanjong Priok, Port of Benoa, Penang Port, Port Klang, and Port Tanjung Pelepas have been identified as green ports or pilot ports for Green Corridors.

Refer Section 5.11 for further details.

5. Feedstock and Product Logistics

High-level review was conducted to evaluate the options for feedstock and product logistics in terms of harvesting techniques, biomass feedstock pre-processing locations and distribution of SAF. The summary of this review is presented in Table ES3 below.

Table ES3: High Level Review on Feedstock and Product Logistic Options

Summary	Cost	Employment	Sector Efficiency	CO2 Emission
Harvesting Technique (Mechanised Vs Manual)	Mechanised harvesting is likely to be more cost-effective in the long run but may require higher initial investment. Manual harvesting has lower initial costs but can potentially lead to higher operational costs.	Manual harvesting supports more jobs, especially in rural areas; mechanised harvesting can lead to job losses but may create opportunities in other sectors with higher skill requirements.	Mechanised harvesting is more efficient and productive. Manual harvesting is less efficient and slower.	Mechanised harvesting can have higher emissions, but advancements in technology are improving this. Manual harvesting has lower emissions. However, the overall impact depends on the scale of operations and the transportation methods used.
Pre-processing Location (Centralised Vs Distributed)	Centralised facilities have higher initial costs but lower operational costs. Decentralised facilities have lower initial costs but higher operational costs.	Centralised facility may create few, but more specialised job. While, decentralised may create jobs in rural areas.	Centralised facility is relatively more efficient but may have more complex logistics. Decentralised facility is less efficient but could have simpler logistics.	Centralised facility may have higher emissions due to transportation, which it likely to have a higher number of trucks to transport the bulky biomass feedstock from the farm to the facilities.
SAF Distribution (Road Freight Vs Pipeline)	Road freight tends to have lower initial investment cost, but a higher operational cost. Whereas, the pipeline distribution will likely have a higher initial investment cost, but a lower operational cost.	Road freight creates more jobs with moderate skill requirements, while pipeline distribution creates fewer, higher-skilled jobs.	Road freight offers higher flexibility and easier scalability, while pipeline distribution provides lower flexibility.	Road freight may potentially have higher emissions, while pipeline distribution has lower emissions.

Refer Section 5.12 for further details.

6. Environmental and Social Aspects

Despite the potential gains in emission reduction, SAF presents both risks and opportunities for communities and the environment. There are common issues to be addressed, but local context is critical. Sustainability must consider all aspects from the supply chain to the end use and integrate E&S into all stages of planning, design and operations. In this section an overview of the feedstock sources, labour issues, environmental impacts, gender equity, social impacts and supply chain from an environmental and social risks and opportunities perspective were covered.

Feedstock Source

Diverting feedstocks to SAF may:

- Displace local livelihoods.
- Stimulate additional demand with unintended consequences on land use, biodiversity, and displacement of food production and food security.
- Export nutrients from soil systems, and increase runoff where agricultural waste is otherwise left in-situ.

Feedstock source (particularly forestry) would need to be obtained from legitimate source.

Utilizing residue can:

- Reduce air pollution and health risks.
- Stimulate local economic development, training and jobs, particularly in rural areas.

Labor Issues

Each country has different labour laws and protections. However, workers in the agricultural sector often face lower wages and more job insecurity. SAF supply chain can consider ways to strengthen labour protections and provide secure and safe workplaces.
The SAF sector provides opportunities for up-skilling through training and employment.

Environmental Impacts

Environmental Impact Assessment for bio-refineries or blending facilities must consider:

- Water use.
- Biodiversity risks.
- Soil and land.
- Pollution risks.
- Waste and hazardous waste.
- Noise emissions.
- Air emissions.

EIA should consider potential impacts from the supply chain, transport, processing, storage and end-use.

Consider local laws and regulations, but also global good practice.

Gender Equity

Women and girls face different challenges in each country. Considerations include access to technical training, perceptions of roles, leadership and decision-making equity, or challenges such as childcare or gender-based violence and sexual harassment. A SAF industry based on equity can lift women and girls from poverty and change the landscape of opportunities.

Social Impacts

SAF can provide jobs and economic benefits. However, risks must also be considered including:

- Loss of livelihoods.
- Loss of access to land.
- Impacts on cultural heritage.
- Impacts on Indigenous groups.
- Potential for exploitation.

Considering opportunities for those most impacted is important, including upskilling and employment for those whose livelihoods may be impacted.

Supply Chain

To provide environmental protection, community well-being, and sustainability in the SAF supply chain, certification schemes are recommended, which must comply with the CORSIA sustainability criteria, verified by third-party certification bodies designated by ICAO—The Roundtable on Sustainable Biomaterials (RSB), the International Sustainability and Carbon Certification (ISCC), and the ClassNK (newly approved by ICAO) offer standards that cover the entire SAF production process. These certifications support that SAF production does not harm ecosystems, respects human rights, and supports local economies.

For SAF to be *sustainable*, risks and opportunities must be addressed from the outset, avoiding a redistribution of environmental burdens, and understanding how agricultural waste (potential feedstock) is currently being used. Collaboration is key. Community voices need to be part of planning and design processes. Robust CORSIA certification programs can provide certainty that SAF provides a better future for all.

7. Institutional Frameworks

As part of the institutional frameworks review the government and private sector activity SAFs activity within each of the focus countries, along with additional global reference points were reviewed. Furthermore, the general regulatory and investment climate for each of the focus countries was also reviewed, referring to known numerical indices and rankings publicly available. The subsequent key findings have been summarised below.

Government and Private Section Key Findings

Refer below a summary and key findings of the government and private section entity for the seven (7) countries.

- Out of the seven countries covered in this report, five (5) – namely the Philippines, Indonesia, Thailand, Malaysia and Vietnam – demonstrate an understanding of utilising SAF across both government and private sectors.
- Each of the five (5) countries have local airlines which have already incorporated SAF into their flights. These are Cebu Pacific Airlines in the Philippines, Garuda Indonesia in Indonesia, Thai Airways and Vietjet Thailand in Thailand, Malaysia Airlines in Malaysia and Vietnam Airlines in Vietnam.
- However, three countries appear to be more advanced in their planning and implementation of SAF use. In 2013, Indonesia became the first in SE Asia to release a SAF mandate, though it was never enforced. As of September 2024, Indonesia has revealed a SAF roadmap and policy action plan, identifying Used Cooking Oil (UCO) and palm fatty acid distillate (Pfad) as priority feedstocks. Additionally, it should be noted that PT Pertamina Patra Niaga, subsidiary of PT Pertamina, has obtained an ISCC and EU RED certification in August 2024. Thailand, on the other hand, has mentioned that an incentive proposal for the use of SAF locally is set to be finalised by 2024. While two (2) local companies, BSGF Company Limited and BAFS, are said to be building their own SAF production plants. Lastly, Malaysia is advancing SAF with policy mandates for blending (47% blend by 2050) and aims to produce one million metric tons annually by 2027. Malaysia Airlines have also launched carbon programmes to include SAF credits and Petronas have form strategic partnerships with oils producers to construct SAF refinery.
- Meanwhile, it appears that both Lao PDR and Cambodia needs to enhance its efforts in planning for the incorporation of SAF particularly in its local aviation industry. As of date, both countries have not published any of its plans with regards to the adoption of SAF use.

Global SAF Policy/Regulation Reference Points

- There is a SAF mandate which requires a minimum of 2% SAF at Union airports by 2025, with an obligation on fuel suppliers, progressively increasing to 70% by 2050.
- Aircraft operators that use SAF that comply with the sustainability criteria are able to reduce the number of ETS allowances they need to buy as an incentive by the European Union Emissions Trading System (EU ETS). However, free aviation emission allowances will be gradually phased out from 2024 to 2026, with up to 20 million allowances available based on the uptake of SAF on a first-come, first served basis.

- **Former**: The Blender's Tax Credit (BTC) was available to blenders that supply SAF with 50% or greater lifecycle emissions reductions. Fuels must have a lifecycle emission level of less than 50kg of CO2eq per MMBTu.
- **2025 Shift**: A Producer's Tax Credit (PTC) will provide a credit to producers based on their fuel's carbon intensity (CI) score.
- The tax incentive is stackable with other Federal and state level credits and can be used to offset excise tax liability and lower selling price of the fuel.

Regulatory and Investment Climate Key Findings

Refer below a summary and key findings of the regulatory and investment climate related index rankings for the seven (7) countries.

- Only five (5) out of the seven (7) countries, namely Thailand, Vietnam, Indonesia, the Philippines and Malaysia ranked in the top 50% of the latest Ease of Doing Business Index (2020) and the latest Global Innovation Index (2023).
- On both indices, Thailand appeared to have more reasonable scores which further translated to its high global rankings. Based on the 2020 data, Thailand scored relatively high on two (2) indicators in the Ease of Doing Business Index: Trading across Borders and Enforcing Contracts. This shows that Thailand is more efficient in terms of documentary compliance and border compliance to export and import, as well as in terms of resolving commercial disputes and maintaining a good quality judicial process.
- Meanwhile, in the latest Corruption Perception Index (2023), Vietnam and Malaysia are the only countries in the top 50%, ranking 83rd out of 180 and ranking 50th out of 180. Based on Transparency International, the global average score is at 43, which indicates that Vietnam and Malaysia along with the five (5) other countries have yet to improve in terms of corruption.
- With regards to the Foreign Direct Investment Regulatory Restrictive Index, the latest available data for all seven (7) countries (2019) show that Cambodia is the most open in terms of foreign direct investment while the Philippines is the most restrictive.

8. Financial Assessment

The financial assessment included the scale of the plant, CAPEX, OPEX, the LCO SAF for technology pathways with the key findings documented and tabulated below.

Key findings

Scale of plant - Given the high costs of a SAF plant (and diseconomies of scale), the minimum size is about 1,000 bpd using ~200k-560k tons of wet biomass, depending on the technology.

Price of SAF - Our levelised cost of SAF calculation and high-level financial modelling, both including the cost of capital, indicate the price of SAF is significantly lower with HTL (not yet ASTM approved) at about 4,500 to 5,600 USD/ton vs 8,000 to 10,000 USD/ton for Gasification FT and ATJ (feedstock to SAF).

Key drivers of SAF price - CAPEX is the key driver with a change of 10% in CAPEX generating a change of about 9% in the price of SAF versus 2% for OPEX and 1% for price of feedstock. However, feedstock supply is the base of the successful commercial feasibility of a SAF project. Without bankable availability, cost and terms of the supply feedstock agreements, projects are unlikely to reach financial close.

Government support - The prices obtained for SAF produced with agriculture and forestry waste are multiples of the price of fossil jet fuel and HEFA SAF. Hence, government support is required to generate demand and/or reduce the green premium. For instance, blending mandate (demand side) or tax breaks, subsidies (supply side) and R&D grants and funding to improve technologies and efficiencies.

ATJ flexibility - The ATJ pathway provide additional commercial and financial flexibility versus Gasification + FT and HTL as its intermediate liquid product (bio-ethanol / butanol) can be sold without having to upgrade to SAF (and renewable diesel), enabling a phased approach.

Please refer to Sections 1.4 and 1.7 for general limitations and assumptions used to prepare this analysis.

Table ES4: Scale, CAPEX and SAF price for each Technology Pathway

	Units	Gasification and FT	ATJ	HTL and Upgrading
Scale Minimum – 1,000 bpd	Feedstock Tpa*	490k	564k	210k
Ideal – 2,000 bpd	Feedstock Tpa*	980k	1,127k	420k
CAPEX 1,000 bpd	USD million	716	700	400
2,000 bpd	USD million	1,251	1,199	699
SAF price 1,000 bpd	USD / ton	9,223 - 10,200	9,154 – 10,150	5,048 – 5,600
2,000 bpd	USD / ton	8,159 – 9,050	7,970 – 8,850	4,454 – 4,940

**Biomass with 40% water content*

9. Concluding Remarks and Recommendations

Southeast Asia SAFs Hub

Southeast Asia has the potential and multiple characteristics to form a regional SAFs hub given the proximity of countries and availability of feedstocks such as wastes from cassava, rice, corn, coconut, corn, oil palm fruit and forestry activities. There are multiple advantages, commenced initiatives and key players active within the SAF sector in the region. Across the seven (7) countries assessed, the developments in Cambodia and Lao PDR appear to be relatively nascent, however these countries' location relative to Thailand may become an advantage given Thailand's observed developments.

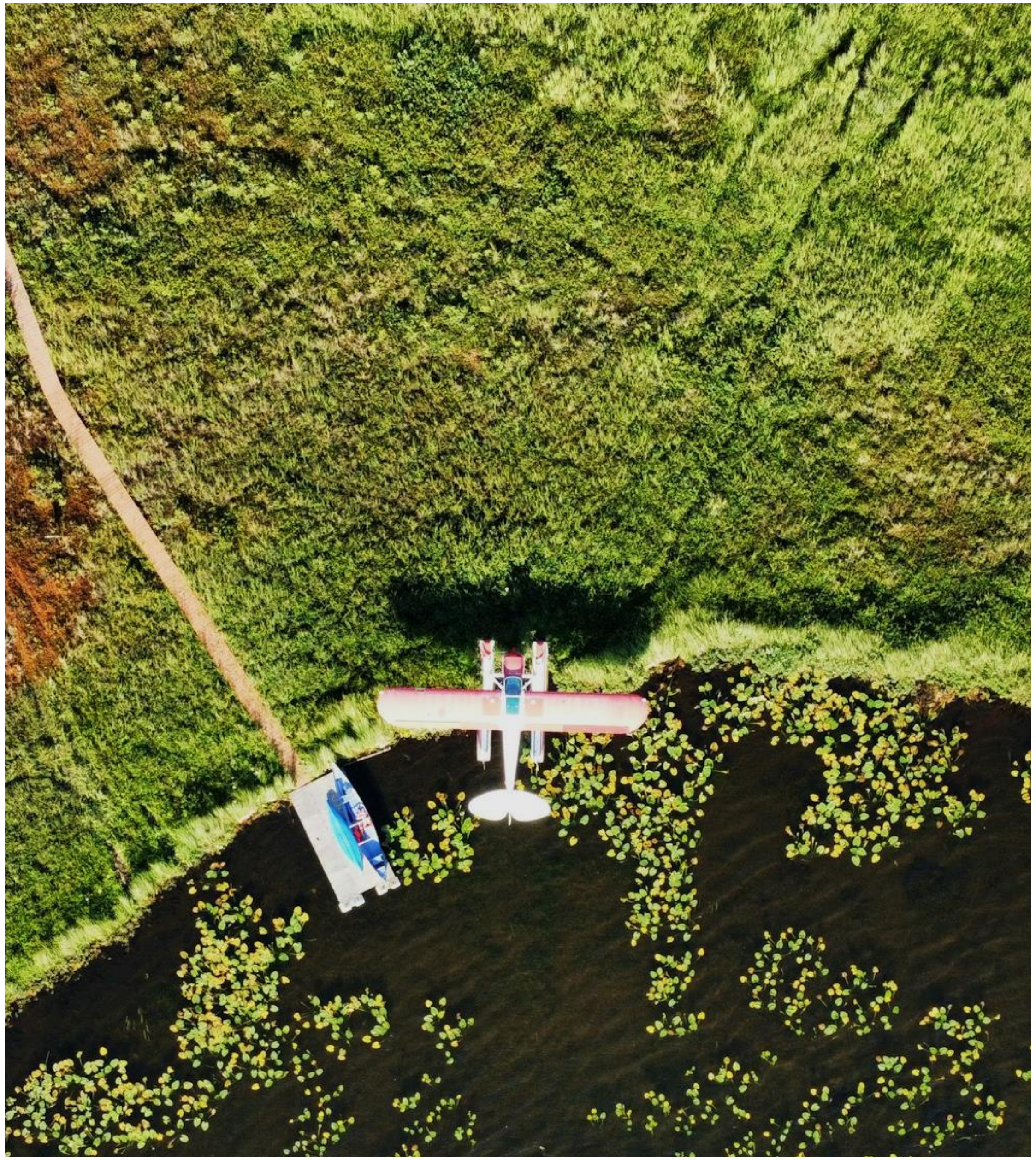
Additional Considerations

There are multiple positive initiatives and advantages across the region for SAF production. Additional feedstock production is unlikely to come from agricultural land expansion, but rather improvements in farming practices, increased irrigation, R&D and large-scale biomass adoption. Smallholder farming makes up the majority of farming activities, which creates some complexity with regards to contracting and aggregation of these feedstocks.

Feedstock certification may also require key consideration given feedstocks such as cassava, palm oil, and forest and wood residues demonstrate certification risks under CORSIA guidelines. Additional and/or redistribution of environmental and social burdens should also be mitigated and further improved where possible. This includes key areas such as considering the environmental impacts of bio-refineries and blending facilities and potential unintended consequences on land use, biodiversity, and food security, as well as social impacts such as displacement and/or creation of jobs.

Technology Pathways

The MCA, using the following criteria: Financial indicators (33%), Environmental/Efficiency indicators (30%), Technical indicators (27%), and Experience indicators (10%), has determined that HEFA ranks the highest overall, followed by ATJ, HTL, Gasification/Fischer-Tropsch, and Gasification/Methanol. However, it should be noted that many of the dryer agricultural and forestry feedstocks identified and assessed as part of this study are typically not compatible with the HEFA pathway, in which case the ATJ pathway would rank the highest for such feedstocks.



9. Concluding Remarks and Recommendations

Thailand

1. Relatively high feedstock availability
2. Equipped with oil import/export facilities that can be upgraded.
3. Have commenced first commercial production of Sustainable Aviation Fuel.
4. Appear to be relatively more mature in the planning and implementation of SAF e.g. incentive proposal is in discussions and SAF product plants being built.
5. *No official SAF mandates yet,* however **SAF Targets by Thai Airways International: 2% to 60% SAF Blending from 2025 to 2050**

Vietnam

1. Equipped with oil import/export facilities that can be upgraded.
2. SAF incorporation initiated by Vietnam Airlines
3. *No official SAF mandates yet*

Philippines

1. Relatively high amount of existing biorefineries
2. Equipped with oil import/export facilities that can be upgraded
3. SAF incorporation initiated by Cebu Pacific Airlines
4. *No official SAF mandates yet,* however **SAF Targets by PAL: min 1% SAF Blending by 2026**

Malaysia

1. Equipped with oil import/export facilities that can be upgraded.
2. Long term plans in place for the use of SAF.
3. SAF incorporation initiated by Malaysia Airlines
4. Appear to be relatively more mature in the planning and implementation of SAF e.g. SAF incentive and credits program, SAF supply chain optimisation plan, and SAF facilities being built.
5. **Target: 47% SAF Blending by 2050**

Indonesia

1. Relatively high feedstock availability
2. Equipped with oil import/export facilities that can be upgraded.
3. Long term plans in place for the use of SAF.
4. SAF incorporation initiated by Garuda Indonesia.
5. Appear to be relatively more mature in the planning and implementation of SAF e.g. released mandate of SAF blending.
6. **Target: 2.5% SAF Blending by 2030, 30% SAF Blending by 2050.**

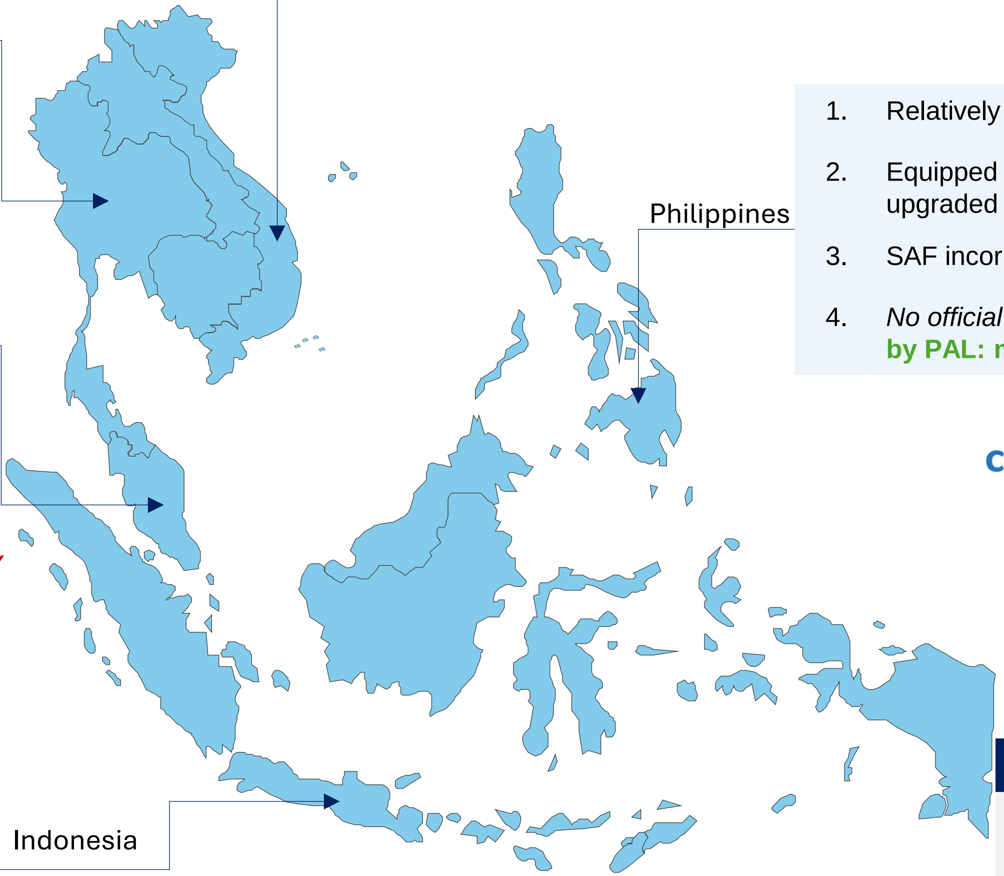


Figure ES10: Example SAF advantages and initiatives across Southeast Asia

SAF Blending Target by Other Countries

- **Cambodia and Lao PDR**: *no official SAF mandates yet*
- **Japan**: **10% SAF Blending by 2030**
- **Singapore**: **3-5% SAF Blending by 2030**
- **South Korea**: **1% SAF Blending by 2027**

9. Concluding Remarks and Recommendations

To conclude the study, key recommendations on potential levers and contract/government initiative enablers that may assist with the growth and development of the SAF sector within the Southeast Asia region are listed below.

Potential Levers (Government Support) for Project Developments

Based on the study completed, the following potential levers may be considered by government stakeholders to assist with the SAF project developments:

- Government to establish a biomass inventory register detailing biomass types, availability, utilization and major stakeholder groups.
- Government to establish land management outreach with farmers and the agricultural sector to promote involvement in SAF feedstock supply and sustainable attitudes to its production.
- Government to consider establishment of SAF carbon accounting methodologies consistent with international best practices, including IATA's newly announced SAF Accounting and Reporting Methodology and upcoming SAF Registry.This includes establishing a local guarantee of origin (GoO) schemes to support product quality and low-carbon integrity for client customers and avoid inconsistencies arising from differing methodologies across countries.
- Government to consider planning for bioenergy precincts enabling the coordination of share services and infrastructure, reducing SAF project development risk.
- Government to consider planning for logistics infrastructure to allow for feedstock and product movement including road planning reservations from key biomass sources to potential SAF production precincts, and product from precincts to export or domestic consumption centres.
- Government to establish a centralised SAF development hub with general information to speed-up and facilitate developments including technology pathways with their costs, yields, utilities requirements, minimum scale, quantities of feedstock required.
- Grants focused on specific studies to structure the feedstock supply for a particular project (not industry wide but project specific), covering feedstock availability, cost, contractibility / bankability, logistics.
- Government to provide guarantees for project finance debt to cover offtake merchant risk, feedstock risk, performance risk or directly provide low-cost loans.

Potential Contract and Government Initiative Enablers

Assuming this is for contracts between the project developer (SAF plant) and the growers, "nice to haves" in the contracts for the growers are:

- Buyer commits to buy 100% of the waste biomass generated, however the grower doesn't have the obligation of a specific number of tons because their waste biomass supply is dependent on factors such as the crop / weather.
- Buyer provides gathering infrastructure required such as bins or warehouses, if required.
- Buyer is responsible for transportation of the biomass.
- Buyer pays a known price per ton and yearly indexation is also known e.g. inflation.

Initiatives that governments can do to facilitate the feedstock supply:

- Provide grants to cooperatives of growers for infrastructure and machinery required to aggregate and store biomass, if required.
- Provide investment incentives for waste management companies as they have been typically known to gather biomass from growers and deliver to SAF plant(s).

9. Concluding Remarks and Recommendations

Below includes multiple examples and areas of policy development identified and/or applied in specific jurisdictions with the objective of accelerating SAF adoption. Furthermore, a high-level review on potential impacts to SAF importing and exporting countries is also included.

1. Incentivisation through Production Credits

Page 192 includes an example whereby US has adopted provision of tax incentives based on fuel's Carbon Intensity (CI) score. Such policies on the fuel supply can have a "push" effect, however, are reviewed to have greater impact on potential export countries, such as Indonesia and Thailand. Although there may also be impacts on countries importing SAFs, this is dependent on economic factors and if the incentives/credits assist with the cost competitiveness of SAF with respect to conventional jet fuel.

2. Mandates at the End Use Location

Page 192 includes an example whereby EU has adopted SAF mandates at union airports. Such policies on the fuel demand can have a "pull" effect and are reviewed to have both an impact on both the potential import countries (e.g. Singapore) as well as export countries (e.g. Indonesia and Thailand i.e. the pull effect may have greater impact on the overall supply chain compared to policies such as tax incentives/credits on the supply side.)

3. Establishment of a Green Trade Lane

Page 149 includes a high-level review on the potential of establishing green trade lanes, which requires collaboration. It is reviewed to have similar impacts on both potential SAF import and export countries given green trade lanes act as trade routes that connects ports and support zero-emission shipping. This may promote SAF trade and therefore has the potential to improve sustainability and efficiency of identified optimal trade routes between importers and exporters such as Indonesia SAF exports to Singapore.

4. SAF Government Support for Project Developments e.g. biomass inventory and land management

Page 219 includes examples of potential government support initiatives that can act as levers to enhance SAF adoption, particularly targeted towards potential SAF exporters, such as Indonesia and Thailand. However, with realised improvements in developing scale, technology readiness and accounting practices, further economic and sustainable advantages may be realised, impacting such SAF adoption from import countries such as Singapore.

5. SAF Contract and Government Enablers

Page 219 includes examples of potential contract enablers that largely assist potential export countries such as Indonesia and Thailand, by providing additional protection to suppliers due to inherent risks such as seasonality, as well as proposes buyers and export countries to have greater involvement in the supply chain and infrastructure developments.

9. Concluding Remarks and Recommendations

Some examples of criteria and diagnostic questions that may be considered for policy developments are included below.

Lock-in and Policy Stability ("Stickiness")

Effective policy is thought to be effective in locking in and have difficulty in reversing. Various policies have different levels of lock-in and policy stability ("stickiness").
A key **diagnostic question** for this criteria is**: What can be done to create "stickiness" making reversibility immediately difficult?** An example includes contractual enablers that have the ability of establishing lock-in clauses and a duration for the contract.

Self Reinforcing

Similar to the concept of "stickiness" mentioned above, policies typically have greater success when they are self reinforcing and the costs of reversing rise over time.
The **diagnostic question** for this criteria is: **What can be done to self-reinforce and make reversibility immediately difficult**. Examples of this typically include government support for project developments that may influence technology readiness, production pathways and subsequent infrastructure developments. Once established, costs of reversing such infrastructure developments e.g. new or repurposes refineries, may increase over time.

Increasing Returns

Effective policy can also occur when the benefits increase over time.
The **diagnostic question** for this criteria is: **What can be done to entrench effectiveness over time?** A positive example may be establishments of Green Trade Lanes, which have the ability to provide long term benefits by accelerating the development and adoption of sustainable shipping technologies, promoting cleaner air quality in port cities, fostering economic growth through green innovation, and potentially contributing to reductions in greenhouse gas emission from international trade over time.

Positive Feedback

In this case, the policy has the ability to achieve positive feedback and expand populators and reinforce original support.
The **diagnostic question** for this criteria is "**What can be done to expand the population that supports the policy"**. In this case it is beneficial to consider both the US and EU policy approaches for SAF support. SAF adoption through production credits (e.g. US policy) may not be as effective as SAF Adoption Mandates at the End Use Location (e.g. EU policy) given adoption mandate appears to have greater ability to impact a greater number of populators. For example, mandate of SAF at airports may impact a greater extent of the supply chain including airports, airlines, shipping, SAF producers and feedstock suppliers. However, SAF adoption through production credits has impact on feedstock suppliers and SAF producers, however the impact on other supply chain stakeholders and further end use customers may not be as effective.

1. Introduction and Background

1. Introduction & Background

1.1 Acknowledgement

GHD acknowledges and extends our gratitude towards all stakeholders for their invaluable support in the development and completion of this Techno-Economic Assessment Report including the Project Sponsor CTIF implemented by Cowater International (Cowater) in associated with the Institute of Public Administrators of Canada (IPAC) under Global Affairs Canada (GAC).

We express our sincere thanks to the ASEAN Secretariat, our Beneficiary, for their continued collaboration and trust.

We also express our appreciation to Boeing as our Knowledge Partner for their expertise and insights that have further enhanced the delivery and content of the Techno-Economic Assessment Report.

1.2 Background

CTIF/Cowater's objective is to foster the development and deployment of Sustainable Aviation Fuels (SAFs) using waste feedstocks across ASEAN Member States.

The mandate focuses on creating and disseminating knowledge products to guide ASEAN's strategic commitments to sustainable agriculture, net-zero carbon emissions in aviation, renewable energy targets, and promoting a circular economy, aiming to yield significant social benefits such as job creation, gender equality, and health improvements, particularly for women and children affected by air pollution.

The expected outcome is recommendations and findings with respect to using SAFs from agricultural and forestry waste feedstocks, which will contribute to increasing SAF production and deployment, aiding in the decarbonisation in the aviation sector.

1.3 Purpose

The Canadian Trade and Investment Facility for Development (CTIF) has engaged GHD to provide techno-economic assessment in seven ASEAN Member States using waste feedstocks for SAF production and furthermore develop knowledge sharing products and a knowledge sharing event to share pertinent learnings, findings and recommendations from the techno-economic assessment to support the intended increase in SAF production, deployment and decarbonisation of the aviation sector.

The Purpose of this Report is to provide a SAF techno-economic assessment studying the feedstock assessment, technology selection, carbon intensity, feedstock and product logistics, environmental and social aspects, institutional frameworks, and a financial assessment. Further details of these workstreams are included in Section 1.9.

1.4 General Scope and Limitations

This report has been prepared by GHD for the Cowater International Inc and may only be used and relied on by Cowater International Inc for the purpose agreed between GHD and Cowater International Inc.

GHD otherwise disclaims responsibility to any person other than Cowater International Inc arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

All assessments, including financial and technical, completed should be considered preliminary in nature and provided on a non-reliance basis and must not be relied on by any party or for any purpose. The feedstocks considered are limited to agricultural waste and forestry waste feedstocks only.

The Report has been prepared for Cowater International Inc. as well as other involved stakeholders for the purpose of facilitating discussion on the initial SAF techno-economic assessment initial findings.

To the maximum extent permitted by law, GHD disclaims any responsibility or liability arising from or in connection with this document.

1. Introduction & Background

1.5 Limitations and assumptions on the feedstock assessment

Feedstock assessments have been executed based on publicly available sources with no field visits and/or in country surveys conducted.

Feedstock assessments for Indonesia, Lao PDR, Philippines, Thailand and Vietnam have utilised FAO data with calculations executed for determining biomass waste volumes. For Cambodia and Malaysia, FAO data along with published biomass waste volumes were utilised for the purposes of the study.

1.6 Limitations and assumptions on the supply chain assessment

Some key assumptions adopted and considered in identifying the potential SAF regional supply chain include:

- ***Feedstock and SAF Capacity & Demand**: The feedstock quantity and the potential max. SAF capacity as outlined in Sections 2 and 5.2 to 5.8 are assumed to only be fully online in 2040. SAF biorefineries are expected to be developed progressively to align with and maximise the potential SAF production derived from the respective feedstock by 2040. The jet fuel demand by the regions is extrapolated based on the projected CAGR of 4.6% up to 2040. Meanwhile, SAF demand from both SAF importers and exporters is estimated to be proportional to the number of airlines operating at the major airports (e.g., SAF blending facilities or ports) identified in Sections 5.2 to 5.8.*
- ***Market Behaviour:** It is assumed that a rational market will prioritise sourcing from the lowest cost producer first, followed by the second lowest, third lowest, and so on.*
- ***Trade Roles:** Each country is classified as either a SAF Importer or Exporter.*
  - *Japan, Singapore and South Korea are assumed to be SAF feedstock and/or SAF importers, relying on their neighbouring countries to meet their SAF production and/or SAF demand.*
  - *SAF Exporters such as the Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam are assumed to be distributing their SAF surplus from the SAF blending facilities/Ports (Sections 5.2 to 5.9) with the highest SAF surplus after meeting their domestic consumption needs.*
  - *Lao PDR will export its products via Vietnam, with the international transportation of SAF between the two nations conducted by shipping on the Mekong River. And Vietnam is considered a re-exporter of products originating from Laos.*
- ***Supply - Demand Balance**: The relationship between production and consumption is defined as: Production - Consumption = Imports - Exports. This implies that there would be no stored inventories of SAF.*
- ***Regional Trade Isolation:** The region under study does not engage in trade with other regions such as Europe, the Americas, or the Middle East.*
- ***Uniform Port Costs**: Port freight, handling charges, and customs duties are assumed to be consistent across all countries in the region.*
- ***Estimated Distance**: The distance assessed for SAF transportation includes the journey from SAF refinery location to the nearest ports and onwards to the demand ports. This computation includes road transport, domestic sea freight and regional sea freight.*

1.7 Limitations and assumptions on the levelised cost of SAF and high-level financial model

The levelised cost of SAF (LCO SAF) calculation and the high-level financial model were prepared using high-level assumptions and order of magnitude data for CAPEX, OPEX, maintenance OPEX, cost of feedstock, product yields, capacity factor, cost of capital, useful life of equipment and others.

These assumptions are based on standard costs and information of SAF projects that GHD has been involved in and in public information. Some of these assumptions haven't been fully tested and require further investigation.

The analysis considered a horizon of 20 years, assuming no major replacement of equipment is necessary during this period.

No bottom-up calculations or estimations of unitary prices were undertaken. No consideration has been given to the impact of exchange rates, specific tax regulation, cost of transport of SAF and other products to customers.

1. Introduction and Background

1.8 Countries

The scope of the Techno-economic Report is a desktop review and assessment. The countries covered includes Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Philippines, Thailand, and Vietnam as per Figure 1.1 below.

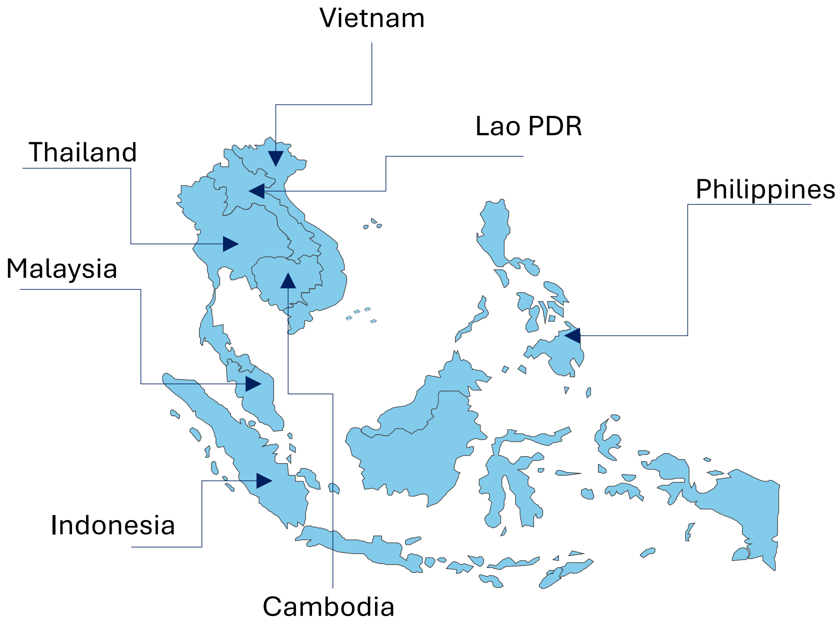


Figure 1.1 ASEAN Member States to be covered for the Mandate

1.9 Methodology

GHD's mandate focuses on agricultural and forestry waste feedstock sources, excluding municipal solid waste. GHD has endeavoured to follow the agricultural and forestry feedstock categories as provided by ICAO.

In this Techno-economic Assessment Report, the findings are focused on the following workstreams to develop a comprehensive understanding of SAFs within the target countries:

- **Feedstock Assessment** – Evaluates availability, location, consumption, and potential production increase of feedstock volumes, detailing quantities, seasonality, storage limitations, and specifications, while estimating agricultural and forestry waste availability.
- **Technology Selection** – Presents ASTM-approved and other viable technology pathways, considering plant capacities, yields, co-products, utility needs, workforce skills, job creation, regulatory requirements, SWOT analysis, and cost rankings.
- **Carbon Intensity** – Assesses typical CORSIA default and GHD-calculated life cycle emissions for identified feedstocks. Ranks SAF products by carbon intensity and emissions savings, with recommendations for CORSIA eligibility.
- **Feedstock and Product Logistics** – Identifies key supply chain locations and infrastructure, associated costs, logistics, regulatory requirements, and potential SAF regional supply chain that include South Korea and Japan.
- **Environmental and Social Aspects** – Identifies key environmental and social risks and opportunities in the SAF value chain, with a high-level stakeholder analysis and potential research opportunities.
- **Institutional Frameworks** – Identifies government and private sector activities and enabling policies for SAF adoption, ranking countries based on development indexes.
- **Financial Assessment** – Assesses scale, CAPEX, OPEX, and LCOE of SAF for likely technology pathways.

2. Feedstock Assessment

GHD Advisory

→ Feedstock Assessment Overview

2. Feedstock Assessment

2.1 Feedstock Assessment Overview

For the feedstock assessment the following pertinent feedstock parameters and properties were studied for each country: Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam.

1. Feedstock Types and Locations

Evaluation of the potential agricultural (plant-based) and forestry waste for Sustainable Aviation Fuel (SAF) production in Southeast Asia including waste volumes generated per region and per country, high and low potential feedstocks identification, waste to product conversion and calculations and waste hotspots identification.

2. Feedstock Growth Potential

Taking into consideration key feedstocks with each country, assessment of business-as-usual activities, practically available feedstock and potential to increase production of selected feedstocks.

3. Feedstock Seasonality

Assessment of the planting and growth, as well as harvesting season for each of the key feedstocks identified.

4. Feedstock Storage

Assessment of typical feedstock storage periods for each feedstock.

5. Feedstock Composition

Assessment of typical feedstock compositions including moisture content, carbon content, ash content and bulk density.

6. Additional Land Assessment

High level overview of the utilised and available land for agricultural and forestry expansion.

7. Feedstock Costs

Additional considerations required for assessment of the feedstock costs.

8. Large-scale Biomass Management Advantages

Identification of large-scale farming, harvesting and transport advantages, particularly from an efficiency, productivity and cost perspective.

2. Feedstock Assessment

2.1 Feedstock Assessment Overview

Key Findings

1. Feedstock types and Locations

For five countries - Cambodia, Indonesia, Lao PDR, Philippines and Vietnam, the types of agricultural waste biomass with apparent higher potential are generated in the production of **cassava, rice and corn.** Thailand is similar, where the types of agricultural waste biomass with apparent higher potential are generated in the production of **cassava, rice and oil palm fruit.** In Malaysia, **oil palm** cultivation dominates agricultural production, followed by rice and a smaller extent of coconut farming. Philippines and Indonesia also produces significant volumes of coconut, yielding waste biomass in the form of coconut husk and non-standard coconut.

While sugarcane is produced in significant quantities in most countries, much of the waste feedstock generated is used for electricity and steam generation for sugar mill operation, and unlikely to be available for fuels production without significant and deliberate changes to the way the mills operate.

Forestry waste generation potential was most prevalent in Indonesia followed by Thailand. In most cases, forestry wastes generated by sawmills could be a good supplementary feedstock for SAF production, since it will already be aggregated at the mills and is typically not bound by seasonality.

Indonesia and Thailand have been assessed to hold the greatest volumes of plant-based agricultural wastes and potential converted product volumes, while **Lao PDR has been assessed to hold the least** as per Figure 2.1. There are multiple agriculture and forestry waste "hot spots", where more than one type of agricultural waste is produced in sufficient quantities for SAF production, as per Figure 2.2.

Feedstock properties such as **moisture content** and **bulk density** require consideration. **Moisture content is generally high** for these feedstocks and drying may be required prior to thermal conversion, although some conversion technologies are more forgiving than others. Moisture in the feedstock also adds to the transport cost on a $/litre of produced fuel basis. Most agricultural waste feedstocks have low bulk densities in the order of 70-100 kg/m^3, resulting in high transport cost. **Forestry wastes have higher densities** in the order of 120-520 kg/m^3 for logging residues and 320-520 kg/m^3 for wood processing residues.

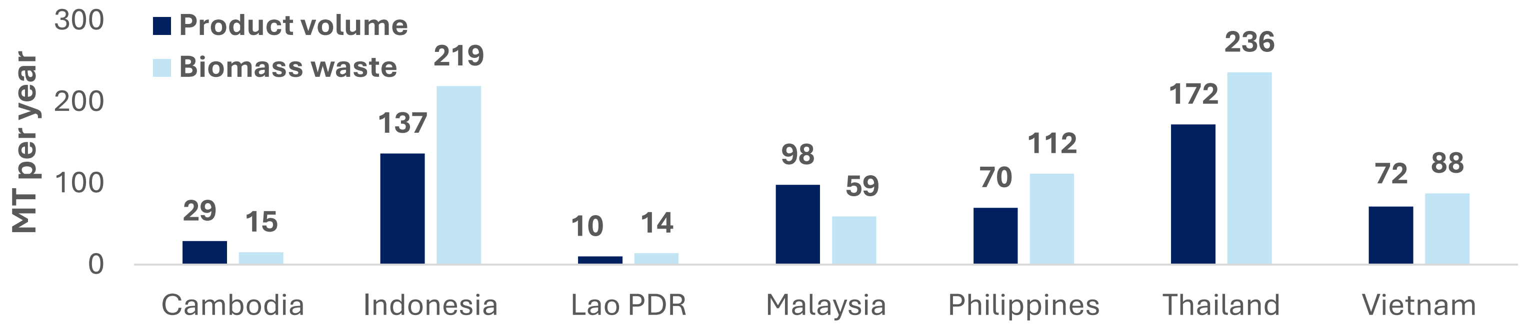


Figure 2.1: Product Volume and Biomass Waste per Country[4]

*Sugarcane is not included in this chart because while sugarcane is typically the most prevalent crop, it is unlikely that sugarcane bagasse would be available for SAF production as it is used for energy generation

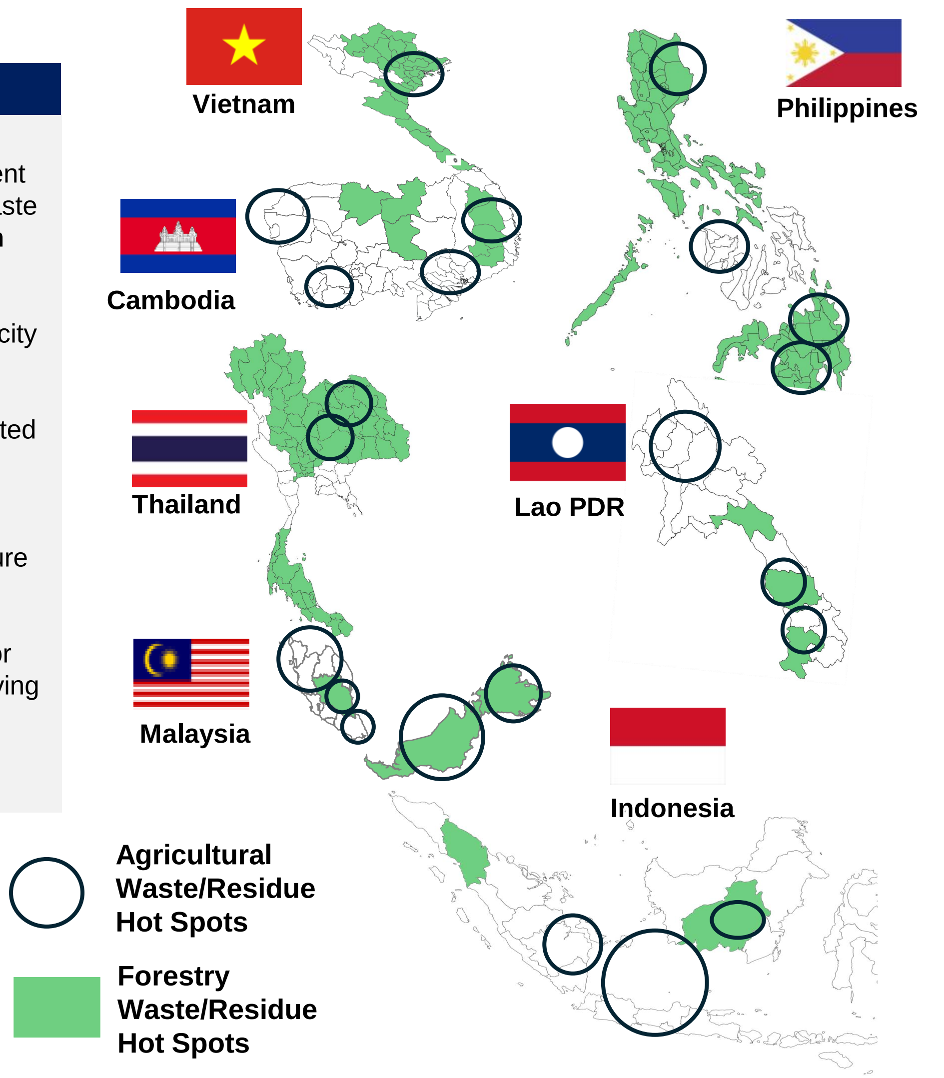


Figure 2.2: Overview of Agriculture and Forestry Waste/Residue Hot Spots in each Country

2. Feedstock Assessment

2.1 Feedstock Assessment Overview

Key Findings

2. Feedstock Growth Potential

While there appears to be significant volumes of agricultural wastes available from rice, corn and sugarcane cropping, access to these wastes may be difficult. In all of the assessed countries, the largest portion of these crops are grown by smallholder farmers, so that contracting and aggregation of the wastes may be difficult to orchestrate. In many cases, the wastes are left on the field or burnt, and in order to access these feedstocks, farming practices will have to change. This is only possible with government and private industry support to educate farmers and make equipment available to make collection of these wastes cheaper. Incentives could also assist to encourage farmers to collect some of these wastes. It is important to understand how much of each of these wastes could be removed from the fields without negatively impacting soil quality and the natural insulation and weed protection that many of these feedstocks offer when left in the field.

In some cases, waste feedstocks are already aggregated at mills, such as EFB at palm oil mills and sugarcane bagasse at sugar mills. SAF production facilities could take advantage of such aggregated feedstocks.

All of the assessed countries already utilise large percentages of land for agricultural purposes, so that it is difficult to imagine that feedstock growth will be the result of expanded agricultural land being made available. Therefore, increased crop and biomass wastes yield will be the result of better farming practices and educating farmers on these practices, increased irrigation, research and development into new and improved species of specific crops and better access for farmers to machinery to mechanise planting and harvesting.

3. Feedstock Seasonality

All of the assessed countries have relatively constant temperature profiles throughout the year, with a notable “wet” and “dry” season only. As a result, many crops can be grown all year round, with planting typically preferred at the beginning of the wet season for many crops. There are fast-growing crops like rice and corn where more than one harvest can be achieved per year. Therefore, relatively fresh feedstocks should be available for SAF production all year round, particularly if more than one type of feedstock is utilised for a SAF facility. The temperate climate with the ability to grow crops all year provides South East Asia with an advantage over many other regions such as Europe and North America for biofuels production.

4. Feedstock Storage

Most of the feedstocks that have been identified for SAF production in the assessed countries can be stored for up to a year, provided that it is stored correctly, in some cases dried, and covered to protect it from rain and wind. In most cases, feedstocks can be stored in baled form or loose, and either stored under a roof or under tarps. Feedstock availability and storage costs should be weighted against each other to determine how much feedstock can be practically stored at the production site. Safety and the fire hazard that the stored feedstock poses should also be considered, particularly when the feedstock is dried prior to storage or stored for prolonged periods of time (becoming dryer over time).

Given that most of the feedstock providers are smallholder farmers, it is unlikely that storage facilities will be available at the farms.

5. Feedstock Composition

Most of the assessed feedstocks, including cassava, corn, coconuts, sugarcane, and forestry wastes have moisture contents between 30-85 mass%, with the exception of rice straws, EFB and cassava peels (once dried in the sun), which all have moisture contents of less than 20% mass. The moisture content influences how much energy is required to dry the feedstock prior to some of the primary processing steps (such as gasification) and therefore influences the overall energy efficiency of the process, or influences how much effluent is produced from the process that requires treatment (HTL technology pathway). It also influences transport cost, as the moisture is transported with the rest of the biomass to site but does not contribute to fuels production, and therefore increasing the unit transport cost per litre of SAF produced.

2. Feedstock Assessment

2.1 Feedstock Assessment Overview

Key Findings

5. Feedstock Composition

Most of the assessed feedstocks have less than 5 mass% ash content (dry basis), so that little solid residue remains for disposal following SAF production. The exceptions are rice straw and husks and sugarcane bagasse, with ash content of around 18-20 mass%. In the case of rice straw and husks, the ash consists mainly of silica, and could be utilised as cement filler for example.

The calorific value of the feedstocks that were assessed were all in the range of 14-18 MJ/kg on a dry basis.

The bulk density directly influences the volume of feedstock that can be transported per for example truck load and therefore directly influences feedstock transport costs. Bulk densities for feedstocks such as straws, cassava peels, sugarcane trash and coconut husks are in the order of 50-80 kg/m^3, while sugarcane bagasse has a bulk density of 80-120 kg/m^3 and wood wastes have the highest bulk density at 235-280 kg/m^3. The bulk density of wood wastes are highly dependent on how these are chipped. The bulk densities of these feedstocks can be increased through mechanical treatment such as crushing, tamping and baling at additional expense at farming sites. This should be weighed against the cost of transport feedstocks with lower bulk densities.

6. Additional Land Assessment

The assessed countries all utilise a large portion of land for agricultural purposes, and most of the rest of the land is classified as forested land and protected areas. Agricultural land in some of the assessed countries such as Vietnam is being acquisitioned for urbanisation as the population grows and socio-economic demands change. It is therefore difficult to foresee that additional land would be made available to agriculture; rather, land that is already used for agricultural activities could be repurposed for specific feedstocks as required.

The types of soil that is available in each country for crops and the types of soil that specific feedstocks thrive in or can tolerate should be considered when land is being repurposed for specific crops For countries with low-lying regions, these regions are mainly suitable for rice cropping during wet seasons. Crops like sugarcane is not sensitive and can be grown in almost all types of soil, from sandy to clay loams and acidic volcanic to calcareous sedimentary deposits. Cassava is resilient and can tolerate low soil fertility and droughts but not water-logged or saline soils. Corn can grow in various soil types but do best in loamy rich soils. Palm oil trees grows well in loamy or alluvial soils, but does not do well in soils prone to water-logging, saline or alkaline soils. Crops that can tolerate poor soils or water-logged conditions should be considered for areas where such conditions could occur, while richer soils should be reserved for those crops that will not do well in any other conditions. This should be considered while keeping biodiversity of specific areas in mind.

7. Feedstock Costs

As most of the agricultural waste feedstocks that have been identified currently have no use or value attached to them, there are no formal markets or pricing for these feedstocks. A number of parameters have to be taken into account to attach value to each type of feedstock, including cost involved to aggregate a particular feedstock, logistics cost to transport the feedstock from farm to processing site, and properties of the feedstock such as bulk density, moisture content and calorific value. [9] Higher calorific feedstocks, feedstocks with lower moisture content and higher bulk density feedstocks are typically preferred and would have a higher value attached to them than others.

8. Large-Scale Biomass Management Advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include lower overheads as a percentage of revenue, access to advanced farming techniques and easier mechanization, less complex and cheaper aggregation of feedstocks and less complex contracting for feedstocks.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

GHD Advisory

→ Feedstock Assessment Deeper Dive

2. Feedstock Assessment

2.2 Cambodia Feedstock Assessment

2.2.1 Feedstock Types and Locations

Agricultural and Forestry Waste Feedstock Summary Assessment

The types of agricultural waste biomass with apparent higher potential are generated in the production of **cassava, rice, and corn** as shown in Figure 2.3. [4] While sugarcane is produced in large quantity, sugarcane bagasse is typically unavailable for biofuels production as sugar mills use it for energy generation. The identified regions, as hubs for barley and malt processing, generate substantial spent grains, offering a steady, aggregated supply for conversion into Sustainable Aviation Fuel (SAF) feedstock.

The area with higher potential to produce SAF from agricultural wastes is **Battambang, Banteay Meanchey, and Kampong Cham** where high quantities of agricultural feedstock may be available all-year-round.

Central and Northeastern Provinces are also areas with forestry production and, hence, harvest waste and waste from sawmills and other forestry industrial plants may be available. Refer to Figure 2.4 for locations and total waste generated volumes per region and per agriculture waste feedstock.

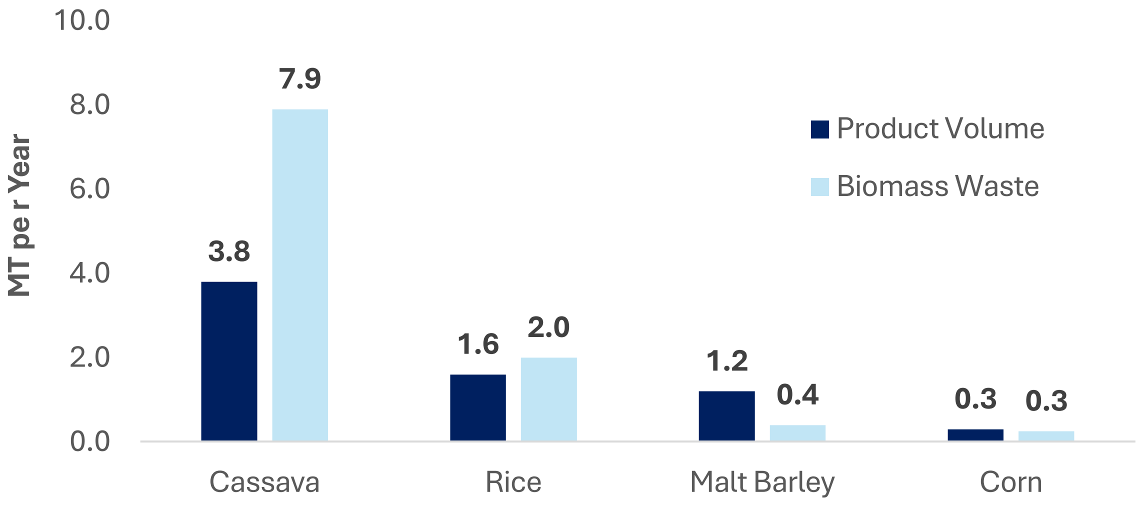
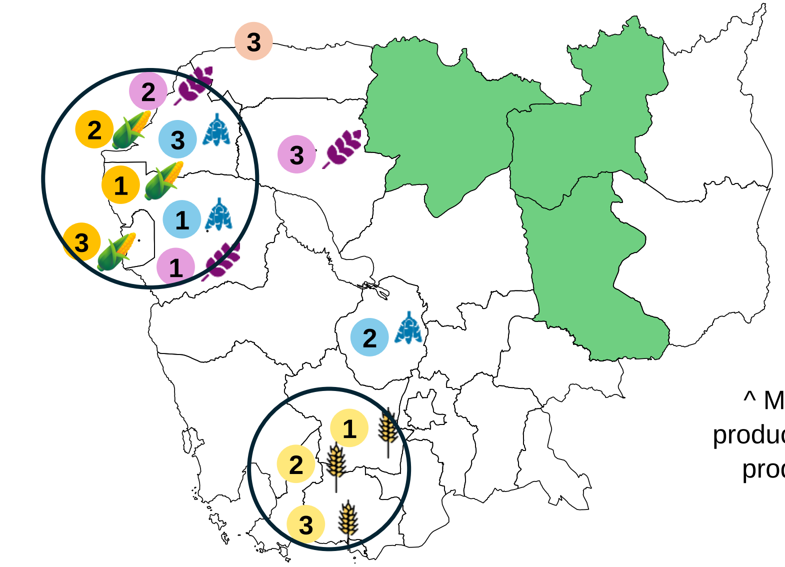


Figure 2.3: Top four Agricultural Feedstock and Biomass Waste Cambodia, 2022

Waste and residues

Cassava		MT/ year
1	Battambang	4
2	Kampong Cham	2
3	Bantheay-meanshey	1.9
Rice		
1	Battambang	1.4
2	Banteay Meanchey	0.4
3	Siem Reap	0.3

Corn		
1	Battambang	0.18
2	Banteay Meanchey	0.04
3	Pailin	0.03
Malt Barley ^		
1	Phnom Penh	
2	Sihanoukville	
3	Kampot	
Forestry**		
1	Harvest Waste	0.11
2	Industrial Waste	0.13



Source: FAOSTAT

**GHD estimation

^ Malt Barley is included for reference although not produced within Cambodia. The map highlights major producers where barley is aggregated but does not provide specific production figures.

Figure 2.4: Top three Locations of top three Agricultural Biomass, and Forestry Waste Locations in Cambodia, 2022

2. Feedstock Assessment

2.2 Cambodia Feedstock Assessment

2.2.2 Growth potential

From the feedstock interrogation, it has been determined that Cassava, rice and corn crop wastes could have significant potential as feedstocks for SAF production in Cambodia as shown in the previous page. In this section, business as usual and current destinations for the wastes are discussed, as well as efforts to increase production of these feedstocks. Cassava and rice are individually discussed.

Cassava wastes
Business as usual and current wastes uses
In Cambodia, over 650,000 ha of land is utilised for Cassava cropping.[42] It is considered a vital crop for smallholder farmers. The Cassava industry in Cambodia faces challenges such as price fluctuations, high logistic costs, natural disasters and disease spread.[43]

Cassava wastes can be classified as stems and leaves and solid residue (thippi). There are other waste streams as well but they are not typically suitable for SAF production. Stems and leaves are left in the field as soil enhancer or burnt. It can also be utilised as animal feed or composted. Thippi can be composted, used as animal feed or as a feedstock for bioplastics and other similar processes (not currently available commercially).

Increasing Cassava production
Improved varietals, modern farming techniques and continuous research and development efforts leading to improved cultivation practices are resulting in increased Cassava yields. This will not necessarily lead to increased Cassava wastes streams though.

Rice wastes
Business as usual and current wastes uses
Cambodia produced over 11 million tonnes of rice in 2022, with over 3 million people working in rice farming and paddy fields covering 75% of the agricultural land. [45] However, rice waste such as husks, straw, bran, and broken rice is largely under utilised. Rice husks are burned as fuel, used for animal bedding, or added to soil, while rice straw is used for livestock feed, mulching, or composting, though much of it is still burned, causing pollution. [46] Rice bran is mainly used in animal feed, with small-scale oil production, and broken rice is used in food and feed. Limited infrastructure and inefficient practices hinder better use of these by-products.

Increasing rice production
The Royal Government of Cambodia (RGC) is striving to transform the country into a leading rice exporter in the international market through its Rice Export Policy. To achieve this, investments have been made in irrigation systems to enable year-round rice farming, significantly improving cultivation efficiency. Programs like the “Climate-Resilient Rice Commercialisation Sector Development Program” aim to boost productivity and promote sustainable farming methods. In 2023, the “Minefields to Rice Fields” initiative was launched to convert cleared minefields into arable land for rice farming, increasing available farmland and raising farmers’ incomes by over 30%. [44] With a target of exporting one million tonnes of milled rice by 2025, these efforts demonstrate Cambodia’s commitment to increasing rice production and strengthening its global competitiveness.

2. Feedstock Assessment

2.2 Cambodia Feedstock Assessment

2.2.3 Feedstock Seasonality

The year can be divided into a rainy season and dry reason:

- Rainy season – from June to October.
- Dry season – from November to May.

The planting, growth and harvesting seasons for each of the feedstocks studied for Cambodia is shown within Table 2.1 below.

Table 2.1: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Rice	Two main seasons [41]: • Rainy Season Rice (Main Crop): Planted from May to July. • Dry Season Rice (Second Crop): Planted from November to January.	• November to December (wet-season crops) • February (Dry-Season Crops)
Maize/Corn	• Planting (Main Crop) in July to September • Planting (Dry Season Crop) in February to April	• June to August (Main Crop) • December to January (Dry-Season Crop)
Cassava	Cassava is normally planted in May at the beginning of the rainy season.	Harvesting season from November to February.
Beer of Barley/Malt	• Sowing period in November to December • Growing season in December to February	• Harvesting period from March to April.
Forestry	Any time of the year, although the rainy months are preferred	• Year-round, although the dry periods when terrain is more accessible is preferred

2. Feedstock Assessment

2.2 Cambodia Feedstock Assessment

2.2.4 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.2 below

Table 2.2: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Maize/Corn wastes	Up to a year [26]	Corn stover is typically baled and stored covered by tarps or other wrapping material. If the stover is dried to less than 40% moisture, the bales can be stored for 365 days, while higher moisture bales (50% moisture) tend to have structural integrity losses after 120 days storage, making them difficult to move for processing.
Cassava wastes	Two to three months [28]	Sun drying required prior to storage
Beer of Barley/Malt	Six to twelve months [47]	Store barley in cool, dry conditions (5-15°C) with 12-14% moisture, ensuring good ventilation and pest control. Store malt in a cool, dry place (10-15°C) with 4-5% moisture, in airtight containers to maintain freshness.
Forestry wastes	Up to a year [29]	Store as whole logs or chips. If chipped, should be stored under cover (tarps).

2. Feedstock Assessment

2.2 Cambodia Feedstock Assessment

2.2.5 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.3 below.

Table 2.3: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
Maize/Corn wastes (husk)	45-55	63	13	80-120
Maize/Corn wastes (leaves)	70-80 (green leaves)	11	5	110-130
Cassava wastes (bagasse)	75-85	5-10	1-3	80-120
Cassava wastes (peel)	60-80, reduced to 10-20% following sun drying	3	14	20-30
Beer of Barley/Malt	4-5	15-20	2-3	550-650
Forestry wastes	70-85, reduced to 40-50% once cut	18	2	235-280

2. Feedstock Assessment

2.2 Cambodia Feedstock Assessment

2.2.6 Additional Land Assessment

In Cambodia, agricultural land accounts for more than 30% of the total land area, serving as a vital component of the country's economy and food security. With agriculture being central to rural livelihoods, the government has made efforts to boost agricultural productivity despite facing challenges like climate change, urban expansion, and limited available land. While rice remains the primary crop, there has been a growing push to diversify the sector, with crops such as cassava, maize, and rubber gaining prominence. However, as urbanisation and industrialisation trends continue, competition for land resources has increased, restricting the expansion of agriculture. To address these challenges and bolster food security, the Cambodian government has introduced several initiatives aimed at maximising land use efficiency. These include utilising idle and marginal lands for agricultural projects, improving irrigation systems, and promoting sustainable farming practices. Through these strategies, Cambodia seeks to reduce its reliance on food imports and enhance domestic food production. By focusing on rural development and optimising agricultural practices, Cambodia aims to secure a stable food supply, strengthen self-sufficiency, and maintain sustainable agricultural growth in the face of changing land use dynamics.

2.2.7 Feedstock Costs

Feedstock costs in Cambodia are influenced by various factors, including the availability of raw materials, transportation costs and market demand. Agriculture plays a significant role in Cambodia’s economy, with key feedstocks like rice, cassava, maize, and forestry. However, fluctuations in global commodity prices, local production constraints, and supply chain challenges can drive up feedstock costs. In rural areas, the cost of transporting feedstocks to processing plants or markets can further inflate prices.

Cambodia relies entirely on imports to meet demands for malt barley. The primary suppliers were Australia ($39.2 million, 60.6 million kg), Germany ($21.9 million, 33.3 million kg), China ($17.6 million, 23.1 million kg), Belgium ($9.7 million, 14.9 million kg), and Denmark ($7.8 million, 11.7 million kg)[48]. The potential to increase imports depends on trade agreements, regional supply availability, and cost competitiveness. Notwithstanding, Cambodia's reliance on imports for certain industrial inputs, like fertilisers and machinery, can also impact the overall cost structure for feedstock production. Efforts to enhance local production and improve infrastructure are critical to reducing costs and supporting sustainable agriculture and bioenergy initiatives in the country.

2.2.8 Large-scale biomass management advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include:

- Large farms have lower overheads as a percentage of revenue. Cost of inputs like seeds, fertilisers and machinery is spread over a larger output, reducing unit cost.
- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
- It is easier and cheaper to collect the harvest and waste streams from centralised large farms and transport them from a single location to another single location.
- Contracting with a single large entity (large scale farm or co-op) is considerably easier than contracting with dozens or hundreds of small-scale farmers. In addition, small-scale farmers tend to be subsistence farmers only, so that very little additional crops are grown beyond their own needs.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

2. Feedstock Assessment

2.3 Indonesia Feedstock Assessment

2.3.1 Feedstock Types and Potential

Agricultural and Forestry Waste Feedstock Summary Assessment

The types of agricultural waste biomass with apparent higher potential are generated in the production of **palm oil, rice, cassava and corn** as shown in Figure 2.5. [4] While sugarcane is produced in large quantity, sugarcane bagasse is typically unavailable for biofuels production as sugar mills use it for energy generation.

The areas with higher potential to produce SAF from agricultural wastes are **Central Java and East Java**, where high quantities of agricultural feedstock may be available all-year-round. **Central Kalimantan** also seem to have high potential as there is large production of oil palm and forestry production and, hence, harvest waste and waste from sawmills and other forestry industrial plants may be available. Refer to Figure 2.6 for locations and total waste generated volumes per region and per agriculture waste feedstock.

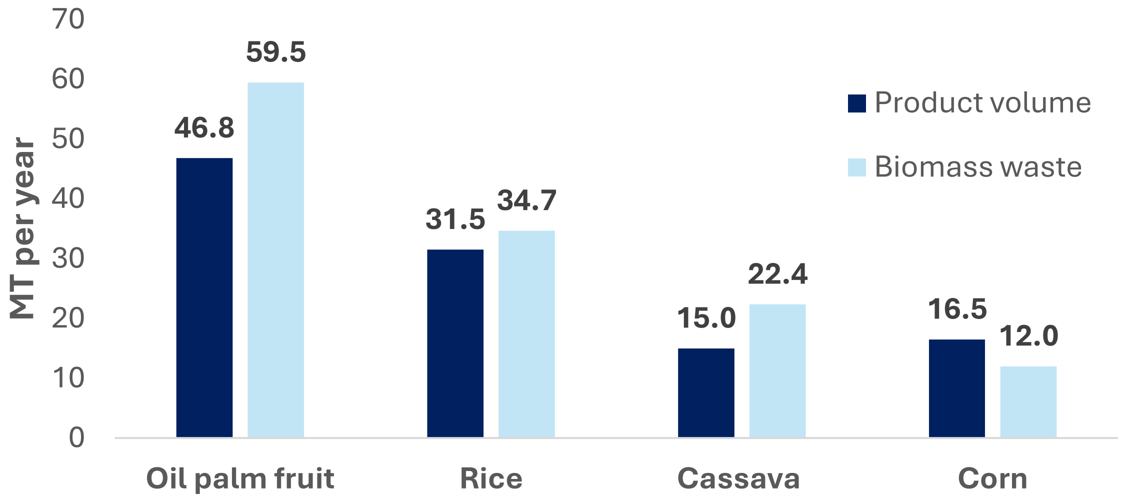
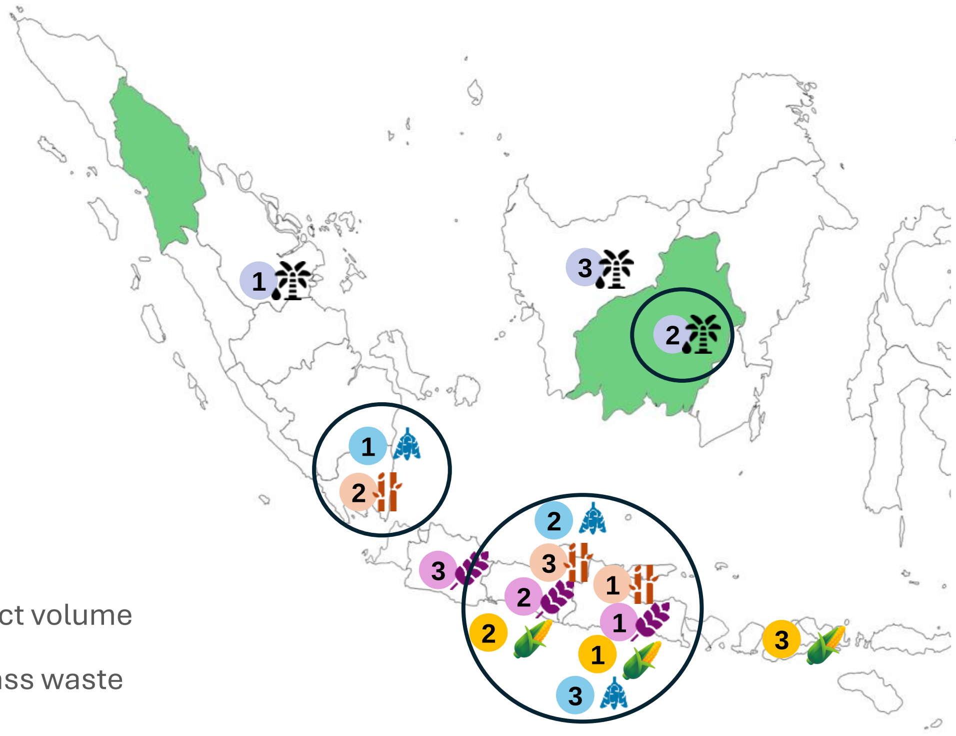


Figure 2.5: Top four Agricultural Feedstock and Biomass Waste in Indonesia, 2022

*While sugarcane is the most prevalent crop, it is unlikely that sugarcane bagasse would be available for SAF production as it is used for energy generation



Waste and residues

	Oil palm fruit wastes	MT/year
1	Riau	15
2	Central Kalimantan	14
3	West Kalimantan	9
Rice wastes		
1	East Java	12
2	Central Java	11
3	West Java	11
Cassava wastes		
1	Lampung	12
2	Central Java	5
3	East Java	3
Forestry wastes		
	Harvest waste	7
	Industrial waste	8
Corn wastes		
1	East Java	5
2	Central Java	2
3	West Nusa Tenggara	2
Sugarcane wastes		
1	East Java	3.0
2	Lampung	2.1
3	Central Java	0.5

Source: FAOSTAT, GHD estimate

Note: Papua and West Papua Provinces are also Forestry plantation locations, however they are not visible in the map

Figure 2.6: Top three Locations of Top Agricultural Biomass, and Forestry Waste Locations in Indonesia, 2022

2. Feedstock Assessment

2.3 Indonesia Feedstock Assessment

2.3.2 Growth potential

From further interrogation of the available feedstocks, it has been determined that oil palm fruit, rice, cassava and corn wastes could have significant potential as feedstocks for SAF production in Indonesia. In this section, business as usual and current destinations for the wastes are discussed, as well as efforts to increase production of these feedstocks. Each feedstock is individually discussed.

Oil palm fruit

Business as usual and current wastes uses

Empty fruit bunches (EFB) can be utilised for mulching, however, only a small portion of EFB is used for this. The remaining EFB is deposited at plantations where it decomposes for soil enhancement, or abandoned at palm oil mills and left to decay as waste. This implies that a large proportion of EFB would already be aggregated at the mills and available for use for SAF production. Ideally, a SAF facility using EFB would be located close to large plan oil mills.

Some potential additional uses are being explored for EFB, but these are all in research phase, including:

- Use in the pulp and paper industry to produce packaging paper.
- Feedstock for biocomposites.

Increasing oil palm fruit production

Indonesia is the world's largest supplier of palm oil. Due to its high yields, low cost to grow and stability of the palm oil market, it is the world's most widely used vegetable oil. Due to increased demand over the last number of years, the production in Indonesia increased by 400% over the past two decades. The production growth was mainly attained through acreage expansion. However, due to the threat to biodiversity the expansion of palm oil is no longer supported and the Indonesian government enacted a moratorium on palm oil permits to clear new land for planting. The palm oil crops growth has therefore slowed considerably, and is expected to remain steady or decline over the next years.

One of the ways to have a constant supply of palm oil is to closely monitor trees and replace old trees on a regular basis before they reach the end of productivity. While this does not impact on the production of EFB, the trees that are removed could potentially be utilised as biomass for SAF production along with EFB.

The Indonesian Sustainable Palm Oil Standard (ISPO) was introduced in 2011 in Indonesia with the aim of improving the sustainability and competitiveness of the Indonesian palm oil industry. The principles include a licensing system and plantation management, technical guidelines for palm oil cultivation and processing, environmental management and monitoring, responsibilities for workers, social and community responsibility, strengthening community economic activities and sustainable business development.

The Roundtable on Sustainable Palm Oil (RSPO) is a global, non-profit organization with voluntary members, focused on bringing together stakeholders from across the palm oil supply chain to develop and implement global standards for sustainable palm oil production.

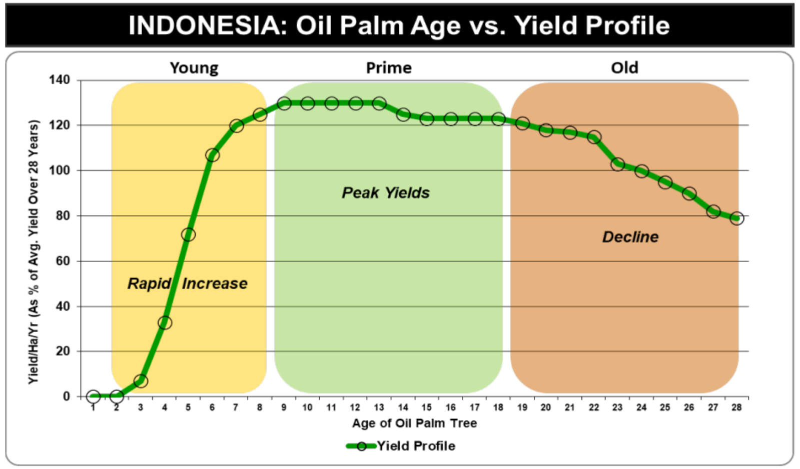


Figure 2.7: Oil Palm age versus yield profile (Indonesia Palm Oil: Historical Revisions using Satellite-derived methodology, Commodity Intelligence Report)

2. Feedstock Assessment

2.3 Indonesia Feedstock Assessment

2.3.2 Growth potential

Sugarcane wastes
Business as usual and current wastes uses
The sugarcane biomass fuels include bagasse, the fibre by-product of sugar extraction from cane stalks, and trash, the tops and leaves of the sugarcane plant that are typically burned off the field before harvest or (with harvest of unburned cane) removed at harvest and left on the field to decompose. To access the tops and leaves, the sugarcane fields can no longer be burnt before harvesting. While this allows for access to this waste biomass and reduces emissions, burning makes cane harvesting cheaper and easier and reduces exposure to pests in the cane. In Indonesia, burning of the cane is not allowed, and therefore sugarcane tops and leaves should be available for harvest/collection.

Increasing rice production
In Indonesia, the increase in middle-income population is causing a structural change in diets from carbohydrate-rich staples (rice, roots, and tubers) to vegetable oils, animal products (meat and dairy foods), and sugar. The demand for sugar is increasing in Indonesia and became the world’s largest sugar importer in 2017-2018. Therefore, there is considerable scope to increase sugarcane production, should land be available to do so.

In order to increase sugarcane production, an increase in sugarcane planting area and an increase in productivity is required. New sugarcane planting areas are being explored in Indonesia at present. To increase productivity, better nutrient management, water management via irrigation and integrated weed, pest and disease control is required.

Corn wastes
Business as usual and current wastes uses
Corn husks, leaves and stalks typically have no economic value. Leaves and stalks are typically left on the field and serves as insulation and to smother weeds and enhance the soil quality. Corn stover is also currently included as animal feedlot finisher rations, with between 5-15% of the rations consisting of corn stover.

Increasing corn production
Indonesia aims to increase corn production through the distribution of higher quality seed that leads to increased yield per hectare. However, this will not necessarily lead to an increase in corn wastes.

2.3 Indonesia Feedstock Assessment

2.3.2 Growth potential

Rice wastes
Business as usual and current wastes uses
Indonesia grows substantial volumes of rice and is also one of the largest rice consumers in the world, with the nation's per capita rice consumption recorded at 150 kg of rice per person per year in 2017. Smallholder farmers account for around 90 percent of Indonesia's rice production, with each farmer holding an average land area of less than 0.8 hectares. This implies that contracting and aggregation of rice wastes could be very difficult in Indonesia.

Approximately 60% of the rice straw produced in Indonesia is burned on the field. Alternatively, it is left on the field and plays a crucial role in maintaining soil stability and fertility.

Studies have been undertaken in Indonesia[31]. The farmers' perception is of critical importance in developing a supply chain for rice straw. It was determined that the primary factors determining the participation of farmers were economic and environmental considerations, and that the government's involvement had a significant impact on farmers' expectations of rice straw valorization.

Increasing rice production
Indonesia has been striving to reach self-sufficiency in rice and therefore there is still room for expansion. However, it is unlikely that land area for rice production will be increased, and rather, agricultural land is decreasing rather than increasing in Indonesia due to other uses for the land. Therefore, more efficient production is required, rather than additional land use.

Large portions of rice in Indonesia is already under irrigation with 95% of the crop relying on irrigation. Therefore, additional irrigation use will not lead to increased rice production.

Farmers tend to use non-optimal production techniques, and therefore production could be improved through improved farming practices. However, it is difficult to implement new farming techniques to a very large volume of smallholder farmers, other than through long-term education and support. Sustainable rice production would require the development and deployment of new crop management technologies and approached.

Lastly, improved upland rice varieties have not been well adopted, and the adoption of higher yielding species could lead to increased crops. However, this does not necessarily produce additional rice wastes material.

2. Feedstock Assessment

2.3 Indonesia Feedstock Assessment

2.3.3 Feedstock Seasonality

The year can be divided into a wet season and dry season:

- Wet season – from November to March,
- Dry season – from April to October.

Temperatures are very similar throughout the year with averages of 25 – 28 ºC. The planting, growth and harvesting seasons for each of the feedstocks studied for Indonesia is shown within Table 2.4 below.

Table 2.4: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Sugarcane	Sugarcane is planted in November to April [32]	April to October
Oil palm fruit	All year	All year
Rice	Two main seasons [33]: • Rainy Season Rice: Planted from November-December. • Dry Season Rice: Planted from February-March.	• January and February (rainy season) • May and June (dry season crop)
Corn	October to December [33]	Harvesting season from February to April.
Cassava	September to November [34]	Harvest takes place 8-12 months after planting, depending on requirements.
Forestry	Any time of the year, although the rainy months are preferred	Year-round, although the dry periods when terrain is more accessible is preferred

2. Feedstock Assessment

2.3 Indonesia Feedstock Assessment

2.3.4 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.5 below.

Table 2.5: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Sugarcane wastes	Up to a year [23, 24]	Can be stored as bales or loose material. For loose storage, the piles should be covered by tarps to reduce losses. Bagasse can be dried first or stored as wet material. Dried material is less likely to undergo significant degradation but is a fire hazard, and requires additional equipment and energy for drying. Wet storage requires no drying up front and the fire risk is reduced to almost zero, but handling of the wet material can be difficult. Baling reduces the transport cost of the wastes but requires additional labour at the harvest sites, and debaling equipment at site. In addition, the storage area required is larger than for loose material.
Oil palm fruit bunches	Up to 6 months [35]	EFB requires drying prior to storage, If wet, EFB can only be stored for a few weeks or up to a month.
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Corn wastes	Up to a year [26]	Corn stover is typically baled and stored covered by tarps or other wrapping material. If the stover is dried to less than 40% moisture, the bales can be stored for 365 days, while higher moisture bales (50% moisture) tend to have structural integrity losses after 120 days storage, making them difficult to move for processing.
Coconut wastes	Six months to a year [27]	Husk has to be stored in a cool, dry area to avoid mould growth Copra can be stored for up to 2 months, or if dried, for up to 8 months. Storage conditions are important; a well-ventilated dry environment helps to preserve the copra for a longer period of time. Coconut shells are highly durable, taking 5–6 years to decompose naturally. When stored in a cool, dry, and well-ventilated area, they can be preserved for extended periods without significant degradation. Proper storage prevents moisture absorption, mould growth, and structural weakening, while keeping the area clean helps avoid pest damage
Cassava wastes	Two to three months [28]	Sun drying required prior to storage
Forestry wastes	Up to a year [29]	Store as whole logs or chips. If chipped, should be stored under cover (tarps).

2. Feedstock Assessment

2.3 Indonesia Feedstock Assessment

2.3.5 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.6 below.

Table 2.6: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
Sugarcane wastes (trash)	45-55	16	18	80-120
Sugarcane wastes (bagasse)	50-75	20	5	50-80
EFB	2.5-14	9-18	4	130-245
POME	90-95	N.A.	<1	1000 (close to water)
PFAD	0.06-7.50	N.A.	<1	900-950
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
Corn wastes (husk)	45-55	63	13	80-120
Corn wastes (leaves)	70-80 (green leaves)	11	5	110-130
Coconut wastes	70-85	17	10	70-80
Cassava wastes (bagasse)	75-85	10-15	2-19	80-120
Cassava wastes (peel)	60-80, reduced to 10-20% following sun drying	3	14	20-30
Forestry wastes	70-85, reduced to 40-50% once cut	18	2	235-280

2. Feedstock Assessment

2.3 Indonesia Feedstock Assessment

2.3.6 Additional Land Assessment

It is difficult to attach specific values to agricultural waste products without extensive work on the ground with farmers and communities. For each type of feedstock the following has to be understood in order to make an assessment:

- Does a particular waste have a current use/value attached to it? Most of the identified feedstocks do not have any value attached to them at present, with the exception of sugarcane bagasse and some others that can be used as animal feed. Therefore, there are no formal markets / price for the feedstocks.
- What are competing future uses? For example, some of these feedstocks could be utilised for AD and biogas production, what would the value attached to the feedstock for that application be? A next decision should be whether a feedstock is better utilised if it is routed to a competing future use or to SAF production.
- What is the cost involved to aggregate a particular feedstock? For example, additional equipment and labour will be required to gather rice straw or corn stover from the fields. Once the cost to aggregate is understood, a value could be attached to a particular feedstock to provide the farmers with the incentive to gather the feedstock. If a feedstock is currently used as soil enhancer or similar purposes, enough should be left to continue this use, or the cost of the product replacing this use should be understood. An example is any fertiliser that is required to assist with soil conditioning once the feedstock is partially removed.
- The properties of the feedstock should be understood, such as bulk density, moisture content and calorific value. Low density feedstocks will be expensive to transport, and therefore would command a lower value (or have no value) than a high-density feedstock. Higher calorific value feedstocks and feedstocks with lower moisture contents would be considered more valuable.

2.3.7 Feedstock costs

In assessing additional land for agricultural use, the following is important to consider:

- Climate: Air temperature, rainfall.
- Plant oxygen requirement: Drainage.
- Rooting condition: Soil texture, coarse fragments, soil thickness.
- Nutrient supply capacity: Cation exchange capacity, base saturation, pH, organic C.
- Nutrient reserve: Total N, total P_2O_5, total K_2O.
- Toxicity: Salinity, sodicity, sulfidic depth.
- Erosion potential and flooding risk.

2.3.8 Large-scale biomass management advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include:

- Large farms have lower overheads as a percentage of revenue. Cost of inputs like seeds, fertilisers and machinery is spread over a larger output, reducing unit cost.
- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
- It is easier and cheaper to collect the harvest and waste streams from centralised large farms and transport them from a single location to another single location.
- Contracting with a single large entity (large scale farm or co-op) is considerably easier than contracting with dozens or hundreds of small-scale farmers. In addition, small-scale farmers tend to be subsistence farmers only, so that very little additional crops are grown beyond their own needs.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

2. Feedstock Assessment

2.4 Lao PDR Feedstock Assessment

2.4.1 Feedstock Types and Locations

Agricultural and Forestry Waste Feedstock Summary Assessment

The types of agricultural waste biomass with apparent higher potential are generated in the production of **cassava, rice and corn** as shown in Figure 2.8. [4] While sugarcane is produced in large quantity, sugarcane bagasse is typically unavailable for biofuels production as sugar mills use it for energy generation. Smaller quantities of these feedstocks are available in Lao PDR compared to some of the other considered countries.

The area with higher potential to produce SAF from agricultural wastes is **the northern region, Savannakhet and the southern region** where high quantities of agricultural feedstock may be available all-year-round.

Savannakhet, Borikhamsay and Champasack are also areas with forestry production and, hence, harvest waste and waste from sawmills and other forestry industrial plants may be available. Refer to Figure 2.9 for locations and total waste generated volumes per region and per agriculture waste feedstock.

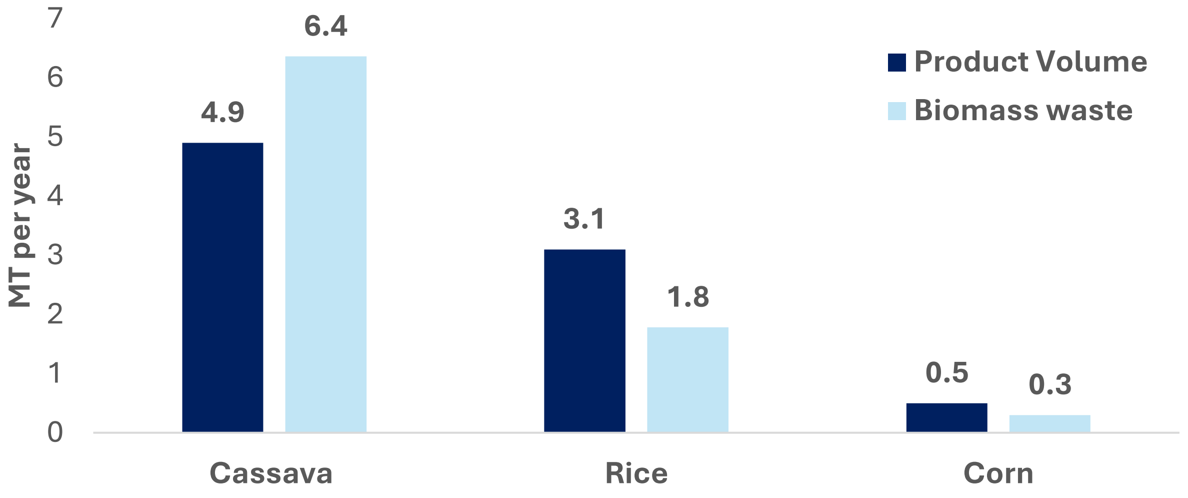
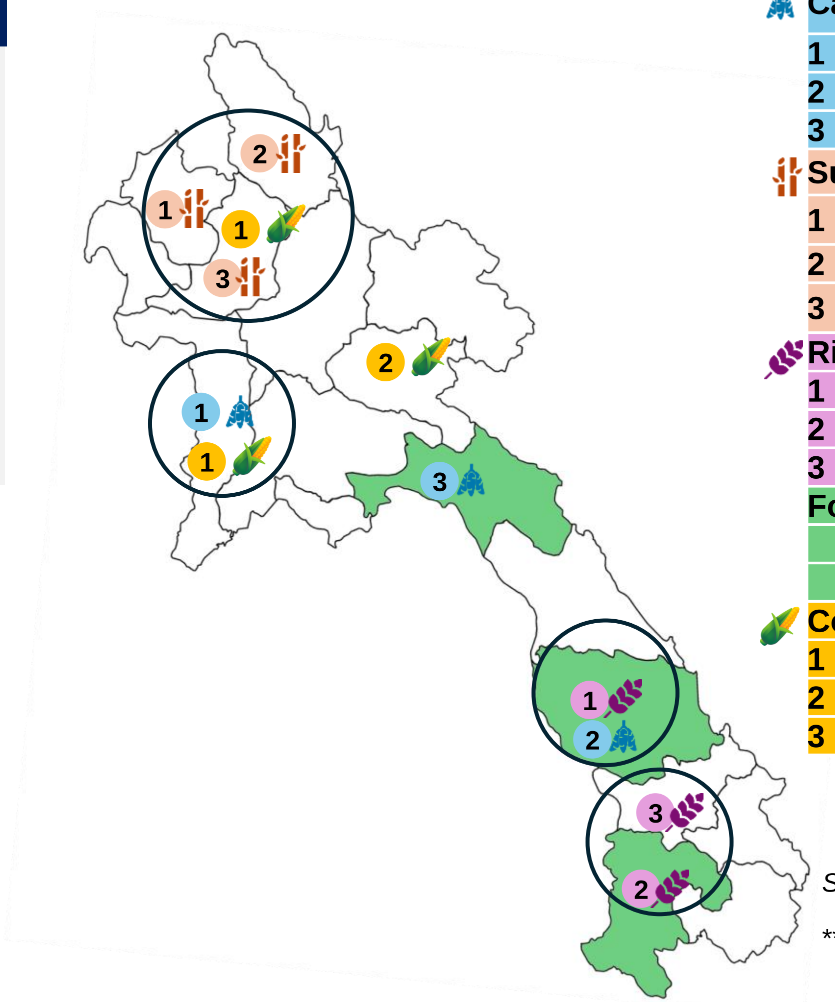


Figure 2.8: Top three Agricultural Feedstock and Biomass Waste Lao PDR, 2022



Waste and residues [4]

Cassava		MT/ year
1	Xayabury	3
2	Savannakhet	1
3	Borikhamsay	1
Sugarcane*		
1	Luangnamtha	2
2	Phongsaly	1
3	Oudomxay	1
Rice		
1	Savannakhet	0.9
2	Champasack	0.5
3	Saravane	0.4
Forestry**		
	Harvest waste	0.14
	Industrial waste	0.16
Corn		
1	Oudomxay	0.1
2	Xiengkhuang	0.1
3	Xayabury	0.1

Source: FAOSTAT

**GHD estimation

Figure 2.9: Top three Locations of top three Agricultural Biomass, and Forestry Waste Locations in Lao PDR, 2022

2. Feedstock Assessment

2.4 Lao PDR Feedstock Assessment

2.4.2 Growth potential

From the feedstocks interrogation, it has been determined that Cassava, rice and corn crops wastes could have significant potential as feedstocks for SAF production in Lao PDR. In this section, business as usual and current destinations for the wastes are discussed, as well as efforts to increase production of these feedstocks. Cassava and rice are individually discussed.

Cassava wastes

Business as usual and current wastes uses

In Lao PDR, 112,000 ha of land is utilised for Cassava cropping. It is considered a vital crop for smallholder farmers. The Cassava industry in Lao PDR faces challenges such as price fluctuations, high logistic costs, natural disasters and disease spread.

Cassava wastes can be classified as stems and leaves and solid residue (thippi). There are other waste streams as well but they are not typically suitable for SAF production. Stems and leaves are left in the field as soil enhancer or burnt. It can also be utilised as animal feed or composted. Thippi can be composted, used as animal feed or as a feedstock for bioplastics and other similar processes (not currently available commercially).

Increasing Cassava production

Improved varietals, modern farming techniques and continuous research and development efforts leading to improved cultivation practices are resulting in increased Cassava yields. This will not necessarily lead to increased Cassava wastes streams though.

Rice wastes

Business as usual and current wastes uses

Rice is grown on 60% of the cultivated area in Lao PDR, with 80% of farmers growing rice. It is therefore the most important crop in Lao PDR . Most of the farming is subsistence farming.

Increasing rice production

The introduction of new varietals, increased irrigation, the introduction of sustainable practices and government support in the form of subsidies and training programs could all assist in increased rice cropping. Improving market access and infrastructure has assisted farmers to sell rice more efficiently, encouraging higher production levels.

2. Feedstock Assessment

2.4 Lao PDR Feedstock Assessment

2.4.3 Feedstock Seasonality

The year can be divided into a rainy season and dry reason:

- Rainy season – from May to October.
- Dry season – from November to April.

The planting, growth and harvesting seasons for each of the feedstocks studied for Lao PDR is shown within Table 2.7 below.

Table 2.7: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Rice	Two main seasons [41]: • Rainy Season Rice (Main Crop): Planted from June-July. • Dry Season Rice (Second Crop): Planted from December-January.	• October to December (rainy season) • April to May (dry season crop)
Corn	Two seasons: • Planting in February-April • Planting in August-September	• Harvesting season from June-August. • Harvesting from December-January
Cassava	Cassava is normally planted in May at the beginning of the rainy season. Earlier plantings in March and April can significantly increase tuber yields.	Harvesting season from October to April.
Forestry	Any time of the year, although the rainy months are preferred	Year-round, although the dry periods when terrain is more accessible is preferred

2. Feedstock Assessment

2.4 Lao PDR Feedstock Assessment

2.4.4 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.8 below

Table 2.8: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Corn wastes	Up to a year [26]	Corn stover is typically baled and stored covered by tarps or other wrapping material. If the stover is dried to less than 40% moisture, the bales can be stored for 365 days, while higher moisture bales (50% moisture) tend to have structural integrity losses after 120 days storage, making them difficult to move for processing.
Cassava wastes	Two to three months [28]	Sun drying required prior to storage
Forestry wastes	Up to a year [29]	Store as whole logs or chips. If chipped, should be stored under cover (tarps).

2.4 Lao PDR Feedstock Assessment

2.4.5 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.9 below.

Table 2.9: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
Corn wastes (husk)	45-55	63	13	80-120
Corn wastes (leaves)	70-80 (green leaves)	11	5	110-130
Cassava wastes (bagasse)	75-85	10-15	2-19	80-120
Cassava wastes (peel)	60-80, reduced to 10-20% following sun drying	3	14	20-30
Forestry wastes	70-85, reduced to 40-50% once cut	18	2	235-280

2. Feedstock Assessment

2.4 Lao PDR Feedstock Assessment

2.4.6 Additional Land Assessment

Only 10% of Lao PDR's land area is currently used for agriculture. There are drives to expand agricultural activities such as the Agriculture Development Strategy to 2025 and Vision to 2040 to increase agricultural productivity and develop sustainable agricultural practices. These initiatives include identifying areas for potential increased agricultural activity. The country is mountainous which limits agricultural land. In addition, the country has a low population density, limiting the opportunity to grow crops for domestic purposes and also leading to labour shortages to farm specific crops.

2.4.7 Feedstock Costs

It is difficult to attach specific values to agricultural waste products without extensive work on the ground with farmers and communities. For each type of feedstock the following has to be understood in order to make an assessment:

- Does a particular waste have a current use/value attached to it? Most of the identified feedstocks do not have any value attached to them at present, with the exception of sugarcane bagasse and some others that can be used as animal feed. Therefore, there are no formal markets / price for the feedstocks.
- What are competing future uses? For example, some of these feedstocks could be utilised for AD and biogas production, what would the value attached to the feedstock for that application be? A next decision should be whether a feedstock is better utilised if it is routed to a competing future use or to SAF production.
- What is the cost involved to aggregate a particular feedstock? For example, additional equipment and labour will be required to gather rice straw or corn stover from the fields. Once the cost to aggregate is understood, a value could be attached to a particular feedstock to provide the farmers with the incentive to gather the feedstock. If a feedstock is currently used as soil enhancer or similar purposes, enough should be left to continue this use, or the cost of the product replacing this use should be understood. An example is any fertiliser that is required to assist with soil conditioning once the feedstock is partially removed.
- The properties of the feedstock should be understood, such as bulk density, moisture content and calorific value. Low density feedstocks will be expensive to transport, and therefore would command a lower value (or have no value) than a high-density feedstock. Higher calorific value feedstocks and feedstocks with lower moisture contents would be considered more valuable.

2.4.8 Large-scale biomass management advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include:

- Large farms have lower overheads as a percentage of revenue. Cost of inputs like seeds, fertilisers and machinery is spread over a larger output, reducing unit cost.
- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
- It is easier and cheaper to collect the harvest and waste streams from centralised large farms and transport them from a single location to another single location.
- Contracting with a single large entity (large scale farm or co-op) is considerably easier than contracting with dozens or hundreds of small-scale farmers. In addition, small-scale farmers tend to be subsistence farmers only, so that very little additional crops are grown beyond their own needs.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

2. Feedstock Assessment

2.5 Malaysia Feedstock Assessment

2.5.1 Feedstock Types and Locations

Agricultural and Forestry Waste Feedstock Summary Assessment

The types of agricultural waste biomass with apparent higher potential are generated in the production of **palm oil, rice, coconut, and pineapples** as shown in Figure 2.10. [4]

In Peninsular Malaysia, **Johor, Kedah and Pahang** are key states producing high quantities of agricultural feedstock all-year-round.

Sabah and Sarawak are key contributors to potential agricultural waste/potential SAF feedstocks in Malaysia, as they account for a significant proportion of Malaysia's Palm Oil production. Additionally, these states appear to possess significant potential due to their extensive forestry and logging operations, which generate sizable amounts of harvest waste and byproducts from sawmills and other forestry-related industries. Refer to Figure 2.11 for locations and total waste generated volumes per region and per agriculture waste feedstock.

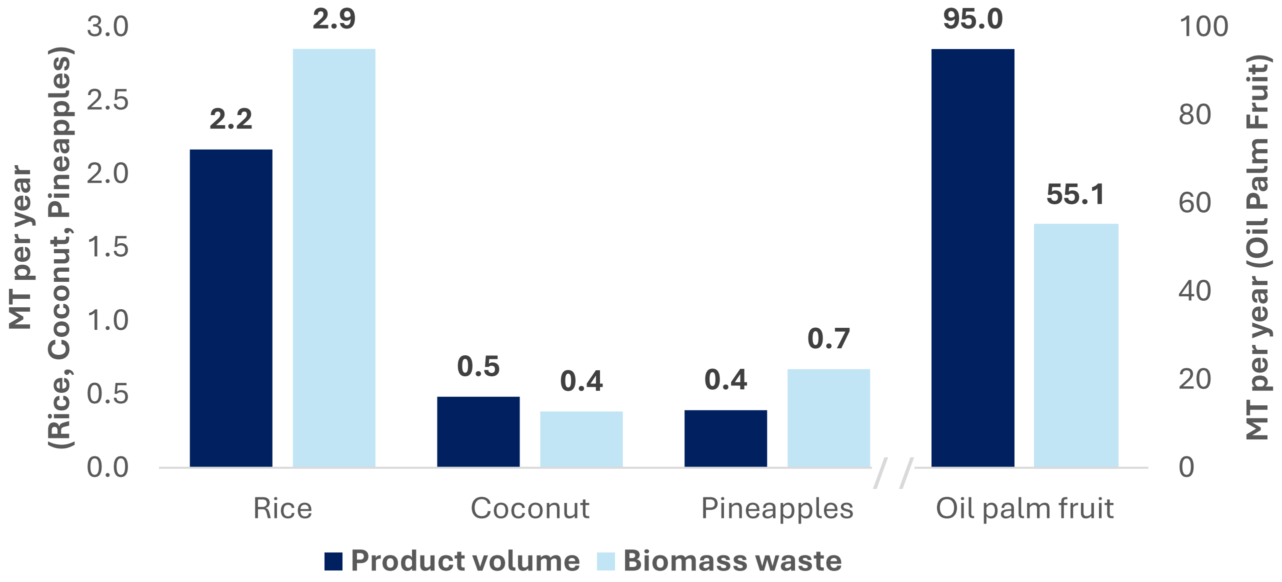


Figure 2.10: Top four Agricultural Feedstock and Biomass Waste Malaysia, 2022

Waste and residues

Oil palm fruit wastes		
1	Sabah	12.95
2	Sarawak	12.16
3	Pahang	8.75

Rice wastes		
1	Kedah	1.04
2	Kelantan	0.34
3	Perak	0.34

Forestry wastes**		
1	Harvest Waste	1.04
2	Industrial Waste	1.17

Coconut husk & non-standard coconut**		
1	Johor	0.08
2	Selangor	0.07
3	Perak	0.06

Pineapple wastes		
1	Johor	0.50
2	Pahang	0.05
3	Sarawak	0.04

Source: FAOSTAT, GHD estimate, International Coconut Community (ICC)
***Assuming 30% of coconuts reports to non-standard coconut.*

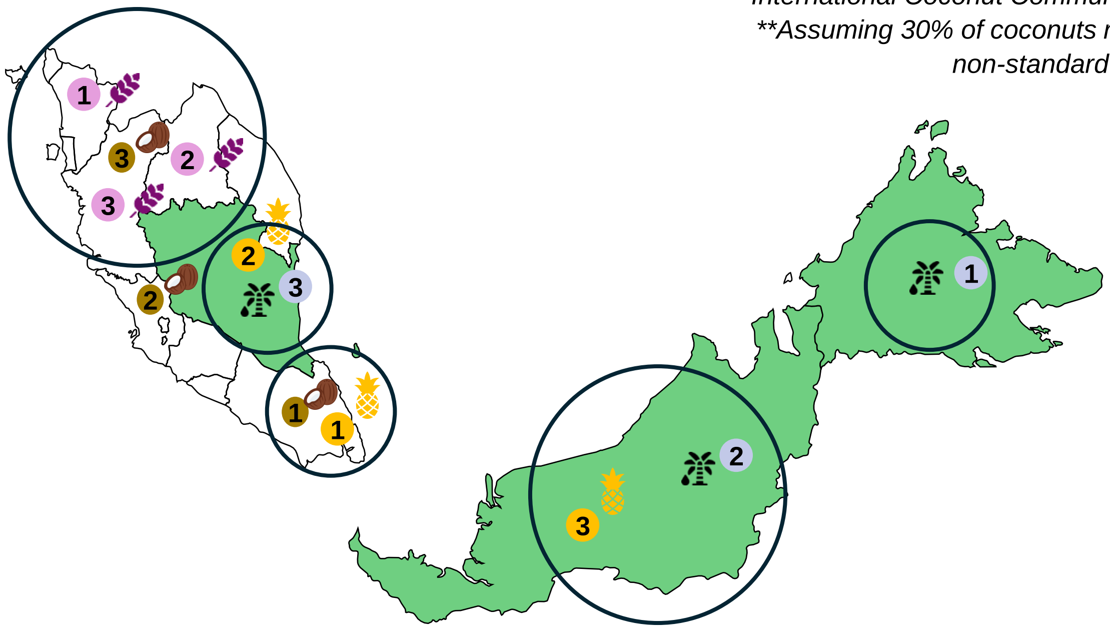


Figure 2.11: Top three Locations of top four Agricultural Biomass, and Forestry Waste Locations in Malaysia, 2022

2. Feedstock Assessment

2.5 Malaysia Feedstock Assessment

2.5.2 Growth potential

Based on our review, we have identified oil palm fruit, rice, coconut, and pineapples as the key feedstocks produced in Malaysia. In this section, business as usual and current destinations for the wastes are discussed, as well as efforts to increase production of these feedstocks. Oil palm and rice are individually discussed.

Oil palm wastes

Business as usual and current wastes uses

The oil palm industry in Malaysia, which occupies approximately 5.65 million hectares of land[49], is a significant contributor to the country's economy, being the second-largest producer of palm oil globally. This extensive cultivation generates substantial waste, including EFBs, PKS, and POME. Traditionally, EFBs and PKS are either left in the field to decompose, used as organic mulch, or incinerated for energy recovery. Additionally, these materials can be composted or utilised as animal feed. POME is often treated in anaerobic ponds to reduce its environmental impact, with potential biogas capture for energy use.

While some oil palm waste streams are not currently suitable for SAF production, significant opportunities exist for EFBs and PKS as feedstocks. These materials can be converted into biofuels through specific technology pathways (see Section 4). However, commercial viability remains a challenge, necessitating further research and development to fully harness the potential of oil palm waste for SAF production.[50]

Increasing Oil palm production

To address stagnant yields and aging plantations, the Malaysian palm oil industry has shifted its focus toward sustainability and replanting initiatives. In 2023, the government successfully replanted 132,000 hectares of oil palm, aiming to enhance productivity without expanding the total plantation area due to competing land use and urbanisation pressures.[51]

Efforts to improve yields are concentrated on promoting high-quality planting materials and Good Agricultural Practices (GAP), particularly among smallholders. These strategies aim to optimise productivity while adhering to global sustainability standards.

However, there are significant challenges in qualifying palm-oil derived wastes as feedstocks for SAF, in terms of meeting the stringent requisite sustainability criteria. Under the CORSIA framework, palm oil-derived SAF must comply with lifecycle emissions reductions and sustainability benchmarks, including having at least 85% of biogas released from POME be captured and oxidised. Given the complexities of ensuring full compliance, palm oil's eligibility as a SAF feedstock remains uncertain and highly dependent on robust certification mechanisms.[52] For oil palm feedstocks like EFBs and PKS to become viable SAF feedstocks, there is a need for: (1) Enhanced research into cost-effective conversion technologies, (2) Incentivisation of circular economy practices within plantations, and (3) Greater alignment with international sustainability certification frameworks.

Rice wastes

Business as usual and current wastes uses

In Malaysia, rice is primarily grown in Kedah, Perlis, and parts of Kelantan and Selangor, generating significant agricultural waste, including husks, straw, and bran. Traditionally, these by-products are used for low-value purposes such as animal feed, mulching, or burned in the fields to clear land for the next planting cycle. This not only wastes valuable biomass but also contributes to air pollution.

Increasing rice production

To enhance rice production, Malaysia focuses on improving yields, sustainability, and farmer livelihoods through government initiatives. These include subsidies for fertilisers and machinery, training programs for farmers, and the introduction of high-yield rice varieties.

Modernizing irrigation systems and adopting precision farming techniques have also boosted productivity. Additionally, investments in infrastructure and improved market access have facilitated more efficient transportation and sales of rice. However, it is crucial to balance yield improvement with sustainability by transitioning to practices that promote water efficiency and reduce chemical inputs to meet global sustainability standards and minimise environmental impact.

2. Feedstock Assessment

2.5 Malaysia Feedstock Assessment

2.5.3 Feedstock Seasonality

The year can be divided into a wet season and dry season, occurring in slightly different months between the east and west coasts of Malaysia, due to the influence of monsoons.

- Wet season – East coast from November to March, west coast from March to September
- Dry season – East coast from March to September, west coast from October to April

Temperatures are very similar throughout the year with averages of 25 – 28 ºC. The planting, growth and harvesting seasons for each of the feedstocks studied for Malaysia is shown within Table 2.10 below.

Table 2.10: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Oil palm fruit	All year	All year
Rice	Two main seasons: • Rainy Season Rice: Planted from August. • Dry Season Rice: Planted from March.	• January and February (rainy season) • June and July(dry season crop)
Coconut	Any time of the year, although warm rainy months are preferred	Year-round
Pineapple	Can be planted throughout the year, ideally after the monsoon season, around March to June and September to November for better establishment.	Year-round
Forestry	Any time of the year, although the rainy months are preferred	Year-round, although the dry periods when terrain is more accessible is preferred

2. Feedstock Assessment

2.5 Malaysia Feedstock Assessment

2.5.4 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.11 below.

Table 2.11: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Oil palm fruit bunches	Up to 6 months [35]	EFB requires drying prior to storage, If wet, EFB can only be stored for a few weeks or up to a month.
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Coconut wastes	Six months to a year [27]	Husk has to be stored in a cool, dry area to avoid mould growth Copra can be stored for up to 2 months, or if dried, for up to 8 months. Storage conditions are important; a well-ventilated dry environment helps to preserve the copra for a longer period of time. Coconut shells are highly durable, taking 5–6 years to decompose naturally. When stored in a cool, dry, and well-ventilated area, they can be preserved for extended periods without significant degradation. Proper storage prevents moisture absorption, mould growth, and structural weakening, while keeping the area clean helps avoid pest damage
Pineapple wastes	One to four months	Pineapple waste, prone to rapid spoilage due to high moisture and sugar content, typically degrades within days unless properly refrigerated.
Forestry wastes	Up to a year [29]	Store as whole logs or chips. If chipped, should be stored under cover (tarps).

2. Feedstock Assessment

2.5 Malaysia Feedstock Assessment

2.5.5 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.12 below.

Table 2.12: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
EFB	2.5-14	9-18	4	130-245
POME	90-95	N.A.	<1	1000 (close to water)
PFAD	0.06-7.50	N.A.	<1	900-950
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
Coconut wastes	70-85	17	10	70-80
Pineapple wastes	40	15	6	650 (compressed)
Forestry wastes	70-85, reduced to 40-50% once cut	18	2	235-280

2.5 Malaysia Feedstock Assessment

2.5.6 Additional Land Assessment

In Malaysia, agricultural land accounts for approximately 26% of the total land area. Efforts in the 1990s aimed to boost agricultural productivity through the expansion of oil palm and rubber cultivation[53]. However, further expansion into uncultivated areas is increasingly constrained by land scarcity. Recent data reveals a slight decline in agricultural land, driven by competing demands from urbanisation and industrialisation. Meanwhile, Malaysia's prominent role in palm oil production has faced mounting environmental scrutiny, particularly regarding deforestation, biodiversity loss, and carbon emissions from land-use changes.

Given these challenges, it is unlikely that additional land will be allocated for agriculture. Enhancing feedstock availability will require a shift towards sustainable practices, including adopting advanced farming technologies, such as precision agriculture, to maximise yields on existing land.[71] Additionally, strengthening logistics and supply chain efficiencies to reduce post-harvest losses, and promoting the use of marginal or degraded lands for non-food crops, could play a crucial role in balancing production needs with environmental considerations.

2.5.7 Feedstock Costs

Determining the cost of agricultural waste feedstocks requires thorough analysis with farmers and local communities. Most feedstocks lack formal markets or assigned values, except for a few like sugarcane bagasse, which is used as animal feed. Evaluating their current uses, potential competing applications (e.g., biogas production), and the costs of aggregation, such as equipment and labour, is essential.

Consideration must also be given to maintaining existing uses, like   enhancement, or accounting for the cost of substitutes like fertilisers.

Feedstock properties, including bulk density, moisture content, and calorific value, significantly impact their value. Low-density feedstocks are costly to transport, while higher calorific value and lower moisture content increase desirability. A comprehensive understanding of these factors allows for an informed assessment of feedstock costs and optimal utilisation.

2.5.8 Large-scale biomass management advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include:

- Large farms have lower overheads as a percentage of revenue. Cost of inputs like seeds, fertilisers and machinery is spread over a larger output, reducing unit cost.
- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
- It is easier and cheaper to collect the harvest and waste streams from centralised large farms and transport them from a single location to another single location.
- Contracting with a single large entity (large scale farm or co-op) is considerably easier than contracting with dozens or hundreds of small-scale farmers. In addition, small-scale farmers tend to be subsistence farmers only, so that very little additional crops are grown beyond their own needs.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.1 Feedstock Types and Locations

Agricultural and Forestry Waste Feedstock Summary Assessment

The types of agricultural waste biomass with apparent higher potential are generated in the production of **rice, corn, coconut and cassava** as shown in Figure 2.12.[4] Large volumes of sugarcane wastes are also produced.

ICAO has announced that non-standard coconut has been included as a potential feedstock for SAF. Non-standard coconut refers to coconuts unfit for human consumption due to insufficient management, tree rot, fungi, etc, and makes up approximately 30% of the total crop.

The areas with higher potential to produce SAF from agricultural wastes are **Cagayan Valley, North Mindanao and the south region** where high quantities of agricultural feedstock may be available all-year-round. Those are also areas with forestry production and, hence, harvest waste and waste from sawmills and other forestry industrial plants may be available. Refer to Figure 2.13 for locations and total waste generated volumes per region and per agriculture waste feedstock.

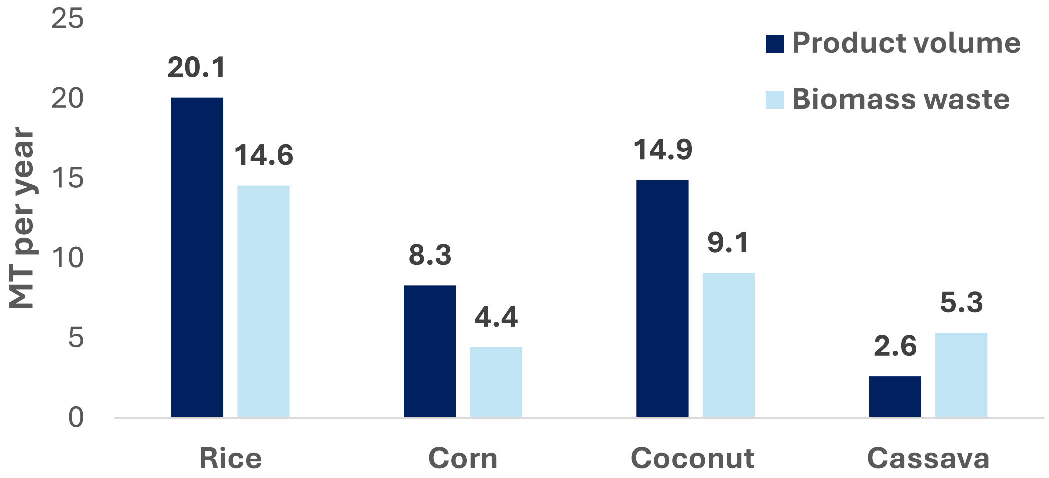


Figure 2.12: Top four Agricultural Feedstock and Biomass Waste in the Philippines, 2022

*While sugarcane bagasse is the most prevalent crop, it may be used for energy generation at the mills rather than for SAF production

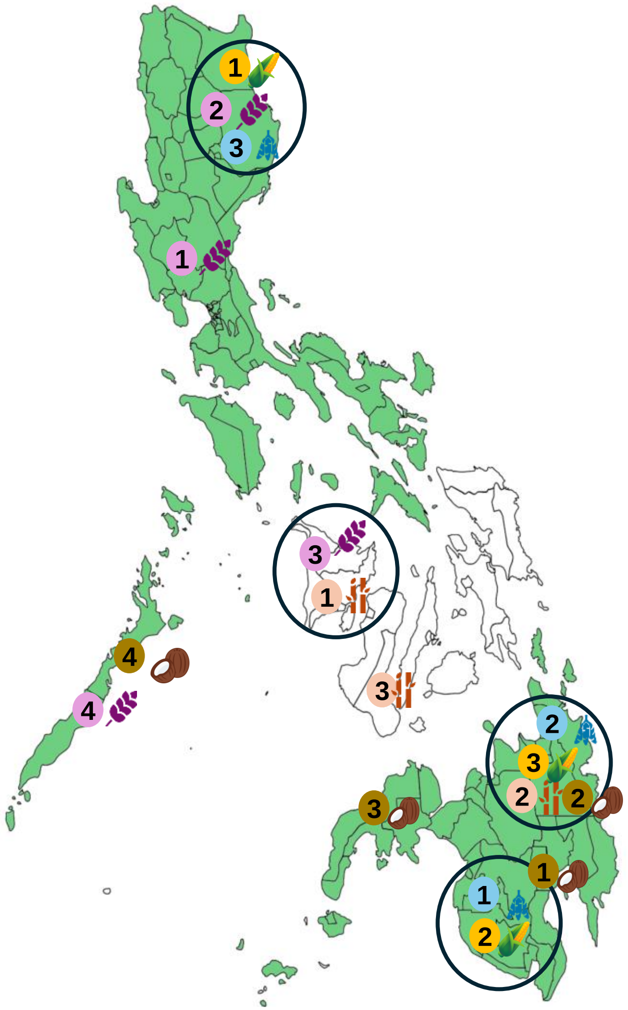


Figure 2.13: Top three Locations of Top Agricultural Biomass, and Forestry Waste Locations in the Philippines, 2022

Waste and residues

Rice husk and straw		
1	Central Luzon	4.8
2	Cagayan Valley	4.0
3	Western Visayas	3.0
4	Palawan	0.6
Cassava wastes		
1	BARMM	5.3
2	Northern Mindanao	
3	Cagayan Valley	
Sugarcane trash and bagasse* MT/ year		
1	Western Visayas	3.8
2	North Mindanao	1.0
3	Central Visayas	0.6
Corn husk and straw		
1	Cagayan Valley	1.9
2	Soccskargen	1.1
3	North Mindanao	1.4
Coconut husk & non-standard coconut**		
1	Davao	1.1
2	Northern Mindanao	1.1
3	Zamboanga peninsula	1.0
4	Palawan	1.0
Forestry wastes*		
	Harvest waste	0.3
	Industrial waste	0.3

Source: FAOSTAT
**GHD estimate*
International Coconut Community (ICC)
***Assuming 30% of coconuts reports to non-standard coconut.*

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.2 Growth potential

From further interrogation of the available feedstocks, it has been determined that sugarcane, rice and corn crop wastes could have significant potential as feedstocks for SAF production in the Philippines. In this section, business as usual and current destinations for the wastes are discussed, as well as efforts to increase production of these feedstocks. Each feedstock is individually discussed.

In many cases, low humidity/higher calorific biomass wastes are used in small boilers or households to generate heat for various purposes.

Sugarcane wastes
Business as usual and current wastes uses
The sugarcane biomass fuels include bagasse, the fibre by-product of sugar extraction from cane stalks, and trash, the tops and leaves of the sugarcane plant that are typically burned off the field before harvest or (with harvest of unburned cane) removed at harvest and left on the field to decompose. To access the tops and leaves, the sugarcane fields can no longer be burnt before harvesting. While this allows for access to this waste biomass and reduces emissions, burning makes cane harvesting cheaper and easier and reduces exposure to pests in the cane. In the Philippines, burning of the cane is no longer practiced extensively, and therefore sugarcane tops and leaves should be available for harvest/collection. The tops is typically used as feed for animals directly from harvest or ensiled for use as animal feed during off-milling season.

Leaving trash on the field serves for weed control, wind and rain erosion protection, increased soil infiltration of water and reduced soil surface evaporation of water, reduced soil temperatures and increased soil biological activity. Studies have shown that between 50% and 65% of the trash should be left on the field to avoid other treatments such as herbicides application[7]. This reduces the volume of trash available for SAF production to 35% to 50% of what is produced. The impact of this is demonstrated by comparing sugarcane wastes produced in the Western Visayas region to what could be available for SAF production; 3.8 Mt/a of sugarcane wastes (trash and bagasse) is produced from this region, with trash making up 1.9 Mt/a of this amount. If only 50% of the trash is available, this reduces the trash to 0.95 Mt/a and the total feed available from that region becomes 2.9 Mt/a.

Bagasse is currently utilised in the Philippines for various economic purposes; these include:
- Combustion for power generation at sugar mills, mainly to generate power for the mills (main use).
- To produce sustainable paper or eco-friendly fabrics.
- Packing material.

Bagasse that is currently utilised at the mills could be made available for SAF production with operational changes at the mill; should a SAF production facility be located close to a sugar mill, steam and/or power from the SAF facility could be utilised by the mill. Bagasse that is currently used for other purposes may have to be diverted to those uses, as it is likely that investments have been made into production facilities and communities may be dependent on the revenue from these products. However, consumption of bagasse for paper, fabrics and packing materials should be relatively small compared to bagasse production. It is estimated that these users could amount to 10-30% of sugarcane bagasse produced, from the estimated value attached globally to bagasse packaging material and assuming a pricing of US$3.5-15/tonne for the bagasse[6].

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.2 Growth potential

Sugarcane wastes
Increasing sugarcane production
Sugarcane is a high-value crop for the Philippines. In August 2022, the Philippines recorded almost 400,000 hectares of sugarcane plantations nationwide[12]. The volume of sugarcane could be increased through increasing the land area for cultivation of sugarcane, but this could lead to decreased crop diversity. It has been found that the productivity of certain regions tends to be higher than others, with block farm systems appearing to be more productive than other farming systems. Therefore, additional block farming could be introduced as another means to increase sugarcane production. The social impact of such a step would have to be interrogated.

The Sugarcane Industry Development Act came in effect in 2015 in the Philippines[11]. Through the Act, government agencies can provide services for ploughing, harrowing, weeding, fertilisation, harvesting and other farm mechanisation services that small farmers would not otherwise have access to. It encourages small farms to consolidate their farming efforts into “block farms” in order to benefit from economies of scale, particularly during planting and harvesting.

The Sugar Regulatory Administration (SRA) was created to assist in the growth and development of the sugar industry through greater participation of the private sector and the improvement conditions of workers in the sugar industry. The Biofuels Act of 2006 mandated the SRA as a member of the National Biofuel Board to develop and implement policies supporting the Philippine Biofuel Program to assist in providing security of a domestic sugar supply. While this was to support bioethanol production, the same principles could be applied to support a sugarcane bagasse to SAF industry in the Philippines. Learnings from that program could also be applied. The SRA funds research programs; two recent programs involved the propagation of high yielding sugarcane varieties and yield performance at different seasons of planting. While the research focuses on sugar yields specifically, they could be adapted to look at bagasse production as well. The Sugarcane Technology Centre (CTC) found that some species with nearly identical sugar yields could yield considerably different biomass yields[8]. Traditionally, cane species are selected for their good sugar yield, but if energy production from the biomass is factored into the economics of sugarcane processing, different species may be preferred.

Sugarcane is not a sensitive crop and can be grown in almost all types of soil, from sandy to clay loams and from acidic volcanic soils to calcareous sedimentary deposits.

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.2 Growth potential

Rice wastes
Business as usual and current wastes uses
While rice is grown extensively in the Philippines, a significant portion of this is still subsistence farming. This could make the aggregation and contracting of rice harvest wastes challenging.

Rice straw is difficult to aggregate, in particular due to the increased utilisation of combine harvesters in the Philippines. As a result of labour shortages and high manual labour cost of collection, rice straw is often burned rather than collected[11] or more often, simply left in the field. An assessment on the technical and economic feasibility of mechanised rice straw collection in the Philippines, Sustainability 2020, 12 (17), 7150). In 2015, it was estimated that 32% of rice straw produced in the Philippines was still burned[12], Enhancing crop residues recycling in the Philippine landscape), despite the Solid Waste Management Act and Philippine Clean Air Act of 1999 prohibiting open-field burning, including burning of rice straws. Research is being conducted in the Philippines to determine how the collection of rice straw on the field could be made cheaper and more efficient. For example, one study has determined that the collection of rice straw could be made more efficient with the use of rice straw balers[13]. The equipment would have to be made available to small-scale farmers to implement this practice.

Work is ongoing to educate farmers on alternate uses for rice straw and rice husk, including use as a mushroom substrate, insulation material or as a cement additive (rice hull ash). As the practice of burning is phased out, increased volumes of rice wastes could be available for SAF production, as well as these other smaller applications.

Increasing rice production
Despite a crop of approximately 20 million tonnes of rice in the Philippines in 2021, imports of 2.2 million tonnes were still required to satisfy the domestic market. This was expected to increase to 2.9 million tonnes by 2022. Therefore, domestic rice cropping could be expanded to satisfy the domestic market and even for export to other nearby countries, increasing the rice wastes production as well. To satisfy the domestic market only, rice production would have to increase by at least 15%[14].

The Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARRD) has an Industry Strategic Science and Technology Program focused on rice production. Some of these efforts are focused on increased rice production, harvesting tools and technology transfer initiatives to transfer best practices to local farmers.

Irrigating rice fields could lead to a significant increase in rice crops, not only with regards to yield, but also the number of crops that could be grown per year. A comparison of the productivity of different rice systems in the Philippines is shown in Table 2.13 (An overview of agricultural pollution in the Philippines – the Crops Sector 2016). From this, rice production could increase 5 fold per hectare with irrigation.

Table 2.13: Comparison of the productivity of different rice systems in the Philippines[15]

System	Area (ha, thousands) (% of total)	Yield, ton/h	Crops/year	Fallow period, year	Productivity, ton/ha/year
Irrigated rice	2,334 (62)	5.0	2.5	1	12.5
Rainfed rice	1,304 (35)	2.5	1.0	0	2.5
Upland rice*	120 (3)	1.0	1.0	8	0.12

*Grown in slash-and-burn, usually on sloping land

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.2 Growth potential

Corn wastes

Business as usual and current wastes uses

Corn is an important crop in the Philippines with 20% of the population using it as a staple food, while yellow corn is mainly grown as livestock feed. Approximately 4 million tonnes per annum of yellow corn is produced, or approximately 50% of the total corn crop[16].

Corn husks, leaves and stalks typically have no economic value. Leaves and stalks are typically left on the field and serves as insulation and to smother weeds and enhance the soil quality. There is limited use of corn husks for craft work, but this has a very small consumption.

Corn production and in particularly white corn is typically grown by subsistence farmers. The small-scale farming implies that aggregating wastes from this type of crop could be difficult. On the other hand, growing corn has low returns in the Philippines and additional revenue that could be generated from collection and selling of corn wastes could aid and encourage farmers.

Increasing corn production

The Philippine livestock industry is expanding and additional corn is required to meet the feed demand. The USDA Manila office forecast a corn import of 1 million tonnes in 2024/2025 to meet the rise in feed consumption[17]. It can therefore be concluded that there is additional opportunity for growing and supplying corn domestically in the Philippines, specifically for animal feed.

Different corn species are under investigation in the Philippines to find high yielding types.

Farming practices such as optimised spacing, planting density and rotation with other crops could increase corn yield through minimizing disease, pest and weeds.

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.3 Non-Standard Coconut

In March 2024, non-standard coconut was registered on the Positive List for CORSIA with ICAO. Non-standard coconut refers to coconuts that are too small, sprouted, cracked or rotten. Per the International Coconut Community (ICC), it is estimated that approximately 1/3 of produced coconut reports to non-standard coconut.

Non-standard coconut opens HEFA as a potential pathway for agricultural wastes feedstocks in the Philippines. HEFA has a lower cost of production than the other SAF pathways at approximately 60% the cost of other identified pathways (gasification and FT and ATJ for example). Copra from the non-standard coconut is pressed and extracted to produce crude coconut oil (CCO). CCO is hydrogenated and fractionated to produce SAF via the HEFA pathway. A hydrogen source is required for hydrogenation; either from gasification of biomass, reforming of biogas or other renewable gas sources or water electrolysis.

Of the non-standard coconut, approximately 30% of the coconut is meat, from which CCO is extracted. Approximately 2.5 mass% of the non-standard coconut reports to SAF following conversion and fractionation, if it is produced via the HEFA pathway.

The husk (and potentially shell) products from standard coconut could still be accessed as feedstock for gasification and FT or HTL. Coconut husk makes up approximately 30mass% of the coconut.

Global annual coconut production is 67 million tonnes, and the Philippines produces approximately 24% of this or 16 million tonnes. If a third of this is non-standard coconut, that is 5.4 million tonnes of non-standard coconut. It is estimated that 335,000 tonnes of SAF could be produced via the HEFA pathway from this volume of non-standard coconut.

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.4 Feedstock Seasonality

The year can be divided into a rainy season, cool dry season and wet dry season:

- Rainy season – from June to November.
- Cool dry season – from December to February.
- Hot dry season – from March to May.

The planting, growth and harvesting seasons for each of the feedstocks studied for the Philippines is shown within Table 2.14 below.

Table 2.14: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Sugarcane	Sugarcane is planted in October to May and requires about 10 months to grow before harvest[18].	November to April
Rice	Two main seasons[19]: • Rainy Season Rice (Main Crop): Planted from May to July. • Dry Season Rice (Second Crop): Planted from January to March.	• November to December (rainy season). • April to June (dry season crop).
Corn	Corn may be planted anytime of the year provided there is adequate soil moisture. However, it is best to plant from May to June during the wet season and from October to November during the dry season[16, 17].	Harvesting season from August to October.
Coconut	Any time of the year, although warm rainy months are preferred	Year-round
Cassava	Cassava is normally planted in May at the beginning of the rainy season. Earlier plantings in March and April can significantly increase tuber yields[22].	Harvesting season from October to March.
Forestry	Any time of the year, although the rainy months are preferred	Year-round, although the dry periods when terrain is more accessible is preferred

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.5 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.15 below.

Table 2.15: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Sugarcane wastes	Several months & up to a year [23, 24]	Can be stored as bales or loose material. For loose storage, the piles should be covered by tarps to reduce losses. Bagasse can be dried first or stored as wet material. Dried material is less likely to undergo significant degradation but is a fire hazard and requires additional equipment and energy for drying. Wet storage requires no drying up front and the fire risk is reduced to almost zero, but handling of the wet material can be difficult. Baling reduces the transport cost of the wastes but requires additional labour at the harvest sites, and deballing equipment at site. In addition, the storage area required is larger than for loose material.
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Corn wastes	Up to a year [26]	Corn stover is typically baled and stored covered by tarps or other wrapping material. If the stover is dried to less than 40% moisture, the bales can be stored for 365 days, while higher moisture bales (50% moisture) tend to have structural integrity losses after 120 days storage, making them difficult to move for processing.
Coconut wastes	Six months to a year [27]	Husk has to be stored in a cool, dry area to avoid mould growth, copra is dried and stored, or dried and pressed to produce crude coconut oil which can be stored in tanks.
Cassava wastes	Two to three months [28]	Sun drying required prior to storage.
Forestry wastes	Up to a year [29]	Store as whole logs or chips. If chipped, should be stored under cover (tarps).

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.6 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.16 below.

Table 2.16: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
Sugarcane wastes (trash)	45-55	16	18	80-120
Sugarcane wastes (bagasse)	50-75	20	5	50-80
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
Corn wastes (husk)	45-55	63	13	80-120
Corn wastes (leaves)	70-80 (green leaves)	11	5	110-130
Coconut wastes	70-85	17	10	70-80
Cassava wastes (bagasse)	75-85	10-15	2-19	80-120
Cassava wastes (peel)	60-80, reduced to 10-20% following sun drying	3	14	20-30
Forestry wastes	70-85, reduced to 40-50% once cut	18	2	235-280

2. Feedstock Assessment

2.6 Philippines Feedstock Assessment

2.6.7 Additional land assessment

The Philippines has 298,170 square km land available. Of this, 52.9% is classified as forested or public land. The remaining 47.1% is classified as alienable and disposable land, which is open to use for agriculture and other purposes. 42% of the land is already used for agricultural purposes, leaving 5.1% for other purposes and agricultural expansion (15,207 square km in total [30]. Therefore, it is difficult to see that more land could be made available for agriculture. To increase crops potential, different types of crops, higher yielding species of specific crops or irrigation should be considered.

Land for agriculture is further limited as the lowland areas are only suitable for rice during the wet months (from June to November).

2.6.8 Feedstock Costs

It is difficult to attach specific values to agricultural waste products without extensive work on the ground with farmers and communities. For each type of feedstock the following has to be understood in order to make an assessment:

- Does a particular waste have a current use/value attached to it? Most of the identified feedstocks do not have any value attached to them at present, with the exception of sugarcane bagasse and some others that can be used as animal feed. Therefore, there are no formal markets / price for the feedstocks.
- What are competing future uses? For example, some of these feedstocks could be utilised for AD and biogas production, what would the value attached to the feedstock for that application be? A next decision should be whether a feedstock is better utilised if it is routed to a competing future use or to SAF production.
- What is the cost involved to aggregate a particular feedstock? For example, additional equipment and labour will be required to gather rice straw or corn stover from the fields. Once the cost to aggregate is understood, a value could be attached to a particular feedstock to provide the farmers with the incentive to gather the feedstock. If a feedstock is currently used as soil enhancer or similar purposes, enough should be left to continue this use, or the cost of the product replacing this use should be understood. An example is any fertiliser that is required to assist with soil conditioning once the feedstock is partially removed.
- The properties of the feedstock should be understood, such as bulk density, moisture content and calorific value. Low density feedstocks will be expensive to transport, and therefore would command a lower value (or have no value) than a high-density feedstock. Higher calorific value feedstocks and feedstocks with lower moisture contents would be considered more valuable.

2.6.9 Large-scale biomass management advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include:

- Large farms have lower overheads as a percentage of revenue. Cost of inputs like seeds, fertilisers and machinery is spread over a larger output, reducing unit cost.
- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
- It is easier and cheaper to collect the harvest and waste streams from centralised large farms and transport them from a single location to another single location.
- Contracting with a single large entity (large scale farm or co-op) is considerably easier than contracting with dozens or hundreds of small-scale farmers. In addition, small-scale farmers tend to be subsistence farmers only, so that very little additional crops are grown beyond their own needs.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

2. Feedstock Assessment

2.7 Palawan Province Assessment

2.7.1 Feedstock Types and Locations

Agricultural and Forestry Waste Feedstock Summary Assessment
The feedstocks exhibiting higher waste potential within the Palawan Province are derived from the production of **rice and coconuts** as shown in Figure 2.14. The areas with higher potential to produce SAF from agricultural wastes are the municipality of Narra for Rice, and Southern municipalities for coconut production. Additionally, seven municipalities—Aborlan, Sofronio Española, Bataraza, Brooke's Point, Narra, Quezon, and Rizal—have been identified as project sites for the Coconut Alliance for Sustainable Coconut Production in the Philippines program, funded by the German Government and the German Agency for International Cooperation (GIZ).

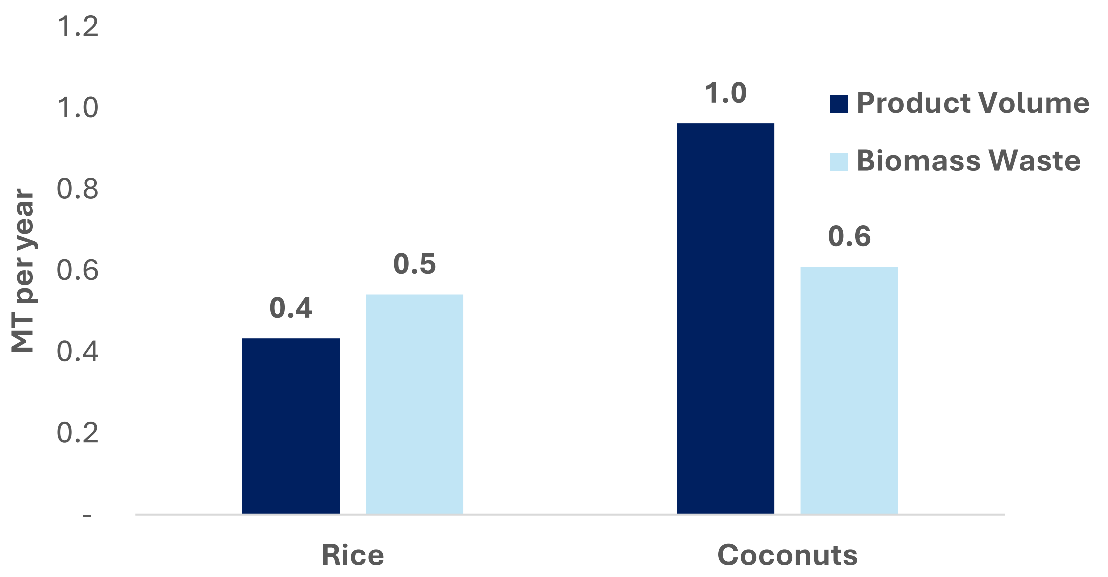


Figure 2.14: Top two Agricultural Feedstock and Biomass Waste, including non-standard coconuts within the Palawan Province, 2022

2.7.2 Growth potential

Rice and coconut have been identified as the key feedstocks produced within the Palawan province. In this section, current practices regarding waste management and the existing destinations for these materials are explored. Additionally, ongoing initiatives aimed at enhancing the production of these feedstocks are highlighted.

Rice wastes

Business as usual and current wastes uses

Aside from coconut farming, agriculture within the Palawan Province is primarily centered on rice cultivation, generating sizable amounts of agricultural residues such as rice straw and husks. Nationally, the Philippines produces approximately 18 million metric tons of rice straw annually. Traditionally, farmers manage rice straw by incorporating it back into the soil to enhance fertility or by burning it in the fields to clear land for subsequent planting. While field burning has been a common practice, recent surveys indicate a reduction in this method, with about 27% of rice straw now burned, 54% incorporated into the soil, and 19% collected for alternative uses[31].

The lack of centralised collection systems and limited infrastructure in Palawan would imply that these residues are typically used near their source. Geographical challenges, including transportation away from the province, alongside a lack of awareness on alternative uses such as bioenergy or sustainable aviation fuel (SAF) feedstocks have resulted in significant underutilization of these resources.

These traditional practices, while cost-effective for small-scale farmers, overlook opportunities for sustainable and large-scale resource utilization that could benefit both the local economy and the environment.

Increasing rice production

Intensifying rice production in Palawan is viable due to its fertile soils, favourable climate, and established agricultural base. However, challenges such as limited transport and logistic infrastructure, water scarcity, and environmental protection should be addressed. Sustainable intensification should focus on:

- Optimising Land Use: Target idle agricultural areas.
- Investing in Irrigation: Implement modern systems.
- Adopting High-Yield Varieties: Use improved rice strains.
- Farmer Training: Promote sustainable practices and mechanisation.
- Enhancing Infrastructure: Improve post-harvest handling and transport to reduce losses and boost market access.

2. Feedstock Assessment

2.7 Palawan Province Feedstock Assessment

2.7.2 Growth potential

Coconut wastes

Business as usual and current wastes uses

Coconut production is the core agricultural activity within the Palawan Province, with the province being one of the top producers in the Philippines. However, similar to rice farming, coconut waste management follows traditional practices that often leave much of the potential feedstock underutilised. Non-standard coconuts, which are coconuts that do not meet the size or quality standards for commercial sale, make up approximately 30% of total coconut production. These coconuts are often discarded or used for local purposes, such as animal feed or fuel, due to their lower economic value.

Coconut residues, including husks and shells, are typically used near their source for lower-value applications, such as in small-scale handicrafts or as fuel for cooking. However, there is limited infrastructure to centralise the collection and transport of these residues, resulting in significant waste. Geographic challenges and a lack of awareness regarding alternative uses, such as for bioenergy or SAF feedstocks, further hinder large-scale resource utilisation. Despite these practices being cost-effective for small-scale farmers, they miss an opportunity to tap into the potential of coconut residues as a valuable resource for SAF production. To unlock this potential, investments in infrastructure for residue collection, processing facilities, and awareness campaigns for alternative uses could help transition coconut production in Palawan into a more sustainable, large-scale resource management system. By focusing on non-standard coconuts and waste products, the province could significantly contribute to SAF feedstock supply while improving environmental sustainability.

Increasing coconut production

Intensifying coconut production in Palawan is feasible but limited by existing land use, as most coconut plantations are already maximised for yields based on current practices. Therefore, the focus should shift to improving productivity on current lands by adopting higher-yielding varieties, better irrigation, pest control, and enhanced harvesting and processing infrastructure.[32]

Given land constraints, the key to increased yield lies in optimising the use of non-standard coconuts, which are often discarded or used for low-value purposes. Better collection and processing of these residues can provide valuable feedstocks for SAF without needing additional land. Instead of expanding coconut plantation areas, optimising current practices and utilising coconut by-products is the most viable approach, particularly when combined with other feedstock sources like rice waste or municipal solid waste. This strategy can assist in achieveing a sustainable, scalable feedstock supply for SAF production while mitigating environmental and economic trade-offs.

2. Feedstock Assessment

2.7 Palawan Province Feedstock Assessment

2.7.3 Feedstock Seasonality

The year in Palawan can be divided into a wet season and a dry season, with slight variations between different parts of the province due to the influence of monsoons.

- **Wet season** – Typically from June to September, influenced by the southwest monsoon.
- **Dry season** – Generally from October to May, with the driest months occurring in February and March.

Temperatures remain relatively consistent throughout the year, averaging 29–31°C, with the warmest months being March to May and the coolest months from November to February. The planting, growth and harvesting seasons for each of the feedstocks studied for Palawan Province is shown within Table 2.17 below.

Table 2.17: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Rice	Two main seasons [33]: • Rainy Season Rice: Planted from August. • Dry Season Rice: Planted from March.	• January and February (rainy season) • June and July(dry season crop)
Coconut	Any time of the year, although warm rainy months are preferred	Year-round

2. Feedstock Assessment

2.7 Palawan Province Feedstock Assessment

2.7.4 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.18 below.

Table 2.18: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Coconut wastes	Six months to a year [27]	Husk has to be stored in a cool, dry area to avoid mould growth. Copra can be stored for up to 2 months, or if dried, for up to 8 months. Storage conditions are important; a well-ventilated dry environment helps to preserve the copra for a longer period of time. Coconut shells are highly durable, taking 5–6 years to decompose naturally. When stored in a cool, dry, and well-ventilated area, they can be preserved for extended periods without significant degradation. Proper storage prevents moisture absorption, mould growth, and structural weakening, while keeping the area clean helps avoid pest damage.

2. Feedstock Assessment

2.7 Palawan Province Feedstock Assessment

2.7.5 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.19 below.

Table 2.19: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
Coconut wastes	70-85	17	10	70-80

2. Feedstock Assessment

2.7 Palawan Province Feedstock Assessment

2.7.6 Additional Land Assessment

Intensifying coconut production in Palawan may be technically not feasible given that coconut plantations are already maximised for yields based on current practices. Therefore, the focus should shift to improving productivity on current lands by adopting higher-yielding varieties, better irrigation, pest control, and enhanced harvesting and processing infrastructure. The national average is about 50 nuts per tree annually, whereas well-managed areas can achieve 300-400 nuts per tree. This suggests substantial room for yield improvement through better farming practices.[32]

Given land constraints, the key to increased yield lies in optimising the use of non-standard coconuts, which are often discarded or used for low-value purposes. Better collection and processing of these residues can provide valuable feedstocks for sustainable aviation fuel (SAF) without needing additional land. Rather than expanding coconut plantations, optimising current practices and utilising coconut by-products is the most viable approach, particularly when combined with other feedstock sources like rice waste or municipal solid waste.

2.7.7 Feedstock Costs

It is difficult to attach specific values to agricultural waste products without extensive work on the ground with farmers and communities. For each type of feedstock the following has to be understood in order to make an assessment:

- Does a particular waste have a current use/value attached to it? Most of the identified feedstocks do not have any value attached to them at present, with the exception of sugarcane bagasse and some others that can be used as animal feed. Therefore, there are no formal markets / price for the feedstocks.
- What are competing future uses? For example, some of these feedstocks could be utilised for AD and biogas production, what would the value attached to the feedstock for that application be? A next decision should be whether a feedstock is better utilised if it is routed to a competing future use or to SAF production.
- What is the cost involved to aggregate a particular feedstock? For example, additional equipment and labour will be required to gather rice straw or corn stover from the fields. Once the cost to aggregate is understood, a value could be attached to a particular feedstock to provide the farmers with the incentive to gather the feedstock. If a feedstock is currently used as soil enhancer or similar purposes, enough should be left to continue this use, or the cost of the product replacing this use should be understood. An example is any fertiliser that is required to assist with soil conditioning once the feedstock is partially removed.
- The properties of the feedstock should be understood, such as bulk density, moisture content and calorific value. Low density feedstocks will be expensive to transport, and therefore would command a lower value (or have no value) than a high-density feedstock. Higher calorific value feedstocks and feedstocks with lower moisture contents would be considered more valuable.

2.7.8 Large-scale biomass management advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include:

- Large farms have lower overheads as a percentage of revenue. Cost of inputs like seeds, fertilisers and machinery is spread over a larger output, reducing unit cost.
- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
- It is easier and cheaper to collect the harvest and waste streams from centralised large farms and transport them from a single location to another single location.
- Contracting with a single large entity (large scale farm or co-op) is considerably easier than contracting with dozens or hundreds of small-scale farmers. In addition, small-scale farmers tend to be subsistence farmers only, so that very little additional crops are grown beyond their own needs.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

2. Feedstock Assessment

2.8 Thailand Feedstock Assessment

2.8.1 Feedstock Types and Locations

Agricultural and Forestry Waste Feedstock Summary Assessment

The types of agricultural waste biomass with apparent higher potential are generated in the production of **cassava, rice and oil palm fruit** as shown in Figure 2.15. [4] While sugarcane is produced in large quantity, sugarcane bagasse is typically unavailable for biofuels production as sugar mills use it for energy generation.

The areas with higher potential to produce SAF from agricultural wastes are **Nakhon Ratchasima and the northeast region** where high quantities of agricultural feedstock may be available all-year-round.

The north and the south regions are also areas with forestry production and, hence, harvest waste and waste from sawmills and other forestry industrial plants may be available. Refer to Figure 2.16 for locations and total waste generated volumes per region and per agriculture waste feedstock.

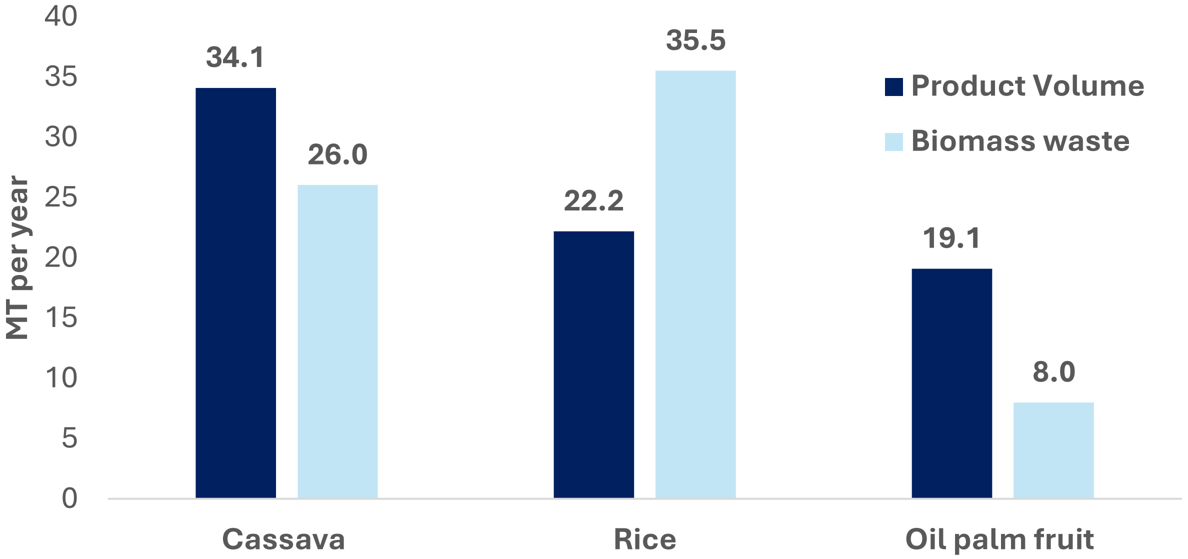
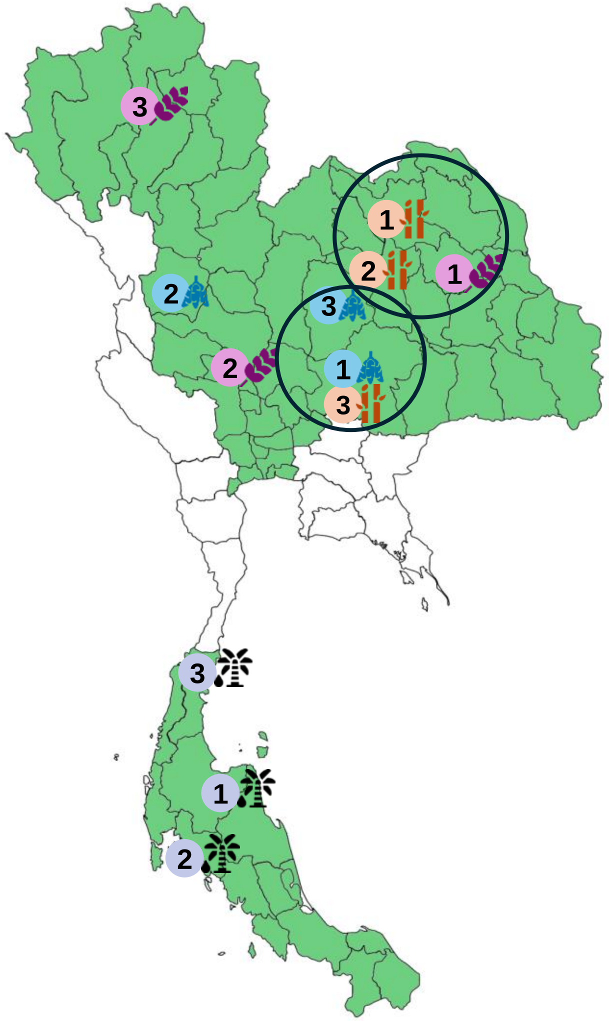


Figure 2.15: Top three Agricultural Feedstock and Biomass Waste in Thailand, 2022

*While sugarcane is the most prevalent crop, it is unlikely that sugarcane bagasse would be available for SAF production as it is used for energy generation



Waste and residues

Rice		
1	Northeast	16
2	Central	7
3	North	6
Cassava		
1	Nakhon Ratchasima	9
2	Kamphaeng Phet	5
3	Chaiyaphum	4
Oil palm fruit		
1	Surat Thani	2
2	Krabi	2
3	Chumphon	2
Sugarcane wastes* MT/ year		
1	Udon Thani	1.9
2	Khon Kaen	1.7
3	Nakhon Ratchasima	1.6
Forestry		
	Harvest waste	1
	Industrial waste	2

Source: FAOSTAT

Figure 2.16: Top three Locations of top three Agricultural Biomass, and Forestry Waste Locations in Thailand, 2022

2. Feedstock Assessment

2.8 Thailand Feedstock Assessment

2.8.2 Growth potential

From the feedstock interrogation, it has been determined that Cassava, EFB and rice wastes could have significant potential as feedstocks for SAF production in Thailand. In this section, business as usual and current destinations for the wastes are discussed, as well as efforts to increase production of these feedstocks. Each feedstock is individually discussed.

Rice wastes
Business as usual and current wastes uses
Rice is Thailand's most important food crop, accounting for roughly half of the country's agricultural land and employing more than 18 million smallholder farmers. 80% of the rice crop is grown by smallholder farmers.
This could make the aggregation and contracting of rice harvest wastes challenging.

Rice straw is still commonly burnt in Thailand. Through education, incentives and mechanization, the burning of rice straw can be replaced with collection of rice straw for SAF production. The International Rice Research Institute (IRRI) has been involved in training Thai farmers on sustainable rice straw management, including techniques for collection and utilization of rice straw to reduce open-field burning. Additional initiatives such as the Thai Rice Nationally Appropriate Mitigation Action Project provide training and support to farmers on best practices for rice straw management.

Rice straw uses could include cattle feed and mushroom substrate.

Making straw balers available to smallholder farmers could make a large impact to make the straw collection process more efficient. The mechanization helps farmers to manage larger quantities of straw and reduces labour costs.

Increasing rice production
The total area under rice production is approximately 11 million hectares or 40% of the cropped land area in Thailand. It is unlikely that the land area for rice cropping will increase, and therefore cropping efficiency has to increase to increase production. Less than 20% of Thailand's rice crops are under irrigation, irrigation could increase the rice yield dramatically. Other measures include improved varieties with higher yield (and higher fibre yield for increased rice straw yield), mechanisation to increase harvesting efficiency, training with regards to best farming practices and introduction of climate-change resistant rice varietals.

2. Feedstock Assessment

2.8 Thailand Feedstock Assessment

2.8.2 Growth potential

Oil palm fruit
Business as usual and current wastes uses
The palm oil industry provides livelihoods for approximately 400,000 farm households across Thailand. RSPO Thailand's oil palm growers' includes 63 groups of small-scale and large-scale farmers. Therefore, although there are many smallholder farmers involved in the production of EFB, it may be relatively easy to contract and collect, given the high level of organisation around palm oil production through the RSPO Thailand [37].

Empty fruit bunches (EFB) can be utilised for mulching, however, only a small portion of EFB is used for this. The remaining EFB is deposited at plantations where it decomposes for soil enhancement, or abandoned at palm oil mills and left to decay as waste. This implies that a large proportion of EFB would already be aggregated at the mills and available for use for SAF production. Ideally, a SAF facility using EFB would be located close to large plan oil mills.

Some potential additional uses are being explored for EFB, but these are all in research phase, including:
- Use in the pulp and paper industry to produce packaging paper.
- Feedstock for biocomposites.

Increasing oil palm fruit production
Thailand's palm oil production has a consistent growth trajectory, with an annual increase of almost 6% from 2012. Improved knowledge with regards to oil palm tree management and sustainability among smallholders is contributing to higher yields.

Adoption of RSPO certification has yielded positive economic outcomes for smallholders, and has resulted in smallholders having better access to resources, market opportunities and premium prices for fresh fruit bunches, resulting in higher yields and returns compared to non-certified counterparts.

2. Feedstock Assessment

2.8 Thailand Feedstock Assessment

2.8.3 Feedstock Seasonality

The year can be divided into a rainy season, cool season and hot season:

- Rainy season – from May to October.
- Cool season – from November to February.
- Hot season – from March to May.

The planting, growth and harvesting seasons for each of the feedstocks studied for Thailand is shown within Table 2.20 below.

Table 2.20: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Sugarcane	Sugarcane is planted in April-May in the Central region and October to November in the North and Northeast regions.	November to March.
Cassava	Cassava is normally planted in April to October.	Harvesting season from December to August.
Rice	Two main seasons: • Rainy Season Rice (Main Crop): Planted from May to July. • Dry Season Rice (Second Crop): Planted from November to February.	• November to December (rainy season). • March to May (dry season crop).
Oil palm fruit	Any time of the year, although warm rainy months are preferred.	Year-round.
Forestry	Any time of the year, although the rainy months are preferred.	Year-round, although the dry periods when terrain is more accessible is preferred.

2. Feedstock Assessment

2.8 Thailand Feedstock Assessment

2.8.4 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.21 below

Table 2.21: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Sugarcane wastes	Up to a year [23, 24]	Can be stored as bales or loose material. For loose storage, the piles should be covered by tarps to reduce losses. Bagasse can be dried first or stored as wet material. Dried material is less likely to undergo significant degradation but is a fire hazard, and requires additional equipment and energy for drying. Wet storage requires no drying up front and the fire risk is reduced to almost zero, but handling of the wet material can be difficult. Baling reduces the transport cost of the wastes but requires additional labour at the harvest sites, and debaling equipment at site. In addition, the storage area required is larger than for loose material.
Cassava wastes	Two to three months [28]	Sun drying required prior to storage.
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Oil palm fruit bunches	Up to 6 months [35]	EFB requires drying prior to storage, If wet, EFB can only be stored for a few weeks or up to a month.
Forestry wastes	Up to a year [29]	Store as whole logs or chips. If chipped, should be stored under cover (tarps).

2. Feedstock Assessment

2.8 Thailand Feedstock Assessment

2.8.5 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.22 below.

Table 2.22: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
Sugarcane wastes (trash)	45-55	16	18	80-120
Sugarcane wastes (bagasse)	50-75	20	5	50-80
Cassava wastes (bagasse)	75-85	10-15	2-19	80-120
Cassava wastes (peel)	60-80, reduced to 10-20% following sun drying	3	14	20-30
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
EFB	2.5-14	9-18	4	130-245
Forestry wastes	70-85, reduced to 40-50% once cut	18	2	235-280

2. Feedstock Assessment

2.8 Thailand Feedstock Assessment

2.8.6 Additional land assessment

In Thailand, 46% of land is utilised for agriculture. This has increased by 1.3 percentage points from 2018. Up until that point, agricultural land use had been relatively stable around 44.7%. Forestry and protected areas account for 39% of available land in Thailand, bringing the total to 85%. It is therefore unlikely that large volumes of additional land will be available for agriculture in Thailand. However, some of the land could be repurposed for different and diverse crops compared to what is currently cultivated.

2.8.7 Feedstock costs

It is difficult to attach specific values to agricultural waste products without extensive work on the ground with farmers and communities. For each type of feedstock the following has to be understood in order to make an assessment:

- Does a particular waste have a current use/value attached to it? Most of the identified feedstocks do not have any value attached to them at present, with the exception of sugarcane bagasse and some others that can be used as animal feed. Therefore, there are no formal markets / price for the feedstocks.
- What are competing future uses? For example, some of these feedstocks could be utilised for AD and biogas production, what would the value attached to the feedstock for that application be? A next decision should be whether a feedstock is better utilised if it is routed to a competing future use or to SAF production.
- What is the cost involved to aggregate a particular feedstock? For example, additional equipment and labour will be required to gather rice straw or corn stover from the fields. Once the cost to aggregate is understood, a value could be attached to a particular feedstock to provide the farmers with the incentive to gather the feedstock. If a feedstock is currently used as soil enhancer or similar purposes, enough should be left to continue this use, or the cost of the product replacing this use should be understood. An example is any fertiliser that is required to assist with soil conditioning once the feedstock is partially removed.
- The properties of the feedstock should be understood, such as bulk density, moisture content and calorific value. Low density feedstocks will be expensive to transport, and therefore would command a lower value (or have no value) than a high-density feedstock. Higher calorific value feedstocks and feedstocks with lower moisture contents would be considered more valuable.

2.8.8 Large-scale biomass management advantages

Large scale farming, harvesting and transport have various advantages, particularly from an efficiency, productivity and cost perspective. These include:

- Large farms have lower overheads as a percentage of revenue. Cost of inputs like seeds, fertilisers and machinery is spread over a larger output, reducing unit cost.
- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
- It is easier and cheaper to collect the harvest and waste streams from centralised large farms and transport them from a single location to another single location.
- Contracting with a single large entity (large scale farm or co-op) is considerably easier than contracting with dozens or hundreds of small-scale farmers. In addition, small-scale farmers tend to be subsistence farmers only, so that very little additional crops are grown beyond their own needs.

However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

2. Feedstock Assessment

2.9 Vietnam Feedstock Assessment

2.9.1 Feedstock Types and Locations

Agricultural and Forestry Waste Feedstock Summary Assessment

The types of agricultural waste biomass with apparent higher potential are generated in the production of **rice, cassava and corn** as shown in Figure 2.17. While sugarcane is produced in large quantity, sugarcane bagasse is typically unavailable for biofuels production as sugar mills use it for energy generation.

The areas with higher potential to produce SAF from agricultural wastes are **Mekong River Delta and a centralised spot between Dak Lak and Phu Yen** where high quantities of agricultural feedstock may be available all-year-round.

Those regions are also areas with forestry production and, hence, harvest waste and waste from sawmills and other forestry industrial plants may be available. Refer to Figure 2.18 for locations and total waste generated volumes per region and per agriculture waste feedstock.

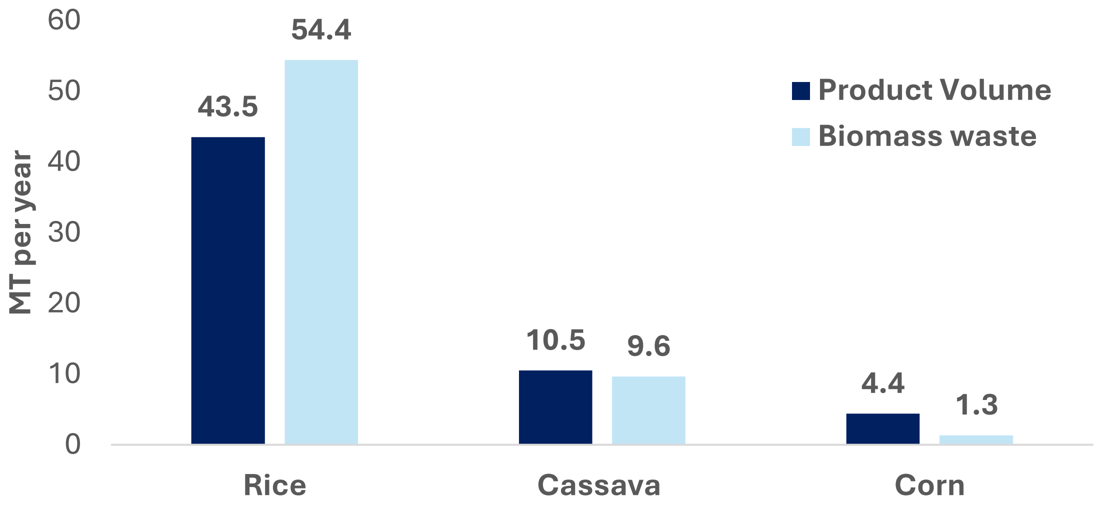
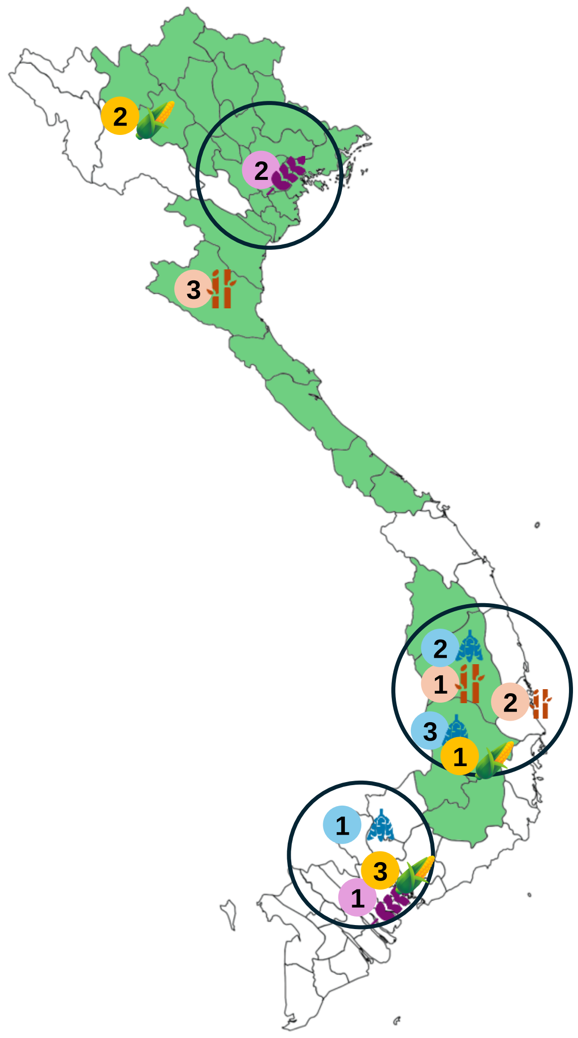


Figure 2.17: Top three Agricultural Feedstock and Biomass Waste in Vietnam, 2022



Waste and residues [4]

Rice		**MT/ year**
1	Mekong River Delta	30
2	Red River Delta	9
Cassava		
1	Tay Ninh	4
2	Gia Lai	3
3	Dak Lak	2
Sugarcane*		
1	Gia Lai	0.7
2	Phu Yen	0.4
3	Nghe An	0.3
Forestry		
	Harvest waste	2.72
	Industrial	3.06
Corn		
1	Dak Lak	0.5
2	Son La	0.3
3	Dong Nai	0.3

Source: FAOSTAT

Figure 2.18: Top three Locations of Top 3 Agricultural Biomass, and Forestry Waste Locations in Vietnam, 2022

2.9 Vietnam Feedstock Assessment

2.9.2 Growth potential

From the feedstock interrogation, it has been determined that rice, Cassava and corn wastes could have significant potential as feedstocks for SAF production in Vietnam. In this section, business as usual and current destinations for the wastes are discussed, as well as efforts to increase production of these feedstocks. Each feedstock is individually discussed.

Rice wastes
Business as usual and current wastes uses
In Vietnam, rice is a very important crop. Around 5.8 million households grow rice, and 80% of the rice produced in Thailand is produced by smallholder farmers. This could make the aggregation and contracting of rice harvest wastes challenging.

Rice straw is still commonly burnt in Vietnam, with 57% of farmers still taking part in this practice. Through education, incentives and mechanization, the burning of rice straw can be replaced with collection of rice straw for SAF production. Rice straw uses could also include cattle feed and mushroom substrate.

Increasing rice production
In Vietnam, approximately 90% of the rice crops are grown with irrigation, so that additional irrigation is unlikely to increase the rice production significantly.

Improves rice varieties to increase production (but not necessarily rice wastes), training and education for smallholder farmers on best practices could assist in increasing rice and rice wastes production.

2.9 Vietnam Feedstock Assessment

2.9.2 Growth potential

Corn wastes

Business as usual and current wastes uses

Corn husks, leaves and stalks typically have no economic value. Leaves and stalks are typically left on the field and serves as insulation and to smother weeds and enhance the soil quality. Corn stover is also currently included as animal feedlot finisher rations, with between 5-15% of the rations consisting of corn stover.

Increasing corn production

In Vietnam, corn production cannot compete with corn imports, making the expansion of corn as a crop difficult. There is now a reliance on corn imports. The introduction of new corn varieties with higher yields, increased irrigation and incentives to farmers are assisting to maintain the corn industry in Vietnam.

Cassava wastes

Business as usual and current wastes uses

Cassava is a crop that provides a good income source to small farmers in Vietnam. The Cassava starch processing industry in Vietnam comprises around 120 industrial-scale factories with a combined capacity of 11 million tonnes per annum. Therefore, significant volumes of wastes may already be aggregated at these factories for use in SAF production.

Vietnam is the second largest exporter of Cassava globally, and the strong export market has driven investment and growth in the Cassava sector in Vietnam.

Cassava wastes can be classified as stems and leaves and solid residue (thippi). There are other waste streams as well but they are not typically suitable for SAF production. Stems and leaves are left in the field as soil enhancer or burnt. It can also be utilised as animal feed or composted. Thippi can be composted, used as animal feed or as a feedstock for bioplastics and other similar processes (not currently available commercially).

Increasing cassava production

Improved varietals, modern farming techniques and continuous research and development efforts leading to improved cultivation practices are resulting in increased Cassava yields.

2. Feedstock Assessment

2.9 Vietnam Feedstock Assessment

2.9.3 Feedstock Seasonality

The year can be divided into a wet season, and dry season:

- Wet season – from June to November.
- Dry season – from December to May.

The planting, growth and harvesting seasons for each of the feedstocks studied for Vietnam is shown within Table 2.23 below.

Table 2.23: Planting, growth and harvesting seasons for feedstocks

Feedstock	Planting and growth season	Harvesting season
Rice	Two main seasons [38]: • Planted from December to February. • Planted from April to June • In the Mekong Delta a third crop is planted in August-September	• Harvested from April-June • Harvested from August-October • Harvested from November-December
Cassava	Cassava is normally planted in June at the beginning of the rainy season [39].	Main harvesting season from December to January.
Corn	Two main seasons [40]: • Planted from February-April • Planted from Augustus-September	• Harvested from June-August. • Harvested from December-January.
Forestry	Any time of the year, although the rainy months are preferred.	Year-round, although the dry periods when terrain is more accessible is preferred.

2. Feedstock Assessment

2.9 Vietnam Feedstock Assessment

2.9.4 Feedstock Storage

The feedstock typical storage periods and associated notes are also included within Table 2.24 below

Table 2.24: Typical storage periods for feedstocks

Feedstock	Typical storage period	Notes
Rice wastes	Up to a year [25]	Can be stored as bales in a covered area or loose material covered by tarps to reduce losses. From studies, uncovered bales were found to lose 40-60% of organic material over a period of a year, while partially covered bales were found to lose 10-20% of organic material over a year.
Cassava wastes	Two to three months [28]	Sun drying required prior to storage.
Corn wastes	Up to a year [26]	Corn stover is typically baled and stored covered by tarps or other wrapping material. If the stover is dried to less than 40% moisture, the bales can be stored for 365 days, while higher moisture bales (50% moisture) tend to have structural integrity losses after 120 days storage, making them difficult to move for processing.
Forestry wastes	Up to a year [29]	Store as whole logs or chips. If chipped, should be stored under cover (tarps).

2.9 Vietnam Feedstock Assessment

2.9.5 Feedstock Composition

The typical feedstock specifications including moisture content, carbon content, ash content and bulk density are also included in Table 2.25 below.

Table 2.25: Feedstock moisture content, carbon content, ash content and bulk density

Feedstock	Moisture content (mass%, as received basis)	Fixed carbon content (mass%, dry basis)	Ash content (mass%, dry basis)	Bulk density (kg/m^3)
Rice wastes (husk)	15 (following milling)	25	21	90-150
Rice wastes (straw)	40-75	65	18	75-80
Cassava wastes (bagasse)	75-85	10-15	2-19	80-120
Cassava wastes (peel)	60-80, reduced to 10-20% following sun drying	3	14	20-30
Corn wastes (husk)	45-55	63	13	80-120
Corn wastes (leaves)	70-80 (green leaves)	11	5	110-130
Forestry wastes	70-85, reduced to 40-50% once cut	18	2	235-280

2.9 Vietnam Feedstock Assessment

2.9.6 Additional land assessment

In Vietnam, agricultural land accounts for 40% of the total land area, while forestry and protected lands account for 47%. Therefore, there appears to be very little additional land to expand agricultural activities. During the 1990's the Vietnam Government promoted the expansion of agricultural land use significantly into uncultivated areas in remote rural communities. This was part of a broad strategy to increase agricultural output and support rural development.

2.9.7 Feedstock costs

It is difficult to attach specific values to agricultural waste products without extensive work on the ground with farmers and communities. For each type of feedstock the following has to be understood in order to make an assessment:

- Does a particular waste have a current use/value attached to it? Most of the identified feedstocks do not have any value attached to them at present, with the exception of sugarcane bagasse and some others that can be used as animal feed. Therefore, there are no formal markets / price for the feedstocks.
- What are competing future uses? For example, some of these feedstocks could be utilised for AD and biogas production, what would the value attached to the feedstock for that application be? A next decision should be whether a feedstock is better utilised if it is routed to a competing future use or to SAF production.
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- Larger farms can typically access advanced farming techniques and mechanisation to achieve higher yields and productivity levels.
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However, it is important to consider the environmental impact and social challenges that large scale farming could have on a community of effectively small-scale farmers.

3. Technology Selection

GHD Advisory

→ Technology Selection Overview

3. Technology Selection

3.1 Technology Selection Overview

This section presents an overview of the technology selection assessment including the technology pathways, job creation, regulatory requirements, SWOT Analysis and a Multi Criteria Analysis (MCA).

Technology Pathways

Currently, drop-in biofuels are primarily produced via **Hydro-processed Esters and Fatty Acids (HEFA) from Hydrotreated Vegetable Oils (HVO)** or animal fats, but due to limited and expensive feedstocks, alternative pathways using more abundant and low-value feedstocks are being explored, despite higher investment costs.

Alternative Pathways:

- **Fischer-Tropsch (FT-SPK & FT-SPK/A):** Uses lignocellulosic feedstocks, requires drying and gasification.
- **Alcohol to Jet (AtJ-SPK):** Converts ethanol to jet fuel, involves biomass pre-treatment.
- **Hydrothermal Liquefaction (HTL):** No feedstock drying needed, high biocrude yield.
- **Gasification & Methanol Synthesis:** Produces methanol, which can be upgraded to jet fuel.

Job Creation

Biorefinery facilities, regardless of technology, will create similar jobs in biomass aggregation, storage, conversion, and upgrading, with significant potential for direct and indirect job creation in SE Asia, as evidenced by biofuels industry developments in the US, Singapore, and Australia.

Regulatory Requirements

A biorefinery requires rigorous regulatory and environmental approvals similar to other chemical facilities, with specific considerations for feedstock transport and storage, and must demonstrate tangible sustainability benefits verified by third-party certification to meet international standards. This includes adherence to standards such as **EU RED II, ISO 13065:2015, and ICAO CORSIA.**

SWOT Analysis

- **HEFA:** Most technically and commercially mature pathway for SAF production, with the ability o produce 100% SAF blend. However, it requires large amounts of hydrogen, which can increase costs and carbon intensity if derived from non-renewable sources.

- **HTL:** Does not require feedstock drying and yielding high biocrude, but faces challenges such as high complexity, CAPEX, and unproven water treatment; offers flexibility in feedstock and by-products, with threats including variability in biocrude properties affecting ASTM approval.

- **ATJ:** ASTM-approved and capable of producing saleable interim products like bio-ethanol or bio-butanol, but faces challenges such as high complexity and CAPEX; offers flexibility in feedstock and by-products, with potential for a hub and spoke model for feedstock processing.

- **Gasification/FT:** ASTM-approved and can be self-sustaining, but faces challenges such as high complexity, CAPEX, and water consumption; offers flexibility in feedstock and by-products, with threats including past failures in similar technologies impacting confidence.

- **Gasification/Methanol Synthesis:** Can be self-sustaining with saleable methanol as an interim product, but faces challenges such as high process complexity and CAPEX; offers flexibility in feedstock and by-products, with threats including the lack of ASTM approval for the final SAF product.

Multi Criteria Analysis

The MCA, using the following criteria: Financial indicators (33%), Environmental/Efficiency indicators (30%), Technical indicators (27%), and Experience indicators (10%), has determined that **HEFA ranks the highest overall**, followed by ATJ, HTL, Gasification/Fischer-Tropsch, and Gasification/Methanol. However, it should be noted that HEFA requires oils and fats as feedstocks, which limits its applicability to many other agricultural and forestry feedstock wastes, in which case the ATJ pathway would rank the highest for these feedstocks.

GHD Advisory

→ Technology Selection Deeper Dive

3. Technology Selection

3.2 Approved and Potentially Viable Technology Pathways

Currently, drop-in biofuels are only produced commercially via Hydro-processed Esters and Fatty Acids (HEFA) from Hydrotreated Vegetable Oils (HVO) or animal fats. ***See Figure 3.1 for an overview of the technology pathway process.***

While the capital cost for this SAF production pathway is lower than other pathways, the feedstocks have limited availability and can be expensive. Therefore, this pathway offers limited SAF production potential. As a result, other, more abundant feedstocks and feedstocks not competing with foodstuffs are being explored. It is understood that these pathways will have higher investment cost requirements (more expensive capital costs), but the feedstocks are generally low or zero value feedstocks. From the feedstock information, the highest volumes of agricultural waste are obtained from rice, coconut, palm fruit wastes and cassava harvesting. Forestry waste volume also exists in all the countries studied (refer Section 2). For these lignocellulosic feedstocks being explored, the following **ASTM D7566-Approved Pathways** may be considered:

- **ASTM D7566 Annex A1 Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)** & **Annex A4 Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics (FT-SPK/A)**. SAF product can be blended with crude derived jet fuel to 50vol%. Feedstock is typically dried to 10-15mass% moisture prior to gasification and sized though crushing and/or milling to produce a feed suitable for gasification. The specific particle size distribution is dependent on the type of gasification technology selected. Interim products from Fischer-Tropsch, like waxes and hydrocarbon liquids, are not directly saleable products and, hence, have to be upgraded. ***See Figure 3.2 for an overview of the technology pathway process.***

- **ASTM D7566 Annex A5 Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK)**, via ethanol production. SAF product can be blended with crude derived jet fuel to 50vol%. Pre-treatment of biomass is required prior to saccharification and fermentation to render the lignocellulose less recalcitrant to hydrolysis. Mechanical, physico-chemical, chemical and biological pre-treatment steps have been developed. Moisture content of the biomass is less important than for gasification. Bio-ethanol produced from the fermentation step is a saleable product before undergoing upgrading and could be directly used as a fuel. ***See Figure 3.3 for an overview of the technology pathway process.***

Potentially Viable Pathways that are not currently certified in ASTM D7566, however may be approved soon include:

- **Hydrothermal liquefaction and upgrading of the produced biocrude**. Hydrothermal liquefaction (HTL) is a developing technology, with Technology readiness level (TRL) at around 8. One of the greatest advantages of this pathway is that no feedstock drying is required prior to processing, as moisture remains in liquid phase in the liquefaction reactor. This pathway is also presented as a pathway that could imminently be approved. ***See Figure 3.4 for an overview of the technology pathway process.***

- **Gasification and methanol synthesis**, followed by methanol-to-jet upgrading. The flow scheme is similar to gasification and Fischer-Tropsch synthesis, and the methanol-to-jet process is similar to methanol-to-gasoline, which is a commercially available technology. The TRL for gasification, methanol synthesis and conversion to jet fuel is 6-7. Methanol is a saleable product and could be produced and sold prior to adding the upgrading units to upgrade methanol to jet fuel.

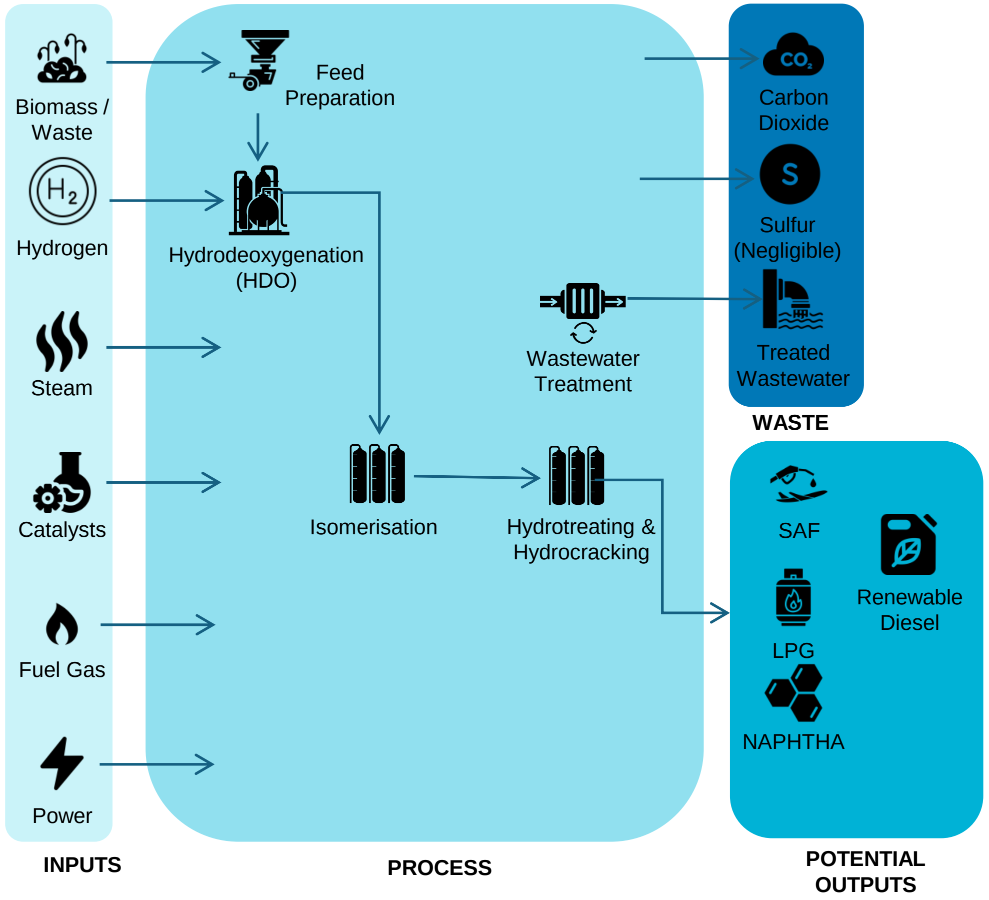


Figure 3.1: Hydro-processed Esters and Fatty Acids (HEFA) process

3. Technology Selection

3.3 Process Overview of Approved Technology Pathways

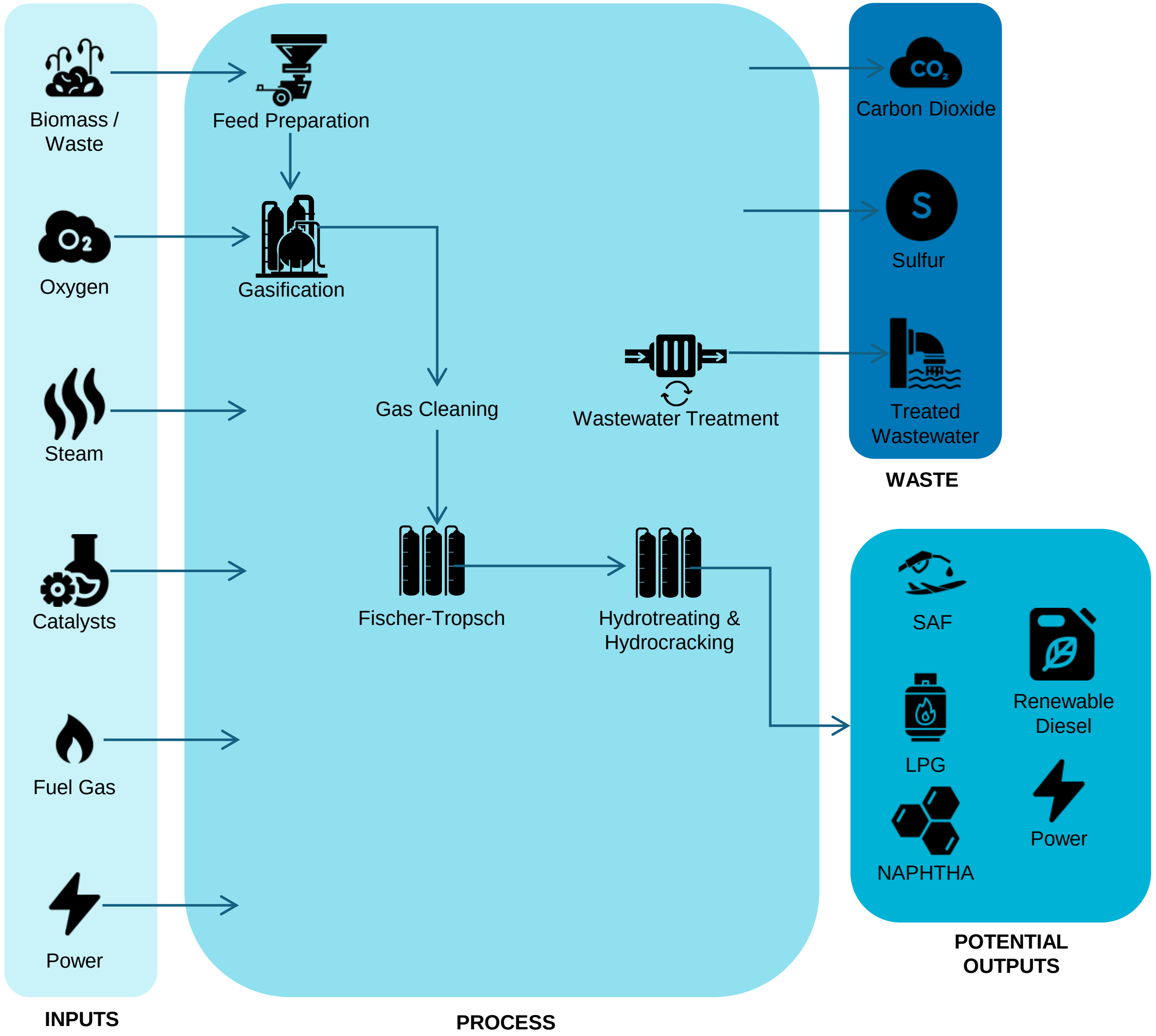


Figure 3.2: Gasification, Fischer-Tropsch and upgrading

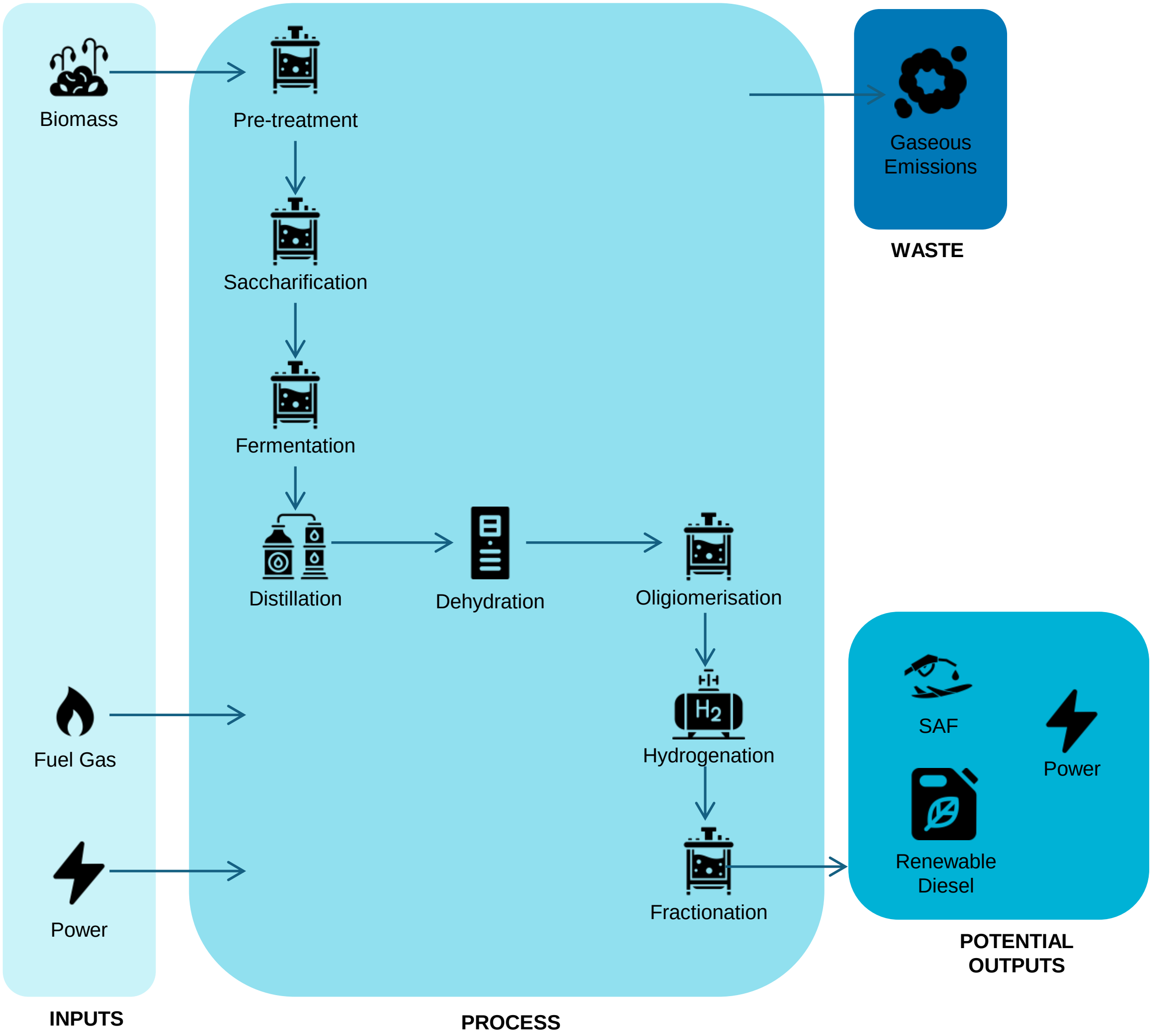


Figure 3.3: Fermentation to alcohol (ethanol) and alcohol to jet upgrading (ATJ)

3. Technology Selection

3.4 Process Overview of a Potentially Viable Technology Pathways

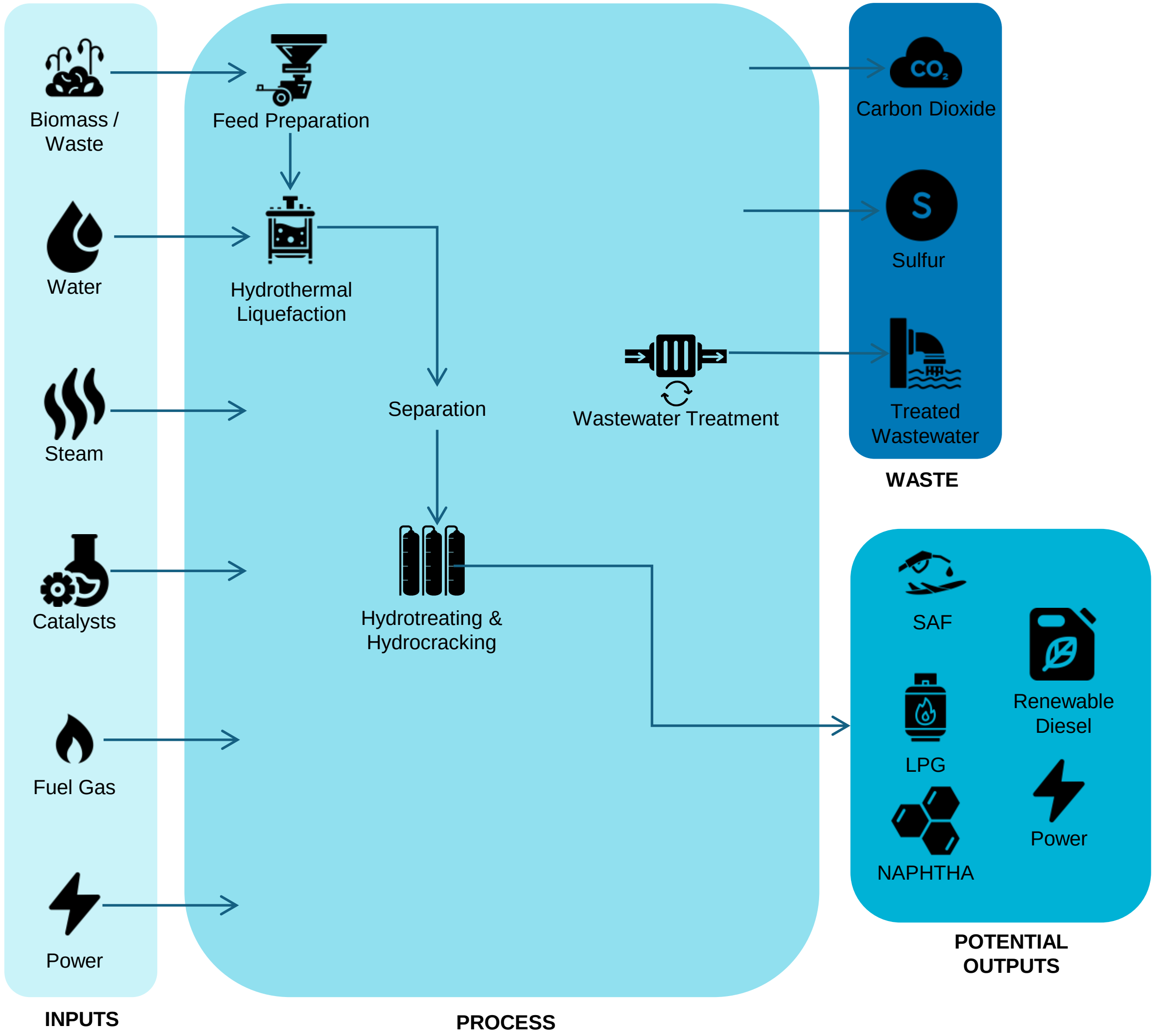


Figure 3.4: Hydrothermal liquefaction and upgrading

3.5 Technology Pathway Production Volumes

Technology Pathway Production Volumes

High capital investment is needed for biomass-to-liquids facilities, making economies of scale essential to reduce costs per barrel. Small-scale facilities are hard to support due to the large biomass volumes and consistent feedstock throughput required.

Production facility volumes selected for this study are (1) 1,000 bpsd final liquid products, (2) 2,000 bpsd final liquid products and (3) 5,000 bpsd final liquid products (stretch target). The split of liquid products is typically SAF: renewable diesel: renewable naphtha 60:15:25 (volume basis). The upgrading unit design can be adapted to some extent to optimise SAF yield at the expense of other liquid products. Typically, a maximum of 70 or 75% liquid products could be converted to SAF with smaller volumes of renewable diesel and naphtha yields. The product splits are assumed to be similar for the Fischer-Tropsch and alcohol-to-jet schemes.

For **gasification, Fischer-Tropsch and product upgrading**, the following yields are expected:

- For **rice straw**, 212 L/0% moisture tonne of feedstock
- For **woodchip**, 246 L/0% moisture tonne of feedstock
- **Other lignocellulosic feedstocks** are expected to have similar yields (between 200-250 L/0% moisture tonne of feedstock).

For **fermentation to ethanol and ethanol to jet**, the following yields are expected:
Each type of feedstock has a varying yield from feedstock to ethanol, depending on the quality of the feedstock. Typically, a 60 mass% conversion is then expected from ethanol to jet fuel.

- For **rice straw**, 200 L EtOH/0% moisture tonne of feedstock, and 128 L jet fuel/0% moisture tonne of feedstock
- For **rice husk**, 60 L EtOH/0% moisture tonne of feedstock, and 40 L jet fuel/0% moisture tonne of feedstock
- For **cassava peel**, 160 L EtOH/0% moisture tonne of feedstock, and 102 L jet fuel/0% moisture tonne of feedstock
- For **woodchip**, 250 L EtOH/0% moisture tonne of feedstock, and 160 L jet fuel/0% moisture tonne of feedstock
- For **sugarcane bagasse**, 198 L EtOH/0% moisture tonne of feedstock, and 127 L jet fuel/0% moisture tonne of feedstock

For **hydrothermal liquefaction and upgrading**, the following yields are expected:

- For **sugarcane bagasse**, 300 L/0% moisture tonne of feedstock
- For **woodchip**, 317-320 L/0% moisture tonne of feedstock

Typically, a mixture of feedstocks are likely to be utilised at any biofuels facility to overcome seasonality and crop failures. Therefore, an average yield value has been selected for each technology type to determine the feedstock requirements for a 1,000, 2000 and 5,000 bpsd plant. An incoming moisture content of 40mass% (typical for many types of agricultural waste feedstocks) is assumed.

3. Technology Selection

3.6 Direct and Indirect Jobs Creation

Biorefinery facilities will have similar activities and number of employees required to construct and operate a facility, regardless of the technology selection. The facilities will all have biomass aggregation activities, biomass storage and preparation, primary conversion and hydrogen and upgrading process units, regardless of the specific technology selection. Therefore, jobs creation is discussed in general, rather than for specific technologies.

To determine the potential impact that an advanced biofuels industry (to produce SAF and renewable diesel) could have on the economy of a region, biofuels industry development in other countries and biofuels facilities that have been constructed or operated are looked to.

In the US, it is estimated that 43,600 people are directly employed in the manufacturing of biofuels, and an additional 5,950 in biofuels research.[58] In addition, it is estimated that 590,000 additional jobs have been created indirectly by the bioeconomy, including more than 190,000 farming and agricultural commodity jobs; or to state it differently, 11 indirect jobs are created in the supply chain for every direct job created in the bioeconomy. These numbers include all types of biofuels manufacturing, such as bio-ethanol, renewable natural gas and others, but is an indication of what an advanced biofuels industry could mean for a region with regards to jobs creation. For the bio-ethanol industry only, which is well-established in the US, and generated 66 billion liters of bio-ethanol in 2020[55], 62,180 direct jobs and 242,600 indirect jobs were the resultant employment in the US (or 4 indirect jobs for every 1 direct job). Advanced biofuels of all types are currently still at pilot, demonstration or small-scale commercial capacity in the US, and it is estimated that 2,364 direct jobs have been generated from these facilities.

In addition, employment numbers from specific advanced biofuels production sites elsewhere in the world are drawn on to estimate how many direct jobs could be created by an advanced biofuels industry in SE Asia:

- In Singapore, the Neste HEFA biorefinery produces 1.2 billion liters of biofuels per annum and employs more than 300 people directly [56].
- JetZero's Project Ulysses in Australia, an ATJ facility, will directly deliver 1,000 construction jobs and more than 100 direct operating jobs. The plant will deliver 102 million liters of SAF and 11 million liters of renewable diesel per annum. It is estimated that a domestic SAF industry in Australia could create up to 15,600 jobs nationwide in Australia by 2050 [57].
- In the US, the Fulcrum project in Nevada generating biofuels from waste via gasification and FT had an installed capacity of 42 million liters of fuel per annum and directly employed 120 people. The plant has been shut down citing financial and technical difficulties [59].

Drawing on the above numbers, it is reasonable to assume that each large scale biorefinery constructed in SE Asia could lead to at least 1,000 construction jobs and 100-300 direct operating jobs, as well as between 500 to 1,200 indirect jobs. The types of jobs will range from engineers, technicians, equipment operators, mechanics and maintenance workers, truck and tractor operators, administration personnel, sales representatives and customer service representatives, and others. In addition to direct and indirect jobs that constructing and operating biorefineries would create in the ASEAN region, research is also required to develop innovative approaches to producing biofuels, particularly from third generation feedstocks such as microalgae. There are already research and development programs in several SE Asian countries, such as in the Philippines where studies into lignocellulosic feedstocks and microalgae for biofuels production are ongoing, and in Indonesia where blending Fatty Acid Methyl Esters (FAME) and renewable diesel blends are being investigated.

In the ASEAN Biofuel Research and Development Roadmap published in 2023 by the ASEAN Centre for Energy, it is stated that research and development efforts should be made at all stages of the biofuels supply chain. The roadmap was proposed to guide collaborative activities between ASEAN Member States to create a pathway for knowledge transfer.

The Association of Southeast Asian Nations have a ten-year Action Plan (2016-2025) to assist in creating focus areas and cooperation in research and development areas between SE Asian countries. One of the focus areas is new and renewable or alternative energy such as biomass/biofuels. Examples of specific university/research programs include the following:

- The Center for Engineering and Sustainable Development Research (CESDR) of the De la Salle University College of Engineering has researched on the Life Cycle Assessment of Algal Biofuels in the Philippines [60].
- The University of the Philippines (Los Baños) Department of Chemical Engineering has a Biofuels Research Team that has released a series of studies on the production of biofuels from different feedstock sources[61].

3.7 Regulatory and environmental requirements for the construction and operation of a biorefinery

A biorefinery is a complex set of process unit operations and requires the same regulatory and environmental approvals rigour that any other chemical facility or refinery would undergo in a specific country, under its own environmental laws. Specific country and regional legislation and policies relevant to a chemical facility or refinery should be investigated and applied, including planning and environmental frameworks and approval processes that would need to be considered during engineering, detailed design, construction, commissioning and operation phases of a biorefinery project.

Specific items such as the transport of equipment to site prior to and during the construction period, and storage and transport of feedstocks to the site during operation of the biorefinery are aspects that should also be considered as part of the regulatory and environmental requirements. The transport of feedstocks, typically by road or rail, is a relatively unique aspect associated with biorefineries that are applicable to most chemical or refinery facilities. The properties of a biomass material and intended use determines how the material should be safely transported and stored (IEA Bioenergy 2013).

In addition to the typical regulatory and environmental requirements, sustainability governance is also essential for biofuels facilities. Tangible social, economic and environmental benefits should be demonstratable for a biorefinery. These include greenhouse gas emissions reduction, sustainable and responsible land and water use, including land use changes, land degradation and biodiversity, waste management and health, safety and security of immediate workers and the larger community. It is typically recommended that adherence to sustainability criteria be verified by third-party certification of biofuel supply chains, particularly when the biofuels are to be exported. Examples of such sustainability criteria are the Renewable Energy Directives (RED I and RED II) in the European Union, the federal Renewable Fuel Standard Program and California’s Low Carbon Fuel Standard in the US.

In the revised EU Renewable Energy Directive (EU/2023/2413) an overarching policy for use of energy from renewable sources is provided. It reinforces the sustainability criteria of bioenergy generation and use, including the negative direct impact that biofuels may have due to indirect land use change. ISO 13065:2015 proscribes sustainability criteria for bioenergy. It specifies principles and criteria for the bioenergy supply chain in order to assess it for environmental, social and economic sustainability. This standard applies to all forms of bioenergy, irrespective of raw material, geographical location, technology or end use. The Roundtable on Sustainable Biomaterials (RSB) is a collaborative network of global organisations advancing the just transition to a net positive world. The RSB has created a sustainability framework with 12 key principles and underlying criteria. The intent of the RSB Standard is ensuring the production and trading of advanced fuels and their intermediates minimise negative environmental, social and economic impacts. There are several organisations operating in ASEAN countries that belong to the RSB.

ICAO prescribes strict sustainability criteria for SAF production to be considered sustainable and eligible for inclusion by fuel producers under the CORSIA scheme. This includes specifications that CORSIA SAF achieves a minimum 10% reduction in GHG emissions compared to fossil-based aviation fuel, as well as specific criteria for feedstock, water consumption, soil health, air quality, biodiversity, waste, human rights and food security impacts of the fuel production process (CORSIA 2022b Chapter 2). Additionally, for a SAF production pathway to be considered for inclusion in the CORSIA scheme, the pathway must be an ASTM certified conversion process, presently be operating at commercial scale and must have sufficient industry data for LCA modelling and indirect land use change modelling where applicable (CORSIA 2011).

3. Technology Selection

3.8 SWOT (Strengths, Weaknesses, Opportunities and Threats) for Technology Pathways

A SWOT analysis was undertaken for each of the considered technology pathways, including HEFA, ATJ, gasification/FT, HTL and upgrading and gasification/methanol production. The results are shown below.

HEFA

STRENGTHS

- **Mature Technology:** HEFA is the most technically and commercially mature pathway for SAF production
- **Selectivity:** Can tailor the product slate to produce almost 100% SAF
- **High Compatibility**: HEFA-derived SAF is chemically similar to conventional jet fuel, making it fully compatible with existing aircraft engines and fuel infrastructure without modifications.
- **CAPEX:** CAPEX is lower than for other biofuels technologies

WEAKNESSES

- Limited availability of sustainable feedstocks (waste oils, fats) can constrain production capacity and lead to competition with other industries.
- Requires large amounts of hydrogen, which can increase costs and carbon intensity if derived from non-renewable sources.
- While the process itself is not water-intensive, upstream feedstock production (e.g., palm oil) can have significant environmental and social impacts if not carefully managed.

OPPORTUNITIES

- Potential to produce oils as feedstock for HEFA from non-traditional sources such as algae and the flesh from non-standard coconut
- Lower hydrogen production costs via electrolysis or other stand-alone production
- **Co-Products**: Production yields valuable by-products, such as renewable diesel, adding economic value.

THREATS

- Competition from emerging SAF technologies
- Regulatory changes: changes in policy or incentives could affect the financial attractiveness of HEFA SAF

3. Technology Selection

3.9 SWOT (Strengths, Weaknesses, Opportunities and Threats) for Technology Pathways

A SWOT analysis was undertaken for each of the considered technology pathways, including ATJ, gasification/FT, HTL and upgrading and gasification/methanol production. The results are shown below.

	Gasification/FT	ATJ
STRENGTHS	• SAF production is ASTM-approved. • Facility can produce all its own power and heat requirements. • Produces hydrogen requirement for refining as part of the process. • Relatively well-known technology, with several commercial installations, although biomass processing is relatively new. • Many technology providers for gasification and Fischer-Tropsch, as well as several providers who can offer integrated sections of the plant. • Sulphur-free SAF is produced.	• SAF production is ASTM-approved. • Relatively well-known technology. • Interim product (bio-ethanol, bio-butanol) is a saleable product and could be sold without upgrading to SAF initially (phased investment approach). • Good quality SAF produced with allowable aromatics content.
WEAKNESSES	• Complex facility. • Interim products are not directly saleable (refinery is required). • High CAPEX requirement. • Requires feedstock drying prior to gasification. • High water consumption.	• Complex facility. • Requires pre-treatment for lignocellulosic feedstocks to make them less recalcitrant for fermentation. • High CAPEX requirement.
OPPORTUNITIES	• Flexible process, can produce various by-products (renewable diesel, LPG, chemicals). • Relatively forgiving with regards to types and quality of feedstock (many feedstocks can be gasified). • Can treat and recycle water produced in the process to reduce raw water import requirements.	• Flexible process, can produce various by-products (renewable diesel, LPG). • Relatively forgiving with regards to types and quality of feedstock. • Can construct central facility to convert alcohol to jet and have smaller feedstock to alcohol fermentation processes closer to feedstock sources (hub and spoke model).
THREATS	• Fulcrum facility based on waste gasification and FT was shut down citing technical and financial difficulties, damaging confidence in the technology (and advanced biofuels production in general).	• At present, no major external threats have been identified. However, continuous monitoring of Technology Pathways will be necessary.

3. Technology Selection

3.10 SWOT (Strengths, Weaknesses, Opportunities and Threats) for Technology Pathways

A SWOT analysis was undertaken for each of the considered technology pathways, including ATJ, gasification/FT, HTL and upgrading and gasification/methanol production. The results are shown below.

	HTL	Gasification/Methanol Synthesis
STRENGTHS	• No drying of feedstocks required. • High biocrude yield possible.	• Facility can produce all its own power and heat requirements. • Produces hydrogen requirement for refining as part of the process. • Interim product is methanol which is directly saleable (could lend itself to a phased investment approach and build the upgrader to SAF later).
WEAKNESSES	• Complex facility. • Interim products are not directly saleable (refinery is required). • High CAPEX requirement, although lower than gasification/FT. • External source of hydrogen, power and process heat required. • Recovery of organics from aqueous phase is unproven (part of the product yield reports to the aqueous phase), and water treatment in general is less developed. • TRL is currently 8, thus not commercially available yet. • Technology scale-up still required (core reactor technology).	• Flexible process, can produce various by-products (renewable diesel, LPG, chemicals). • Relatively forgiving with regards to types and quality of feedstock (many feedstocks can be gasified). • Similar technology pathways exist commercially that could be drawn upon for experience, that is biomass gasification, and methanol-to-jet technology.
OPPORTUNITIES	• Flexible process, can produce various by-products (renewable diesel, LPG). • Biocrude is easier to upgrade than pyrolysis oil, although the oxygen content is still high. • Very forgiving with regards to types and quality of feedstock (including moisture content). • As liquid feedstocks and very wet feedstocks could be fed, it opens the opportunity to feedstocks such as microalgae, food wastes, manures and sewage sludge for SAF production.	• Flexible process, can produce various by-products (renewable diesel, LPG). • Relatively forgiving with regards to types and quality of feedstock. • Can construct central facility to convert alcohol to jet and have smaller feedstock to alcohol fermentation processes closer to feedstock sources (hub and spoke model).
THREATS	• Not currently ASTM-approved SAF product. • Due to large variety of feedstock potentially suitable, the biocrude properties and therefore SAF properties could vary significantly from project to project and for a specific project. Could increase the complexity to get SAF approved through ASTM process, would also require significant test work to characterise SAF from various feedstocks.	• Not currently ASTM-approved SAF product.

3. Technology Selection

3.11 Multi-Criteria Analysis of Technologies

The following criteria has been utilised to evaluate and rank the four technologies considered as part of this work:

Financial Indicators
33%

- CAPEX ($$/bbl or $$/ML)
- OPEX ($$/bbl or $$/ML)
- Levelised cost of SAF ($/L)

Environmental/ Efficiency Indicators
30%

- Input energy use, that is external import of power and fuel gas for heating (MWh/L)
- Land use change impact
- GHG emissions reduction

Technical Indicators
27%

- Technology Readiness Level (TRL)
- Blending limit of SAF in jet fuel (if ASTM-approved)
- Similarity to conventional jet fuel
- SAF yield (L/tonne)
- Scalability
- Hub and spoke applicability versus only centralised facilities
- Saleability of interim product

Experience Indicators
10%

- Number of global installations (commercial/demonstration scale)
- Global SAF production capacity
- Number of reputable technology vendors

Ranking of the technologies was completed in the following manner:

Worse than other technologies	Similar to other technologies	Better than other technologies
1	2	3

3. Technology Selection

3.12 Multi-Criteria Analysis of Technologies

The outcomes from the MCA are shown below within Table 3.1. **Overall HEFA ranks the best, followed by ATJ, HTL, Gasification/Fischer-Tropsch and Gasification/Methanol.**

Table 3.1: Technology Pathway Multi Criteria Analysis

	%	HEFA	Gasification/FT	ATJ	HTL	Gasification/ Methanol
Financial indicators	**33**					
CAPEX	11	3	1	2	2	1
OPEX	11	2	1	3	2	1
Levelised cost of SAF	11	3	1	2	2	1
Environmental/efficiency indicators	**30**					
Input energy use	10	3	1	2	2	1
Land use change impact	10	2^	1	3	2	1
GHG emissions reduction	10	2^	3	2	2	3
Technical indicators	**27**					
TRL	3.4	3	2	2	2	1
Blending limit of SAF in jet fuel	3.4	3	3	3	0	0
Similarity to conventional jet fuel	3.4	3	3	2	1	2
SAF yield	3.4	3	2	2	2	2
Scalability	3.4	3	2	3	1	2
Hub and spoke applicability versus only centralised facilities	3.4	3	1	3	1	3
Saleability of interim product*	3.4	3	1	2	1	2
Feedstock Compatibility	3.4	1	3	2	3	2
Experience indicators	**10**					
Number of global installations	3.3	3	1	2	0	2
Number of planned installations	3.3	3	2	3	1	1
Number of technology vendors	3.3	3	2	2	1	2
Total		**87%**	**52%**	**78%**	**57%**	**47%**

*Gasification/FT and HTL produces hydrocarbon products that are not saleable and require upgrading. Alternatively, ATJ and Gasification/Methanol produce saleable alcohols such as bio-ethanol/butanol and bio-methanol respectively.
^ Highly dependent on the type of oil/feedstock

GHD Advisory

4. Carbon Intensity

GHD Advisory

→ Carbon Intensity Overview

4. Carbon Intensity

4.1 Overview of Carbon Intensity and LCA Scope

Life Cycle Assessment (LCA) is commonly used to estimate GHG emissions from SAF in comparison to fossil derived jet fuel. To be certified as “sustainable” fuel, SAF products will have to meet a specific carbon intensity reduction threshold (compared to crude-derived jet fuel).

The International Civil Aviation Organisation (ICAO) has published the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), to measure, report and verify emissions from the aviation sector for each of its member states. While the methodology may still be modified, it is currently the most likely to be widely adopted for SAF carbon intensity calculations and accreditation. CORSIA allows the use of SAF to reduce airlines carbon offsetting requirements. Under CORSIA, emissions reductions from using SAF are calculated using an LCA approach, as set out in ISO 14040 and 14044 [61].

L_{CEF} (life cycle emissions value for a CORSIA eligible fuel in gCO_2e/MJ) = Core LCA value + ILUC – Emission credits

Where:

- Core LCA value = Case C SAF, residue according to Section 4, calculated using methodologies from Sections 4.2 and 4.4, or approved by CORSIA (Default Life Cycle Emissions, June 2022.
- ILUC = 0, Case 1 based on residue as feedstock.
- Emissions credits = 0.
- 100-year GWP and Fifth Assessment report of the IPCC (CH4 = 28, N2O = 265).

Figure 4.1 shows an overview of the typical CORSIA SAF System Boundary scenarios for both non-by-product and by-product SAF production scenarios. System boundary for SAF derived from waste has been used to estimate high level carbon intensities of various waste feedstocks into SAF for this project, in accordance with the ICAO document, CORSIA Methodology for Calculating Actual Life Cycle Emissions Values, March 2024. The approach typically follows a well-to-wake approach, which focuses on the emissions of aviation fuels from fuel production (well) to its final use during flight (wake).

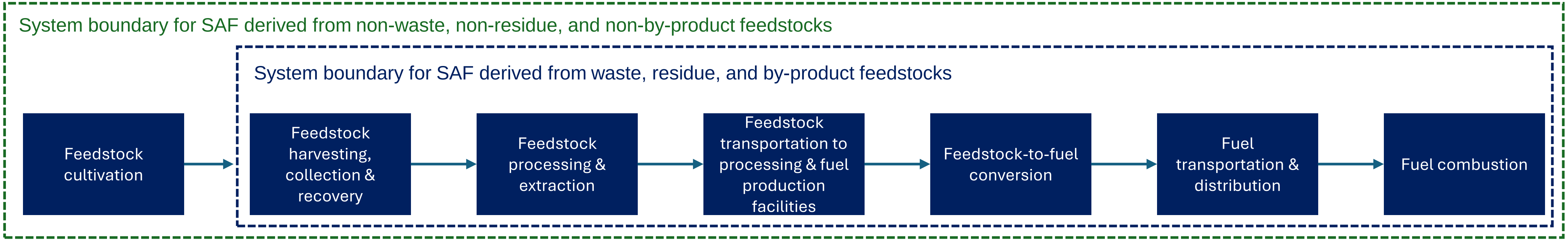
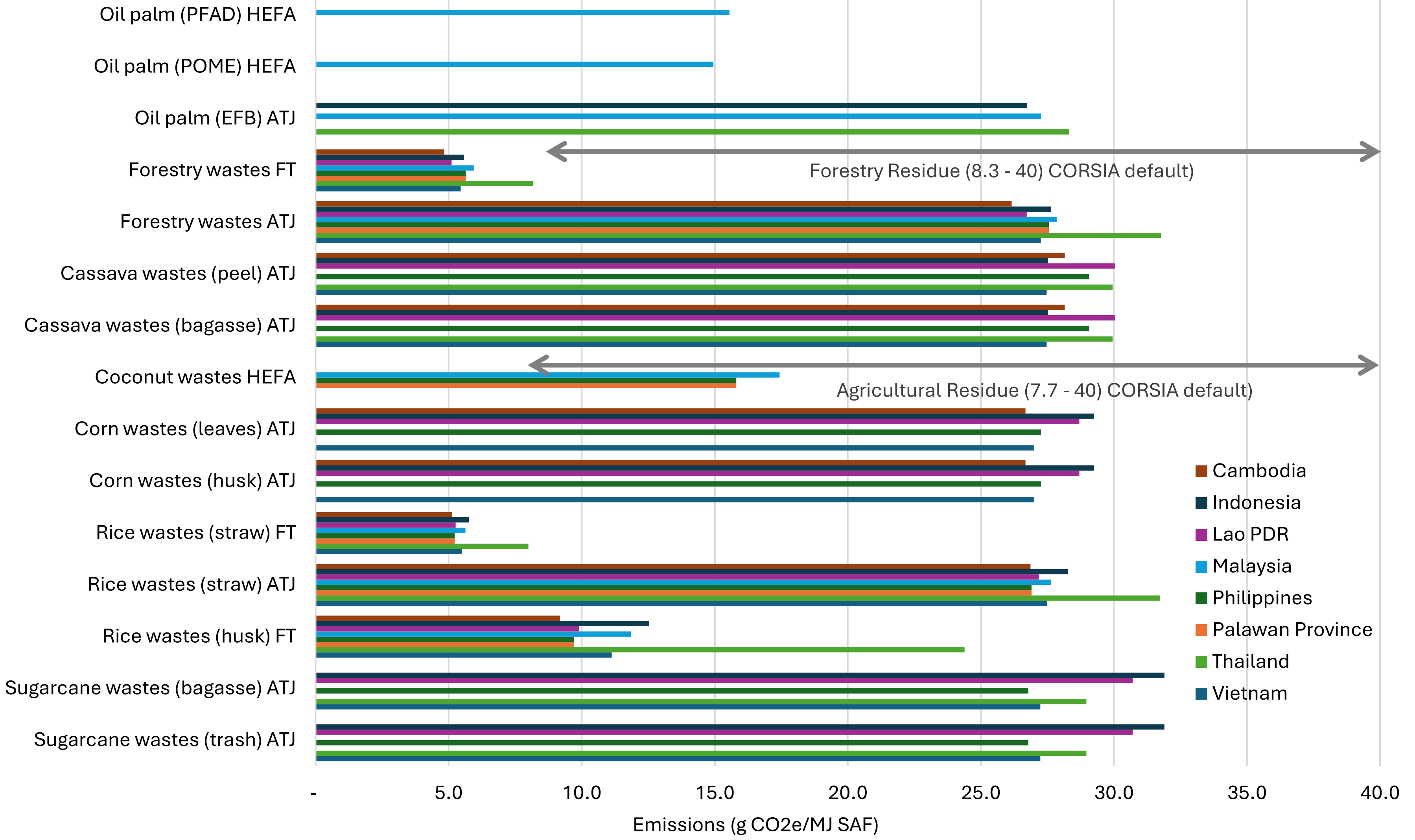


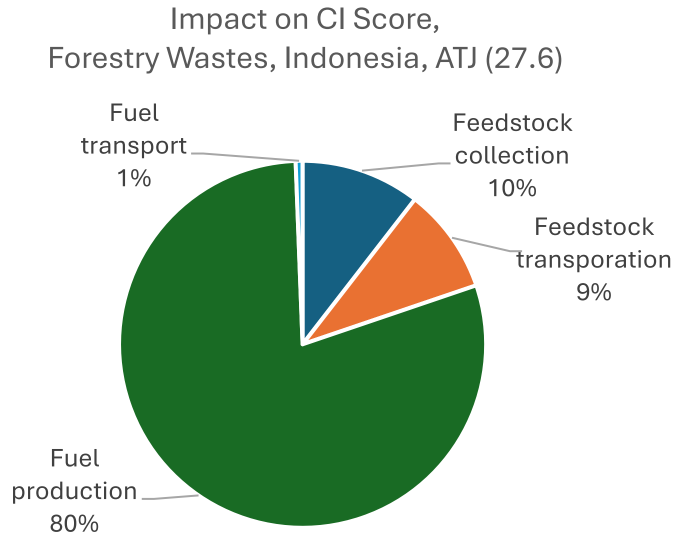
***Figure 4.1: CORSIA SAF System Boundary Scenarios** [62]*

4. Carbon Intensity

4.1 Overview of Carbon Intensity and LCA Scope

Figure 4.2 shows an overview of the estimated carbon intensities for the selected wastes per country.





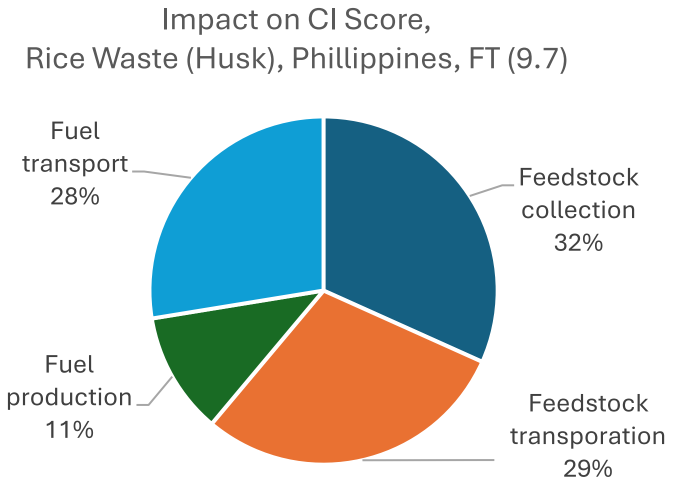


Figure 4.2: Estimated Carbon Intensities for Select Agriculture and Forestry Wastes

4. Carbon Intensity

4.1 Overview of Carbon Intensity and LCA Scope

CORSIA and Carbon Intensity Estimation Key Findings

CORSIA

- ICAO published the CORSIA scheme to measure, report and verify emissions from the aviation sector for each member state, still in pilot phase.
- CORSIA default life cycle emissions are available for ATJ and FT using agricultural residues and forestry residues. There are no HEFA default core LCA values for agricultural or forestry residues.
- ICAO-GREET version can be used to estimate and verify default core LCA values of the CORSIA-approved SAF pathways (only includes wheat straw and corn stover as agricultural residues).
- Sufficient data on the conversion process, feedstock and region of interest is required to be evaluated for CORSIA default LCA emissions values.

CORSIA certification uncertainties

- Rice husks and rice straw (FT), sugarcane bagasse, tops and leaves (ATJ) and corn cob, husks, stover and straw (FT) display minimal to no certification risk under RSB CORSIA.
- Forest and wood residues (FT) and palm oil residues (PKS, EFB, old trunk) (FT) display certification risks under RSB CORSIA, due to potential sustainability risks.
- Uncertainties for other residue feedstocks studied in this project are unknown.

Carbon Intensity Estimates for the Study

- The fuel production stage has the greatest carbon intensity for ATJ, followed by HEFA and then FT.
- The FT technology pathway has significantly lower total emissions compared to ATJ due to the fuel production stage.
    - More research is needed to confirm FT conversion process gives a lower CI value when compared with other conversion processes. There is limited available information for agricultural residue other than sugarcane and corn stover.[59]
    - The FT method produces syngas which is used as a fuel in the process. Electricity is generated from excess steam from gasification and FT synthesis. The CI for FT generally is lower than ATJ due to the self-sufficiency of the process and excess electricity production. ATJ requires hydrogen and if hydrogen can be sourced from renewable sources rather than through steam methane reforming using fossil-based energy sources, the CI for the SAF will improve.[60]
- There are many considerations when it comes to estimating the CI for SAF from the agricultural and forestry residues. These include determining the most suitable technology for the feedstock, identifying the source of hydrogen if Alcohol-to-Jet (ATJ) technology is used, and assessing the emission intensity of the local electrical grid or whether the electricity is sourced from renewable energy.
- Indonesia, Lao PDR, and Thailand generally have higher CI scores for most feedstocks due to high feedstock transport distances.
- Rice husk has a high CI score due to low fuel yield.
- Thailand rice husk has a significantly higher CI score due to the fuel transport distance of 660 km compared to <120 km for other feedstocks.
- Detailed analysis of collection and process will improve accuracy of estimates.

GHG Intensity Summary by Country for Top Feedstocks (gCO_2e/MJ fuel)

- **Indonesia**: Rice wastes (straw) (5.8, FT) has the lowest CI, rice waste (husks) (12.5, FT) has a moderate CI, and palm oil (EFB; ATJ), cassava waste (bagasse and peel, ATJ) and corn waste (husks and leaves; ATJ) have the highest CIs (26.7 - 29.2).
- **Malaysia**: Palm oil pathways show varying carbon intensities—EFB (27.3, ATJ), POME (14.9, HEFA), and PFAD (15.6, HEFA). Rice waste (straw) (5.6, FT) has the lowest CI, while rice waste (husks) (11.8, FT) and coconut wastes (17.4, HEFA) have moderate CIs, and rice wastes (straw; ATJ) has the highest CI (27.6).
- **Philippines**: Rice waste (straw) (5.2, FT) has the lowest CI, while rice waste (husks) (9.7, FT) and coconut wastes (15.8, HEFA) have moderate CIs, and corn wastes (leaves and husks; ATJ), rice wastes (straw; ATJ) and cassava wastes (bagasse and peel; ATJ) have the highest CIs (26.9 - 29.1).
- **Thailand**: Rice wastes (straw) (8.0, FT) has the lowest CI, while rice waste (husks; FT), rice waste (straw; ATJ), palm oil (EFB; ATJ), and cassava waste (bagasse and peel, ATJ) have the highest CIs (24.4 - 31.7).
- **Vietnam**: Rice wastes (straw) (5.5, FT) has the lowest CI, rice waste (husks; FT) has a moderate CI (11.1, FT), while rice waste (straw; ATJ), corn wastes (leaves and husks, ATJ) and cassava waste (bagasse and peel, ATJ) have the highest CIs (27.0 - 27.5).

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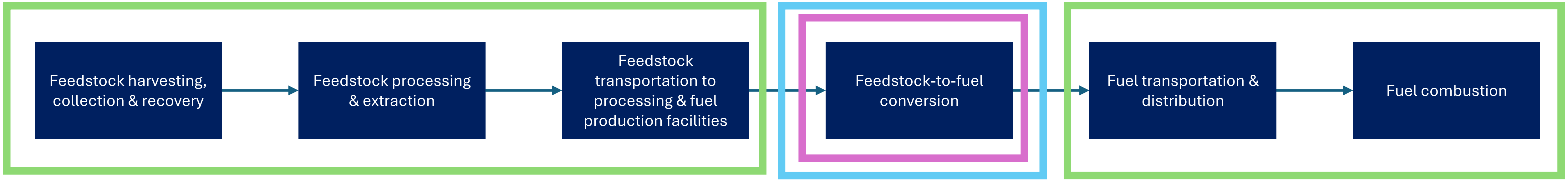
→ Carbon Intensity Deeper Dive

4. Carbon Intensity

4.2 Scope 1, 2 and 3 GHG Emissions

Figure 4.3 shows the various scoped GHG emissions as it may relate to the SAF producer.

Figure 4.3: CORSIA SAF System Boundary Scenarios (Scope 1, 2 and 3 Emissions)



Scope 3 Emissions
Third party suppliers, transportation, waste disposal.
For SAF producers, all other emissions outside of the Feedstock-to-fuel conversion process are considered Scope 3 emissions if these activities are not controlled/operated by the SAF producer.

Scope 1 Emissions
Direct energy used in operations (such as company vehicles, burning fuel directly for heating, energy demand - for example: SAF Fuel combustion is considered Scope 1 for an airline but Scope 3 for a traveler).
For SAF producers, ***Feedstock-to-fuel conversion*** is considered the only Scope 1 emissions for the SAF producer through direct emissions from fuel combustion, etc.

Scope 2 Emissions
Indirect emissions from purchased electricity and heating (for example: steam).
For SAF producers, ***Feedstock-to-fuel conversion*** is considered the only Scope 2 emissions for the SAF producer through electricity and/or steam purchase and use.

For the purposes of this study Scope 1, 2 and 3 GHG emissions have not been evaluated individually given the specific level of data and information that is typically required at the asset levels across the SAF system boundary. Such information/data is not available/established in this case.

4. Carbon Intensity

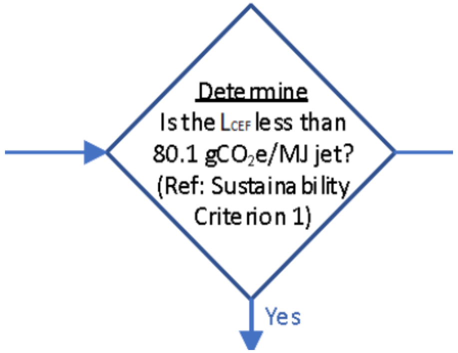
4.3 CORSIA Program

Default Life Cycle Emission Parameters per Technology Pathway

CORSIA default life cycle emissions values for Alcohol to Jet (ATJ) and gasification and Fischer-Tropsch (FT) pathways are reported for agricultural wastes and forestry wastes in Table 4.1. Carbon intensities for specific projects must be calculated based on carbon emissions from the production facility from any fossil-based fuels used, as well as specific releases that are accounted for from biomass under CORSIA, emissions from biomass transport to site, transport of final products to market/end users and combustion of the SAF in jet engines. Additional components may have materiality with regards to lifecycle emissions including emissions from pumping and treating raw water to the production site, manufacture and supply of catalysts and chemicals required for production and others [63].

Table 4.1: CORSIA default life cycle emissions values for ATJ and FT/SPK

Residue	Units	Gasification and FT	ATJ (standalone conversion design)	ATJ (integrated conversion design)
Agricultural residues	g CO2-e/MJ SAF	7.7	39.7	24.6
Forestry residues	g CO2-e/MJ SAF	8.3	40.0	24.9



All gasification/FT pathways can deliver very low carbon intensity SAF.

There are no default LCA values using the HEFA method.

While not currently included in the CORSIA default life cycle emissions numbers, it is expected that SAF from HTL will have similar carbon intensity numbers or slightly lower. ATJ has relatively high carbon intensity, comparable to some SAFs from the HEFA pathway (although some feedstocks for HEFA has even higher carbon intensity).

CORSIA Methodology for Calculating Actual Life Cycle Emissions Values (ICAO document 07 - Methodology for Actual Life Cycle Emissions - March 2024; section 6) specifies that avoided landfill emissions credits for SAF from Municipal Solid Waste as feedstock can be claimed. The CI values presented in the report do not assume landfill emissions credits. The credit is directly applicable to MSW in the CORSIA documentation but may have the potential to apply to other wastes/residues in the future. If feedstocks are currently being used as a fuel and being redirected to generate SAF, or if the feedstock is currently left on the field for added nutrients to the soil, these changes in baseline should be considered. Similarly, other aspects of the baseline should be considered, such as whether the residue is landfilled and is generating methane emissions that could be offset.

4. Carbon Intensity

4.3 CORSIA Program

ICAO CORSIA scope and sustainability requirements for the production and use of SAF

- CORSIA is being implemented in three phases: pilot, first phase and second phase. Scheme is currently in pilot phase still. For pilot and first phase, participation is voluntary. Second phase is planned to commence in 2027 [64].

- For SAF to be CORSIA-eligible, all companies in the value chain (production & usage of SAF's) must be certified by recognised sustainability certification schemes:
    - Roundtable on Sustainable Biomaterials (RSB), International Sustainability & Carbon Certification (ISCC), and ClassNK are recognised by ICAO CORSIA.

- CORSIA certification GHG requirements [65]:
    - SAF producers must demonstrate the SAF achieves net GHG emission reductions of at least 10% on a life cycle basis compared to the baseline life cycle emissions values for aviation fuel
        - Emission values are allocated in proportion to the lower heating value of the products and co-products.
    - The total life cycle emission value for a given CORSIA-eligible fuel is the sum of core life cycle assessment (LCA) emissions.
    - Certain pathways and feedstocks have been defined through CORSIA.
    - The ICAO-GREET version can be used to estimate and verify the default core life cycle assessment values of the CORSIA-approved SAF pathways [66].
    - Agricultural residues considered by CORSIA in the GREET model are currently wheat straw and corn stover [62, 66].

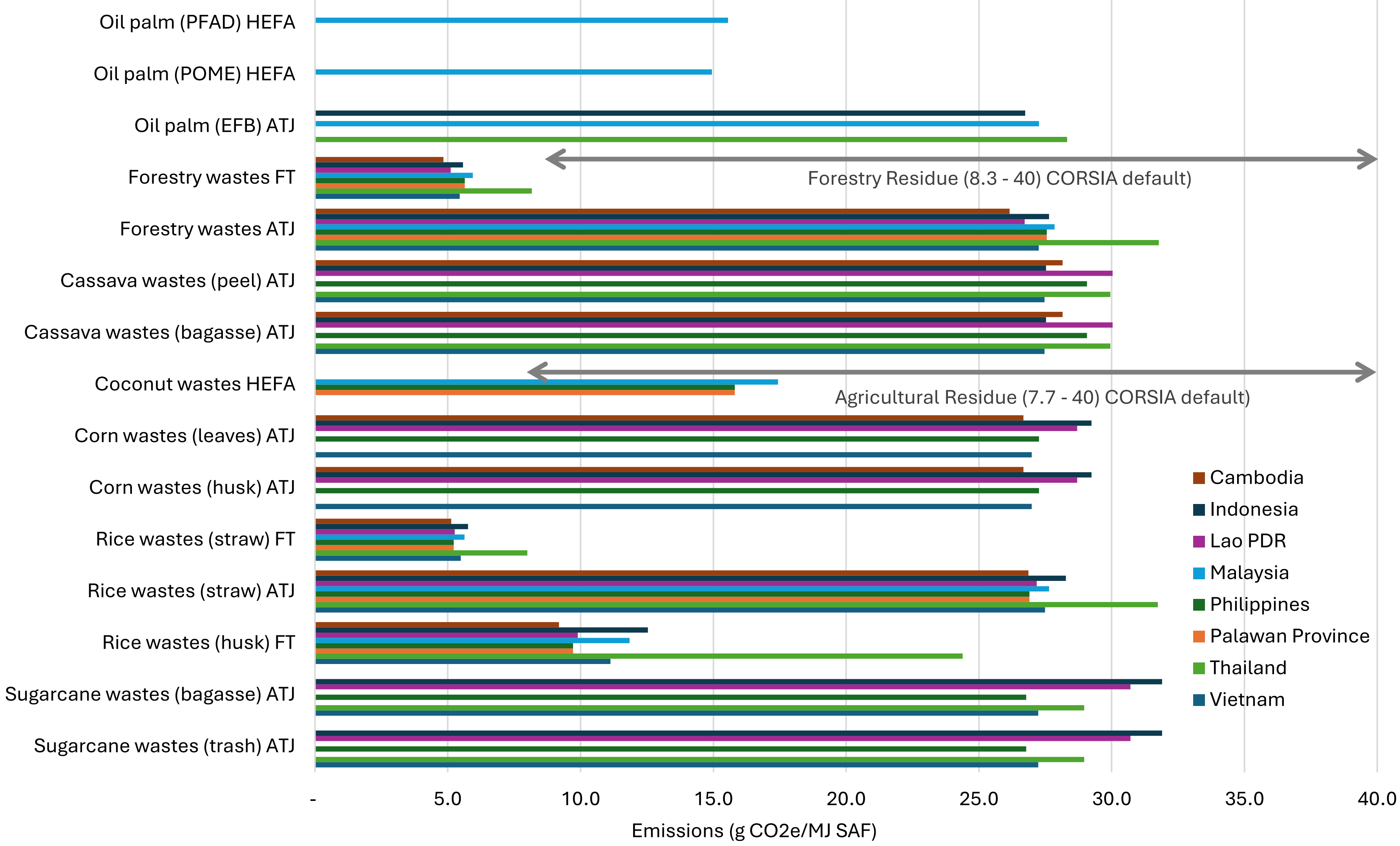
- Feedstocks that are 'low risk' for land use change are incentivised in CORSIA as they benefit from an emission factor of zero for that activity (for example, waste, residues, by-products such as used cooking oil and sugarcane bagasse).

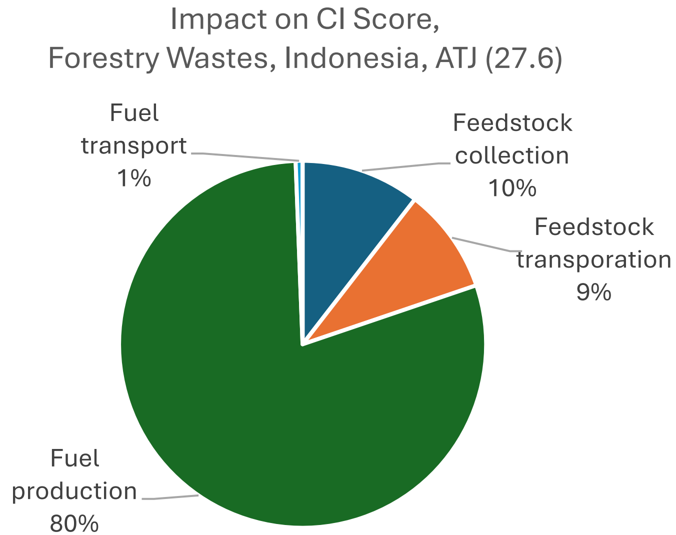
- For an additional pathway to be evaluated for inclusion in the ICAO document 'CORSIA Default Life Cycle Emissions Values (core LCA and ILUC) for CORSIA Eligible fuels' the following criteria must be met [62]:
    1. The pathway uses an ASTM certified conversion process or, a conversion process for which the Phase 2 ASTM Research Report has been reviewed and approved by the OEMs.
    2. The conversion process has been validated at sufficient scale to establish a basis for facility design and operating parameters at commercial scale.
    3. There are sufficient data on the conversion process of interest to perform LCA modelling.
    4. There are sufficient data on the feedstock of interest to perform LCA modelling.
    5. There are sufficient data on the region of interest to perform ILUC modelling, where applicable to the pathway.

4. Carbon Intensity

4.4 SAF Carbon Intensity for countries and feedstocks

Figure 4.4 shows an overview of the estimated carbon intensities for the selected wastes per country.





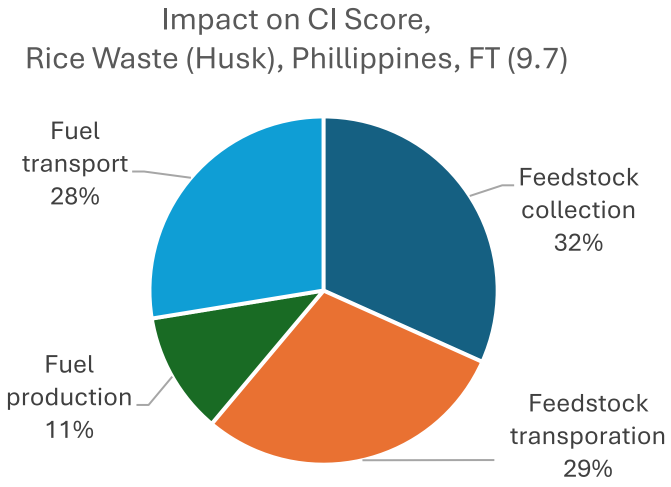


Figure 4.4: Estimated Carbon Intensities for Select Agriculture and Forestry Wastes

4. Carbon Intensity

4.5 SAF Carbon Intensity Ranking, Uncertainty and Notes

Table 4.2 presents the ranges of estimated CI scores from Section 4.4 per feedstock and country.

Table 4.2: Estimated Carbon Intensity Rankings for Select Agriculture and Forestry Wastes

Carbon Intensity Range (gCO2e/MJ SAF)	Waste Feedstock	Country
0 – 5	Forestry waste (FT)	Cambodia
5 – 10	Rice wastes (straw) (FT) Rice wastes (husks) (FT) Forestry wastes (FT)	Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Palawan Province, Thailand, and Vietnam Philippines, Palawan Province, Lao PDR, Cambodia Philippines, Palawan Province, Indonesia, Thailand, Vietnam, Lao PDR, Malaysia
10 – 15	Rice wastes (husks) (FT) Oil palm (POME) (HEFA)	Indonesia, Vietnam, Malaysia Malaysia
15 – 20	Coconut wastes (HEFA) Oil palm (PFAD) (HEFA)	Philippines, Palawan Province, Malaysia Malaysia
20 – 25	Rice wastes (husks) (FT)	Thailand
25 – 30	Sugarcane wastes (trash, bagasse) (ATJ) Rice wastes (straw) (ATJ) Corm wastes (husks, leaves) (ATJ) Cassava wastes (bagasse, peels) (ATJ) Forestry waste (ATJ) Oil palm (EFB) (ATJ)	Philippines, Vietnam, Thailand Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Palawan Province, and Vietnam Philippines, Indonesia, Vietnam, Lao PDR, Cambodia Philippines, Indonesia, Thailand, Vietnam, Cambodia Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Palawan Province, and Vietnam Indonesia, Thailand, Malaysia
30 – 35	Sugarcane wastes (trash, bagasse) (ATJ) Rice wastes (straw) (ATJ) Cassava wastes (bagasse, peels) (ATJ) Forestry wastes (ATJ)	Indonesia, Lao PDR Thailand Lao PDR Thailand

Uncertainties in CI estimates

- SAF production quantity per dry tonne feedstock and per technology
- Technology process inputs and outputs per feedstock type

Detailed analysis of collection and process will improve accuracy of estimates

Notes on CI estimates

Feedstock collection: Assumed CI averages from CORSIA guidance for ag and forestry residue, no nutrient recovery necessary, allocated, equivalent for each country. No HEFA values; assumed average of ATJ and FT.

Feedstock transport to processing and fuel production facilities: Calculated CI based on distance and type of transport identified in project, allocated transport emissions (65-85% to SAF, remaining to biproducts)

Fuel production (FT, ATJ, HEFA): assumed averages from CORSIA guidance for ag and forestry residue, no nutrient recovery necessary, allocated, equivalent for each country. HEFA based on palm oil.

Fuel transport to blend point and to aircraft uplift location: Calculated CI based on distance and type of transport identified in project, not allocated to other products as only MJ SAF accounted for in transport

Fuel combustion (in aircraft engine): Biogenic CO2 emissions not included

4. Carbon Intensity

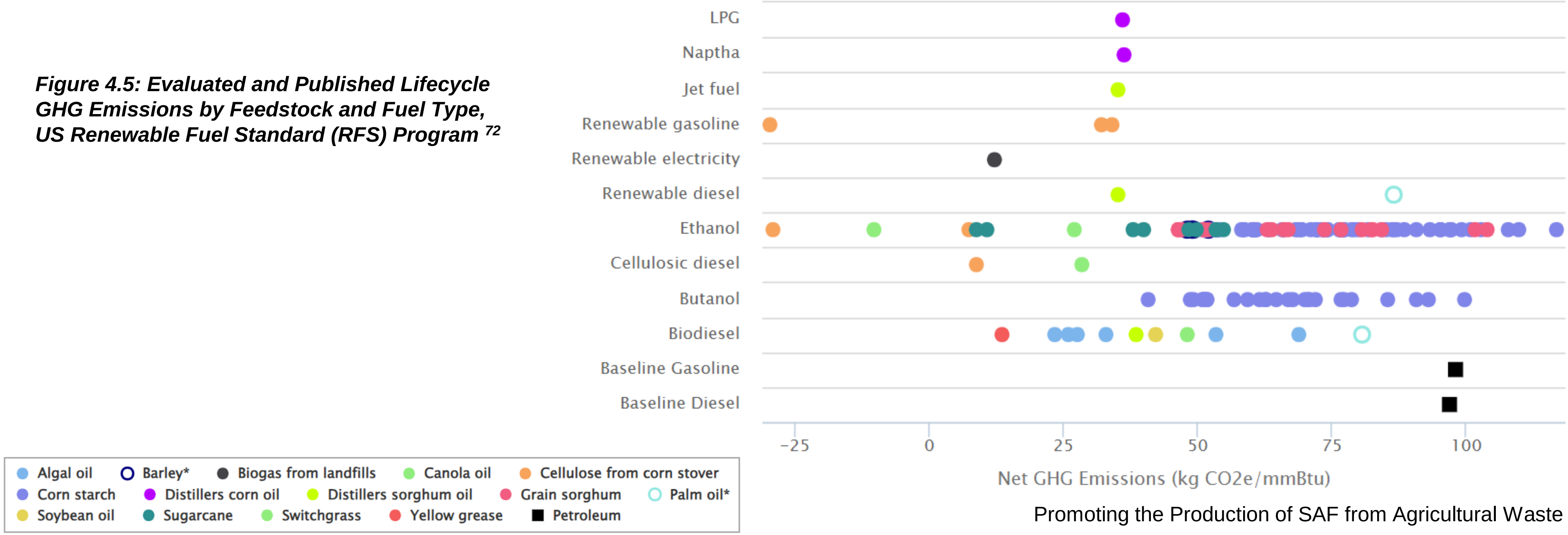
4.6 SAF Carbon Intensity in Literature

Table 4.3 presents other carbon intensities of SAF in literature that relate to the feedstocks reviewed during this study and the renewable fuels, and Figure 4.4 shows evaluated and published CI scores under the US Renewable Fuel Standard Program (RFS).

Table 4.3: CI Scores in Literature for US RFS, Agricultural and Forestry Residue Producing Jet Fuel, Renewable Naphtha and Renewable Diesel

Carbon Intensity (gCO2e/MJ SAF)	Waste Feedstock	Sustainable Fuel Type
14.4 (15.2 kg CO2e/mm Btu)	Waste fats, oils and greases [67]	Jet Fuel, LPG Naphtha, Renewable Diesel
19.3 (20.4 kg CO2e/mm Btu)	Distillers Corn Oil [68]	Renewable Diesel
36.5 (38.6 kg CO2e/mm Btu)	Carinata Oil [69]	Renewable Diesel
41.7 (44 kg CO2e/mm Btu)	Sugarcane Ethanol [70]	Jet Fuel & Renewable Diesel
42.3	Soybean Oil [71]	Jet fuel

Figure 4.5: Evaluated and Published Lifecycle GHG Emissions by Feedstock and Fuel Type, US Renewable Fuel Standard (RFS) Program [72]



4. Carbon Intensity

4.7 CORSIA certification uncertainties

The RSB identified that the following SAF feedstocks displayed minimal to no certification risk for RSB CORSIA:

- Rice husks, rice straw (FT).
- Sugarcane bagasse, tops and leaves (ATJ).
- Corn cob/husk/stover/straw (FT).

The following feedstocks displayed certification risks under RSB CORSIA:

- Forest and wood industry residues (FT); depending on the type of woody residue.
- Palm oil residues (PKS, EFB, old trunk) (FT); because of sustainability risks. Some residues. are not included in CORSIA's positive list of waste materials.

4.7.1 Stakeholder concerns on policy

- Consistent definitions and calculation methodologies (CORSIA default versus GREET model versus literature).
- Renewable diesel is a major competitor of SAF.
- Uncertainty in duration of policy incentives.
- Lack of incentives for farmers to consider sustainable farming practices.
- Access to financing.
- Competing for capital funding with other renewables.
- Fuel purchasers reluctant to commit to more than 3-year offtake agreements.
- Lack of proven industry inhibits investments.

4.8 Other certification methods under development

Clean Fuels Standard: Clean Fuel Standard regulatory design - Canada.ca

- Clean Fuels Standard requires a 10 g CO2e/MJ reduction from the Canadian average carbon intensity of each fossil fuel in 2016 – this represents a 10% to 12% decrease in carbon intensity below 2016 fossil fuel carbon intensity values, depending on the fuel type.
- Incentivise the Clean Fuel Standard by using a credit system to promote clean fuel generation:
    - The Clean Fuel Standard allows for credit generation by three methods:
        1. Actions that reduce the carbon intensity of the fossil fuel throughout its lifecycle.
        2. The supply of renewable and other low-carbon intensity fuels.
        3. Some end-use fuel switching.
    - Credits may be generated by fossil fuel primary suppliers or by voluntary credit generators that undertake the above actions.

US SAF policies & incentives: Sustainable Aviation Fuel (SAF) State-of-Industry Report: State of SAF Production Process (nrel.gov) (Includes tax incentives, GREET):

- The Inflation Reduction Act (IRA) was passed in August 2022 defines a SAF fuel credit for the sale or use of a qualified blend instead of a SAF mandate, and provides grants to support the production, storage, and distribution of SAF.
- The IRA introduced three tax schemes and provided additional funding for a grant program administers by the Federal Aviation Administration's Fueling Aviation's Sustainable Transition (FAST) program.
- Tax schemes are dependent on the amount of SAF generated/produced/used, and the reduction in GHG life cycle emissions for SAF usage.

5. Feedstock and Product Logistics

GHD Advisory

Feedstocks and Product Logistics Overview

5. Feedstock and Product Logistics

5.1 Feedstock and Product Logistics Overview

For the feedstock and product logistics assessment three key locations were considered and linked for each country as per Figure 5.1 below.

Major Feedstock Location

Feedstock locations as per the feedstock assessment conducted (Refer Section 2).

SAF Biorefinery Facilities

Existing facilities within each country that, with upgrades, may be used for conversion of biomass product to SAF.

Blending SAF Facilities / Port

Considered to be within 50 km of airport locations within each country. This may include existing or new facilities. The unblended SAF may also be shipped out for an export for both domestic and international usage via the identified key ports in respective countries.

Figure 5.1: Key Locations considered for the Feedstock and Product Logistics Assessment

Key Findings

Out of the seven countries covered in this report, the Philippines had the most number of biorefineries in reasonable proximity to the identified feedstock locations as per Section 2. However, for the Palawan province, despite being identified to have SAF potential from Non-Standard Coconut, the region does not have any biorefineries facilities, and the feedstock would likely need to be transported to CCO refineries located across Davao, Quezon and Albay.

Based on the estimated SAF potential, it is envisaged that a significant additional infrastructure (or proportional to SAF potential capacity) such as pre-processing facilities, SAF biorefinery, and truck fleet operation, will likely be required in these countries.

In Indonesia, existing biorefineries are primarily owned by PT Pertamina, in which the locations are sparse given the archipelagic nature of the country. In Thailand, the biomass feedstock sources are located within the North and Northeast regions of Thailand, however, there are limited biorefineries observed within these regions (with only two identified). Malaysia has biorefineries that spread across the Malaysian Peninsular Malaysia and East Malaysia. However, there are fewer biorefineries observed within East Malaysia as compared to Peninsular Malaysia, despite the feedstock potential in this region is identified to be greater. Similarly, in Vietnam and Lao PDR, there are only two biorefineries for each country, and there is only one biorefineries in Cambodia, which can be considered SAF biorefinery facilities.
Palawan province, despite being identified to have SAF potential from Non-Standard Coconut, the region does not have any biorefineries facilities, and the feedstock would likely need to be transported to CCO refineries located across Davao, Quezon and Albay or alternatively, crude coconut oil factory can be established to process the feedstock locally

Airports in each country identified can serve as both domestic market and international markets within ASEAN. Major ports in Cambodia, Indonesia, Malaysia, Philippines, Thailand and Vietnam appear to be equipped with oil/petroleum product import/export facilities that can be upgraded to be capitalised for SAF distribution domestically and internationally.
For Lao PDR, being a landlocked country, SAF produced in Laos can be transported via the Mekong River to Vietnam, which serves as a key re-export hub. Vietnam facilitates the onward shipping of SAF to international markets, effectively acting as a transit point for Lao PDR's SAF exports.

Cost of road transport across the seven countries has been found to vary from a range of approximately US$ 0.06 to 0.50 per ton-km, where the sea freight varies from a range of approximately US$ 0.001 to 0.007 per ton-km.
Refer to Sections 5.2 to 5.9 for further details.

5. Feedstock and Product Logistics

5.1 Feedstock and Product Logistics Overview

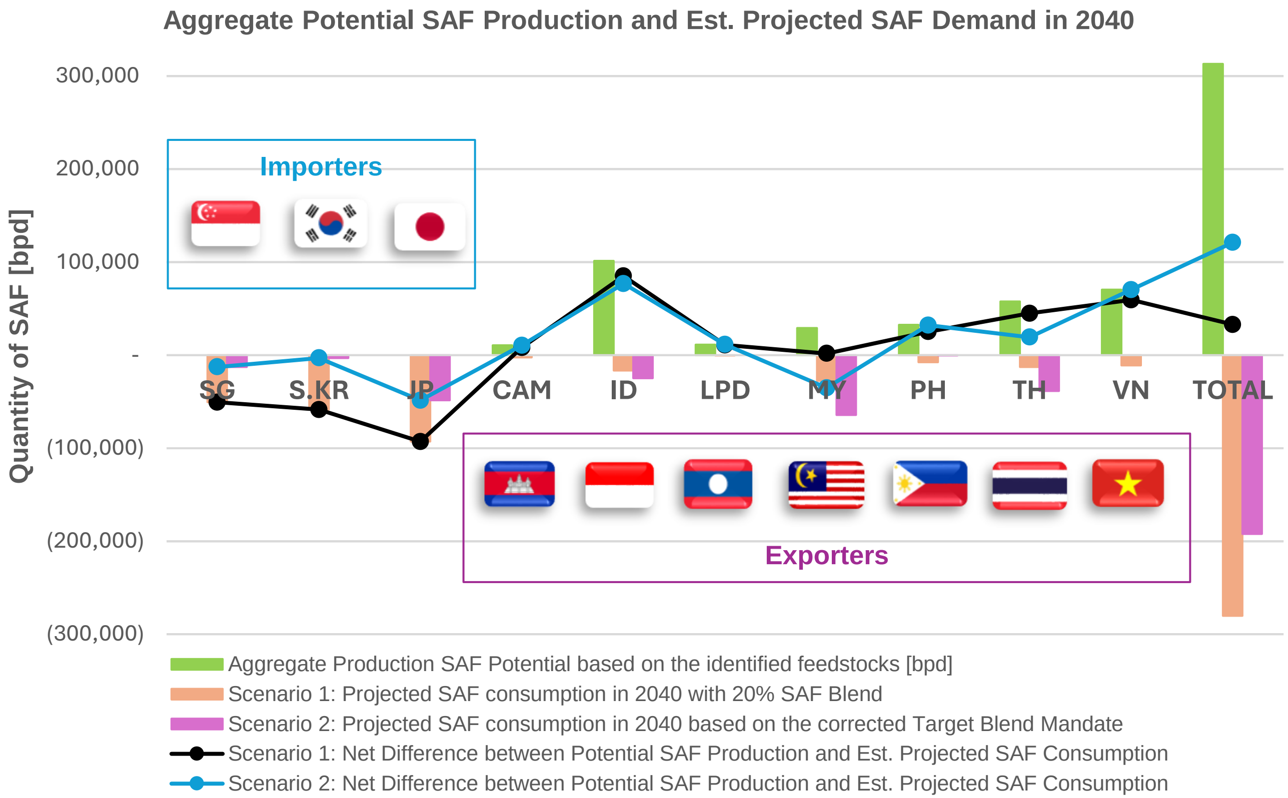


Figure 5.2: SAF Regional Supply – Demand Distribution

As part of the study, a SAF Demand-Supply Analysis was conducted using the projected Sustainable Aviation Fuel (SAF) consumption and production potential in Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Philippines, Singapore, South Korea, Thailand, and Vietnam by 2040 under two different scenarios:

Scenario 1

This scenario assumes that all countries (Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Philippines, Singapore, South Korea, Thailand, and Vietnam) are progressing towards achieving a 20% SAF blend by 2040.

The 20% SAF blend target is derived from the average Target Blend Mandate set by countries that have committed to SAF adoption goals.

Scenario 2

Est. Projected SAF Consumption in 2040 is corrected for different target years of the Target Blend Mandate stated independently by Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, and Thailand. In this scenario, the projected domestic SAF consumption of Cambodia, Lao PDR and Vietnam are assumed to be zero, as there is no SAF Mandate by these nations to date.

Key Assumptions

- The feedstock quantities and potential SAF production outlined in Section 5.2 to 5.8 are assumed to be fully operational by 2040. SAF biorefineries are expected to be developed progressively to align with and maximise the potential SAF production derived from the respective feedstock by 2040.
- Figure 5.2 indicates the supply and demand for SAF in the region, expressed in potential SAF production and est. projected SAF demand in 2040. Acknowledging that Japan, Singapore and South Korea may have their own SAF refineries or future plans for development of SAF refineries for SAF, this has not been accounted for in Figure 5.2.
- Japan, Singapore and South Korea are assumed to be SAF feedstock and/or SAF importers, relying on their neighbouring countries to meet their SAF production and/or SAF demand.

Summary Assessment

- In both Scenarios, there is a possibility of a surplus of Sustainable Aviation Fuel (SAF) within ASEAN, excess supply could potentially be distributed, in region, to other countries, including Australia and New Zealand, Melanesia, Micronesia, and Polynesia or be sold as diesel in regional markets.
- Countries like Cambodia, Indonesia, Lao PDR, Philippines, Thailand, and Vietnam could potentially be SAF exporters due to their excess in SAF after their domestic SAF consumption is considered. Based on the feedstock quantity from the most prominent region within each country (Sections 2 and 5.2 to 5.8), all countries have the potential to be a net SAF exporter. In particular, this includes Indonesia, Malaysia, Philippines, Thailand, and Vietnam. Cambodia and Lao PDR also have a potential of being a net SAF exporter, however as per Sections 2, 5.2 to 5.8, the feedstock availability is relatively low compared to the other assessed countries.
- Under Scenario 1, Malaysia is projected to likely have a surplus of SAF as the country progresses toward achieving a 20% SAF blend by 2040. However, in Scenario 2, Malaysia is anticipated to face a potential SAF deficit, necessitating imports from other member states to meet its domestic SAF consumption requirements.

5. Feedstock and Product Logistics

5.1 Feedstock and Product Logistics Overview

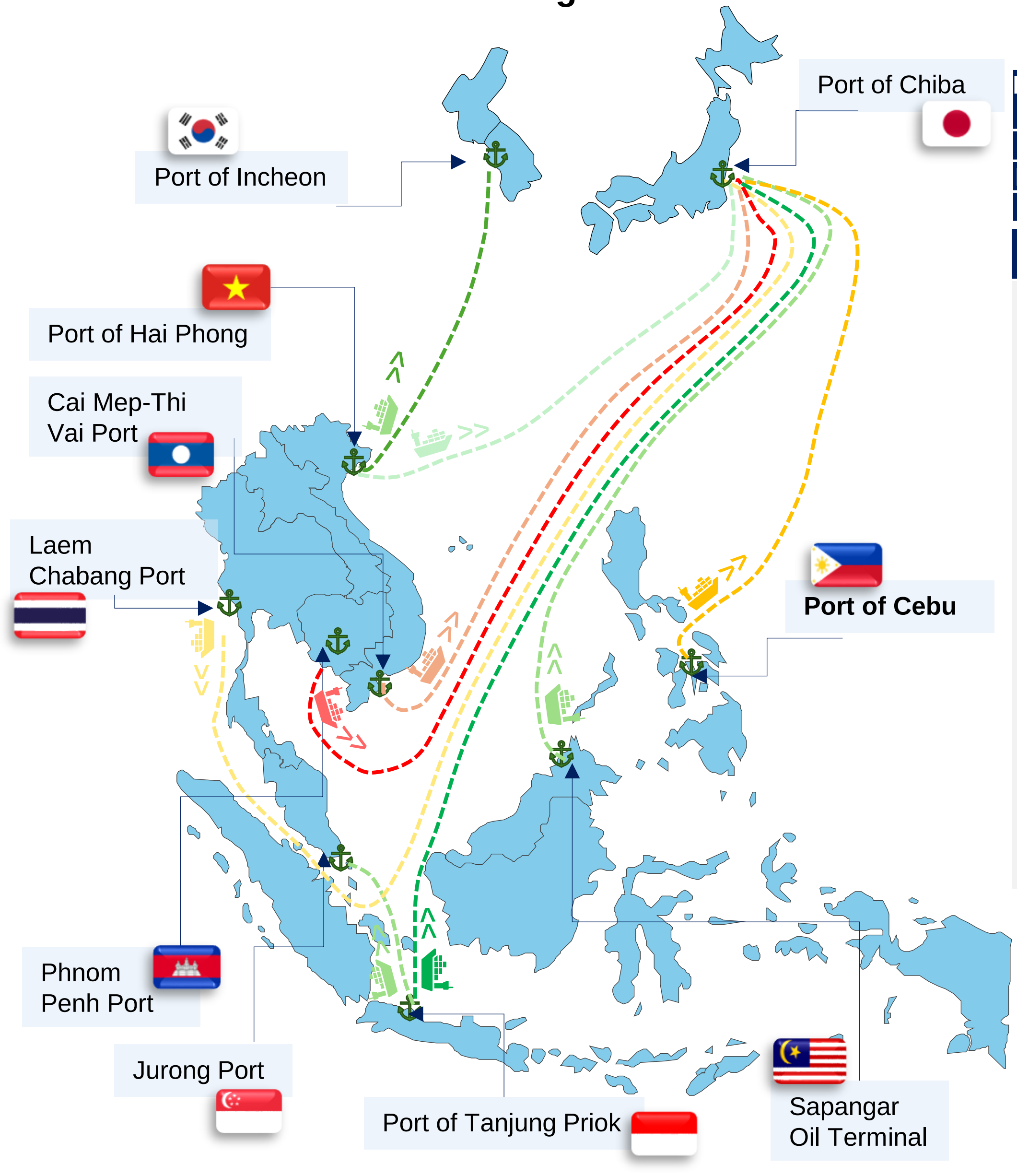


Figure 5.3: Potential SAF Regional Distribution Supply Chain – Scenario 1

Table 5.1: Relative Est. Cost Comparison of SAF Logistics from Refinery to Japan, Singapore and South Korea

Demand\Supply Port	Phnom Penh Port	Port of Tanjung Priok	Cai Mep-Thi Vai Port	Sapangar Oil terminal	Port of Cebu	Laem Chabang Port	Port of Hai Phong
Jurong Port	6	2	5	1	7	3	4
Port of Incheon	6	3	5	1	7	4	2
Port of Chiba	6	3	5	1	7	4	2

Summary Assessment

Considering the cost-distance of SAF produces from the ASEAN Members, it appears the most cost-effective supply chain to distribute SAF to Singapore, South Korea and Japan is from Malaysia, Vietnam and Indonesia respectively. Despite its strategic location, the Philippines is noted to have higher road freight costs than other member states, potentially reducing its competitiveness as a SAF distributor. However, further review and investigation of its road conditions and improvement measures may improve the Philippines' competitiveness as an exporter to the import countries mentioned.

Scenario 1 – Projected 20% SAF Blend in 2040 for all jurisdictions

Considering the surplus SAF and the relative logistics costs (from **cheapest (#1)** to **most expensive (#7)**), the likely SAF supply chain routes for Japan, Singapore and South Korea are as follows:

- Singapore (Jurong Port): import from Indonesia (Port of Tanjung Priok)
- South Korea (Port of Incheon): import from Vietnam (Port of Hai Phong)
- Japan (Port of China): import from Indonesia# (Port of Tanjung Priok), Malaysia (Sapangar Oil Terminal), Vietnam # (Port of Hai Phong), Thailand (Laem Chabang Port), Lao PDR (Cai Mep-Thi Vai Port), Cambodia (Phnom Penh Port) and the Philippines (Port of Cebu)

This study scenario requires selecting a specific point or localised port within the country. The chosen port is selected based on the highest surplus of SAF available after meeting the domestic consumption needs of the nearest major airport. Key feedstocks contributing to the SAF supply chain at these distribution ports have been identified based on their availability in the surrounding areas, and they are:

Country	Feedstock Type	Country	Feedstock Type	Country	Feedstock Type

Note:

- Rankings 1 to 7 indicate cost-effectiveness, with 1 being the most cost-effective supply chain route and 7 being the least across the Demand Ports.
- # Indonesia and Vietnam excess SAF surplus after distributing to Singapore and South Korea respectively.

5. Feedstock and Product Logistics

5.1 Feedstock and Product Logistics Overview

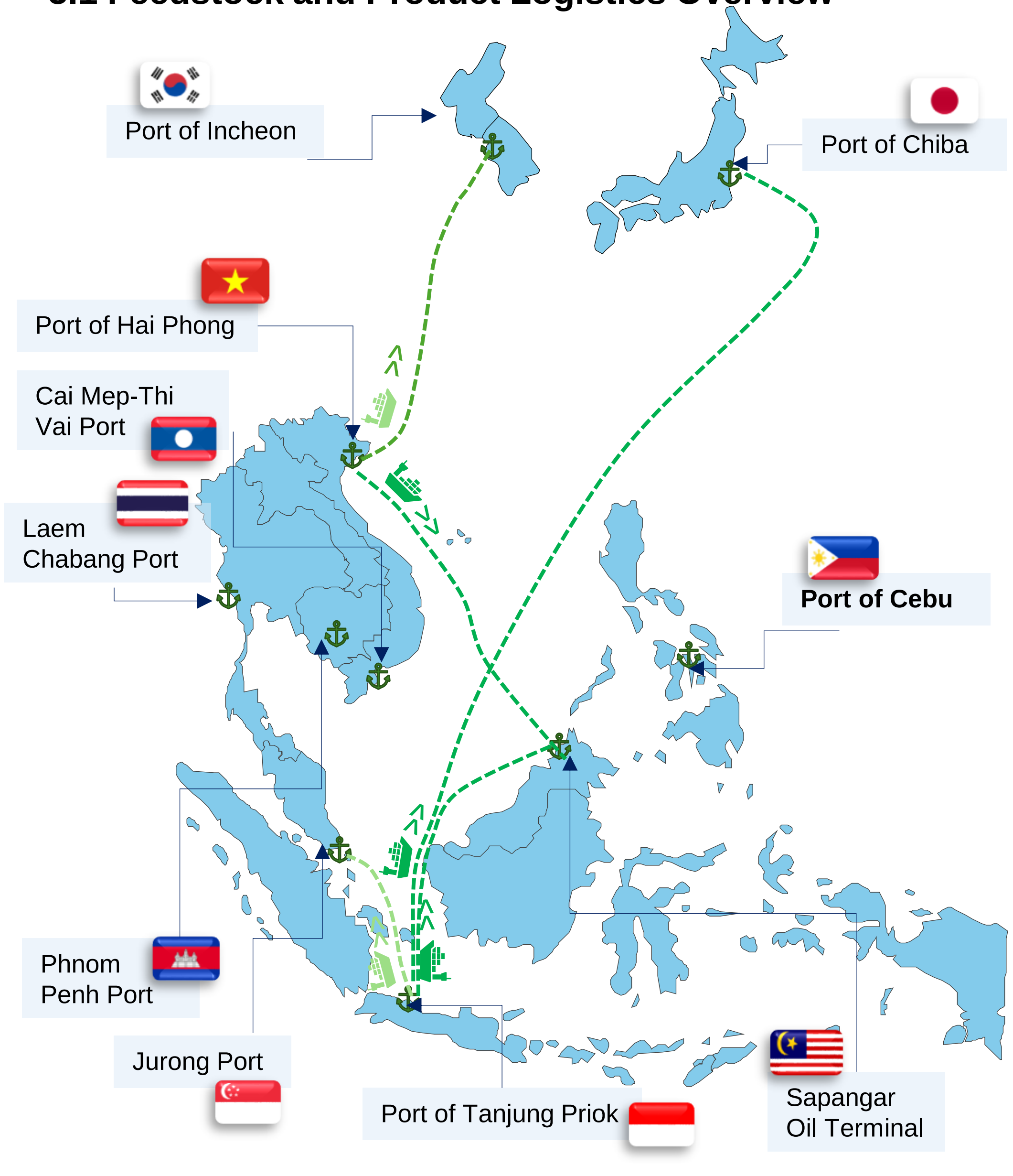


Figure 5.4: Potential SAF Regional Distribution Supply Chain – Scenario 2

Table 5.2: Relative Est. Cost Comparison of SAF Logistics from Refinery to Japan, Singapore and South Korea

Demand\Supply Port	Phnom Penh Port	Port of Tanjung Priok	Cai Mep-Thi Vai Port	Sapangar Oil terminal	Port of Cebu	Laem Chabang Port	Port of Hai Phong
Jurong Port	6	2	5	1	7	3	4
Port of Incheon	6	3	5	1	7	4	2
Port of Chiba	6	3	5	1	7	4	2
Sapangar Oil Terminal	3	1	4		5	2	1

Summary Assessment

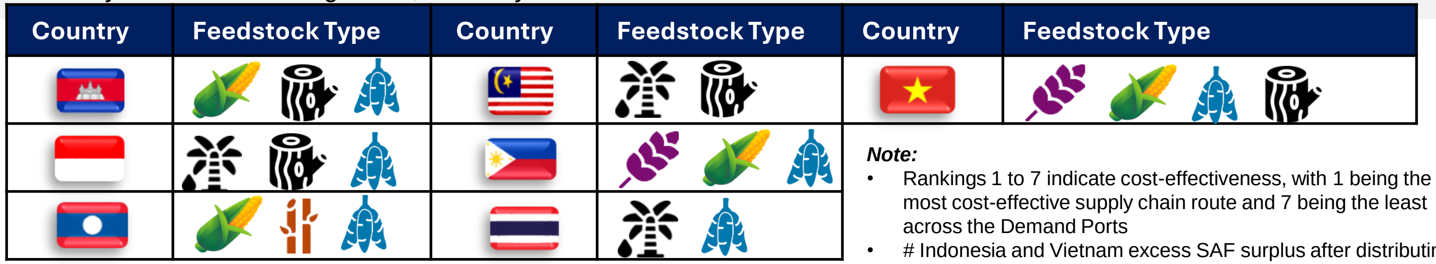
Considering the cost-distance of SAF produced from the ASEAN Members, likewise, it appears the most cost-effective supply chain to distribute SAF to Singapore, South Korea and Japan is from Malaysia, Vietnam and Indonesia respectively. Similarly, despite its strategic location, the Philippines is noted to have higher road freight costs than other member states, potentially reducing its competitiveness as a SAF distributor. However, further review and investigation of its road conditions and improvement measures may improve the Philippine's competitiveness as an exporter to the import countries mentioned. In this scenario, Malaysia is likely to face the SAF deficit for its own domestic consumption and possibly would have to import SAF from either Indonesia (Port of Tanjung Priok) or Vietnam (Port of Hai Phong) since the cost-distance for sea freight is computed to be approximately similar.

Scenario 2 – Est. % SAF Blend based on Corrected Mandate Target Year

Considering the surplus SAF and the relative logistics costs (from **cheapest (#1)** to **most expensive (#7)**), the likely SAF supply chain routes for Japan, Singapore and South Korea are as follows:

- Singapore (Jurong Port): import from Indonesia (Port of Tanjung Priok)
- South Korea (Port of Incheon): import from Vietnam (Port of Hai Phong)
- Japan (Port of China): import from Indonesia# (Port of Tanjung Priok) and Vietnam# (Port of Hai Phong)

This study scenario requires selecting a specific point or localised port within the country. The chosen port is selected based on the highest surplus of SAF available after meeting the domestic consumption needs of the nearest major airport. Key feedstocks contributing to the SAF supply chain at these distribution ports have been identified based on their availability in the surrounding areas, and they are:



Note:

- Rankings 1 to 7 indicate cost-effectiveness, with 1 being the most cost-effective supply chain route and 7 being the least across the Demand Ports
- # Indonesia and Vietnam excess SAF surplus after distributing to Singapore and South Korea respectively

5. Feedstock and Product Logistics

5.1 Feedstock and Product Logistics Overview

Key Findings

Domestic transportation of both biomass feedstock and SAF is likely governed and limited by the Transportation Regulation such as on the size, weight, height, speed limit of the fleets and also domestic infrastructure. International transportation of biomass feedstock may be subjected to phytosanitary regulations. Furthermore, in-country regulations on the import and export of oil, and petrochemical products are also likely to apply to SAF regional or international trading.

While biomass stockpiling is not necessarily regulated, however, it is important to consider the degradation and loss of energy content over time when storing the biomass feedstock. Prolonged storage without proper infrastructure can potentially lead to issues like feedstock wastage, buildup, decomposition, and safety hazards such as fire risks and the release of toxic gases. Hence, storage infrastructure may need to be in compliance with the in-countries regulations and standards on as fire-fighting systems, ventilation, health & safety, and drainage.

Within ASEAN, the Common Effective Preferential Tariff (CEPT) scheme aims to gradually reduce and eliminate intra-regional tariffs based on product sensitivity to domestic industries. The ASEAN-Korea Free Trade Agreement (AKFTA) and ASEAN-Japan Comprehensive Economic Partnership (AJCEP) facilitate trade between ASEAN, Korea, and Japan. While SAF is not explicitly listed, it could potentially be included.

A review of regional supply chains suggests that Indonesia and Vietnam might consider Free Trade Agreements (FTAs) with Japan and South Korea for SAF distribution due to market demand, supply chain efficiency, and cost competitiveness.

The establishment of a Green Trade Lane or Green Corridor in Southeast Asia may potentially be feasible, aligning with the International Maritime Organization's (IMO) GHG Emission Goals and existing sustainable shipping initiatives. Key ports like Port of Tanjong Priok, Port of Benoa, Penang Port, Port Klang, and Port Tanjung Pelepas have been identified as green ports or pilot ports for Green Corridors.

Refer Section 5.11 for further details.

5. Feedstock and Product Logistics

5.1 Feedstock and Product Logistics Overview

High-level review was conducted to evaluate the options for feedstock and product logistics in terms of harvesting techniques, biomass feedstock pre-processing locations and distribution of SAF. The summary of this review is presented in Table 5.3 below.

Table 5.3: High Level Review on Feedstock and Product Logistic Options

Summary	Cost	Employment	Sector Efficiency	CO2 Emission
Harvesting Technique (Mechanised Vs Manual)	Mechanised harvesting is likely to be more cost-effective in the long run but may require higher initial investment. Manual harvesting has lower initial costs but can potentially lead to higher operational costs.	Manual harvesting supports more jobs, especially in rural areas; mechanised harvesting can lead to job losses but may create opportunities in other sectors with higher skill requirements.	Mechanised harvesting is more efficient and productive. Manual harvesting is less efficient and slower.	Mechanised harvesting can have higher emissions, but advancements in technology are improving this. Manual harvesting has lower emissions. However, the overall impact depends on the scale of operations and the transportation methods used.
Pre-processing Location (Centralised Vs Distributed)	Centralised facilities have higher initial costs but lower operational costs. Decentralised facilities have lower initial costs but higher operational costs.	Centralised facility may create few, but more specialised job. While, decentralised may create jobs in rural areas.	Centralised facility is relatively more efficient but may have more complex logistics. Decentralised facility is less efficient but could have simpler logistics.	Centralised facility may have higher emissions due to transportation, which it likely to have a higher number of trucks to transport the bulky biomass feedstock from the farm to the facilities.
SAF Distribution (Road Freight Vs Pipeline)	Road freight tends to have lower initial investment cost, but a higher operational cost. Whereas, the pipeline distribution will likely have a higher initial investment cost, but a lower operational cost.	Road freight creates more jobs with moderate skill requirements, while pipeline distribution creates fewer, higher-skilled jobs.	Road freight offers higher flexibility and easier scalability, while pipeline distribution provides lower flexibility.	Road freight may potentially have higher emissions, while pipeline distribution has lower emissions.

Refer Sections 5.12 for further details.

GHD Advisory

Feedstock and Product Logistics Deeper Dive

5. Feedstock and Product Logistics

5.2 Cambodia Feedstock and Product Logistics

Feedstock	Major Feedstock Location	Distance	SAF Biorefinery Facilities	Distance	Blending SAF Facilities / Port [119]
Cassava (bagasse, peel)	Battambang Province Harvesting technique: likely manual[56] Potential SAF cap.: 7,400 bpd #	396 km	Sangkat Preaek Pnov, Phnom Penh **MH Bio-Energy Group** [61] Existing biorefinery cap*.: 620 bpd Note: Since the SAF comes from only one refinery, it is assumed that the surplus SAF will be transported directly from the refinery to the nearest port, which is PAP. The surplus plus is computed from the potential SAF minus the local demand by the three major airports	34 km	Phnom Penh International Airport - 29 Airlines [62]
Rice (husk, straw)	Battambang Province Harvesting technique: manual[57] Potential SAF cap.: 2,600 bpd #	291 km		300 km	Sieam Reap – Angkor International Airport - 10 Airlines [63]
Corn (leaves, stack, husk, cobs)	Battambang Province (Ratanak Mondul district)[58] Harvesting technique: likely manual[59] Potential SAF cap.: 370 bpd #	318 km		216 km	Sihanoukville International Airport - 3 Airlines [64]
Sawlogs, veneer logs	Kratie Province[60] Harvesting technique: likely combination of manual and mechanised Potential SAF cap.: 185 bpd #	225 km			

Figure 5.5: **Cambodia Feedstock and Product Logistics Assessment**

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

Summary Assessment

Battambang Province of Cambodia has the highest potential biomass feedstock for SAF.

However, only one biorefinery, which can be considered as SAF biorefinery facility, is identified to be still in operation and is located in the country's central region, close to Phnom Penh.

Establishing SAF supply chain in Cambodia may present significant challenges[65] due to substantial gaps in infrastructure for both feedstock and product logistics. Key issues include:

- A lack of large agro-processing infrastructure facilities and a 'missing middle' in the agribusiness distribution network, making it difficult to aggregate sufficient feedstock for SAF production[116];
- Logistic centers are mostly dry port (small distribution warehouse) with limited capacity. Equipment of logistics are reported to be insufficient due to lack of centralised logistic centers, and an appropriate level of efficiency which may affect storage, distribution, traffic, and management of distribution processes[65] effectively, resulting in higher logistic costs.
- Poor quality of road infrastructure, despite road transport being the primary mode of domestic transportation[66].

In general, domestically, feedstock biomass and SAF can be transported via road freight, with an average road freight cost of US$ 0.10 per ton-km[67].

Based on the regional SAF potential, it is envisaged that a significant additional (or proportional to SAF potential capacity) infrastructure (such as pre-processing facilities, SAF biorefinery, truck fleet operation) will likely be required in Cambodia.

5. Feedstock and Product Logistics

5.3 Indonesia Feedstock and Product Logistics

Major Feedstock Location

Oil Palm (shell, fibre, EFB)
Sumatera (Riau, Indragiri)
Harvesting Technique: manual [71]
Potential SAF cap.: 28,000 bpd [#]
400 km

Sawlogs, veneer logs
Sumatera (North Sumatera, Deli Serdang)
Harvesting Technique: Combination of manual and mechanised harvesting [72]
Potential SAF cap.: 15,000 bpd [#]
540 km

Cassava (bagasse, peel)
Sumatera (Lampung)
Harvesting Technique: manual [73]
Potential SAF cap.: 22,000 bpd [#]
317 km

Rice (husk, straw)
Java (East Java, Pasuruan)
Harvesting Technique: Combination of manual and mechanised harvesting [74, 75]
Potential SAF cap.: 22,000 bpd [#]
550 km

Sugarcane (cane tops, bagasse)
Java (East Java, Kediri)
Harvesting Technique: Combination of manual and mechanised harvesting [76]
Potential SAF cap.: 5,500 bpd [#]
580 km

Corn (leaves, stack, husk, cobs)
Java (East Java, Tuban)
Harvesting Technique: likely combination of manual and mechanised
Potential SAF cap.: 9,000 bpd [#]
440 km

SAF Biorefinery Facilities [77, 78]

Sumatera Island
RU II Dumai Refinery
- Crucial refinery that produces approximately 20% of national fuel and avtur supply.
- Existing fuel supply is distributed to North Sumatera Region and allocated to Soekarno Hatta International Airport
- Existing biorefinery cap*.: 170,000 bpd

4.2 days 30 km

Sumatera Island
RU III Green Plaju Refinery
- In development to produce Pertamina RD (HVO), Bioavtur (SAF), and BioNaphtha.
- Targeted completion 2027
- Existing biorefinery cap*.: 20,000 bpd

1.4 days 30 km

Java Island
RU IV Cilacap Green Refinery
- Successfully produced SAF for trial flights of Garuda Indonesia and Military Aircraft.
- Expansion and upgrading work-in- progress to increase processing and production capacity.
- Location is closed to Port of Cilacap, which can potentially be a good distribution point to Port of Benoa in Bali
- Existing biorefinery cap*.: 348,000 bpd

2 days 15 km

500 km

Blending SAF Facilities / Port [79]

Soekarno-Hatta International Airport
- 52 Airlines

Ngurah Rai (Bali) International Airport
- 45 Airlines

Juanda International Airport
- 17 Airlines

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

***Figure 5.6:* Indonesia Feedstock and Product Logistics Assessment**

Summary Assessment

Major biomass feedstock are found in the island of Sumatera and Java.

In Indonesia, existing biorefineries are primarily owned by PT. Pertamina [80], in which the locations are sparse and sporadic given the archipelagic nature of the countries (i.e. 6 refineries facilities across the country).
Given the locations of the feedstock, 3 keys refineries identified include Dumai Refinery. Plaju Refinery and Cilacap Green Refinery that are located in Sumatera and Java island respectively. Although these existing refineries have capacity more than SAF potential capacity, it is to note that the existing infrastructure can be mainly used for producing other petrochemical products.

Despite the suitability of these Pertamina refineries to be capitalised as SAF biorefineries facilities, distance between the source of feedstock biomass and the biorefineries is relatively far.

Prior to blending, there is also an opportunity for exporting the pure SAF (unblended) domestically and internationally via shipping.

SAF transportation to the blending facilities located close to the major airports around Indonesia via both road and ship freight, have the following average costs:
- Average commodity shipping costs from Port of Jakarta to other ports in Indonesia: Rp 58,000 per kg (USD3.6 per kg) [81]
- Average price for renting an oil tanker [82] ship is approximately USD44,153 per day.
- Average road freight cost USD 0.085 per ton-km [93].

5. Feedstock and Product Logistics

5.4 Lao PDR Feedstock and Product Logistics

Major Feedstock Location

Cassava (bagasse, peel)
Xayabury Province
Harvesting technique: Combination of manual and semi- mechanised harvesting [97]
Potential SAF cap.: 5,500 bpd #
→ 300 km to Pek District, Xieng Khouang

Sugarcane (cane tops, bagasse)
Luang Namtha Province
Harvesting technique: likely manual
Potential SAF cap.: 3,700 bpd #
→ 580 km to Pek District, Xieng Khouang

Corn (leaves, stack, husk, cobs)
Oudomxay Province
Harvesting technique: likely manual
Potential SAF cap.: 200 bpd #
→ 510 km to Pek District, Xieng Khouang

Rice (husk, straw)
Savannakhet Province
Harvesting technique: Manual [98]
Potential SAF cap.: 1,700 bpd #
→ 354 km to Vientiane

Sawlogs, veneer logs
Savannakhet Province
Harvesting technique: likely combination of manual and mechanised
Potential SAF cap.: 190 bpd #
→ 354 km to Vientiane

SAF Biorefinery Facilities[109]

Pek District, Xieng Khouang
Yodngeum Power Mix Fuel Factory
Existing biorefinery cap*.: 1723.2 bpd
→ 331 km to Luang Prabang International Airport

Vientiane
Saysettha Comprehensive Development Zone (Lao Petroleum & Chemical Co. Ltd)
Existing biorefinery cap*.: 0.1 bpd
→ 25 km to Wattay International Airport

Blending SAF Facilities / Port [110]

Luang Prabang International Airport
- 7 Airlines

Wattay International Airport
- 21 Airlines

Figure 5.7: **Lao PDR Feedstock and Product Logistics Assessment**

Summary Assessment

Each regions (North, Central, and South) of Lao PDR produce potential biomass feedstock for SAF.

However, till date only two biorefineries, which can be considered as SAF biorefinery facilities, are identified to be still in operation, and are located in central region of the country.

In Lao PDR, river ports are generally used as a transport goods and passengers, However, they are still natural condition without concrete ramp and difficult for berthing and lack facility equipment for loading and unloading cargo (usually done manually)[109], which may not be appropriate to support the biomass feedstock and SAF.

General logistics is mainly by trucks (road freight). The average road freight cost US$ 0.073 per ton-km and US$ 0.061 per ton-km for agricultural products and bulk liquids respectively.[111]

Based on the regional SAF potential, it is envisaged that a significant additional (or proportional to SAF potential capacity) infrastructure (such as pre-processing facilities, SAF biorefinery, truck fleet, and river port infrastructure operation) will likely be required in Lao PDR.

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

5. Feedstock and Product Logistics

5.5 Malaysia Feedstock and Product Logistics

Feedstock	Major Feedstock Location	Distance	SAF Biorefinery Facilities	Distance	Blending SAF Facilities / Port [128]
Oil Palm (shell, fibre, EFB)	Sabah State[147] Harvesting technique: combination of manual and mechanised[143] Potential SAF cap.: 24,000 bpd #	73.4 km	Sabah **SPC Biodiesel** Existing biorefinery cap*.: 2,044 bpd [146] Additional SAF biorefinery of 5,000 bpd capacity has been planned in Sabah[129].	413 km	Kota Kinabalu International Airport - 18 Airlines
Sawlogs, veneer logs	Sarawak State[127] Harvesting technique: mechanised[142] Potential SAF cap.: 2,200 bpd #	220 km	Sarawak **SOP Green Energy** [141] Existing biorefinery cap*.: 4,055 bpd [140]	340 km	Kota Kinabalu International Airport - 18 Airlines
Pineapple (peel)	Johor State (Pontian)[146] Harvesting technique: likely to be combination of manual and mechanised Potential SAF cap.: 190 bpd #	150 km	Johor **Pengerang Integrated Petroleum Complex (PIPC)** [134] Biorefinery cap*.: 12,500 bpd [135] Additional SAF cap,: 3,661 bpd to be ready in 2025 [144]	402 km	Kuala Lumpur International Airport - 63 Airlines
Coconut (husk)	Johor (Batu Pahat) State[127 133] Harvesting technique: manual [133] Potential SAF cap.: 190 bpd #	220 km	Johor (PIPC)		
Rice (husk, straw)	Kedah (Kawasan Muda) State[127, 137] Harvesting technique: combination of manual and mechanised[136] Potential SAF cap.: 1,900 bpd #	250 km	Perak **Petron Lumut POME Plant** [138] Biorefinery cap*.: 1,230 bpd [139]	180 km	Penang International Airport - 17 Airlines

Summary Assessment

The biomass feedstock source is primarily located in East Malaysia (Sarawak and Sabah).

Malaysia has numerous biorefineries across both Peninsular and East Malaysia [129], with Peninsular Malaysia having a more refinery capacity than East Malaysia.
Upcoming SAF refineries are in development, with locations in Johor and Sabah[132].

Despite a higher feedstock availability in East Malaysia, the demand for SAF is higher in Peninsular Malaysia.

Road transportation dominates the logistics industry (70% of freight movement) [133] General logistics is mainly by trucks (road freight). The average road freight cost varied between US$ 0.30 to 0.50 per ton-km for agricultural products.[145]

Based on the regional SAF potential, it is envisaged that a significant additional (or proportional to SAF potential capacity) infrastructure (such as pre-processing facilities, SAF biorefinery, truck fleet/port operation) will likely be required in Malaysia.

Figure 5.8: **Malaysia Feedstock and Product Logistics Assessment**

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

5. Feedstock and Product Logistics

5.6 Philippines Feedstock and Product Logistics

Feedstock	Major Feedstock Location	Distance	SAF Biorefinery Facilities [127, 128]	Distance	Blending SAF Facilities / Port [129]
Sugarcane (cane tops, bagasse)	Western Visayas (Negro Island Region) Harvesting Technique: mechanised harvesting [123] Potential SAF cap.: 7,000 bpd#	102 km	Western Visayas – La Carlota City **Universal Robina Corporation (La Carlota Distillery)** Existing bioethanol cap*.: 775.5 bpd	180 km	Mactan Cebu International Airport - 25 Airlines
Rice (husk, straw)	Central Luzon (Pampanga) Harvesting Technique: manual [124] Potential SAF cap.: 9,000 bpd #	196 km	Central Luzon – Quezon **Tantuco Enterprises** Existing bioethanol cap*.: 1,550.9 bpd	120 km	Ninoy Aquino International Airport - 46 Airlines
Corn (leaves, stack, husk, cobs); Cassava (bagasse, peel)	Cagayan Valley Corn Harvesting Technique: combination of manual with mechanised harvesting [125] Potential SAF cap.: 4,000 bpd # Cassava Harvesting Technique: manual (likely) Potential SAF cap.: 9,000 bpd #	30 km	North-East Luzon – Cagayan Valley **Green Future Innovations** Existing bioethanol cap*.: 930.5 bpd	450 km	Ninoy Aquino International Airport - 46 Airlines
Sawlogs, veneer logs	Mindanao (Cagayan de Oro City) Harvesting Technique: manual [126] Potential SAF cap.: 500 bpd #	365 km	South Cotabato – Polomolok **Ecoenergy Corporation** Existing biodiesel cap*.: 1,723.2 bpd	164 km	Francisco Bangoy International Airport - 7 Airlines
Coconut (husk)	Mindanao (Davao) Harvesting Technique: manual [127] Potential SAF cap.: 2,000 bpd #	157 km	South Cotabato – Polomolok **Ecoenergy Corporation** Existing biodiesel cap*.: 1,723.2 bpd	164 km	Francisco Bangoy International Airport - 7 Airlines

Summary Assessment

Each region (Luzon, Visayas, Mindanao) produces feedstock and also consists of biorefineries.

In the Philippines, biorefineries appear strategically located closer to the feedstock sources, except for the Mindanao region. It appears that major biomass feedstock is located within Northen Mindanao, whereas the identified biorefinery with largest capacity are located within Southern Mindanao.

Prior to blending, there is also an opportunity for exporting the pure SAF (unblended) domestically and internationally via shipping.

The primary mode of logistics considered to facilitate the transportation of feedstock and SAF is via road freight, with an average road freight cost of US$ 0.097 per ton-km. [130]

Based on the regional SAF potential, it is envisaged that a significant additional (or proportional to SAF potential capacity) infrastructure (such as pre-processing facilities, SAF biorefinery, truck fleet operation) will likely be required in Philippines.

Figure 5.9: **Philippines Feedstock and Product Logistics Assessment**

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

5. Feedstock and Product Logistics

5.6.1 Case Study: Palawan Province (Philippines) Feedstock and Product Logistics

Coconut (husk)

Major Feedstock Location

Palawan Province
Harvesting technique: Manual
Potential SAF cap.: 1,100 bpd #

280 km 3.7days

SAF Biorefinery Facilities

New Davao Oil Mill[157]
Existing biorefinery cap*.: 1,480 bpd

20 km

Blending SAF Facilities / Port

Francisco Bangoy International Airport
- 7 Airlines[79] -

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

Figure 5.10: Palawan Province (Philippines) **Feedstock and Product Logistics Assessment**

Summary Assessment

Palawan Province has been identified to have a SAF production potential from Non-Standard Coconut.

No biorefinery facilities have been identified within the Palawan Province.
SAF biorefinery facilities will be required to be established and constructed to promote SAF infrastructure in Palawan.
The coconut feedstock can potentially be collected centrally within Palawan and transported to one of the Crude Coconut Oil (CCO) producers[152], such as Primex Coco Products[157] and Samar Coco Products Manufacturing Corporation[154]. They have CCO refineries located across Davao, Quezon and Albay.

Considering the distance between the milling/refinery facilities and Palawan's domestic airports[149], transporting the SAF to the nearest major airport to these facilities is likely to be more cost-effective and environmentally friendly.

In addition, the CCO produced could be exported internationally via shipping for SAF production. One key stakeholder identified include Green Power Development Corporation of Japan[155].

The primary mode of logistics considered to facilitate the transportation of feedstock and SAF is via sea and road freight, with an average road freight cost of US$ 0.097 per ton-km [80] and US$ 1.52 per ton-km[159] respectively.

There are 3 main ports[158] within Palawan Province, namely Port of Puerto Princesa, Buliyan Port and Coron Port. However, these ports are known to be ferry terminals and they do not have the port infrastructure for oil tankers. Only Port of Puerto Princesa is known to be a multipurpose quay that could handle containers and be used for petroleum products and LPG imports to the Province[156]. Therefore, this port can potentially be used to ship the coconut feedstock to its nearest refineries.

Alternatively, establishing a coconut crude oil factory within Palawan could be explored and considered, which may enhance supply chain efficiency and reduce transportation challenges. Some considerations include:

1. Availability of coconut feedstock
2. Capability of Port Puerto Princesa to handle petroleum products
3. Feedstock storage and shelf life – Biomass feedstock, including coconuts, could have a limited storage duration, making local processing a more viable option. Therefore, transporting perishable raw coconut feedstock over long distances risks spoilage and quality degradation.
4. Optimisation of transport logistics – CCO is denser and could be easier to transport compared to raw coconut feedstock, reducing shipment frequency and logistical costs.

5. Feedstock and Product Logistics

5.7 Thailand Feedstock and Product Logistics

Major Feedstock Location

Sugarcane (cane tops, bagasse)
North-East Region (Udon Thani)
Harvesting Technique: manual [160]
Potential SAF cap.: 4,000 bpd #
180 km

Cassava (bagasse, peel)
North-East Region (Nakhon Ratchasima)
Harvesting Technique: manual [161]
Potential SAF cap.: 17,000 bpd #
230 km

Oil Palm (shell, fibre, EFB)
Southern Region (Surat Thani)
Harvesting Technique: manual [162]
Potential SAF cap.: 4,000 bpd #
53 km

Rice (husk, straw)
North-East Region (Ubon Ratchathani)
Harvesting Technique: mechanised[97]
Potential SAF cap.: 30,000 bpd #
375 km

Sawlogs, veneer logs
Northern Region (Chiang Mai)
Harvesting Technique: Combination of manual and mechanised harvesting[163]
Potential SAF cap.: 2,700 bpd #
670 km

SAF Biorefinery Facilities [168]

North-East Region
Mitr Phol Bio-Fuel Co., Ltd.
Existing biofuel refinery cap*.: 19 bpd
425 km
380 km

South Region
New Biodiesel Co., Ltd.
Existing biodiesel cap*.: 22.4 bpd
644 km

North-East Region
BBGI Bioethanol Public Company Limited (BBGI-NP)
Existing bioethanol cap*.: 5.2 bpd
660 km

Blending SAF Facilities / Port [170]

Suvarnabhumi Airport
- 98 Airlines

Don Mueang International Airport
- 22 Airlines

Chiang Mai International Airport
- 28 Airlines

Summary Assessment

Primarily, the biomass feedstock source is located in the North and Northeast region of Thailand.

However, currently there is no bio-refineries identified within the Northern region of Thailand, and there are only two biorefineries located within the North-East Region.

Lack of existing biorefinery facilities at these regions (Especially the North) may result in longer transport distances, that may decrease the biomass feedstock quality and increase emissions.

It may not be ideal to transport the forestry waste from the North region to the nearest biorefinery at North-East Region, and transport the SAF back to the blending facility located at Chiang Mai to serve the airlines at Chiang Mai International Airport.

In general, feedstock biomass and SAF can be transported via road freight, with an average road freight cost of US$ 0.08 per ton-km[163].

Based on the regional SAF potential, it is envisaged that a significant additional (or proportional to SAF potential capacity) infrastructure (such as pre-processing facilities, SAF biorefinery, truck fleet operation) will likely be required in Thailand.

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

Figure 5.11: **Thailand Feedstock and Product Logistics Assessment**

5. Feedstock and Product Logistics

5.8 Vietnam Feedstock and Product Logistics

Feedstock	Major Feedstock Location	Distance	SAF Biorefinery Facilities [173, 174]	Distance	Blending SAF Facilities / Port [175]
Rice (husk, straw)	Southern Vietnam (Mekong River Delta, Hau Giang) Harvesting technique: mechanised Potential SAF cap.: 55,000 bpd #	300 km	Dong Nai **Tunglam Ethanol Factory** Existing bioethanol cap*.: 1,309.7 bpd	115 km	Tan Son Nhat International Airport - 47 Airlines
Cassava (bagasse, peel)	Southern Vietnam (Tay Ninh) Harvesting technique: likely combination of manual and mechanised Potential SAF cap.: 7,000 bpd #	210 km			
Sawlogs, veneer logs	Central Highlands (Dalak) Harvesting technique: likely combination of manual and mechanised Potential SAF cap.: 5,500 bpd #	360 km			
Corn (leaves, stack, husk, cobs)	Central Highlands (Dalak) Harvesting technique: likely mechanised Potential SAF cap.: 900 bpd #	360 km			
Sugarcane (cane tops, bagasse)	Central Vietnam (Gia Lai) Harvesting technique: mechanised Potential SAF cap.: 2,000 bpd #	330 km	Quang Nam **Vietnam Biofuel Factory** Existing biofuel refinery cap*.: 2,154 bpd	50 km	Danang International Airport - 31 Airlines

Summary Assessment

Primarily, the biomass feedstock source is located in the Southern (Mekong Delta) and Central Highland of Vietnam.

Currently only two biorefineries, which can be considered as SAF biorefinery facilities, are identified to be still in operation. Distance between the feedstock biomass to refineries may not be so ideal.

In Vietnam, transportation by trucks (road freight) is typical over short distances (<400km)[16]; The average road freight cost of US$ 0.07 per ton-km.

Based on the regional SAF potential, it is envisaged that a significant additional (or proportional to SAF potential capacity) infrastructure (such as pre-processing facilities, SAF biorefinery, truck fleet operation) will likely be required in Vietnam.

Figure 5.12: **Vietnam Feedstock and Product Logistics Assessment**

Note:
assuming full utilization of biomass for SAF production
*at this specific location of Biorefinery
Manual – by hand, hand tool, low technology such as sickle, bulldozer etc.

5. Feedstock and Product Logistics

5.9 Potential SAF Export/Import port locations

Thailand[174, 175, 176]

1.	Port of Bangkok	3.	Laem Chabang Port
2.	Map Ta Phut Industrial Port		

Cambodia[160]

1.	Sihanoukville Autonomous Port (sea port)	2.	Phnom Penh Autonomous Port (PAP) (river port)

Malaysia[161]

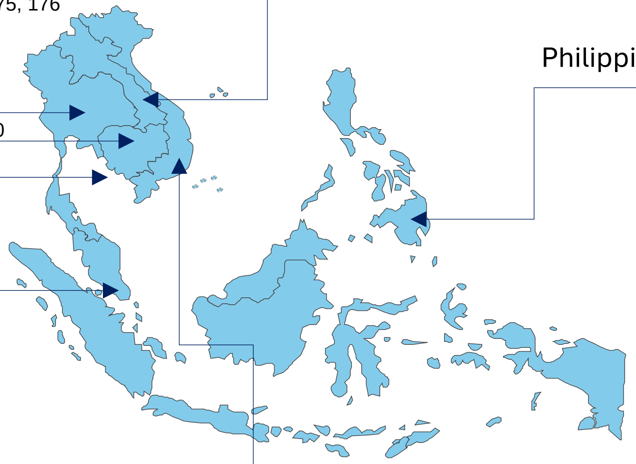
1.	Port of Klang	4.	Port of Bintulu
2.	Port of Pasir Gudang	5.	Port of Kuantan
3.	Port of Penang	6.	Sapangar Oil Terminal

Indonesia[177]

1.	Port of Dumai	6.	Port of Cirebon
2.	Port of Palembang	7.	Port of Gresik
3.	Port of Cilacap	8.	Port of Benoa
4.	Port of Jakarta	9.	Port of Balikpapan
5.	Port of Belawan	10.	Port of Teluk Bayur

Lao PDR[178]

1.	Port of Luang Prabang	3.	Port of Lak Si
2.	Port of Huay Sai	4.	Port of Pak Beng



Philippines[182]

1.	Port of Manila	4.	Port of Cagayan de Oro
2.	Port of Cebu	5.	Port of Davao
3.	Port of Iloilo	6.	Batangas Port

Ports at Palawan Province [162] include:

1. Puerto Princesa

Vietnam[179, 180, 181]

1.	Port of Saigon	3.	Port of Da Nang
2.	Port of Hai Phong	4.	Cai Mep – Thi Vai Port

Figure 5.13: Major Key Ports in Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam

Key ports in Cambodia, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam above are identified to be equipped with the infrastructure and capabilities (such as docking facilities, berths, oil storage tanks, bunkering, and loading/unloading systems) to support the import and export of oil and petrochemical products.
These ports can potentially be leveraged for the distribution of Sustainable Aviation Fuel (SAF) for domestic, regional, and international purposes.
However, upgrades to the existing infrastructure may be necessary to accommodate the expected SAF volumes and increased operational demands at the ports.

In Lao PDR, river ports also may not have sufficient equipment for loading and unloading cargo, as these tasks are usually performed manually. The ports along the Mekong River are underdeveloped and may need to be upgraded to make them suitable for SAF shipping. It is noted that the primary means of import/export of oil products are via overland routes (e.g. Chiang Khong Custom Point between Lao PDR and Thailand), using tanker trucks [178, 183]. Furthermore, there are plans and discussions about developing pipeline infrastructure to facilitate the import/export of oil in Lao PDR such as the oil pipeline from (Hon La Harbor in Vietnam to Kammuan Province)[184].
The SAF from Cambodia and Lao PDR can also be transported via the Mekong River to Cai Mep – Thi Vai Port, located in Vietnam, as a gateway to regional and international distribution [80].

5. Feedstock and Product Logistics

5.10 Potential SAF Regional Supply Chain: Supply-Demand Analysis

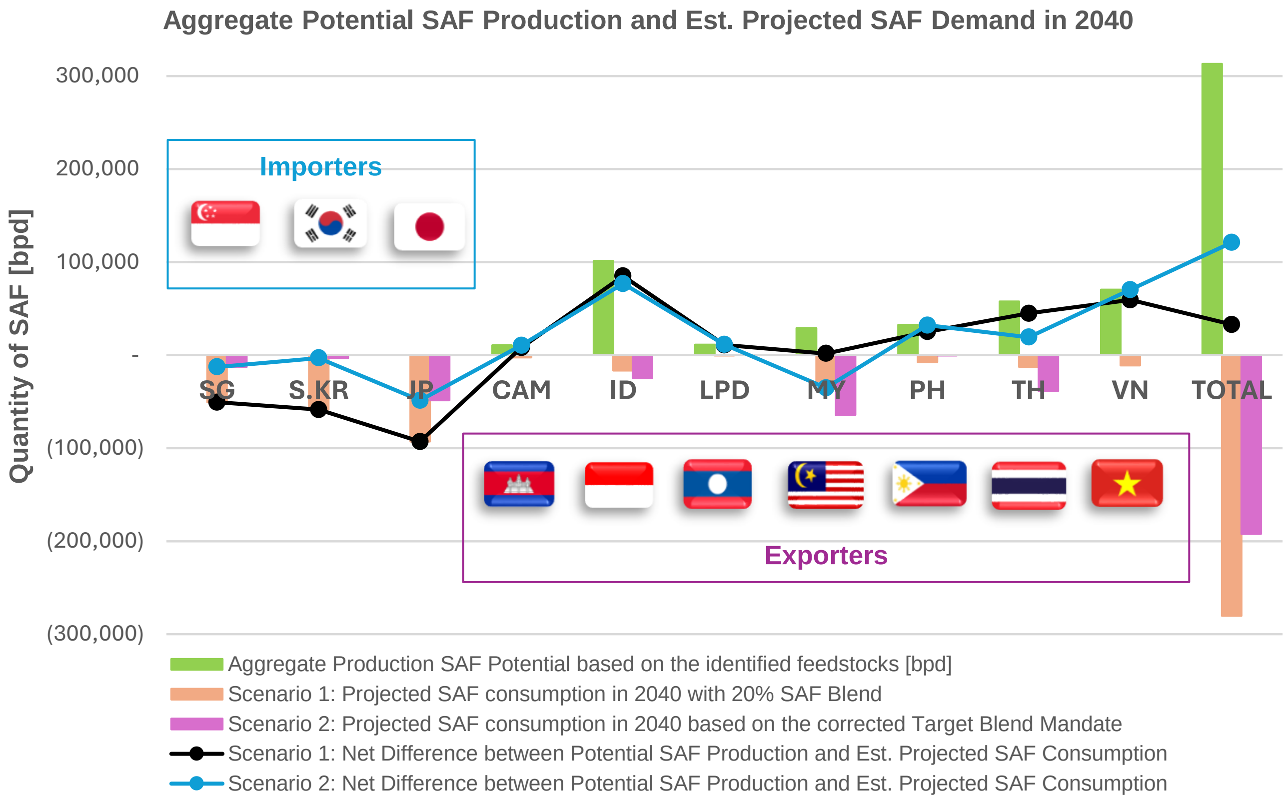


Figure 5.14: SAF Regional Supply – Demand Distribution

As part of the study, a SAF Demand-Supply Analysis was conducted using the projected Sustainable Aviation Fuel (SAF) consumption and production potential in Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Philippines, Singapore, South Korea, Thailand, and Vietnam by 2040 under two different scenarios:

Scenario 1

This scenario assumes that all countries (Cambodia, Indonesia, Japan, Lao PDR, Malaysia, Philippines, Singapore, South Korea, Thailand, and Vietnam) are progressing towards achieving a 20% SAF blend by 2040.

The 20% SAF blend target is derived from the average Target Blend Mandate set by countries that have committed to SAF adoption goals.

Scenario 2

Est. Projected SAF Consumption in 2040 is corrected for different target years of the Target Blend Mandate stated independently by Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, and Thailand. In this scenario, the projected domestic SAF consumption of Cambodia, Lao PDR and Vietnam are assumed to be zero, as there is no SAF Mandate by these nations to date.

Key Assumptions

- The feedstock quantities and potential SAF production outlined in Section 5.2 to 5.8 are assumed to be fully operational by 2040. SAF biorefineries are expected to be developed progressively to align with and maximise the potential SAF production derived from the respective feedstock by 2040.
- Figure 5.14 indicates the supply and demand for SAF in the region, expressed in potential SAF production and est. projected SAF demand in 2040. Acknowledging that Japan, Singapore and South Korea may have their own SAF refineries or future plans for development of SAF refineries for SAF, this has not been accounted for in Figure 5.14.
- Japan, Singapore and South Korea are assumed to be SAF feedstock and/or SAF importers, relying on their neighbouring countries to meet their SAF production and/or SAF demand.

Summary Assessment

- In both Scenarios, there is a possibility of a surplus of Sustainable Aviation Fuel (SAF) within ASEAN, excess supply could potentially be distributed, in region, to other countries, including Australia and New Zealand, Melanesia, Micronesia, and Polynesia or be sold as diesel in regional markets.
- Countries like Cambodia, Indonesia, Lao PDR, Philippines, Thailand, and Vietnam could potentially be SAF exporters due to their excess in SAF after their domestic SAF consumption is considered. Based on the feedstock quantity from the most prominent region within each country (Sections 2 and 5.2 to 5.8), all countries have the potential to be a net SAF exporter. In particular, this includes Indonesia, Malaysia, Philippines, Thailand, and Vietnam. Lao PDR and Cambodia also have a potential of being a net SAF exporter, however as per Sections 2, 5.2 to 5.8, the feedstock availability is relatively low compared to the other assessed countries.
- Under Scenario 1, Malaysia is projected to likely have a surplus of SAF as the country progresses toward achieving a 20% SAF blend by 2040. However, in Scenario 2, Malaysia is anticipated to face a potential SAF deficit, necessitating imports from other member states to meet its domestic SAF consumption requirements.

5. Feedstock and Product Logistics

5.10 Potential SAF Regional Supply Chain: Cost-Distance Scenario

Figure 5.15: SAF Regional Distribution Countries and Key Ports

Key Assumptions

- **Feedstock and SAF Capacity & Demand**: The feedstock quantity and the potential max. SAF capacity as outlined in Sections 5.2 to 5.8 are assumed to only be fully online in 2040. The jet fuel demand by the regions is extrapolated based on the projected CAGR of 4.6%[178] up to 2040. Meanwhile, SAF demand from both SAF importers and exporters is estimated to be proportional to the number of airlines operating at the major airports (e.g., SAF blending facilities or ports) identified in Sections 5.2 to 5.8.
- **Market Behaviour:** It is assumed that a rational market will prioritise sourcing from the lowest cost producer first, followed by the second lowest, third lowest, and so on.
- **Trade Roles:** Each country is classified as either a SAF Importer or Exporter.
  - Japan, Singapore and South Korea are assumed to be SAF feedstock and/or SAF importers, relying on their neighbouring countries to meet their SAF production and/or SAF demand.
  - SAF Exporters such as the Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam are assumed to be distributing their SAF surplus from the SAF blending facilities/Ports (Section 5.2 to 5.9) with the highest SAF surplus after meeting their domestic consumption needs.
  - Lao PDR will export its products via Vietnam, with the international transportation of SAF between the two nations conducted by shipping on the Mekong River. And Vietnam is considered a re-exporter of products originating from Laos.
- **Supply - Demand Balance**: The relationship between production and consumption is defined as: Production - Consumption = Imports - Exports. This implies that there would be no stored inventories of SAF.
- **Regional Trade Isolation:** The region under study does not engage in trade with other regions such as Europe, the Americas, or the Middle East.
- **Uniform Port Costs**: Port freight, handling charges, and customs duties are assumed to be consistent across all countries in the region.
- **Estimated Distance**: The distance assessed for SAF transportation includes the journey from SAF refinery location to the nearest ports and onwards to the demand ports. This computation includes road transport, domestic sea freight and regional sea freight.

5. Feedstock and Product Logistics

5.10 Potential SAF Regional Supply Chain: Cost-Distance (Scenario 1)

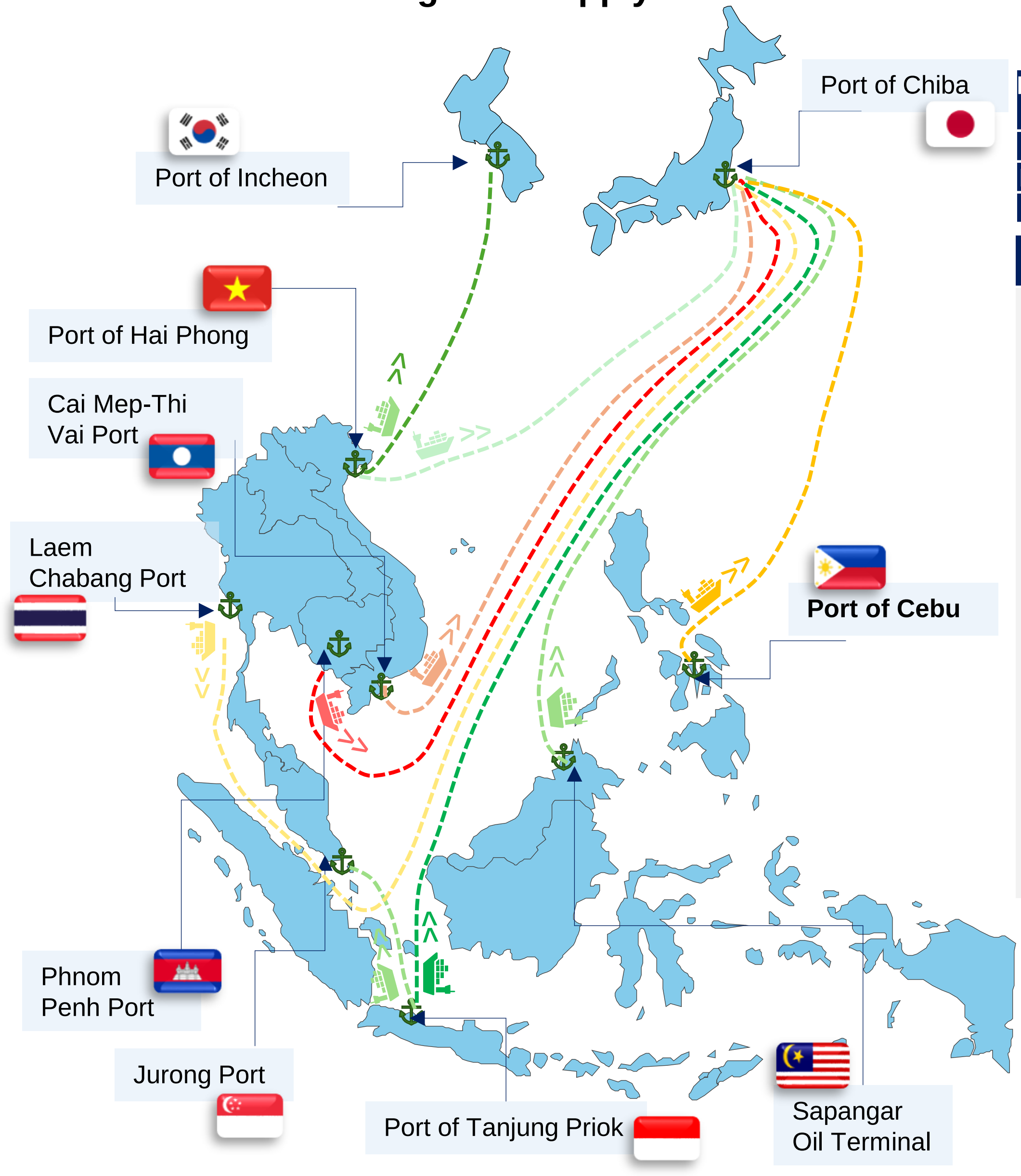


Figure 5.16: Potential SAF Regional Distribution Supply Chain – Scenario 1

Table 5.4: Relative Est. Cost Comparison of SAF Logistics from Refinery to Japan, Singapore and South Korea

Demand\Supply Port	Phnom Penh Port	Port of Tanjung Priok	Cai Mep-Thi Vai Port	Sapangar Oil terminal	Port of Cebu	Laem Chabang Port	Port of Hai Phong
Jurong Port	6	2	5	1	7	3	4
Port of Incheon	6	3	5	1	7	4	2
Port of Chiba	6	3	5	1	7	4	2

Summary Assessment

Considering the cost-distance of SAF produces from the ASEAN Members, it appears the most cost-effective supply chain to distribute SAF to Japan, Singapore and South Korea is from Malaysia, Vietnam and Indonesia respectively. Despite its strategic location, the Philippines is noted to have higher road freight costs than other member states, potentially reducing its competitiveness as a SAF distributor. However, further review and investigation of its road conditions and improvement measures may improve the Philippine's competitiveness as an exporter to the import countries mentioned.

Scenario 1 – Projected 20% SAF Blend in 2040 for all jurisdictions

Considering the surplus SAF and the relative logistics costs (from **cheapest (#1)** to **most expensive (#7)**), the likely SAF supply chain routes for Japan, Singapore and South Korea are as follows:

- Singapore (Jurong Port): import from Indonesia (Port of Tanjung Priok)
- South Korea (Port of Incheon): import from Vietnam (Port of Hai Phong)
- Japan (Port of China): import from Indonesia# (Port of Tanjung Priok), Malaysia (Sapangar Oil Terminal), Vietnam # (Port of Hai Phong), Thailand (Laem Chabang Port), Lao PDR (Cai Mep-Thi Vai Port), Cambodia (Phnom Penh Port) and the Philippines (Port of Cebu)

This study scenario requires selecting a specific point or localised port within the country. The chosen port is selected based on the highest surplus of SAF available after meeting the domestic consumption needs of the nearest major airport. Key feedstocks contributing to the SAF supply chain at these distribution ports have been identified based on their availability in the surrounding areas, and they are:

Country	Feedstock Type	Country	Feedstock Type	Country	Feedstock Type
					
					
					

Note:

- Rankings 1 to 7 indicate cost-effectiveness, with 1 being the most cost-effective supply chain route and 7 being the least across the Demand Ports
- # Indonesia and Vietnam excess SAF surplus after distributing to Singapore and South Korea respectively

5. Feedstock and Product Logistics

5.10 Potential SAF Regional Supply Chain: Cost-Distance (Scenario 2)

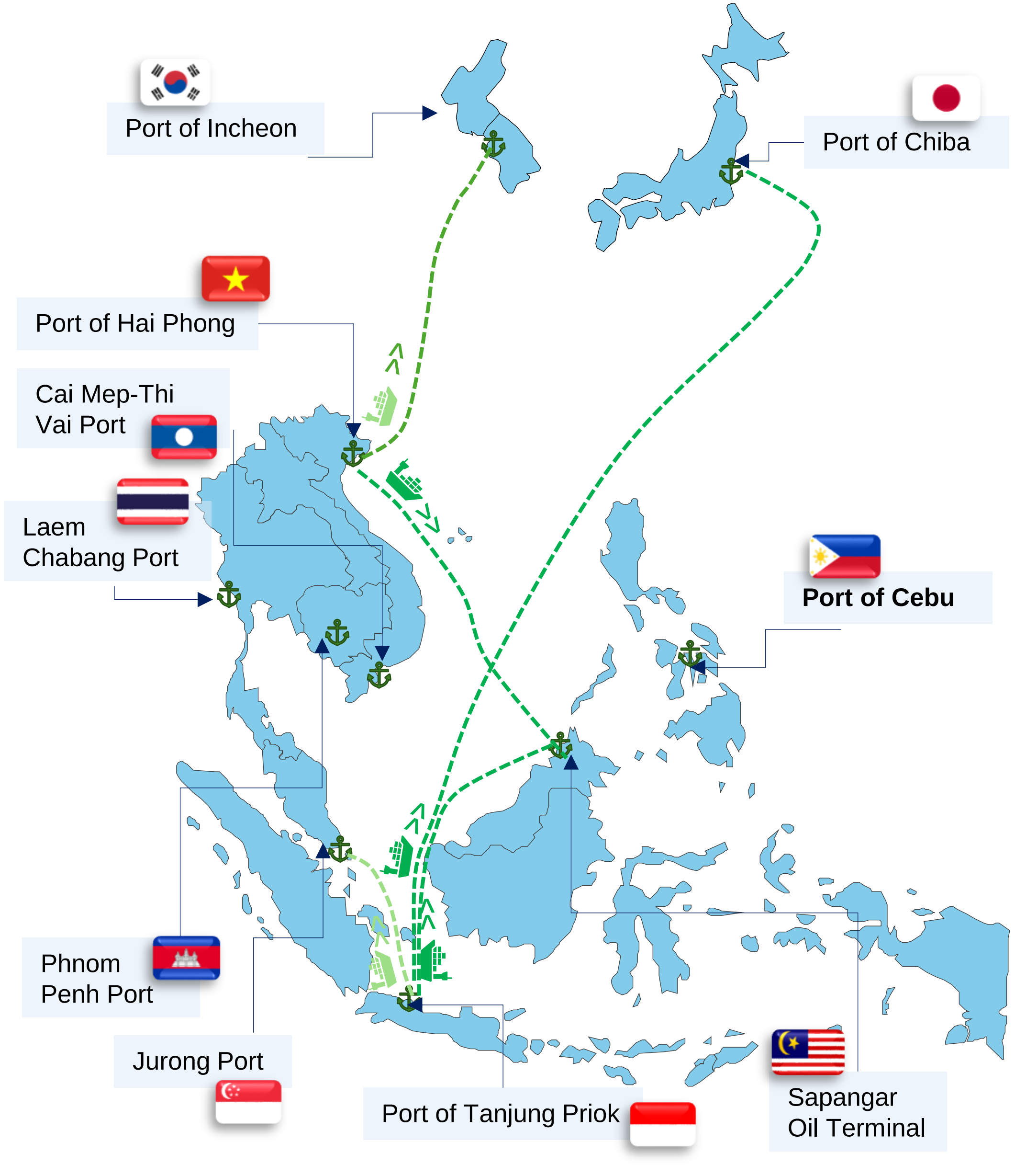


Figure 5.17: Potential SAF Regional Distribution Supply Chain – Scenario 2

Table 5.5: Relative Est. Cost Comparison of SAF Logistics from Refinery to Japan, Singapore and South Korea

Demand\Supply Port	Phnom Penh Port	Port of Tanjung Priok	Cai Mep-Thi Vai Port	Sapangar Oil terminal	Port of Cebu	Laem Chabang Port	Port of Hai Phong
Jurong Port	6	2	5	1	7	3	4
Port of Incheon	6	3	5	1	7	4	2
Port of Chiba	6	3	5	1	7	4	2
Sapangar Oil Terminal	3	1	4		5	2	1

Summary Assessment

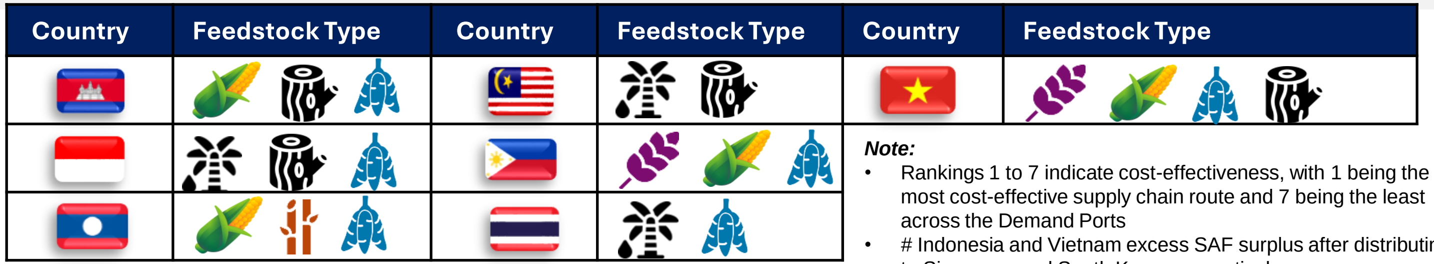
Considering the cost-distance of SAF produced from the ASEAN Members, likewise, it appears the most cost-effective supply chain to distribute SAF to Japan, Singapore and South Korea is from Malaysia, Vietnam and Indonesia respectively. Similarly, despite its strategic location, the Philippines is noted to have higher road freight costs than other member states, potentially reducing its competitiveness as a SAF distributor. However, further review and investigation of its road conditions and improvement measures may improve the Philippine's competitiveness as an exporter to the import countries mentioned. In this scenario, Malaysia is likely to face the SAF deficit for its own domestic consumption and possibly would have to import SAF from either Indonesia (Port of Tanjung Priok) or Vietnam (Port of Hai Phong) since the cost-distance for sea freight is computed to be approximately similar.

Scenario 2 – Est. % SAF Blend based on Corrected Mandate Target Year

Considering the surplus SAF and the relative logistics costs (from **cheapest (#1)** to **most expensive (#7)**), the likely SAF supply chain routes for Japan, Singapore and South Korea are as follows:

- Singapore (Jurong Port): import from Indonesia (Port of Tanjung Priok)
- South Korea (Port of Incheon): import from Vietnam (Port of Hai Phong)
- Japan (Port of China): import from Indonesia# (Port of Tanjung Priok) and Vietnam# (Port of Hai Phong)

This study scenario requires selecting a specific point or localised port within the country. The chosen port is selected based on the highest surplus of SAF available after meeting the domestic consumption needs of the nearest major airport. Key feedstocks contributing to the SAF supply chain at these distribution ports have been identified based on their availability in the surrounding areas, and they are:



Note:

- Rankings 1 to 7 indicate cost-effectiveness, with 1 being the most cost-effective supply chain route and 7 being the least across the Demand Ports
- # Indonesia and Vietnam excess SAF surplus after distributing to Singapore and South Korea respectively

5. Feedstock and Product Logistics

5.11 Regulatory Requirements

Transportation

Domestic Transportation - The regulatory requirements for transporting the biomass are likely governed by in-countries regulations on the size/volume and allowable weight limit by the transportation modes, speed limit, road /sea freight limitations, and domestic infrastructure for example, the load limit on the bridges, roads, and highways.[106]

International Transportation for Biomass Feedstock – phytosanitary regulations may likely to be imposed. When plants and plant products are traded, there is a risk that new plant pests come with them, such as insects, nematodes, bacteria and virus. The regulation aims to prevent the spread of pests and destructive organisms, thus restricting the trade in raw wood products, and instead providing support for trade in processed wood products such as pellets.[107]

In-country regulations on the import and export of oil, and petrochemical products are likely to apply to SAF regional or international trading as well.

Biomass Feedstock Stockpiling

Regulations may not specifically address biomass stockpiling, as it largely depends on process parameters and the quality of the biomass itself. However, there can be regulations governing the storage infrastructure, such as fire-fighting systems, ventilation, health & safety, and drainage. These requirements may vary by country.[107, 108]

As per Section 2 on storage period, there is a limitation on the storage duration of each biomass feedstock type.

While stockpiling is not necessarily regulated, it is important to consider the degradation and loss of energy content over time when storing the biomass feedstock. Prolonged storage without proper infrastructure can potentially lead to issues like feedstock wastage, moisture buildup, decomposition, and safety hazards such as fire risks and the release of toxic gases and leachates.[109]

5. Feedstock and Product Logistics

5.11 Regulatory Requirement

Trade Agreement

Within ASEAN members, Common Effective Preferential Tariff (CEPT) schemes for a gradual reduction and elimination of intra-regional tariffs within the ASEAN, on the level of sensitivity of products to the respective ASEAN Member States domestic industry[171]. Since the exchange of CEPT concessions is based on reciprocity, the size of the inclusion list by a Member Country indicates the coverage of those concessions that it would be eligible to receive.

The ASEAN and Korea Free Trade (AKFTA) [173] and ASEAN-Japan Comprehensive Economic Partnership (AJCEP) [172] scheme is present between ASEAN and Korea and Japan.

SAF does not appear to have been explicitly mentioned as a product listed [173], however, can potentially be considered to be included as part of the list.

Based on the demand-supply and cost-distance review in Section 5.10 on the regional supply chain, countries such as Indonesia and Vietnam may consider establishing a Free Trade Agreement (FTA) with Japan and South Korea respectively for SAF distribution due to market demand, supply chain efficiency and cost competitiveness. These countries could negotiate the pathway intended for the SAF distribution.

The establishment of Green Trade Lane or Green Corridor in Southeast Asia appears feasible, given the alignment of key countries in the region with the International Maritime Organization's (IMO) GHG Emission Goals, existing policies, and ongoing initiatives to promote sustainable shipping[163,165] where some of the ports (e.g. Port of Tanjong Priok and the Port of Benoa [165], Penang Port, Port Klang and Port Tanjung Pelepas[166]) have been identified to green ports and / or pilot port for Green Corridors[170].

Table 5.6: Policies and Initiatives of Green Port in ASEAN, South Korea and Japan[169]

Country	Green Port Policies/Initiatives	Themes
Indonesia	Ministry of Transport Decree No. 8 of 2023 and MARVES Green Port Certification [165]	-. Reduce fuel consumption -. Increase energy efficiency -. Adopt clean fuel -. Utilise renewable energy.
Malaysia	JPA Green Port Policy	
Philippines	Port Environmental Policy	
Thailand	PAT Green Port Plan	
Vietnam	Vinamarine Green Port Criteria	
Singapore	Green Port Program and Maritime Singapore Decarbonisation Blueprint: Working Towards 2050	
South Korea	Special Act on the Improvement of Air Quality in Ports and Other Areas	
Japan	MLIT Carbon Neutral Port Initiative and Port of Tokyo CNP Implementation Plan	

5. Feedstock and Product Logistics

5.12 High Level Review on Feedstock Logistic Options

Harvesting Techniques	Cost	Employment	Sector Efficiency	CO2 Emission
Mechanised	Generally, it involves higher initial capital investment due to the cost of machinery and maintenance. However, it can lead to lower operational costs over time due to increased efficiency and reduced labour costs.	Reduces the need for manual labour, potentially leading to job losses in rural areas. However, it can create jobs in machinery operation, maintenance, and manufacturing sectors.	It is more efficient in terms of the speed and volume of biomass harvested and can cover larger areas in a shorter time, leading to higher productivity.	It may lead to higher CO_2 emissions due to the use of fossil fuels in machinery. However, advancements in technology are leading to more fuel-efficient and even electric machinery, which can reduce emissions.
Manual (e.g. by hand, simple hand-tool, low-level technology such as sickle, bulldozer)	Lower initial investment as it relies on human labour. However, operational costs can be higher due to the need for more labour over time.	Provides more employment opportunities, especially in rural areas where job creation is crucial. It supports local economies by employing a larger workforce.	Less efficient compared to mechanised methods. It is slower and may not be able to handle large-scale operations as effectively.	Generally, it may have lower CO_2 emissions as it relies on human labour rather than machinery.
Summary	Mechanised harvesting is likely to be more cost-effective in the long run but may require higher initial investment. Manual harvesting has lower initial costs but can potentially lead to higher operational costs.	Manual harvesting supports more jobs, especially in rural areas; mechanised harvesting can lead to job losses but may create opportunities in other sectors with higher skill requirements.	Mechanised harvesting is more efficient and productive. Manual harvesting is less efficient and slower.	Mechanised harvesting can have higher emissions, but advancements in technology are improving this. Manual harvesting has lower emissions. However, the overall impact depends on the scale of operations and the transportation methods used.

5. Feedstock and Product Logistics

5.12 High Level Review on Feedstock Logistic Option

Pre-processing Location	Cost	Employment	Sector Efficiency	CO2 Emission
At SAF Biorefinery Facility (Centralised)	The initial investment can be high due to the need for a large-scale infrastructure to pre-process the biomass feedstock from the farm. However, the operation cost is potentially lower due to economies of scale and a centralised management.	Fewer jobs created locally; However, more specialised job opportunities can be made available at the biorefinery. These jobs will require higher skill levels for operating more advanced machinery and larger scale operation.	Centralised pre-processing generally leads to higher efficiency with better resource management. However, there may be a need for a larger biomass stockpiling infrastructure. A more complex logistics for transporting the biomass feedstock may be required, due to its bulkiness.	A higher emission is likely due to a higher number of road freight required to transport the bulky biomass feedstock.
At Farm (Distributed: Hub and spoke type)	Investment cost may be lower due to smaller and localised facilities. However, the operational cost can be high due to multiple pre-processing facilities.	More job opportunities can be available locally, hence supporting the local economy. The jobs creation can be more accessible a broader workforce as the skill level requirement may potentially be lower.	Smaller-scale operations may lead to lower efficiency and potential inconsistencies in the pre-processing quality of the biomass feedstock. When pre-processing the biomass closer to the source, less heavy-duty transport may be required.	A lower emission is potentially expected from the transport of pre-processed biomass feedstock due to higher density of biomass to be transported.
Summary	Centralised facilities have higher initial costs but lower operational costs. Decentralised facilities have lower initial costs but higher operational costs.	Centralised facility may create few, but more specialised job. While, decentralised may create jobs in rural areas.	Centralised facility is relatively more efficient but may have more complex logistics. Decentralised facility is less efficient but could have simpler logistics.	Centralised facility may have higher emissions due to transportation, which it likely to have a higher number of trucks to transport the bulky biomass feedstock from the farm to the facilities.

5. Feedstock and Product Logistics

5.12 High Level Review on Product Logistic Options

Product Logistic	Cost/Investment	Employment	Sector Efficiency (Supply Chain Flexibility)	CO2 Emission
Road Freight	Lower initial investment as it relies on the existing road infrastructure and tanker truck. However, the operating cost may be higher due to fuel, maintenance, and labour for the road freight.	Higher employment opportunities for truck driver, maintenance and logistics. The job creation is likely to be of moderate skill levels, such as for driving and maintaining the trucks.	Higher flexibility as trucks deployed can be scaled up/down and rerouted easily to meet the changing demand and supply conditions.	Although bio-fuel or EV fleets may be considered, it may likely have a higher emission overall.
Pipeline Distribution	Higher initial investment from the cost of constructing the pipelines. However, once the infrastructure is in place, there may be lower operational cost.	Higher at the beginning due to the construction work; however, lower during the operational stage. It likely create higher skill levels jobs for the pipeline construction, monitoring and maintenance.	Lower flexibility as the pipelines are fixed and cannot be easily rerouted.	Likely to have a lower emission. Electric pumps and renewable energy sources can be used.
Summary	Road freight tends to have lower initial investment cost, but a higher operational cost. Whereas, the pipeline distribution will likely have a higher initial investment cost, but a lower operational cost.	Road freight creates more jobs with moderate skill requirements, while pipeline distribution creates fewer, higher-skilled jobs.	Road freight offers higher flexibility and easier scalability, while pipeline distribution provides lower flexibility.	Road freight may potentially have higher emissions, while pipeline distribution has lower emissions.

6. Environmental and Social Aspects

GHD Advisory

→ Environmental and Social Aspects Overview

Environmental and Social Aspects

6.1 Environmental and Social (E&S) Aspects Overview

Despite the potential gains in emission reduction, SAF presents both risks and opportunities for communities and the environment. There are common issues to be addressed, but local context is critical. Sustainability must consider all aspects from the supply chain to the end use and integrate E&S into all stages of planning, design and operations. In this section an overview of the feedstock sources, labour issues, environmental impacts, gender equity, social impacts and supply chain from an environmental and social risks and opportunities perspective were covered.

Feedstock Source

Diverting feedstocks to SAF may:

- Displace local livelihoods.
- Stimulate additional demand with unintended consequences on land use, biodiversity, and displacement of food production and food security.
- Export nutrients from soil systems, and increase runoff where agricultural waste is otherwise left in-situ.

Feedstock source (particularly forestry) would need to be obtained from legitimate sources.

Utilizing residue can:

- Reduce air pollution and health risks.
- Stimulate local economic development, training and jobs, particularly in rural areas.

Labor Issues

Each country has different labour laws and protections. However, workers in the agricultural sector often face lower wages and more job insecurity. SAF supply chain can consider ways to strengthen labour protections and provide secure and safe workplaces.
The SAF sector provides opportunities for up-skilling through training and employment.

Environmental Impacts

Environmental Impact Assessment for bio-refineries or blending facilities must consider:

- Water use.
- Biodiversity risks.
- Soil and land.
- Pollution risks.
- Waste and hazardous waste.
- Noise emissions.
- Air emissions.

EIA should consider potential impacts from the supply chain, transport, processing, storage and end-use.

Consider local laws and regulations, but also global good practice.

Gender Equity

Women and girls face different challenges in each country. Considerations include access to technical training, perceptions of roles, leadership and decision-making equity, or challenges such as childcare or gender-based violence and sexual harassment. A SAF industry based on equity can lift women and girls from poverty and change the landscape of opportunities.

Social Impacts

SAF can provide jobs and economic benefits. However, risks must also be considered including:

- Loss of livelihoods.
- Loss of access to land.
- Impacts on cultural heritage.
- Impacts on Indigenous groups.
- Potential for exploitation.

Considering opportunities for those most impacted is important, including upskilling and employment for those whose livelihoods may be impacted.

Supply Chain

To provide environmental protection, community well-being, and sustainability in the SAF supply chain, certification schemes are recommended, which must comply with the CORSIA sustainability criteria, verified by third-party certification bodies designated by ICAO—The Roundtable on Sustainable Biomaterials (RSB), the International Sustainability and Carbon Certification (ISCC), and the ClassNK (newly approved by ICAO) offer standards that cover the entire SAF production process. These certifications support that SAF production does not harm ecosystems, respects human rights, and supports local economies.

For SAF to be *sustainable*, risks and opportunities must be addressed from the outset, avoiding a redistribution of environmental burdens, and understanding how agricultural waste (potential feedstock) is currently being used. Collaboration is key. Community voices need to be part of planning and design processes. Robust CORSIA certification programs can provide certainty that SAF provides a better future for all.

GHD Advisory

→ Environmental and Social Aspects Deeper Dive

6. Environmental and Social Aspects

6.2 Cambodia Environmental and Social Aspects

	Cassava	Rice	Corn	Other Agricultural Residues	Forestry
Overview of feedstocks from environmental and social perspective	In Cambodia, cassava waste, especially peel and root debris, is commonly repurposed as animal feed or fertiliser. The National Biodigester Program encourages the use of cassava waste for biogas production. When considering the potential for SAF production using cassava waste, it is crucial to assess the most effective and sustainable utilization and avoid unintended displacement of feedstock from existing businesses.	In Cambodia, rice waste is commonly used as animal feed ,[181] fertiliser, and for biogas production.[182] However, a significant portion is also burned, contributing to air pollution.[270] Utilizing this waste stream for SAF could help minimise the waste and associated impacts.	In Cambodia, corn waste is used as animal feed, composted for soil fertility, or converted into biogas and bio-energy, though the latter is less common.[183] Corn waste is also commonly burned in-situ in fields. Diverting corn waste for SAF requires careful consideration to minimise displacement of existing applications. Assessing the most effective use and environmental and social benefits of each alternative should inform decision making.	While specific statistics on other agricultural wastes is limited, it is known that a significant portion of these residues is often burned in fields. This practice contributes to air pollution, greenhouse gas emissions, and negatively impacts soil health.[184] Creating a viable end use through SAF may help mitigate this practice and the associated impacts.	In Cambodia, sawmill waste is primarily used for energy production, wood products, and as animal bedding or mulch.[185] When considering its potential for SAF production, it is crucial to account for these existing applications to ensure the most effective and sustainable utilization of the resource.
Current Resource Utilization	When considering feedstocks, **local community context and risks must be considered**. Diverting feedstocks may displace local livelihoods or stimulate additional demand that can have **unintended consequences** on land use, biodiversity, and displacement of food production impacting food security. Utilizing residue can reduce air pollution and health risks but exports nutrients from soil systems (compared to de-composition in-situ). In Cambodia, agricultural waste is commonly repurposed for animal feed, fertiliser, energy production, and biogas, though some wastes are burned, contributing to pollution.				
Regulatory Context	The **Environmental Protection and Natural Resources Code** establishes rules for environmental protection, conservation, and sustainable development, including guidelines to manage the environmental impacts of biofuel production. Particularly the protection of biodiversity. For a biofuel production project to commence, it must undergo an **Environmental Impact Assessment (EIA)** to evaluate potential impacts and propose mitigation measures.[274] Principles that must be considered as part of the EIA include sustainable development, avoiding harm to the environment and natural resources, public participation, environmental information, the polluter pays principle, user pays principle, precautionary principle, reduction or prevention of environmental harm, evidence-based decision making, public interest, and environmental integration.[185] The allocation of land for biofuel crops in Cambodia **must consider the impact on food production and local communities** to prevent food insecurity and displacement. The **National Bio-energy Policy** emphasises sustainable practices and involves local communities in decision-making processes for biofuel and rural renewable energy development.[187]				

6. Environmental and Social Aspects

6.2 Cambodia Environmental and Social Aspects

Environmental Risks & Opportunities	
Water	Cambodia's water resources are heavily reliant on the Mekong River and the Tonle Sap Lake, which are crucial for the country's hydrological system, agricultural outputs and fishing resources for livelihoods and subsistence (noting that aquaculture is a major pillar of the economy). The water bodies in Cambodia also have cultural significance. Water resources are under strain due to population growth and industrialization, with growing demand and lack of safeguards leading to decline in quality and quantity. The country faces challenges from sedimentation, pollution, and limited water resource management. Challenges are exacerbated through seasonal variations, with periods of both water surplus and shortage that are intensified in a changing climate. [188] SAF production requires significant water resources from growing crops to processing steps such as washing the feedstock and cooling. This can strain local water resources and lead to potential disputes, especially in regions already facing water scarcity. EIA work should account for the increased water demand and the effects on local communities.
Biodiversity	Cambodia boasts one of the richest systems of ecological diversity in Southeast Asia, with diverse ecosystems including the Central Indochina dry forests, the moist forests of Cardamon Mountains and the Annamite Range, and the Mekong freshwater ecoregion. This biodiversity is critical not only to natural systems, but also to local livelihoods and well-being; yet biodiversity in Cambodia faces significant threats. Deforestation, illegal logging, land clearance for agriculture, urban sprawl, and infrastructure development are major challenges. [189] While there are significant biodiversity conservation efforts in Cambodia, the threats and pressures need to be met with increased resources, strengthened management planning, community participation for conservation of protected areas, and capacity building for enforcement of laws. Utilizing agricultural waste for SAF has limited implications for biodiversity. However, creating feedstock demand may inadvertently lead to land conversion, affecting ecosystems and increasing existing pressures on biodiversity.
Soil & Land	Cambodia faces significant land degradation, costing about 8% of its GDP annually. Efforts to combat this soil degradation include research, fieldwork and education in conservation agriculture using methods such as cover crops for soil health, no till planting, land levelling and breaking hardpan soils, and green sowing techniques. Research initiatives by organizations such as the Cambodian Conservation Agriculture Research for Development Center (CARDEC) are crucial to improving soil health and achieving land degradation neutrality by 2030. [190] In SAF production, harvesting biomass residues can deplete soil organic matter and nutrients, affecting fertility and erosion prevention. Sustainable supply chains should consider improved farming practices to mitigate these impacts, with potential to partner with leading agricultural institutions to implement improved farming practices.
Air & Noise Emissions	Cambodia faces significant air pollution challenges, with the country ranking 37th out of 134 countries in terms of air quality. [192] Recognizing this, Cambodia has taken significant steps under the Clean Air Plan of Cambodia adopted in 2022 with a multi-sector approach to change. Agricultural waste management, particularly from practices like burning rice straw and other crop residues, significantly contributes to air pollution. [191] Information dissemination to reduce slash-and-burn practices and reduce burning of agricultural waste are part of the measures to restore air quality. Using crop residues for SAF production can reduce local air pollution and associated health impacts. However, noise and air emissions from transport and processing, including VOCs and particulates, must be considered in the impact assessment and mitigation measures.
Pollution & Waste	Cambodia's waste management infrastructure faces significant challenges due to rapid urbanization and population growth coupled with limited investment in waste management infrastructure. Waste collection services are available in 86% of cities and towns, but many rural areas lack proper waste services. [193] In urban areas like Phnom Penh, waste collection has improved, but facilities like the Dangkor landfill are already over capacity. SAF production generates wastewater and processing residues. Waste reduction, reuse and safe disposal of feedstock residues, processing by-products like char and ash, wastewater treatment sludge, and catalyst waste, must be considered given the waste management limitations in Cambodia's rural areas.

6.2 Cambodia Environmental and Social Aspects

Social Risks & Opportunities	
Social	Agriculture remains a vital part of Cambodia's economy, employing around 31% of the total workforce. [194] However, the sector faces several challenges, including a notable shortage of agricultural labor due to migration to urban areas and other sectors offering higher wages and the seasonal nature of many agricultural jobs, which leads to periods of unemployment or underemployment for rural workers. [195] The SAF sector, particularly production from agricultural and forestry waste may pose opportunities and challenges. The challenges include potential for SAF production to compete for land and water resources due to unintended consequences of allocating land for biofuel crops, creating food insecurity and potential displacement of livelihoods and traditional industries. This risk is signficant, particularly if local communities are not adequately involved or compensated. Opportunities include economic benefits, creating jobs and livelihoods in agriculture, manufacturing and ancillary industries such as transport. Investments in SAF infrastructure can lead to improved local infrastructure and services, benefiting communities. By tapping into the regional and global SAF market, Cambodia can attract foreign investment and boost its economy whilst reducing dependency on imported fossil fuels. Efforts to develop SAF production must balance these factors to ensure sustainable and equitable growth. Careful planning and inclusive policies that embed human rights and local development are fundamental to sustainability.
Gender	Gender equality in Cambodia's employment landscape has seen some progress, but significant challenges remain. Women face a persistent gender employment gap, characterised by less access to work opportunities, more vulnerable employment, and lower wages compared to men. [196] Women still experience pervasive discrimination and lack of social protection in most aspects of their employment and work. Less total years of schooling for women and a quantitative difference between men and women in literacy constrain women's participation in the labor market. Women also bear a disproportionate burden of unpaid domestic and care work, limiting their access to education, training, and financial services. In the agriculture sector, women play a crucial role making up a significant portion of the workforce, but they often have limited opportunities due to poor pay and conditions, work insecurity and imbalanced workloads due to seasonality and fluctuating demands. [197] Women own less land than men and are disadvantaged through inheritance laws, land titling systems, and their ability to purchase land. They are less likely to receive agricultural training, are underrepresented in management and professional roles and face a notable gender pay gap. Efforts like the Gender Mainstreaming Policy and Strategic Framework in Agriculture Sector (GMPSFAS) 2022-2026 aim to promote gender equality and improve women's recognition and benefits in the agricultural sector. [198] In the energy sector, women are also underrepresented, particularly in higher-paying and secure jobs. [199] To improve social outcomes, SAF initiatives can make a significant difference to opportunities for women through setting targets, providing training opportunities, and addressing constraints in the workplace.

6.2 Cambodia Environmental and Social Aspects

Table 6.1 provides a summary of the stakeholders involved in the SAF value chain in Cambodia. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

In developing or expanding SAF industries, effective engagement is fundamental to improving social and environmental outcomes and reducing risk of harm. A detailed stakeholder identification process at a local level is required, followed by meaningful and inclusive engagement to understand and mitigate risk and harness opportunities attuned to local aspirations.

Table 6.1: Summary of high-level stakeholders in Cambodia

Stakeholder	Entity
Biomass Growers and Landowners	Smallholder farmers, Agribusiness companies; (Battambang Province of Cambodia has been identified with the highest potential biomass feedstock for SAF)
SAF Facilities	MH Bio-Energy Group
Major Airports	Phnom Penh International Airport, Sieam Reap – Angkor International Airport, Sihanoukville International Airport
Major Airlines	Lanmei Airlines, Cambodia Airways, Sky Angkor Airlines
NGOs and Related Organizations	Cooperation Committee for Cambodia (CCC) GERES: French NGO that runs biomass and farming resilience projects
Financial Institutions	IFC: Collaborates with the Association of Banks in Cambodia to boost green finance and support sustainable growth National Bank of Cambodia: Partners with IFC to create a supportive financial ecosystem for green projects ACLEDA Bank and Canadia Bank: Major commercial banks that can provide financing for green projects, including those related to biomass and SAF.
State-owned Companies	Council for the Development of Cambodia (CDC): Grants Qualified Investment Project (QIP) status to significant green projects, such as BECIS' biomass plant project

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6. Environmental and Social Aspects

6.3 Indonesia Environmental and Social Aspects

	Oil Palm	Rice	Sugarcane	Other Agricultural Residues	Forestry
Overview of feedstocks from environmental and social perspective	Oil palm fruit residues are commonly used for local bioenergy, biogas, fertiliser, and animal feed. Utilizing it for SAF requires careful consideration of these existing applications to ensure the most effective use of resources in Indonesia [209].	Burning rice straw is a common practice in Indonesia resulting in air pollution and emissions. Repurposing it for SAF can help divert some of these residues to more beneficial uses[210].	Utilizing sugarcane residue for SAF can help reduce waste in some areas. However, this may not be feasible everywhere, as the residue is also used for local energy generation by sugar mills [211].	In Indonesia, agricultural residues are most commonly burned or composted. To utilise it for SAF, it is essential to consider these existing applications to ensure the most effective and sustainable use[212].	In Indonesia, sawlog waste is frequently landfilled or burned, leading to air pollution and emissions. Repurposing it for SAF can mitigate these effects, but it should be balanced with new applications such as biochar production and biocomposites[199].
Current Resource Utilization	When considering feedstocks, **local community context and risks must be considered**. Diverting feedstocks may displace local livelihoods or stimulate additional demand that can have **unintended consequences** on land use, biodiversity, and displacement of food production impacting food security. A significant proportion of oil palm fruit is wasted (up to 40%). Sugarcane trash, coconut husks and agricultural residue is often left in-situ or burned. Utilising this residue can reduce air pollution and health risks but exports nutrients from soil systems.				
Regulatory Context	The **Environmental Protection and Management Law 2009 and Regulation No 22 of 2021** provide environmental protections and an environmental approval framework. However, implementation can be inconsistent due to limited capacity and resourcing, and economic pressures. To improve environmental impacts in the oil palm industry, companies and smallholders operating in Indonesia must obtain **ISPO certification by 2025**. ISPO covers criteria like **GHG emissions, land use, biodiversity, and labor**. As of 2022, 918 ISPO certificates were issued, with **97% for companies and 3% for smallholders**, covering 3.6 million hectares or about 22% of total palm plantations [213]. The EU's Renewable Energy Directive III (RED III) **does not accept SAF made from palm oil due to its high carbon intensity**, often exceeding that of conventional jet fuel. This is mainly due to significant emissions from land use changes for palm oil cultivation. Aligning domestic SAF certification with CORSIA would ensure broad market access for Indonesian SAF.				

6. Environmental and Social Aspects

6.3 Indonesia Environmental and Social Aspects

Environmental Risks & Opportunities	
Water	Water is used during the **conversion of feedstock into SAF** and during **blending with conventional jet fuel**. SAF production **requires substantial water resources** for crop cultivation. Expansion of existing plantations, especially for oil palm can increase pressures on water resources. Overuse of water can lead to depletion of local water sources, affecting ecosystems and communities. Indonesia has significant renewable water resources, but they are unevenly distributed. Regions such as Sumatra, Kalimantan, and Papua have abundant freshwater, whereas densely populated islands like Java experiences water scarcity[214]. Additionally, biofuel feedstock operations, especially palm oil plantations, have caused water-related issues like land clearing, erosion, runoff, and pollution from palm oil mill effluent (POME)[215].
Biodiversity	Indonesia is **one of 17 mega-diverse countries** in the world, hosting 17% of the world's wildlife [215], including a significant number of endemic species. However, the country also has one of the highest rates of deforestation in the world, primarily driven by expansion of palm oil, agriculture and logging [216]. While there is limited direct biodiversity impact of SAF derived from waste residues, there is a risk that expanding SAF production will drive further land clearance and exacerbate biodiversity loss.
Soil & Land	In Indonesia, deforestation for agriculture, especially palm oil, causes severe soil erosion and biodiversity loss. Additionally, intensive farming in the country without proper soil management, coupled with extensive slash-and-burn agriculture further degrades land, diminishing its productivity. Rapid urban expansion into agricultural and forest areas also presents significant challenges, resulting in extensive habitat loss and increased soil erosion [217]. Apart from land conversion, harvesting biomass residues for use as SAF feedstock **can lead to the depletion of organic matter and soil nutrients**, thereby affecting soil fertility. Without proper soil management practices, these factors collectively contribute to diminished land productivity.
Air & Noise Emissions	Agricultural practices for biofuel feedstock, particularly the open burning of crop residues, significantly contribute to air pollution in Indonesia [218]. Additionally, the expansion of oil palm plantations has caused significant deforestation, further exacerbating air pollution [219]. In Indonesia, it is estimated that about 21% of crop residues [220] are subjected to open burning. In areas where biomass burning is still prevalent, including for rice straws, **utilizing residues for SAF may help reduce air emissions and the associated health impacts**. However, in some local studies in Indonesia, **odors from bio-digesters and noise from machinery** have been reported as environmental issues in biogas plants.
Pollution & Waste	In Indonesia, most waste is disposed of in landfills, with open dumping and controlled methods being prevalent. Many regions lack sufficient waste management infrastructure, resulting in improper disposal and environmental contamination. Although the government has introduced policies to enhance waste management, such as waste segregation and extended producer responsibility, challenges remain [221]. During SAF production**, wastewater containing processing residues is generated**. **Biogas leakage** can contribute to both global warming and atmospheric pollution. Disposal of solid waste such as spent biomass, filter materials and by-products must be considered along with safe handling and disposal of chemical waste.

6.3 Indonesia Environmental and Social Aspects

Social Risks & Opportunities	
Social	The biofuel industry in Indonesia has created jobs and alleviated poverty, but it also grapples with labor rights issues [222]. Workers on palm oil plantations frequently endure poor conditions, low wages, and weak enforcement of labor rights. Addressing these issues is essential for ensuring fair labor practices and sustainable biofuel production. **Adverse perceptions of technology and insufficient knowledge and skills** create barriers to biofuel adoption, compounded by cultural factors such as religious beliefs and stigmatization. Low literacy levels further impede awareness, influencing adoption rates across Indonesia's diverse regions due to varying cultural norms. **Resource constraints limit government initiatives for biofuel adoption, and centralised systems may discourage private investment**. To overcome these challenges, clear policies, robust industry support, and effective public-private cooperation are crucial for successfully disseminating biofuel technology nationwide. In terms of gender, particularly in agriculture, **women farmers often have restricted access to inputs, labor, and extension advice**, leading to lower productivity. Women face wage disparity and limited access to leadership positions, and violence against women remains a significant issue [218]. To develop the SAF sector in Indonesia within a framework of benefits and development for all, social inclusion needs to be considered, with community dialogue providing a potential pathway for improved outcomes.
Gender	Women in Indonesia are entitled to equal employment opportunities, including equal pay, paid maternity leave, and protection against gender discrimination, but they still face challenges such as wage disparities and underrepresentation in leadership roles. The country is addressing gender disparities through policies like the ISPO certification, capacity-building programs for women in the renewable energy sector, and gender-responsive measures in its NDC implementation roadmap. Currently, specific gender-disaggregated data for the SAF industry is limited. However, women play a significant role in the **agricultural sector**. According to the 2018 Agriculture Census, approximately 49% of agricultural households are composed of women farmers [223]. In the **energy sector**, a 2019 survey indicated that women hold 9% of leadership positions in the country [208]. Some efforts to improve the gender situation are outlined below: • **Policy**: Efforts are underway to address gender disparities through policies and certification standards such as the Indonesian Sustainable Palm Oil (ISPO) certification, which includes gender-related criteria. • **Capacity Building**: Various training programs aim to empower women with the skills needed to participate in the renewable energy sector. • **Action Plan**: Indonesia’s Nationally Determined Contributions (NDCs) implementation roadmap includes gender-responsive energy policies.

6. Environmental and Social Aspects

6.3 Indonesia Environmental and Social Aspects

Table 6.2 provides a summary of the stakeholders involved in the SAF value chain in Indonesia. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

For logistical details, including distances between entities and available transportation options, which may provide insights into potential environmental impacts, please refer to Section 5.

Table 6.2: Summary of high-level stakeholders in Indonesia

Stakeholder	Entity
Biomass Growers and Landowners	Large agribusinesses (e.g., Sinar Mas Agribusiness for oil palm, Wilmar Internation for oil palm), smallholder farmers, forestry companies (e.g., APP, APRIL), community and cooperative groups, government-owned enterprises (e.g., Perum Perhutani).
SAF Facilities	RU II Dumai Refinery (Oil Palm, Forestry), RU III Green Plaju Refinery (Cassava), RU IV Cilacap Green Refinery (Rice, Sugarcane, Maize).
Major Airports	Soekarno-Hatta International Airport, Ngurah Rai (Bali) International Airport, Juanda International Airport.
Major Airlines	Garuda Indonesia, PT Pertamina.
NGOs and Related Organisations	CIFOR: focuses on forest conservation and sustainable agriculture. Rikolto: an international NGO working with smallholder farmers to promote sustainable agriculture. Aliansi Organis Indonesia: an organisation that promotes environmental protection along with improved agricultural productivity.
Financial Institutions	ADB, Bank Indonesia, Indonesia Investment Authority (sustainable infrastructure projects, including those related to renewable energy and SAF)
State-owned Companies	PT Pertamina (heavily involved in the production and development of SAF, including the SAF J2.4 blend), Garuda Indonesia

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6. Environmental and Social Aspects

6.4 Lao PDR Environmental and Social Aspects

	Cassava	Rice	Sugarcane	Other Agricultural Residues	Forestry
Overview of feedstocks from environmental and social perspective	Cassava residues in Lao PDR are often burned or discarded leading to air pollution. Repurposing it for SAF can help divert the waste and its associated impacts. This can be balanced with emerging uses in the country like production of bio-plastics[3].	Burning rice straw is a common practice in Lao PDR resulting in air pollution and emissions. Repurposing it for SAF can help divert some of these residues to more beneficial uses [221].	Sugarcane residues, like leaves and tops, are often burned in-situ, causing air pollution. Repurposing them for SAF can mitigate this waste and its impacts, but must be balanced with their current use for energy production in some sawmills [222].	In Lao PDR, agricultural residues are most commonly burned or composted. To utilise it for SAF, it is essential to consider these existing applications to ensure the most effective and sustainable use [221].	In Lao PDR, sawlog waste is frequently landfilled or burned, leading to air pollution and emissions. Repurposing it for SAF can mitigate these effects, but it should be balanced with new applications such as biochar production and biocomposites[225].
Current Resource Utilization	When considering feedstocks, **local community context and risks must be considered**. Diverting feedstocks may displace local livelihoods or stimulate additional demand that can have **unintended consequences** on land use, biodiversity, and displacement of food production impacting food security. Utilizing residue can reduce air pollution and health risks but exports nutrients from soil systems.				
Regulatory Context	The **Decree on Environmental Impact Assessment (EIA)** provides the guidelines for evaluating potential beneficial and adverse impacts on the social and natural environment caused by various projects, including biofuel initiatives. The **Environmental Protection Law**, initially issued in 1999, sets principles, rules, and measures for managing, monitoring, restoring, and protecting the environment. There is a lack of environmental data and inadequate planning procedures in Laos, which can affect the quality and effectiveness of the EIA process. Limited public participation can also reduce pathways for local input to strengthen environmental and social protections[230].				

6. Environmental and Social Aspects

6.4 Lao PDR Environmental and Social Aspects

Environmental Risks & Opportunities	
Water	Lao PDR has abundant water resources, mainly from the Mekong River, but faces challenges including contamination from chemicals and human waste[234], as well as climate change impacts like floods and droughts. The government's promotion of hydropower investment also adds further pressure on these water resources[235]. Water is critical throughout the process of converting feedstock into SAF and blending it with conventional jet fuel. Cultivating feedstocks like sugarcane or cassava requires substantial water resources, risking local water source depletion and impacting ecosystems and communities. [2186] Some areas in the country face water shortages, which can be exacerbated by prolonged droughts and changing weather patterns predicted under climate change scenarios.
Biodiversity	Lao PDR is among the world's most biodiverse countries, with numerous endemic species and unique ecosystems. However, its biodiversity faces threats from illegal logging, wildlife trafficking, infrastructure development, and agricultural expansion. The government is addressing these challenges through the establishment of national parks and ongoing conservation efforts[236]. Utilizing agricultural waste for SAF has limited implications for biodiversity. However, creating feedstock demand may inadvertently lead to land conversion, affecting ecosystems and species. While there are significant biodiversity conservation efforts in Laos, the threats and pressures remain.
Soil & Land	About 78% of Lao PDR's land is mountainous and heavily forested. However, land degradation is a major problem, driven by soil erosion, deforestation, excessive chemical use in agriculture, and shifting cultivation practices. Additionally, unexploded ordnance (UXO) restricts the land's usability for agriculture[237]. In terms of SAF production, apart from land conversion, harvesting biomass residues for use as SAF feedstock can lead to the depletion of organic matter and soil nutrients, thereby affecting fertility. Excessive removal of residues may affect soil health and erosion prevention. Sustainable supply chains can include consideration of improved farming practices.
Air & Noise Emissions	Air pollution in Lao PDR is largely driven by agricultural practices such as biomass burning and slash-and-burn methods. These practices lead to elevated levels of particulate matter, especially during the dry season[238]. Specific data on the percentage of agricultural residues burned is currently limited. Utilizing crop residues for SAF production can reduce local air pollution and health impacts associated with the practice. Noise and air emissions from transport and processing must be considered in the impact assessment. Air emissions in production depend on feedstock and production process, with VOCs and particulates important to consider.
Pollution & Waste	Solid waste management in Lao PDR faces significant challenge with inadequate collection and disposal systems. In Vientiane, only about half of the waste generated is effectively managed. There is a pressing need to improve waste segregation and enhance recycling practices[239]. SAF production generates wastewater containing residues from processing. Solid waste, including feedstock residues, processing by-products such as char and ash, wastewater treatment sludge, and catalyst waste need to be considered, particularly given the limited waste management services and infrastructure in the rural areas in Laos.

6. Environmental and Social Aspects

6.4 Lao PDR Environmental and Social Aspects

Social Risks & Opportunities	
Social	Labor rights in Lao PDR are evolving, with ongoing efforts to enhance social protection and working conditions. Majority of the workers are employed in the informal sector, which leaves them exposed to socio-economic risks. The government is actively working to strengthen labor rights and social protection[240]. Whilst SAF production can create jobs, there is a risk of poor labor conditions especially if regulations and labor rights are not strictly enforced. For SAF to claim social credentials, there needs to be assurances in place around protecting food production land, respect of land rights and processes of local consent, and the protection of workers and feedstock suppliers from exploitation. Despite safeguards in the **2013 Labor Law**, a significant proportion of the workforce (86.4%) is in informal employment that lacks basic social protection. It is crucial to involve communities in decisions[241]. Finding a balance between developing SAF and considering these social issues is key for sustainability and just transition. Laos ranks second in ASEAN after the Philippines for gender equality, excelling in economic participation and opportunity. Despite this, significant challenges persist in areas like poverty reduction and inequality[242].
Gender	Women in Lao PDR are entitled to equal pay for equal work, social protection, and support for balancing productive and reproductive roles through maternity leave and child-care facilities. Lao PDR is advancing gender equality through inclusive policies, capacity-building programs, and support for women entrepreneurs, particularly in the renewable energy sector, while integrating gender-responsive plans into national and sectoral frameworks. Currently, specific gender-disaggregated data for the SAF industry in Lao PDR is limited. However, women play a crucial role in **agriculture**, comprising over 50% of the agricultural workforce and significantly contributing to various aspects of agricultural production[243]. In the **energy sector**, while specific statistics are not available, a 2019 survey indicated that women hold between 3% and 15% of leadership positions in Asia[235]. Some efforts to improve the gender situation are outlined below: • **Policy Integration**: Lao PDR is making significant efforts to address gender disparities through inclusive policy frameworks and national action plans. • **Capacity Building**: Various programs aim to empower women with skills for the renewable energy sector, focusing on technical training, leadership, and entrepreneurship. • **Support for Women Entrepreneurs**: Initiatives provide financial instruments and capacity-building activities to support women entrepreneurs in the renewable energy field. • **Action Plans**: The Lao Government has integrated the Fourth National Plan of Action on Gender Equality (2021-2025) into provincial, ministerial, and sectoral plans. This plan aims to promote gender equality across various sectors, including renewable energy. Additionally, Lao PDR's Nationally Determined Contributions (NDCs) implementation roadmap includes gender-responsive energy policies.

6.4 Lao PDR Environmental and Social Aspects

Table 6.3 provides a summary of the stakeholders involved in the SAF value chain in Lao PDR. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

For logistical details, including distances between entities and available transportation options, which may provide insights into potential environmental impacts, please refer to Section 5.

Table 6.3: Summary of high-level stakeholders in Lao PDR

Stakeholder	Entity
Biomass Growers and Landowners	Large agribusinesses (e.g., PhouThong Group for sugarcane and others, Lao Sugar Co. Ltd. For sugarcane), smallholder farmers, forestry companies (e.g., Asia Biogas, Lao Forest Products), community and cooperatives, government entities (e.g., Department of Forestry, Lao National Chamber of Commerce and Industry).
SAF Facilities	Yodngeum Power Mix Fuel Factory (Cassava, Sugarcane, Maize), Saysettha Comprehensive Development Zone (Lao Petroleum & Chemical Co. Ltd) (Rice, Forestry).
Major Airports	Luang Prabang International Airport, Wattay International Airport.
Major Airlines	Lao Airlines, Lao Skyway, Lao Central Airlines.
NGOs and Related Organizations	Food and Agriculture Organization (FAO): supports various agriculture projects in Lao PDR. World Vision: engages multiple agricultural and community projects focusing on livelihoods and food security. Green Climate Fund (GCF): supports programs promoting climate-resilient agricultural practices.
Financial Institutions	ADB, Bank of Lao PDR, IFC
State-owned Companies	Lao State Fuel Company, Lao Airlines

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6. Environmental and Social Aspects

6.5 Malaysia Environmental and Social Aspects

	Coconut	Rice	Oil Palm	Other Agricultural Residues	Forestry
Overview of feedstocks from environmental and social perspective	In Malaysia, coconut waste is used as animal feed, composted or mulched for soil fertility, or processed into value-added products like cocopeat and cocofibre, at waste management centers focused on reducing waste to landfill and promoting recycling. [253] When considering its potential for SAF production, it is crucial to account for these existing applications to ensure the most effective and sustainable utilization of the resource.	In Malaysia, rice waste is commonly used as animal feed, biomass fuel for energy production, and for composting to create organic fertilisers. [254] However, a significant portion of rice waste, particularly rice husks and straw, is still either dumped or burned. Repurposing it for SAF could help minimise this waste and associated impacts with current practices.	In Malaysia, oil palm waste is used to generate bioenergy, composted for soil improvement, utilised as animal feed, and applied in various emerging industrial applications like building materials and bioplastics. [255] Repurposing it for SAF requires consideration of these existing applications to ensure the most effective use and avoid displacement of enterprises and livelihoods.	In Malaysia, approximately 1.2 million tonnes of agricultural waste is disposed of in landfills annually. [256] While specific data on the amount burned is not readily available, it is known that a significant portion is often discarded or burned. SAF may help mitigate this practice by creating viable markets, thereby reducing the impacts or burning and landfilling (including greenhouse gas emissions).	In Malaysia, the sawmilling sector generates a significant amount of waste, with ~45-50% of the total volume of saw-log input being converted into waste. While specific data on the exact amount discarded or burned is not readily available, it is known to be a substantial portion. [257] Repurposing it for SAF can mitigate the impacts from burning or unmanaged decomposition but needs to be considered with new applications such as biochar production and bio-composites.
Current Resource Utilization	When considering feedstocks, **local community context and risks must be considered**. Diverting feedstocks may displace local livelihoods or stimulate additional demand that can have **unintended consequences** on land use, biodiversity, and displacement of food production impacting food security. Utilizing residue can reduce air pollution and health risks but exports nutrients from soil systems. In Malaysia, agricultural residues are commonly used for animal feed, bioenergy production, and composting, but significant portions are still discarded or burned.				
Regulatory Context	The **National Biofuel Policy (NBP)** promotes the use of biofuels for transportation, industry, and export to achieve a cleaner environment, while the **Environmental Quality Act 1974** regulates emissions, waste management, and pollution control in biofuel production, and the **Malaysian Biofuel Industry Act 2007** mandates the licensing of biofuel activities, including production, blending, and export. The **Biofuel Division under the Ministry of Plantation and Commodities** oversees **the licensing and enforcement of biofuel-related activities** to ensure compliance with regulations, while policies encourage community involvement and awareness to ensure that biofuel production benefits local communities and minimises social impacts. [258] An **Environmental Impact Assessment (EIA)** is required for biofuel projects in Malaysia if they fall under the prescribed activities listed in the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order 2015.				

6. Environmental and Social Aspects

6.5 Malaysia Environmental and Social Aspects

Environmental Risks & Opportunities	
Water	Malaysia receives ~3,000 mm of rainfall annually, providing around 900 billion cubic meters of water resources, with rivers supplying 97% of the raw water. Despite this abundance, water security issues stem from rising demand, population growth, urbanization, industrialization, agriculture, river pollution, excessive demand, climate change, and unsustainable land-use practices. [249] Producing SAFs demands substantial water resources, from crop cultivation to feedstock washing and cooling processes. This can place a strain on local water supplies, particularly in areas already experiencing water scarcity. Environmental Impact Assessments (EIA) should consider the increased water demand and its effects on local communities.
Biodiversity	Malaysia is recognised as a megadiverse country, boasting a rich variety of flora and fauna. However, this biodiversity is under significant threat due to habitat loss and illegal wildlife trade. Conservation efforts are ongoing, but challenges such as climate change and unsustainable land-use practices continue to impact biodiversity. [259] Utilizing agricultural waste for SAF has limited implications for biodiversity. However, creating feedstock demand may inadvertently lead to land conversion, affecting ecosystems and habitat for critical or endangered species. While there are significant biodiversity conservation efforts in Malaysia, the threats and pressures remain and must be considered at both a local and regional level as a part of any SAF development.
Soil & Land	Malaysia has adopted various soil conservation practices, such as terracing, grassed waterways, strip cropping, and conservation tillage, to combat soil erosion and degradation. Despite these efforts, soil health remains threatened by deforestation, unsustainable agricultural practices, and urbanization. [291] In the context of SAF production, harvesting biomass residues can deplete soil organic matter and nutrients, impacting fertility and erosion prevention. Therefore, sustainable supply chains should incorporate improved farming practices to mitigate these effects.
Air & Noise Emissions	Malaysia's air pollution is considered moderate, with an average Air Quality Index (AQI) of 73 in 2023. [256] Key contributors include vehicle emissions, industrial activities, and the burning of plantations for land clearing. Agricultural waste, especially from rice and oil palm, significantly adds to air pollution when burned, releasing particulate matter and greenhouse gases. This practice worsens air quality, particularly during dry seasons. Utilizing crop residues for SAF production can help reduce local air pollution and health impacts. [259] However, it's essential to consider noise and air emissions from transport and processing, including VOCs and particulates, in the impact assessment.
Pollution & Waste	Malaysia faces significant waste management challenges, with around 30,000 tons of municipal waste produced daily, or 1.17 kg of waste per person each day. The majority of waste is sent to landfills, many nearing capacity. The country has a relatively low recycling rate compared to neighbouring countries of about 31%, with a target to increase this to 40% by 2025. [254] SAF production generates wastewater with processing residues, and solid waste, including feedstock residues, processing by-products like char and ash, wastewater treatment sludge, and catalyst waste. Efforts to avoid, reuse or recycle wastes must be considered given the current waste management status in Malaysia with landfills reaching capacity.

6. Environmental and Social Aspects

6.5 Malaysia Environmental and Social Aspects

Social Risks & Opportunities	
Social	Agriculture in Malaysia is a crucial sector, employing about 10% of the total workforce. However, it faces several significant challenges, including labor shortages and reliance on foreign labor as locals often perceive agricultural work as low-paying and labor-intensive. Additionally, the workforce is aging, with fewer young people entering the sector. [257] Efforts to modernise agriculture through mechanization and technology are ongoing, but adoption rates vary. Furthermore, there are concerns about low productivity and high post-harvest losses. Similar to the broader agricultural sector, the biofuel industry also struggles with labor shortages, particularly in plantation and processing operations. [256] The SAF sector, especially production from agricultural and forestry waste, presents both opportunities and challenges. On the one hand, challenges include potential competition for land and water resources, potentially disrupting local livelihoods and food security. This is exacerbated if SAF feedstocks move from waste products to growing crops as SAF feedstock and land conversion. On the other hand, opportunities encompass economic benefits such as job creation, improved livelihoods, and reduced dependency on imported fossil fuels. Opportunities for upskilling and training in improved agriculture practices, manufacturing and logistics can strengthen local economies and resilience, and can target those who are socially disadvantaged. Therefore, efforts to develop SAF production must carefully balance these factors to ensure sustainable and equitable growth.
Gender	Malaysia has made progress in gender equality, but challenges remain. Women's labor force participation remains low at around 55%, compared to 81% for men. Barriers include unpaid domestic work, limited access to education and training, and restrictive cultural norms. [257] In the corporate world, women hold 26.4% of top positions in the top 100 public listed companies but are underrepresented in decision-making roles. [258] In agriculture, women make up less than 30% of the workforce, often in less visible roles like small-scale farming and unpaid family labor. Women face limited access to land, credit, and technology. Efforts to improve gender equality include promoting women's access to resources and decision-making can be a platform where an emerging or growing SAF industry can make a difference. [259] The energy sector, particularly renewable energy, also faces gender disparities, with women underrepresented in technical and leadership roles. Initiatives like the ASEAN Renewable Energy and Gender Roadmap aim to integrate gender considerations into energy policies, promoting women's participation and leadership. [260] Given that the energy transition requires a highly skilled and resourced workforce, targeting training and employment opportunities for women can shift the balance in gender equity.

6. Environmental and Social Aspects

6.5 Malaysia Environmental and Social Aspects

Table 6.4 provides a summary of the stakeholders involved in the SAF value chain in Malaysia. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

In developing or expanding SAF industries, effective engagement is fundamental to improving social and environmental outcomes and reducing risk of harm. A detailed stakeholder identification process at a local level is required, followed by meaningful and inclusive engagement to understand and mitigate risk and harness opportunities attuned to local aspirations.

Table 6.4: Summary of high-level stakeholders in Malaysia

Stakeholder	Entity
Biomass Growers and Landowners	Smallholder farmers, Agribusiness companies (e.g., oil palm plantations)
SAF Facilities	SPC Biodiesel (Sabah), SOP Green Energy (Sarawak), Pengerang Integrated Petroleum Complex (PIPC) (Johor), Petron Lumut POME Plant (Perak)
Major Airports	Kota Kinabalu International Airport, Kuala Lumpur International Airport, Penang International Airport
Major Airlines	Malaysia Airlines, Air Asia, Batik Air Malaysia
NGOs and Related Organizations	Bioeconomy Corporation: Facilitates local and international collaborations to maximise Malaysia’s biomass potential for SAF production Malaysian Nature Society (MNS): Focuses on environmental conservation and sustainable practices
Financial Institutions	Maybank and CIMB: Provide financing for green projects, which can include those related to biomass and SAF Agrobank: Focuses on financing agricultural projects, which can include biomass initiatives. Green Technology Financing Scheme (GTFS): Administered by various financial institutions, this scheme supports renewable energy projects, which can include biomass and SAF IFC
State-owned Companies	Petronas: Involved in SAF production and other renewable energy projects, including developing a biorefinery facility with SAF production capabilities Felda Global Ventures (FGV): Collaborates with Petronas to develop palm oil waste-based SAF

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6. Environmental and Social Aspects

6.6 Philippines Environmental and Social Aspects

	Sugarcane	Rice	Coconut	Other Agricultural Residues	Forestry
Overview of feedstocks from environmental and social perspective	Utilizing sugarcane residue for SAF can help reduce in-situ burning in some areas [261]. However, this may not be feasible everywhere, as the residue is also used for local energy generation by sugar mills in the Philippines. Sugarcane has high-water demand, which needs consideration in the Philippines which is vulnerable to water stress exacerbated by climate change.[260]	Rice straw is often left unused in the Philippines [262]. Utilizing it for SAF can help reduce waste from rice cultivation, which contributes to air pollution from burning, soil degradation, and potential water pollution.[263]	In the Philippines, coconut husks are often discarded or burned after harvest. Repurposing it for SAF can help reduce waste accumulation. However, it's important to balance this with its current uses in textiles, biochar, and other applications. Coconuts discarded from processing due to not meeting quality or size standards, are also a potential feedstock.	In the Philippines, agricultural residues are most commonly burned in-situ or composted. To utilise it for SAF, it's essential to consider incentives to promote more effective and sustainable use.[246]	In the Philippines, sawlog waste is often landfilled or burned, contributing to air pollution and GHG emissions. Utilizing it for SAF can help reduce these impacts but should be balanced with emerging uses like biochar production and biocomposites.[247]
Current Resource Utilization	When considering feedstocks, **local community context and risks must be considered**. Diverting feedstocks may displace local livelihoods or stimulate additional demand that can have **unintended consequences** on land use, biodiversity, and displacement of food production impacting food security. A significant proportion of sugarcane trash, coconut husks and agricultural residue is left in-situ or burnt. Utilizing this residue can reduce air pollution and health risks but exports nutrients from soil systems.				
Regulatory Context	The **Biofuels Act** lacks specific responsibilities for the Department of Environment and Natural Resources (DENR), but environmental impact assessment is required under **Presidential Decrees 1586 and 1151** if the facility is classed as Category A or B. Assessment stages include screening, scoping and baseline data collection, Initial Environmental Examination (and Environmental Impact Statement if required), and public consultation. Biofuel investors are exempt from wastewater fees but must secure a discharge permit, aligned with the **Philippine Clean Water Act 2004**. Implementation of the Biofuels Act aligns with the goal of cleaner alternative fuels outlined in the **Philippine Clean Air Act 1999.** Currently, only government-issued permits exist for bio-fuel facilities; no third-party certification is in place. The **Ecological Solid Waste Management Act 2000** provides a comprehensive framework for waste reduction, segregation, recycling, composting and disposal. The **Agriculture and Fisheries Modernization Act 1997** aims to protect the rich biodiversity of the Philippines and enact sustainable land use practices [268, 269]. Social protections in the Philippines are covered by a range of laws, including the **Anti-Trafficking in Persons Act 2003, Special Protection of Children Against Abuse, Exploitation and Discrimination Act,** and the **Labor Code of the Philippines (Presidential Decree 442).** Gender equity and social inclusion are covered by a range of instruments including the **Magna Carta of Women Act No 9710, Anti-Violence Against Women and their Children Act 2004, Safe Spaces Act No 11313, Anti-Sexual Harassment Act 1995.** The proposed **SOGIESC Equality Bill** also brings into effect legislation to prohibit discrimination on the basis of sexual orientation, gender identity/expression, or sex characteristics.				

6. Environmental and Social Aspects

6.6 Philippines Environmental and Social Aspects

Environmental Risks & Opportunities	
Water	Water is used during the conversion of feedstock into SAF and blending with conventional jet fuel. Feedstock production **requires substantial water resources** for crop cultivation. Overuse of water can lead to depletion of local water sources, affecting ecosystems and communities. Also, harvesting of forest biomass **may reduce soil productivity and affect the hydrological cycle**. In some areas of the Philippines, water resources are already experiencing stress. This includes the over-extraction of groundwater and surface water due to urbanization and growth in demand, as well as pollution from industrial and agricultural chemicals and inadequate water storage distribution and treatment infrastructure in rural areas [181]. Water availability and quality are further affected by the high vulnerability of the Philippines to natural disasters and the more frequent and intense typhoons and droughts predicted for the Philippines due to climate change [267].
Biodiversity	Land conversion due to **biofuel crop cultivation affects ecosystems and species**. While there is limited biodiversity impact of SAF derived from waste residues, it is important to consider the potential for unintended consequences from additional land clearance once a market demand for feedstock increases. The Philippines is the host of one of the greatest concentrations of wildlife in the world, but this is under increasing threat due to habitat loss and degradation driven by agricultural land use and land use change through development. Areas that are designated as Protected Areas and Important Bird Areas often overlap with agricultural development, exacerbating biodiversity loss. Data on species decline is not harnessed to inform policy responses, with the need for improved interventions and regulations on land clearance and biodiversity protection measures, along with consumer-led campaigns to change market demands [268]. Any SAF scheme in the Philippines needs to consider supply chain certification processes that can provide assurance that the end product is not made at the cost of species decline and land degradation [269].
Soil & Land Resources	In the Philippines, illegal logging and widespread land clearance have led to a significant loss of vegetation cover, not only reducing biodiversity but also contributing to soil erosion and loss of productive topsoil. Over-cultivation and the expansion of slash-and-burn agriculture, especially on critical slopes, have also contributed to the degradation of soils over recent decades[270]. Water-induced erosion is a major concern in the Philippines, with high rainfalls combined with unsustainable practices that have been difficult to change, particularly in areas where land tenure is insecure, and farmers have no incentive to improve soil conservation measures. Apart from land conversion, harvesting biomass residues for use as SAF feedstock **can lead to the depletion of organic matter and soil nutrients**, thereby affecting soil fertility. Sustainable farming practices such as crop rotation, reuse of organic matter and reduced tillage can be considered as a part of supply chain sustainable procurement practice.
Air & Noise Emissions	Burning of rice straw and sugarcane trash is common in the Philippines, with a significant portion of these residues being burned annually. Rice straw burning is prevalent at an estimated 76% of rice farms, with 32% of the rice straw produced burned in situ. For sugarcane trash it is estimated that 64% is still burned [271]. This practice not only contributes to local air pollution but also to transboundary haze, affecting neighbouring regions. Whilst there are national laws and local ordinances in place for air pollution, monitoring and enforcement is challenging. Providing incentives for crop residue recycling, such as through a SAF initiative, can potentially make a bigger difference compared to legal approaches [272]. **Diversion for SAF production can help reduce local air pollution and reduce health risks** associated with the practice. Transport and processing feedstock, as well as SAF use, **generates air and noise emissions**. Developing local production facilities and supply chains can reduce transport emissions and support regional economies. Hazardous air pollution emissions such as CO_2 and VOCs from bio-fuel plants must be considered in EIA.
Pollution & Waste	SAF production **generates wastewater containing processing residues**. The Biofuels Act mandates compliance with the Philippine Clean Water Act, with the DENR ensuring the **monitoring of effluent quality** [274]. Disposal of solid waste such as spent biomass, filter materials and by-products must be considered along with safe handling and disposal of chemical waste. The Ecological Solid Waste Management Act 2000 provides a comprehensive framework for segregation, recycling, composting and material recovery facilities for each barangay, along with waste reduction initiatives. However, many local government units (LGUs) lack the necessary infrastructure for effective waste management, often due to resource constraints.[276]

6.6 Philippines Environmental and Social Aspects

Social Risks & Opportunities	
Social	The Philippines is among the **most vulnerable countries to modern slavery** in the region with the seventh highest prevalence out of 27 countries in the Asia Pacific region. This high risk is largely driven by conflict- and climate-related displacement, inequality, and discrimination [276], with the agricultural industries one of the sectors reported to include forced labour. The high incidence of modern slavery has led to a strong government response with both effective coordination of responses and robust criminal justice systems in place. The Philippines is proactively addressing ongoing risk and is one of six countries in the region taking action to address forced labour in supply chains. However, this will take some time, and the **SAF industry must consider supply chain measures to prevent this type of exploitation within the supply chain.** The **Social Amelioration and Welfare Program (SAWP**) in the Philippines is designed to improve the socio-economic well-being of workers, particularly those in the sugar and biofuel industries. This requires biofuel producers to contribute a "lien" per liter of biofuel sold, benefiting biofuel workers through livelihood support, training, education, social protection, and emergency assistance. The SAF industry creates jobs in agriculture, processing and distribution, stimulating economic growth, particularly in regions with abundant feedstock. It can drive investment in education and training. The risks include displacement of communities and livelihood disruption from large-scale SAF production. There are strong labor protections in place, although the average basic pay for agricultural workers is generally lower, with inconsistent work and job insecurity [274].
Gender	Laws to promote gender equality, advancing women's rights and addressing discrimination and sexual harassment are in place, but women face ongoing challenges despite progress, with barriers such as childcare access, social attitudes on gender roles, and lower levels of technical training. There is an opportunity for the SAF sector to adopt inclusive employment practices and target training for women or other socially disadvantaged groups. The Gender Equality and Women's Empowerment (GEWE) Plan 2019-2025 guides the implementation of gender-responsive policies and programs, including the encouragement of industry to develop Gender and Development Plans to set targets and report on progress. The Philippines' Nationally Determined Contributions (NDCs) implementation roadmap includes gender-responsive energy policies. Currently, specific gender-disaggregated data for the SAF industry in the Philippines is limited. However, in the **agricultural sector**, women constitute approximately 25% of the workforce[277]. In the **energy sector**, a 2019 survey revealed that women hold 8% of leadership positions in the country [278]. Some efforts to improve the gender situation are outlined below: • **Training and Capacity Building**: Initiatives aimed at training women in biofuel production and management are part of broader efforts to enhance gender equality in the renewable energy sector. By considering current barriers to employment and retention of women, particularly in technical and leadership roles, a SAF enterprise can impact gender equity outcomes. • **Research**: Studies and pilot projects often incorporate gender components to ensure that advancements in biofuel technologies benefit both men and women. • **Action Plan**: As per the GEWE Plan, the SAF industry can make significant gains by setting targets, monitoring progress and taking a leadership stance on women's empowerment.

6.6 Philippines Environmental and Social Aspects

Table 6.5 provides a summary of the stakeholders involved in the SAF value chain in the Philippines. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

For logistical details, including distances between entities and available transportation options, which may provide insights into potential environmental impacts, please refer to Section 5.

Table 6.5: Summary of high-level stakeholders in the Philippines

Stakeholder	Entity
Biomass Growers and Landowners	Large agribusinesses (e.g., Tarlac Agricultural Land Holdings for sugarcane, Central Azucarera de Tarlac for sugarcane), smallholder farmers, forestry companies, community and cooperatives, government landowners (e.g., DENR).
SAF Facilities	Universal Robina Corporation (Sugarcane), Tantuco Enterprises (Rice), Green Future Innovations (Corn, Cassava), Ecoenergy Corporation (Wood, Coconut), Prime Infrastructure Capital (planned investment)
Major Airports	Mactan Cebu International Airport (Cebu), Ninoy Aquino International Airport (Metro Manila), Francisco Bangoy International Airport (Davao City).
Major Airlines	Cebu Pacific, Philippine Airlines, AirAsia Philippines, SkyJet Airlines.
NGOs and Related Organizations	Agro-Eco Philippines (AEP): an NGO working with small farmers in Mindanao, Eastern Visayas, and Eastern Luzon, focusing on the transition to regenerative agriculture Philippines Partnership for Sustainable Agriculture (PPSA): focuses on partnerships and knowledge exchange to improve the lives of Filipino farmers.
Financial Institutions	IFC, ADB, BDO Unibank, Development Bank of the Philippines, LandBank of the Philippines (renewable energy projects including SAF)
State-owned Companies	Philippine National Oil Company (PNOC) (actively exploring SAF), Civil Aviation Authority of the Philippines (CAAP)

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6. Environmental and Social Aspects

6.7 Case Study: Environmental and Social Aspects for SAF Production in Palawan

Non-Standard Coconut as SAF Feedstock

Feedstock Overview: Non-Standard Coconut	Palawan has been recognised for its potential in producing SAF from **non-standard coconuts**. While detailed information on the current utilization of these non-standard coconuts within the province is limited, the Philippine Coconut Authority (PCA) actively promotes the use of coconut waste for various processing options to produce marketable end-products. [273] This initiative not only aids in waste reduction but also provides additional income opportunities for farmers.
Regulatory Context	In addition to national regulations, Palawan has specific environmental regulations to consider. The **Strategic Environmental Plan (SEP) for Palawan Act** (Republic Act No. 7611) provides a framework for sustainable development, ensuring that activities like biofuel production protect and enhance natural resources. It mandates administrative machinery for implementing environmental plans and involves all sectors of society in resource management. Local municipalities and barangays enforce specific environmental laws, such as solid waste management and forestry regulations, crucial for monitoring biofuel production's impact. [274] The **Palawan Council for Sustainable Development (PCSD)** requires several permits, including the **SEP Clearance**, to ensure projects align with sustainable development goals. Additionally, the **Indigenous Peoples' Rights Act (IPRA) of 1997** (Republic Act No. 8371) protects indigenous communities' rights, requiring free, prior, and informed consent (FPIC) for projects on ancestral lands. [278] Prominent indigenous groups in Palawan include the **Tagbanua, Palaw'an, Tao't Bato, Molbog, Batak, Agutaynen,** and **Cuyonon**. [279]

6. Environmental and Social Aspects

6.7 Case Study: Environmental and Social Aspects for SAF Production in Palawan

Environmental Risks & Opportunities	
Water	Palawan relies on surface and groundwater, with 24 watersheds crucial for water recharge. These watersheds are under threat from deforestation and land conversion. Currently, Puerto Princesa City faces a severe water crisis due to prolonged dry spells, leading to a Water Crisis Alert Level 3 and measures such as water rationing and reactivating deep wells. SAF production requires significant water resources, potentially straining local supplies in water-scarce areas.[285] Environmental Impact Assessments (EIA) should account for this increased demand and its impact on communities.
Biodiversity	Palawan is a biodiversity hotspot with habitat for unique and endangered species and important ecosystems. Its global significance is evident in its designation as a UNESCO Man and Biosphere Reserve in 1990, and the presence of Wetlands of International Importance and World Heritage Sites. Despite ongoing conservation efforts, these ecosystems face ongoing challenges such as illegal hunting and deforestation, with the associated violence and even tragic death of environmental defenders in ongoing conflicts in the area.[286] Using agricultural waste for SAF has limited direct impact on biodiversity, but increased feedstock demand could lead to land conversion, affecting ecosystems. While conservation efforts are significant, threats to Palawan's biodiversity persist and must be at the center of environmental considerations for the development of the SAF industry in this province.
Soil & Land	Palawan's land faces pressure from deforestation and land conversion for agriculture and infrastructure, with the loss of 4.59 thousand hectares of natural forest documented in 2023. Efforts are underway to promote sustainable land use and governance. In SAF production, harvesting biomass residues can deplete soil nutrients and organic matter, affecting fertility and erosion prevention.[280] Sustainable supply chains should adopt improved farming practices to mitigate these effects.
Air & Noise Emissions	Recent data indicates that air quality in Puerto Princesa City is generally within safe limits, though particulate matter levels occasionally rise during specific events. Past pollution spikes have been linked to factors like haze from Indonesian palm oil fires.[281] In the context of SAF production, it is crucial to consider potential air and noise emissions from biorefinery facilities and related transport activities. Currently, Palawan lacks a biorefinery facility, so emissions from constructing and operating such facilities must be taken into account. Transporting coconut feedstock to existing Crude Coconut Oil (CCO) refineries in Davao, Quezon, and Albay could also be considered as an alternative, but considering noise and air emissions from transport.
Pollution & Waste	Puerto Princesa has made significant progress in waste management, particularly through initiatives like the Eco-Kolek project, which has boosted waste pickers' incomes and improved practices.[289] Utilizing coconut waste can further reduce waste in Palawan. However, SAF production generates wastewater and solid waste, including feedstock residues, char, ash, sludge, and catalyst waste, which must be managed. Emphasizing waste avoidance, reuse and recycling will be an important consideration in process design.
Social Risks & Opportunities	
Social	Palawan faces a relatively high unemployment rate of around 9.5%, with underemployment at 16.2%. In the agricultural sector, rising costs for farm inputs and climate challenges, such as dwindling irrigation water, have driven some farmers to seek better pay as farm laborers.[290] The region also grapples with la labor issues, exacerbated by the pandemic, as economic hardships force families to rely on income from their children.[282] Indigenous communities, like the Palawan, practice sustainable farming methods, but these often go unrecognised and unsupported, highlighting the need for greater acknowledgment and assistance.[283] In the SAF sector, production from agricultural and forestry waste presents both opportunities and challenges. Opportunities encompass economic benefits such as job creation and improved livelihoods, Social outcomes could be enhanced through targeted training and work opportunities for socially disadvantaged groups. Efforts to develop SAF production must carefully balance these factors to ensure sustainable and inclusive growth.
Gender	Gender equality in Palawan has improved, but challenges persist. The Provincial Government promotes equality through Gender and Development (GAD) programs, focusing on empowering women, gender-sensitive education, and economic participation. Barangay GAD monitors outcomes in each municipality, collecting data to understand the effectiveness of measures, measure equality in access to services, and to raise awareness.[285] Despite these efforts, ongoing action is needed to address gender disparities and achieve true equality.

6.7 Case Study: Environmental and Social Aspects for SAF Production in Palawan

Table 6.6 provides a summary of the stakeholders involved in the SAF value chain in Palawan. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

In developing or expanding SAF industries, effective engagement is fundamental to improving social and environmental outcomes and reducing risk of harm. A detailed stakeholder identification process at a local level is required, followed by meaningful and inclusive engagement to understand and mitigate risk and harness opportunities attuned to local aspirations.

Table 6.6: Summary of high-level stakeholders in Palawan

Stakeholder	Entity
Biomass Growers and Landowners	Smallholder farmers, agricultural waste facilities (e.g., farmers in Bataraza and Brooke's Point provide agricultural waste), agribusiness companies/coconut farms (e.g., Lionheart Farms, Palawan)
SAF Facilities	*No SAF facilities are currently available in Palawan*
Major Airports	Puerto Princesa International Airport (Palawan), Francisco Bangoy International Airport (Davao)
Major Airlines	Philippine Airlines, Cebu Pacific
NGOs and Related Organizations	Palawan NGO Network, Inc. (PNNI): Focuses on sustainable development and environmental protection in Palawan
Government Stakeholders	Palawan Council for Sustainable Development (PCSD), Department of Environment and Natural Resources (DENR), Provincial Government of Palawan

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6. Environmental and Social Aspects

6.8 Thailand Environmental and Social Aspects

	Sugarcane	Cassava	Rice	Other Agricultural Residues	Forestry
Overview of feedstocks from environmental and social perspective	In Thailand, sugarcane trash is typically discarded resulting in waste accumulation and potential burning. Repurposing it for SAF can help reduce this waste[301].	Cassava residues in Thailand, such as leaves, stems, and rhizomes, are frequently used for animal feed and bioethanol and biogas production. Using it for SAF may require consideration of these existing uses [302].	Burning is still the most common practice for rice straws in Thailand resulting air pollution. Using it for SAF may help divert them to more beneficial uses[303].	In Thailand, agricultural residues are most commonly burned or composted. To utilise it for SAF, it's essential to consider these existing applications to ensure the most effective and sustainable use [304].	In Thailand, sawlog waste is frequently landfilled or burned, leading to air pollution and emissions. Repurposing it for SAF can mitigate these effects, but it should be balanced with new applications such as biochar production and biocomposites[305].
Current Resource Utilization	When considering feedstocks, **local community context and risks** must be considered. Diverting feedstocks may displace local livelihoods or stimulate additional demand that can have **unintended consequences** on land use, biodiversity, and displacement of food production impacting food security. A significant proportion of sugarcane trash and agricultural residue is often left in-situ or burnt. Utilizing this residue can reduce air pollution and health risks but exports nutrients from soil systems. Other waste products are used within existing activities such as biofuel and compost production, which need to be considered to avoid displacement of existing livelihoods.				
Regulatory Context	In the early 2000s, the Thai **government prioritised biofuel promotion** through cabinet resolutions. They aimed for 8% renewable energy consumption by 2011, with **1.9% from biofuels**. Given heavy reliance on energy imports, Thailand actively promotes domestic biofuel production, benefiting farmers' incomes. In 2019, Thailand mandated that locally produced biodiesel must meet the Euro 5 standard by 2024. The **Enhancement and Conservation of National Environmental Quality Act** stipulates EIA requirements, including public participation. Thailand has robust protections for air and water quality, along with waste management and health and safety requirements. However, enforcement remains inconsistent, and limited resources and corruption can hinder effective environmental protection[306].				

6. Environmental and Social Aspects

6.8 Thailand Environmental and Social Aspects

Environmental Risks & Opportunities	
Water	Thailand faces major water resource challenges, including severe flooding in the rainy season and extreme droughts during the dry season. Many regions suffer from poor surface water quality due to untreated sewage, industrial wastewater, and agricultural runoff. Groundwater is also overexploited and polluted [309]. Climate change worsens these problems by causing irregular rainfall patterns and increasing water scarcity. The production process for SAF **requires a high amount of water**, which, if not effectively managed, can strain local water resources. In Thailand, over-consumption of water in cassava starch processing is recognised as an environmental risk. Overuse of water can lead to **depletion of local water sources**, affecting ecosystems and communities.
Biodiversity	Thailand, one of the region's most biodiverse countries, boasts a wide range of ecosystems and species. However, illegal hunting, deforestation, pollution, and invasive species pose significant threats to its biodiversity. While conservation efforts are underway, challenges remain in terms of effective deployment of programs [308]. There is a risk of feedstock moving beyond agricultural and forestry waste, with SAF demand potentially causing land conversion to meet **SAF crop demand affecting ecosystems and biodiversity**. While there is limited biodiversity impact of SAF derived from waste residues, it is still important to consider.
Soil & Land	In Thailand, land degradation is primarily a result of improper land use, deforestation, and unsustainable agricultural practices. Common issues include soil erosion, salinity, and acidity, which negatively impact agricultural productivity and livelihoods. To address these challenges, efforts focus on soil conservation techniques and sustainable land management practices[311]. Apart from land conversion and potential loss of agriculture and food production land, harvesting biomass residues for use as SAF feedstock **can lead to the depletion of organic matter and soil nutrients**, thereby affecting fertility.
Air & Noise Emissions	Biomass burning remains common in Thailand. Agricultural burning of sugarcane and rice stubble is a major contributor to air pollution in the country, significantly increasing PM2.5 levels, particularly during harvest season[312]. In terms of figures, the percentage of agricultural residues burned varies by crop – around 57% of off-season rice farms, 47% of sugarcane farms, 35% of maize farms, and 29% of wet-season rice farms engage in burning[59]. To mitigate this issue, efforts are being made to promote alternative uses for crop residues and adopt sustainable farming practices. **Repurposing the residues for SAF production can mitigate local air pollution and reduce health risks**. Transport, feedstock processing, and SAF use **contribute to air and noise emissions**. SAF plants emit hazardous air pollutants that must be considered in the impact assessment.
Pollution & Waste	Thailand generates significant amounts of solid waste and faces challenges with proper disposal and recycling. The government is addressing these issues through public awareness campaigns, investments in waste management technology, and promotion of the circular economy. Despite these efforts, improper disposal and open burning continue to be persistent problems[320]. In terms of SAF production, a study on palm biodiesel production in Thailand found that while it can reduce GHG emissions by 46%–73% compared to conventional diesel, its production and use also **result in other pollutants and impacts such as photochemical oxidation, toxicity, acidification, and eutrophication**. It is important to consider the pollution and waste specific to SAF production, including solid and chemical wastes and wastewater containing residues from processing.

6. Environmental and Social Aspects

6.8 Thailand Environmental and Social Aspects

Social Risks & Opportunities	
Social	Thailand’s labor laws aim to safeguard workers' rights and promote fair employment practices. Key concerns include ensuring compliance with labor standards, tackling exploitation, and enhancing working conditions. The Labour Protection Act B.E. 2541 (1998) and its amendments establish the legal framework for employment contracts and workers' rights[313]. In Thailand, biofuel development presents **significant potential for employment**, estimated at 238,700 to 382,400 person-years. This sector also **contributes $150 million to GDP** and reduces imports by $2,547 million compared to petroleum fuels. However, high production costs and the necessity of subsidies to ensure affordability remain critical challenges. Thailand has strong labour laws, but enforcement can be challenging with resource constraints limiting inspection regimes. Jobs within the informal sector are more challenging for the protection of worker rights [318]. It is imperative that SAF production respects labour rights and local land tenure, seeking opportunities to ensure that development benefits flow to all, including the potential to improve opportunities for women in the sector.
Gender	Women in Thailand are protected by laws ensuring equal rights and opportunities in education, employment, and political participation, but they still face challenges such as wage disparities and underrepresentation in leadership positions. The country is advancing gender equality in the renewable energy sector through capacity-building programs, financial support for women entrepreneurs, and gender-responsive policies integrated into national and provincial action plans. Currently, specific gender-disaggregated data for the SAF industry in Thailand is limited. However, approximately 55.8% of women are engaged in **agricultural activities** [314], highlighting their vital role in Thailand’s agricultural sector and their contributions to farming and rural development. In the **energy sector**, a 2019 survey indicated that women hold 9% of leadership positions in the country [315]. Some efforts to improve the gender situation are outlined below: • **Capacity Building**: Various programs aim to empower women with skills for the renewable energy sector, focusing on technical training, leadership, and entrepreneurship. For instance, the “Srikandi” program certifies women as energy managers and auditors. • **Support for Women Entrepreneurs**: Initiatives provide financial instruments and capacity-building activities to support women entrepreneurs in the renewable energy field. • **Action Plan**: Thailand’s Nationally Determined Contributions (NDC) implementation roadmap includes gender-responsive energy policies and provincial action plans, ensuring gender considerations are integrated into renewable energy project planning and execution.

6. Environmental and Social Aspects

6.8 Thailand Environmental and Social Aspects

Table 6.7 provides a summary of the stakeholders involved in the SAF value chain in Thailand. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

For logistical details, including distances between entities and available transportation options, which may provide insights into potential environmental impacts, please refer to Section 5.

Table 6.7: Summary of high-level stakeholders in Thailand

Stakeholder	Entity
Biomass Growers and Landowners	Large agribusinesses (e.g., Sinar Mas Agribusiness for oil palm, Wilmar Internation for oil palm), smallholder farmers, forestry companies (e.g., APP, APRIL), community and cooperative groups, government-owned enterprises (e.g., Perum Perhutani).
SAF Facilities	Mitr Phol Bio-Fuel Co., Ltd. (Sugarcane, Cassava), New Biodiesel Co., Ltd. (Oil Palm), BBGI Bioethanol Public Company Limited (BBGI-NP) (Rice, Forestry), Bangchak Corporation (SAF from used cooking oil)
Major Airports	Suvarnabhumi Airport, Don Mueang International Airport, Chiang Mai International Airport.
Major Airlines	Thai Airways, VietJet Thailand.
NGOs and Related Organizations	Food and Agriculture Organization (FAO): a UN agency that leads efforts to address food insecurity; involved in the Bioenergy and Food Security (BEFS) initiative in Thailand. Thailand Environment Institute (TEI): an NGO focusing on environmental issues, including sustainable agriculture and bioenergy. Kenan Foundation Asia: An organization working on sustainable agriculture and rural development. Green Net Cooperative: a social enterprise promoting organic agriculture and fair trade in Thailand.
Financial Institutions	ADB, Bank for Agriculture and Agricultural Cooperatives, Export-Import Bank of Thailand
State-owned Companies	PTT Public Company Limited (partnered with Thai Airways to use SAF)

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6. Environmental and Social Aspects

6.9 Vietnam Environmental and Social Aspects

	Rice	Sugarcane	Cassava	Other Agricultural Residues	Forestry
Overview of feedstocks from environmental and social perspective	In Vietnam, burning rice straw remains the most prevalent method, causing air pollution. Utilizing rice straw for SAF could offer a more beneficial alternative[319].	In Vietnam, sugarcane trash is usually discarded, leading to waste buildup and possible burning. Repurposing it for SAF could help minimise this waste and associated impacts[320].	Cassava residues in Vietnam are often discarded or landfilled, leading to pollution. Repurposing it for SAF could provide better uses, though it requires careful consideration of the collection and processing methods involved [321].	In Vietnam, agricultural residues are most commonly burned or composted. To utilise it for SAF, it's essential to consider these existing applications to ensure the most effective and sustainable use[322].	In Vietnam, sawlog waste is frequently landfilled or burned, leading to air pollution and emissions. Repurposing it for SAF can mitigate these effects, but it should be balanced with new applications such as biochar production and biocomposites[323].
Current Resource Utilization	When considering feedstocks, local community context and risks must be considered. Diverting feedstocks may displace local livelihoods or stimulate additional demand that can have unintended consequences on land use, biodiversity, and displacement of food production impacting food security. A significant proportion of rice straw, sugarcane trash and agricultural residue is often left in-situ or burnt. Utilizing this residue can reduce air pollution and health risks but exports nutrients from soil systems. Other waste products are used within existing activities such as biofuel and compost production, which need to be considered to avoid displacement of existing livelihoods.				
Regulatory Context	The **Law on Environmental Protection 2020** provides a comprehensive framework for environmental protection, pollution control and climate change adaptation. However, limited resources, interagency cooperation issues and over-decentralization can hinder effective implementation. An initial scoping determines classification, with Group I and II projects (high and moderate risk) required to conduct an EIA. Aligned with its **Net Zero by 2050 commitment**, Vietnam is advancing the transition to green energy, with actions aiming to achieve **20-35% sustainable fuel use in aviation by 2035** [330].				

6. Environmental and Social Aspects

6.9 Vietnam Environmental and Social Aspects

Environmental Risks & Opportunities	
Water	Vietnam faces **major water resource challenges**, including pollution, scarcity, and inefficient management. Rapid economic development has exacerbated water pollution from industrial and agricultural activities[331]. Rural areas struggle with limited access to clean water, with only 39% of the rural population having access to safe water and sanitation. Additionally, natural hazards such as typhoons and floods worsen these water-related issues [331]. Vietnam faces a mismatch between water supply and demand, especially during the dry season. If current trends continue, by 2030, all but five river basins are expected to experience water stress. The water demand to grow feedstock crops and produce SAF may exacerbate existing water scarcity issues. **EIA work needs to consider additional water demand** and impacts on local communities.
Biodiversity	Vietnam, **one of the world's most biodiverse countries** with over 50,000 species, faces significant threats to its biodiversity from illegal logging, wildlife trafficking, and agricultural expansion. About 21% of mammals, 6.5% of birds, and 38% of fish species are currently threatened. While policies and national strategies are in place to combat biodiversity loss, challenges persist due to the complex interplay between biodiversity and economic activities[243]. Although the focus of this study is on agricultural processing waste and residues, an unintended consequence may be increased demand for SAF feedstock cropping. Land conversion due to this demand potentially affects ecosystems. Impact assessment must consider supply chain issues holistically and seek to implement safeguards from land clearance, particularly in areas with high biodiversity values.
Soil & Land	Since the 1990s, Vietnam's land use has shifted from predominantly rice farming to a wide range of crops and permanent tree plantations. However, this transition has led to significant concerns about soil degradation and erosion, especially in the northern highlands[323]. Additionally, land pollution issues have arisen from the overuse of fertilizers and unsuitable agricultural practices[245]. Removal of biomass residues for SAF may reduce organic matter returned to the soil, which **can impact nutrient cycling, carbon storage and overall soil health.**
Air & Noise Emissions	Intensive **biomass burning is still common** contributing to air pollution[338]. As an example, ~87% of the generated rice straw is burned on fields. Although there may be logistical constraints to harnessing this feedstock, reducing this burning would be beneficial. It is important to note and consider air and noise emissions in transport, feedstock processing, and SAF use, and the associated air and noise emissions. The location of plants will need to consider risk in relation to noise and air pollution receptors.
Pollution & Waste	Vietnam's rapid urbanization and industrialization have resulted in increased waste generation. To address this, the country has introduced policies such as the National Strategy on Integrated Solid Waste Management to enhance recycling and reduce landfill waste[330]. Despite the efforts, challenges persist in waste segregation, recycling efficiency, and hazardous waste management [321]. The World Bank reports that the main threat to Vietnam's economy is the impact of water pollution on human health, with urban and industrial wastewater being the largest contributor. SAF production **generates wastewater containing residues from processing** [330]. If this wastewater is released untreated, it could lead to eutrophication of surface water bodies and exacerbation of poor aquatic eco-system health and increase human health risks from poor water quality.

6. Environmental and Social Aspects

6.9 Vietnam Environmental and Social Aspects

Social Risks & Opportunities	
Social	Vietnam has made strides in labor rights, notably through the **EU-Vietnam Free Trade Agreement**, which includes commitments to enhance labor conditions. However, challenges remain, including the absence of independent unions and limited collective bargaining rights. Workers in particular sectors continue to experience labor rights violations [249]. SAF production in Vietnam can create work opportunities but also carries the risk of impact on local livelihoods if not carefully assessed through a robust social impact assessment and community consultation. Also, equity considerations underscore the **importance of ensuring that SAF projects provide fair access to resources and benefit marginalised communities** in the country. In terms of gender, the Vietnam government considers gender equality as critical in policy-making, including the New Rural Development framework. Efforts are being made to ensure gender-equitable consultations in decision-making, policy development, and legislative processes related to land, agriculture and industry. Vietnam has one of the highest female labor-force participation rates in the world and women increasingly hold leadership positions[311]. SAF producers and investors can contribute to these gains, particularly with a focus on equitable training opportunities.
Gender	Women in Vietnam are protected by laws ensuring equal rights in education, employment, healthcare, and political participation, with one of the highest female labor force participation rates globally. The country is advancing gender equality through inclusive policies, capacity-building programs, and support for women entrepreneurs in the renewable energy sector, integrating gender-responsive measures into national energy plans. Currently, specific gender-disaggregated data for the SAF industry in Vietnam is limited. However, women play a significant role in **agriculture**, with approximately 36.1% of female employment in this sector as of 2019. In the **energy sector**, while specific statistics are not available, a 2019 survey indicated that women hold between 3% and 15% of leadership positions in Asia[310]. Some efforts to improve the gender situation are outlined below: • **Policy Integration**: Vietnam is making significant efforts to address gender disparities through inclusive policy frameworks and certification standards. • **Capacity Building**: Various programs aim to empower women with skills for the renewable energy sector, focusing on technical training, leadership, and entrepreneurship. • **Support for Women Entrepreneurs**: Initiatives provide financial instruments and capacity-building activities to support women entrepreneurs in the renewable energy field. • **Action Plan**: Vietnam's Nationally Determined Contributions (NDCs) implementation roadmap includes gender-responsive energy policies, ensuring that gender considerations are integrated into renewable energy project planning and execution.

6.9 Vietnam Environmental and Social Aspects

Table 6.8 provides a summary of the stakeholders involved in the SAF value chain in Vietnam. While large enterprises remain the primary players, involving smallholder farmers and community cooperatives can significantly bolster local economies and improve livelihoods.

For logistical details, including distances between entities and available transportation options, which may provide insights into potential environmental impacts, please refer to Section 5.

Table 6.8: Summary of high-level stakeholders in Vietnam

Stakeholder	Entity
Biomass Growers and Landowners	Large agribusinesses (e.g., Vietnam Sugarcane – VISUC, Dong Nai for cassava and sugarcane), smallholder farmers, forestry companies (VinaWood, Thuan Hoa Wood Processing Company), community and cooperative groups, government-owned enterprises (e.g., FIDI).
SAF Facilities	Tunglam Ethanol Factory (Rice, Cassava, Forestry, Maize), Vietnam Biofuel Factory (Sugarcane).
Major Airports	Tan Son Nhat International Airport, Danang International Airport.
Major Airlines	Vietnam Airlines, Vietjet Air.
NGOs and Related Organizations	Rikolto: an organization working with smallholder farmers to promote sustainable agriculture and food security. SNV Netherlands Development Organisation: works on projects related to agricultural productivity, energy, and WASH. Vietnam Farmers' Union: supports farmers by promoting sustainable agriculture and rural development. Sustainable Agriculture and Natural Resources Management (SANRM) Working Group: a group comprised of various organizations working together to promote sustainable. agriculture and natural resources management in Vietnam.
Financial Institutions	ADB, Novus Aviation Capital (with VietJet to support the financing of SAF infrastructure in Vietnam)
State-owned Companies	Vietnam Airlines, Vietnam Aviation Administration (not a company but plays a crucial role in SAF development), PetroVietnam (no prominent initiatives yet on SAF)

This list is not exhaustive and is intended to offer a general overview of potential stakeholders.

6.10 Potential Research and Development Areas

Research and development for SAF usually has a focus on technology, economics and engineering. There are also significant opportunities to leverage research findings on social and environmental aspects, or partner with institutions to advance the research on how to provide sustainability outcomes and assurances, maximizing benefits to local communities in the development of alternative fuels. Table 6.9 provides potential areas of beneficial research.

For potential collaborations, the following institutions in Australia and Canada can be considered:

- **Australia**
  - CSIRO (Commonwealth Scientific and Industrial Research Organisation).
  - Bioenergy Australia.
  - Sustainable Aviation Fuel Alliance of Australia and New Zealand.
  - Australian Renewable Energy Agency.
- **Canada**
  - Canadian Council for Sustainable Aviation Fuels (C-SAF).
  - National Research Council Canada (NRC).
  - Natural Resources Canada (NRCan).

Table 6.9: Potential research and development areas

Topic	Description / Components	Relevant Resources
Strengthening safeguards within the SAF supply chain	**Current risks, opportunities, and strategies to enhance the environmental and social protections for the SAF supply chain** • Analysis of potential unintended consequences (e.g., diversion of biomass from existing livelihoods, land conversion, modern slavery) due to creation of new demand through SAF production. • Understanding transboundary risks and mitigations to provide environmental and social safeguards in ASEAN region. • Role of certification schemes that provide supply chain assurances. Risks, opportunities, gaps, and lessons learned from case studies. It is crucial that a fuel must meet the ICAO-CORSIA sustainability criteria and be certified by a Sustainability Certification Scheme (SCS), to be considered as sustainable.	• IATA's SAF Handbook detailing supply chain best practices • US Department of Energy's SAF Grand Challenge on building supply chains • McKinsey's report on sustainable fuel supply strategies
Social license and benefit sharing mechanisms	**Frameworks for obtaining social license and implementing benefit-sharing mechanisms to ensure community support and equitable distribution of benefits from SAF projects** • Community engagement and acceptance (i.e., looking at acceptance and cultural values). • Role of participatory approaches in building the social license of SAF projects. • Community benefit sharing models that are applicable to SAF. • Analysis of case studies and lessons learned.	• CIFOR's analysis of benefit-sharing in REDD+ countries • Columbia University's policy guidance on community benefit-sharing • MDPI's systematic view on benefit sharing in resource extraction
Comprehensive evaluation of environmental impacts	**Assessments of the environmental impacts associated with SAF production and use, including lifecycle analysis and mitigation strategies** • Impacts of the removal of waste biomass to soil and biodiversity. • Potential reduction in community air pollution from burning due to the diversion of biomass waste to SAF. • Analysis of environmental impacts and benefits from SAF production utilizing different feedstocks.	• Resource Options and Challenges for Sustainable Aviation Fuels • Techno-economic and environmental impacts assessments of sustainable aviation fuel production from forest residues • Near-zero environmental impact aircraft

6. Environmental and Social Aspects

6.10 Potential Research and Development Areas

Table 6.9: Potential research and development areas (cont.)

Topic	Description / Components	Relevant Resources
Comprehensive evaluation of social and economic impacts	**Assessments of the social and economic impacts of SAF projects, focusing on community well-being, job creation, and economic development** • Job creation, income generation, and potential for economic development. • Gaps in institutions and policies. • Health and safety aspects, working conditions in SAF facilities. • Women's participation and access to decision-making roles and technical training. • Skills development requirements.	• Social Science Applications in Sustainable Aviation Biofuels Research: Opportunities, Challenges, and Advancements
Resource management and the role of ASEAN governments	**Review of the role of ASEAN governments in managing resources and promoting policies that support the sustainable development of the SAF industry** • Government regulatory frameworks, subsidies, and incentives. • Public-private partnerships, including legal frameworks, incentives, and risk-sharing models. • Impact of sustainability certifications. • Market dynamics and competition.	• ASEAN Sustainable Aviation Action Plan (ASAAP) • RSB Sustainable Feedstock Assessment for SAF Production in Southeast Asia • ASEAN's progress towards sustainable development goals • Analysis of ASEAN's role in global governance and SDGs
Alternative feedstock sources	**Research on alternative feedstock sources and technologies** • Low-risk crops in terms of environment, social, and economic factors. • Technologies and logistics that can be leveraged to allow for the use of alternative feedstock sources.	• RSB Sustainable Feedstock Assessment for SAF Production in Southeast Asia

7. Institutional Frameworks

GHD Advisory

Institutional Frameworks Overview

7. Institutional Frameworks

7.1 Institutional Frameworks Overview

As part of the institutional frameworks review the government and private sector activity SAFs activity within each of the focus countries, along with additional global reference points were reviewed. Furthermore, the general regulatory and investment climate for each of the focus countries was also reviewed, referring to known numerical indices and rankings publicly available. The subsequent key findings have been summarised below.

Government and Private Section Key Findings

Refer below a summary and key findings of the government and private section entity for the seven (7) countries.

- Out of the seven countries covered in this report, five (5) – namely the Philippines, Indonesia, Thailand, Malaysia and Vietnam – demonstrate an understanding of utilising SAF across both government and private sectors.
- Each of the five (5) countries have local airlines which have already incorporated SAF into their flights. These are Cebu Pacific Airlines in the Philippines, Garuda Indonesia in Indonesia, Thai Airways and Vietjet Thailand in Thailand, Malaysia Airlines in Malaysia and Vietnam Airlines in Vietnam.
- However, three countries appear to be more advanced in their planning and implementation of SAF use. In 2013, Indonesia became the first in SE Asia to release a SAF mandate, though it was never enforced. As of September 2024, Indonesia has revealed a SAF roadmap and policy action plan, identifying Used Cooking Oil (UCO) and palm fatty acid distillate (Pfad) as priority feedstocks. Additionally, it should be noted that PT Pertamina Patra Niaga, subsidiary of PT Pertamina, has obtained an ISCC and EU RED certification in August 2024. Thailand, on the other hand, has mentioned that an incentive proposal for the use of SAF locally is set to be finalised by 2024. While two (2) local companies, BSGF Company Limited and BAFS, are said to be building their own SAF production plants. Lastly, Malaysia is advancing SAF with policy mandates for blending (47% blend by 2050) and aims to produce one million metric tons annually by 2027. Malaysia Airlines have also launched carbon programmes to include SAF credits and Petronas have form strategic partnerships with oils producers to construct SAF refinery.
- Meanwhile, it appears that both Lao PDR and Cambodia needs to enhance its efforts in planning for the incorporation of SAF particularly in its local aviation industry. As of date, both countries have not published any of its plans with regards to the adoption of SAF use.

Global SAF Policy/Regulation Reference Points

- There is a SAF mandate which requires a minimum of 2% SAF at Union airports by 2025, with an obligation on fuel suppliers, progressively increasing to 70% by 2050.
- Aircraft operators that use SAF that comply with the sustainability criteria are able to reduce the number of ETS allowances they need to buy as an incentive by the European Union Emissions Trading System (EU ETS). However, free aviation emission allowances will be gradually phased out from 2024 to 2026, with up to 20 million allowances available based on the uptake of SAF on a first-come, first served basis.

- **Former**: The Blender's Tax Credit (BTC) was available to blenders that supply SAF with 50% or greater lifecycle emissions reductions. Fuels must have a lifecycle emission level of less than 50kg of CO2eq per MMBTu.
- **2025 Shift**: A Producer's Tax Credit (PTC) will provide a credit to producers based on their fuel's carbon intensity (CI) score.
- The tax incentive is stackable with other Federal and state level credits and can be used to offset excise tax liability and lower selling price of the fuel.

Regulatory and Investment Climate Key Findings

Refer below a summary and key findings of the regulatory and investment climate related index rankings for the seven (7) countries.

- Only five (5) out of the seven (7) countries, namely Thailand, Vietnam, Indonesia, the Philippines and Malaysia ranked in the top 50% of the latest Ease of Doing Business Index (2020) and the latest Global Innovation Index (2023).
- On both indices, Thailand appeared to have more reasonable scores which further translated to its high global rankings. Based on the 2020 data, Thailand scored relatively high on two (2) indicators in the Ease of Doing Business Index: Trading across Borders and Enforcing Contracts. This shows that Thailand is more efficient in terms of documentary compliance and border compliance to export and import, as well as in terms of resolving commercial disputes and maintaining a good quality judicial process.
- Meanwhile, in the latest Corruption Perception Index (2023), Vietnam and Malaysia are the only countries in the top 50%, ranking 83rd out of 180 and ranking 50th out of 180. Based on Transparency International, the global average score is at 43, which indicates that Vietnam and Malaysia along with the 5 other countries have yet to improve in terms of corruption.
- With regards to the Foreign Direct Investment Regulatory Restrictive Index, the latest available data for all seven (7) countries (2019) show that Cambodia is the most open in terms of foreign direct investment while the Philippines is the most restrictive.

Institutional Frameworks Deeper Dive

7. Institutional Frameworks

7.2 Cambodia

7.2.1 Government and Private Sector Activity

Government

- The Cambodian government has set ambitious goals for the broader transportation sector, aiming for all vehicles, including public transport, to operate on electricity or green energy by 2050.[316]
- Southeast Asia accounts for nearly 8% of global jet fuel demand and thus plays a crucial role in contributing to the global sustainable aviation fuel (SAF) supply, which is essential for achieving global aviation decarbonisation goals.[317]
- Cambodia is observed to be actively working toward the sustainable growth of its aviation sector by integrating energy-efficient technologies, while airlines are adopting fuel-efficient aircraft to minimise carbon emissions.[330,331] However, currently, Cambodia does not have government policies or initiatives directly targeting SAF.[33]

Private Sector

- DHL Express makes it easy for businesses in Cambodia to opt for sustainable fuel for their standard international shipping and courier pickup services using GoGreen Plus service, enabling a 30% reduction in carbon emissions by using sustainable aviation fuel (SAF) instead of traditional aircraft fuel. [239]

7.2 Cambodia

7.2.2 Regulatory and Investment Climate

Table 7.1 below presents a summary of the rank of Cambodia in several Regulatory and Investment Climate related indices:

Table 7.1: Cambodia Regulatory and Investment Climate related indices

CAMBODIA						
Index	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
THE WORLD BANK [264] **Ease of Doing Business Index**	**135** of 190	**138** of 190	**187** of 190	N/A	N/A	N/A
TRANSPARENCY INTERNATIONAL[265] **Corruption Perception Index**	**20** of 180	**20** of 180	**21** of 180	**23** of 180	**24** of 180	**22** of 180
Global Innovation Index [266]	**98** of 126	**98** of 129	**110** of 131	**109** of 132	**97** of 132	**101** of 132
OECD [267] **Foreign Direct Investment Regulatory Restrictiveness Index** (from 0 to 1)	N/A	0.054	N/A	N/A	N/A	N/A

Notes:

1. Ease of Doing Business Index: The higher the rank, the more business-friendly regulations a country has.
2. Corruption Perception Index: The higher the rank, the less corrupt the country's public sector is perceived to be relative to the other countries in the index.
3. Global Innovation Index: The higher the rank, the more successful a country's innovation performance is compared to other countries in the index.
4. Foreign Direct Investment Regulatory Restrictiveness Index: The closer to 1, the more restrictive the environment is.

7. Institutional Frameworks

7.3 Indonesia

7.3.1 Government and Private Sector Activity

Government

- Based on the Ministry of Energy and Mineral Resources Decree No. 25 Year 2013 and further enforced by the Ministerial Regulation of Ministry of Energy and Mineral Resources No. 12 Year 2015, there is a mandate of 2% SAF blending in 2016, 3% by 2020, and 5% by 2025. However, as of 2020, the target has not been met as Indonesia has only developed a 2.0% and 2.4% mixture of J2.0 and J2.4, respectively.[314,313]
- In 2015, the Federal Aviation Administration and Indonesian Directorate General of Civil Aviation signed an agreement to promote developing and using sustainable, alternative aviation fuels and additional environmental collaboration between the United States and Indonesia.[312]
- On 18 September 2024, the Coordinating Ministry for Maritime Affairs and Investment has revealed Indonesia's SAF roadmap and policy action plan. Starting 2027, international flights departing Indonesia will be required to use SAF in their fuel mix. This includes an initial 1% SAF blending target by 2027, 2.5% SAF blending target by 2030 and a 30% SAF blending target by 2050.[288]

Ministerial Regulation of Ministry of Energy and Mineral Resources No. 12 Year 2015

- The Regulation of the Minister of Energy and Mineral Resources Number 12 of 2015 pertains to the third amendment to the Regulation of the Minister of Energy and Mineral Resources Number 32 of 2008.
- It discusses the regulation regarding the minimum mixture requirement of biofuel usage.
- For air transport, the stages of minimum requirements to use pure vegetable oil (E100) as a mixture of fuel oil are the following: 2% by 2016, 3% by 2020, and 5% by 2025.

Private Sector

Garuda Indonesia

- Garuda Indonesia has flown commercial flights using palm oil-blended jet fuel produced by PT Pertamina.[289]
- Pertamina has supplied 2.4% SAF-blended jet fuel to Garuda.[288]

PERTAMINA

- PT Pertamina through PT Kilang Pertamina Internasional has developed its own SAF, Bioavtur J2.4, in the Kilang Cilacap refinery using hydro-treated esters and fatty acid technology.[288]
- J2.4 is the first SAF in the Southeast Asia region and is made up of refined bleached deodorised palm kernel oil.[290,288]
- On 18 September 2024, PT Pertamina and Airbus signed a Memorandum of Understanding for the exploration of various local raw materials to encourage SAF development in Indonesia.[291]
- PT Pertamina Patra Niaga, a subsidiary of PT Pertamina, obtained the International Sustainability and Carbon Certification (ISCC) for the CORSIA and the Renewable Energy Directive-European Union (RED-EU) last August 2024, making it the first in SE Asia to do so.[292]

7. Institutional Frameworks

7.3 Indonesia

7.3.2 Regulatory and Investment Climate

Table 7.2 below presents a summary of the rank and score of Indonesia in several Regulatory and Investment Climate related indices:

Table 7.2: Indonesia Regulatory and Investment Climate related indices

INDONESIA						
Index	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
THE WORLD BANK [264] **Ease of Doing Business Index**	**72** of 190	**73** of 190	**73** of 190	N/A	N/A	N/A
TRANSPARENCY INTERNATIONAL[265] **Corruption Perception Index**	**89** of 180	**85** of 180	**102** of 180	**96** of 180	**110** of 180	**115** of 180
Global Innovation Index [266]	**85** of 126	**85** of 129	**85** of 131	**87** of 132	**75** of 132	**61** of 132
OECD [267] **Foreign Direct Investment Regulatory Restrictiveness Index** (from 0 to 1)	0.35	0.35	0.35	N/A	N/A	N/A

Notes:

1. Ease of Doing Business Index: The higher the rank, the more business-friendly regulations a country has.
2. Corruption Perception Index: The higher the rank, the less corrupt the country's public sector is perceived to be relative to the other countries in the index.
3. Global Innovation Index: The higher the rank, the more successful a country's innovation performance is compared to other countries in the index.
4. Foreign Direct Investment Regulatory Restrictiveness Index: The closer to 1, the more restrictive the environment is.

7. Institutional Frameworks

7.4 Lao PDR

7.4.1 Regulatory and Investment Climate

Table 7.3 below presents a summary of the rank of Lao PDR in several Regulatory and Investment Climate related indices:

Table 7.3: Lao PDR Regulatory and Investment Climate related indices

LAO PDR						
Index	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
THE WORLD BANK [264] **Ease of Doing Business Index**	**141** of 190	**154** of 190	**154** of 190	N/A	N/A	N/A
TRANSPARENCY INTERNATIONAL[265] **Corruption Perception Index**	**132** of 180	**130** of 180	**134** of 180	**128** of 180	**126** of 180	**136** of 180
Global Innovation Index [266]	N/A	N/A	**113** of 131	**117** of 132	**112** of 132	**110** of 132
OECD [267] **Foreign Direct Investment Regulatory Restrictiveness Index** (from 0 to 1)	N/A	0.19	N/A	N/A	N/A	N/A

Notes:

1. Ease of Doing Business Index: The higher the rank, the more business-friendly regulations a country has.
2. Corruption Perception Index: The higher the rank, the less corrupt the country's public sector is perceived to be relative to the other countries in the index.
3. Global Innovation Index: The higher the rank, the more successful a country's innovation performance is compared to other countries in the index.
4. Foreign Direct Investment Regulatory Restrictiveness Index: The closer to 1, the more restrictive the environment is.

7. Institutional Frameworks

7.5 Malaysia

7.5.1 Government and Private Sector Activity

Government
• The Malaysian government aims to begin producing sustainable aviation fuel (SAF) by 2027, with an initial production capacity of one million metric tons per year.[231] The Malaysia government plans to boost SAF production from the use of palm oil waste.[319] • Under the government's National Energy Transition Roadmap published in 2023, the government established a SAF blending mandate starting with 1%, aiming for a 47% blend by 2050.[318] • To encourage domestic production of SAF and biodiesel, the government will introduce additional higher tax brackets for crude palm oil (CPO) exports and increase the windfall profit levy threshold for the palm sector[319]. • The government will also allocate 100m ringgit to incentivise smallholders to replant unproductive, ageing oil palm trees in Malaysia.[320] • Malaysia government launched the "Malaysia Aviation Decarbonization Blueprint (MADB)", which aims to help the aviation industry achieve net zero emissions by 2050, with the estimated contribution to emissions reduction is highest from SAF (46%). [321]

Private Sector	
Malaysia Airlines	• On June 5, 2022, Malaysia Airlines operated its first passenger flight using SAF on this flight from Kuala Lumpur International Airport (KLIA) to Singapore Changi Airport (SIN). The flight was operated by a Boeing 737-800 aircraft and used a blend of conventional jet fuel and Neste MY SAF [322]. • On 6th March 2024, Malaysia Airlines launched the Malaysia Airlines Corporate Carbon Programme to empower corporate customers to offset the carbon emissions associated with their travel. The programme will extend its offerings to include SAF credits, allowing corporate clients to actively contribute to sustainable aviation practices [325].
PETRONAS	• Petronas and Idemitsu Kosan have signed a memorandum of understanding (MoU) to enhance capabilities across the supply chain and optimise the route to market for sustainable aviation fuel (SAF) [324]. • In 2023, Petronas has signed a sustainable aviation fuel (SAF) offtake agreement with Malaysian Aviation Group (MAG) to supply more than 230,000 tonnes of SAF with first delivery in 2027 [323]. • As per the country's 2025 financial budget, Petronas will collaborate with palm oil producers, including FGV and SD Guthrie, to develop palm oil waste-based SAF [319]. • Petronas and EcoCeres Renewable Fuels Sdn Bhd are in partnership with Enilive and Euglena, are constructing a SAF refinery and production plant with capacity of 350,000 and 650,000 metric tons per year, respectively[318].
VANDELAY VENTURES	• In February 2022, Vandelay Venture and Suria Capital Holdings signed a Memorandum of Understanding (MoU) to develop the Sabah Maju Jaya Renewable Energy Industrial Complex. This project involves the construction of a production facility for SAF and renewable diesel, with an expected SAF production capacity of 250,000 tonnes, which will be completed by 2025. [329]

7. Institutional Frameworks

7.5 Malaysia

7.5.2 Regulatory and Investment Climate

Table 7.4 below presents a summary of the rank of Malaysia in several Regulatory and Investment Climate related indices:

Table 7.4: Malaysia Regulatory and Investment Climate related indices

MALAYSIA						
Index	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
THE WORLD BANK [264] **Ease of Doing Business Index**	**24** of 190	**15** of 190	**12** of 190	N/A	N/A	N/A
TRANSPARENCY INTERNATIONAL[265] **Corruption Perception Index**	**47** of 180	**53** of 180	**51** of 180	**48** of 180	**47** of 180	**50** of 180
Global Innovation Index [266]	**45** of 126	**42** of 129	**33** of 131	**36** of 132	**36** of 132	**36** of 132
OECD [267] **Foreign Direct Investment Regulatory Restrictiveness Index** (from 0 to 1)	N/A	0.252	N/A	N/A	N/A	N/A

Notes:

1. Ease of Doing Business Index: The higher the rank, the more business-friendly regulations a country has.
2. Corruption Perception Index: The higher the rank, the less corrupt the country’s public sector is perceived to be relative to the other countries in the index.
3. Global Innovation Index: The higher the rank, the more successful a country’s innovation performance is compared to other countries in the index.
4. Foreign Direct Investment Regulatory Restrictiveness Index: The closer to 1, the more restrictive the environment is.

7. Institutional Frameworks,

7.6 Philippines

7.6.1 Government and Private Sector Activity

Government
• There are two (2) key regulations promoting biofuels production and use in the Philippines, namely the Renewable Energy Act and Biofuels Act of the Philippines.[191] Section 9.2 of the Biofuels Act of 2006 recommends the use of biofuel blends in air transport.[282] • In 2023, the Department of Trade and Industry (DTI) announced that the Philippine government has plans to develop a SAF industry in the country. The Department of Energy (DOE) also mentioned that it is working to establish the necessary framework and regulations governing SAF.[283] • As of October 2024, a SAF committee under the National Biofuels Board and led by the Department of Energy has been formed. [284] • Per the DOE, the roadmap for the SAF will be developed this July and released once finalised[271]. As per liaison and feedback from Boeing (key stakeholder of this study), the SAF roadmap is expected in 2025.

Private Sector	
cebu pacific	• The first low-cost carrier to use SAF in the Southeast Asia and had its first SAF-powered flight in 2022 using 35% blended SAF.[285] • Signed a memorandum of understanding (MOU) with Shell on 27 September 2022 for the supply of 25,000t of blended SAF from 2026 to 203.[279] • Signed a five-year MOU with Neste on 19 October 2023 for the supply of SAF. [183, 286] • Aims to integrate SAF to all its commercial fleet by 2030.[263]
Philippine Airlines The Heart of the Filipino	• Aims to use at least 1% SAF blend for its Singapore flights by 2026 due to Singapore's mandate that all flights departing from its airport shall use at least 1% SAF by 2026.[80] • In discussions with potential suppliers to hopefully secure a SAF supply as early as 2025. [80] • Pledged to adopt 5% of SAF by 2030.[81]

7. Institutional Frameworks

7.6 Philippines

7.6.2 Regulatory and Investment Climate

Table 7.5 below presents a summary of the rank of the Philippines in several Regulatory and Investment Climate related indices.

Table 7.5: Philippines Regulatory and Investment Climate related indices

PHILIPPINES						
Index	2018	2019	2020	2021	2022	2023
THE WORLD BANK [264] **Ease of Doing Business Index**	**113** of 190	**124** of 190	**95** of 190	N/A	N/A	N/A
TRANSPARENCY INTERNATIONAL[265] **Corruption Perception Index**	**99** of 180	**113** of 180	**115** of 180	**117** of 180	**116** of 180	**115** of 180
Global Innovation Index [266]	**82** of 126	**76** of 129	**50** of 131	**51** of 132	**59** of 132	**56** of 132
OECD [267] **Foreign Direct Investment Regulatory Restrictiveness Index** (from 0 to 1)	N/A	0.37	N/A	N/A	N/A	N/A

Notes:

1. Ease of Doing Business Index: The higher the rank, the more business-friendly regulations a country has.
2. Corruption Perception Index: The higher the rank, the less corrupt the country's public sector is perceived to be relative to the other countries in the index.
3. Global Innovation Index: The higher the rank, the more successful a country's innovation performance is compared to other countries in the index.
4. Foreign Direct Investment Regulatory Restrictiveness Index: The closer to 1, the more restrictive the environment is.

7. Institutional Frameworks

7.7 Thailand

7.7.1 Government and Private Sector Activity

Government
• A biodiesel blending mandate was launched in 2012. Both biodiesel and bioethanol have been produced in the country for more than ten (10) years. [279] • A new edition of the oil plan, which is said to promote SAF production, is currently on the works, with public consultation ending on 12 July 2024. The revised plan proposes that a working panel be formed to explore the use of sugarcane bagasse, molasses, cassava residues, and used cooking oil as raw materials for SAF production. [277, 280] • According to the Department of Energy Business, the revised plan covers the expectation that SAF be mixed at 1% of total aviation fuel by 2026. [281] • The Department of Energy Business Deputy Director-General said that they aim to finalise an investment incentive proposal for SAF manufacturing by early 2024.[282] As of writing, this has not yet been finalised.

Private Sector	
bangchak	• Bangchak Corporation Public Company Limited (Bangchak) and BBGI Public Company Limited, together with Thanachok Oil Light Company Limited signed an MOU on 1 September 2022 to establish BSGF Company Limited, which is targeted to be Thailand's first and only producer of SAF from UCO.[283] • On January 2024, Bangchak Group announced that the construction of the SAF production plant to be operated by BSGF Company has begun. The plant is located within Bangchak Phra Khanong Refinery and has a production capacity of 1 million liters/day. It is expected to start operations in Q1 2025. [284, 285, 286] • Bangchak and Japan's Sumitomo Corp. signed a cooperative framework agreement on 3 April 2024 for the procurement of used cooking oil and the sale of SAF. [287] • Bangchak currently has a "Fry to Fly" and "No Refry" campaign which enables them to collect UCO from 162 collection points at designated service stations nationwide. This encourages households or restaurants to recycle UCO.
THAI ptt	• Thailand commenced its first commercial output of sustainable aviation fuel (SAF) in January 2025 to promote greener air travel. • Thai Airways and PTT Oil and Retail Business Public Company Limited signed a MOU for the use of SAF for pilot flights. [289] • Thai Airways has flown its first flight using Neste MY SAF and blended SAF from PTT last December 2023. [288] • Pledged to a sustainable aviation fuel (SAF) utilisation target of 5% by 2030. • PTT also began the country's first commercial production of SAFs and plans six million litres in annual output for the first phase using used cooling oil as the feedstock. [333]
BAFS	• Bangkok Aviation Fuel Services (BAFS), together with EA Bio Innovation, is planning to develop SAF using jet A-1.[290] • Energy Absolute Plc (EA) is said to be building a SAF production plant in Rayong [290] • In 2023, BAFS encouraged its employees to bring used cooking oil (UCO) to sell to Bangchak. The UCO will be used in producing SAF. [291] • Nathasit Diskul, president of BAFS, has suggested that excise tax for jet fuel which is currently at 20% be reduced to promote the use of SAF. [290]
vietjet Air	• Vietjet Thailand is the first budget airline in the region to use SAF in its commercial flight. The flight occurred on 10 July 2024. [297] • The airline is striving to use 1% SAF by 2026 and 5% by 2030. [292] • Vietjet Thailand and PTT Oil and Retail Business Public Co. Ltd. signed a MOU for the use of SAF across Vietjet Thailand flights starting July 2024. [297]

7. Institutional Frameworks

7.7 Thailand

7.7.2 Regulatory and Investment Climate

Table 7.6 below presents a summary of the rank of Thailand in several Regulatory and Investment Climate related indices:

Table 7.6: Thailand Regulatory and Investment Climate related indices

THAILAND						
Index	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
THE WORLD BANK [264] **Ease of Doing Business Index**	**26** of 190	**27** of 190	**21** of 190	N/A	N/A	N/A
TRANSPARENCY INTERNATIONAL[265] **Corruption Perception Index**	**99** of 180	**101** of 180	**104** of 180	**110** of 180	**101** of 180	**108** of 180
Global Innovation Index [266]	**44** of 126	**47** of 129	**44** of 131	**43** of 132	**43** of 132	**43** of 132
OECD [267] **Foreign Direct Investment Regulatory Restrictiveness Index** (from 0 to 1)	N/A	0.27	N/A	N/A	N/A	N/A

Notes:

1. Ease of Doing Business Index: The higher the rank, the more business-friendly regulations a country has.
2. Corruption Perception Index: The higher the rank, the less corrupt the country’s public sector is perceived to be relative to the other countries in the index.
3. Global Innovation Index: The higher the rank, the more successful a country’s innovation performance is compared to other countries in the index.
4. Foreign Direct Investment Regulatory Restrictiveness Index: The closer to 1, the more restrictive the environment is.

7. Institutional Frameworks

7.8 Vietnam

7.8.1 Government and Private Sector Activity

Government
• At the COP26 in November 2021, Prime Minister Pham Minh Chinh mentioned that the Vietnam government will be taking necessary steps to achieve a full green energy transition by 2050. This includes a pledge to use 100% SAF and green energy for its local aircrafts.[225] • Decision No. 876/QD-TTg dated 22 July 2022 discusses the action plan for Vietnam's transition to green energy. From 2035, the goal is to use at least 10% SAF for some short-distance flights.[296] • As per liaison and feedback from Boeing (key stakeholder of this study), Vietnam's SAF Roadmap is currently under development and is expected in 2025.

Private Sector	
Vietnam Airlines	• Vietnam Airlines has flown its first SAF-powered commercial flight from Changi Airport to Hanoi, Vietnam using a blend of Neste MY SAF and conventional jet fuel on 27 May 2024. [293] • The SAF was produced by Neste at its Singapore refinery.[293]
vietjet AIR	• Vietjet has signed a MOU with SAF One Energy Management Limited in 2023 to collaborate on SAF supply in Vietnam.[294]

7. Institutional Frameworks

7.8 Vietnam

7.8.2 Regulatory and Investment Climate

Table 7.7 below presents a summary of the rank of Vietnam in several Regulatory and Investment Climate related indices:

Table 7.7: Vietnam Regulatory and Investment Climate related indices

VIETNAM						
Index	2018	2019	2020	2021	2022	2023
THE WORLD BANK [264] Ease of Doing Business Index	**68** of 190	**69** of 190	**70** of 190	N/A	N/A	N/A
TRANSPARENCY INTERNATIONAL[265] Corruption Perception Index	**117** of 180	**96** of 180	**104** of 180	**87** of 180	**77** of 180	**83** of 180
Global Innovation Index [266]	**45** of 126	**42** of 129	**42** of 131	**44** of 132	**48** of 132	**46** of 132
OECD [267] Foreign Direct Investment Regulatory Restrictiveness Index (from 0 to 1)	N/A	0.13	N/A	N/A	N/A	N/A

Notes:

1. Ease of Doing Business Index: The higher the rank, the more business-friendly regulations a country has.
2. Corruption Perception Index: The higher the rank, the less corrupt the country's public sector is perceived to be relative to the other countries in the index.
3. Global Innovation Index: The higher the rank, the more successful a country's innovation performance is compared to other countries in the index.
4. Foreign Direct Investment Regulatory Restrictiveness Index: The closer to 1, the more restrictive the environment is.

8. Financial Assessment

GHD Advisory

Financial Assessment Overview

8. Financial Assessment

8.1 Financial Assessment Overview

The financial assessment included the scale of the plant, CAPEX, OPEX, the LCO SAF for technology pathways with the key findings documented and tabulated below.

Key findings

Scale of plant - Given the high costs of a SAF plant (and diseconomies of scale), the minimum size is about 1,000 bpd using ~200k-560k tons of wet biomass, depending on the technology.

Price of SAF -Our levelised cost of SAF calculation and high-level financial modelling, both including the cost of capital, indicate the price of SAF is significantly lower with HTL (not yet ASTM approved) at about 4,500 to 5,600 USD/ton vs 8,000 to 10,000 USD/ton for Gasification FT and ATJ (feedstock to SAF).

Key drivers of SAF price - CAPEX is the key driver with a change of 10% in CAPEX generating a change of about 9% in the price of SAF versus 2% for OPEX and 1% for price of feedstock. However, feedstock supply is the base of the successful commercial feasibility of a SAF project. Without bankable availability, cost and terms of the supply feedstock agreements, projects are unlikely to reach financial close.

Government support - The prices obtained for SAF produced with agriculture and forestry waste are multiples of the price of fossil jet fuel and HEFA SAF. Hence, government support is required to generate demand and/or reduce the green premium. For instance, blending mandate (demand side) or tax breaks, subsidies (supply side) and R&D grants and funding to improve technologies and efficiencies.

ATJ flexibility - The ATJ pathway provide additional commercial and financial flexibility versus Gasification + FT and HTL as its intermediate liquid product (bio-ethanol / butanol) can be sold without having to upgrade to SAF (and renewable diesel), enabling a phased approach.

Please refer to section 1.6 for general limitations and assumptions used to prepare this analysis.

Table 8.1: Scale, CAPEX and SAF price for each Technology Pathway

	Units	Gasification and FT	ATJ	HTL and Upgrading
Scale Minimum – 1,000 bpd	Feedstock Tpa*	490k	564k	210k
Ideal – 2,000 bpd	Feedstock Tpa*	980k	1,127k	420k
CAPEX 1,000 bpd	USD million	716	700	400
2,000 bpd	USD million	1,251	1,199	699
SAF price 1,000 bpd	USD / ton	9,223 - 10,200	9,154 – 10,150	5,048 – 5,600
2,000 bpd	USD / ton	8,159 – 9,050	7,970 – 8,850	4,454 – 4,940

**Biomass with 40% water content*

GHD Advisory

→ Financial Assessment Deeper Dive

8. Financial Assessment

8.2 Financial Assessment including Scale, CAPEX, OPEX and LCO SAF for Technology Pathways

Key findings – SAF production with agriculture and forestry biomass

Scale of plant

CAPEX for SAF production facilities is high as the available technologies are relatively young and, hence, their total installed cost is still very high. Table 2 shows order of magnitude CAPEX values.

There are economies of scale in CAPEX for SAF production facilities. From our experience with SAF projects, we believe the minimum scale of plant is ~1,000 bpd using ~200k-560k tons of wet biomass as feedstock, depending on the technology. Achieving financial feasibility for smaller plants becomes more difficult as the CAPEX / bpd is too high.

To take advantage of economies of scale, facilities producing larger volumes of fuels are desirable. However, this should be balanced with a practical volume of biomass to source, transport and store at site. Therefore, the plant capacities were limited to 2,000 bpsd.

In our experience, successful projects are likely to mix several types of biomass to mitigate the risk of feedstock supply, including seasonality.

The ATJ pathway provide additional commercial and financial flexibility versus Gasification + FT and HTL as its intermediate liquid product (bio-ethanol / butanol) can be sold without having to upgrade to SAF (and renewable diesel). This implies that the section of the plant from biomass to alcohol could be constructed initially and the facility run to generate revenue from the bio-alcohol produced, followed by investment in and construction of the alcohol-to-jet facility at a later stage of the project, thereby staggering CAPEX investment. This has not been tested in the financial model.

Please refer to Sections 1.4 and 1.7 for general limitations and assumptions used to prepare this analysis.

Table 8.2: Scale, CAPEX and OPEX for each Technology Pathway

	Units	Gasification and FT	ATJ	HTL and Upgrading
Scale				
Minimum	Bpd	1,000	1,000	1,000
Ideal	Bpd	2,000	2,000	2,000
Minimum	Feedstock Tpa*	490k	564k	210k
Ideal	Feedstock Tpa*	980k	1,127k	420k
CAPEX				
1,000 bpd	USD million	716	700	400
2,000 bpd	USD million	1,251	1,199	699
1,000 bpd	USD / bpd	716k	700k	400k
2,000 bpd	USD / bpd	625k	599k	350k
OPEX				
1,000 & 2,000 bpd				
Maintenance CAPEX	% of CAPEX pa	2%	2%	2%
Non-feedstock CAPEX	% of CAPEX pa	5%	5%	5%

**Biomass with 40% water content*

8. Financial Assessment

8.3 Financial Assessment including Scale, CAPEX, OPEX and LCO SAF for Technology Pathways

Key findings – SAF production with agriculture and forestry biomass

Estimated cost of producing SAF

To assess the financial feasibility of producing SAF, GHD used two approaches: (1) calculation of the levelised cost of SAF* (LCO SAF)
(2) ran a 20-year high-level financial model to calculate the required price of SAF to generate an IRR to equity investors of 20%.

1. LCO SAF
We define the LCO SAF as: LCO SAF = (CAPEX + OPEX) / units produced, all for a period of 20 years.

As shown in Table 3, the LCO SAF obtained, including the cost of capital, is about 8,000-9,000 USD/ton for Gasification + FT and ATJ and 4,500-5,000 USD/ton for HTL. However, as mentioned before HTL is not yet an approved ASTM approved pathway to SAF. From our experience, the certification process can take 2-3 years. However, there are currently proponents exploring this pathway for SAF certification.

The key driver of the LCO SAF is CAPEX. A change of 10% in CAPEX, generates a change of 9% in the LCO SAF versus 2% for OPEX and 1% for price of feedstock.

However, in our opinion, feedstock supply is the base of the successful commercial feasibility of a SAF project. Without bankable availability, cost and terms of the supply feedstock agreements, projects are unlikely to reach financial close.

These LCO SAF obtained are multiples of the current price of fossil jet fuel and, hence, a blending mandate or similar support regulation like the one in EU, UK and US is required for major adoption of SAF produced from agricultural and forestry waste.

Table 8.3: LCO SAF for each Technology Pathway

	Units	Gasification and FT	ATJ	HTL and Upgrading
LCO SAF 1,000 bpd	USD / ton	9,223	9,154	5,048
2,000 bpd	USD / ton	8,159	7,970	4,454

The LCO SAF calculations and our assumptions are shown on the next slide. Please refer to section 1.4 for general limitations and assumptions.

8. Financial Assessment

8.4 Financial Assessment including Scale, CAPEX, OPEX and LCO SAF for Technology Pathways

Table 8.4: Calculations of LCO SAF

1,000 bpd					
Assumptions in blue					
		Gasification + FT	**ATJ**	**HTL**	
Installed capacity	bpd	1,000	1,000	1,000	
SAF portion of total production	bpd	70%	70%	70%	
Feedstock used, wet	tpa '000	490	564	210	
Feedstock Price	USD/ton wet	40	40	40	
Maintenance Opex	% of Capex pa	2%	2%	2%	
Non-feedstock Opex	% of Capex pa	5%	5%	5%	
Capacity factor	%	92%	92%	92%	
Cost of Capital (blended debt & equity)	%	14%	14%	14%	
Number of years		20	20	20	
Capex	USD MM	716	700	400	
Cost of Capital	USD MM	2,406	2,352	1,344	20 years
Maintenance Opex	USD MM	286	280	160	20 years
Non-feedstock Opex	USD MM	716	700	400	20 years
Feedstock	USD MM	392	451	168	20 years
Total Costs 20 years	**USD MM**	**4,516**	**4,483**	**2,472**	
Total products	barrels	6,716,000	6,716,000	6,716,000	20 years
Total SAF	barrels	4,701,200	4,701,200	4,701,200	20 years
Total SAF	Ton	342,779	342,779	342,779	20 years
LCO SAF	**USD/ton**	**9,223**	**9,154**	**5,048**	

2,000 bpd					
Assumptions in blue					
		Gasification + FT	**ATJ**	**HTL**	
Installed capacity	bpd	2,000	2,000	2,000	
SAF portion of total production	bpd	70%	70%	70%	
Feedstock used, wet	tpa '000	980	1,127	420	
Feedstock Price	USD/ton wet	40	40	40	
Maintenance Opex	% of Capex pa	2%	2%	2%	
Non-feedstock Opex	% of Capex pa	5%	5%	5%	
Capacity factor	%	92%	92%	92%	
Cost of Capital (blended debt & equity)	%	14%	14%	14%	
Number of years		20	20	20	
Capex	USD MM	1,251	1,199	699	
Cost of Capital	USD MM	4,204	4,027	2,348	20 years
Maintenance Opex	USD MM	500	479	280	20 years
Non-feedstock Opex	USD MM	1,251	1,199	699	20 years
Feedstock	USD MM	784	902	336	20 years
Total Costs 20 years	**USD MM**	**7,990**	**7,805**	**4,362**	
Total products	barrels	13,432,000	13,432,000	13,432,000	20 years
Total SAF	barrels	9,402,400	9,402,400	9,402,400	20 years
Total SAF	Ton	685,557	685,557	685,557	20 years
LCO SAF	**USD/ton**	**8,159**	**7,970**	**4,454**	

8. Financial Assessment

8.5 Financial Assessment including Scale, CAPEX, OPEX and LCO SAF for Technology Pathways

Key findings – SAF production with agriculture and forestry biomass

2. High-level financial model
Our high-level financial model indicates that the SAF prices required to generate an IRR to equity investors of 20% is about 9,000-10,000 USD/ton for Gasification + FT and ATJ and 5,000-5,600 USD/ton for HTL.

These results are in-line with the LOC SAF calculations.

Table 8.5: Price of SAF – High-level financial model

	Units	Gasification and FT	ATJ	HTL and Upgrading
Price of SAF				
1,000 bpd	USD / ton	10,200	10,150	5,600
2,000 bpd	USD / ton	9,050	8,850	4,940

The assumptions used in our high-level financial model are shown on the next slide. Please refer to Sections 1.4 and 1.7 for general limitations and assumptions.

8. Financial Assessment

8.6 Financial Assessment including Scale, CAPEX, OPEX and LCO SAF for Technology Pathways

Table 8.6: Assumptions of high-level financial model

General Assumptions		
Periods		
Constructon duration	years	3
Operational duration	years	20
Financial Parameters		
Tax rate	%	30%
Annual inflation rate	%	3.0%
Terminal value of the SAF plant	%	0.0%
Capital Structure		
Total capital requied by capital expenditure	USD	716,191,520
Pre-Operating Expenses + Contingencies	USD	-
Working Capital (Minimum Initial)	USD	-
Project percent debt financed	%	60%
Project percent equity financed	%	40%
Debt interest rate	%	9.6%
Debt Tenor (years)	years	15
Debt Raised	USD	429,714,912
Equity	USD	286,476,608
Target equity IRR		20%
Blended Cost of Capital		14%
OPEX		
Maintenance OPEX % of CAPEX	%	2%
Other OPEX as % of CAPEX	%	5%
Depreciation		
Depreciation	Years	20
Products Splits (as a % of barrels produced)		
Naptha	tonnes	18%
Jetfuel	tonnes	70%
Renewable diesel	tonnes	12%
Pricing		
Biomass	USD per tonne	40
Capacity factor	%	92%

All CAPEX and feedstock consumption assumptions for each technology and size of plant are as shown in the previous pages of this section.

9. Concluding Remarks and Recommendations

9. Concluding Remarks and Recommendations

9.1 Concluding Remarks

Southeast Asia SAFs Hub

Southeast Asia has the potential and multiple characteristics to form a regional SAFs hub given the proximity of countries and availability of feedstocks such as wastes from cassava, rice, corn, coconut, corn, oil palm fruit and forestry activities. There are multiple advantages, commenced initiatives and key players active within the SAF sector in the region. Across the seven (7) countries assessed, the developments in Cambodia and Lao PDR appear to be relatively nascent, however these countries' location relative to Thailand may become an advantage given Thailand's observed developments.

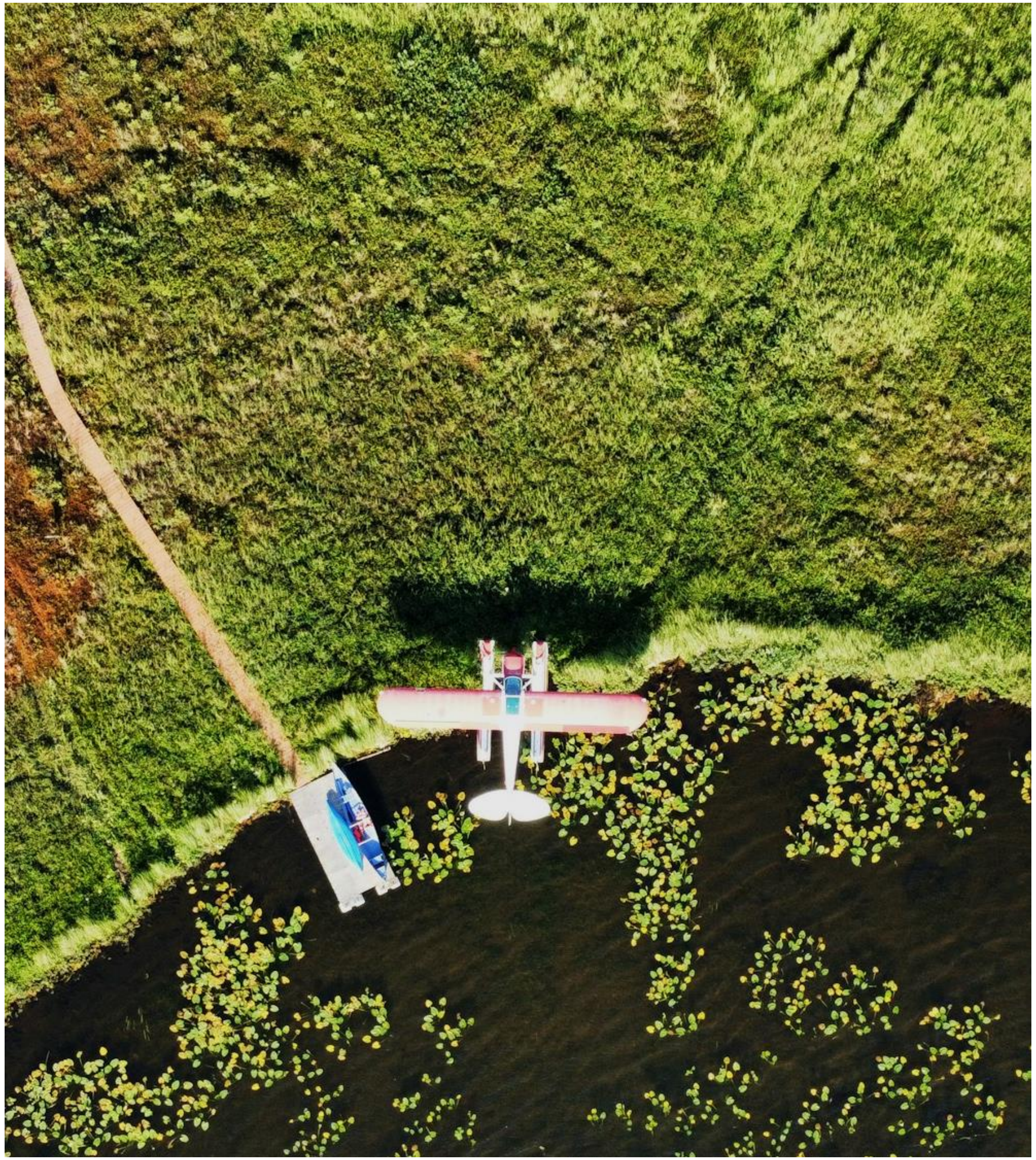
Additional Considerations

There are multiple positive initiatives and advantages across the region for SAF production. Additional feedstock production is unlikely to come from agricultural land expansion, but rather improvements in farming practices, increased irrigation, R&D and large-scale biomass adoption. Smallholder farming makes up the majority of farming activities, which creates some complexity with regards to contracting and aggregation of these feedstocks.

Feedstock certification may also require key consideration given feedstocks such as cassava, palm oil, and forest and wood residues demonstrate certification risks under CORSIA guidelines. Additional and/or redistribution of environmental and social burdens should also be mitigated and further improved where possible. This includes key areas such as considering the environmental impacts of bio-refineries and blending facilities and potential unintended consequences on land use, biodiversity, and food security, as well as social impacts such as displacement and/or creation of jobs.

Technology Pathways

The Technology Pathway MCA, using the following criteria: Financial indicators (33%), Environmental/Efficiency indicators (30%), Technical indicators (27%), and Experience indicators (10%), has determined that HEFA ranks the highest overall, followed by ATJ, HTL, Gasification/Fischer-Tropsch, and Gasification/Methanol. However, it should be noted that HEFA requires oils and fats as feedstocks, which limits its applicability to many other agricultural and forestry feedstock wastes, in which case the ATJ pathway would rank the highest for these feedstocks.



9. Concluding Remarks and Recommendations

9.1 Concluding Remarks

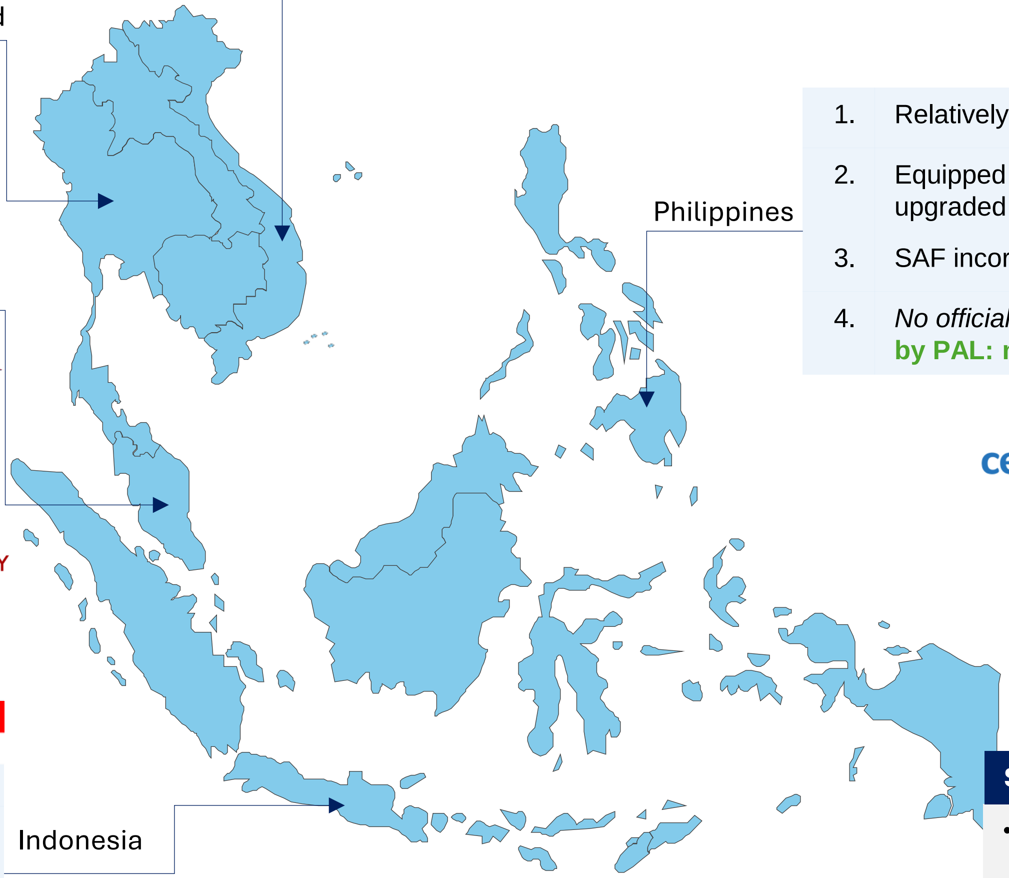
1. Relatively high feedstock availability
2. Equipped with oil import/export facilities that can be upgraded.
3. Have commenced first commercial production of Sustainable Aviation Fuel.
4. Appear to be relatively more mature in the planning and implementation of SAF e.g. incentive proposal is in discussions and SAF product plants being built.
5. *No official SAF mandates yet,* however **SAF Targets by Thai Airways International: 2% to 60% SAF Blending from 2025 to 2050**

1. Equipped with oil import/export facilities that can be upgraded.
2. SAF incorporation initiated by Vietnam Airlines
3. *No official SAF mandates yet*

1. Equipped with oil import/export facilities that can be upgraded.
2. Long term plans in place for the use of SAF.
3. SAF incorporation initiated by Malaysia Airlines
4. Appear to be relatively more mature in the planning and implementation of SAF e.g. SAF incentive and credits program, SAF supply chain optimisation plan, and SAF facilities being built.
5. **Target: 47% SAF Blending by 2050**

1. Relatively high amount of existing biorefineries
2. Equipped with oil import/export facilities that can be upgraded
3. SAF incorporation initiated by Cebu Pacific Airlines
4. *No official SAF mandates yet,* however **SAF Targets by PAL: min 1% SAF Blending by 2026**

1. Relatively high feedstock availability
2. Equipped with oil import/export facilities that can be upgraded.
3. Long term plans in place for the use of SAF.
4. SAF incorporation initiated by Garuda Indonesia.
5. Appear to be relatively more mature in the planning and implementation of SAF e.g. released mandate of SAF blending.
6. **Target: 2.5% SAF Blending by 2030, 30% SAF Blending by 2050**



SAF Blending Target by Other Countries

- **Cambodia and Lao PDR**: *no official SAF mandates yet*
- **Japan**: **10% SAF Blending by 2030**
- **Singapore**: **3-5% SAF Blending by 2030**
- **South Korea**: **1% SAF Blending by 2027**

Figure 9.1: Example SAF advantages and initiatives across Southeast Asia

9. Concluding Remarks and Recommendations

9.2 Recommendations on potential levers and contract/government initiative enablers

Potential Levers (Government Support) for Project Developments

Based on the study completed, the following potential levers may be considered by government stakeholders to assist with the SAF project developments:

- Government to establish a biomass inventory register detailing biomass types, availability, utilization and major stakeholder groups.
- Government to establish land management outreach with farmers and the agricultural sector to promote involvement in SAF feedstock supply and sustainable attitudes to its production.
- Government to consider establishment of SAF carbon accounting methodologies consistent with international best practices, including IATA's newly announced SAF Accounting and Reporting Methodology and upcoming SAF Registry.This includes establishing a local guarantee of origin (GoO) schemes to support product quality and low-carbon integrity for client customers and avoid inconsistencies arising from differing methodologies across countries.
- Government to consider planning for bioenergy precincts enabling the coordination of share services and infrastructure, reducing SAF project development risk.
- Government to consider planning for logistics infrastructure to allow for feedstock and product movement including road planning reservations from key biomass sources to potential SAF production precincts, and product from precincts to export or domestic consumption centres.
- Government to establish a centralised SAF development hub with general information to speed-up and facilitate developments including technology pathways with their costs, yields, utilities requirements, minimum scale, quantities of feedstock required
- Grants focused on specific studies to structure the feedstock supply for a particular project (not industry wide but project specific), covering feedstock availability, cost, contractibility / bankability, logistics.
- Government to provide guarantees for project finance debt to cover offtake merchant risk, feedstock risk, performance risk or directly provide low-cost loans.

Potential Contract and Government Initiative Enablers

Assuming this is for contracts between the project developer (SAF plant) and the growers, "nice to haves" in the contracts for the growers are:

- Buyer commits to buy 100% of the waste biomass generated, however the grower doesn't have the obligation of a specific number of tons because their waste biomass supply is dependent on factors such as the crop / weather.
- Buyer provides gathering infrastructure required such as bins or warehouses, if required.
- Buyer is responsible for transportation of the biomass.
- Buyer pays a known price per ton and yearly indexation is also known e.g. inflation.

Initiatives that governments can do to facilitate the feedstock supply:

- Provide grants to cooperatives of growers for infrastructure and machinery required to aggregate and store biomass, if required.
- Provide investment incentives for waste management companies as they have been typically known to gather biomass from growers and deliver to SAF plant(s).

9. Concluding Remarks and Recommendations

9.3 Policy Development Guidance Overview

Below includes multiple examples and areas of policy development identified and/or applied in specific jurisdictions with the objective of accelerating SAF adoption. Furthermore, a high-level review on potential impacts to SAF importing and exporting countries is also included.

1. Incentivisation through Production Credits

Page 192 includes an example whereby US has adopted provision of tax incentives based on fuel's Carbon Intensity (CI) score. Such policies on the fuel supply can have a "push" effect, however, are reviewed to have greater impact on potential export countries, such as Indonesia and Thailand. Although there may also be impacts on countries importing SAFs, this is dependent on economic factors and if the incentives/credits assist with the cost competitiveness of SAF with respect to conventional jet fuel.

2. Mandates at the End Use Location

Page 192 includes an example whereby EU has adopted SAF mandates at union airports. Such policies on the fuel demand can have a "pull" effect and are reviewed to have both an impact on both the potential import countries (e.g. Singapore) as well as export countries (e.g. Indonesia and Thailand i.e. the pull effect may have greater impact on the overall supply chain compared to policies such as tax incentives/credits on the supply side.)

3. Establishment of a Green Trade Lane

Page 149 includes a high-level review on the potential of establishing green trade lanes, which requires collaboration. It is reviewed to have similar impacts on both potential SAF import and export countries given green trade lanes act as trade routes that connects ports and support zero-emission shipping. This may promote SAF trade and therefore has the potential to improve sustainability and efficiency of identified optimal trade routes between importers and exporters such as Indonesia SAF exports to Singapore.

4. SAF Government Support for Project Developments e.g. biomass inventory and land management

Page 219 includes examples of potential government support initiatives that can act as levers to enhance SAF adoption, particularly targeted towards potential SAF exporters, such as Indonesia and Thailand. However, with realised improvements in developing scale, technology readiness and accounting practices, further economic and sustainable advantages may be realised, impacting such SAF adoption from import countries such as Singapore.

5. SAF Contract and Government Enablers

Page 219 includes examples of potential contract enablers that largely assist potential export countries such as Indonesia and Thailand, by providing additional protection to suppliers due to inherent risks such as seasonality, as well as proposes buyers and export countries to have greater involvement in the supply chain and infrastructure developments.

9.3 Policy Development Guidance Overview

Some examples of criteria and diagnostic questions that may be considered for policy developments are included below.[332]

Lock-in and Policy Stability ("Stickiness")

Effective policy is thought to be effective in locking in and have difficulty in reversing. Various policies have different levels of lock-in and policy stability ("stickiness").
A key **diagnostic question** for this criteria is**: What can be done to create "stickiness" making reversibility immediately difficult?** An example includes contractual enablers that have the ability of establishing lock-in clauses and a duration for the contract.

Self Reinforcing

Similar to the concept of "stickiness" mentioned above, policies typically have greater success when they are self reinforcing and the costs of reversing rise over time.
The **diagnostic question** for this criteria is: **What can be done to self-reinforce and make reversibility immediately difficult**. Examples of this typically include government support for project developments that may influence technology readiness, production pathways and subsequent infrastructure developments. Once established, costs of reversing such infrastructure developments e.g. new or repurposes refineries, may increase over time.

Increasing Returns

Effective policy can also occur when the benefits increase over time.
The **diagnostic question** for this criteria is: **What can be done to entrench effectiveness over time?** A positive example may be establishments of Green Trade Lanes, which have the ability to provide long term benefits by accelerating the development and adoption of sustainable shipping technologies, promoting cleaner air quality in port cities, fostering economic growth through green innovation, and potentially contributing to reductions in greenhouse gas emission from international trade over time.

Positive Feedback

In this case, the policy has the ability to achieve positive feedback and expand populators and reinforce original support.
The **diagnostic question** for this criteria is "**What can be done to expand the population that supports the policy"**. In this case it is beneficial to consider both the US and EU policy approaches for SAF support. SAF adoption through production credits (e.g. US policy) may not be as effective as SAF Adoption Mandates at the End Use Location (e.g. EU policy) given adoption mandate appears to have greater ability to impact a greater number of populators. For example, mandate of SAF at airports may impact a greater extent of the supply chain including airports, airlines, shipping, SAF producers and feedstock suppliers. However, SAF adoption through production credits has impact on feedstock suppliers and SAF producers, however the impact on other supply chain stakeholders and further end use customers may not be as effective.

10. References

10. References

1. Stephens, H. (2024, January 4). Bagasse sweetens the case for compostable packaging. Packaging Dive. https://www.packagingdive.com/news/bagasse-sugarcane-compostable-packaging-food-service/703382/
2. ICAO. (2024, March). CORSIA Methodology for Calculating Actual Life Cycle Emissions Values. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2007%20-%20Methodology%20for%20Actual%20Life%20Cycle%20Emissions%20-%20March%202024.pdf
3. Sustainable Valorization of Waste and By-Products from Sugarcane Processing. MDPI. https://www.mdpi.com/2071-1050/13/11/6495
4. FAOSTAT. (n.d.). Retrieved from http://www.fao.org/faostat/en/#home.
5. Larson, E. D. (2023, April). Final Evaluation Report for UNDP/GEF Project BRA/96/G31, Biomass Power Generation: Sugar Cane Bagasse and Trash.
6. Sugar Regulatory Administration. (2022). Sugar Production Bulletin for CY 2021-2022.
7. Sugar Regulatory Administration. (n.d.). Mandate. http://sra.da.gov.ph/aboutUs/mandate
8. Larson, E. D. (2003, April). Final evaluation report for UNDP/GEF Project BRA/96/G31, Biomass Power Generation: Sugar Cane Bagasse & Trash. Princeton Environmental Institute, Princeton University.
9. Kurzawska-Pietrowicz, P. (2023). Life Cycle Emission of Selected Sustainable Aviation Fuels – A Review. Transportation Research Procedia, 75, 77-85. https://www.sciencedirect.com/science/article/pii/S235214652301253X
10. de Jong, S., Antonissen, K., Hoefnagels, R., Lonza, L., Wang, M., Faaij, A., & Junginger, M. (2017). Life-cycle analysis of greenhouse gas emissions from renewable jet fuel production. Biotechnology for Biofuels, 10, Article 64. https://biotechnologyforbiofuels.biomedcentral.com/articles/10.1186/s13068-017-0739-7
11. Balingbing, C., et al. (2020).
12. Mendoza, T. (2015).
13. Balingbing, C., et al.
14. Congressional Policy and Budget Research Department. (2024). Tariff Revenues from Rice Imports. https://cpbrd.congress.gov.ph/images/PDF%20Attachments/Facts%20in%20Figures/FF2024-16_Tariff_Revenues_from_Rice_Imports.pdf
15. Mutert, E., & Fairhurst, T. (2002). IRRI Rice Facts.
16. CEIC. (n.d.). Philippines Production: Annual: Corn: Yellow. https://www.ceicdata.com/en/philippines/production-cereals/production-annual-corn-yellow
17. USDA Foreign Agricultural Service. (2024). Grain and Feed Annual. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain+and+Feed+Annual_Manila_Philippines_RP2024-0009.pdf
18. Pinoy Entrepreneur. (2011, June 2). Sugarcane Production. https://www.pinoy-entrepreneur.com/2011/06/02/sugarcane-production/
19. National Democratic Front. (n.d.). Factsheet: Philippines Rice. https%3A%2F%2Fwww.ndf.int%2Fmedia%2Ffiles%2Fnews_attach%2Ffactsheet_philippines_rice.pdf&usg=AOvVaw1F53KAJekxozo8qqw2j6Uj&opi=89978449
20. GoDyaryo. (2023, August 16). Growing a lifeline: Corn cultivation in the Philippines. https://godyaryo.com/2023/08/16/growing-a-lifeline-corn-cultivation-in-the-philippines/
21. USDA Foreign Agricultural Service. (2016). Philippines: Drought in Mindanao Causes Corn Production Decline. https://ipad.fas.usda.gov/highlights/2016/03/Philippines/Index.htm
22. Juan Magsasaka. (2020, December). Cassava Production Part 1: Site Selection. https://www.juanmagsasaka.com/2020/12/cassava-production-part-1-site.html
23. University of the Witwatersrand. (n.d.). Storage of Sugar Cane Bagasse. https://www.wits.ac.za/media/wits-university/conferences/misgsa/documents/1.%20Storage%20of%20Sugar%20Cane%20Bagasse-1.pdf
24. Purchase, B. S., Rosettenstein, S., & Bezuidenhoudt, D. V. (2014). Challenges and potential solutions for storage of large quantities of bagasse for power generation. International Sugar Journal, 116, 592-602.
25. Van Hung, N., et al. (2020). Rice Straw Overview: Availability, Properties, and Management Practices. In Gummert, M., Hung, N., Chivenge, P., & Douthwaite, B. (Eds.), Sustainable Rice Straw Management. Springer, Cham. https://doi.org/10.1007/978-3-030-32373-8_1
26. Farm Progress. (n.d.). Long-term Corn Storage Checklist. https://www.farmprogress.com/corn/long-term-corn-storage-checklist
27. Lampoon Magazine. (2020, December 27). Coconut Husk Fibers. https://lampoonmagazine.com/article/2020/12/27/coconut-husk-fibers/
28. Homestead in Hawaii. (n.d.). All About Processing, Storing, and Cooking Cassava. https://www.homesteadinhawaii.com/all-about-processing-storing-and-cooking-cassava/
29. Grist. (n.d.). Wood Vaulting: Carbon Storage Solution. https://grist.org/solutions/wood-vaulting-carbon-storage-solution/
30. Land Links. (n.d.). Philippines Country Profile. https://www.land-links.org/country-profile/philippines/#:~:text=Under%20the%201987%20Constitution%2C%20all,be%20subject%20of%20private%20ownership.
31. MDPI. (2020). Title of the article. Sustainability, 12(17), 7150. https://doi.org/10.3390/su12177150
32. Rhofita, E. I., et al. (2024). Mapping analysis of farmers' perceptions of rice straw valorization in Indonesia. Environmental Development, 51, 101021.
33. Food and Agriculture Organization. (n.d.). Rice Straw Management. https://www.fao.org/4/X0513E/x0513e21.htm
34. MDPI. (2021). Sustainability, 13(11), 6495. https://www.mdpi.com/2071-1050/13/11/6495
35. IntechOpen. (n.d.). Chapter on Rice Straw Management. https://www.intechopen.com/chapters/82865
36. Malaysian Palm Oil Board. (2000). Journal of Oil Palm Research, 12(December), 21. http://jopr.mpob.gov.my/wp-content/uploads/2013/09/joprv12dec2000-lim21.pdf
37. Roundtable on Sustainable Palm Oil. (n.d.). Enhancing Thai Palm Oil Production to Meet Global Sustainability Demands. https://rspo.org/press-release-enhancing-thai-palm-oil-production-to-meet-global-sustainability-demands/
38. Vietnam Amazing. (n.d.). Rice Culture in Vietnam: A Way of Life. https://vietnam-amazing.com/vietnam-culture/rice-culture-in-vietnam-a-way-of-life/
39. Hanoi Journey. (n.d.). Rice Harvest Season in Northern Vietnam. https://www.hanoijourney.com/rice-harvest-season-northern-vietnam/
40. Nguyen Starch. (n.d.). A Comprehensive Guide to Vietnam Tapioca Starch. https://nguyenstarch.com/a-comprehensive-guide-to-vietnam-tapioca-starch/
41. USDA Foreign Agricultural Service. (n.d.). Philippines Corn Summary. https://ipad.fas.usda.gov/countrysummary/Default.aspx?id=VM&crop=Corn
42. Sustainable Cassava. (n.d.). Current status of sustainable cassava. https://sustainablecassava.org/information-hub/current-status/
43. Government Outcomes Lab. (n.d.). Mine Fields to Rice Fields, INDIGO-POJ-0291. https://golab.bsg.ox.ac.uk/knowledge-bank/indigo/impact-bond-dataset-v2/INDIGO-POJ-0291/#:~:text=The%20Mine%20Fields%20to%20Rice,and%20agricultural%20development%20in%20Cambodia
44. Huan, Y., Zhang, J., & Wang, X. (2020). Sustainable aviation fuels from waste biomass: Opportunities and challenges. ScienceDirect. https://www.sciencedirect.com/science/article/pii/S2369969820300931
45. Brew Your Own. (n.d.). Storing ingredients properly for homebrewing. https://byo.com/article/storing-ingredients/#:~:text=Stored%20properly%2C%20it%20has%20a,Director%20of%20Homebrewing%20at%20Briess
46. Malaysian Palm Oil Board. (2023). Palm oil statistics: Area summary 2023. https://bepi.mpob.gov.my/images/area/2023/Area_summary2023.pdf
47. Zhao, X., & Lin, J. (2020). Techno-economic assessment of biofuels from lignocellulosic biomass in Southeast Asia. ScienceDirect. https://www.sciencedirect.com/science/article/pii/S2589299120300343
48. World Bank. (2022). Cambodia trade statistics: Imports by product. https://wits.worldbank.org/trade/comtrade/en/country/KHM/year/2022/tradeflow/Imports/partner/ALL/product/110710
49. Malaysian Palm Oil Board. (2023). Palm oil statistics: Area summary 2023. https://bepi.mpob.gov.my/images/area/2023/Area_summary2023.pdf
50. Zhao, X., & Lin, J. (2020). Techno-economic assessment of biofuels from lignocellulosic biomass in Southeast Asia. ScienceDirect. https://www.sciencedirect.com/science/article/pii/S2589299120300343

10. References

51. Malaysian Palm Oil Board. (n.d.). Palm oil industry news: Biodiesel developments in Malaysia. https://prestasisawit.mpob.gov.my/en/palmnews/news/37414
52. International Civil Aviation Organization (ICAO). (2022). CORSIA Default Life Cycle Emissions Values. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2006%20-%20Default%20Life%20Cycle%20Emissions%20-%20June%202022.pdfWorld Bank. (n.d.). Agricultural land (% of land area) - Malaysia. https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?locations=MY
53. Owen, N. (2019). Biofuels and sustainability: Challenges and opportunities. Oxford Research Encyclopedia of Environmental Science. https://oxfordre.com/environmentalscience/environmentalscience/view/10.1093/acrefore/9780199389414.001.0001/acrefore-9780199389414-e-207
54. Theng, D., Sothorn, P., & Poch, K. (2019). Understanding waste-to-energy potential in Cambodia: A case study. PLOS ONE. https://journals.plos.org/plosone/article/file?id=10.1371%2Fjournal.pone.0210628&type=printable
55. IEA. (2023, June). Assessment of successes and lessons learned for biofuels deployment: Report Work package 2 Meta-analysis of existing studies.
56. Neste. (2012). Responsibility Report. https://www.responsibilityreports.com/HostedData/ResponsibilityReportArchive/n/neste_2012.pdf
57. State Development and Infrastructure. (2024, August 6). Fuelling the future - Queensland’s sustainable aviation revolution. https://www.statedevelopment.qld.gov.au/news/fuelling-the-future-queenslands-sustainable-aviation-revolution
58. TEConomy Partners. (2024, June). The Economic Impact of the US Industrial Bioeconomy.
59. Rischar, H. (2024, June 5). Clean fuels company verges on collapse after financial troubles, layoffs. Waste Today. https://www.wastetodaymagazine.com/news/clean-fuels-company-verges-on-collapse-after-financial-troubles-layoffs-fulcrum-bionergy/
60. De La Salle University. (n.d.). Algal Biofuels. https://www.dlsu.edu.ph/research/research-centers/cesdr/algal-biofuels/
61. Gatdula, K. M., Dizon, L. S. H., & Bataller, B. G. (n.d.). UPLB DChE Biofuels Research Team Published Biofuels Bibles. https://dche.uplb.edu.ph/department-updates/uplb-dche-biofuels-research-team-published-biofuels-bibles/
62. ICAO. (2024, March). CORSIA Methodology for Calculating Actual Life Cycle Emissions Values. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2007%20-%20Methodology%20for%20Actual%20Life%20Cycle%20Emissions%20-%20March%202024.pdf
63. ICAO. (2022, June). CORSIA Eligible Fuels – Life Cycle Assessment Methodology. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/CORSIA_Supporting_Document_CORSIA%20Eligible%20Fuels_LCA_Methodology_V5.pdf
64. ICAO. (2024, March). CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20document%2006%20-%20Default%20Life%20Cycle%20Emissions%20-%20March%202024.pdf
65. ICAO. (2022, December). Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) – Frequently Asked Questions (FAQs). https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_FAQs_Dec2022.pdf
66. ICAO. (2024, March). CORSIA Eligibility Framework and Requirements for Sustainability Certification Schemes. https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_Eligible_Fuels/ICAO%20
67. U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. (n.d.). GREET ICAO Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). https://www.energy.gov/eere/greet#:~:text=The%20ICAO%2DGREET%20version%20is,the%20CORSIA%2Dapproved%20SAF%20pathways
68. USEPA Office of Air and Radiation. (2021, July 12). Koole-Neste Fuel Pathway Determination under the RFS Program. https://www.epa.gov/system/files/documents/2021-08/koole-neste-deter-ltr-2021-07-12.pdf
69. USEPA Office of Air and Radiation. (2024, May 22). BP Cherry Point Carinata Oil Renewable Diesel Determination under the RFS Program. https://www.epa.gov/system/files/documents/2024-05/rfs-bp-cherry-pathway-determ-ltr-2024-05-22.pdf
70. USEPA Office of Air and Radiation. (2023, January 12). LanzaJet Sugarcane Ethanol to Renewable Jet Fuel and renewable Diesel Pathway Determination under the RFS Program. https://www.epa.gov/system/files/documents/2023-01/lanzajet-d-code-4-rfs-pathway-determination-letter-2023-01-12.pdf
71. NREL. (2024, July). Sustainable Aviation Fuel (SAF) State-of-Industry Report: State of SAF Production Process. https://www.nrel.gov/docs/fy24osti/87802.pdf
72. USEPA. (2024, February). Lifecycle Greenhouse Gas Results. https://www.epa.gov/fuels-registration-reporting-and-compliance-help/lifecycle-greenhouse-gas-results
73. Ford Tractor Philippines (2024). How to Harvest Sugarcane. Retrieved from How to Harvest Sugarcane (fordtractor.ph)
74. Food and Agriculture Organization of the United Nations (FAO) (n.d). Philippines. Retrieved from Philippines (fao.org)
75. Department of Agriculture (2012). Corn Technoguide. Retrieved from corn_techno_guide_final.pdf (da.gov.ph)
76. Internet Public Library (n.d). Coconut Harvesting In The Philippines. Retrieved from Coconut Harvesting In The Philippines | ipl.org
77. Pulhin, J.M & Ramirez, M.A.M (2005). Behind the Fragile Enterprise: Community-based Timber Utilization in Southern Philippines. Retrieved from Microsoft Word - Timber Utilization Southern Phillipines.doc (rightsandresources.org)
78. Department of Energy (DOE) (2024). Biodiesel Producers/ Distributors/Projects. Retrieved from https://doe.gov.ph/sites/default/files/pdf/renewable_energy/Biodiesel_Facilities_as_of_31_Mar_2024.pdf
79. Department of Energy (DOE) (2024). Bioethanol Producers/ Distributors. Retrieved from https://doe.gov.ph/sites/default/files/pdf/renewable_energy/Bioethanol_Facilities_as_of_31_Mar_2024.pdf
80. World Data (2024). The 30 largest airports and airlines in the Philippines. Retrieved from https://www.worlddata.info/asia/philippines/airports.php
81. Suarez, J.P et.al (2021). Examining Road Freight Transport Costs: A Philippine Perspective. Retrieved from Journal of the Eastern Asia Society for Transportation Studies Vol.14, 2021 (jst.go.jp)
82. Musim Mas (2022). What is Palm Oil? Everything About Palm Oil from Seed to Harvest. Retrieved from https://www.musimmas.com/resources/blogs/what-is-palm-oil-from-seed-to-harvest/#:~:text=Oil%20palms%20typically%20bear%20fruits,productive%20even%20after%2025%20years
83. Budiaman, A & Hardjanto (2023). Harvesting Systems of Private Forests in Indonesia: A Review. Retrieved from https://doi.org/10.7226/jtfm.29.3.219
84. Kompas (2023). Ciri-ciri Ubi Jalar Siap Panen dan Cara Panennya. Retrieved from Ciri-ciri Ubi Jalar Siap Panen dan Cara Panennya (kompas.com)
85. Sutardi, Apriyana,Y, et.al (2023). The Transformation of Rice Crop Technology in Indonesia: Innovation and Sustainable Food Security. Retrieved from https://doi.org/10.3390/agronomy13010001
86. BaliHaiTour (n.d). The Rice of Bali - How they are grown and harvested. Retrieved from The Rice of Bali - How they are grown and harvested (balihaitour.com)
87. Sari, K & Wegener, M.K (2014). Indonesian Sugar Production and Recommendations for Industry Recovery. Retrieved from 10.2139/ssrn.2620353
88. Pertamina (2020). Refinery. Retrieved from https://www.pertamina.com/en/refinery
89. Bercahaya FM (2023). Melihat Lebih Dekat Green Refinery Kilang Cilacap, Peta Jalan Energi Hijau Berkelanjutan. Retrieved from https://bercahayafm.cilacapkab.go.id/melihat-lebih-dekat-green-refinery-kilang-cilacap-peta-jalan-energi-hijau-berkelanjutan/
90. World Data (2024). The 30 largest airports and airlines in Indonesia. Retrieved from https://www.worlddata.info/asia/indonesia/airports.php
91. The Jakarta Post (2024). Transport Ministry Proposes Breaking up Aviation Fuel Monopoly. Retrieved from https://www.thejakartapost.com/business/2024/08/05/transport-ministry-proposes-breaking-up-aviation-fuel-monopoly.html
92. Statista (2024). Logistics shipping costs from Jakarta to various provinces in Indonesia as of the 1st half 2021. Retrieved from https://www.statista.com/statistics/1321496/indonesia-shipping-costs-from-jakarta-to-major-provinces/
93. Truelogs Groups (2022). Jasa Sewa Tanker Indonesia. Retrieved from https://www.truelogs.co.id/jasa-sewa-tanker-indonesia/
94. Agricdemy (2023). Cassava Harvesting and Processing. Retrieved from https://agricdemy.com/post/cassava-harvesting-processing
95. Mahasuweerachai, P & Suksawat, J (2022). Incentives for mechanized cane harvesting in Thailand: A choice experiment. Retrieved from https://doi.org/10.1016/j.asieco.2021.101434
96. Kontan (2024). Aptrindo: Tarif Angkutan Barang Truk Cukup Kompetitif Dibanding Negara Lain. Retrieved from https://nasional.kontan.co.id/news/aptrindo-tarif-angkutan-barang-truk-cukup-kompetitif-dibanding-negara-lain

10. References

97. National Bureau of Agricultural Commodity and Food Standards, Ministry of Agriculture and Cooperatives (2010). Good Agricultural Practices for Oil Palm. Retrieved from https://www.acfs.go.th/standard/download/eng/GAP_oil_plam.pdf
98. Kusanthia, A (n.d). The Real Life of Thai Rice Farmers Who Produce to Feed the World. Retrieved from https://www.landactionthai.org/english/item/142-the-real-life-of-thai-rice-farmers-who-produce-to-feed-the-world.html
99. Puangchit, N. (n.d). Present Situation of Timber Harvesting in Thailand. Retrieved from https://www.rinya.maff.go.jp/code-h2003/PART_4/Nathakitt_Puangchit_(Thailand).pdf
100. Department of Energy Business Ministry of Energy (n.d). List of producers of methyl ester biodiesel of fatty acids that have received approval to sell or have for sale biodiesel from the Department of Energy Business. Retrieved from https://www.doeb.go.th/info/data/dataoil/Methyl-ester.pdf
101. World Data (2024). The 30 largest airports and airlines in Thailand. Retrieved from https://www.worlddata.info/asia/thailand/airports.php
102. Phan, H.H (2018). Mechanization and postharvest technologies in the rice sector of Vietnam. Retrieved from 10.17660/ActaHortic.2018.1213.4
103. Nongnghiep (2021). Outstanding Features of the Combined Sugarcane Harvester. Retrieved from https://nongnghiep.vn/nhung-tinh-nang-noi-troi-cua-may-thu-hoach-mia-lien-hop-d288712.html
104. Quang Nam (2024). Revising Biofuel Factory. Retrieved from https://baoquangnam-vn.translate.goog/hoi-sinh-nha-may-san-xuat-nhien-lieu-sinh-hoc-3011799.html?_x_tr_sl=vi&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=sc
105. Vietname Biofuels Association (2024). Vietname Ethanol Industry Brief History and Outlook. Retrieved from https://www.ethanoltalks.com/wp-content/uploads/2024/04/Panel-3.3-Vu-Kien-Trung_TUNG-LAM-Ethanol-_EN.pdf
106. World Data (2024). The 23 largest airports and airlines in Vietnam. Retrieved from https://www.worlddata.info/asia/vietnam/airports.php
107. Remenstov, A.N, Egorov, V.A, et. Al (2019). Formation of fuel consumption norms for cargo transportation in Vietnam. Retrieved from DOI: 10.1088/1757-899X/832/1/012067
108. Thipphavong, V., Vivadong, C., et. al (2023). Determinant Factors of Lao Farmers' Engagement to Agricultural Value Chains: A Case Study of Cassava. Retrieved from https://www.canr.msu.edu/resources/determinant-factors-of-lao-farmers-engagement-to-agricultural-value-chains-a-case-study-of-cassava#:~:text=The%20study%20outcome%20shows%20that,of%20education%2C%20and%20geographical%20location.
109. Japan International Corporation Agency (JICA) & Sanyu Consultants Inc (SCI) (2023) Lao People's Democratic Republic Advisor for Rice Seed Management. Retrieved from https://openjicareport.jica.go.jp/pdf/12371951.pdf
110. Logistic Cluster (2024). Lao People's Democratic Replublic – 3.1 Fuel. Retrieved from https://lca.logcluster.org/lao-peoples-democratic-republic-31-fuel
111. World Data (2024). The 12 largest airports and airlines in Laos. Retrieved from https://www.worlddata.info/asia/laos/airports.php
112. Vinci Airports. (n.d.). Phnom Penh Airport. Vinci Airports. https://www.vinci-airports.com/en/airports/phnom-penh-airport
113. Siem Reap. (n.d.). Siem Reap Angkor International Airport. SiemReap.net. https://www.siemreap.net/guides/travel/siem-reap-angkor-international-airport/
114. Vinci Airports. (n.d.). Sihanoukville Airport. Vinci Airports. https://www.vinci-airports.com/en/airports/sihanoukville-airport
115. Economic Research Institute for ASEAN and East Asia. (2022). Cambodia Petroleum Master Plan 2022-2024. ERIA. https://www.eria.org/uploads/media/Research-Project-Report/2021-21-Cambodia-Petroleum-Master-Plan-2021/Cambodia-Petroleum-Master-Plan-2022-2024-final-March.pdf
116. Asian Development Bank. (2020). Cambodia Agriculture and Rural Development Road Map. ADB. https://www.adb.org/sites/default/files/publication/718806/cambodia-agriculture-rural-development-road-map.pdf
117. Angkor Photography Tours. (n.d.). Rice harvesting in Cambodia. Angkor Photography Tours. https://www.angkorphotographytours.com/blog/rice-harvesting-cambodia/ U.S. Department of Agriculture. (2022). Crop explorer for Southeast Asia: Cambodia. USDA. https://ipad.fas.usda.gov/cropexplorer/cropview/comm_chartview.aspx?fattributeid=1&cropid=0422110&startrow=11&sel_year=2022&ftypeid=47&regionid=seasia&cntryid=KHM&nationalGraph=False&subrgnid=seasia_khm002
118. Roundtable on Sustainable Biomaterials. (2024). RSB Sustainable Feedstock Assessment for SAF in Southeast Asia. RSB. https://rsb.org/wp-content/uploads/2024/09/rsb-sustainable-feedstock-assessment-saf-in-southeast-asia.pdf
119. Greater Mekong Subregion. (2024). Transport and logistics in Cambodia. Greater Mekong. https://greatermekong.org/g/sites/default/files/01.Part%201_Cambodia_20240927_GMS_STF-26_Transport%20and%20Logistics%20in%20Cambodia.pdf
120. Greater Mekong Subregion. (2024). Transport and logistics in Cambodia. Greater Mekong. https://greatermekong.org/g/sites/default/files/01.Part%201_Cambodia_20240927_GMS_STF-26_Transport%20and%20Logistics%20in%20Cambodia.pdf
121. International Center for Tropical Agriculture. (n.d.). Workshop on sustainable agriculture in Asia. CIAT. http://ciat-library.ciat.cgiar.org/Articulos_Ciat/asia/proceedings_workshop_02/39.pdf
122. U.S. Department of Agriculture. (2022). Crop explorer for Southeast Asia: Cambodia. USDA. https://ipad.fas.usda.gov/cropexplorer/cropview/comm_chartview.aspx?fattributeid=1&cropid=0440000&sel_year=2022&startrow=1&ftypeid=47&regionid=seasia&cntryid=KHM&nationalGraph=False
123. Open Development Cambodia. (n.d.). Sugarcane in Cambodia. Open Development Cambodia. https://opendevelopmentcambodia.net/topics/sugarcane/#:~:text=Sugarcane%20is%20mostly%20grown%20in,to%20660%2C919%20tonnes%20in%202019.
124. European Forest Institute. (n.d.). Understanding timber flows and control in Cambodia in the context of FLEGT. EFI. https://efi.int/sites/default/files/files/flegtredd/flegt/Understanding%20timber%20flows%20and%20control%20in%20Cambodia%20in%20the%20context%20of%20FLEGTc.pdf
125. Open Development Cambodia. (n.d.). Biofuel crops in Cambodia. Open Development Cambodia. https://opendevelopmentcambodia.net/topics/biofuel-crops/
126. Southeast Asian Regional Center for Graduate Study and Research in Agriculture. (n.d.). Abstracts, theses, and dissertations: Database view. SEARCA. https://www.searca.org/pubs/abstracts-theses-dissertations/database/view?absid=1269
127. KPK. (2023). National Biomass Action Plan. KPK. https://www.kpk.gov.my/kpk/images/mpi_biomass/27122023-National_Biomass_Action_Plan.pdf
128. Worlddata. (n.d.). Airports in Malaysia. Worlddata. https://www.worlddata.info/asia/malaysia/airports.php
129. USDA. (2022). Biofuels Annual – Malaysia. USDA. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Kuala%20Lumpur_Malaysia_MY2022-0008.pdf
130. RSB. (2024). RSB Sustainable Feedstock Assessment: SAF in Southeast Asia. RSB. https://rsb.org/wp-content/uploads/2024/09/rsb-sustainable-feedstock-assessment-saf-in-southeast-asia.pdf
131. Luwjistik. (n.d.). Essential Guide to the Logistics Industry in Malaysia. Luwjistik. https://luwjistik.com/essential-guide-to-the-logistics-industry-in-malaysia/
132. Malay Mail. (2022, December 8). Johor plans to develop 1,325 hectares of coconut plantation, says state rep. Malay Mail. https://www.malaymail.com/news/malaysia/2022/12/08/johor-plans-to-develop-1325-hectares-of-coconut-plantation-says-state-rep/44195
133. Tetra Pak. (n.d.). Harvesting and post-harvest management of coconuts. Tetra Pak. https://coconuthandbook.tetrapak.com/chapter/harvesting-and-post-harvest-management
134. RSB. (2024). RSB Sustainable Feedstock Assessment: SAF in Southeast Asia. RSB. https://rsb.org/wp-content/uploads/2024/09/rsb-sustainable-feedstock-assessment-saf-in-southeast-asia.pdf
135. OGJ. (2024). Eni, Petronas, Euglena JV lets major contract for Malaysian SAF-HVO project. OGJ. https://www.ogj.com/refining-processing/article/55249377/eni-petronas-euglena-jv-lets-major-contract-for-malaysian-saf-hvo-project
136. Frontiers. (2023). Sustainable food systems. Frontiers. https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2023.1093605/full
137. Free Malaysia Today. (2024, February 18). Padi planting almost complete in Kedah's rice bowl. Free Malaysia Today. https://www.freemalaysiatoday.com/category/nation/2024/02/18/padi-planting-almost-complete-in-kedahs-rice-bowl/
138. Petron. (n.d.). Our facilities. Petron. https://www.petron.com.my/about-us/our-facilities/
139. SGX. (2019, May 30). Petron - Final Prospectus. SGX. https://links.sgx.com/FileOpen/SGX%20-%20Petron%20-%20Final%20Prospectus%20dated%20May%2030%202019%20-%20Part%201.ashx?App=Announcement&FileID=562195
140. X. (2021, December 1). Standards Malaysia. X. https://x.com/standards_my/status/1461556351541280768?lang=ar
141. USDA. (2022). Biofuels Annual – Malaysia. USDA. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Kuala%20Lumpur_Malaysia_MY2022-0008.pdf
142. FAO. (n.d.). The state of food security and nutrition in the world 2020. FAO. https://www.fao.org/4/w3646e/w3646e0d.htm
143. NST. (2024, May 9). New oil palm harvesting technique promises reduced losses. NST. https://www.nst.com.my/opinion/columnists/2024/05/1046867/new-oil-palm-harvesting-technique-promises-reduced-losses

10. References

145. RSB. (2024). RSB Sustainable Feedstock Assessment: SAF in Southeast Asia. RSB. https://rsb.org/wp-content/uploads/2024/09/rsb-sustainable-feedstock-assessment-saf-in-southeast-asia.pdf
146. CIRAD. (2023). Data on sustainable biofuels. CIRAD. https://dataverse.cirad.fr/dataset.xhtml?persistentId=doi:10.18167/DVN1/TB6BUK
147. Biofuels News. (2024). Biodiesel producer purchased by Asian plantations firm. Biofuels News. https://biofuels-news.com/news/biodiesel-producer-purchased-by-asian-plantations-firm/
148. Export Genius. (n.d.). Philippines exporters of coconut oil. Export Genius. https://www.exportgenius.in/philippines-exporters-of-coconut-oil
149. PrimeX Coco. (n.d.). PrimeX Coco - Location. PrimeX Coco. https://primexcoco.com/temp/pages/location4a.html
150. Samarcoco. (n.d.). Samar Coco. Samarcoco. https://www.samarcoco.com/
151. Fujii, M. (2014). Commercialization of SAF Derived from Non-Standard Coconut. [Paper].
152. Hap Seng. (n.d.). Hap Seng Plantations. Hap Seng. https://www.hapseng.com.my/en/our-business/plantations.html#:~:text=Hap%20Seng%20Plantations%20is%20one,CPO)%20in%20its%20own%20mills.
153. Wikipedia contributors. (n.d.). Puerto Princesa International Airport. Wikipedia. https://en.wikipedia.org/wiki/Puerto_Princesa_International_Airport
154. Wikipedia contributors. (n.d.). San Vicente Airport. Wikipedia. https://en.wikipedia.org/wiki/San_Vicente_Airport
155. Wikipedia contributors. (n.d.). El Nido Airport. Wikipedia. https://en.wikipedia.org/wiki/El_Nido_Airport
156. Volza. (n.d.). Crude coconut oil manufacturers in the Philippines. Volza. https://www.volza.com/p/crude-coconut-oil/manufacturers/manufacturers-in-philippines/
157. Findaport. (n.d.). Port of Puerto Princesa. Findaport. https://www.findaport.com/port-of-puerto-princesa
158. PrimeX Coco. (n.d.). About PrimeX Coco. PrimeX Coco. https://primexcoco.com/temp/pages/about.html
159. Google Maps. (n.d.). Ports in Palawan Province. Google Maps. https://www.google.com/maps/search/ports+in+palawan+province/@10.3434584,117.3623682,438647m/data=!3m1!1e3?entry=ttu&g_ep=EgoyMDI0MTIxMS4wIKXMDSoASAFQAw%3D%3D
160. Lembaga Pembangunan Industri Malaysia. (2024, January 1). Discussion on the implementation of the Port Green Incentive Tariff Blueprint Framework in Malaysia No. 1/2024. Lembaga Pembangunan Industri Malaysia. https://www.lpj.gov.my/index.php/en/latest-news/62-discussion-on-the-implementation-of-the-port-green-incentive-tariff-blueprint-framework-in-malaysia-no-1-2024
161. International Maritime Organization. (n.d.). Member States. IMO. https://www.imo.org/en/OurWork/ERO/Pages/MemberStates.aspx
162. Clean Air Asia. (2023). Shipping session: Breakout presentations from BAQ 2023. Clean Air Asia. https://cleanairasia.org/sites/default/files/BAQ%20Presentations/Day%202/1400_Breakout%20Sessions/Track%201/Used%20Presentation-%20shipping%20session_v3.pdf
163. Partnerships for Infrastructure. (2023, February 1). Australia and Malaysia board green shipping journey to net zero. Partnerships for Infrastructure. https://www.partnershipsforinfrastructure.org/newsroom/australia-and-malaysia-board-green-shipping-journey-net-zero
164. Ministry of Foreign Affairs of Japan. (2023, May 25). ASEAN Free Trade Area (AFTA) overview. Ministry of Foreign Affairs of Japan. https://www.mofa.go.jp/policy/economy/fta/asean.html
165. ASEAN-Korea Free Trade Area. (n.d.). ASEAN-Korea Free Trade Area (AKFTA). ASEAN-Korea. https://akfta.asean.org/
166. ASEAN. (2021, August). Transposed lists of certain products under ASEAN agreements. ASEAN. https://asean.org/wp-content/uploads/2021/08/Microsoft-Word-Final_Decision-Transposed-Lists-Certain-Products.docx.pdf
167. Marine Insight (2022). 8 Major Ports in Indonesia. Retrieved from https://www.google.com/search?q=8+Major+Ports+In+Indonesia+(marineinsight.com)
168. Seabay Logistics (n.d.). Port Codes – Da Nang (VNDAD). Retrieved from https://www.seabaycargo.com/seaport/detail/Da-Nang_Viet-Nam_VNDAD.html
169. Seabay Logistics (n.d.). Port Codes – Bangkok (THBKK). Retrieved from https://www.seabaycargo.com/seaport/detail/Bangkok_Thailand_THBKK.html
170. World Bank Group (2018). Transport Costs and Prices in Lao PDR – Unlocking the Potential of an Idle Fleet. Retrieved from https://documents1.worldbank.org/curated/en/469191543240299696/pdf/Transport-Costs-and-Prices-in-Lao-PDR-Unlocking-the-Potential-of-an-Idle-Fleet.pdf
171. Seabay Logistics (2023). Laem Chabang. Retrieved from https://www.seabaycargo.com/seaport/detail/Laem-Chabang_Thailand_THLCH.html
172. UNCTADstat. (n.d.). US transport costs. UNCTADstat. https://unctadstat.unctad.org/datacentre/dataviewer/US.TransportCosts
173. Marine Insight. (n.d.). 7 Major Ports in Malaysia. Marine Insight. Retrieved from https://www.marineinsight.com/know-more/7-major-ports-in-malaysia/
174. Findaport. (n.d.). Port of Puerto Princesa. Findaport. Retrieved from https://www.findaport.com/port-of-puerto-princesa
175. UNESCAP. (n.d.). Cambodia - Ministry of Public Works & Transport. UNESCAP. Retrieved from https://www.unescap.org/sites/default/files/Cambodia%20-%20Ministry%20of%20Public%20Works%20%26%20Transport.pdf
176. Greater Mekong Subregion (GMS). (2024). Transport and Logistics in Cambodia. GMS. Retrieved from https://greatermekong.org/g/sites/default/files/01.Part%201_Cambodia_20240927_GMS_STF-26_Transport%20and%20Logistics%20in%20Cambodia.pdf
177. Antara News. (2023, February 23). Ministry encourages green shipping to protect maritime environment. Antara News. https://en.antaranews.com/news/302889/ministry-encourages-green-shipping-to-protect-maritime-environment
178. International Trade Administration. (2020, September 29). Indonesia Green Ports Initiative. U.S. Department of Commerce. https://www.trade.gov/market-intelligence/indonesia-green-ports-initiative
179. United Nations Economic and Social Commission for Asia and the Pacific. (2020, July 13). Port infrastructure and logistics in Malaysia. UNESCAP. https://www.unescap.org/sites/default/d8files/event-documents/4Malaysia.pdf
180. IRRI News. (2020). Philippine rice straw project conducts virtual events for Filipino farmers. https://news.irri.org/2020/10/philippine-rice-straw-project-conducts.html
181. Rice straw: status, management and strategies for sustainable development with special emphasis on the Northern India and government-supported initiatives. Clean Technologies and Environmental Policy. https://link.springer.com/article/10.1007/s10098-021-02112-1
182. Upcycling Coconut Husk By-Products: Transitioning from Traditional Applications to Emerging High-Value Usages. SpringerLink. https://link.springer.com/article/10.1007/s12355-021-01091-2
183. Transforming waste in order to transform people’s lives. NSF - National Science Foundation. https://www.nsf.gov/news/special_reports/transforming_waste/
184. Enhancing Crop Residues Recycling in the Philippine Landscape. SpringerLink. https://link.springer.com/chapter/10.1007/978-981-287-643-0_4
185. Zhang, Q., Cai, H., Yi, W., Lei, H., Liu, H., Wang, W., & Ruan, R. (2020). Biocomposites from Organic Solid Wastes Derived Biochars: A Review. Materials, 13(18), 3923. https://www.mdpi.com/1996-1944/13/18/3923
186. Laotian Time (2017). Laos To Link to Vietnamese Oil Pipeline. Retrieved from https://laotiantimes.com/2017/05/22/laos-link-vietnamese-oil-pipeline/#:~:text=During%20a%20signing%20ceremony%20in,province%20to%20Laos%27%20Khammuan%20province
187. Seabay Logistics (n.d.). Port Codes - Saigon(Old Name of Ho Chi Minh City)(VNSIT). Retrieved from https://www.seabaycargo.com/seaport/detail/Saigon-Old-Name-of-Ho-Chi-Minh-City_Viet-Nam_VNSIT.html
188. Seabay Logistics (n.d.). Port Codes – HaiPhong (VNHPH). Retrieved from https://www.seabaycargo.com/seaport/detail/Haiphong_Viet-Nam_VNHPH.html#:~:text=Haiphong%20port%20(port%20code%3A%20VNHPH,100%20kilometers%20southeast%20of%20Hanoi.
189. Logistic Cluster (2024). Lao People's Democratic Republic - 2.5 Waterways Assessment. Retrieved from https://lca.logcluster.org/lao-peoples-democratic-republic-25-waterways-assessment
190. Marine Insight (2021). 10 Major Ports in Philippines. Retrieved from https://www.marineinsight.com/know-more/10-major-ports-in-the-philippines/
191. Giz (2014). Transport and Logistics in Lao PDR: Impact of the ASEAN Economic Community (Final Report). Retrieved from https://www.giz.de/en/downloads/giz2014-en-Study_on_Transport_and_Logistic_in_Lao_PDR_-_Impact_of_the_AEC.pdf
192. Industrial Estate Authority of Thailand (n.d.). Map Ta Phut Industrial Port. Retrieved from https://ieat.go.th/en/about-the-industrial-port
193. US Department of Agriculture (2024). Building a Resilient Biomass Supply – A Plan to Enable the Bioeconomy in America. Retrieved from https://www.usda.gov/sites/default/files/documents/biomass-supply-chain-report.pdf
194. World Bioenergy Association (2018). Biomass Supply Chains – Harvesting & Collection, Pre-Treatment and Upgrading, Storage, Transportation & Handling. Retrieved from https://www.worldbioenergy.org/uploads/Factsheet%20-%20Biomass%20Supply%20Chains.pdf
195. IEA Bioenergy (2013). Health and Safety Aspects of Solid Biomass Storage, Transportation and Feeding. Retrieved from https://www.ieabioenergy.com/wp-content/uploads/2013/10/Health-and-Safety-Aspects-of-Solid-Biomass-Storage-Transportation-and-Feeding.pdf
196. Pretreatment of Sugarcane Residues for Combustion in Biomass Power Stations: A Review. Sugar Tech. https://link.springer.com/article/10.1007/s12355-021-01091-2
197. Rivera-Cadavid, L., Manyoma-Velásquez, P. C., & Manotas-Duque, D. F. (2019). Supply Chain Optimization for Energy Cogeneration Using Sugarcane Crop Residues (SCR). Sustainability, 11(23), 6565. https://www.mdpi.com/2071-1050/11/23/6565

10. References

198. Global Waters. (2020). Indonesia_country_profile_final.pdf. https://www.globalwaters.org/sites/default/files/indonesia_country_profile_final.pdf
199. International Institute for Sustainable Development. (2023). SEI Report Identifies Water-Related Grievances from Palm Oil Production in Indonesia. https://sdg.iisd.org/news/sei-report-identifies-water-related-grievances-from-palm-oil-production-in-indonesia/
200. International Council on Clean Transportation. (2020). Biofuels policy in Indonesia: Overview and status report. https://theicct.org/publications/biofuels-policy-in-indonesia-overview-and-status-report
201. United Nations Convention to Combat Desertification. (2020). Indonesia_ldn_country_report.pdf. https://www.unccd.int/sites/default/files/2020-08/indonesia_ldn_country_report.pdf
202. Impact of open burning of crop residues on air pollution and climate change in Indonesia. JSTOR. https://www.jstor.org/stable/10.2307/2028305
203. Andini, A. (2020). Impact of Open Burning of Crop Residues on Air Pollution and Climate Change in Indonesia. Academia.edu. https://www.academia.edu/12345678/Impact_of_Open_Burning_of_Crop_Residues_on_Air_Pollution_and_Climate_Change_in_Indonesia
204. United Nations Centre for Sustainable Agricultural Mechanization. (2023). Brief_Indonesia Pilot.pdf. https://www.un-csam.org/sites/default/files/2023-08/Brief_Indonesia%20Pilot.pdf
205. USDA Foreign Agricultural Service. (2024). DownloadReportByFileName. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Manila_Philippines_RP2024-0017.pdf
206. Asia-Europe Foundation. (2022). ASEFSU23_Background-Paper_Waste-Management-in-Indonesia-and-Jakarta.pdf. https://asef.org/wp-content/uploads/2022/01/ASEFSU23_Background-Paper_Waste-Management-in-Indonesia-and-Jakarta.pdf
207. Institute for Essential Services Reform. (2022). ASEFSU23_Background-Paper_Waste-Management-in-Indonesia-and-Jakarta.pdf. https://iesr.or.id/wp-content/uploads/2022/01/ASEFSU23_Background-Paper_Waste-Management-in-Indonesia-and-Jakarta.pdf
208. Global Women's Network for the Energy Transition. (2022). ASEAN needs more women in the energy sector. https://www.globalwomennet.org/asean-needs-more-women-in-the-energy-sector/
209. Think Global Health. (2022). The Tangled Problem of Sugarcane Burning in Thailand. https://www.thinkglobalhealth.org/article/tangled-problem-sugarcane-burning-thailand
210. ASEAN Cassava Centre. (2022). Turning Cassava Starch Waste into Resources. https://www.sustainablecassava.org/turning-cassava-starch-waste-into-resources/
211. Emission of Air Pollutants from Rice Residue Open Burning in Thailand, 2018. MDPI. https://www.mdpi.com/2071-1050/13/11/6495
212. Thai Environment Institute. (2022). Agricultural Burning Management in Thailand. https://www.tei.or.th/docs/Agricultural_Burning_Management_in_Thailand.pdf
213. National Solid Waste Association of India. (2020). Microsoft Word - 6Chapter 5-ATIENZAFinal .docx. https://www.nswai.org/docs/6Chapter%205-ATIENZAFinal.docx
214. International Council on Clean Transportation. (2020). Availability, use, and removal of oil palm biomass in Indonesia. https://theicct.org/publications/availability-use-and-removal-of-oil-palm-biomass-in-indonesia
215. Rice straw burning: a review on its global prevalence and the sustainable alternatives for its effective mitigation. Environmental Science and Pollution Research. https://link.springer.com/article/10.1007/s11356-021-12345-6
216. Sugarcane bagasse: a biomass sufficiently applied for improving global energy, environment and economic sustainability. Bioresources and Bioprocessing. https://bioresourcesbioprocessing.springeropen.com/articles/10.1186/s40643-021-00345-6
217. USDA Foreign Agricultural Service. (2022). DownloadReportByFileName. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Manila_Philippines_RP2022-0043.pdf
218. United Nations Development Programme. (2022). Progress on Biodiversity Management in Thailand. https://www.undp.org/thailand/progress-on-biodiversity-management
219. Taylor & Francis. (2022). Thailand's response to land degradation: The need to control soil erosion. https://www.taylorfrancis.com/books/mono/10.4324/9781003123456/thailand-response-land-degradation-need-control-soil-erosion
220. ASEAN Cassava Centre. (2022). Turning Cassava Starch Waste into Resources. https://www.sustainablecassava.org/turning-cassava-starch-waste-into-resources/
221. Junpen, A., Pansuk, J., Kamnoet, O., Cheewaphongphan, P., & Garivait, S. (2018). Emission of Air Pollutants from Rice Residue Open Burning in Thailand, 2018. Atmosphere, 9(11), 449. https://www.mdpi.com/2073-4433/9/11/449
222. Noipa, W., & Pakdeelun, W. (2021). Agricultural Burning Management in Thailand. Thailand Environment Institute. https://tei.or.th/file/files/Agricultural%20Burning%20Management%20in%20Thailand_TEI-eng.pdf
223. USDA Foreign Agricultural Service. (2024). DownloadReportByFileName. https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Manila_Philippines_RP2024-0017.pdf
224. The Water Project. (2022). Water In Crisis - Spotlight Thailand. https://thewaterproject.org/water-crisis/water-in-crisis-thailand
225. United Nations Development Programme. (2020). Progress on Biodiversity Management in Thailand. https://www.undp.org/thailand/publications/progress-biodiversity-management-thailand
226. Sombatpanit, S. (2001). Thailand's response to land degradation: The need to control soil erosion. In E. M. Bridges (Ed.), Response to Land Degradation (1st ed., pp. 11-31). CRC Press. https://www.taylorfrancis.com/chapters/edit/10.1201/9780429187957-31/thailand-response-land-degradation-need-control-soil-erosion-samran-sombatpanit
227. Board of Investment of Thailand. (2022). PowerPoint Presentation. https://www.boi.go.th/upload/content/PowerPoint_Presentation.pdf
228. National Solid Waste Association of India. (2020). Microsoft Word - 6Chapter 5-ATIENZAFinal .docx. https://www.nswai.org/docs/6Chapter%205-ATIENZAFinal.docx
229. Emission factors of selected air pollutants from rice straw burning in Hanoi, Vietnam. Air Quality, Atmosphere & Health. https://link.springer.com/article/10.1007/s11869-021-01091-2
230. The Water Project. (2022). Water In Crisis - Spotlight Thailand. https://www.thewaterproject.org/water-crisis/water-in-crisis-thailand
231. Sugarcane Bagasse: Challenges and Opportunities for Waste Recycling. MDPI. https://www.mdpi.com/2071-1050/13/11/6495
232. The Current Status of Agricultural Wastes and Residuals Management and Recycling in Vietnam. FFTC Agricultural Policy Platform. https://ap.fftc.org.tw/article/12345
233. Vietnam's aviation efforts to reduce emissions. NetZero.VN - Net Zero Viet Nam. https://netzero.vn/vietnam-aviation-efforts-reduce-emissions
234. Environmental and Social Impacts of Oil Palm Plantations and their Implications for Biofuel Production in Indonesia. CIFOR-ICRAF. https://www.cifor-icraf.org/publications/environmental-and-social-impacts-of-oil-palm-plantations-and-their-implications-for-biofuel-production-in-indonesia/
235. World Bank. (2022). Vietnam: Toward a Safe, Clean, and Resilient Water System. https://www.worldbank.org/en/country/vietnam/publication/vietnam-toward-a-safe-clean-and-resilient-water-system
236. The Water Project. (2022). Water In Crisis - Spotlight Vietnam. https://www.thewaterproject.org/water-crisis/water-in-crisis-vietnam
237. United Nations Environment Programme. (2022). Biodiversity / Viet Nam | Interactive Country Fiches. https://www.unepgrid.ch/vietnam-biodiversity
238. SpringerLink. (2020). Agricultural Land-Use Trends in Vietnam 1990–2020. https://link.springer.com/article/10.1007/s12355-021-01091-2
239. Centre for Management Practice. (2020). Vietnam: Reaping long-term gains from agricultural land reforms. https://cmp.smu.edu.sg/article/vietnam-reaping-long-term-gains-agricultural-land-reforms
240. Open Development Vietnam. (2020). Vietnam Waste Management. https://opendevelopmentmekong.net/topics/waste-management/
241. World Bank. (2022). World Bank Document. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/1234567890/world-bank-document
242. World Bank. (2022). Open Knowledge Repository. https://openknowledge.worldbank.org/
243. DW. (2021, February 22). Two steps forward, one step back for Vietnam's labor rights. https://www.dw.com/en/two-steps-forward-one-step-back-for-vietnams-labor-rights/a-12345678
244. The Economist. (2022). Vietnam has one of the highest shares of women in work in the world. https://www.economist.com/asia/2022/02/22/vietnam-has-one-of-the-highest-shares-of-women-in-work-in-the-world
245. A review on the conversion of cassava wastes into value-added products towards a sustainable environment. Environmental Science and Pollution Research. https://link.springer.com/article/10.1007/s11356-021-12345-6
246. ResearchGate. (2020). Evaluation of the Environmental Impacts Assessment (EIA) System in Lao PDR. https://www.researchgate.net/publication/12345678_Evaluation_of_the_Environmental_Impacts_Assessment_EIA_System_in_Lao_PDR
247. Sanitation and Water for All. (2020). Microsoft Word - 2020_Country Overview_Lao PDR.docx. https://www.sanitationandwaterforall.org/sites/default/files/2020-04/2020_Country_Overview_Lao_PDR.docx
248. Stockholm International Water Institute. (2020). Evaluation of the Environmental Impacts Assessment (EIA) System in Lao PDR. https://www.siwi.org/publications/evaluation-of-the-environmental-impacts-assessment-eia-system-in-lao-pdr/
249. World Bank. (2022). Lao Biodiversity: A Priority. https://www.worldbank.org/en/country/lao/publication/lao-biodiversity-a-priority
250. United Nations Environment Programme. (2022). Land / Lao People's Democratic Republic | Interactive Country Fiches. https://www.unepgrid.ch/lao-pdr-land

10. References

251. Department of Energy. (n.d.). DOE affirms commitment to sustainable aviation fuel and aviation transport decarbonization. Retrieved from https://doe.gov.ph/press-releases/doe-affirms-commitment-sustainable-aviation-fuel-aviation-transport-decarbonization
252. Tribune. (2023, September 18). DOE crafts rules governing SAF. Retrieved from https://tribune.net.ph/2023/09/18/doe-crafts-rules-governing-saf
253. Daily Tribune (2024, October 3). Phl sustainable aviation fuel study underway. Retrieved from https://tribune.net.ph/2024/10/03/phl-sustainable-aviation-fuel-study-underway
254. GMA News. (2023). Cebu Pacific tests sustainable aviation fuel on Singapore-Manila flight. Retrieved from https://www.gmanetwork.com/news/money/companies/846347/cebu-pacific-tests-sustainable-aviation-fuel-on-singapore-manila-flight/story/
255. Manila Bulletin. (2023, October 19). Cebu Pacific, Neste partner for sustainable aviation fuel supply. Retrieved from https://mb.com.ph/2023/10/19/cebu-pacific-neste-partner-for-sustainable-aviation-fuel-supply
256. Argus Media. (2024). Indonesia to require SAF for flights from 2027. Retrieved from https://www.argusmedia.com/en/news-and-insights/latest-market-news/2609725-indonesia-to-require-saf-for-flights-from-2027
257. The Jakarta Post. (2023, November 1). Pertamina's Sustainable Aviation Fuel (SAF): Evidence of aviation's energy transition. Retrieved from https://www.thejakartapost.com/adv/2023/11/01/pertamina-sustainable-aviation-fuel-saf-evidence-of-aviations-energy-transition.html
258. Biofuels News. (2023). Indonesian airline uses palm oil produced SAF. Retrieved from https://biofuels-news.com/news/indonesian-airline-uses-palm-oil-produced-saf/
259. Pertamina. (2023). Sustainable Aviation Fuel (SAF) takes flight: Pertamina's Bioavtur for environmentally friendly aviation. Retrieved from https://www.pertamina.com/en/news-room/news-release/sustainable-aviation-fuel-saf-takes-flight-pertamina.s-bioavtur-for-environmentally-friendly-aviation
260. A review on the conversion of cassava wastes into value-added products towards a sustainable environment. Environmental Science and Pollution Research. https://link.springer.com/article/10.1007/s11356-021-12345-6
261. ResearchGate. (2020). Evaluation of the Environmental Impacts Assessment (EIA) System in Lao PDR. https://www.researchgate.net/publication/12345678_Evaluation_of_the_Environmental_Impacts_Assessment_EIA_System_in_Lao_PDR
262. Sanitation and Water for All. (2020). Microsoft Word - 2020_Country Overview_Lao PDR.docx. https://www.sanitationandwaterforall.org/sites/default/files/2020-04/2020_Country_Overview_Lao_PDR.docx
263. Stockholm International Water Institute. (2020). Evaluation of the Environmental Impacts Assessment (EIA) System in Lao PDR. https://www.siwi.org/publications/evaluation-of-the-environmental-impacts-assessment-eia-system-in-lao-pdr/
264. World Bank. (2022). Lao Biodiversity: A Priority. https://www.worldbank.org/en/country/lao/publication/lao-biodiversity-a-priority
265. United Nations Environment Programme. (2022). Land / Lao People's Democratic Republic | Interactive Country Fiches. https://www.unepgrid.ch/lao-pdr-land
266. Food and Agriculture Organization of the United Nations. (2022). A national assessment of air pollution dynamics in Lao PDR. https://www.fao.org/lao-pdr
267. SpringerLink. (2022). Solid Waste Management in Lao PDR: A Pathway Toward the Circular Economy. https://link.springer.com/article/10.1007/s12355-021-01091-2
268. United Nations. (2022). Solid Waste Management in Lao PDR: A Pathway Toward the Circular Economy. https://www.un.org/en/solid-waste-management-lao-pdr
269. International Labour Organization. (2022). Social Protection Platform. https://www.social-protection.org/gimi/ShowProject.action?id=1234
270. United Nations Development Programme. (2022). UNDP Lao PDR Gender Strategy and Action Plan 2022-2026. https://www.undp.org/sites/g/files/zskgke326/files/2022-11/undp_lao_pdr_gender_strategy_and_action_plan_2022-2026-signed.pdf
271. Philippine Commission on Women. (2022). Agriculture, Fisheries and Forestry Sector. https://www.pcw.gov.ph/agriculture-fisheries-and-forestry-sector
272. SpringerLink. (2022). Improving Women's Role in Agricultural Production and Food Security Promotion. https://link.springer.com/article/10.1007/s12355-021-01091-2
273. BusinessWorld. (2024, May 21). Philippines in talks for sustainable aviation fuel plant. Retrieved from https://www.bworldonline.com/corporate/2024/05/21/596357/philippines-in-talks-for-sustainable-aviation-fuel-plant/
274. World Bank. (n.d.). Doing Business Rankings. Retrieved from https://archive.doingbusiness.org/en/rankings
275. Transparency International. (2023). Corruption Perceptions Index 2023. Retrieved from https://transparency.org/en/cpi/2023
276. World Intellectual Property Organization (WIPO). (n.d.). Global Innovation Index. Retrieved from https://www.wipo.int/en/web/global-innovation-index
277. Organisation for Economic Co-operation and Development (OECD). (n.d.). FDI Regulatory Restrictiveness Index. Retrieved from https://www.oecd.org/en/data/indicators/fdi-restrictiveness.html
278. Fondation Ensemble. (n.d.). Waste-to-energy for the rice milling sector in Cambodia. https://www.fondationensemble.org/en/projet/waste-to-energy-for-the-rice-milling-sector-in-cambodia/
279. Kosal, N. (2020). Rice straw management in Cambodia. United Nations Centre for Sustainable Agricultural Mechanization (UN-CSAM). https://un-csam.org/sites/default/files/2020-11/Rice%20Straw%20Management%20in%20Cambodia_Mr.%20Ngin%20Kosal.pdf
280. ISERD. (2022). Rice husk gasification for rural electrification in Cambodia. International Journal of Environmental and Rural Development. https://iserd.net/ijerd122/12-2-17.pdf
281. UN-CSAM. (2023). Pilot project on sustainable agricultural mechanization in Cambodia. https://un-csam.org/sites/default/files/2023-08/Brief_Cambodia%20Pilot.pdf
282. National Committee for Sub-National Democratic Development (NCDD). (2015). Waste management in Cambodia: Policies and practices. https://lib.ncdd.gov.kh/storage/app/public/test_library/CAT_11673_1/2015-Waste-en.pdf
283. Open Development Cambodia. (2023). Royal Kram No. 0623/007 on Environment and Natural Resources Code. https://data.opendevelopmentcambodia.net/laws_record/royal-kram-no-0623-007-on-environment-and-natural-resources-code
284. Asian Development Bank (ADB). (2009). Biofuels in Cambodia: Current situation and prospects. https://www.adb.org/sites/default/files/publication/30309/biofuels-cambodia.pdf
285. Centre for Sustainable Agricultural Mechanization (CSAM). (2021). Sustainable agricultural mechanization in Asia and the Pacific. https://un-csam.org/sites/default/files/2021-01/0208.pdf
286. Open Development Cambodia. (n.d.). Water resources in Cambodia. https://opendevelopmentcambodia.net/topics/water-resources/
287. Corruption Perceptions Index 2023: Highlights & Insights. https://www.transparency.org/en/news/cpi-2023-highlights-insights-corruption-injusticeOpen Development Cambodia. (n.d.). Cassava. https://opendevelopmentcambodia.net/topics/cassava/
288. USDA Foreign Agricultural Service. (2023). Flying Green - Sustainable Aviation Fuel in the Philippines. Retrieved from https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Flying%20Green%20-%20Sustainable%20Aviation%20Fuel%20in%20the%20Philippines_Manila_Philippines_RP2023-0006.pdf
289. FlightGlobal. (2023). Cebu Pacific inks SAF supply deal from 2026. Retrieved from https://www.flightglobal.com/airlines/cebu-pacific-inks-saf-supply-deal-from-2026/150342.article
290. BusinessWorld. (2024, April 4). PAL targets to operate SAF-powered flights by 2026. Retrieved from https://www.bworldonline.com/corporate/2024/04/04/585665/pal-targets-to-operate-saf-powered-flights-by-2026/
291. Manila Bulletin. (2023, November 16). PAL to invest in SAF for green fleet. Retrieved from https://mb.com.ph/2023/11/16/pal-to-invest-in-saf-for-green-fleet
292. Pertamina. (2024). Pertamina and Airbus Explore Collaboration on Sustainable Aviation Fuel Development in Indonesia. Retrieved from https://www.pertamina.com/en/news-room/news-release/Pertamina-and-Airbus-Explore-Collaboration-on-Sustainable-Aviation-Fuel-Development-in-Indonesia
293. BioEnergyTimes (2024). PT Pertamina Patra Niaga strengthens its commitment to sustainability by securing ISCC for Sustainable Aviation Fuel. Retrieved from https://bioenergytimes.com/pt-pertamina-patra-niaga-strengthens-its-commitment-to-sustainability-by-securing-iscc-for-sustainable-aviation-fuel/
294. RSB. (n.d.). Sustainable feedstock assessment for Sustainable Aviation Fuel Production in Southeast Asia. Retrieved from RSB.org
295. Bioenergy Times. (2024). Thailand biofuels expected to generate new investment worth 114 billion baht. Retrieved from https://bioenergytimes.com/thailand-biofuels-expected-to-generate-new-investment-worth-114-billion-baht/#:~:text=Thailand's%20revised%20national%20oil%20plan,13%20years%2C%20reported%20Bangkok%20Post
296. Nation Thailand. (2024). Renewable green energy initiatives. Retrieved from https://www.nationthailand.com/sustainability/renewable-green-energy/40039229
297. Bangkok Post. (2024). National oil plan to promote sustainable fuel. Retrieved from https://www.bangkokpost.com/business/general/2716601/national-oil-plan-to-promote-sustainable-fuel
298. Bangchak. (2024). Bangchak Group to produce Thailand's first and only SAF from used cooking oil. Retrieved from https://www.bangchak.co.th/en/newsroom/bangchak-news/948/bangchak-group-to-produce-thailand-s-first-and-only-saf-from-used-cooking-oil

10. References

299. Bangchak. (2024). Bangchak Group lays the foundation stone for Thailand's first sustainable aviation fuel (SAF) production plant. Retrieved from https://www.bangchak.co.th/en/newsroom/bangchak-news/1271/bangchak-group-lays-the-foundation-stone-for-thailand-s-first-sustainable-aviation-fuel-saf-production-plant
300. S&P Global. (2024, April 3). Thailand's Bangchak, Japan's Sumitomo join forces for green UCO to SAF supply chain. Retrieved from https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/agriculture/040324-thailands-bangchak-japans-sumitomo-join-forces-for-green-uco-to-saf-supply-chain
301. SAF Investor. (2024). Bangchak Group breaks ground on 1mbpd SAF production unit in Thailand. Retrieved from https://www.safinvestor.com/news/144036/bangchak-group-breaks-ground-on-1mbpd-saf-production-unit-in-thailand/
302. S&P Global. (2024, April 3). Thailand's Bangchak, Japan's Sumitomo join forces for green UCO to SAF supply chain. Retrieved from https://www.spglobal.com/commodityinsights/en/oil/refined-products/jetfuel/040324-thailands-bangchak-japans-sumitomo-join-forces-for-green-uco-to-saf-supply-chain
303. Neste. (2024). Neste enables first Thai Airways flight using sustainable aviation fuel in cooperation with PTT and Petco Trading. Retrieved from https://www.neste.com/news/neste-enables-first-thai-airways-flight-using-sustainable-aviation-fuel-in-cooperation-with-ptt-and-petco-trading
304. Thai Airways. (2024). MOU with OR. Retrieved from https://www.thaiairways.com/sites/en/news/news_announcement/news_detail/mou-tg-or.page
305. Bangkok Post. (2024). New green aviation fuel venture formed. Retrieved from https://www.bangkokpost.com/business/general/2773646/new-green-aviation-fuel-venture-formed
306. BAFS. (2023). Sustainability Report 2023. Retrieved from https://www.bafsthai.com/storage/document/sustainability-reports/2023/bafs-sdreport2023-en.pdf
307. Pattaya Mail. (2024). Thai Vietjet pioneers sustainable fuel on Bangkok-Da Nang route from Suvarnabhumi Airport. Retrieved from https://www.pattayamail.com/thailandnews/thai-vietjet-pioneers-sustainable-fuel-on-bangkok-da-nang-route-from-suvarnabhumi-airport-465318
308. Neste. (2024). Neste enables Vietnam Airlines' first flight using sustainable aviation fuel. Retrieved from https://www.neste.com/news/neste-enables-vietnam-airlines-first-flight-using-sustainable-aviation-fuel
309. Novus Aviation Capital. (2024). Vietjet and Novus Aviation Capital sign MOUs to establish an aircraft financing and leasing vehicle and the development of sustainable aviation fuel. Retrieved from https://www.novus.aero/vietjet-and-novus-aviation-capital-sign-mous-to-establish-an-aircraft-financing-and-leasing-vehicle-and-the-development-of-sustainable-aviation-fuel/
310. Vietcetera. (2024). From trains to planes: Vietnam pledges green transport by 2050. Retrieved from https://vietcetera.com/en/from-trains-to-planes-vietnam-pledges-green-transport-by-2050
311. LawNet. (2022). Decision 876/QD-TTg: Program for mitigation of carbon dioxide from transportation. Retrieved from https://lawnet.vn/en/vb/Decision-876-QD-TTg-2022-program-for-mitigation-of-carbon-dioxide-from-transportation-7FEB3.html
312. Vietjet Air. (2024). Vietjet Thailand pilots sustainable aviation fuel as region's 1st low-cost airline. Retrieved from https://th.vietjetair.com/news/vietjet-thailand-pilots-sustainable-aviation-fuel-as-regions-1st-low-cost-airline
313. CAAFI. (2016). Biennial Meeting Special Guest Comment. Retrieved from https://caafi.org/resources/pdf/Biennial_Meeting_Oct252016_Special_Guest_Comment1.pdf
314. ResearchGate. (2023). Sustainable aviation fuel development: Case study in Indonesia. Retrieved from https://www.researchgate.net/publication/378027161_Sustainable_aviation_fuel_development_case_study_in_Indonesia
315. ICAO. (n.d.). Project on Sustainable Aviation Fuel. Retrieved from https://www.icao.int/environmental-protection/GFAAF/Pages/Project.aspx?ProjectID=40
316. DHL. (n.d.). Sustainable transport and logistics in Cambodia. https://www.dhl.com/discover/en-kh/logistics-advice/sustainability-and-green-logistics/sustainable-transport-and-logistics-in-cambodia
317. Southeast Asia Infrastructure. (2023). Cambodia's transport sector to be fully electric by 2050. https://southeastasiainfra.com/cambodias-transport-sector-to-be-fully-electric-by-2050/
318. Roundtable on Sustainable Biomaterials. (2024). Sustainable feedstock assessment for SAF in Southeast Asia. https://rsb.org/wp-content/uploads/2024/09/rsb-sustainable-feedstock-assessment-saf-in-southeast-asia.pdfTransparency International. (2023).
319. Reuters. (2024). Malaysia plans to produce sustainable jet fuel in 2027. Retrieved from https://www.reuters.com/business/energy/malaysia-plans-produce-sustainable-jet-fuel-2027-2024-11-26/
320. SAF Investor. (2024). Malaysia to promote palm oil-to-SAF production in 2025 budget. https://www.safinvestor.com/news/146231/malaysia-2/
321. Harrington. (2024). Malaysia to produce SAF from palm oil waste, while Thailand pumps first SAF shipments to Bangkok's airports. https://www.greenairnews.com/?p=6142#:~:text=Both%20the%20latter%20SAF%20consignments,the%20country%27s%202025%20financial%20budget
322. Reccessary. (2024). Malaysia launches aviation decarbonization blueprint, highlights SAF adoption https://www.reccessary.com/en/news/my-regulation/malaysia-launches-aviation-decarbonization-blueprint.
323. Malaysia Airlines. (2022). Malaysia Airlines Flies First Passenger Flight with Neste MY Sustainable Aviation Fuel Supplied by PETRONAS. https://www.malaysiaairlines.com/ph/en/mh-media-centre/news-releases/2022/malaysia-airlines-flies-first-passenger-flight-with-neste-my-sustainable-aviation-fuel-supplied-by-petronas.html
324. Reuters. (2023). Malaysian Aviation Group inks sustainable aviation fuel deal with Petronas Dagangan. https://www.reuters.com/sustainability/malaysian-aviation-group-inks-sustainable-aviation-fuel-deal-with-petronas-2023-05-26/
325. Petronas. (2023). PETRONAS and Idemitsu Collaborate to Accelerate Development of Sustainable Aviation Fuel for the Aviation Industry. https://www.petronas.com/media/media-releases/petronas-and-idemitsu-collaborate-accelerate-development-sustainable-aviation#:~:text=(Idemitsu)%20have%20signed%20a%20Memorandum,energy%20solutions%20for%20customers%20worldwide.
326. Malaysia Airlines. (2024). Malaysia Airlines Elevates Its Sustainability Initiatives with the Launch of Its Corporate Carbon Programme. https://www.malaysiaairlines.com/sg/en/mh-media-centre/news-releases/2024/corporate-carbon-programme.html
327. UPM Institute of Tropical Agriculture and Food Security. (n.d.). Creating Wealth from Waste Towards Sustainable Agriculture. Universiti Putra Malaysia. https://ikp.upm.edu.my/article/creating_wealth_from_waste_towards_sustainable_agriculture-51163
328. IQAir. (n.d.). Malaysia Air Quality Index. https://www.iqair.com/malaysia
329. F&L Asia. (2022, November 17). Sulzer to provide technology for world-scale SAF plant in Malaysia. F&L Asia. https://www.fuelsandlubes.com/sulzer-to-provide-technology-for-world-scale-saf-plant-in-malaysia/
330. Airports Council International Asia-Pacific & Middle East. (2024, February 5). Sihanoukville International Airport's environmental commitment gains new recognition. Retrieved from https://www.aci-asiapac.aero/media-centre/news/sihanoukville-international-airport-s-environmental-commitment-gains-new-recognition
331. Khmer Times. (2024, February 5). Cambodia's Techo International Airport takes pioneering step towards sustainability with GreenSky initiative. Retrieved from https://www.khmertimeskh.com/501422307/cambodias-techo-international-airport-takes-pioneering-step-towards-sustainability-with-greensky-initiative/
332. Lee Kuan Yew School of Public Policy. (n.d.). *Benjamin William Cashore*. National University of Singapore. Retrieved from https://lkyspp.nus.edu.sg/our-people/faculty/benjamin-william-cashore](https://lkyspp.nus.edu.sg/our-people/faculty/benjamin-william-cashore
333. Reuters (2025). PTTGC starts first sustainable jet fuel production in Thailand. Retrieved from PTTGC starts first sustainable jet fuel production in Thailand | Reuters

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11. Acknowledgements

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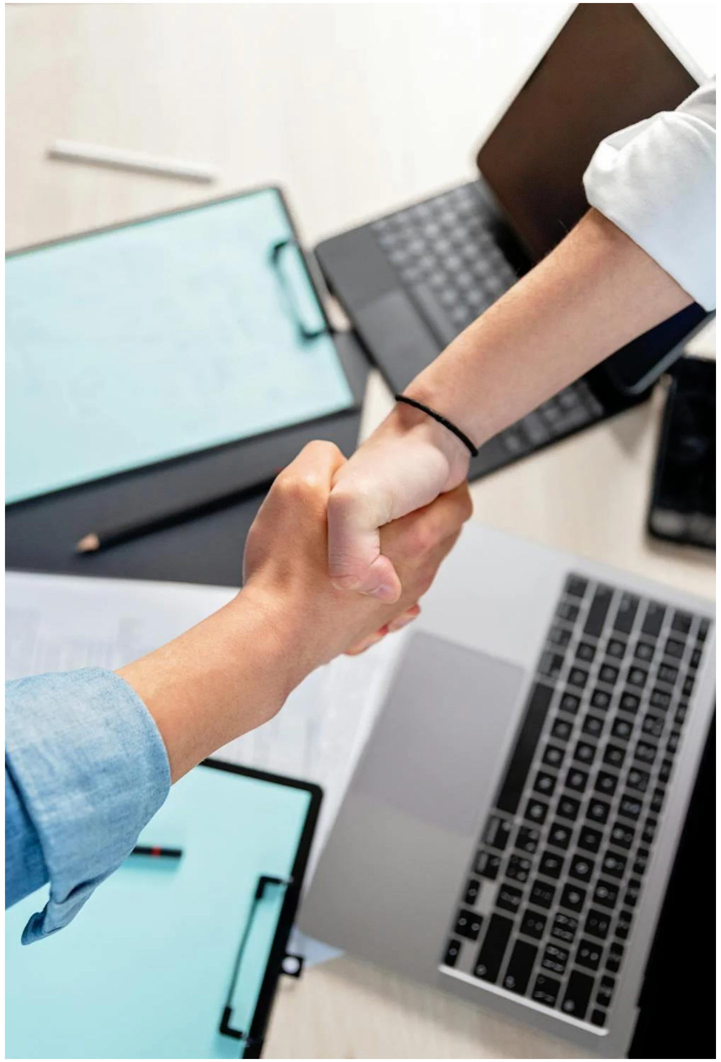

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