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BIOFUEL DEVELOPMENT FROM BIOMASS STOCK

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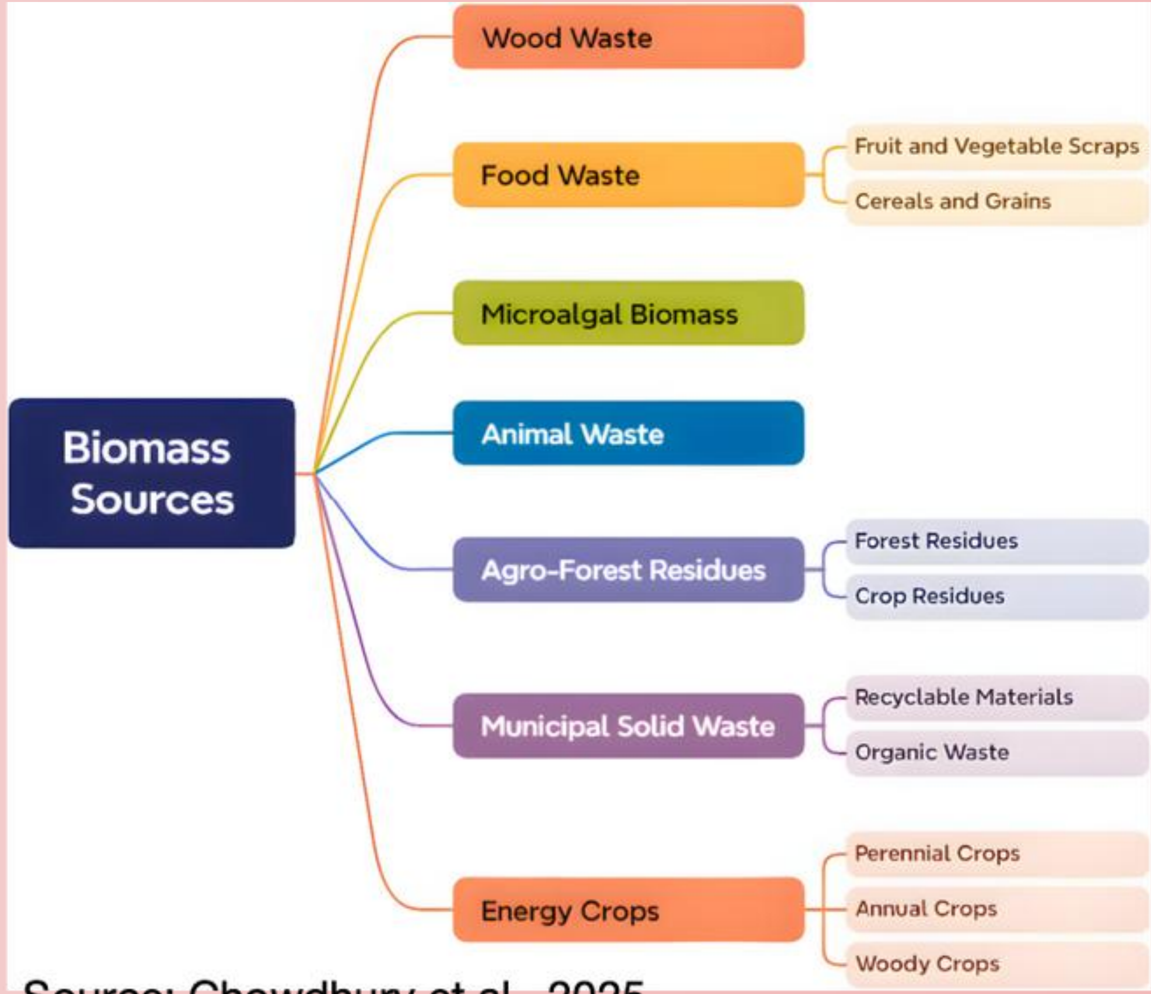
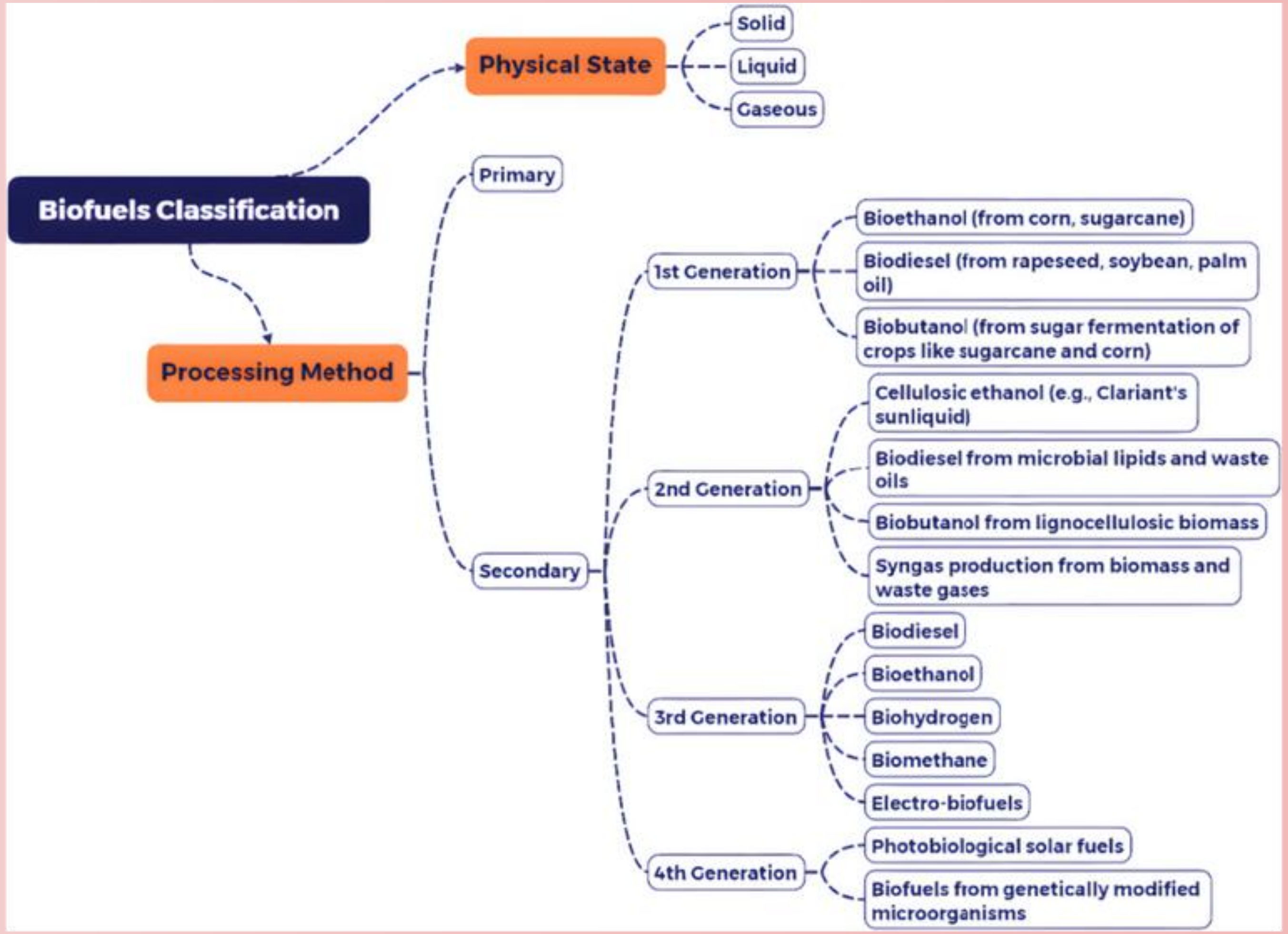
BIOMASS TO BIOFUEL

- Biofuels from biomass have significant potential to meet sustainable energy needs and help mitigate climate change.
- Potential biomass sources include wood waste, food waste, microalgae, animal waste, agroforestry residues, municipal solid waste, and energy crops.
- Second- and third-generation biofuels are more sustainable than first-generation biofuels, but technological and cost barriers remain high.

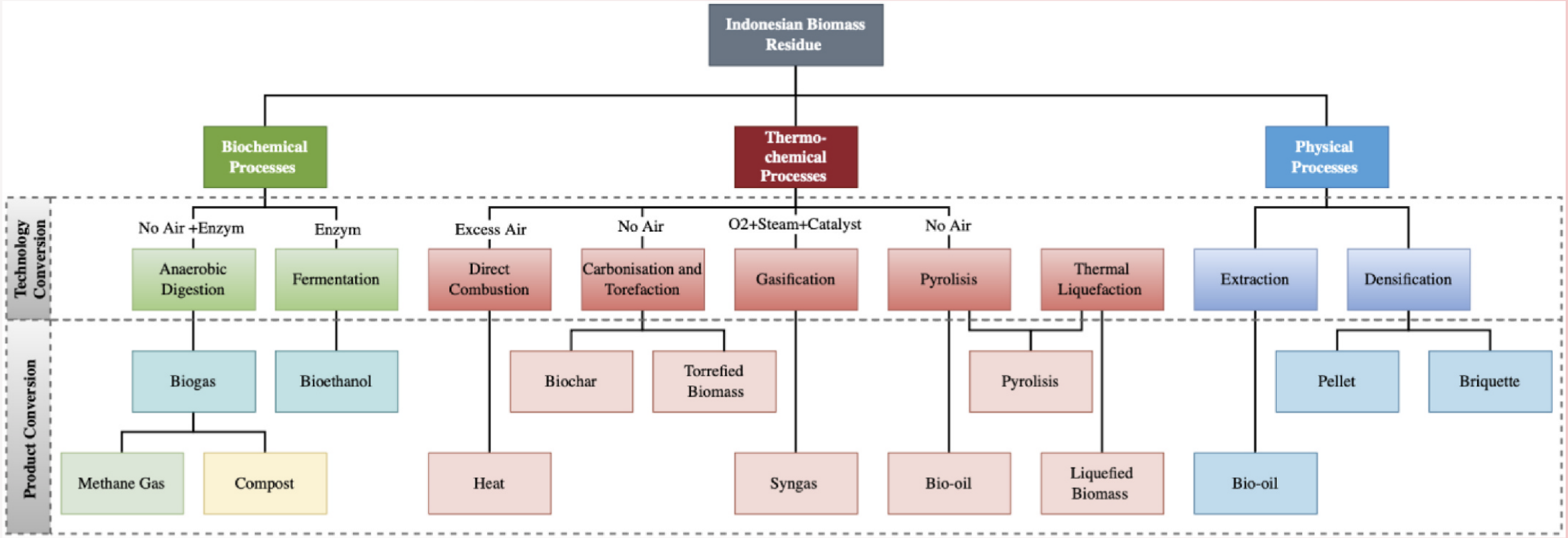


Source: Chowdhury et al., 2025

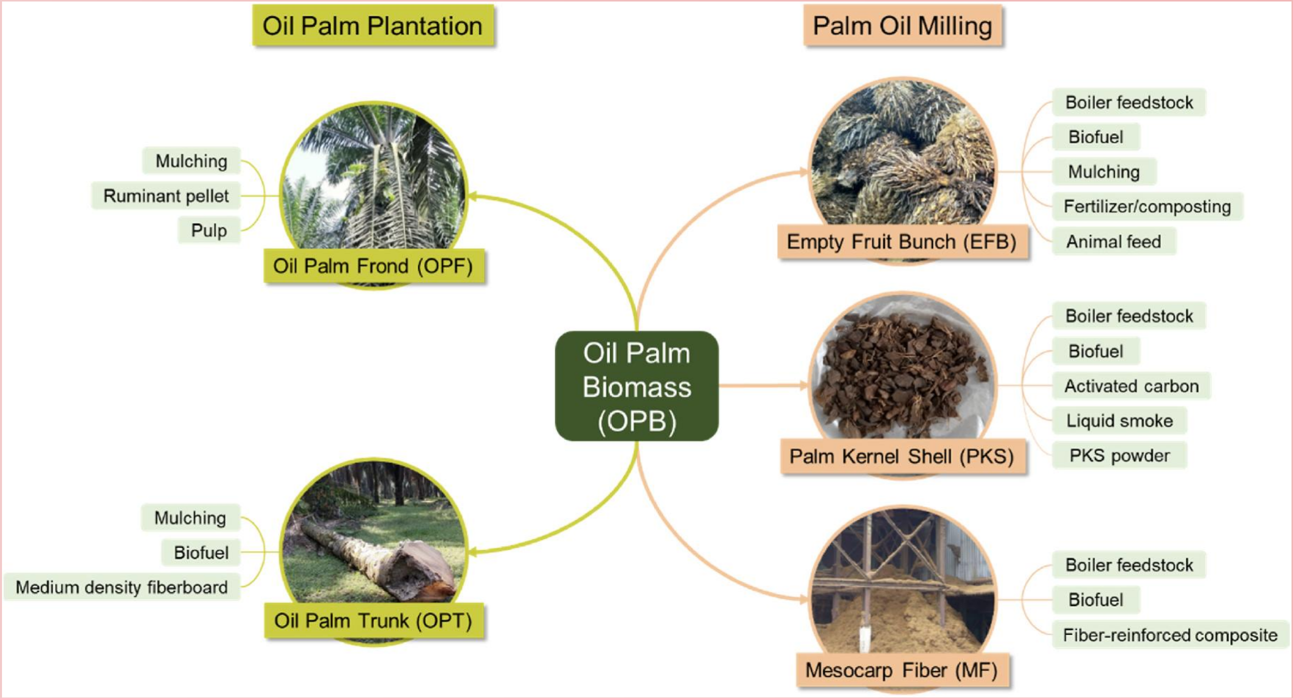


BIOMASS POTENTIAL IN INDONESIA

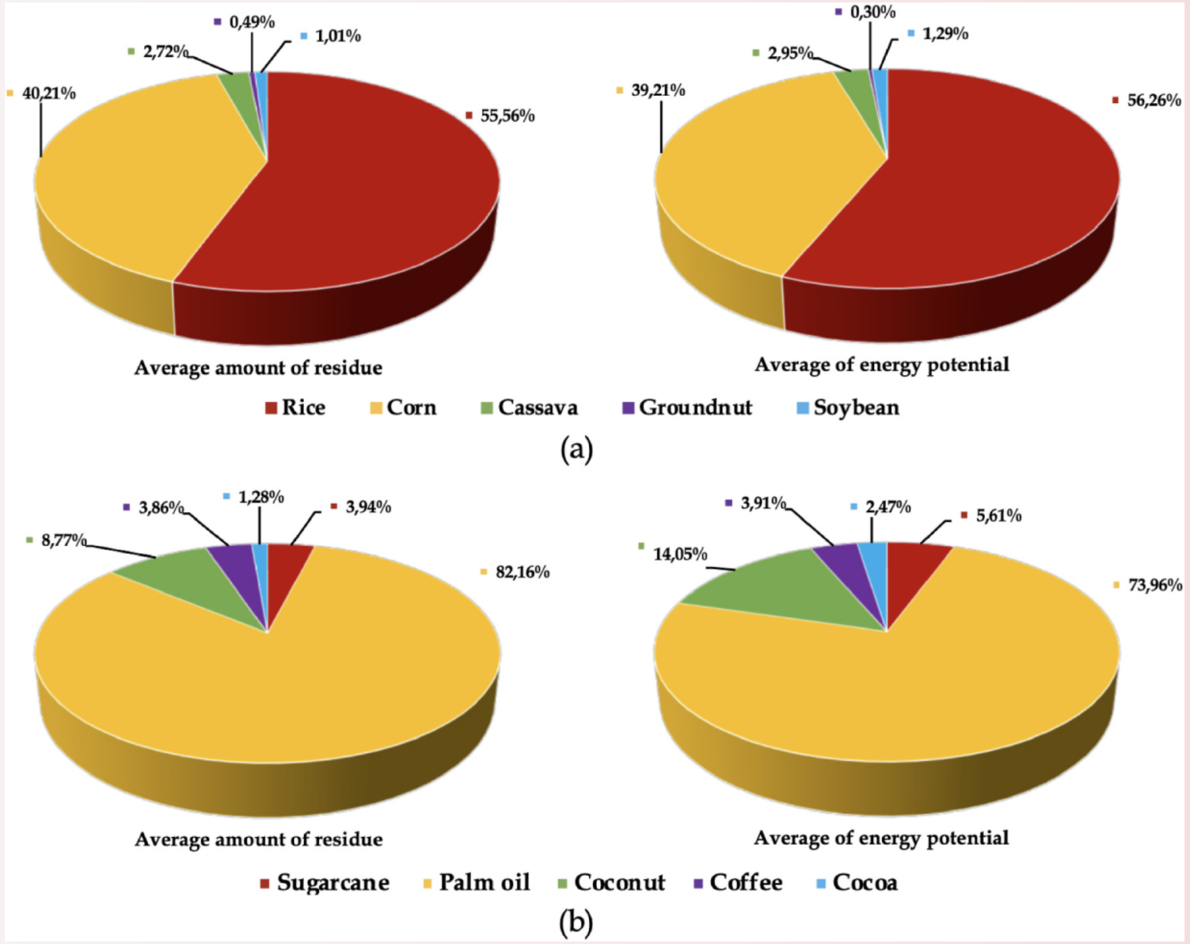
Indonesian biomass residue processes



Utilization of oil palm biomass in Indonesia



Source: Nabila et al., 2023



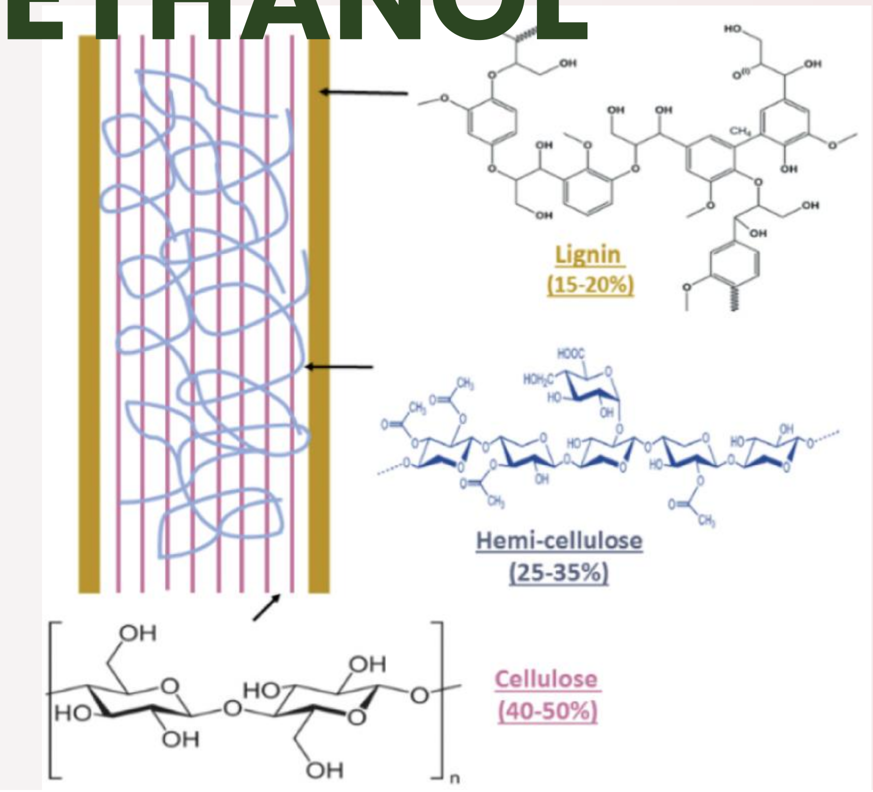
Residue production availability and energy potential

- Indonesia possesses significant potential for green energy development by utilizing agricultural and forestry biomass residues.
- Agricultural residues amount to approximately 155.3 million tons annually, offering an energy potential exceeding 300 PJ per year, with rice straw and palm oil waste being the primary contributors.
- Forestry residues from wood waste total around 7.9 million tons per year, corresponding to an energy potential of 59 PJ annually.

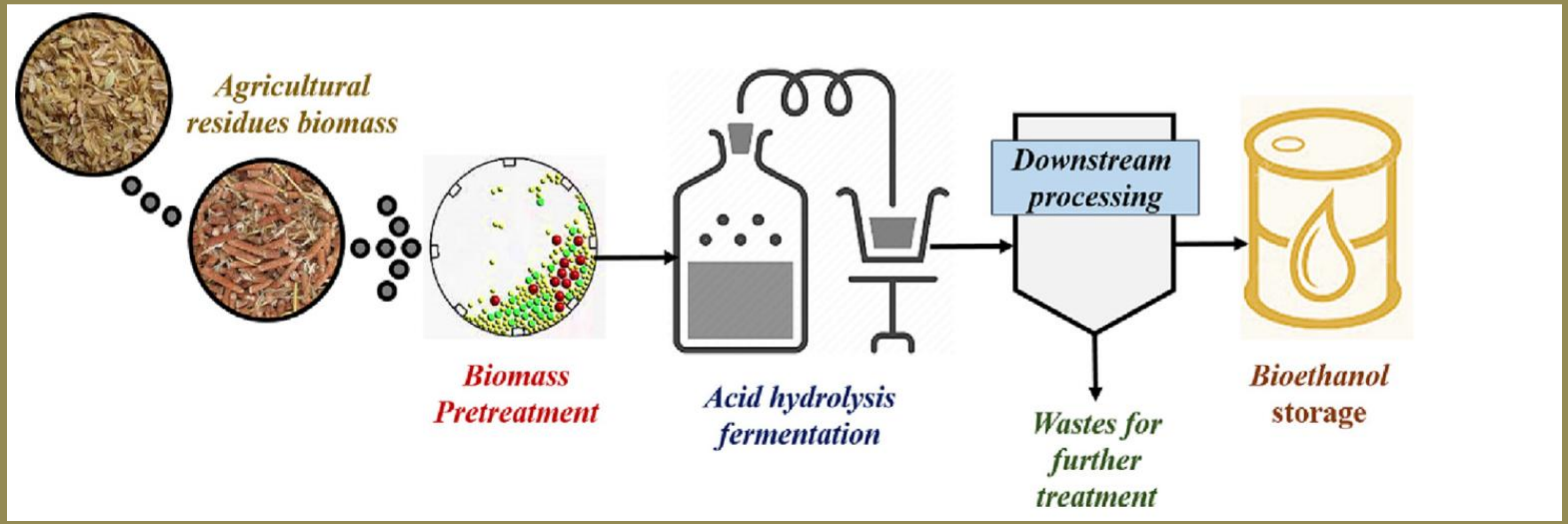
BRIN
BADAN RISET
DAN INOVASI NASIONAL

BIOETHANOL

BIOMASS TO BIOETHANOL



Source: Jayakumar et al., 2023



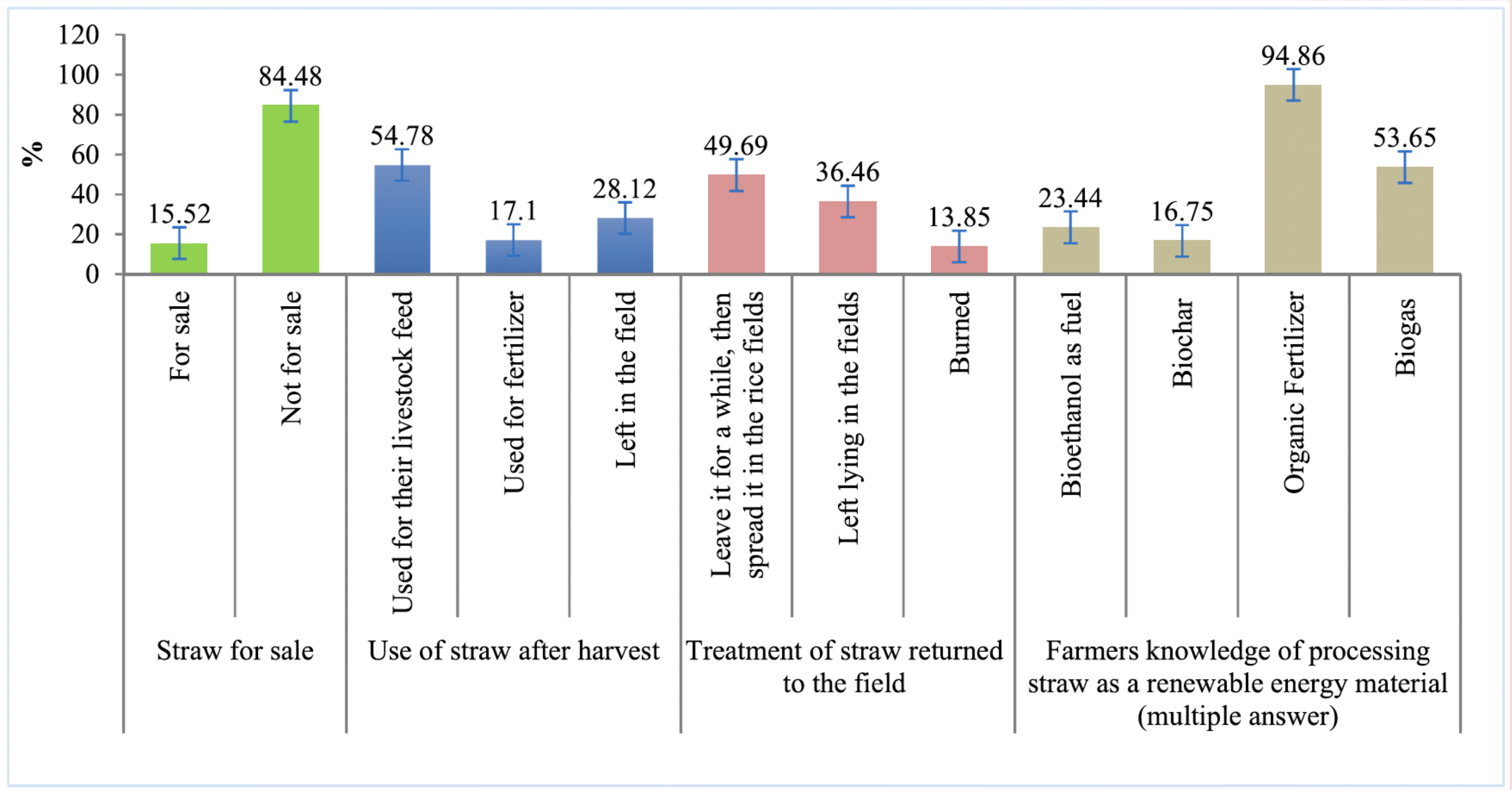
The cellulose (40-50 wt%) and hemicellulose (20-30 wt%) content of biomass can be utilized to produce ethanol.

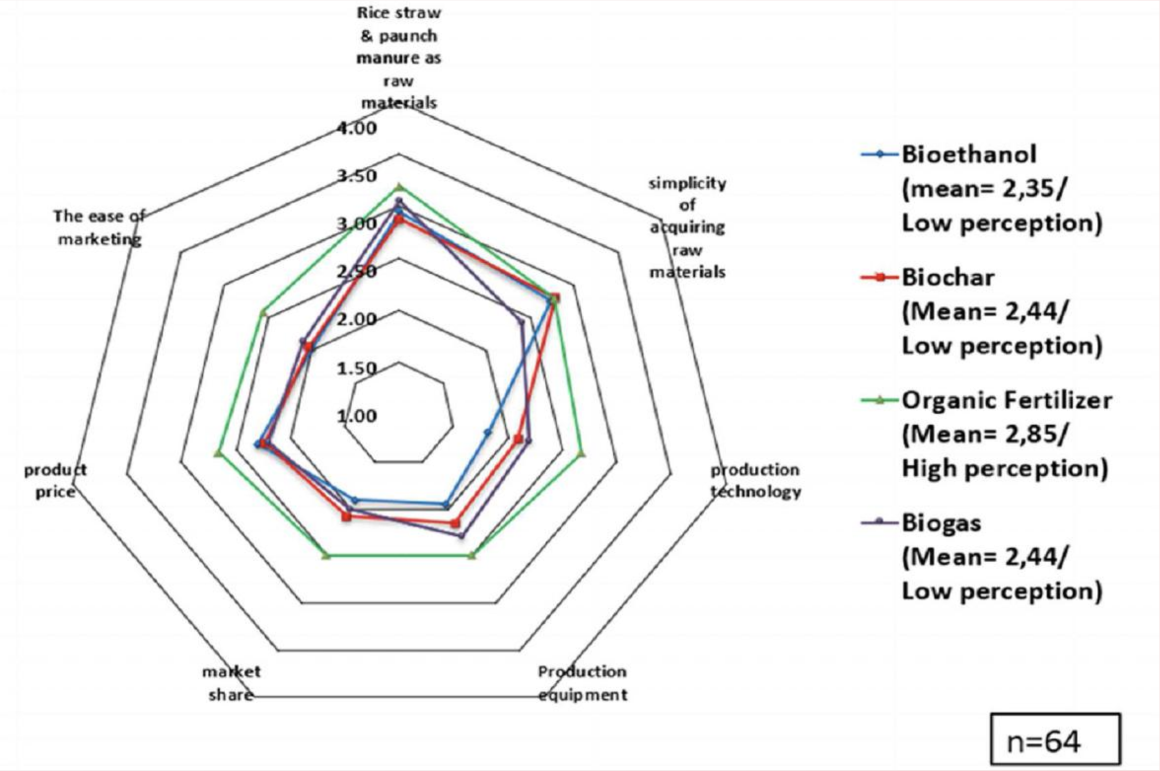
The global potential for bioethanol production from waste is quite large (e.g., rice straw: 205 billion L/year).

Challenges:

- Variation in biomass composition, high moisture content, and processing costs.
- Costs of biomass pretreatment and logistics.

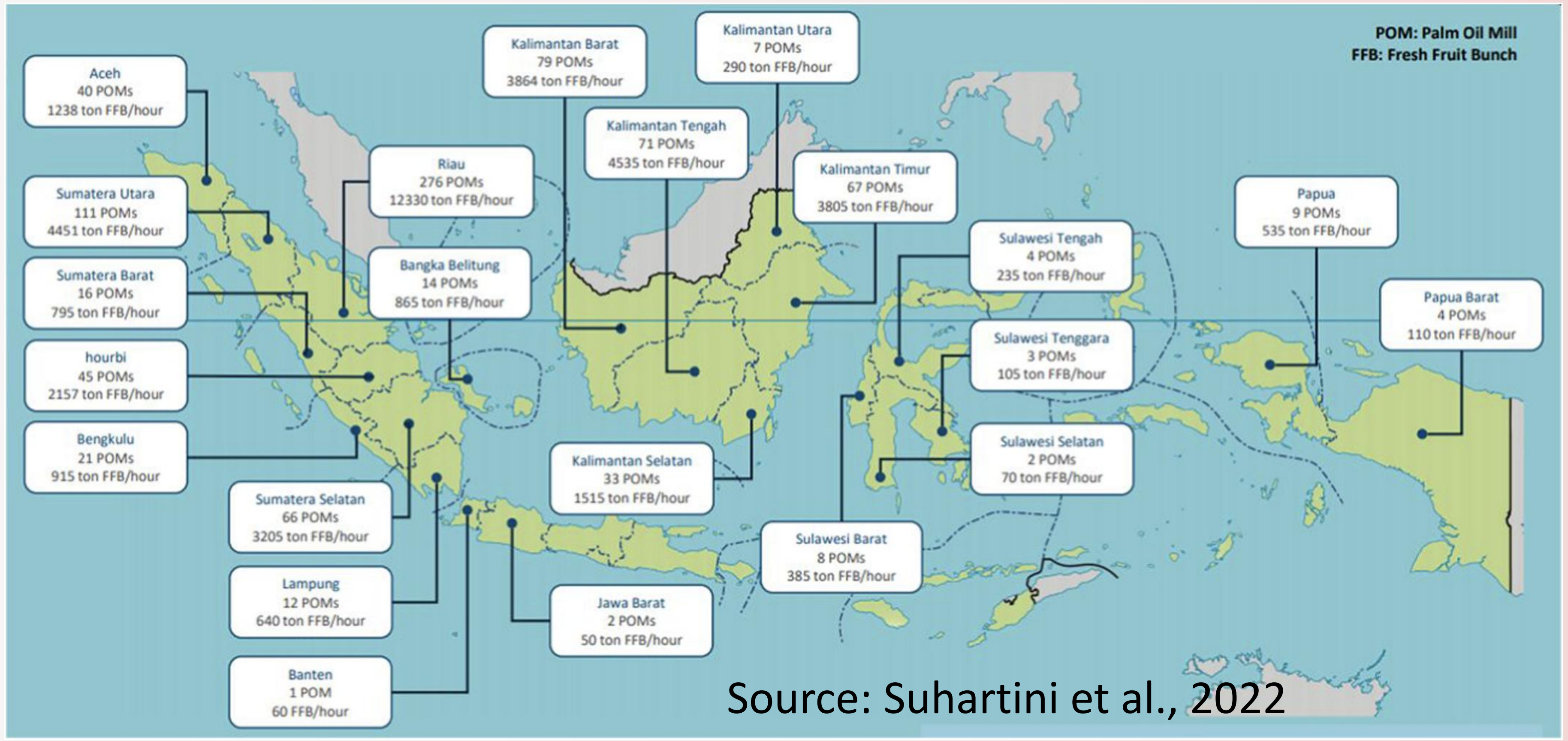
Potential Agricultural Residue for Bioethanol





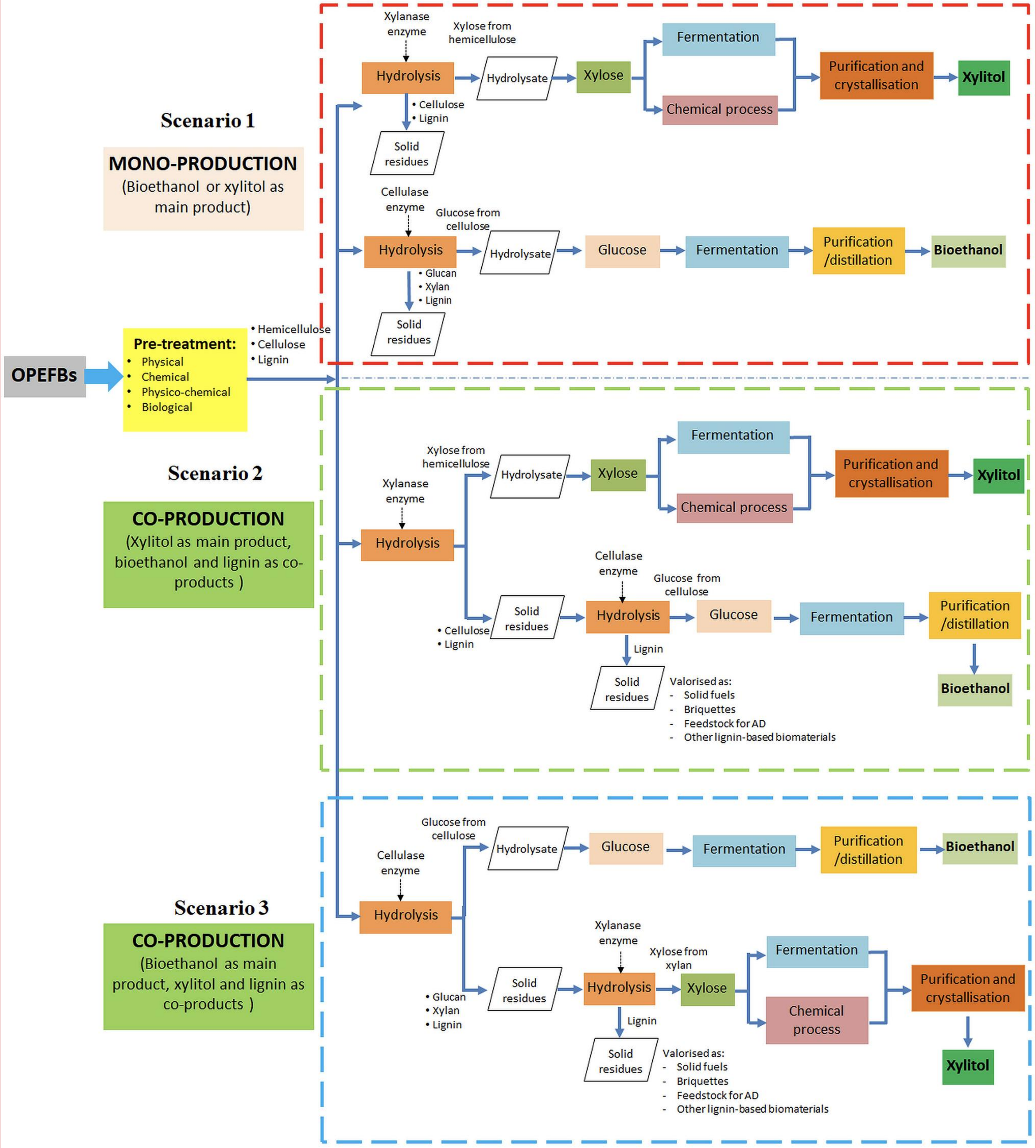
1. Rice straw and paunch manure (livestock waste) are biomass with potential as raw materials for bioethanol.
2. Primary data was collected through interviews and surveys with 64 farmers in Karanganyar.
3. The majority of farmers remain unaware of the potential of these two waste streams as renewable energy sources.
4. Farmers' perceptions of bioethanol are low due to the difficult production process, expensive equipment, small market, and perceived high product prices.

Technoeconomic feasibility of OPEFBs as bioethanol feedstock

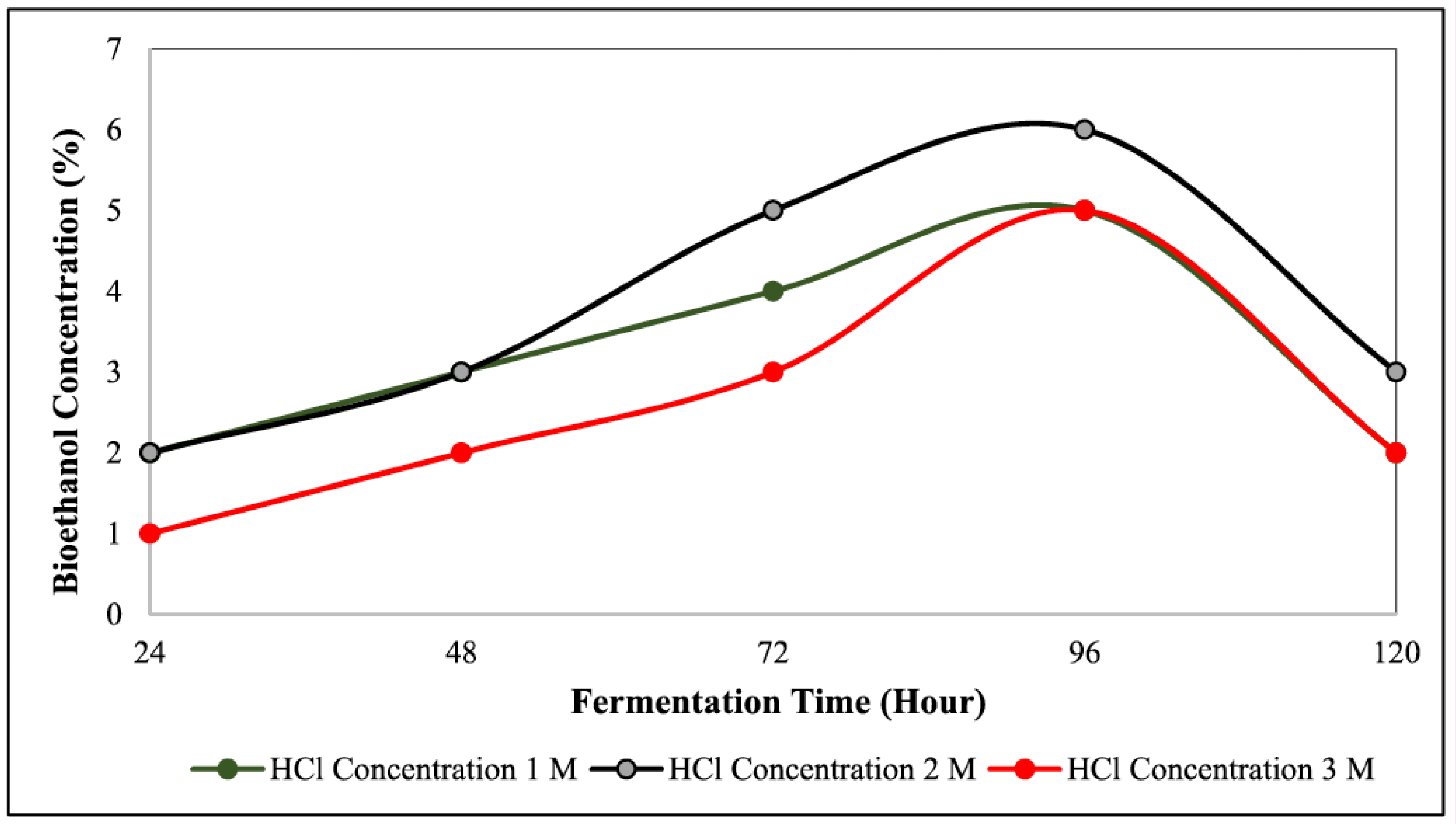


Source: Suhartini et al., 2022

- The national energy policy targets the use of biomass for renewable energy, but the implementation of lignocellulosic biomass-based bioethanol remains limited.
- The potential availability of OPEFBs in Indonesia is 45.86 million tons/year, equivalent to 828 MW/year.
- Domestic bioethanol demand is projected to increase from 0.22 billion liters (2019) to 10.38 billion liters (2025), while xylitol demand reached 2.2 thousand tons/year (2020).
- Three OPEFB-based biorefinery scenarios were proposed, all of which were concluded to be economically feasible.



Abundant palm oil residue for bioethanol



Source: Ahmad et al., 2023

- Oil palm empty fruit bunches (OPEFBs) from oil palm are a promising lignocellulosic biomass source for second-generation bioethanol production, contributing to the development of renewable energy and the effective management of plantation waste.
- The delignification and bleaching process significantly reduced the lignin (16.8%→11.2%) and hemicellulose (25.2%→14%) content, while increasing the cellulose content (36.4%→59.8%).
- Chemical hydrolysis was conducted using different concentrations of HCl (1 M, 2 M, and 3 M) at 100°C for 3 hours.
- Fermentation was performed with Saccharomyces cerevisiae for 24 to 120 hours, with bioethanol content measured.
- The optimal bioethanol yield of 6% v/v was obtained after 96 hours of fermentation with Saccharomyces cerevisiae.
- Hydrolysis of oil palm empty fruit bunches using 2 M HCl for 3 hours was the best condition for producing high fermentable sugars.

Bioethanol development timeline of Indonesia

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2008 - 2009 **2015 - 2016** **2020** **2021 - 2022** **2023 - 2024** **2025**

2008 - 2009
Biopremium and Biopertamax were sold on a limited basis in Java and Bali.

2015 - 2016
- ESDM Ministerial Regulation No. 12/2015.
- Limited mixing of E2 with RON92 and RON95.

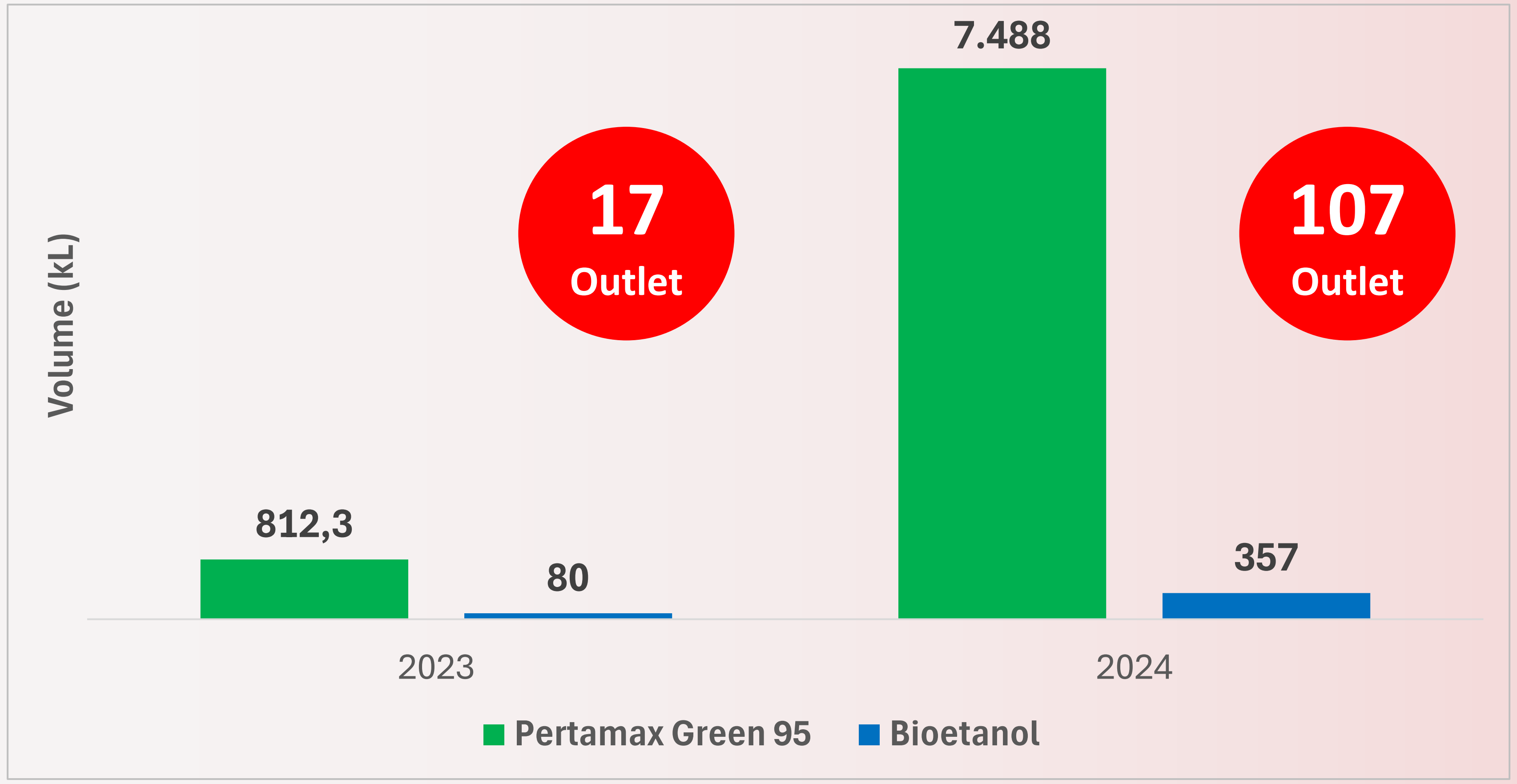
2020
Mandatory E5-PSO and E10-NPSO **have not been implemented**

2021 - 2022
- Study by the ITB Bioethanol Study Team and PT Pertamina.
- Presidential directive to immediately blend bioethanol (November 2022)

2023 - 2024
- Bioethanol Road Test.
- E5 Market Trial in Surabaya and Jakarta.
- Presidential Decree 40/2023.

2025
Implementation of E5 implementation for the Non PSO sector in the Surabaya and Jakarta areas.

Realization of Bioethanol Utilization



Source: Lahadalia et al., 2025

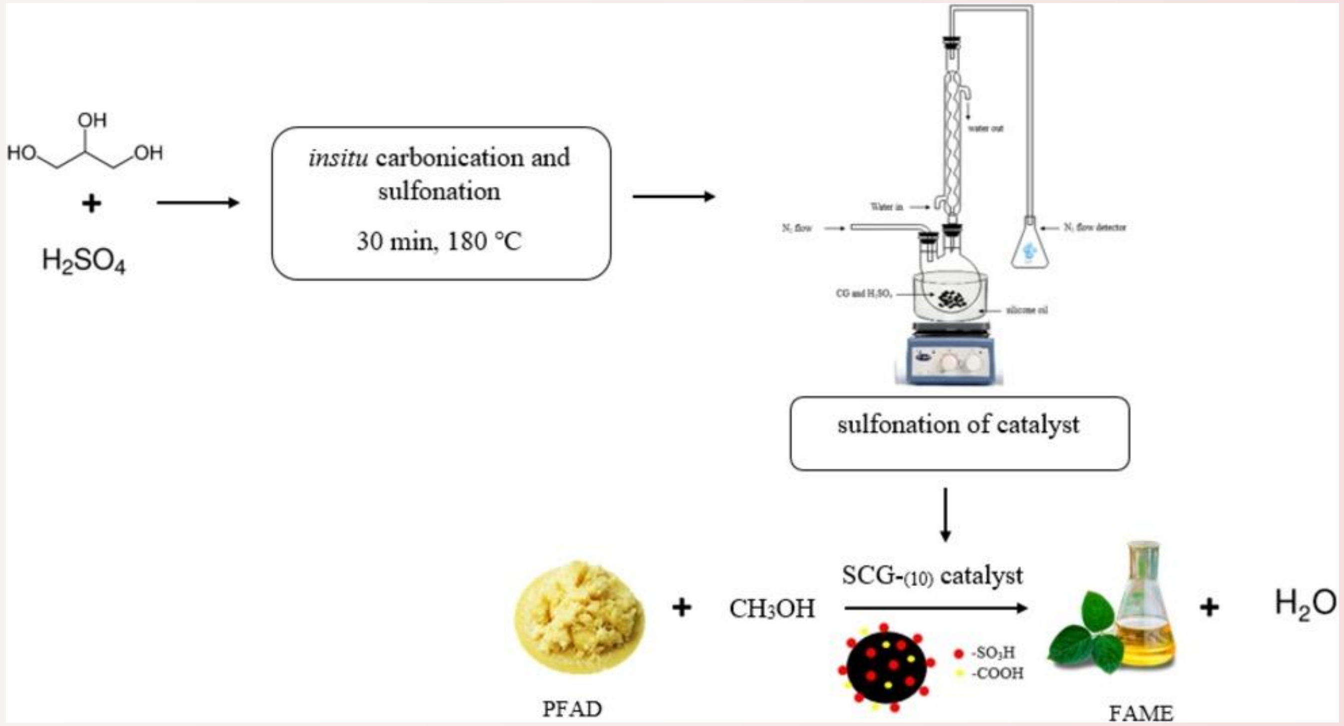
Bioethanol producers in Indonesia

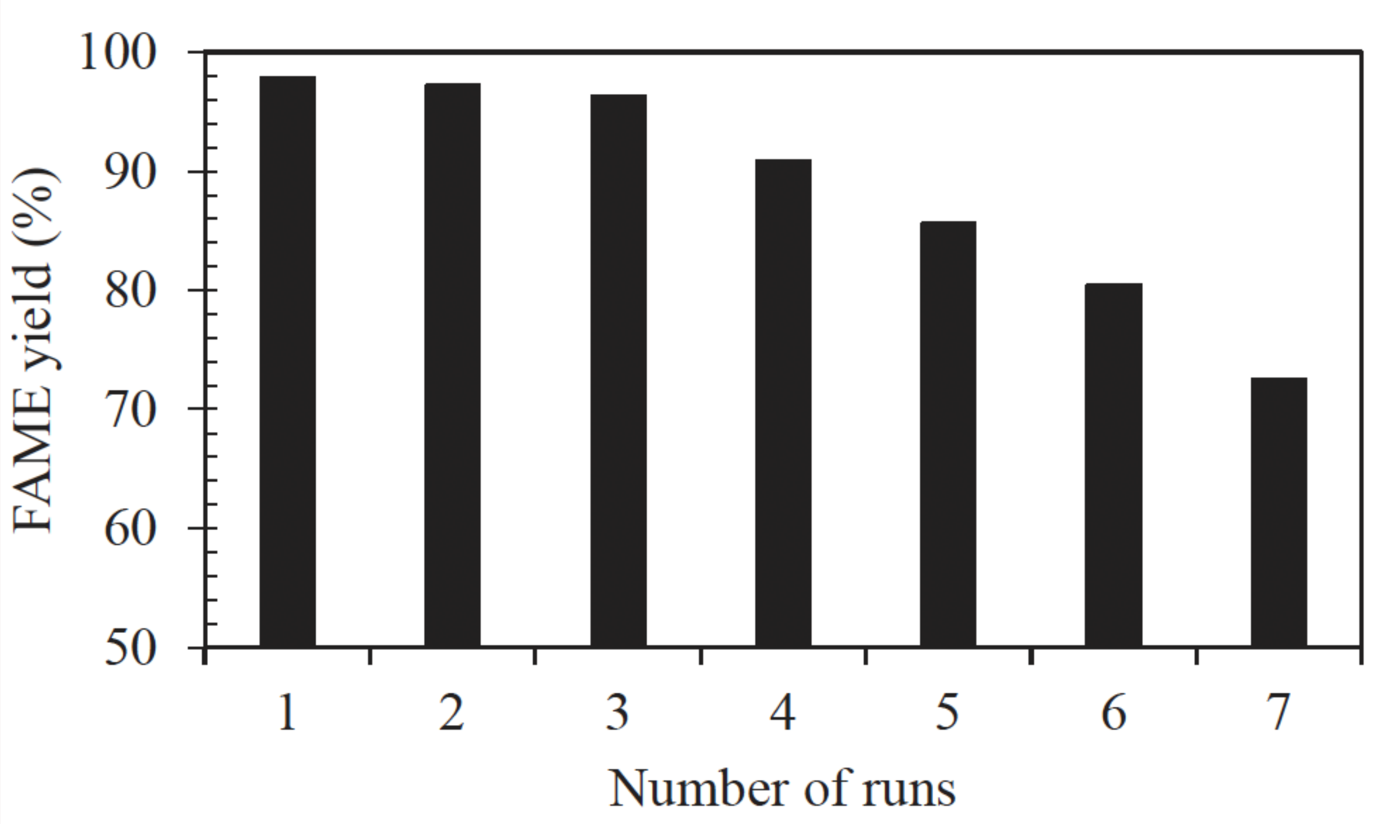
Bioethanol producers	Location	Capacity (kL/year)	FGE capacity (kL/year)	Feedstock
Molindo Raya Industrial	Malang, East Java	80,000	10,000	Molasses
PASA Jatiroto PTPN XI	Lumajang, East Java	2025	–	Molasses
Ethanol Ceria Abadi	Jombang, East Java	13,200	–	Molasses
Energi Agro Nusantara	Mojokerto, East Java	30,000	30,000	Molasses
Indo Acidatama	Solo, Central Java	58,825	–	Molasses
Madu Baru	Yogyakarta	7500	3000	Molasses
PSA Palimanan	Cirebon, West Java	3000	–	Molasses
Indonesia Ethanol Industry	Lampung	62,000	20,000	Cassava, corn
Molasindo	Medan, North Sumatera	3600	–	Molasses
Basis Indah	Bone, South Sulawesi	3000	–	Molasses
Medco Ethanol	Lampung	50,000	–	Molasses
Semarang Herbal Indoplant	Semarang, Central Java	2000	–	Molasses
Indo Lampung Distillery	Lampung	50,000	–	Molasses
Total		365,150	63,000	

Source: Wirawan et al., 2025

BIODIESEL

Palm oil waste for biodiesel feedstock

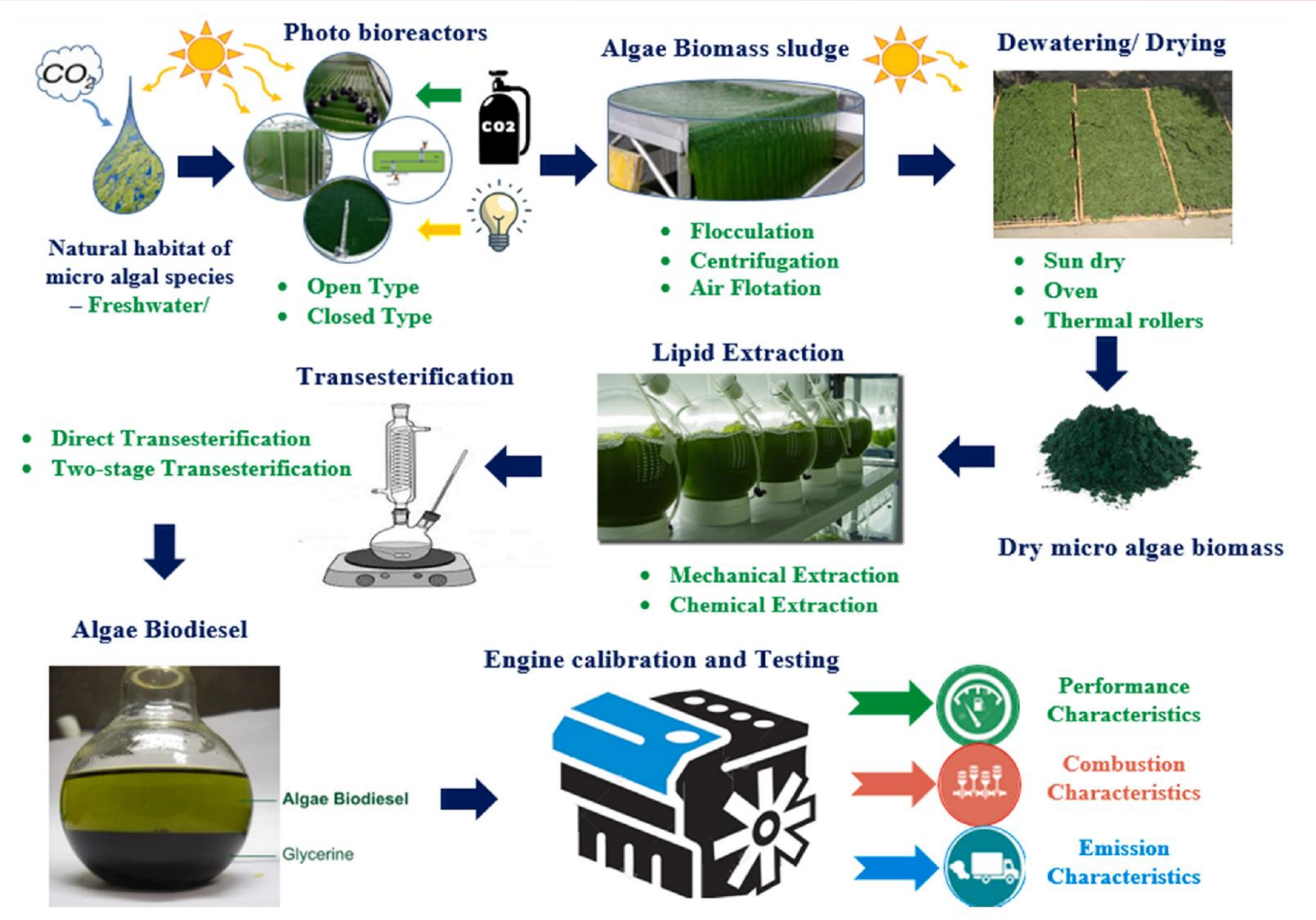




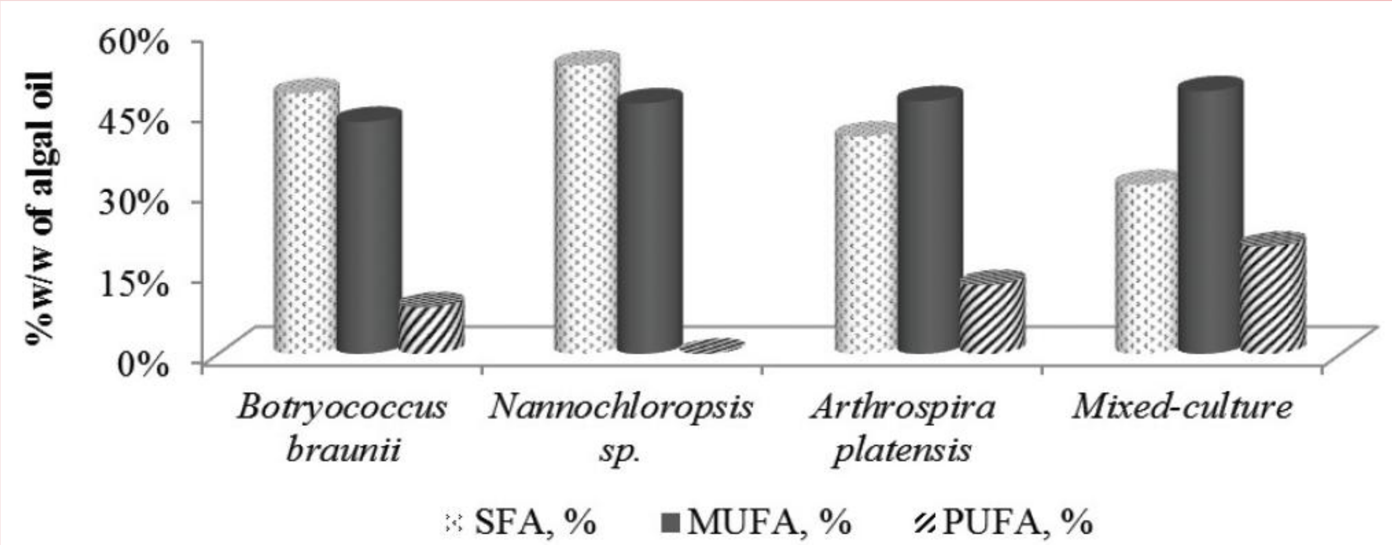
Source: Sangar et al., 2019

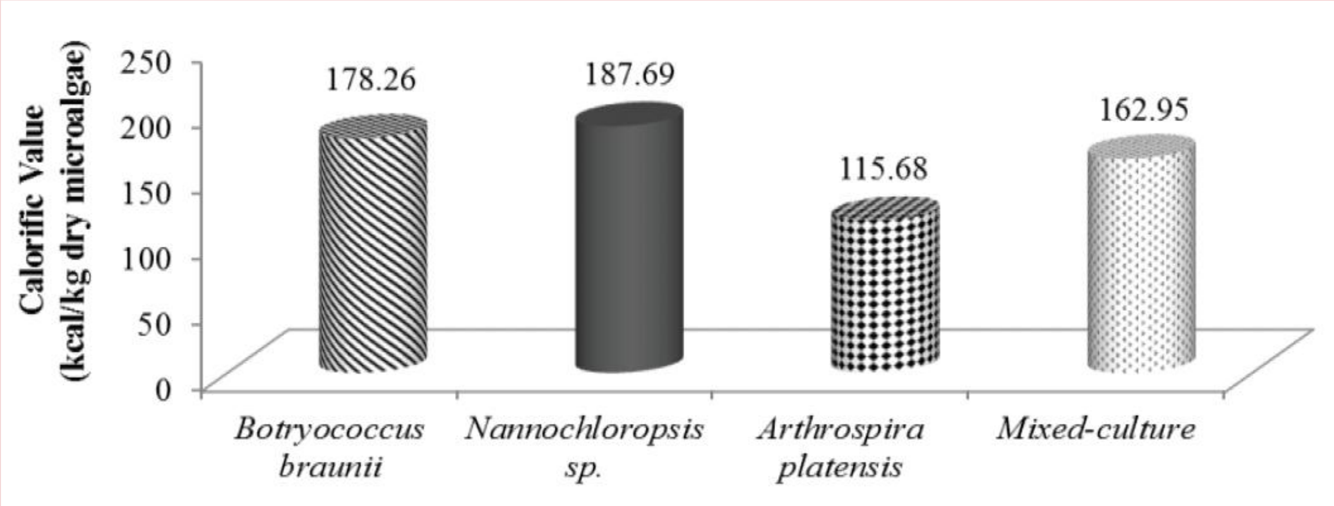
- Palm Fatty Acid Distillate (PFAD), a low-cost byproduct of the palm oil industry, contains a high level of free fatty acids (FFA).
- Glycerol, which accounts for roughly 10% of biodiesel production by weight, is abundantly available worldwide and can be converted into reusable, eco-friendly sulfonated solid carbon catalysts.
- Sulfonated Carbon-derived Glycerol (SCG) catalysts were synthesized via in-situ carbonization followed by sulfonation.
- The optimal esterification parameters were a temperature of 90 °C, a methanol-to-PFAD molar ratio of 18:1, a reaction duration of 1 hour, and a catalyst loading of 5 wt%.
- The maximum FAME yield of 97.8% was achieved, with the catalyst maintaining a stable yield (≥96%) over three reuse cycles.

Microalgae biomass for biodiesel feedstock



Source: Jacob et al., 2021





Source: Pradana et al., 2017

- Microalgae cultivation for biodiesel can be carried out in open or closed photobioreactors. Open photobioreactors are less expensive but offer poor quality control. Closed photobioreactors, on the other hand, offer optimal control but are more expensive.
- Key parameters: light intensity, medium composition, pH, PBR design, aeration pressure/rate, solvent ratio, reaction time, and temperature.
- Direct transesterification allows for the production of wet biomass without a separate extraction step.

- Pradana et al. (2017) studied oil extraction from several microalgae species in single and mixed cultures obtained from local coastal areas.
- The microalgae species included Botryococcus braunii, Nannochloropsis sp., and Arthrospira platensis.
- Oil extraction was carried out using the Soxhlet method with n-hexane as the solvent at 80°C for 3 hours.
- Nannochloropsis sp. was selected as the best candidate for biodiesel feedstock due to its higher oil yield and calorific value compared to other species.

Towards Biodiesel B50 – Indonesia as the leading country of biodiesel users

1 It is necessary to increase the production capacity of the National Biodiesel factory.

2025 - B40

Production capacity

24 business entity 15,6 million kL
81,5% of installed capacity
(19,15 million kL)

CPO needs: 14,2 million kL

- Technical testing
- Funding Adequacy and Sustainability Study
- CPO Availability Study

- There is a need to add new factories, especially in Eastern Indonesia.

2026 : existing production capacity ~ 17,3 million kL
(including expansion and addition of new factories with a production capacity of 1.72 million kL)

20XX - B50

Production capacity

20XX : 20,1 million kL
~ 80% installed capacity
(25 million kL)

CPO needs: 18,69 million kL

2 Need to Improve Supporting Infrastructure

2025 - B40

Delivery point: 92

- Transportation Mode Limitations
- Ship Facility Limitations (Flow Rate Pump)
- Infrastructure Limitations at TBBM
  (Storage Tanks, Piping, and Blending Facilities)

Ship Certification (PSA) and Upgrading of Facilities and Infrastructure

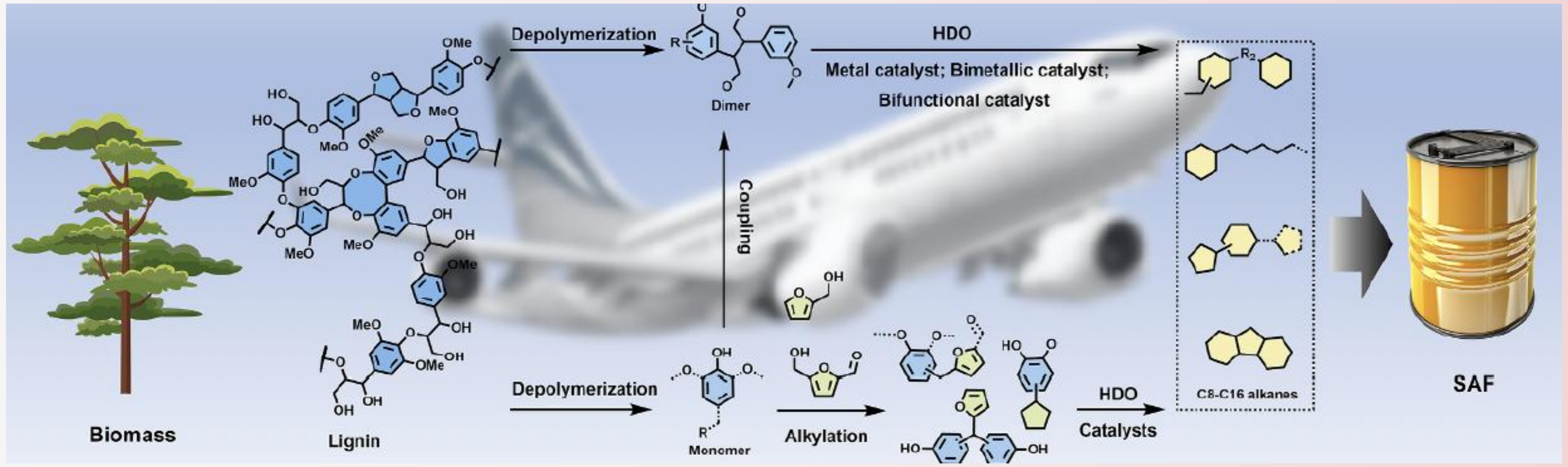
20XX - B50

- Sufficient and efficient transportation modes are available
- Sufficient ship facilities
- TBBM infrastructure supports B50 implementation

SUSTAINABLE AVIATION FUEL (SAF)

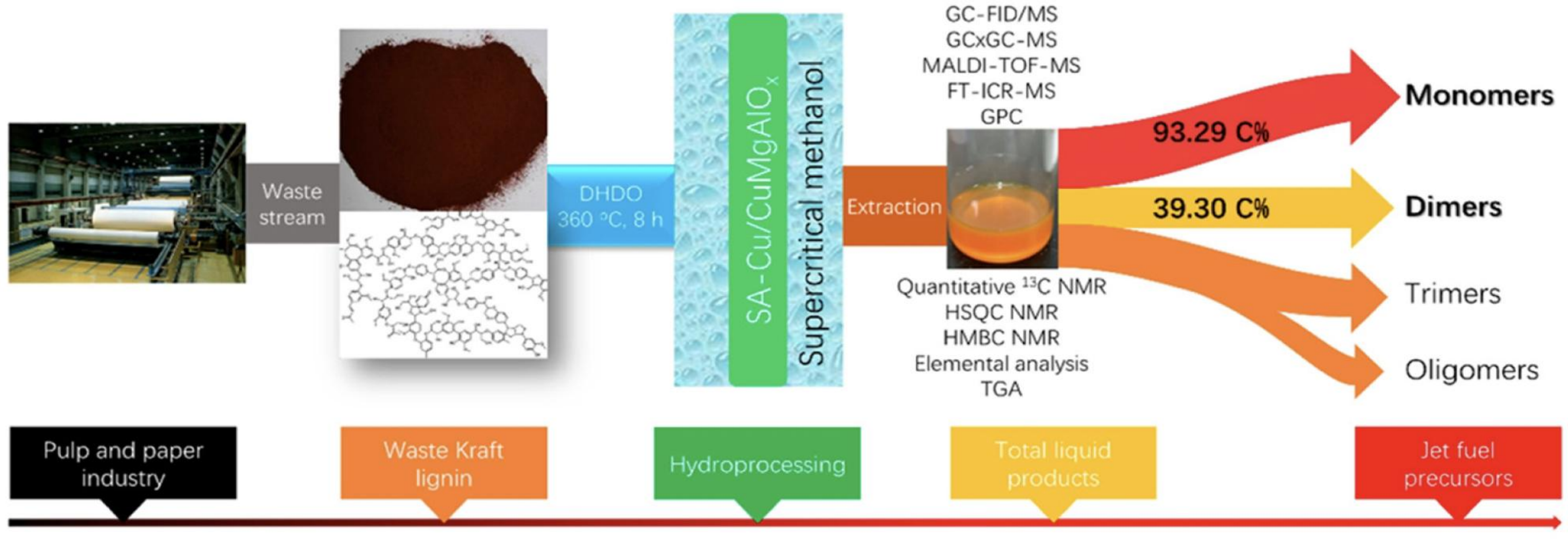
Biomass to bioavtur

SAF production route from biomass feedstocks



Source: Xianqing et al (2025)

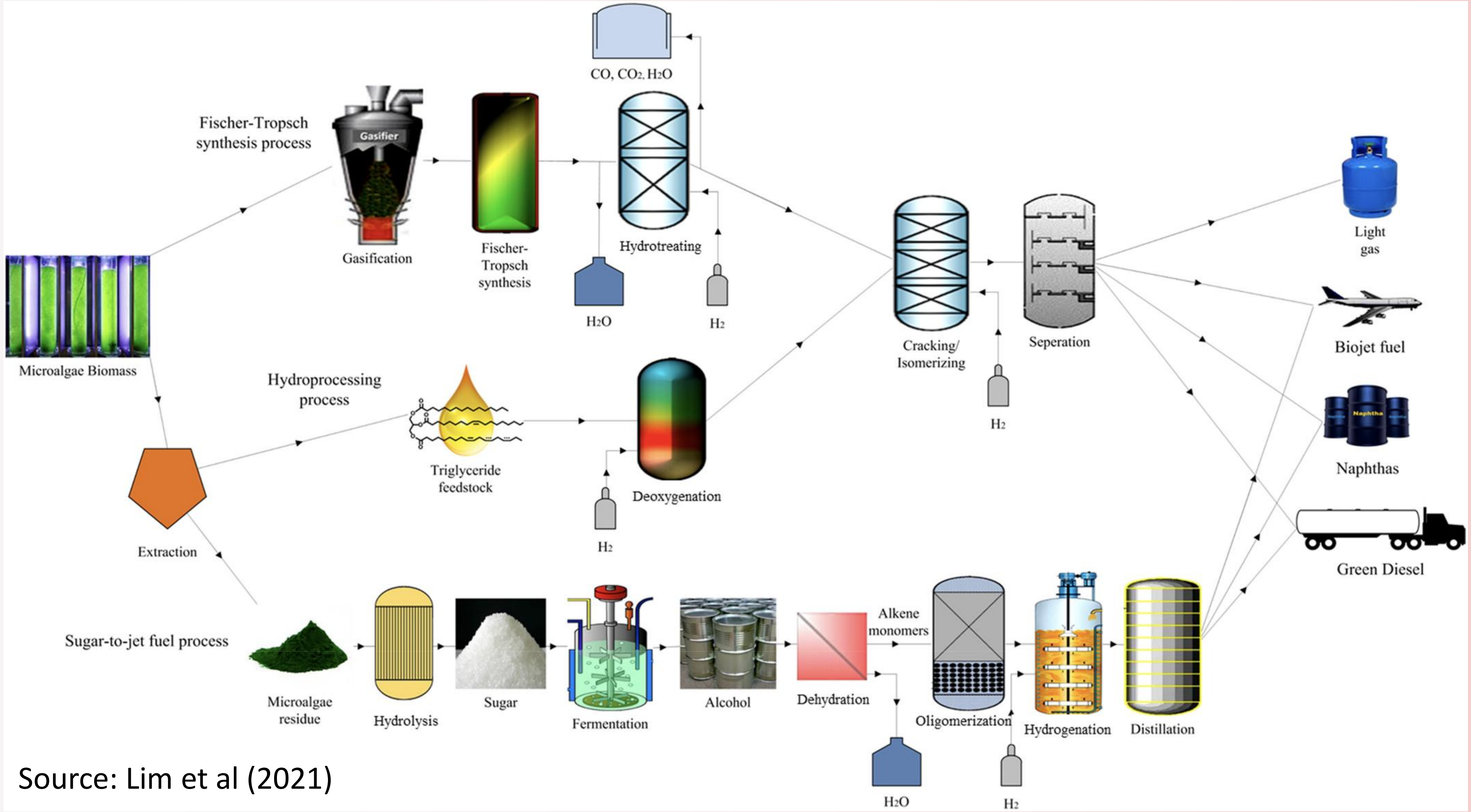
Preparation of aviation fuel precusors from waste kraft lignin



Source: Xianqing et al (2025)

- Lignin has great potential as a feedstock for SAF through a combination of depolymerization, alkylation, and HDO.
- A two-stage strategy using phenolic bio-oil holds greater promise for the industry.
- Innovation in efficient non-precious catalysts is key to scaling up.

Microalgae biomass for SAF feedstock



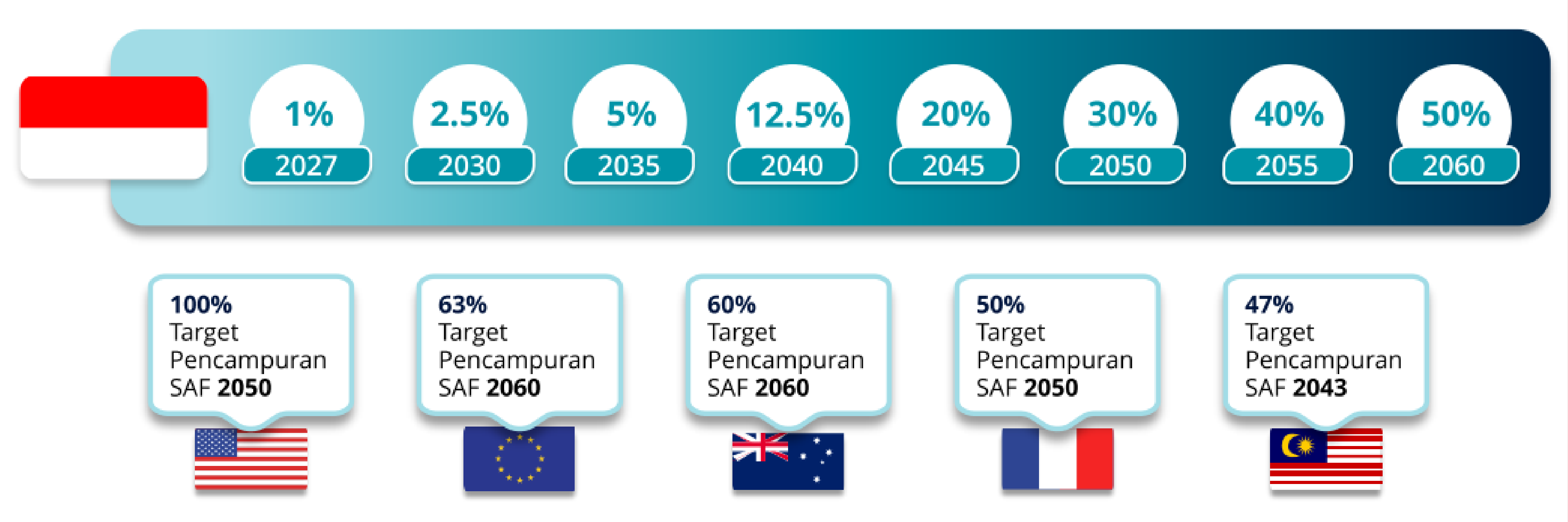
Source: Lim et al (2021)

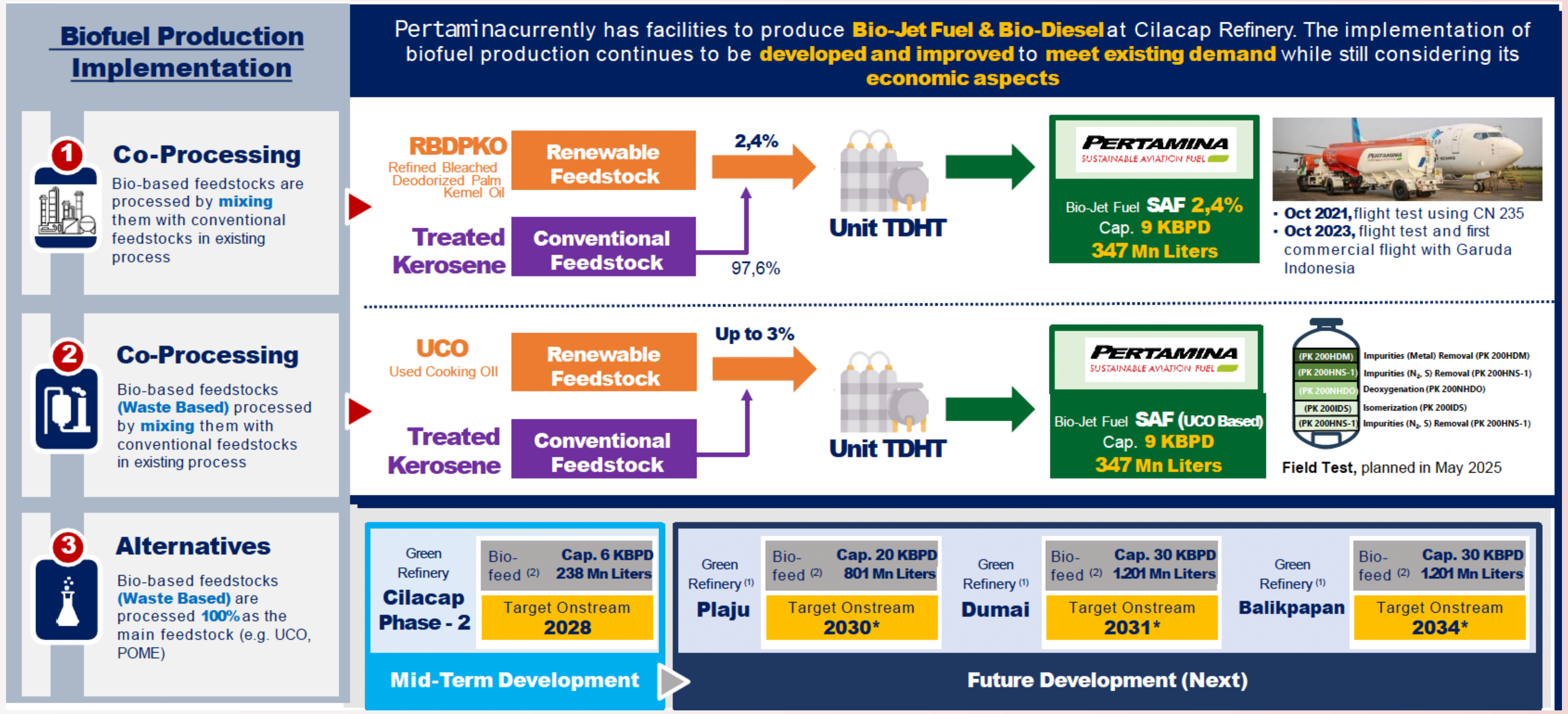
Microalgae-based SAF holds great promise for the aviation sector due to its high lipid production potential, non-competitive nature with food, and ability to reduce GHG emissions by >90%.

Three SAF production pathways from microalgae are HEFA, FT, and AtJ.

Microalgae SAF specifications:
Heat value ~44 MJ/kg (higher than Jet-A, 42.8 MJ/kg)
Freezing point: −30°C (additives required to meet ASTM standards of −40°C)
High flash point (68°C) → safe handling.
Low viscosity according to specifications
Low sulfur content (0.27%) → low SOx emissions, but reduced lubricity.

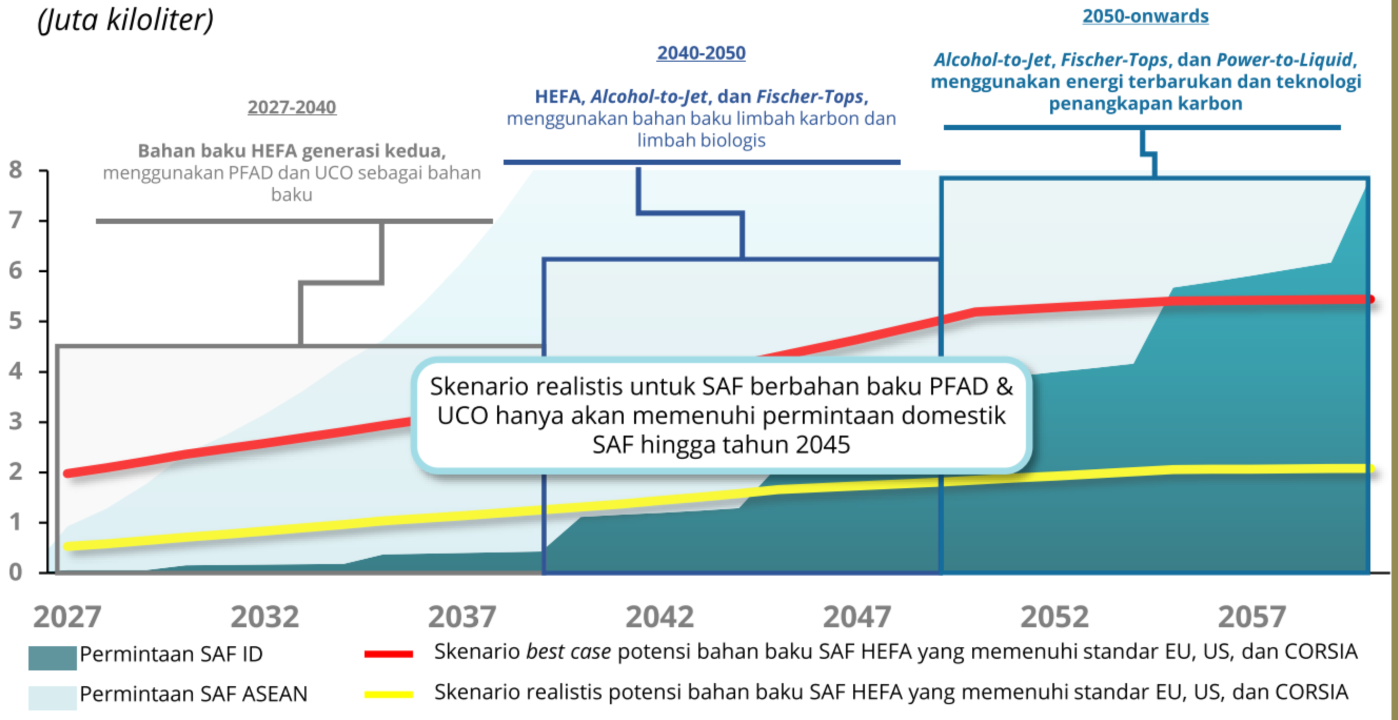
SAF roadmap published by Coordinating Ministry for Maritime & Investment Affairs (2024)





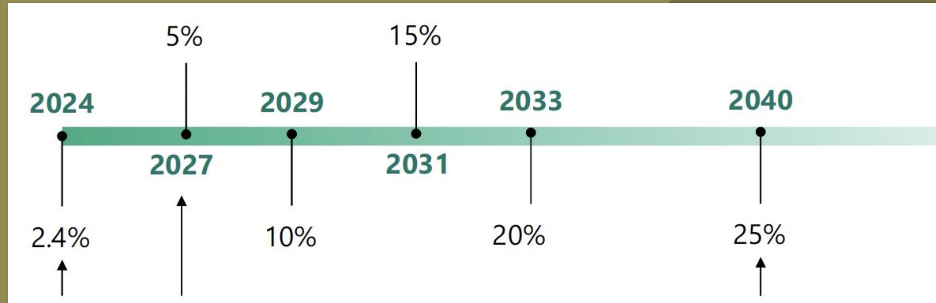
Previously, SAF production in Indonesia utilizes the HEFA process with PKO as the primary feedstock. POME and UCO are expected to replace PKO due to their greater availability.

Realistic scenario for UCO and PFAD as the main feedstocks



Source: Coordinating Ministry for Maritime & Investment Affairs (2024)

- The supply of HEFA feedstock for SAF production in Indonesia is projected to be adequate for meeting domestic SAF needs only until 2040.
- It is necessary to develop alternative production pathways such as AtJ, FT, and PtL.
- Biomass represents a promising feedstock option in the future.



Source: UGM, 2023

THANK YOU

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