13º Fórum do

BIOGÁS

O ponto de encontro
internacional de investidores
em **BIOGÁS** e **BIOMETANO**

FROM WASTE TO WHEELS

Turning organic waste into renewable fuel for transport

Gláucia Mendes Souza
University of São Paulo (USP)

Instituto MBCBrasil
MOBILIDADE DE BAIXO CARBONO

Universidade de São Paulo
Instituto de Química

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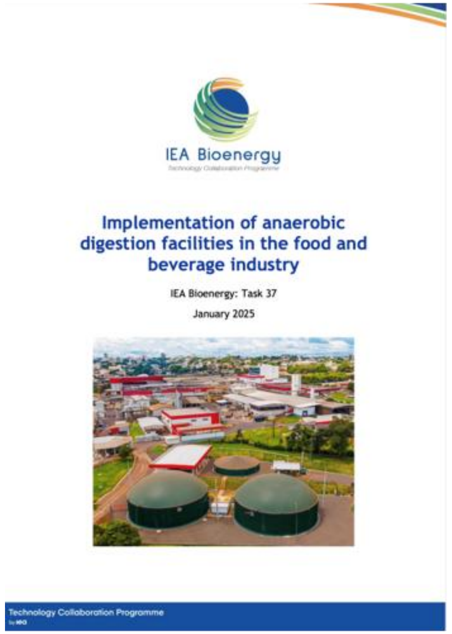
GLAUCIA MENDES SOUZA
USP

LUIZ AUGUSTO HORTA NOGUEIRA
UNIFEI

CLAYTON ZABEU
INSTITUTO MAUÁ

HEITOR CANTARELLA
IAC

13º Fórum do BIOGÁS
BIOGÁS e BIOMETANO

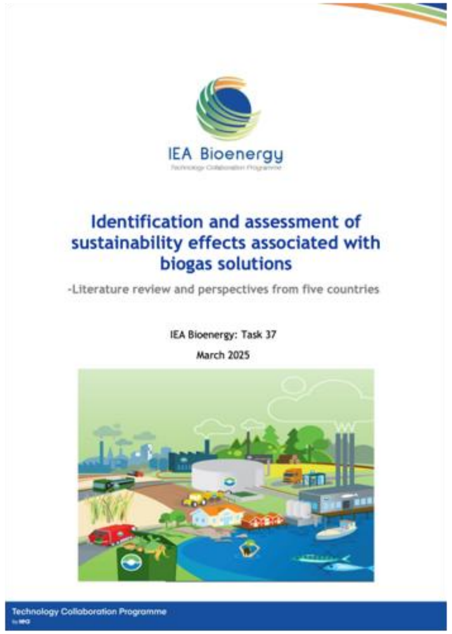

IEA Bioenergy

Implementation of anaerobic digestion facilities in the food and beverage industry

IEA Bioenergy: Task 37

January 2025

Technology Collaboration Programme


IEA Bioenergy

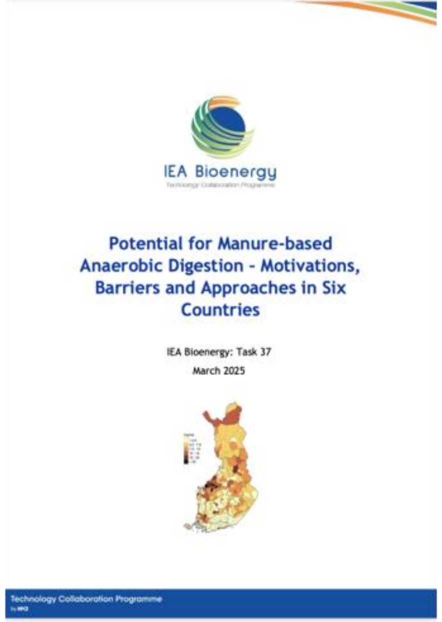
Identification and assessment of sustainability effects associated with biogas solutions

-Literature review and perspectives from five countries

IEA Bioenergy: Task 37

March 2025

Technology Collaboration Programme


IEA Bioenergy

Potential for Manure-based Anaerobic Digestion - Motivations, Barriers and Approaches in Six Countries

IEA Bioenergy: Task 37

March 2025

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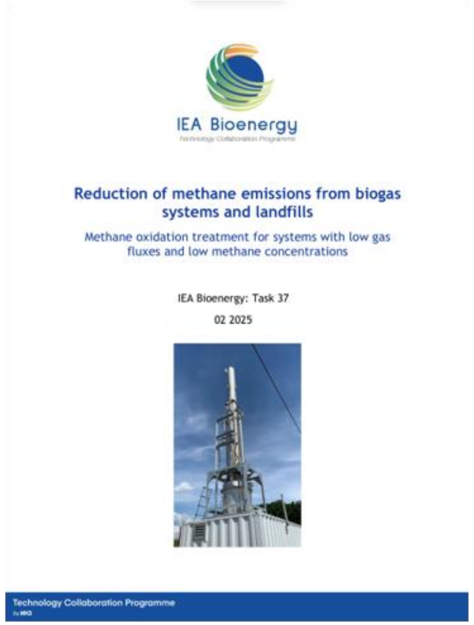
IEA Bioenergy

Reduction of methane emissions from biogas systems and landfills

Methane oxidation treatment for systems with low gas fluxes and low methane concentrations

IEA Bioenergy: Task 37

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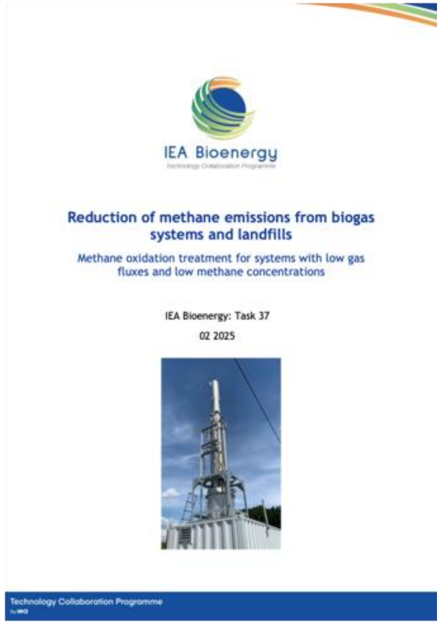
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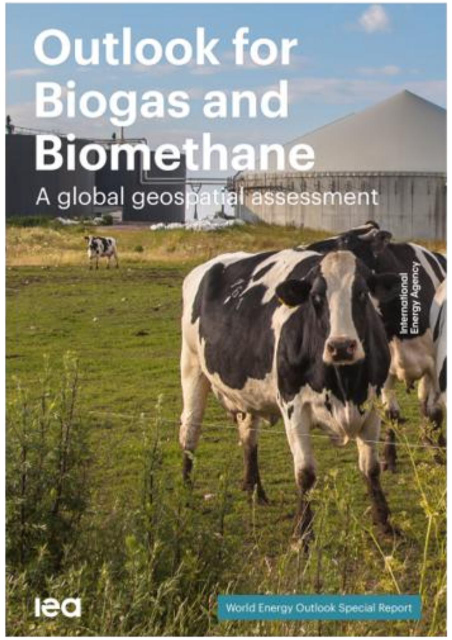
Outlook for Biogas and Biomethane

A global geospatial assessment

International Energy Agency

iea

World Energy Outlook Special Report


IEA Bioenergy

Executive Summary - Potential for Manure-based Anaerobic Digestion - Motivations, Barriers and Approaches in Six Countries

Summary Series

IEA Bioenergy: Task 37: 03 2025

UTILIZATION OF LIVESTOCK AND POULTRY MANURE FOR ENERGY PRODUCTION

Technology Collaboration Programme


IEA Bioenergy

The role of biogas and biomethane in pathway to net zero

Position paper

IEA Bioenergy Task 37: 12 2022

The role of biogas and biomethane in pathway to net zero

PERSPECTIVES OF BIOGAS AND BIOMETHANE

Pathway to Net Zero

Technology Collaboration Programme


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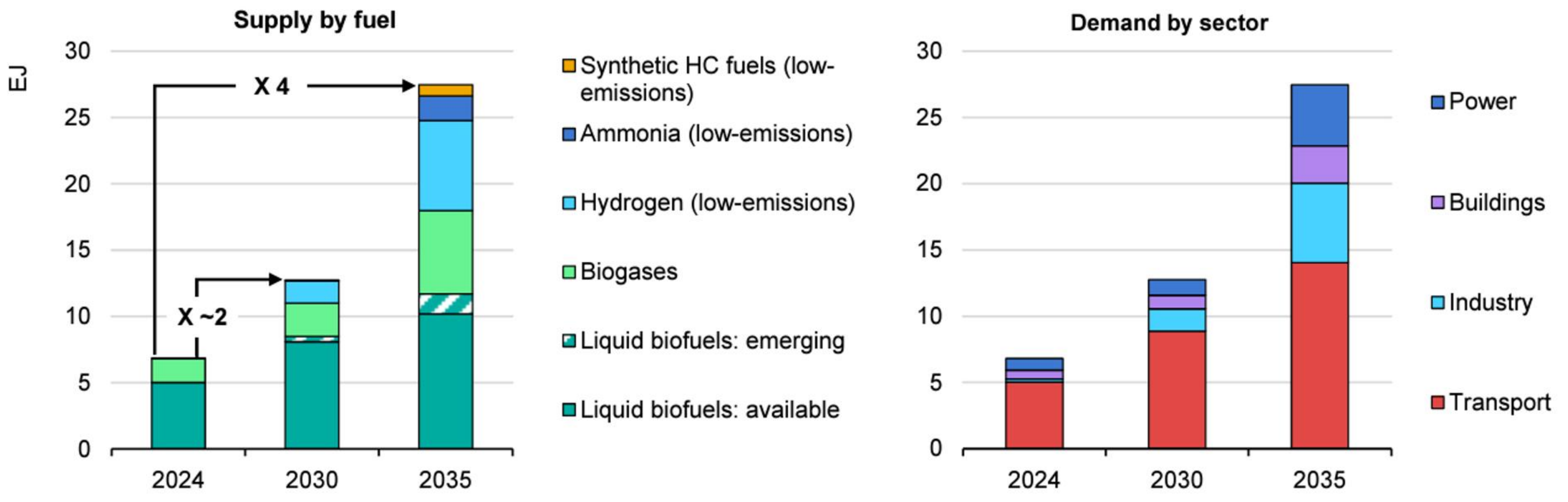
PERSPECTIVES OF BIOGAS AND BIOMETHANE

Pathway to Net Zero

Technology Collaboration Programme

IEA Sustainable Fuels, 2025
If fully legislated and implemented, current and proposed national and international policies would put sustainable fuel use on a path to nearly double from the 2024 level by 2030, and quadruple by 2035

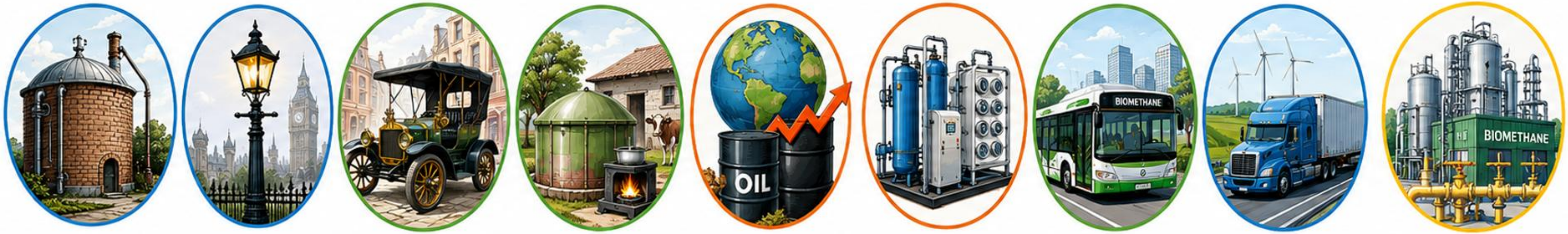
Figure 5.7 Sustainable fuel supply by fuel and demand by sector in the accelerated case, 2024-2035



IEA. CC BY 4.0.

Timeline of Biomethane Production & Sustainable Transport

From 1859 to 2030: The journey of biogas from street lamps to global decarbonization



1 — **1859–1895:** anaerobic digestion reactor

2 — **1895:** old style English street light

3 — **1900s–1930s:** natural gas old style vehicle

4 — **1940s–1970s:** small-scale digesters for cooking and farm energy

5 — **1970s–1980s:** Global oil crises, biogas as a domestic, secure clean energy source that avoids pollution

6 — **1980s–1990s:** upgrading technologies (water scrubbing, PSA, and membranes) for use in Compressed Natural Gas (CNG) vehicles and injection into gas grids.

7 — **1990s–2000s:** biomethane into buses and municipal fleets.

8 — **2010s:** global growth, biomethane as vehicle fuel; Heavy-Duty Shift, long-distance trucking.

10 — **2018–2030:** scaling industrially for both transport and grid substitution.

MATURE BIOMETHANE ECONOMIES

STATE OF PRODUCTION, MOTIVATIONS, FEEDSTOCKS AND PRACTICES

Production & Use | Motivations & Practices | Main Feedstocks | Transport Use

BRAZIL

- **Production & Use:** Expanding biomethane sector linked to transport, grid injection and industrial decarbonization. More than 755 biogas plants reported and growing production.
- **Motivations & Practices:** Integration with sugar-energy sector; use in trucks, industry and agricultural machinery; linkage with RenovaBio and Future Fuel Law.
- **Main Feedstocks:** Sugarcane vinasse, filter cake, livestock manure, MSW, sewage sludge, agro-industrial residues.
- **Transport Use:** Used in trucks, industry and agricultural machinery.

CANADA

- **Production & Use:** Strong landfill gas and wastewater biogas sector with growing RNG market.
- **Motivations & Practices:** Methane mitigation strategy linked to landfill gas capture and agricultural anaerobic digestion (AD).
- **Main Feedstocks:** Landfill gas, wastewater sludge, source-separated organics, dairy manure.
- **Transport Use:** Growing use in heavy-duty transport.

CHINA

- **Production & Use:** One of the world's largest biogas systems with ~40 million household digesters and >100,000 non-household plants. Biomethane sector still emerging.
- **Motivations & Practices:** Rural energy access, manure management, pollution control and renewable gas development.
- **Main Feedstocks:** Livestock manure, crop residues, rural organic waste, industrial residues.
- **Transport Use:** Growing use in heavy-duty transport and rural energy.

DENMARK

- **Production & Use:** Highly integrated centralized biogas system with extensive grid injection.
- **Motivations & Practices:** Circular-economy model connecting farms, biomethane, biofertilizer and CO_2 recovery.
- **Main Feedstocks:** Manure, agricultural residues, straw, catch crops.
- **Transport Use:** Widespread use in heavy-duty transport and industry.

FINLAND

- **Production & Use:** Moderate biogas scale with strong transport orientation for biomethane.
- **Motivations & Practices:** Heavy-duty transport decarbonization, nutrient cycling and regional energy security.
- **Main Feedstocks:** Bio-waste, WWTP sludge, landfill gas, manure.
- **Transport Use:** Used in heavy-duty trucks (liquid biomethane) and buses.

FRANCE

- **Production & Use:** Rapidly growing agricultural biomethane sector with major grid injection expansion.
- **Motivations & Practices:** Farm diversification, intermediate crops, nutrient recycling and climate policy.
- **Main Feedstocks:** Manure, intermediate crops, agricultural residues, bio-waste.
- **Transport Use:** Expanding use in heavy-duty transport and buses.

GERMANY

- **Production & Use:** Europe's largest biogas producer with >10,000 plants and ~87 TWh/year biogas production.
- **Motivations & Practices:** Long-standing feed-in tariff system and agricultural biogas model.
- **Main Feedstocks:** Energy crops, manure, agricultural residues, wastewater sludge.
- **Transport Use:** Extensive use in transport, industry and heating.

IRELAND

- **Production & Use:** Emerging biomethane market focused on agricultural feedstocks.
- **Motivations & Practices:** Rural development, farm income diversification and transport decarbonization.
- **Main Feedstocks:** Grass silage, slurry, manure, food-processing residues.
- **Transport Use:** Growing use in transport and industry.

NORWAY

- **Production & Use:** Significant transport biomethane use, especially from waste streams.
- **Motivations & Practices:** Decarbonization of transport and management of fish-processing and food waste.
- **Main Feedstocks:** Food waste, fish-processing sludge, sewage sludge, manure.
- **Transport Use:** Used in heavy-duty transport and buses.

SWEDEN

- **Production & Use:** One of the strongest transport biomethane systems globally; major use in buses and vehicles.
- **Motivations & Practices:** Urban air-quality improvement, transport decarbonization and waste valorization.
- **Main Feedstocks:** Bio-waste, sewage sludge, industrial residues, agricultural substrates.
- **Transport Use:** Widespread use in buses, trucks and passenger vehicles.

SWITZERLAND

- **Production & Use:** Extensive wastewater biogas adoption and strong digestate quality systems.
- **Motivations & Practices:** Wastewater treatment, sanitation and nutrient recovery.
- **Main Feedstocks:** Wastewater sludge, agricultural residues, bio-waste.
- **Transport Use:** Used in transport and combined heat & power.

UNITED KINGDOM

- **Production & Use:** Mature AD market with agricultural and food-waste focus.
- **Motivations & Practices:** Methane reduction, renewable energy and rural economic development.
- **Main Feedstocks:** Food waste, manure, agricultural residues, sewage sludge.
- **Transport Use:** Used in heavy-duty transport and industry.

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Gustafsson, M., Meneghetti, R., Souza Marques, F., Trim, H., Dong, R., Al Seadi, T., Rasi, S., Thual, J., Kornatz, P., Wall, D., Berntsen, I.C., Saxegaard, S., Lyng, K.-A., Nägele, H.-J., Heaven, S., Bywater, A. (2024). A perspective on the state of the biogas industry in 12 member countries of IEA Bioenergy Task 37. IEA Bioenergy Task 37.

EMERGING BIOMETHANE ECONOMIES

STATE OF PRODUCTION, MOTIVATIONS, FEEDSTOCKS AND PRACTICES

Country	Production & Use	Motivations & Practices	Main Feedstocks	Transport Use
INDIA	One of the world's major biogas producers after EU, China and US.	Rural energy access, residential gas use and growing transport gas market.	Agricultural residues, manure, municipal organic waste.	Used in rural households and increasing role in transport gas market.
ARGENTINA	Early-stage biomethane sector with strong agricultural potential.	Agro-industrial waste utilization and decentralized rural energy systems.	Livestock waste, agro-industrial residues, urban organic waste.	Emerging use in local transport and rural applications.
BOLIVIA	Biomethane development constrained by low waste-management infrastructure.	Opportunity associated with municipal organic waste and agricultural residues.	Organic solid waste, agricultural residues, livestock residues.	Potential future use in urban transport and industry.
CHILE	Existing biogas experience provides a platform for biomethane expansion.	Renewable-energy diversification and waste valorization.	Wastewater sludge, municipal organic waste.	Potential for transport and industrial use.
COLOMBIA	One of the countries with regulation allowing biomethane injection into natural gas networks.	Integration of renewable gas into existing gas infrastructure.	Agricultural residues, wastewater sludge, municipal waste.	Used in transport and distributed natural gas networks.
ECUADOR	Renewable-energy tariff framework exists but with limited effect on current biomethane growth.	Waste treatment and renewable diversification potential.	Agricultural residues, municipal organic waste.	Early-stage use in transport and local energy markets.
PARAGUAY	Very low recycling and reuse rates currently limit biomethane deployment.	Opportunity to connect waste management and energy production.	Agricultural residues, municipal organic waste.	Potential for transport and rural energy use.
PERU	Large opportunity from urban organic waste and agriculture, but low implementation so far.	Waste-management modernization and renewable-energy diversification.	Municipal organic waste, agricultural residues.	Potential future use in transport and industry.
URUGUAY	Limited deployment despite agricultural potential; only a few facilities produce electricity from biogas.	Industrial methane recovery and waste-management opportunity.	Industrial methane streams, livestock residues.	Future potential for transport and industrial uses.
VENEZUELA	Large fossil natural gas availability reduces biomethane competitiveness.	Waste regulation and methane management identified as important gaps.	Municipal waste, wastewater, industrial methane streams.	Potential future integration in transport and industry.

REFERENCE

Gustafsson, M., Meneghetti, R., Souza Marques, F., Trim, H., Dong, R., Al Seadi, T., Rasi, S., Thual, J., Kornatz, P., Wall, D., Berntsen, I.C., Saxegaard, S., Lyng, K.-A., Nägele, H.-J., Heaven, S., Bywater, A. (2024). A perspective on the state of the biogas industry in 12 member countries of IEA Bioenergy Task 37. IEA Bioenergy Task 37.

The Global Land Transport Transition: Scale, Lock-In and Urgency

NEED FOR COORDINATED ACTION

4.7 EJ

GLOBAL ROLE

Biofuels use in transportation is global

Blending mandates can reduce emissions immediately in existing fleets.

41.7% vs 1.5%

FLEET TURNOVER

Electrified sales vs electricity share in transport energy

Vehicle sales are changing faster than the energy matrix.

+36.9 EJ vs 3.7 EJ

REGIONAL ASYMMETRY

Transport growth outside OECD (2000–2023)

Most transport demand growth is occurring in emerging economies.

94.7% fossil

FOSSIL LOCK IN

Transport energy still fossil-based

Oil products alone provide 90.1% of transport energy.

122.9 EJ
8.44 GtCO2eq

SCALE

Global transport energy demand (2023)

Transport accounts for 28.6% of world final energy consumption.

IEA World Energy Balances Highlights 2025; IEA Global EV Outlook 2026; Robbie Andrew vehicle sales, World Bank WDI AR5 GHG series; transport GHG = transport CO2 + CH4 + N2O from energy.

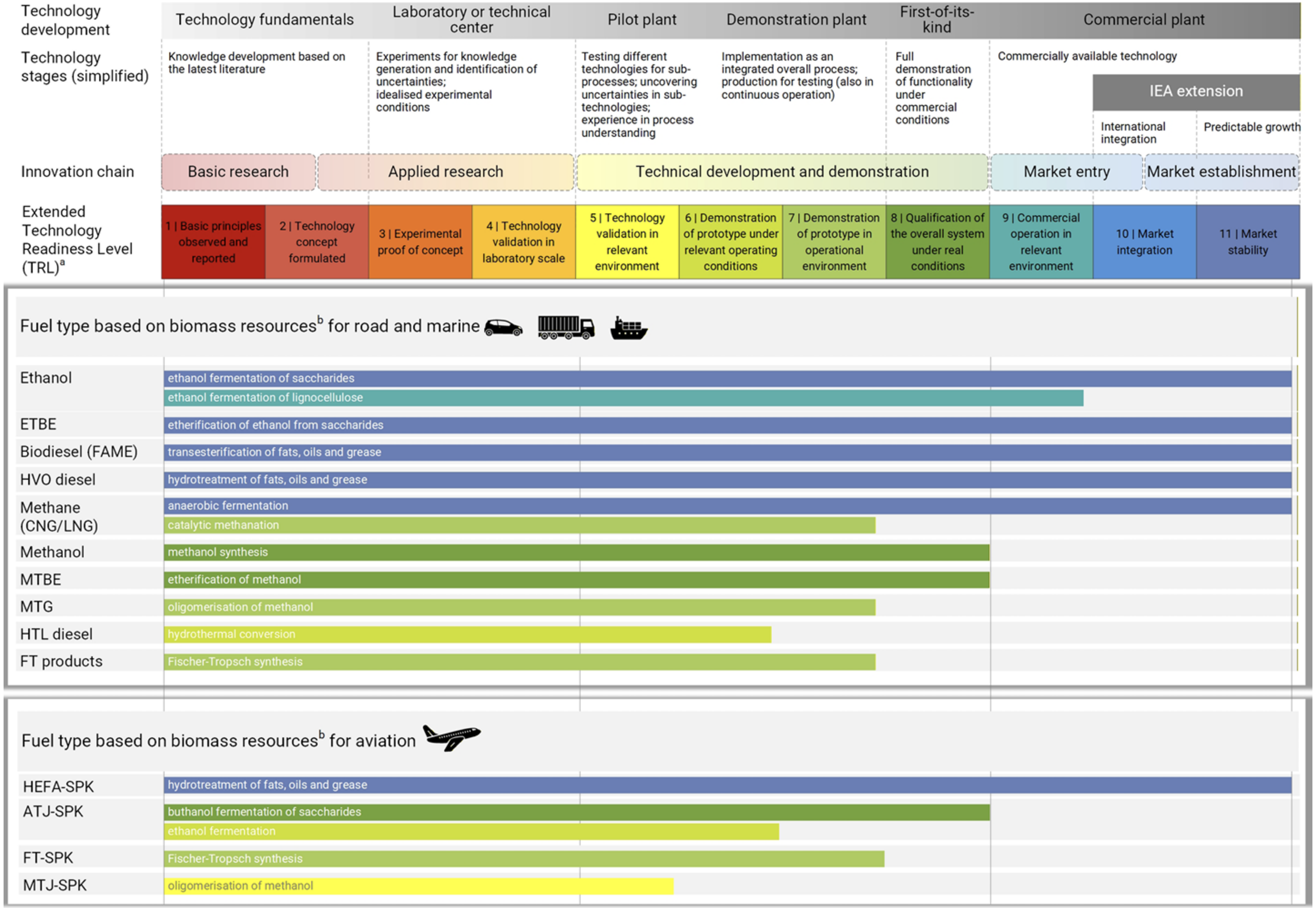
Biofuels technologies have reached maturity with international market integration, stability and predictable growth

Defossilization of transportation will occur through:

Immediate reductions from mature biofuels already produced at scale

Near-term expansion through emerging technologies approaching commercialization

Long-term breakthroughs from advanced pathways currently under development



© DBFZ 03/2026

[a] The commonly known TRL level from 1-9 is extended to 10-11 to show which fuel options are established on an international market; details cf. https://www.dbfz.de/fileadmin/Projektseiten/Monitoring_EE/Renewable_Energies_in_Transport_Monitoring_Report_DBFZ.pdf#page=57, Fig. 4-1 as well as https://iea.imgix.net/29484d47-f66d-4b96-ac4b-979623c44c29/box3.2-01.png?auto=compress%2Cformat&fit=min&q=80&rect=0%2C0%2C3188%2C2101&w=1400&fit=crop&fm=jpg&q=70&auto=format&h=923; [b] here for most relevant fuel options (ATJ - alcohol-to-jet, CNG/LNG – compressed/liquefied natural gas, ETBE - Ethyl tertiary-butyl ether, FAME – Fatty acid methyl ester, FT – Fischer-Tropsch, HEFA - Hydrotreated esters and fatty acids, HTL - Hydrothermal liquefaction, HVO – hydrotreated vegetable oils, MTBE - Methyl tertiary-butyl ether, MTG – methanol-to-gasoline, MTJ – methanol-to-jet, SPK - Synthetic paraffinic kerosene)

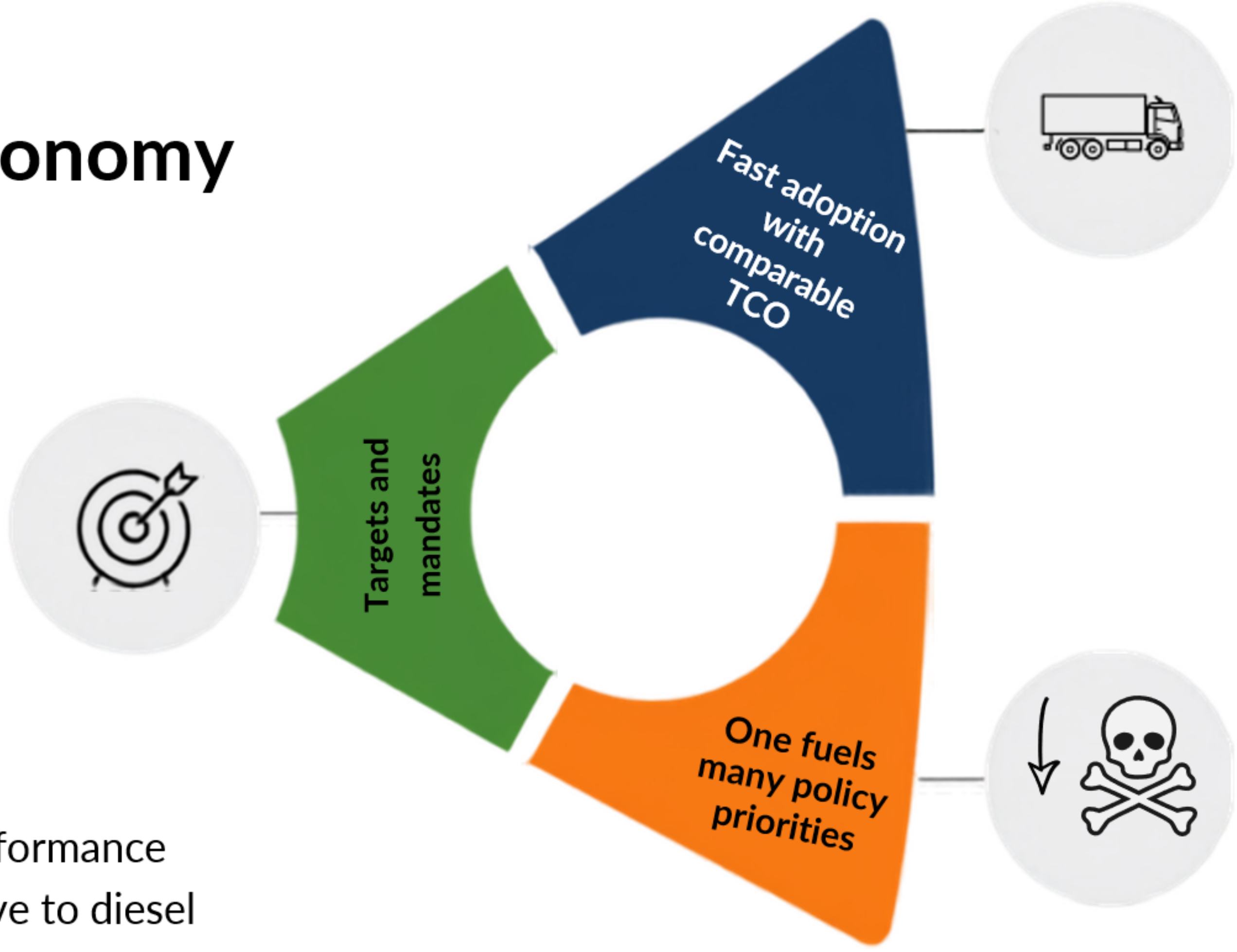
IEA Bioenergy
Technology Collaboration Programme
TASK 39
Biofuels for Decarbonization of Transportation

Why biomethane matters

Circular Economy

GHG emissions reduction in transport

Energy security
Energy sovereignty
Better life cycle performance
50-75% GHG relative to diesel



Technology compatibility

Compressed and liquified biomethane trucks already available in the market

Compatibilty with current fuel distribution systems

Environmental and economic benefits

Methane mitigation
Improvements in air quality/noise
Water quality
Waste management

The biomethane economy addresses several policy priorities

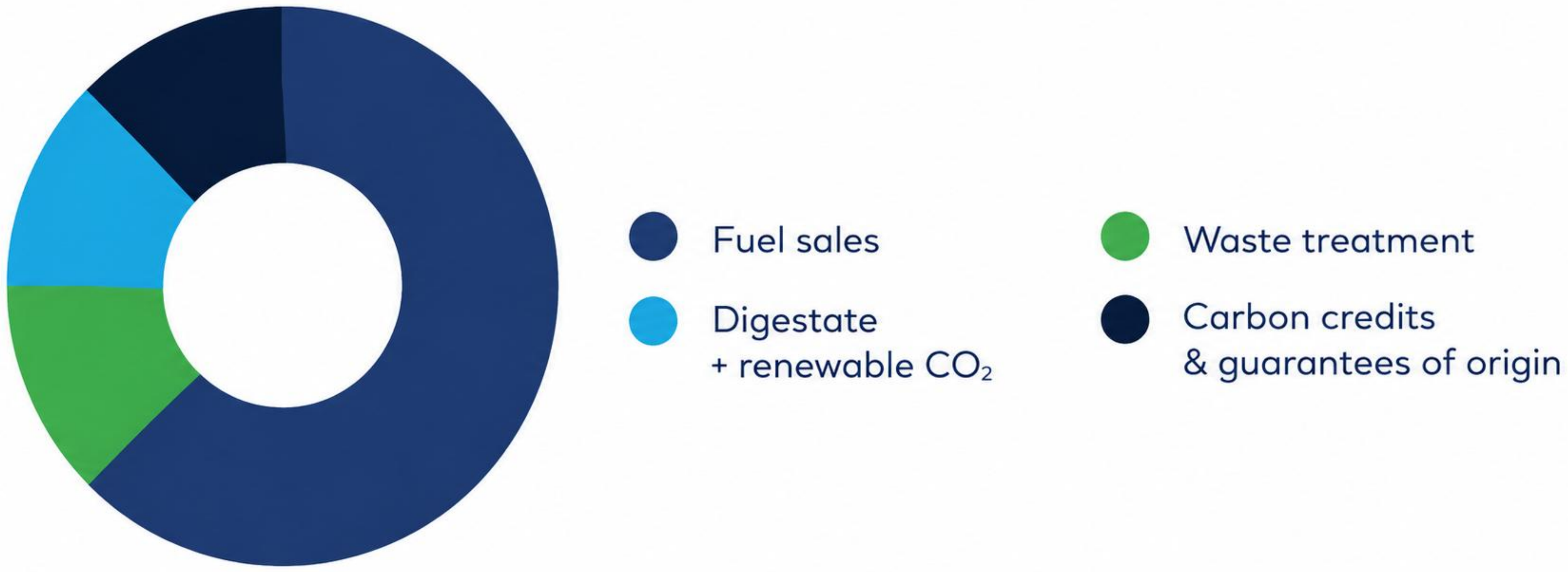
- Transport Decarbonization
- Methane Mitigation
- Waste Management
- Energy Security
- Rural Development

Recommended Policy Package for Heavy-Duty Biomethane

Experience from leading markets shows that successful biomethane deployment typically combines climate policy, waste-management regulation, infrastructure support and market incentives.

Policy Element	Recommended Instrument	Authority Reference
Carbon Pricing	CI-based credit trading (LCFS-style) + methane avoidance credits for manure/waste feedstocks	IEA (2025); CARB LCFS; EU RED III
Fuel Pricing	Tax parity/exemption for biomethane vs. diesel; technology-neutral production tax credits	Sweden Law 1994:1776; IRA 48E/45X; AFTC
Infrastructure	Cost-shared grid injection (50% public funding); mandated grid operator connection obligations; freight hub refueling corridors	California interconnector program; India pipeline scheme; U.S. MHDV Corridor Strategy
Waste Integration	Mandatory organic waste separation (2024+); manure management regulations limiting raw application; digestate valorization support	EU Waste Framework Directive; EU Nitrates Directive; GOBAR-Dhan
Credits/Incentives	Feed-in tariffs differentiated by feedstock and end-use; blending mandates with double-counting for advanced/waste-derived; vehicle purchase vouchers	Italy Biomethane Decree; EU RED III; HVIP; Quebec RNG Mandate

AVERAGE REVENUE MIX • NON-FUEL REVENUES CAN REPRESENT APPROXIMATELY 20–60% OF TOTAL PROJECT REVENUE IN MATURE MARKETS.



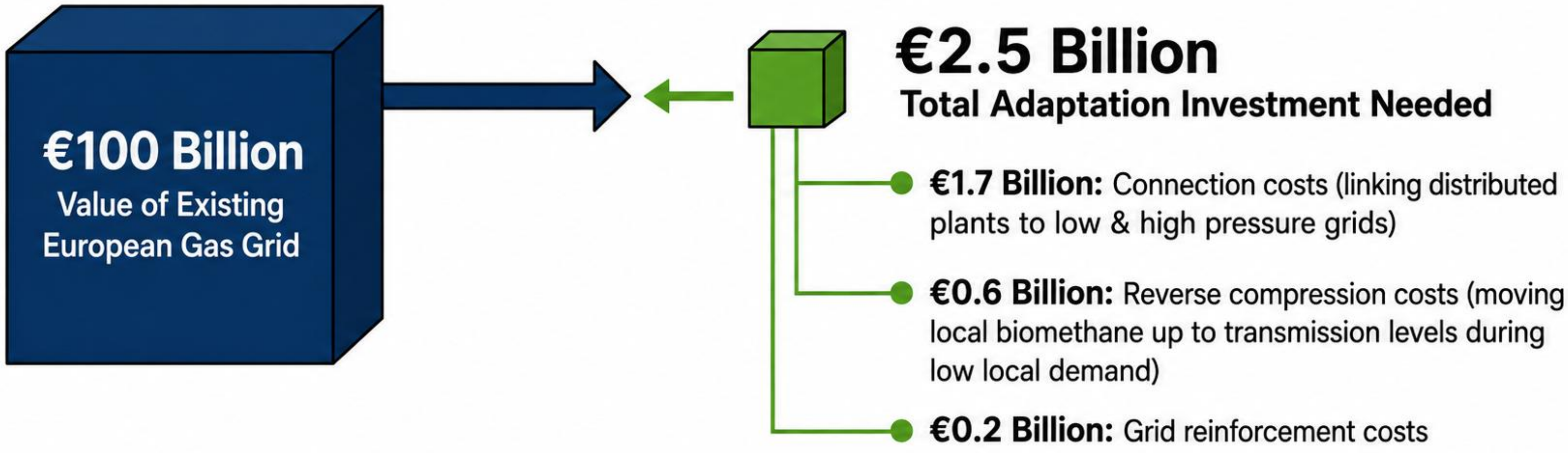
ABiogás

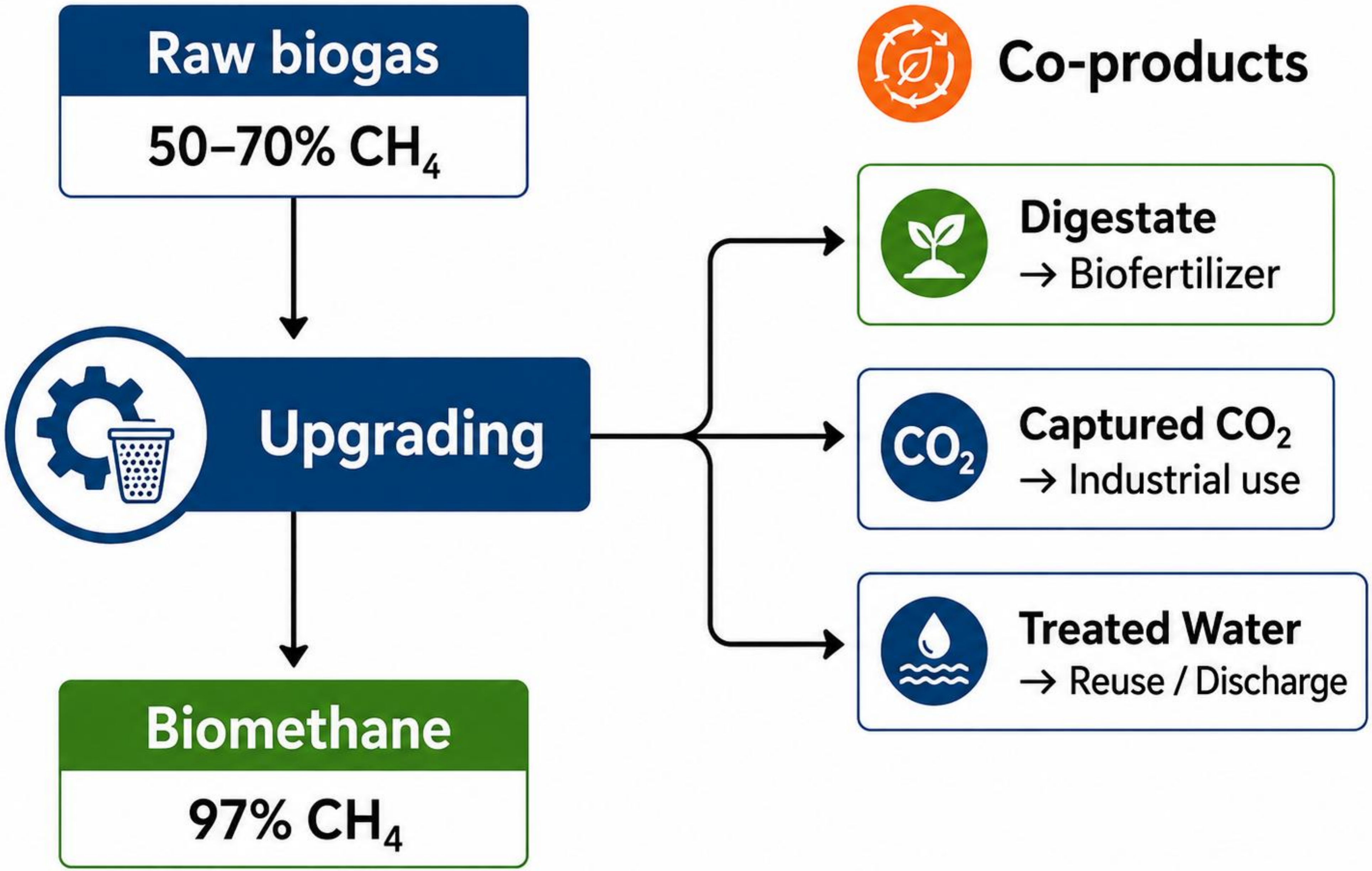
Illustrative Monetisation of Biomethane System Benefits

Value Stream	Typical Value (USD/GJ)	Comments
Renewable fuel	8–18	Depends on gas and diesel prices
Waste treatment services	1–6	Landfill diversion and manure management
Digestate / Biofertilizer	0.5–4	Dependent on fertiliser markets
Carbon credits	1–8	Strongly dependent on carbon price
Renewable CO_2	0.5–5	Emerging market
Guarantees of Origin	0.5–3	Common in Europe
Energy-security value*	Difficult to monetise	Strategic value

* Energy-security benefits are generally captured through reduced imports and improved resilience rather than direct project revenues.

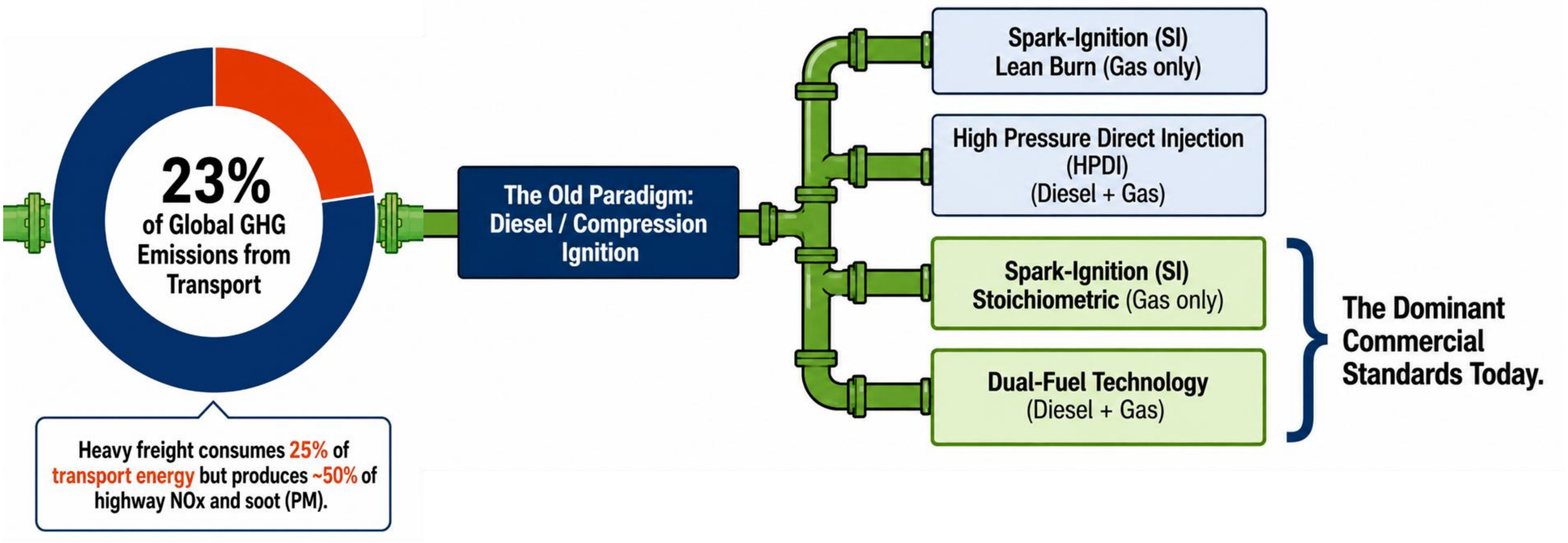
Sources: Adapted from (17,218,220) FAO (2026).

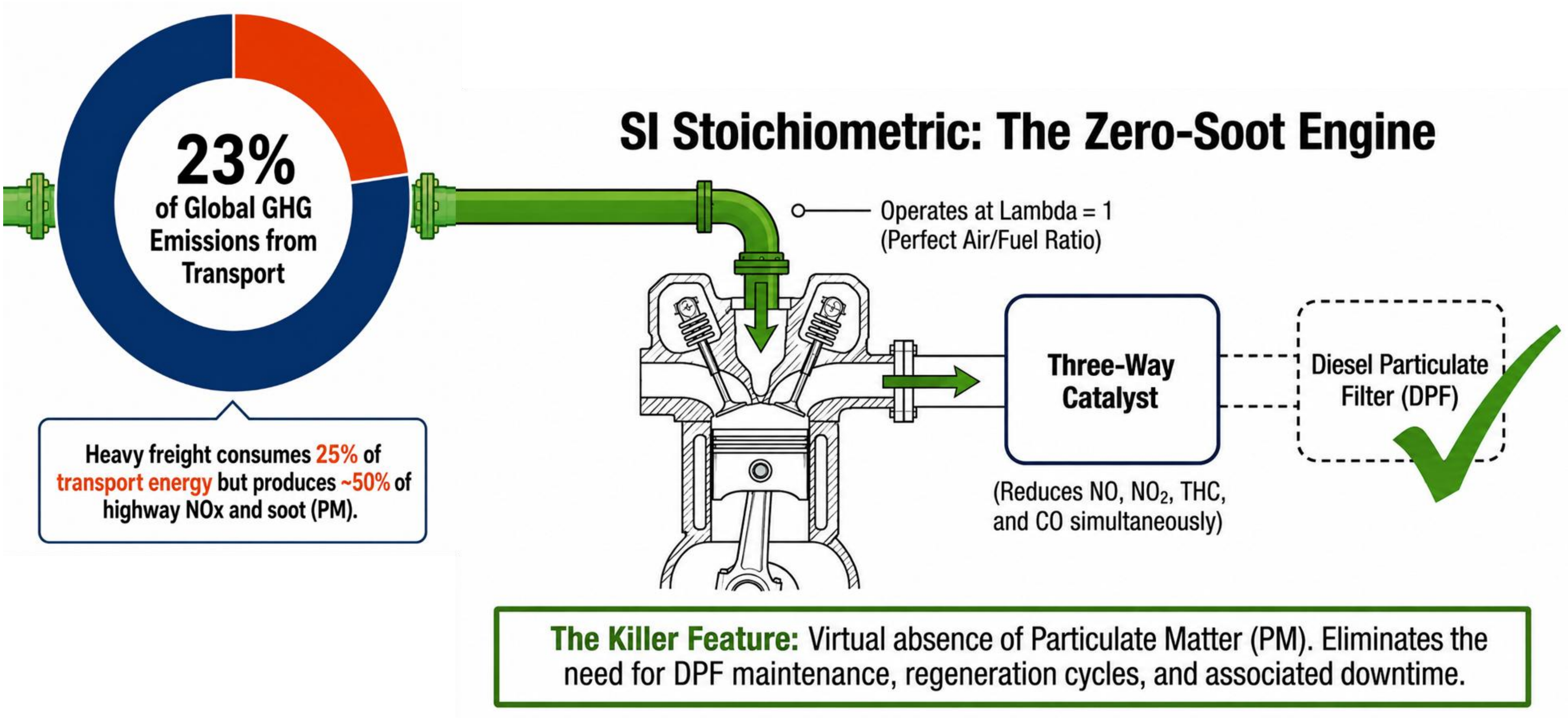

€100 Billion
Value of Existing European Gas Grid
€2.5 Billion
Total Adaptation Investment Needed
€1.7 Billion: Connection costs (linking distributed plants to low & high pressure grids)
€0.6 Billion: Reverse compression costs (moving local biomethane up to transmission levels during low local demand)
€0.2 Billion: Grid reinforcement costs


Raw biogas
50–70% CH_4
Upgrading
Biomethane
97% CH_4
Co-products
Digestate
→ Biofertilizer
CO_2
Captured CO_2
→ Industrial use
Treated Water
→ Reuse / Discharge


OTHER ENVIRONMENTAL AND SOCIOECONOMIC BENEFITS
ENERGY SECURITY
Strengthens energy independence
IMPROVEMENTS IN AIR QUALITY
Cleaner air for healthier cities
BIOMETHANE
BIOMETHANE CLEAN ENERGY
WATER QUALITY
Protects water resources and ecosystems
WASTE MANAGEMENT
Turns organic waste into valuable resources
CIRCULAR ECONOMY
Closes loops and creates value from resources
CH_4
METHANE MITIGATION
Captures methane emissions and turns them into clean energy

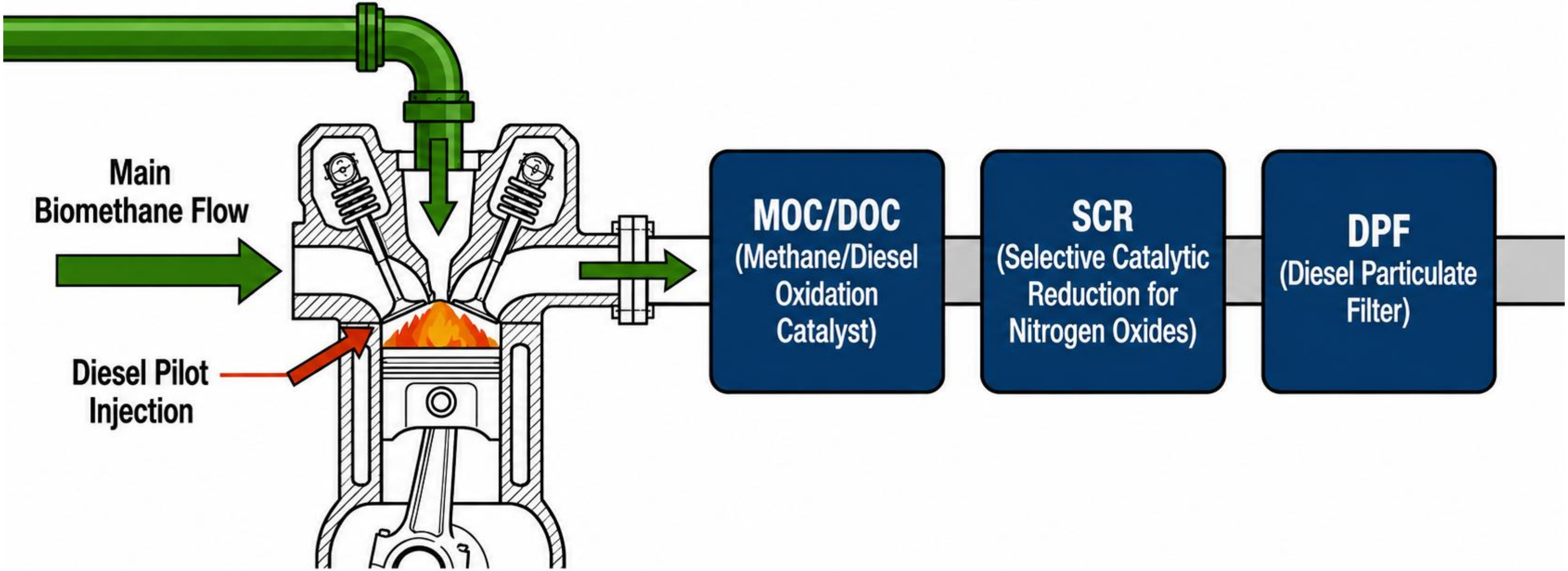
Engine Architecture: Four Pathways to Deployment





23%
of Global GHG Emissions from Transport
Heavy freight consumes 25% of transport energy but produces ~50% of highway NOx and soot (PM).
SI Stoichiometric: The Zero-Soot Engine
Operates at Lambda = 1 (Perfect Air/Fuel Ratio)
Three-Way Catalyst
(Reduces NO, NO₂, THC, and CO simultaneously)
Diesel Particulate Filter (DPF)
The Killer Feature: Virtual absence of Particulate Matter (PM). Eliminates the need for DPF maintenance, regeneration cycles, and associated downtime.

Dual-Fuel Technology



The Trade-Off: Diesel pilot injection provides excellent torque and fallback capability, but re-introduces soot. A DPF remains strictly necessary to meet EURO VI / P8 emission standards.

Biomethane Lifecycle GHG Emissions Reductions in Transport

Waste- and Residue-Based Biomethane Delivers the Largest Climate Benefits

Feedstock / Pathway	Typical GHG Reduction vs Fossil Fuels	Key Observation
Manure / Slurry	Up to net-negative emissions	Strongest pathway due to avoided methane emissions from manure storage
Food Waste / OFMSW	50–75% lower than diesel	Can become carbon-negative with digestate fertilizer substitution
Municipal Solid Waste (MSW)	68–98% lower	Very strong performance in waste collection fleets
Compressed Biomethane Trucks	55–75% lower	Significant reductions versus fossil CNG
Urban Bus Applications	70–85% lower CO_2	Demonstrated in urban mobility systems
Wastewater / Sewage Sludge	Strong reductions	Results depend strongly on LCA methodology
Landfill Gas	Significant reductions	Lower benefits than manure pathways
Catch Crops	Can exceed 100% reduction	Soil carbon gains may create net-negative outcomes
Crop-Based Maize / Silage	Highly variable	Can lose benefits or exceed fossil emissions if land-use change is included

Net-negative / Strongest reductions — Moderate reductions — Uncertain or Poor performance

Key Conclusions

- **Best performance:** manure, food waste, sewage sludge, landfill gas, and catch crops
- **Heavy-duty transport** is one of the highest-impact applications for biomethane
- **Methane leakage,** baseline assumptions, and land-use change strongly affect results
- **Crop-based pathways** are substantially less robust than waste/residue pathways

Biomethane from wastes and residues can reduce transport GHG dramatically — and in some systems achieve net-negative emissions.

Cutting methane emissions yields a fast climate benefit

Methane has:

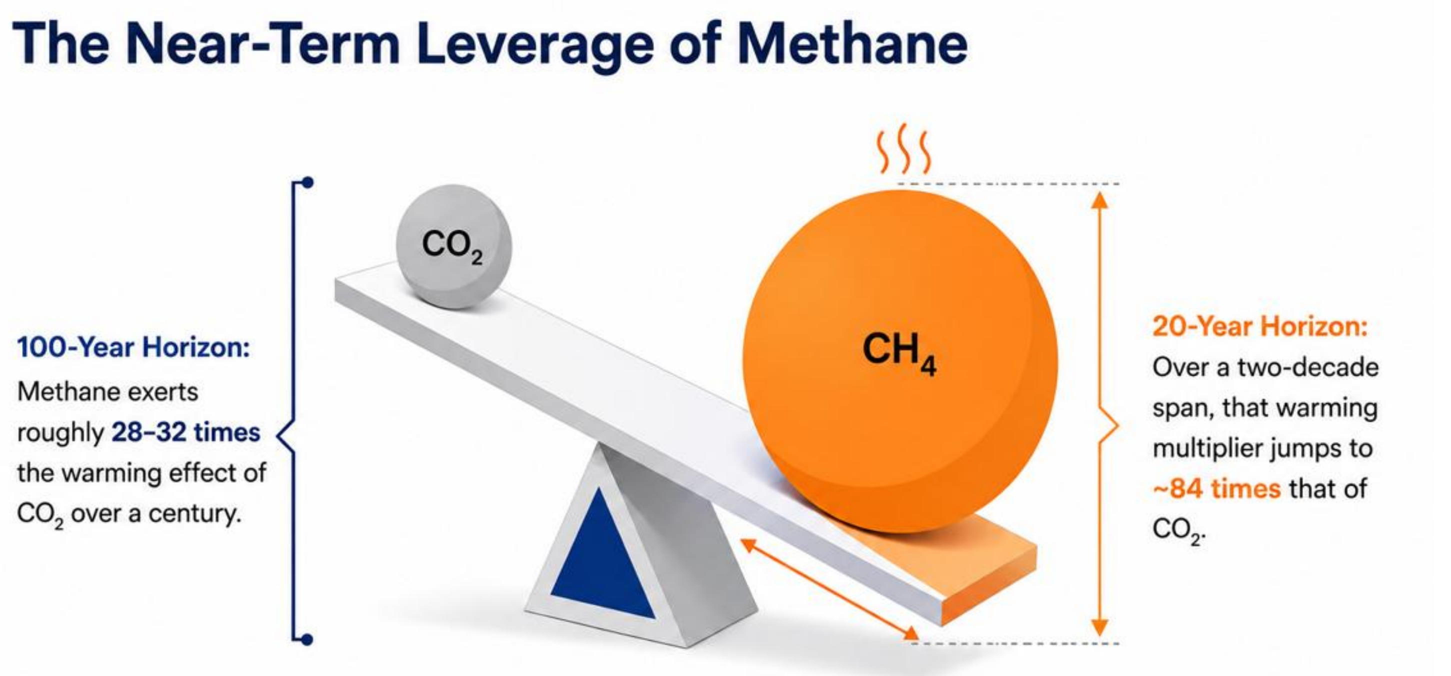
- ~28–32× higher warming effect than CO_2 over 100 years
- ~84× over 20 years

Anaerobic digestion

Diverts organic waste from landfills

Produces biomethane and digestate

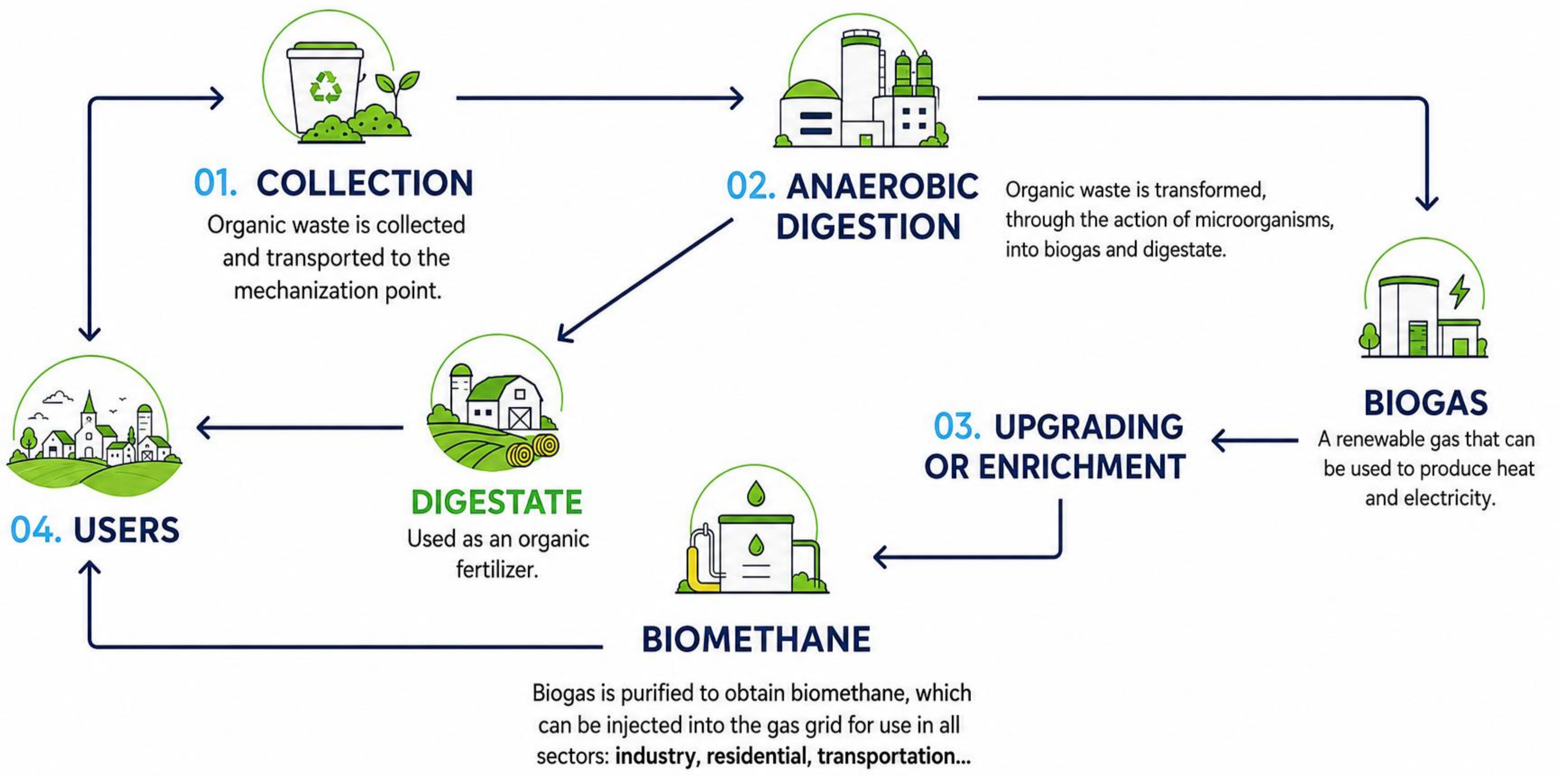
Reduces uncontrolled methane emissions



The Mitigation Pathway Hierarchy

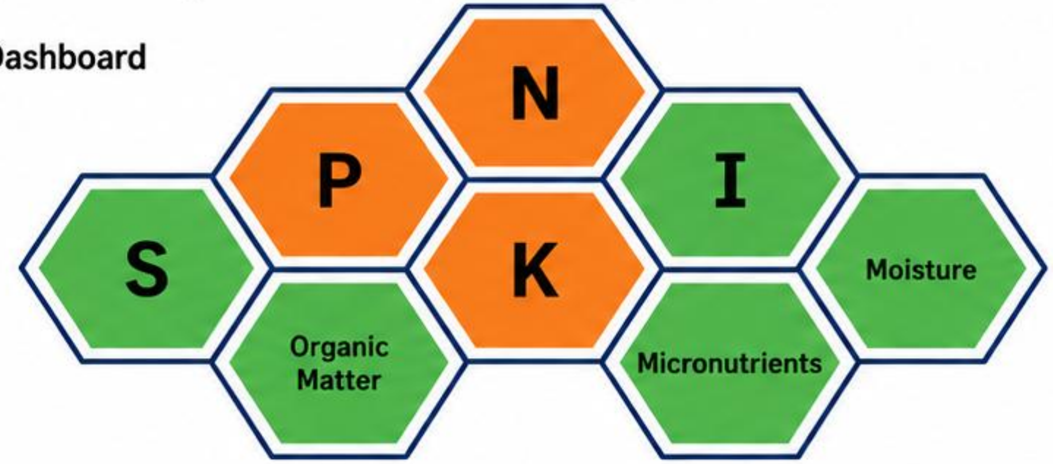
	A	B	C
	Flaring (Baseline Mitigation)	**Electricity/Heat Generation** (Active Utilization)	**Transport Biomethane** (Advanced Utilization)
Greenhouse Gas Emission Reduction	**≥55% reduction**	**≥83% mitigation** (avoids 52–63 kg CO_2 eq per ton of waste)	**Up to 79%** lower Global Warming Potential than using the same waste for electricity/heat only.
Strategic Displacement	**None.** Simply destroys CH_4.	**Displaces fossil electricity** on the grid.	**Displaces high-emission** fossil transport fuels.

The mitigation hierarchy prioritizes pathways that maximize emissions reduction and societal benefit. Advanced utilization of methane as transport fuel delivers the highest climate and energy value.


01. COLLECTION
Organic waste is collected and transported to the mechanization point.
02. ANAEROBIC DIGESTION
Organic waste is transformed, through the action of microorganisms, into biogas and digestate.
BIOGAS
A renewable gas that can be used to produce heat and electricity.
03. UPGRADING OR ENRICHMENT
DIGESTATE
Used as an organic fertilizer.
04. USERS
BIOMETHANE
Biogas is purified to obtain biomethane, which can be injected into the gas grid for use in all sectors: industry, residential, transportation...

The elemental profile of raw digestate reveals a complete agronomic package

Elemental Dashboard



(Chozhavendhan et al., 2023; Czekała et al., 2022; Neri et al., 2023; Samoraj et al., 2022)

BIOCHEMICAL ANALYSIS

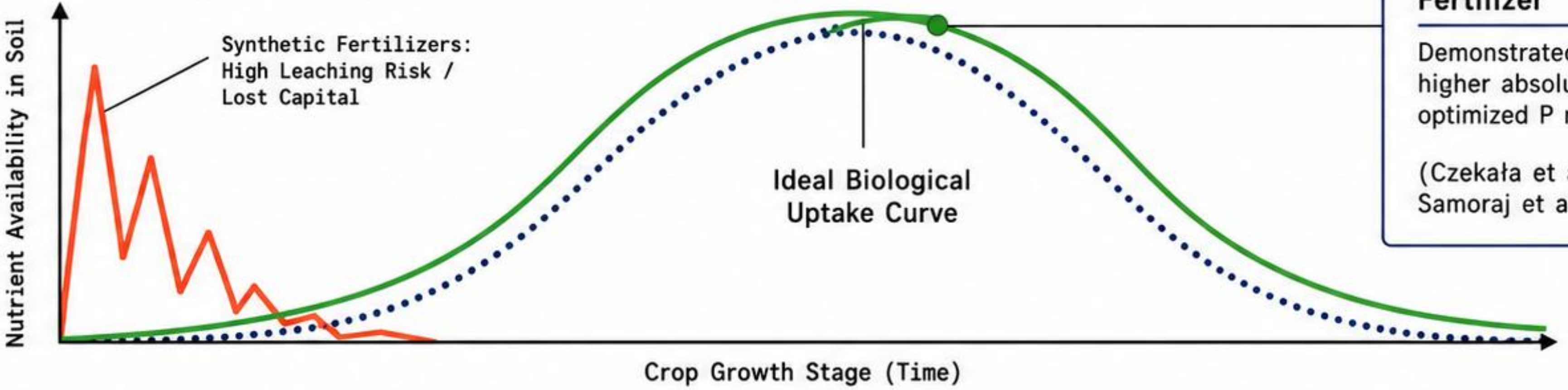
DIRECT APPLICATION CAPACITY: HIGH

PRIMARY FUNCTION:
Immediate deployment as foundational soil conditioner.

SECONDARY FUNCTION:
Direct replacement for N-P-K synthetics.

OUTPUT QUALITY:
Rich in bio-available organic matter.

Slow-release kinetics synchronize nutrient availability with biological crop uptake

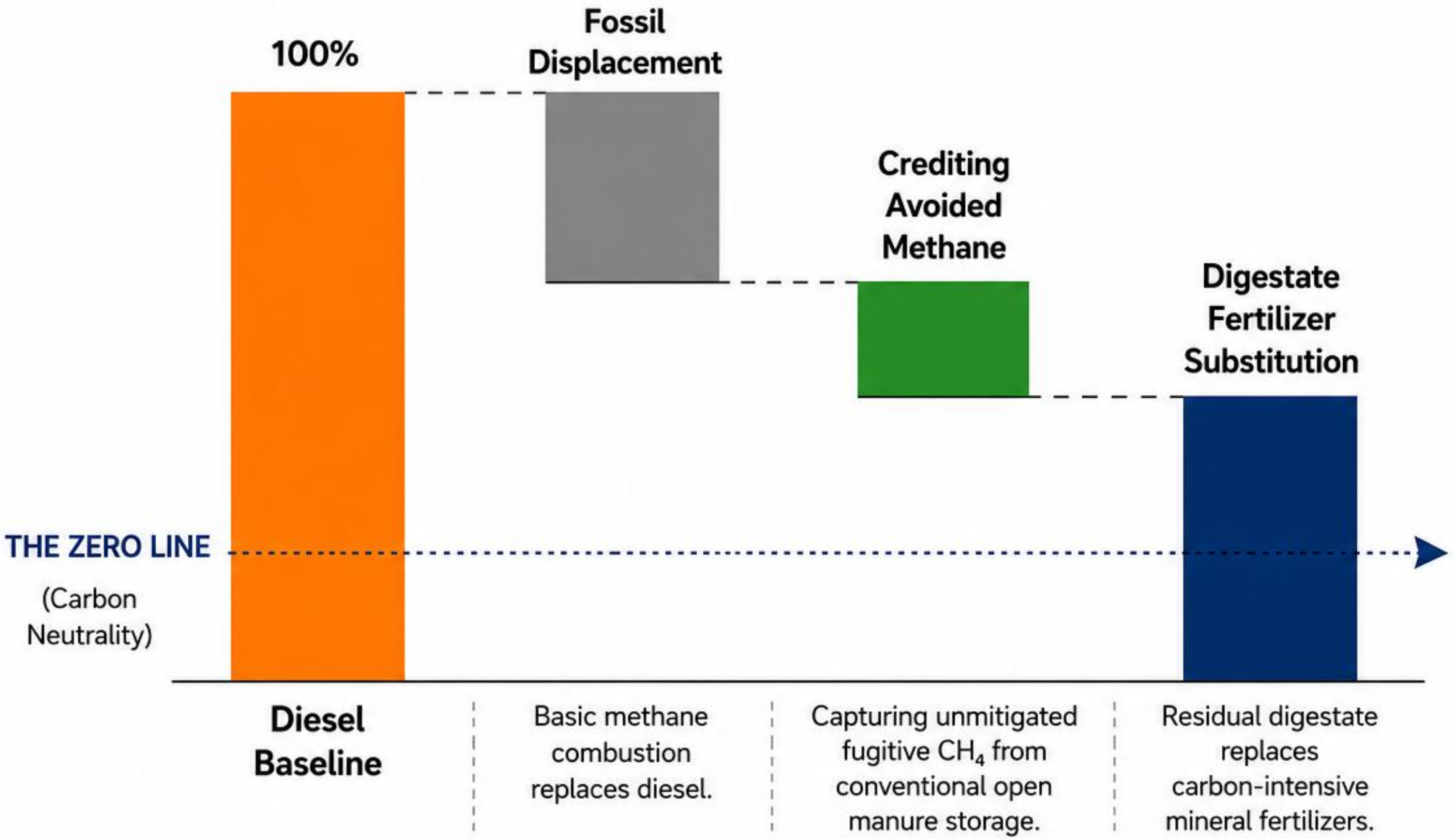


Digestate Organomineral Fertilizer

Demonstrated yield increases, higher absolute N uptake, and optimized P recovery.

(Czekała et al., 2022; Samoraj et al., 2022)

The Mechanics of Going Below Zero



Literature from Gustafsson & Svensson and JEC confirms that when avoided methane and nutrient recycling are properly credited in liquid biomethane (LBM) systems, total emissions plunge into **net-negative territory.**

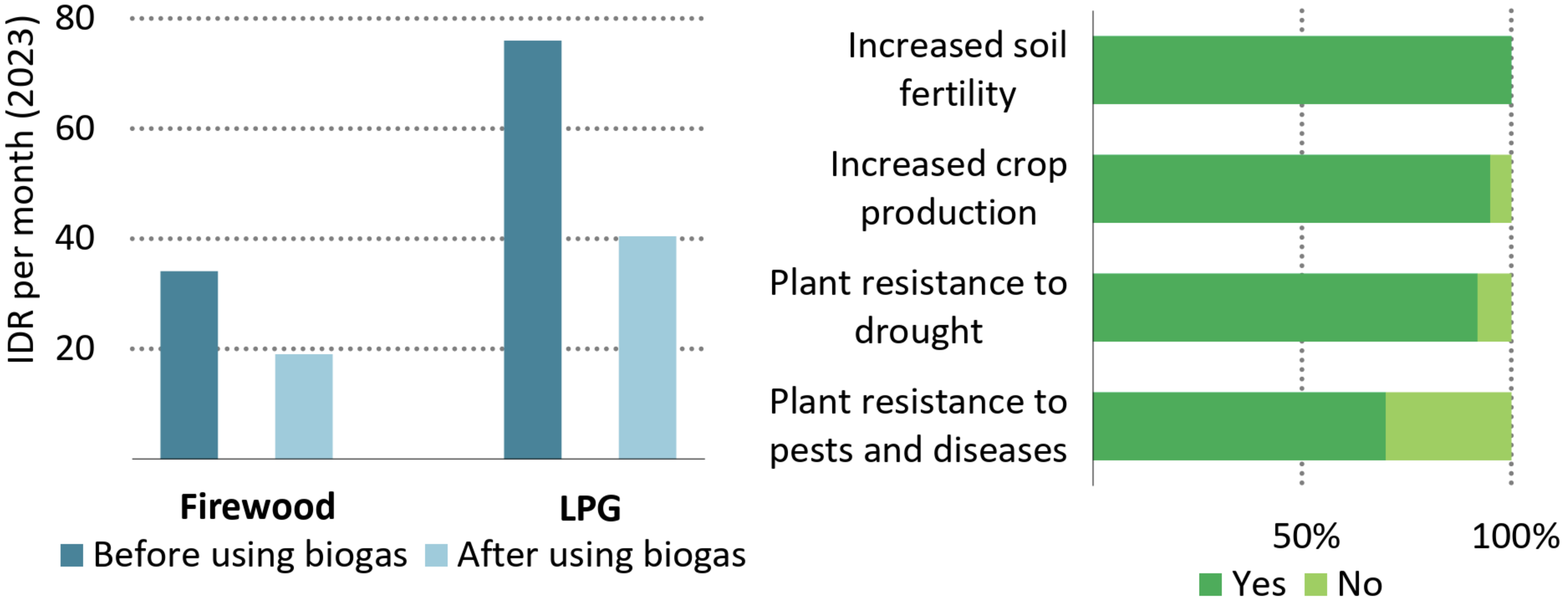
Diesel Baseline
100% emissions from baseline diesel use.

Fossil Displacement
Basic methane combustion replaces diesel.

Crediting Avoided Methane
Capturing unmitigated fugitive CH_4 from conventional open manure storage.

Digestate Fertilizer Substitution
Residual digestate replaces carbon-intensive mineral fertilizers.

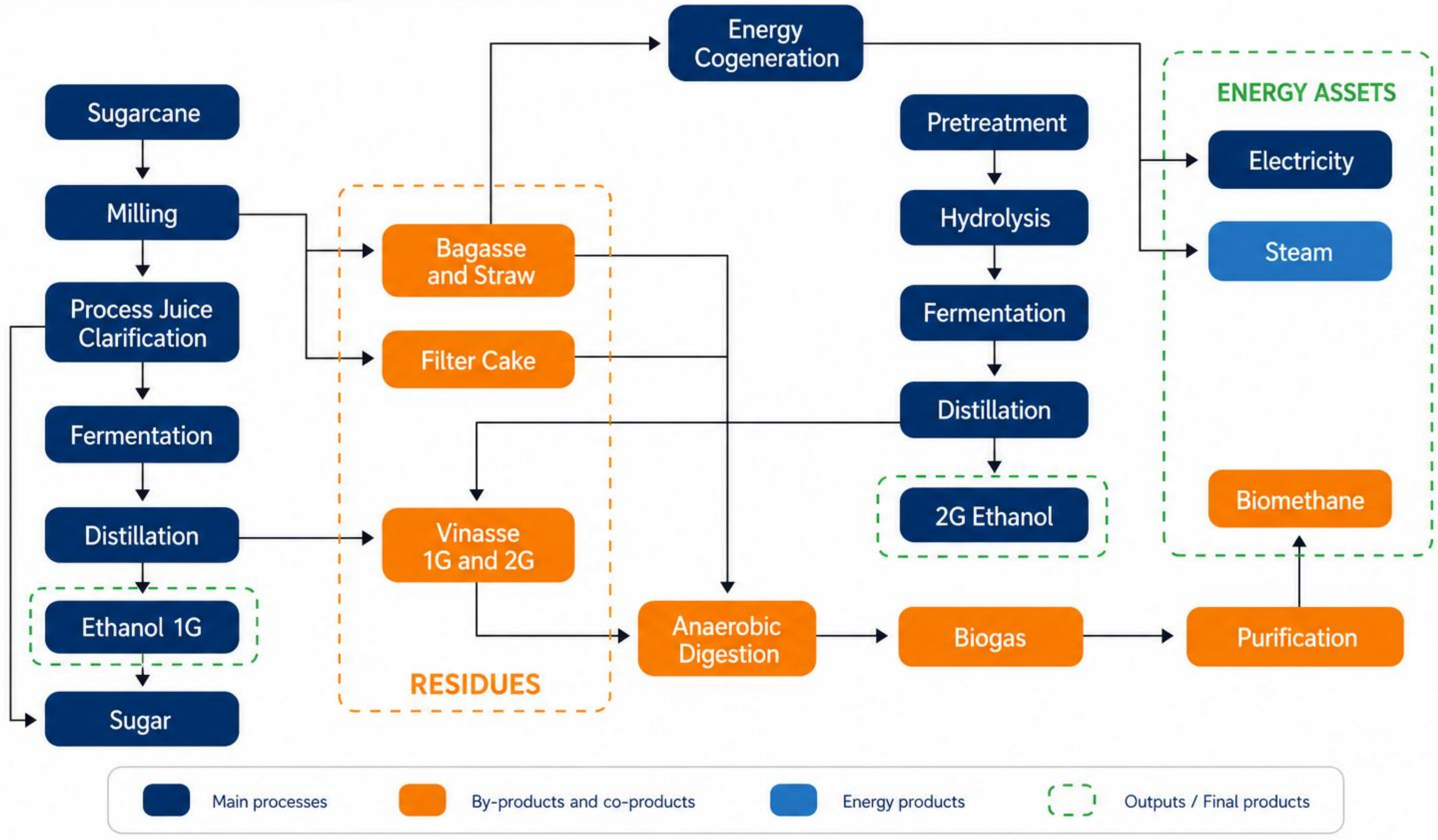
Figure 1.8 ▷ Impact of biogas adoption on average monthly household fuel cost and perceived benefits of digestate use, Indonesia, 2023



IEA. CC BY 4.0.

In addition to halving monthly fuel expenses, using biogas and subsequently using digestate as a fertiliser have generated valuable co-benefits to farmers in Indonesia

FIGURE 5
Productive chain of sugarcane biorefineries

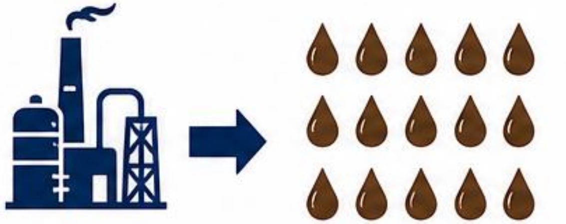


https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-781/Panorama%20de%20Biometano.pdf

Vinasse Characteristics and Production Volume

Sugarcane ethanol production generates approximately **10 to 15 liters** of vinasse for every liter of ethanol produced.

In Brazil, this results in an annual generation of roughly **360 billion liters.**



1 LITER ETHANOL

10 TO 15 LITERS VINASSE

~360 BILLION LITERS ANNUALLY IN BRAZIL

ACIDIC pH

Average **4.6**

HIGH ORGANIC LOAD

Average COD

46,000 mg/L

HIGHLY POLLUTING

Liquid effluent with significant environmental risk

~11%

OF THE ORIGINAL ENERGY

from sugarcane juice

Vinasse is a highly polluting effluent due to its acidic pH and high organic load. However, it also represents a **valuable energy resource**, containing about **11%** of the original energy from sugarcane juice.

Sugarcane residues (vinasse and filter cake) → Biogas production → Biomethane upgrading → Heavy-duty trucks → Sugar transport to the Port of Santos

Scale of the operation

Launched in **April 2024**, BioRota has rapidly reached commercial scale:

More than **70 biomethane-powered trucks**
More than **13,000 freight trips**
Approximately **11 million km** traveled
About **600,000 tonnes of sugar** transported to the Port of Santos
Around **5 million liters of diesel displaced**
More than **8,000 tonnes of CO_2 emissions avoided**
Up to **90% lower GHG emissions** compared with diesel-powered trucks.

Biomethane supply

The renewable fuel is supplied by **Cocal**, one of Copersucar's associated mills, which operates two commercial biomethane plants in western São Paulo: **Narandiba:** up to **25,000 m³/day**
Paraguaçu Paulista: up to **60,000 m³/day** during the harvest season

BIOMETHANE IN ETHANOL PRODUCTION

Question: How much could ethanol lifecycle Emission Factor fall if fossil energy is replaced by biomethane?

	Current EF (gCO_2eq/MJ)	→	With biomethane (gCO_2eq/MJ)	Reduction (%)
SUGARCANE ETHANOL **Direct diesel** in machinery/logistics	27.7	→	21.6	-6.1 gCO_2eq/MJ (-22%)
Broad fossil energy	27.7	→	20.5	-7.2 gCO_2eq/MJ (-26%)

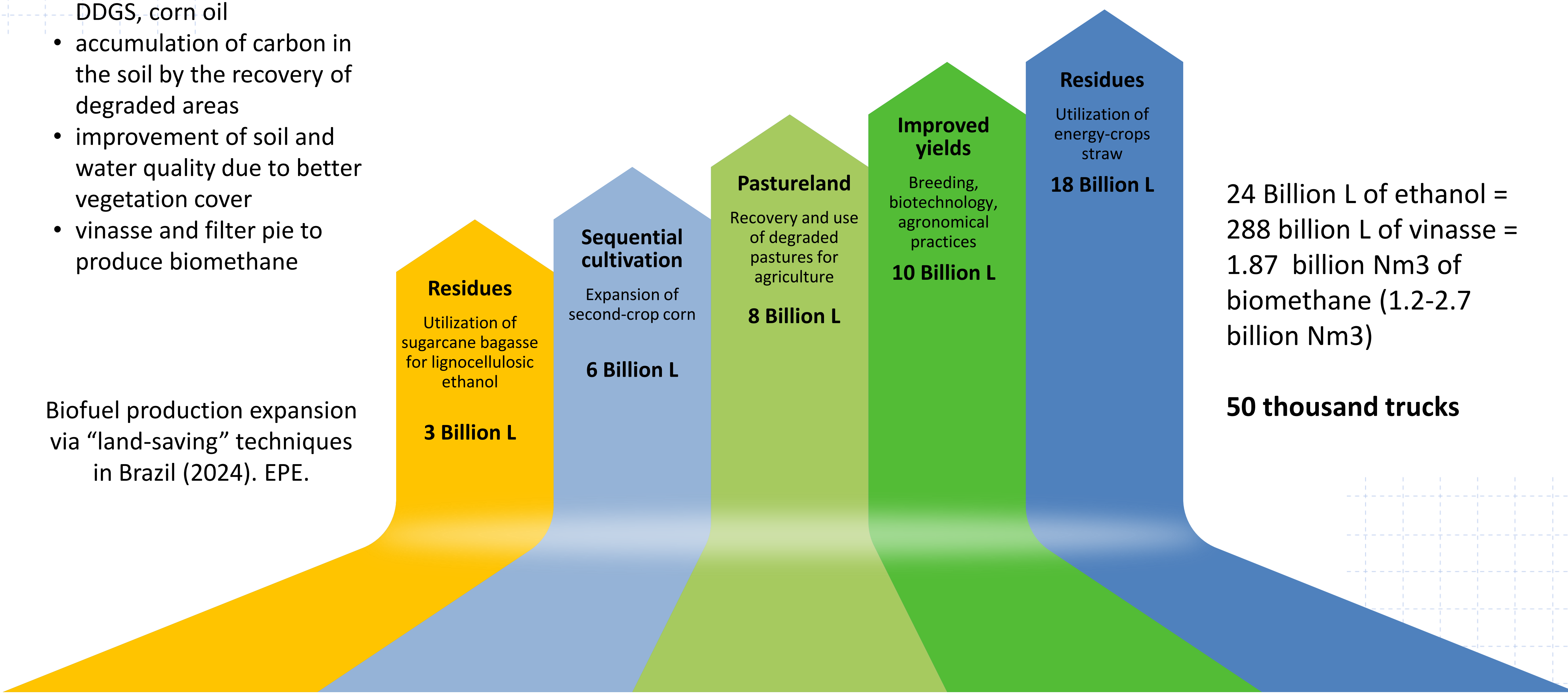
Replacing fossil energy with biomethane reduces the ethanol lifecycle Emission Factor for sugarcane ethanol by 22–26%.

Sugarcane diesel/logistics from Bartholomeu et al. (2020); broad cases use energy ratios: sugarcane 9.3 MJ ethanol/MJ fossil. RenovaBio baseline EF:
sugarcane 27.7 (439 certifications), biomethane 7.8 (6) gCO_2eq/MJ.

LAND SAVING TECHNIQUES

Additional co-benefits:

- additional food production such as soybean meal, DDGS, corn oil
- accumulation of carbon in the soil by the recovery of degraded areas
- improvement of soil and water quality due to better vegetation cover
- vinasse and filter pie to produce biomethane



Biofuel production expansion via “land-saving” techniques in Brazil (2024). EPE.

24 Billion L of ethanol = 288 billion L of vinasse = 1.87 billion Nm3 of biomethane (1.2-2.7 billion Nm3)

50 thousand trucks

SUGARCANE IS THE WORLD'S LARGEST BIOMASS CROP

Latin America & Caribbean (≈30)

Africa (≈35)

Asia (≈25–30)

Oceania (≈10)

Europe (very limited, ≈5–8)

North America (2)

IEA Bioenergy

A tropical/subtropical C4 crop
Highly efficient photosynthesis

Adapted to hot, sunny, and dry climates - maize, sugarcane, sorghum - produce 50–100% more biomass than C3 plants

Extremely adaptable (rainfed + irrigated systems)

Grown across Africa, Asia, and Latin America as a rural livelihood crop

Cultivated" ≠ economically relevant

~20 countries account for >80% of global sugarcane sugar

Global bioethanol production ~117 billion liters
~ 5 countries account for 30–35% of sugarcane ethanol
Brazil, India, Thailand, Colombia, Paraguay

Sugar
Brazil (#1), Mexico, Colombia, Argentina, Guatemala, Peru, Paraguay, Costa Rica
Brazil the largest with >40 Mt
Ethanol
~40 billion (36 billion from Brazil)

Blending mandates
2-30%; Brazil and Paraguay 30%

Sugar
India, Thailand (#2 and #3), Philippines, China, Pakistan, Vietnam, Myanmar
Ethanol
~5–6 billion L/year in India and climbing; Thailand, Philippines: ~1–2 billion L each

Blending mandates
India (12% → 20% by 2025), Thailand, Philippines (10%), China (10% in 9 provinces), Japan (~3%)

Sugar
South Africa, Sudan, Ethiopia, Kenya, Malawi, Mozambique, Egypt
Ethanol
Malawi, Mozambique, South Africa, Ethiopia, Kenya, Sudan <1 billion L/year combined

Blending mandates
5-10%

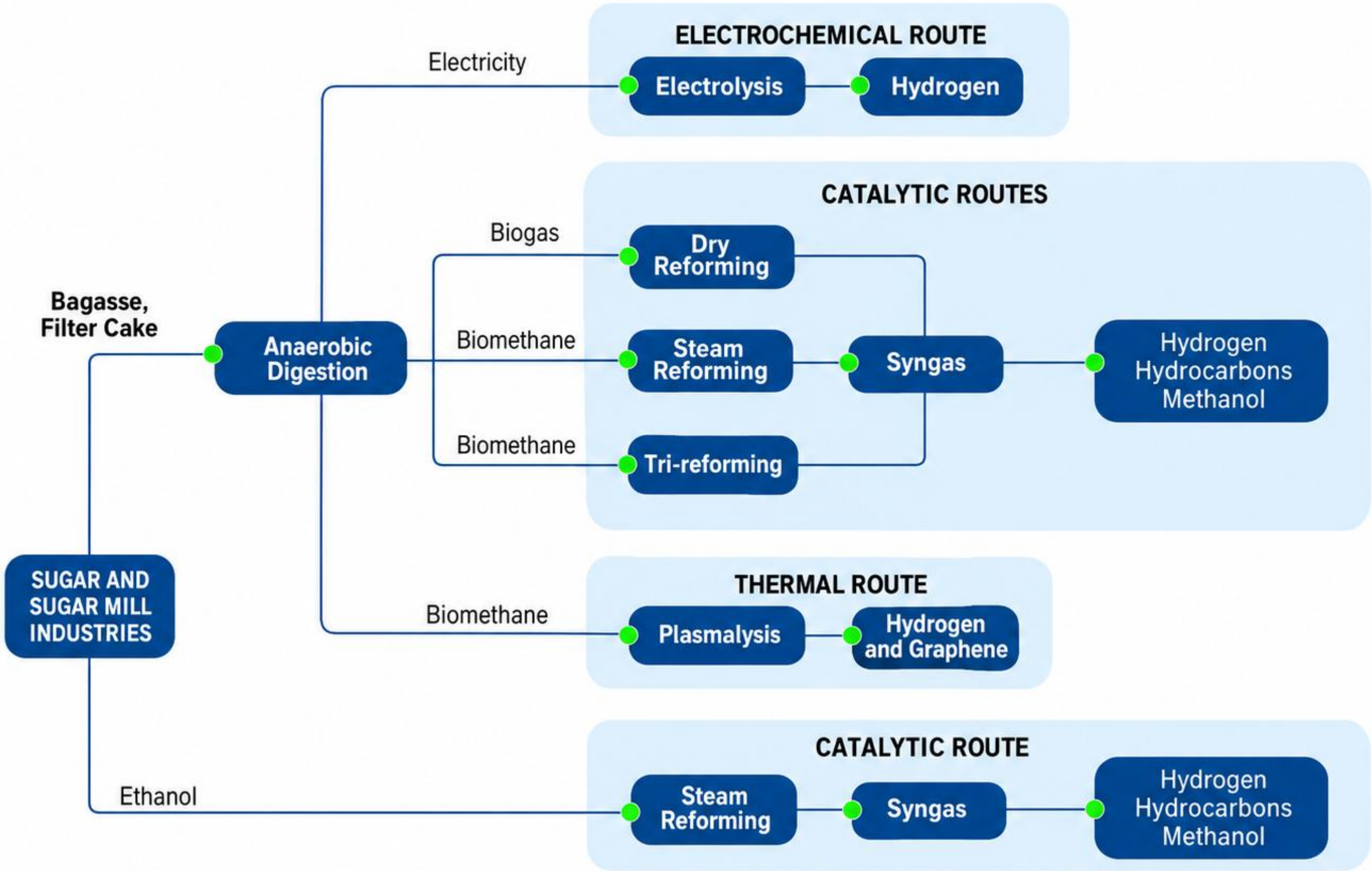
Sugar
Australia (#10), ~4–5 Mt sugar); Fiji also small-scale producer
Ethanol
Queensland ~0.3–0.5 billion L/year

Blending mandates
New South Wales, 4%

Sugar
Small, from overseas territories
Ethanol
Minimal imports from Brazil

Blending mandates
EU average ~6.4%, E10 France, Germany, Spain, Sweden, UK, Norway (24.5%), Netherlands (18.9%), Finland (13.5%)

FIGURE 13
Technological routes for hydrogen production in the sugarcane energy sector



Fossil Products Replaced

Using Biomethane as a Platform Chemical

Biomethane enables the production of multiple renewable products that replace fossil-based products across many sectors

1. Fossil natural gas
2. Grey hydrogen (from natural gas)
3. Fossil ammonia
4. Synthetic nitrogen fertilizers
5. Fossil methanol
6. Fossil synthesis gas (syngas)
7. Petroleum-derived diesel
8. Petroleum-derived jet fuel
9. Petroleum-derived marine fuels
10. Fossil LPG
11. Fossil CO_2 (industrial-grade carbon dioxide)
12. Petrochemical feedstocks (natural gas liquids and naphtha)
13. Coal (for industrial heat and chemical production)
14. Coke/coal-derived reducing agents (partially, in selected industrial applications such as green steel production via hydrogen)

From a single molecule – biomethane – a wide range of fossil products can be replaced, supporting the transition to a low-carbon and circular economy.

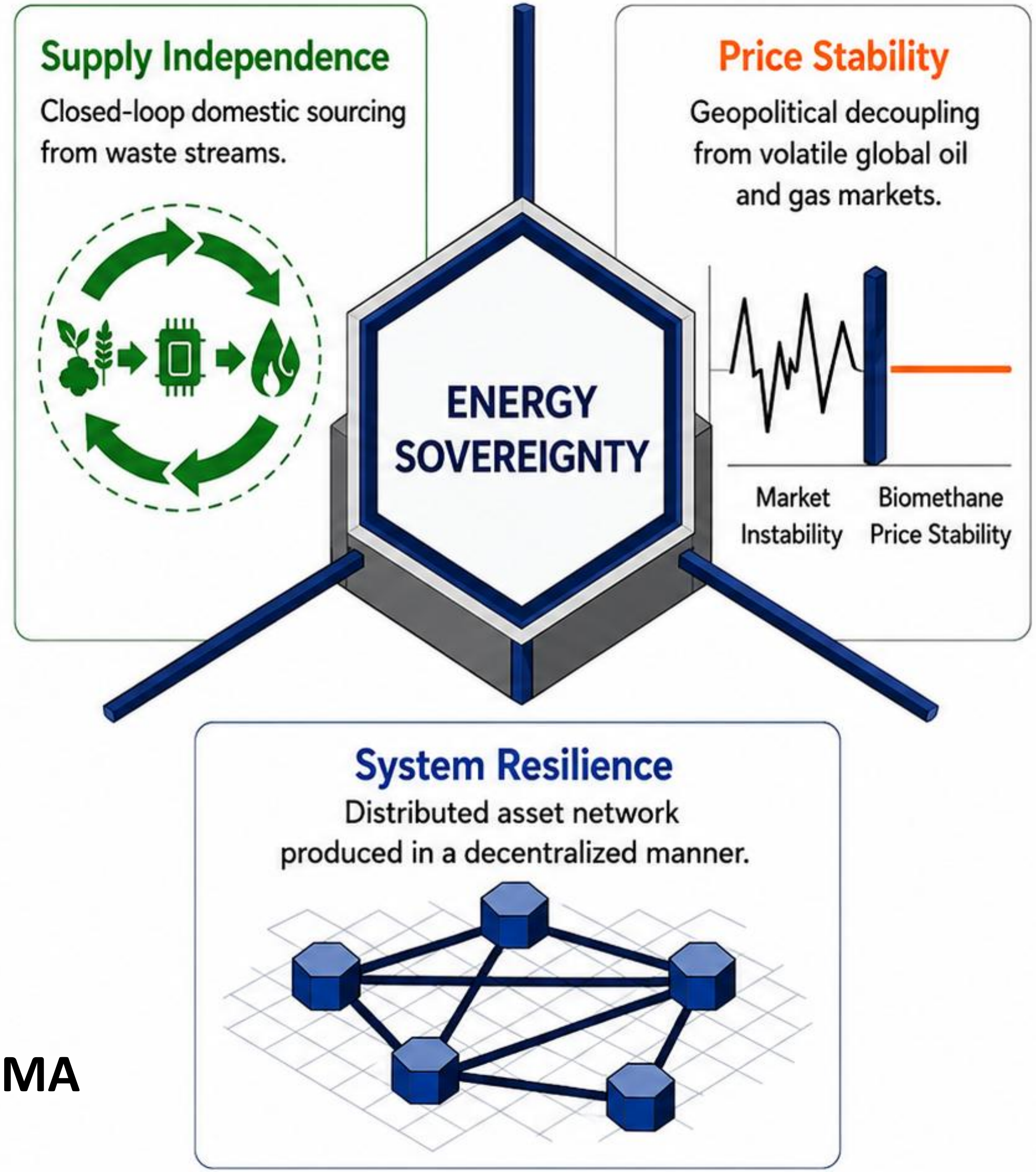
Energy security increasingly driving energy transition policy

Recent geopolitical crises reinforced:

- Vulnerability of fossil fuel dependence
- Link between energy security and national security

Biomethane increasingly viewed as:

- Strategic sovereignty fuel
- Domestic energy source
- Non-geopolitical fuel option



BIOMETHANE SOLVES THE ENERGY TRILEMMA

https://saebrasil.org.br/eventos/biofuels-for-decarbonization-of-land-transport-industry-hearing/

https://task39.ieabioenergy.com/industry-hearing-on-biofuels-for-decarbonization-of-land-transport-call-for-experts-and-stakeholders/

Factsheet to be released in September 8th, 2026 at the IEA Bioenergy Task 39 Industry Hearing Organized by SAE Brasil and Society of Bioenergy (SBE)

Glaucia Mendes Souza
University of São Paulo (USP)
glmsouza@iq.usp.br