Biofuel Carbon Footprint

Biomethane Carbon Intensity Methodology

Dustin Courage, 27/05/25

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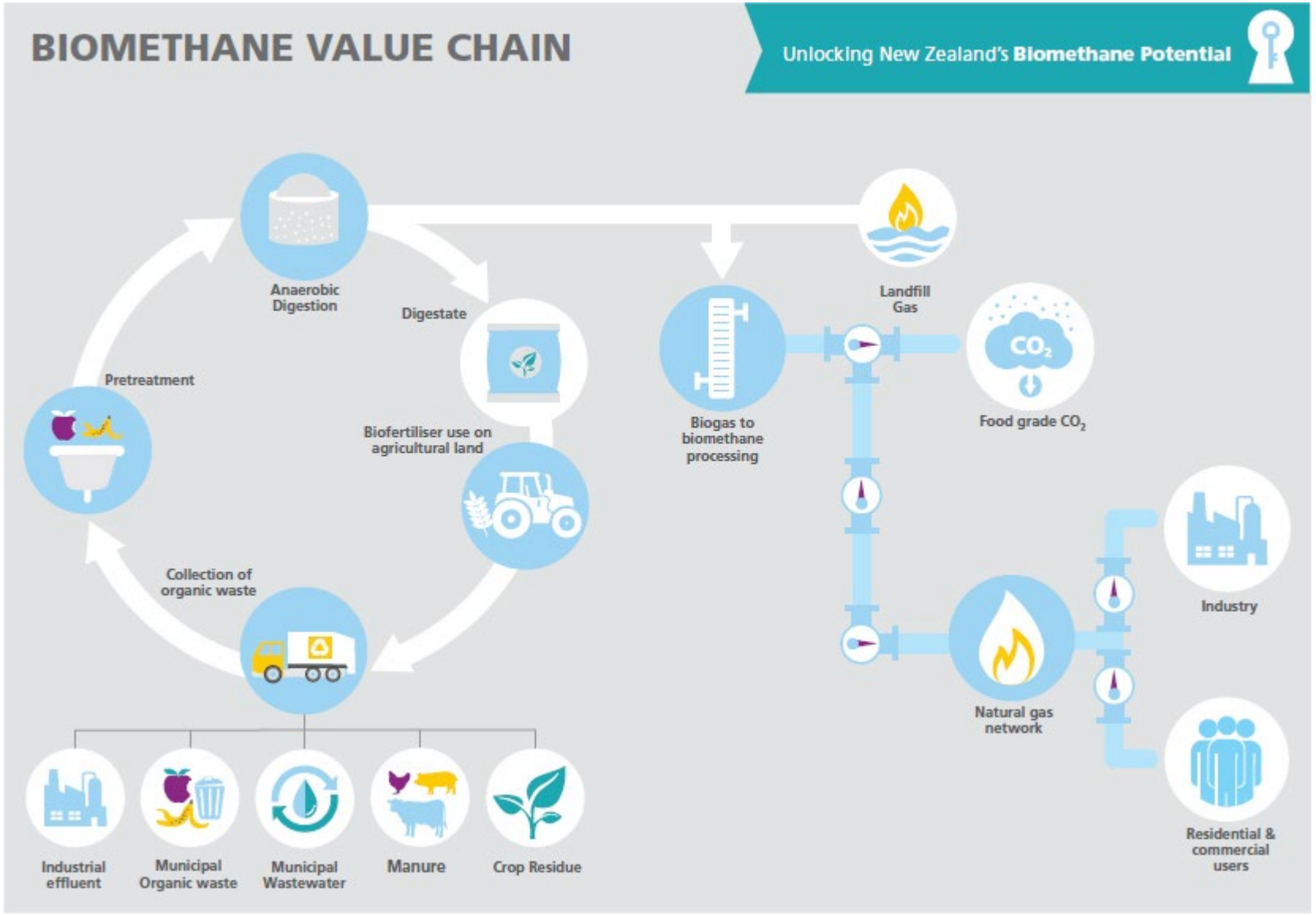
Agenda

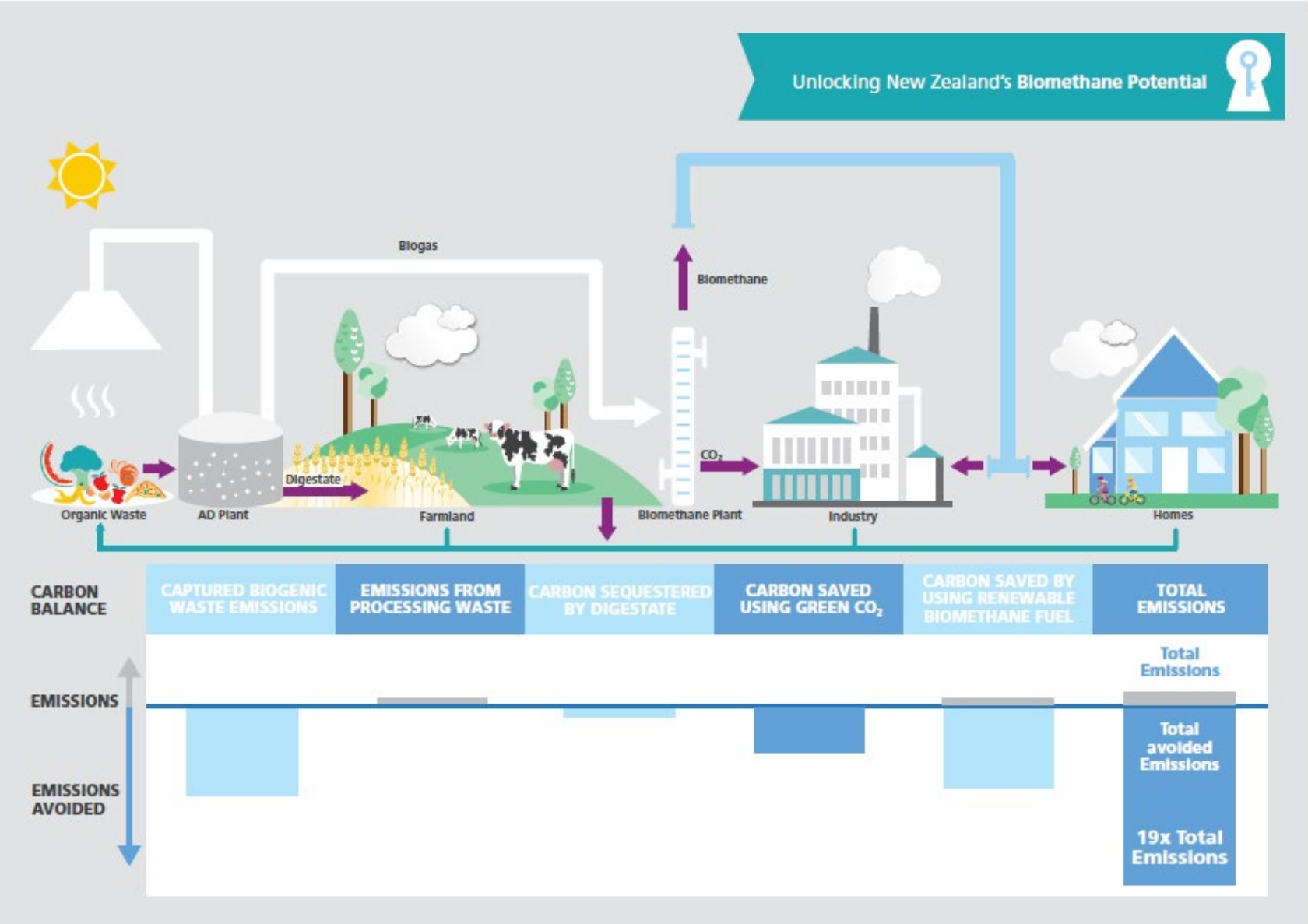
+ Intros
+ Anaerobic Digestion (AD)
+ Biomethane GHG methodology development
+ LCA principles
+ Engagement exercises
+ Avoided emissions
+ Workshop and questions

What is Biomethane?



Credit. Unlocking New Zealand's Biomethane Potential

What is Biomethane?



Credit. Unlocking New Zealand's Biomethane Potential

Purpose: GHG Methodology for Gaseous Biofuel

“Organic Waste” management processes

1. Landfill Gas Recovery

2. AD at Municipal Waste Water Treatment Plant

3. Organic waste diversion to AD Plant

Intended Use and Users

Stakeholder Type	Standards / References	GHG Accounting Typology
Certifier / Verifier / Peer Reviewer	14064-1 Organisation GHG; 14067 Product GHG Standard; GHG protocol organisational inventory ISO 14064-3 GHG assurance	Organisational emissions / Product Carbon Footprint
Project Developers / Producers	14064-2 Project GHG accounting; 14067 Product GHG Standard; International REC schemes; International Clean Fuel Standards	biogas /biomethane Carbon Intensity
Biofuel REC Certificate Scheme	European Energy Certificate System (EECS); Green Gas Certification Scheme (GGCS) UK; International REC (I-REC)	biogas /biomethane Carbon Intensity
Clean / Low Carbon Fuels standards	Canada's Clean Fuel Regulations (CFR); U.S. Renewable Fuel Standard (RFS) California's Low Carbon Fuel Standard (LCFS)	Biomethane Carbon Intensity
Consumers / Organisation GHG	14064-1 Organisation GHG; 14067 Product Standard; PAS 2050;	Organisational emissions / Product Carbon Footprint

Summary of key international REC/ LCFS scheme methodologies:

Jurisdiction	Scheme Name	CI methodology / model	Functional Unit	System Processes Covered (LFG, WWTP, AD)	System Boundary	Allocation	Verification	Avoided Emissions	Methodology Alignment
Europe	**European Energy Certificate System EECS** EECS | AIB	Renewable Energy Directive II (RED-II). REDcert standards. 2023 Scheme principles for GHG calculation - Version EU 06 Logo REDCERT	grams of CO2 equivalent per MJ of biofuel/bioliquid/biomass fuel [gCO2eq/MJ]. Use lower heating value (LHV) into the unit gCO2eq/MJ of final fuel	Generic	Cradle to Grave, Feedstock extraction/ transportation to RNG combustion.	Energy Allocation	Annual	Not addressed.	Mass Balance, Sustainable Feedstock, Calculation.
Australia	**Greenpower Renewable Gas Certification**	2024 - RGGO Scheme – certifier / auditor Renewable Gas Certification - Rules V2.0.pdf	Kg CO2e / GJ - HHV	"Technology agnostic"	Cradle to Gate	Energy Allocation, Expansion if other products (sold)	Annual	NO	Must use Renewable electricity. REC. Materiality: 1% individual, 5% cumulative.
Canada	**Canada's Clean Fuel Regulations (CFR)**	2024, Environment and Climate Change Canada, Fuel life cycle assessment model methodology. Fuel Life Cycle Assessment Model - Canada.ca	1 MJ of energy content based on the Higher Heating Value (HHV) delivered to the end user and used for its energy content.	Generic	Cradle to Grave; Includes end use combustion	Energy Allocation	Annual	Not required. Calculated separate to CI. Optional Reporting.	Default Values and Fugitive emissions., Exclusions, PDF requirements
USA	**U.S. Renewable Fuel Standard (RFS)**	GREET T1, US EPA GREET | Department of Energy Renewable Fuel Standard Program | US EPA	g CO2e / MJ - HHV	Generic.	Cradle to Grave; includes Cradle to Gate, Gate to tank, tank to wheel.	Energy Allocation	Annual	Calculated separate to CI.	Many transportation fuel types. Hydrogen, BioOil to RNG. Well to Wheel LCA, LHV Default.

Jurisdiction	Scheme Name	CI methodology / model	Functional Unit	System Processes Covered (LFG, WWTP, AD)	System Boundary	Allocation	Verification	Avoided Emissions	Methodology Alignment
California	**California's Low Carbon Fuel Standard (LCFS),**	2024 CA-GREET 4.0 (under consultation), CA-GREET 3.0, LCFS Life Cycle Analysis Models and Documentation | California Air Resources Board	g CO2e / MJ - HHV	Methodologies for WWTP, LFG and Food / Organic to AD.	Cradle to Grave; includes Cradle to Gate, Gate to tank, tank to wheel.	Energy Allocation	Annual	Calculated separate to CI.	Many transportation fuel types. Hydrogen, BioOil to RNG. DOC Default, Well to Wheel LCA, LHV Default.
UK	**UK Green Gas Certification Scheme (GGCS)**	2024, Emissions Reporting - Certificates - Green Gas Certification Scheme	gCO2e / MJ (measured as net calorific value / LHV)	Generic	Cradle to Grave; Includes end use combustion	Energy Allocation	Annual	Not addressed.	REC Producer/ User reporting. CI less than = 34.8 kg CO_2e/GJ
USA	American Biogas Association;	2024, Carbon Accounting Methodology for Biogas American biogas council	grams of CO2e per megajoule (MJ) of fuel (LHV) or grams of CO2e per kilowatt hour (kWh) depending on the end-use	Methodologies for WWTP, LFG and Food / Organic to AD.	Cradle to Grave; Includes end use combustion	Energy Allocation (primary); System Expansion (Mass, Economic Value) if cant be avoided.	Annual	Covered	Avoided emissions, Data Quality Measurement requirement, frequency. Upstream boundaries.
World Biogas Association	International Anaerobic Digestion Certification Scheme	2024, International Anaerobic Digestion Certification Scheme, Life Cycle Assessment LCA Guidance for AD	grams of CO2 equivalent per MJ of biofuel/bioliquid/biomass fuel [gCO2eq/MJ]. Use lower heating value (LHV) into the unit gCO2eq/MJ of final fuel	Generic	Cradle to Gate;	Energy Allocation (primary; secondary use System Expansion (Mass, Economic Value)	Silent	Not covered.	Cradle to Gate Boundary

LCA Key Steps

1. Purpose and scope of LCA
2. System boundary of LCA
3. Functional unit
4. Allocation approach for Co-products
5. Life Cycle Inventory (LCI) Analysis - Inputs / Outputs (significance)
6. Life Cycle Impact Assessment
7. Interpretation – e.g. Hot spots, Improvements etc.

Lifecycle Assessment (LCA)

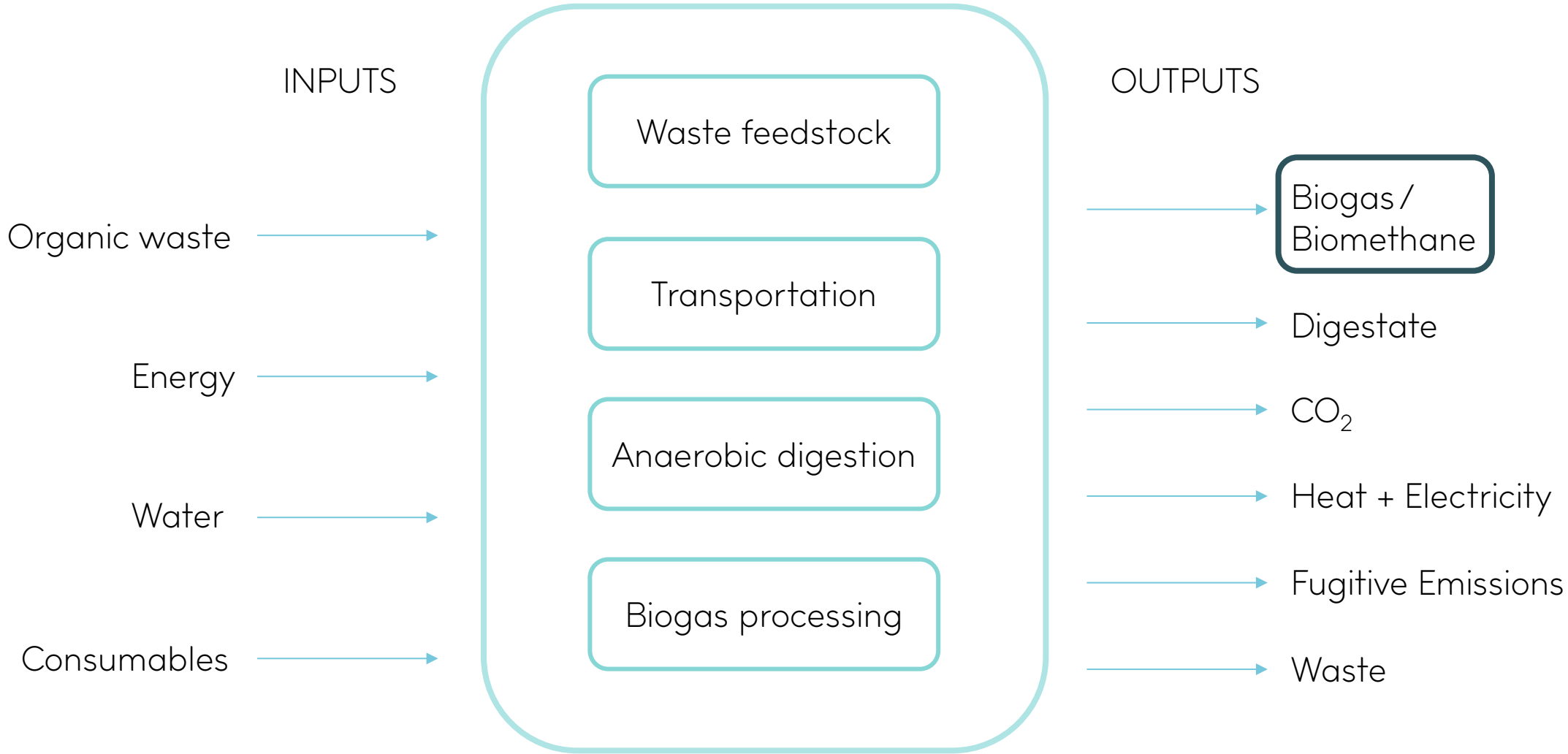
System Boundary

Functional Unit – (energy- GJ)

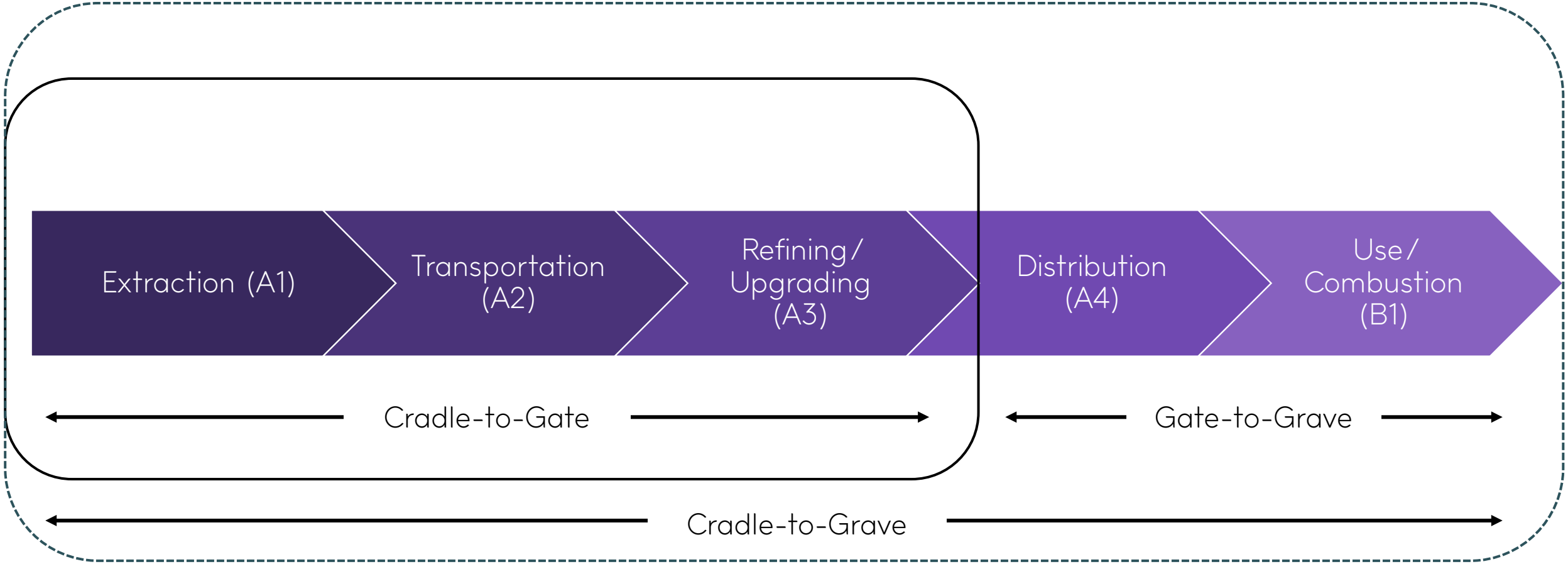
Carbon Intensity – kg CO_2e/GJ

Carbon Footprint of Products ISO 14067-1

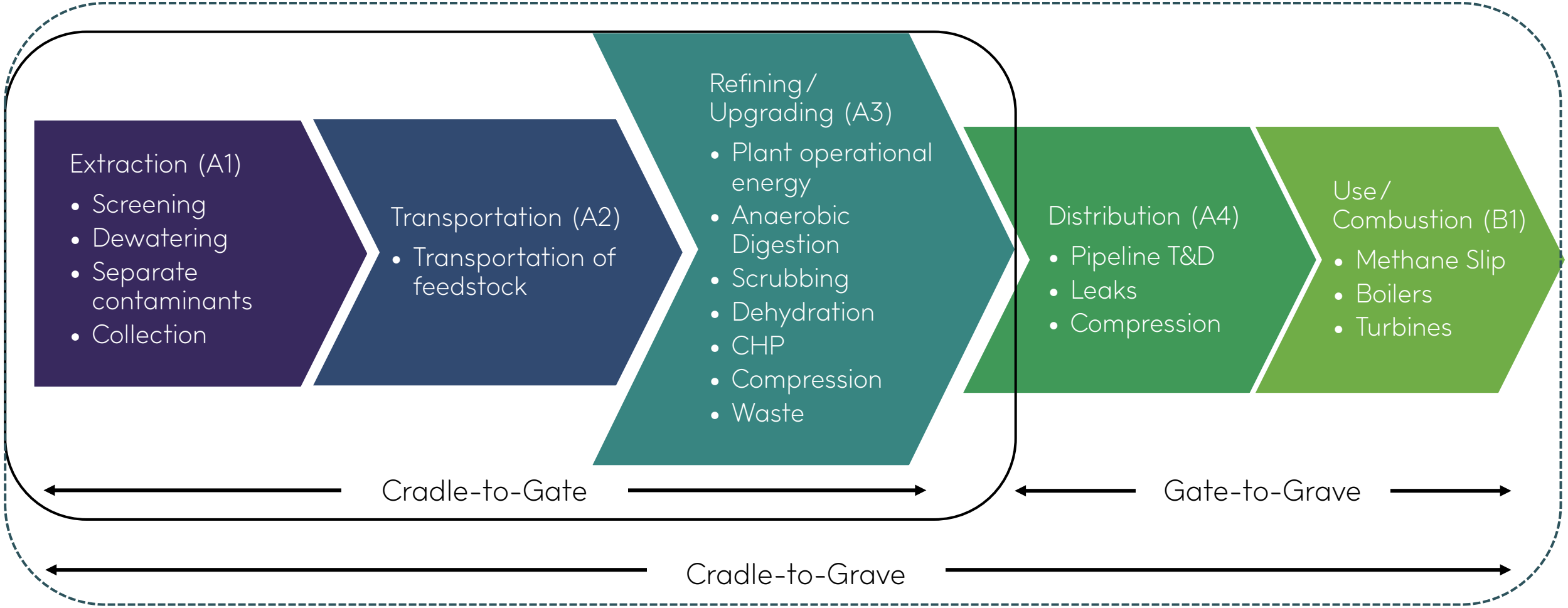
System Boundary Cradle-to-Gate



Waste to AD – Product LCA



Biomethane Product LCA = Carbon Intensity



Exclusions from Cradle to Gate

Embodied emissions of plant

Embodied emissions of equipment

End use combustion

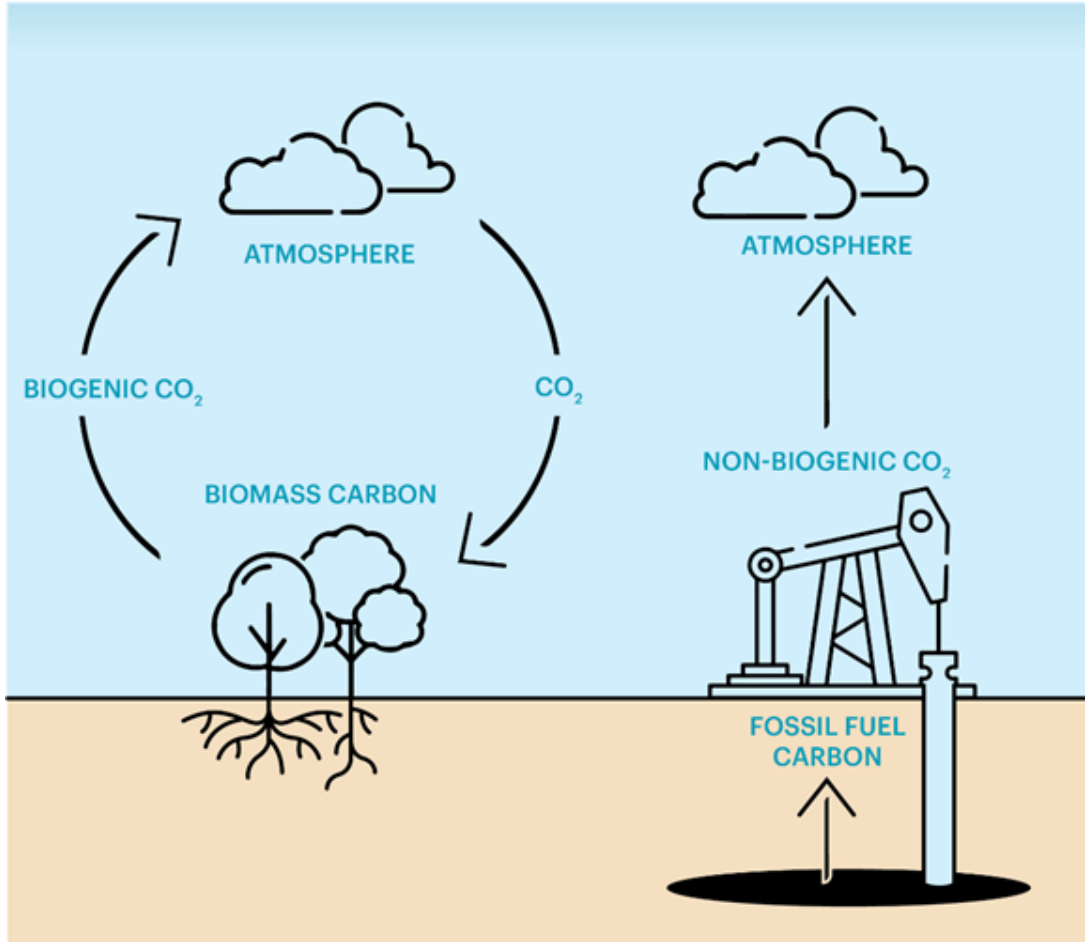
Digestate application to land

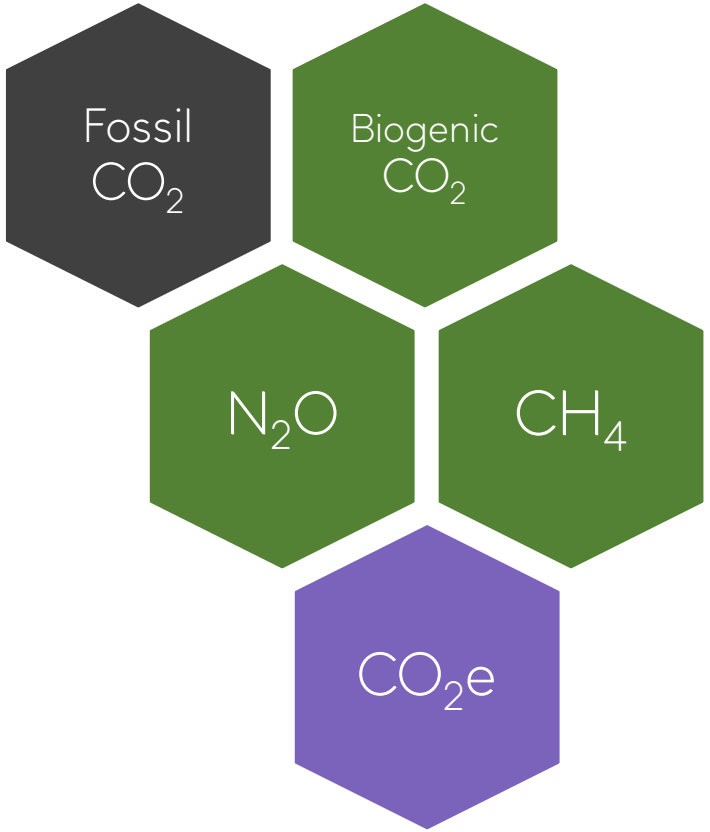
Exclusion	Justification
Construction and decommissioning of equipment and facilities	Excluded from all the international methodologies researched. Considered non-material while being inside the system boundary.
Indirect land use change from construction of facilities.	Excluded from all the international methodologies researched. Due to exclusion of non-waste feedstocks is assumed to be zero.
The manufacturing of fuel transportation infrastructure (i.e., pipelines, trucks, ships, roads)	Considered non-material while being inside the system boundary.
The manufacturing of fuel combustion infrastructure (i.e., vehicles, boilers)	Considered non-material while being inside the system boundary.
Wastewater treatment processes upstream of the waste diversion to AD Plant.	Outside of system boundary based on polluter pays principal (waste management is a cost item/ environmental burden to prior lifecycle of materials being disposed).
Indirect activities associated with fuel production, such as marketing, accounting, commuting, and legal activities	Considered non-material while being inside the system boundary.
Digestate application to land & CO_2 use	Digestate has positive value and is considered a coproduct and not a waste treatment process. Impacts of application are attributed to the user of the digestate as it provides positive economic and environmental benefits to the users.

Co-Products

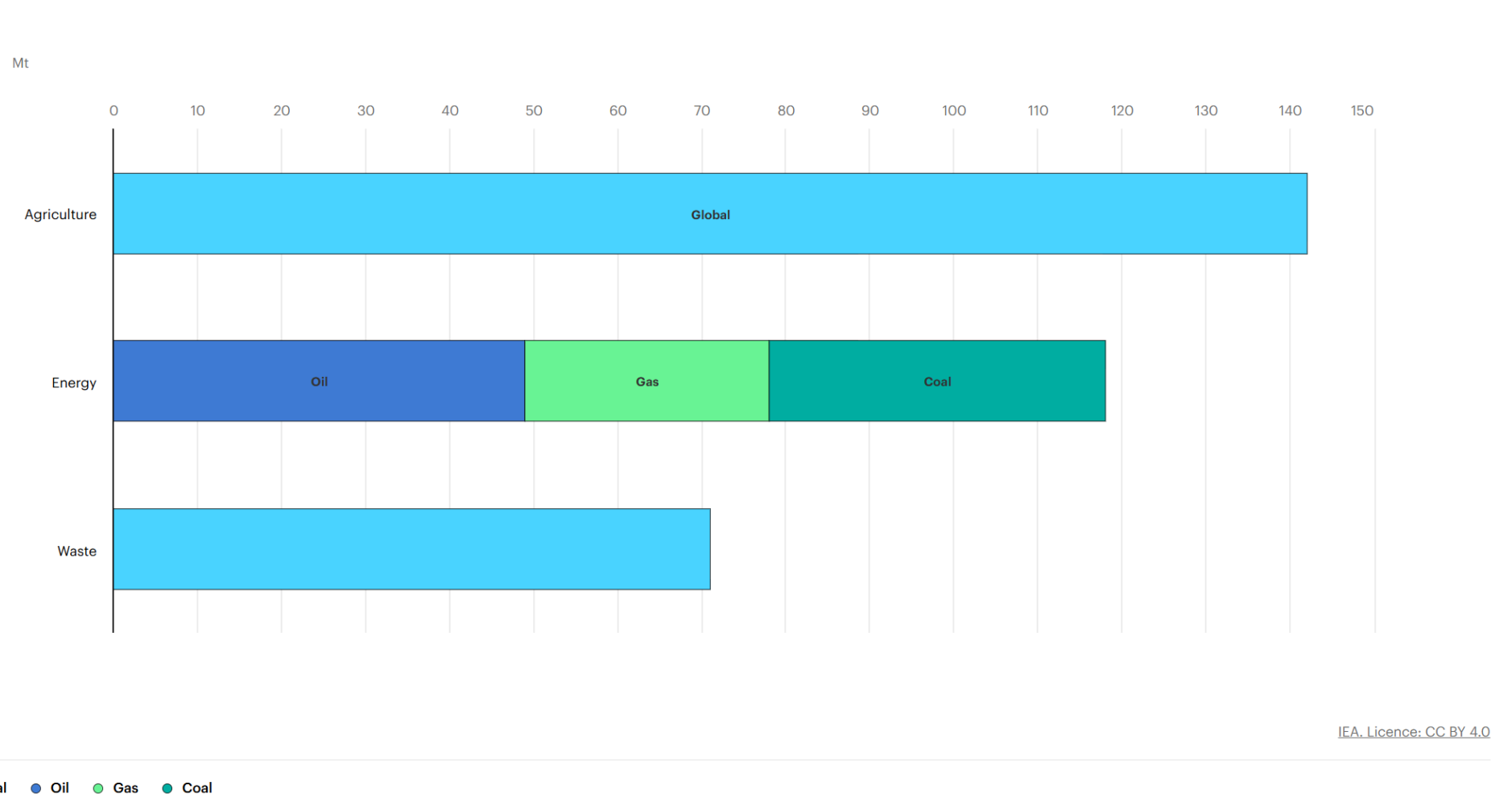
Digestate	CI for digestate is Zero
CO_2	CI for CO_2 is Zero
Electricity	Equation 12 Electricity Co-product Carbon Intensity: $CI_{elect} = EF_{biogas} \times (\eta_{elect} / \eta_{CHP})$ [kg CO_2e/GJ of electricity]
Heat	Equation 13 Heat Co-product Carbon Intensity: $CI_{heat} = EF_{biogas} \times (\eta_{heat} / \eta_{CHP})$ [kg CO_2e/GJ of heat]

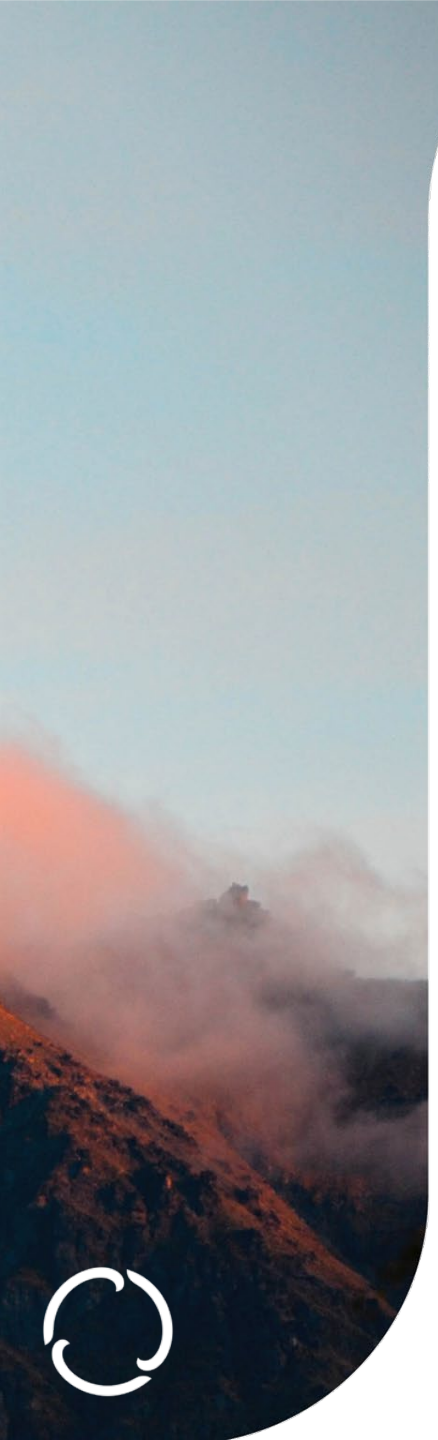
Biomethane Production - Greenhouse Gases





Methane emissions sources globally





Emissions Reduction- Biomethane vs Fossil Gas

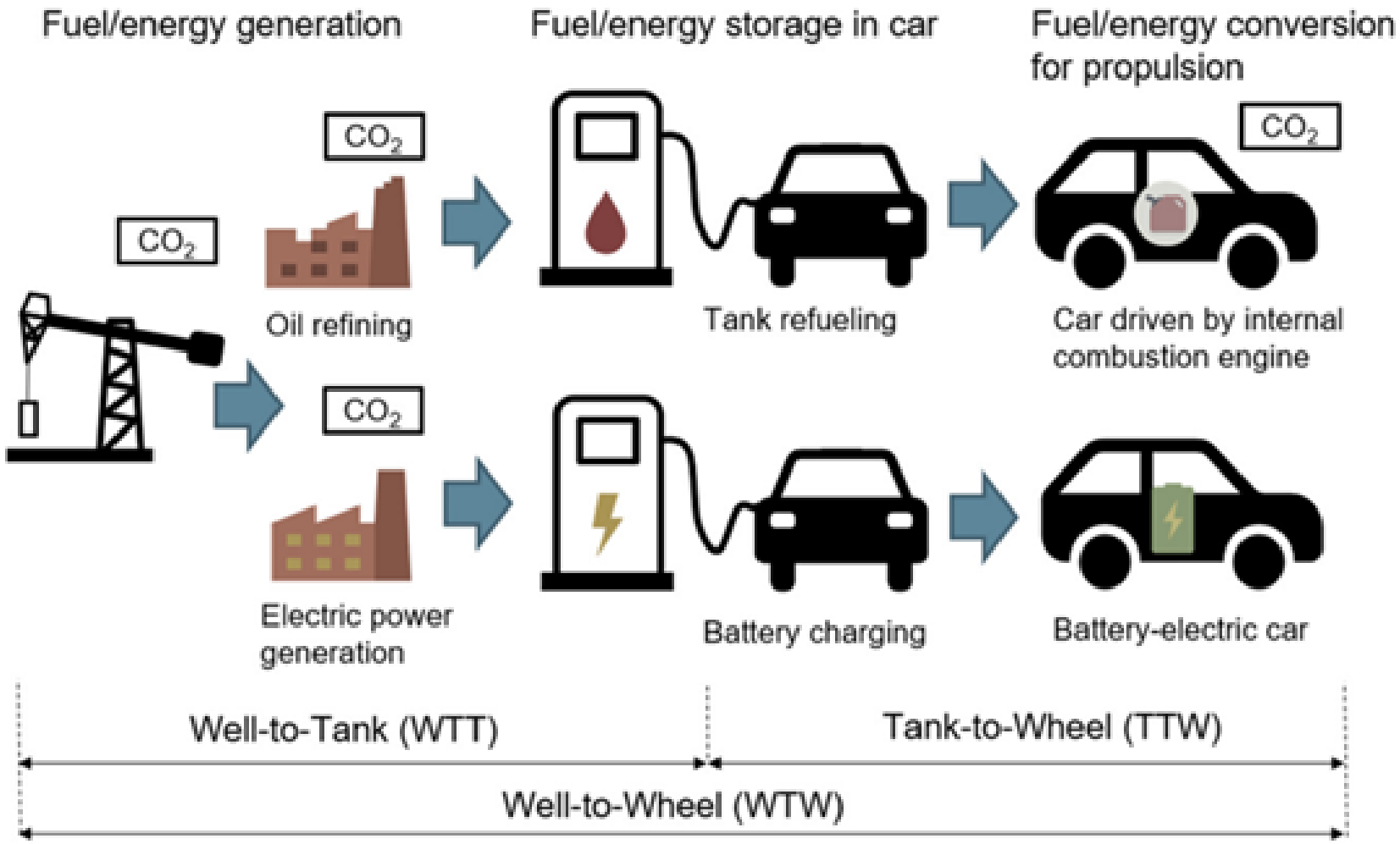
Cradle to Grave

Fossil Gas Emissions	Biomethane Emissions
Upstream GHG Cradle to Gate ~ 13-23kg CO_2e/GJ	Upstream GHG Cradle to Gate ~ 25kg CO_2e/GJ
T&D	T&D
Use phase Combustion ~ 54 kg CO_2e/GJ	Use phase Combustion ~ 0 kg CO_2e/GJ
CI ~ 70 kg CO_2e/GJ	CI ~ 25kg CO_2e GJ

Reduction of GHG ~ 65%

Well to tank

Cradle to gate



Organisational GHG Accounting

REC Scheme meets GHG P Scope 2 - Market Based Reporting Quality Requirements (8 Criteria)- Adapted per UK GGCS.

Scope 1: Direct biogenic CO_2 emissions linked to the use of gaseous biofuel are zero

Scope 1: Direct biogenic emissions from other GHGs (CH_4 and N_2O) to be reported

Scope 3: Upstream emissions of gaseous biofuel production and transport must be reported.

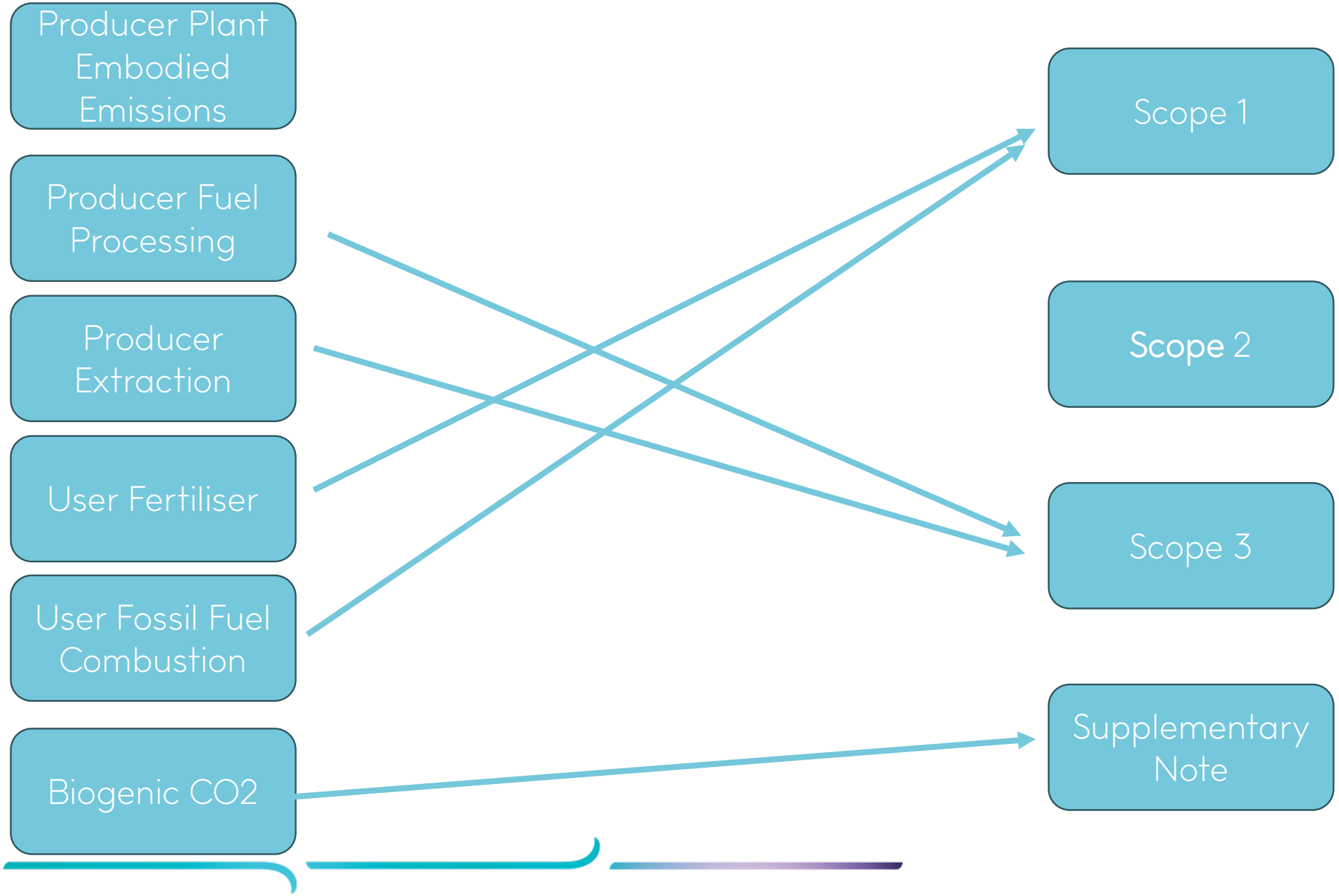
ISO Category 4 - Indirect GHG emissions from products used by organisation,

Scope 3 Cat.3 - Fuel and energy related activities.

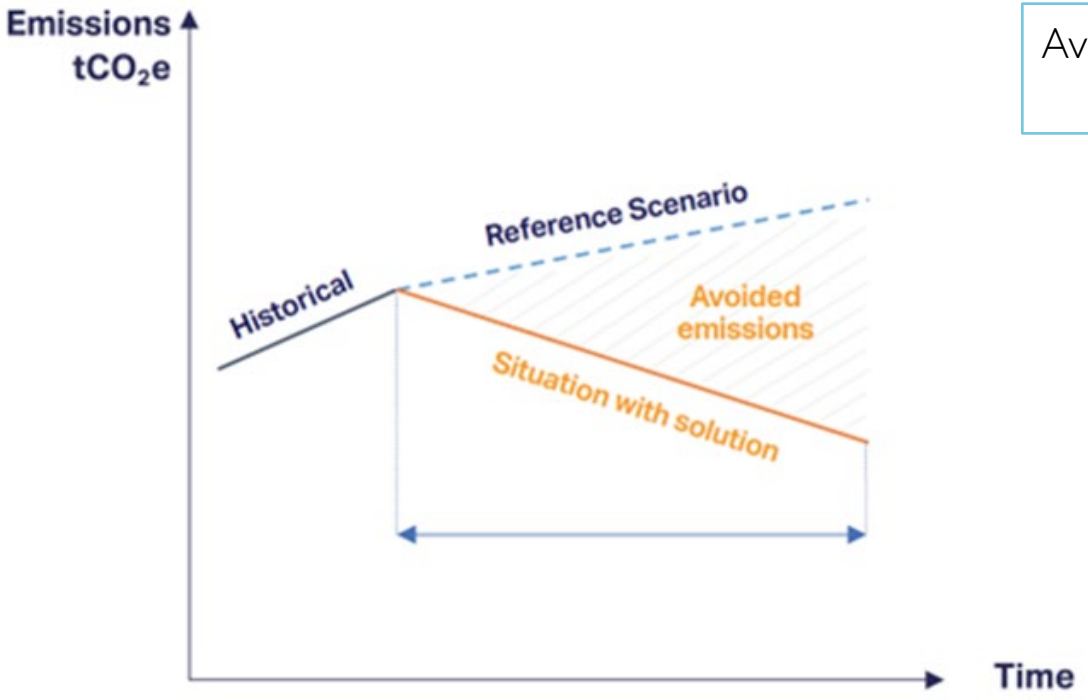
Scope 1 & 3

User Emissions	GHG P Category	Gaseous Biofuel System Boundary	Product LCA
Indirect Upstream	Scope 3, Cat.3	Upstream = $(CI_{biofuel}) \times V_{biofuel}$	Cradle to Gate
Indirect Upstream	Scope 3, Cat.3	Downstream = $T\&D_{GHG}$	Gate to Grave
Direct Emissions	Scope 1	Combustion	Gate to Grave

LCA Activities → Org. Inventory



Avoided Emissions



Upstream waste diversion
30-60kg CO2e/GJ

Avoided CH4 or N20 from organic waste BAU landfill etc.

Combustion emissions
50kg CO2e/GJ

Avoided fossil combustion with "zero" carbon biogenic emissions

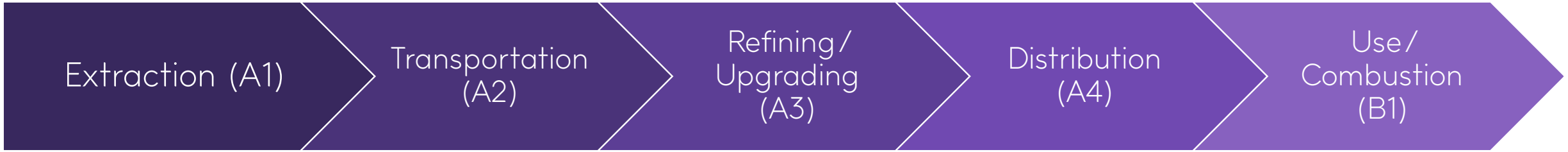
Fertiliser/Land use
5-20kg CO2e/GJ

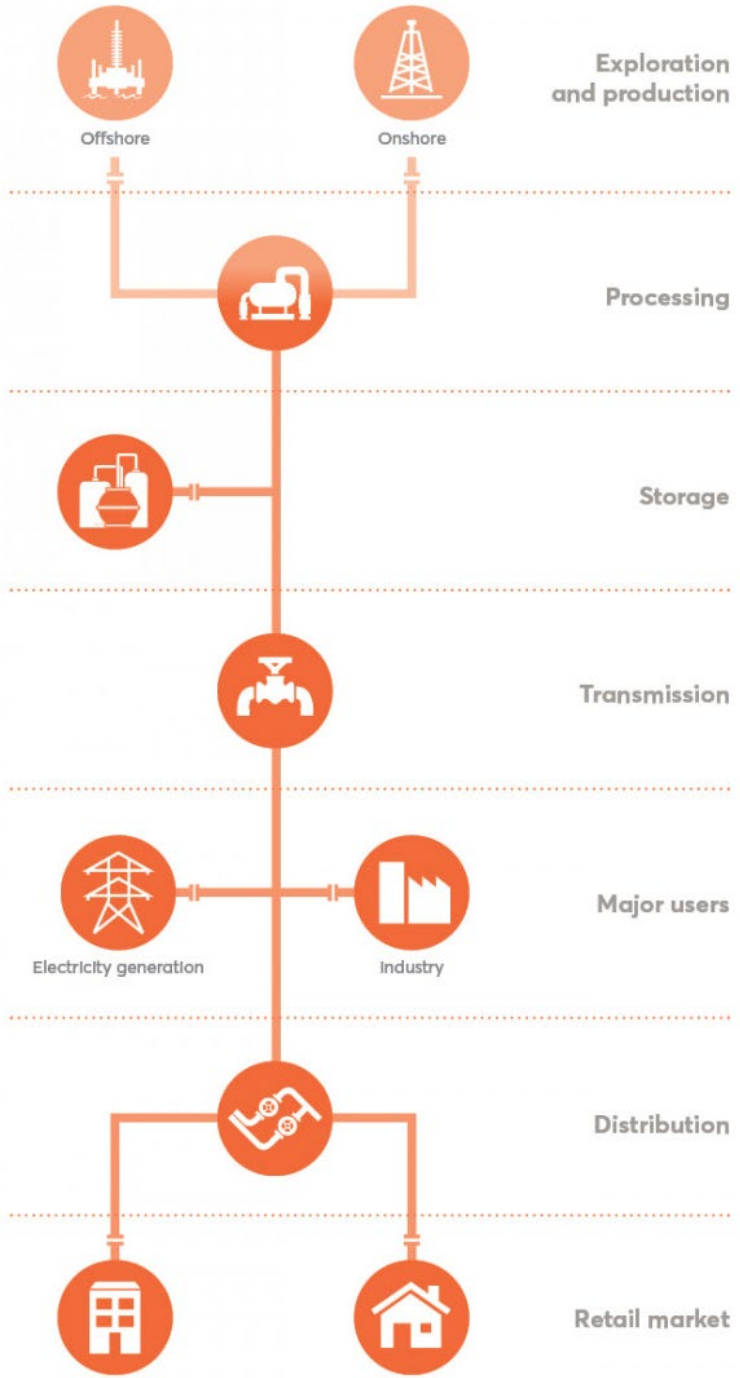
Avoided fossil based fertiliser and increase in soil carbon

Avoided LCA Impacts for AD

Ecotoxicity Air quality	Fossil resource depletion	Eutrophication	Waste reduction
Landfill leachate VOCs Fossil fuel flaring and waste	Avoided fossil gas extraction	Reduce fertiliser runoff	Waste to landfill Drilling waste

Fossil gas product LCA





OMV

GREYMOUTH PETROLEUM

TODD ENERGY

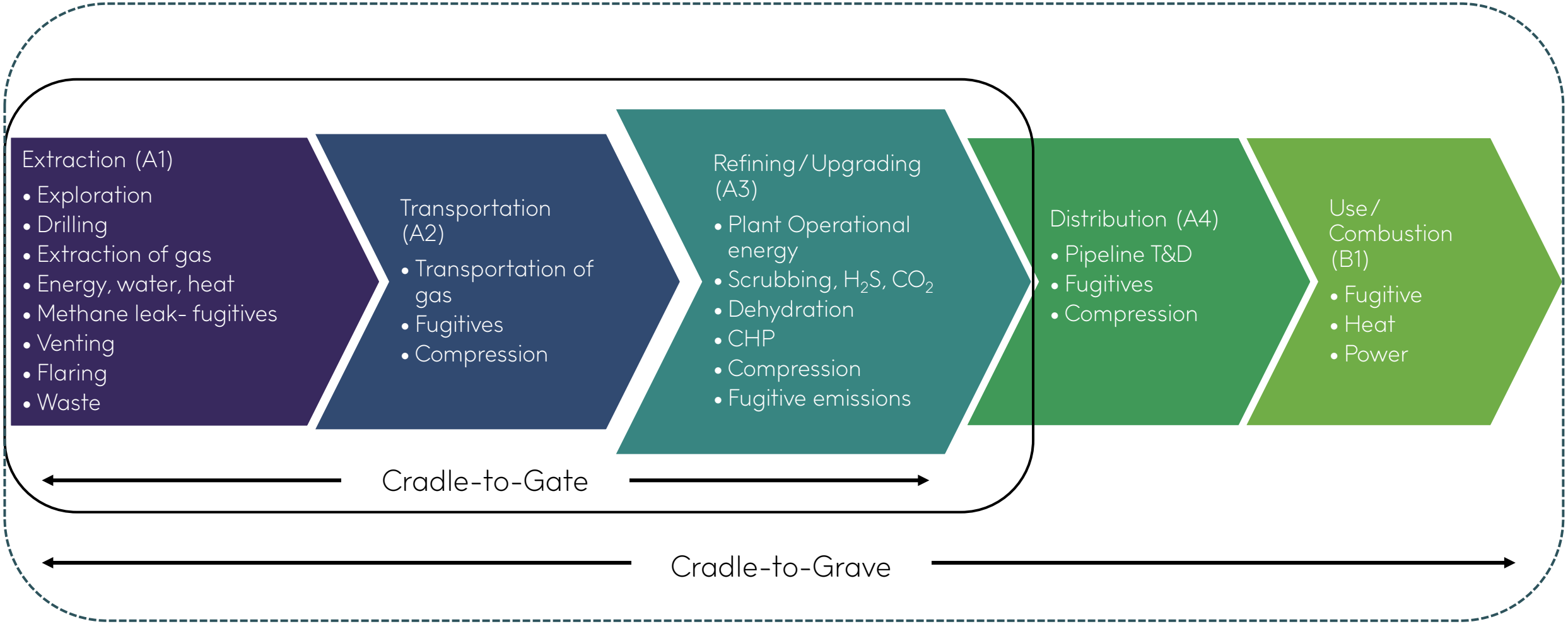
Clarus

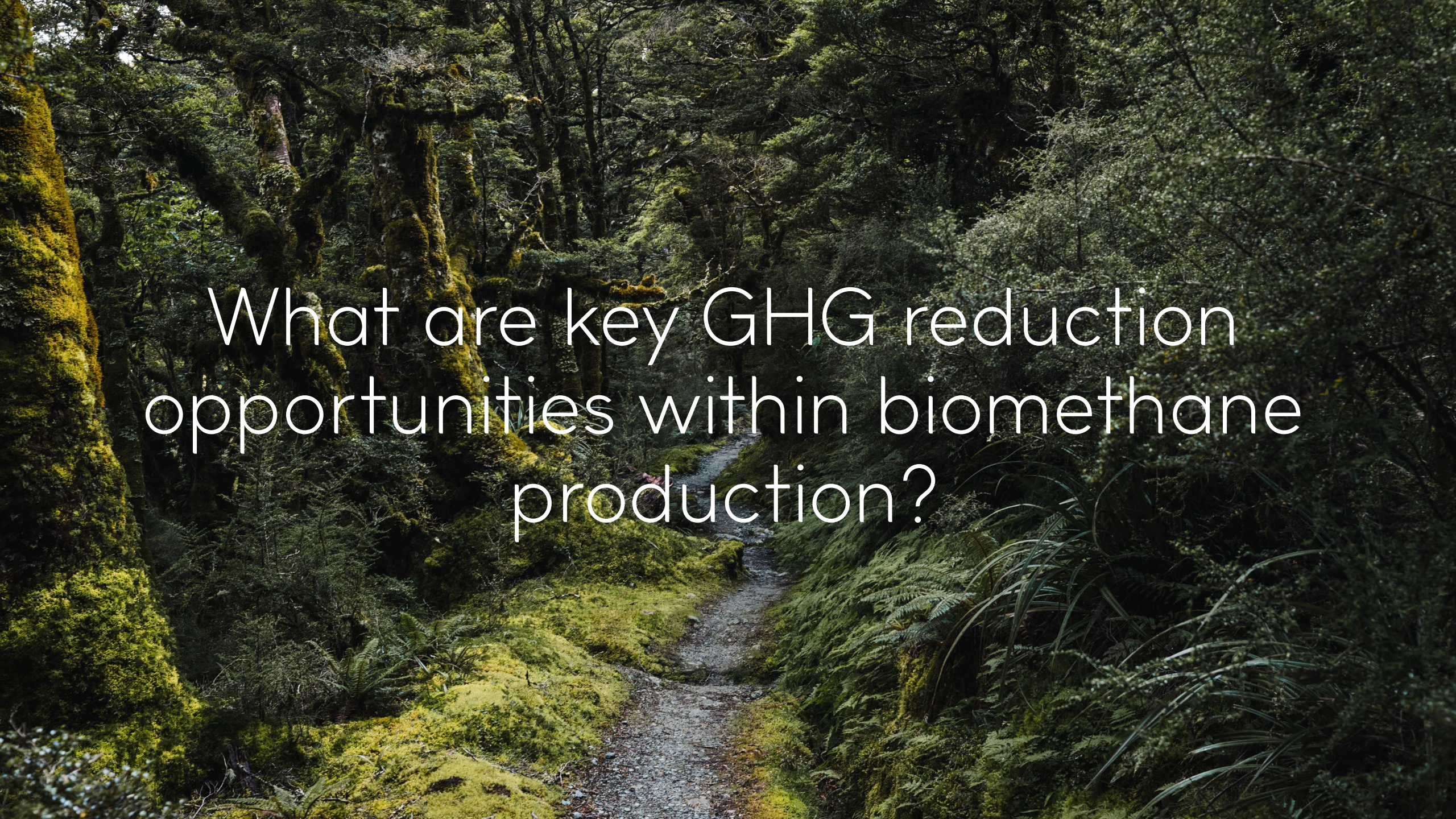
vector

POWERCO

nova energy

Fossil gas product LCA




What are key GHG reduction opportunities within biomethane production?

Ngā mihi

Background slides

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Biofuel carbon intensity

Equation 1: $CI_{biofuel} = PE \div (V_{biofuel} \times Ed_{biofuel})$

CI = Carbon Intensity of gaseous biofuel ($kgCO_2e/GJ$)

PE = Annual total production emissions of gaseous biofuel (Cradle to Gate) ($kgCO_2e$)

$V_{biofuel}$ = Volume of gaseous biofuel produced for the annual period at atmospheric pressure and temperature (m^3)

$Ed_{biofuel}$ = Energy density of gaseous biofuel; (GJ/m^3)

$Ed_{biogas} / Ed_{BM} = \%CH_4 \times 0.0358$ (LHV of CH_4, GJ/m^3)

Annual production emissions

Equation 2: $PE = F+CE + EU + FE_T + CU+W$

PE = Annual total historical production emissions of gaseous biofuel (Cradle to Gate) ($kgCO_2e$)
F = Feedstock Emissions
CE = Combustion Emissions
EU = Electricity Use Onsite
FE_T = Fugitive Emissions
CU = Consumables Used Onsite
W = Waste Emissions

Feedstock Emissions

Equation 3: $F = \sum S_x (E_x + T_x)$

F = Feedstock Emissions ($kgCO_2e$)

S_x = Share of feedstock ***x***, mass of feedstock input to the digester. (kg)

E_x = Emissions from the extraction of the feedstock **x**. ($kgCO_2e/kg$)

T_x = Emissions from transport of feedstock **x** to gaseous biofuel system. ($kgCO_2e/kg$)

Fugitive Emissions

Equation 10: $FE_T = FE_{ad} + FE_{su} + FE_{ds} + FE_{LFG}\ (kgCO_2e)$

1. Anaerobic digester leakage, (FEad)
2. Fugitive emissions during scrubbing biogas and upgrading to biomethane, (FEsu)
3. Digestate storage, (FEds)
4. Landfill Gas, (FELFG) – (null if not a landfill gas process)

Data Quality

1. **Primary data - quantified value of a process or an activity obtained from a direct measurement, or a calculation based on direct measurements.**

For instance, kWh of electricity purchased, measured at meter.

2. **Secondary data - obtained from proxy processes or estimates.**

For instance, using spend data to estimate emissions of a quantity of purchased consumables or using average sector default values for fugitive emissions.

Table 7: Gaseous biofuel, GHG activity data and data quality

Life cycle stage	Parameter / GHG source	Activity Data unit	Primary or Secondary	Activity Data source	EF source / Default
Waste feedstock extraction	Waste Input per waste type eg. food waste, DAF sludge, WWTP Sludge. Report percentage of degradable organic carbon (DOC) and percentage total solids / dry solids.	kg, DOC, %DS	Primary (based on actual formulation)	Project/ Site specific	DOC Table Calculated
Waste feedstock transportation	Road freight	L fuel / or t.km	Primary / secondary	Freight fuel use; alternatively, Feedstock Weight and distance travel	MFE direct fuel use + WTT indirec emissions
Biogas Processing (Indirect emissions)	Chemicals	kg or $	Primary or Secondary	Site Records or expenditure	Ecoinvent
	Electricity used from grid	kWh	Primary	energy invoices	MFE location-based EF
	Consumables	kg or $	Primary or Secondary	Site Records, expenses	Supplier specific or Ecoinvent, MFE
Biogas Processing (Direct emissions)	Fugitive emissions	m^3 gas	Primary or Secondary		default fugitive emissions c calculate
Biogas Processing (Direct emissions)	Digester Leakage	m^3 gas	Primary or Secondary	Site Measurements preferable	default fugitive emissions c calculate
	Flaring / Combustion	m^3 gas	Primary	Flare Flow control	MFE
	Digestate storage and Lagoons	m^3 CH_4	Primary or Secondary	input rate of volatile solids (VS) measured monthly	Calculated per Equatio 15 Default: 0.48 m^3 CH_4/kg VS

WTT NZ

Geography	kg CO2-e/GJ
UK	13
NZ	7
Australia	4 to 23

Table 17: Upstream WTT emission factors for fuels and electricity (New Zealand)

Source: Agrilink New Zealand fuel and electricity total primary energy and life cycle greenhouse gas emission factors 2022 - July 2022. August 2023 (Table 2 Summary of fuel energy and life cycle emission factors)

Fuel type	Unit	Fugitive Energy Coefficient	GHG[2] – 2007 (gCO_2e/ unit)	GHG[2] – 2007 (gCO_2e/ unit)[3]	GHG[2] – 2007 (gCO_2e/ unit)
					WTT - Upstream Emissions
			Scope 1 & 3	*Scope* 1	
Diesel	litres	1.21	3,147	2,689	458
Petrol (regular unleaded)	litres	1.21	2,760	2,341	419
Biodiesel (tallow) †	kg	0.50	1,750	-	-
Light fuel oil	litres	1.21	3,415	2,930	485
Marine diesel oil	litres	1.21	3,342	2,879	463
Bunker/Heavy fuel oil	litres	1.21	3,539	3,046	493
Intermediate fuel oil	litres	1.21	3,520	3,030	490
Heavy fuel oil (electricity)	litres	1.21	3,498	3,007	491
Aviation gasoline	litres	1.21	2,634	2,230	404
Natural Gas (Commercial)	MJ	1.13	60.7	53.8	7
LPG	kg	1.13	3,313	2,972	341
Coal (bituminous)	kg	1.02	2,761	2,607	154
Coal (sub-bituminous)	kg	1.02	2,068	1,955	113
Coal (lignite)	kg	1.02	1,512	1,433	79

Next Steps:

1. Worked examples and calculator.
2. Avoided emissions methodology.
3. Cover feedstocks from agricultural crops.

Gas transition plan

Policy & Regulatory

Potential roles:

- Carbon price (NZ ETS).
- Renewable energy certificates.
- Recognise CCUS.
- Financial or other incentives/ penalties.
- Target setting.

Upstream gas sector

Potential roles:

- Eliminate fugitive emissions of methane.
- Become net zero in operations.
- Lead investment in nascent, low-emissions technologies.
- Support and facilitate CCUS.

Midstream gas sector

Potential roles:

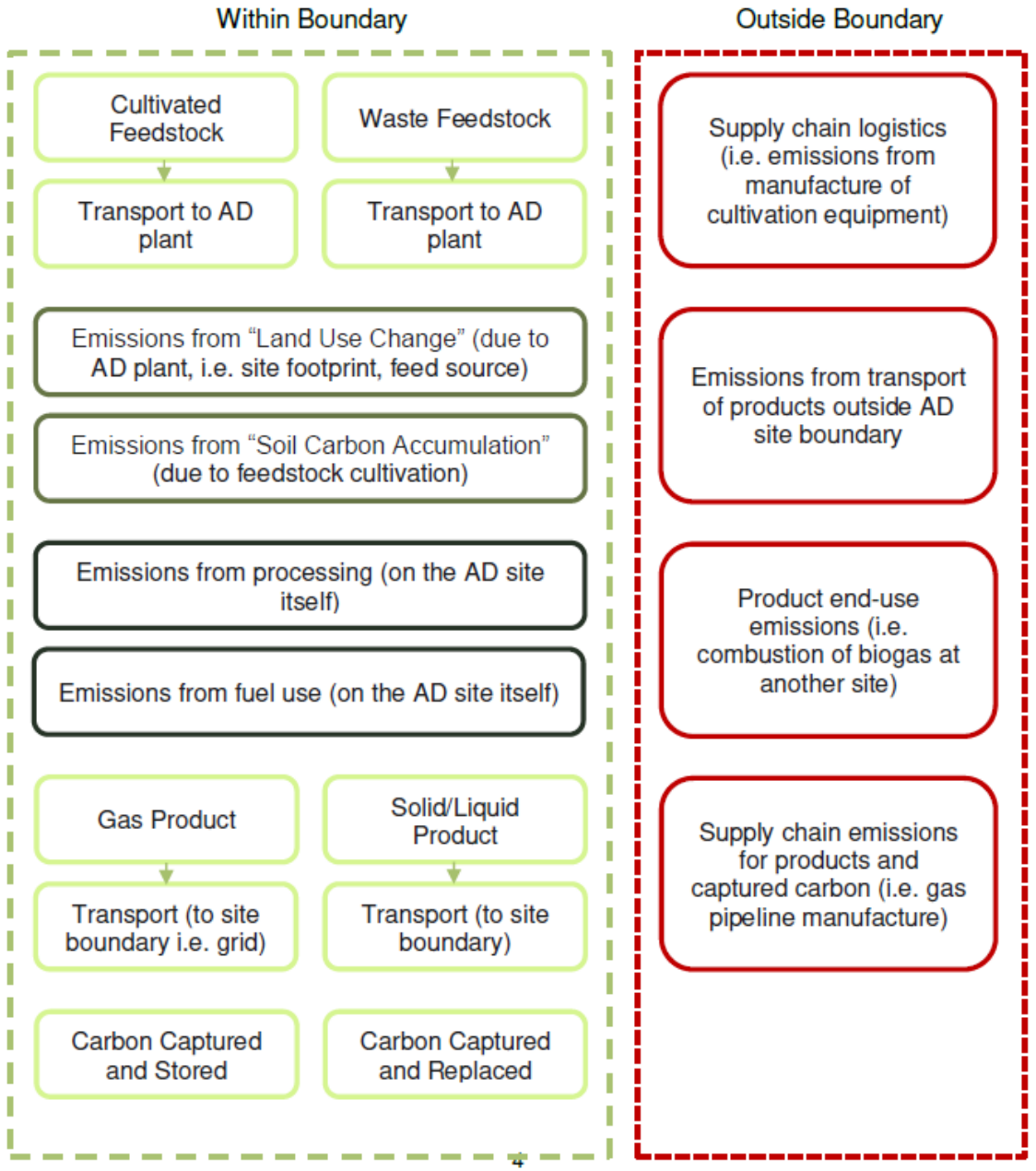
- Eliminate fugitive emissions. through better monitoring.
- Enable pipeline hydrogen.
- Support and facilitate CCUS.

Downstream gas sector

Potential roles:

- Improve energy efficiency.
- Switch to renewable alternatives.
- Employ CCUS.
- Enter into long term supply agreements to underwrite investment in renewable energy.

World Biogas Association



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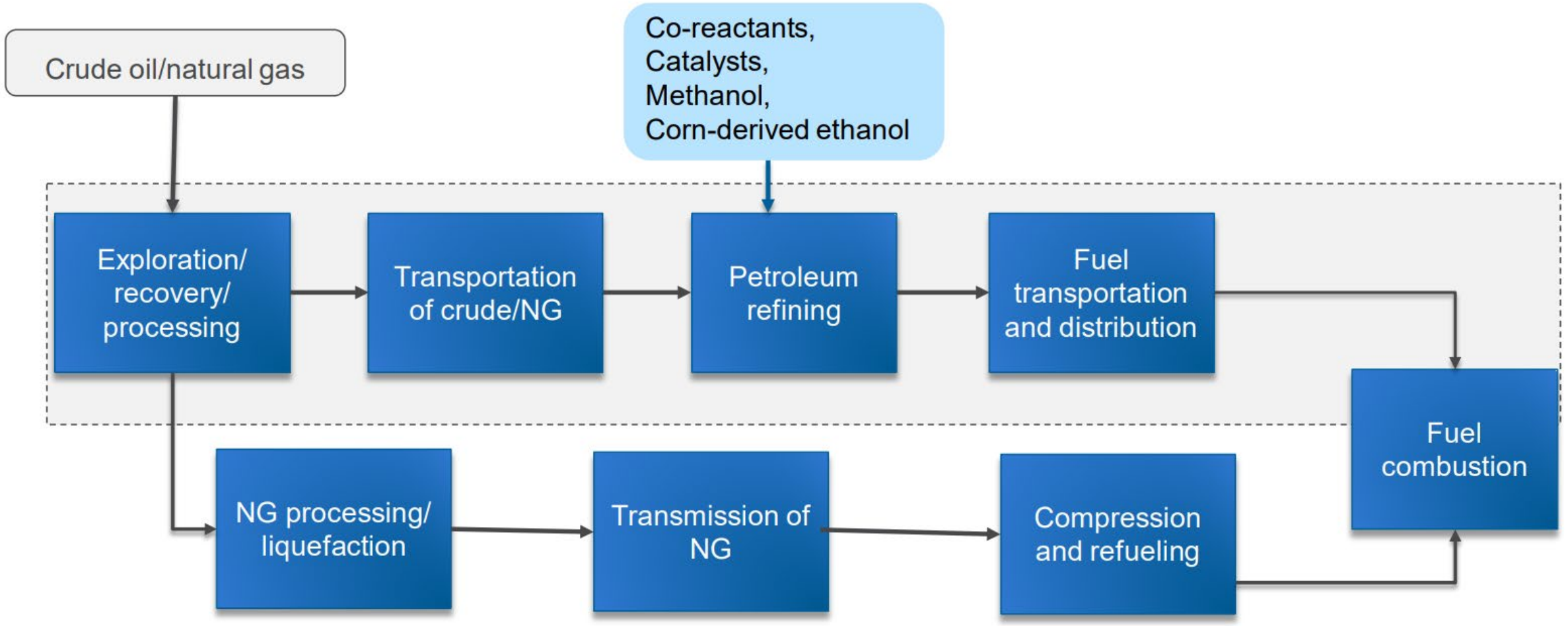
Crude oil/natural gas
Co-reactants,
Catalysts,
Methanol,
Corn-derived ethanol
Exploration/
recovery/
processing
Transportation
of crude/NG
Petroleum
refining
Fuel
transportation
and distribution
Fuel
combustion
NG processing/
liquefaction
Transmission of
NG
Compression
and refueling