AIST Environmental Value Assessment for e-Fuels and Global Standardization

Enabling International Collaboration through Harmonized LCA & TEA Methodologies

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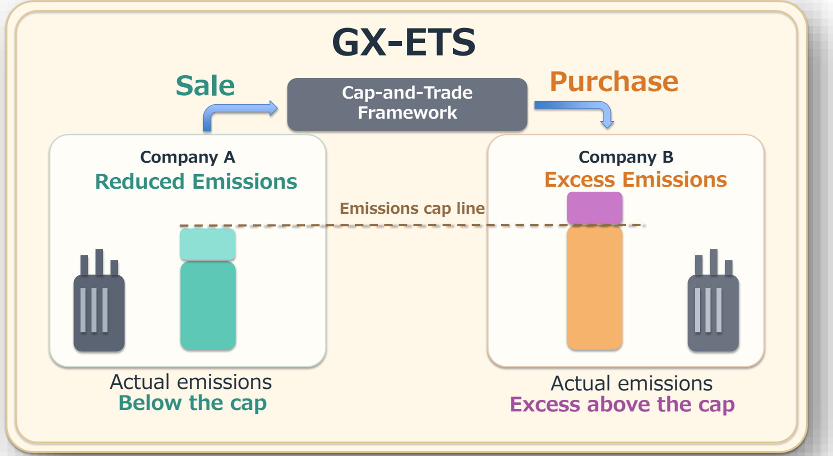
Need for CCUS and CDR

Demand for Establishing Energy Security

- Strait of Hormuz disruption could spike oil prices and harm the economy.
- Energy supply risks are increasing.
- Stable domestic energy sources are urgently needed, even at higher cost.
- CCUS/CDR won't replace primary energy, but are valuable as emergency domestic options.

Launch of GX-ETS and Expansion of Carbon Credit Markets

- Full operation will begin in FY2026.
- Applicable to 300–400 domestic companies; global expansion is expected.
- CCUS/CDR markets are immature and based on bilateral transactions.
- Uncertainty remains around a global CCUS/CDR credit market, but proper environmental value assessment is increasingly important as ETS expands.



Market Formation Needs for CCUS and CDR

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Critical Requirements for Market Establishment

Transparent Assessment

Carbon credits for CCUS/CDR require rigorous, transparent lifecycle assessment and techno-economic assessment (LCA/TEA). Inconsistent methods across countries and organizations erode market trust and prevent cross-border comparison.

Fair Credit Valuation

CCUS/CDR are currently cost-uncompetitive (2–5× higher cost). Carbon credit markets can bridge this gap only if environmental benefits are accurately quantified per unit. Scaling e-fuels requires harmonized LCA/TEA methodologies.

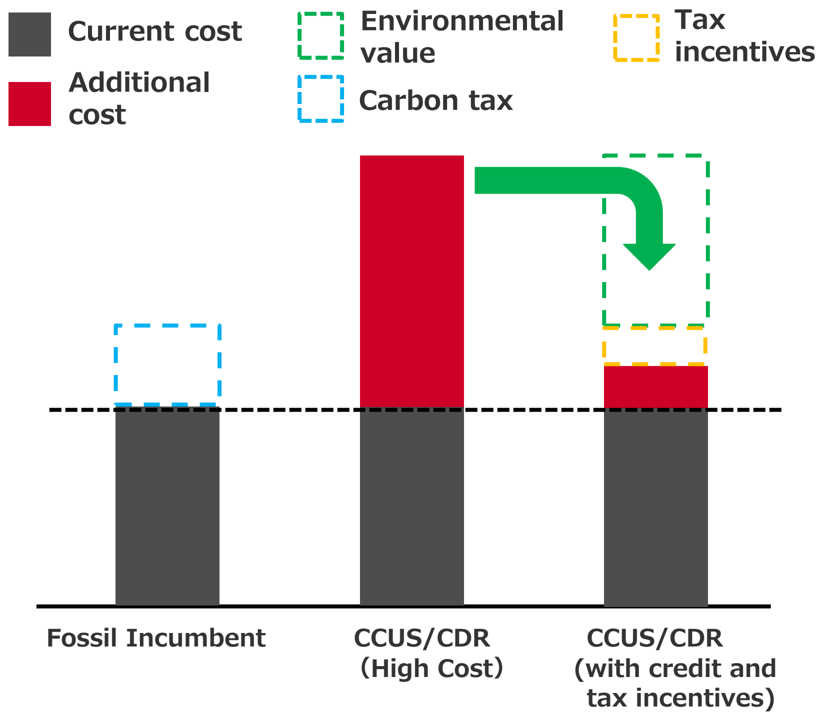
Alignment with Int'l Policy

Currently, key frameworks mandate assessment: Japan 7th Basic Energy Plan (creating CDR market), EU RFNBO Regulation (lifecycle GHG calc), and IEA Net Zero by 2050 (essential for hard-to-abate sectors). Consistency with global frameworks (IEA, Mission Innovation, EU delegated acts) is crucial to reduce investment risk and regulatory uncertainty across borders.

Evidence-Based Scaling

Current markets lack sufficient liquidity due to verification challenges. Scalable, standardized assessment tools are prerequisites for broad market adoption.

Cost Gap & Credit Potential (Conceptual)



Concept: Credits act as a financial bridge. High-cost CCUS/CDR technologies become competitive against fossil incumbents only when "Environmental Value" is monetized.

Requirements for Environmental Value Assessment

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Environmental Value = Net environmental benefit per functional unit across the product lifecycle

For CCUS/CDR: expressed as net CO_2 equivalents removed or avoided per unit product/service, integrated with economic value (TEA).

Key Challenge: Data Confidentiality

Most CCUS/CDR performance data is **commercially sensitive**, preventing transparent assessment. National and project-level alignment of evaluation methods, boundary conditions, and input datasets is urgently needed.

What is Needed: Standardization

International standardization is required for:

- Common system boundaries & functional units
- Standardized data sources (e.g., Ecoinvent)
- Aligned crediting and accounting
- Validated MRV protocols

Selected International Guidelines and Standards for CCUS/CDR

Org.	Document / Standard	Scope	Year
ISO	ISO 14040/14044 — Life Cycle Assessment	LCA methodology (general)	2006
EU Comm.	Delegated Regulation (EU) 2023/1185	GHG calc. for renewable fuels	2023
IEA	Towards Common Criteria for Sust. Fuels	E-fuels LCA/TEA criteria	2024
ICAO	CORSIA Lifecycle Emissions Methodology	SAF carbon intensity (aviation)	2019/2 2
IMO	LCA Guidelines for Marine Fuels (MEPC 80)	Shipping fuel CI (WtW)	2023
GCI	CO_2 Utilization: Environmental Implications	CCU system boundary & LCA	2016
CONCAWE	E-Fuels Techno-Economic Assessment	Synthetic fuel cost & GHG	2024

Data sources and evaluation conditions are not harmonized.

AIST's Solution: A Unified LCA+TEA Assessment Tool

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Current Challenges

Proprietary Black Box
Lack of transparency in company data prevents verification, leading to trust issues in the market.

Inconsistent Methods
Varied boundaries and functional units make comparison across technologies impossible.

Uncertainty Risk
High uncertainty in early-stage tech hinders investment decisions and policy support.

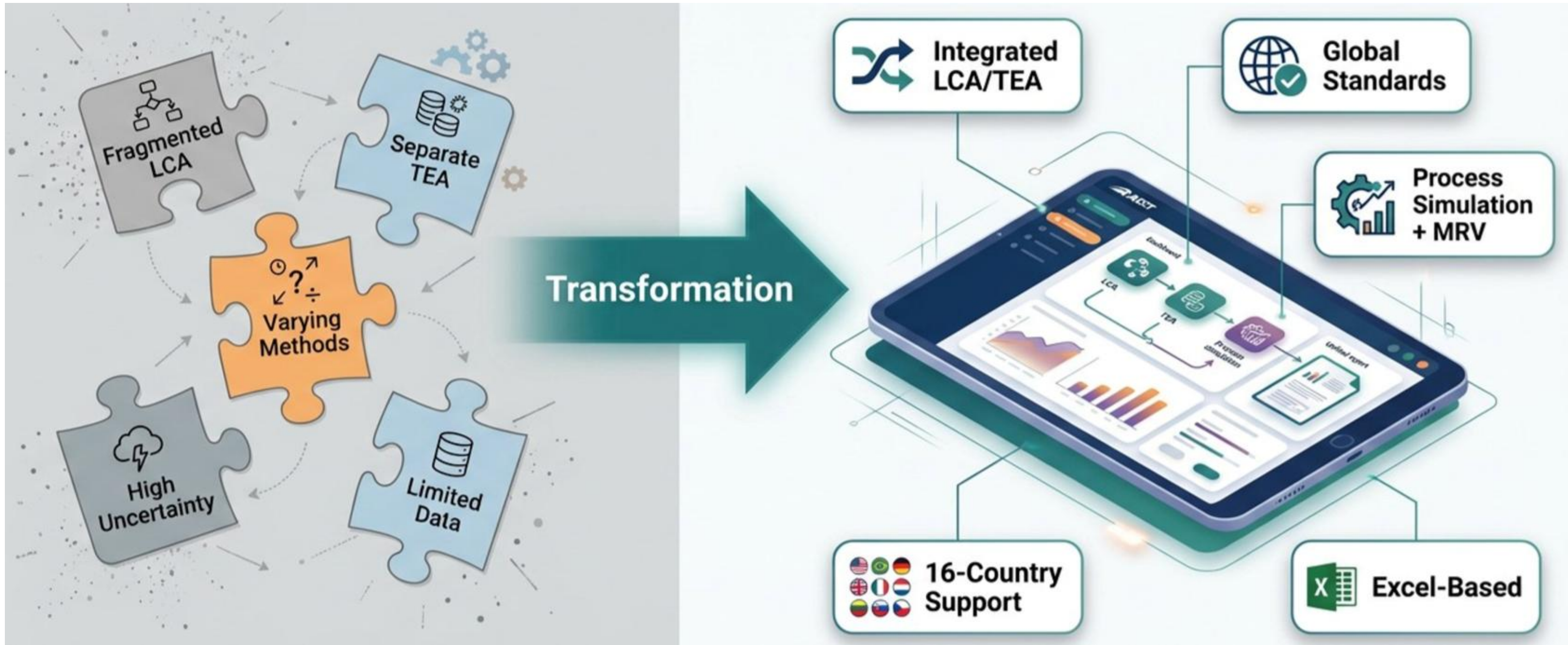
AIST Unified Solution

Global Harmonization
Unifies methods, boundary conditions, and datasets internationally.

Simultaneous LCA & TEA
Links climate impact directly with cost and credit valuation.

Data Fidelity
Uses process simulation & MRV-quality primary data + regional backgrounds.

Transparent Platform
Excel-based open structure: separates inventory from indicators.



Capabilities of AIST Assessment Tool

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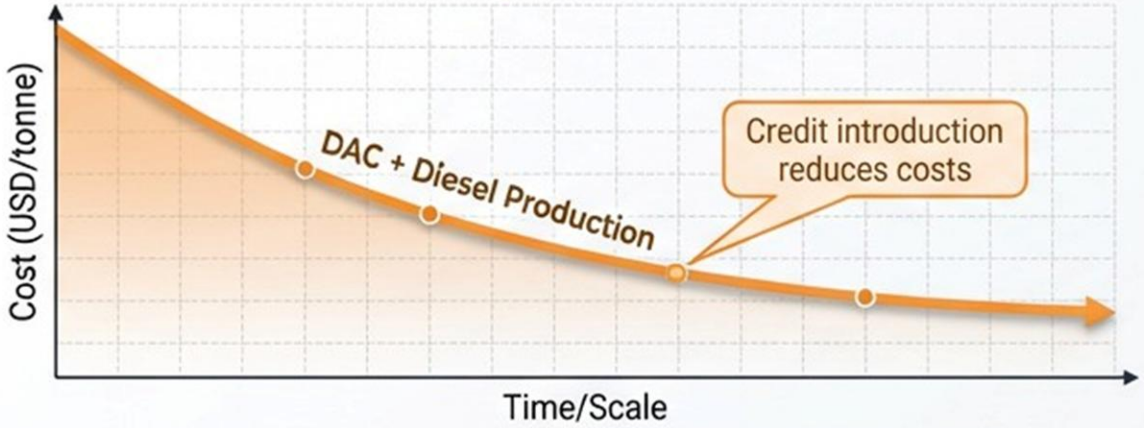
Baseline & Credit Approach

Cost Reduction Pathway



SWOT Analysis

S (Strengths)
Physical Adsorption, High Selectivity, Scalability

W (Weaknesses)
High Energy Demand, Sorbent Regeneration Cost, Water Footprint

O (Opportunities)
Carbon Markets, EOR Integration, Policy Incentives, DAC Hubs

T (Threats)
Regulatory Uncertainty, Public Perception, Competition from Other Technologies

Multi-Stakeholder Value

Companies

- Accurate self-assessment
- Global value communication
- Supply chain optimization
- Compliance reporting

Investors/Traders

- Objective evaluation
- Risk assessment
- Portfolio diversification
- Due diligence support

Governments

- Policy design
- International negotiation
- Regulatory framework development
- National emissions inventory

AIST vs Competitors: LCA & TEA Integration

	LCA	TEA
AIST	✓	✓
GREET (LCA only)	✓	✗
NETL (LCA only)	✓	✗
NREL (TEA only)	✗	✓
Planet A (TEA only)	✗	✓

Capabilities of AIST Assessment Tool

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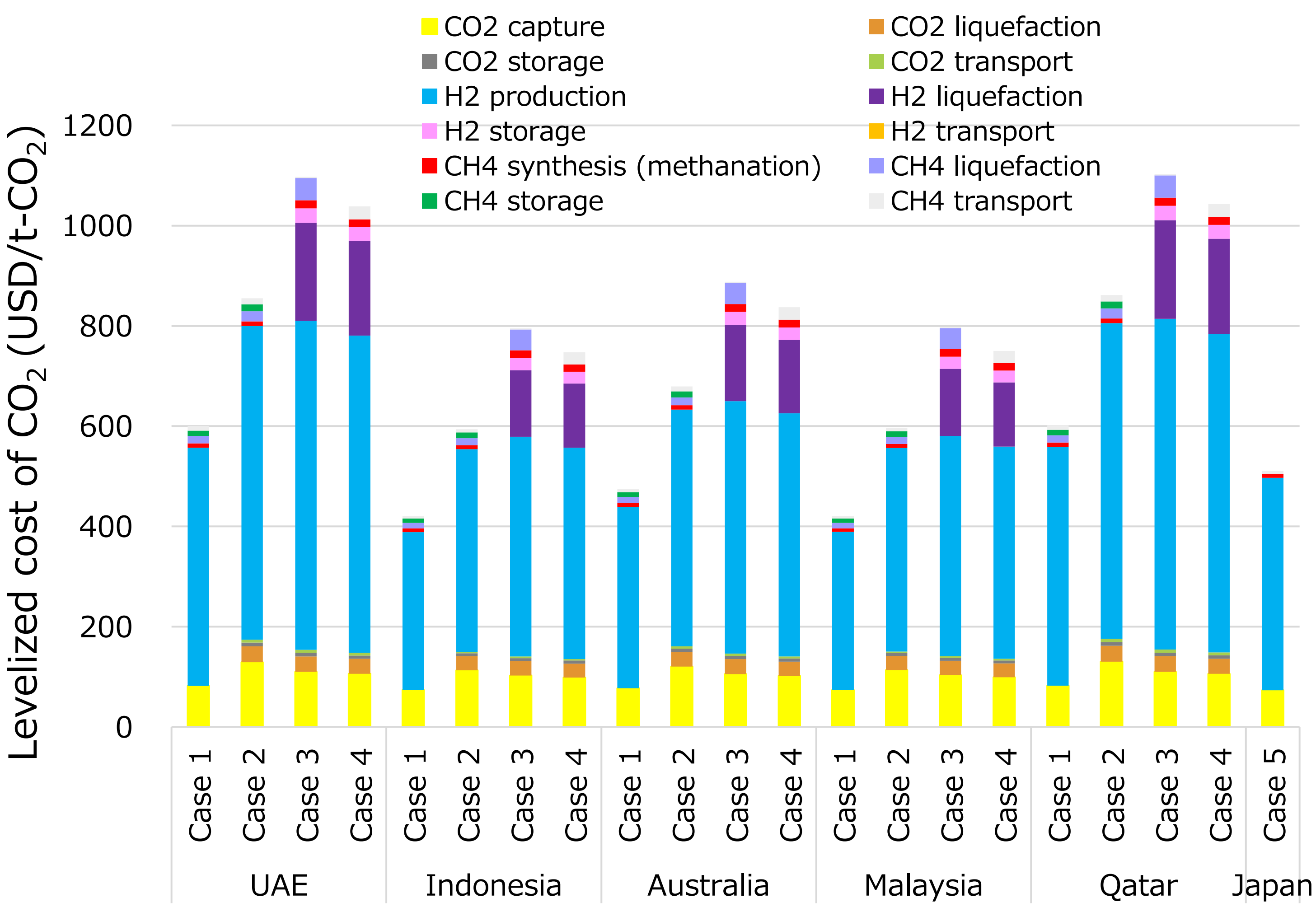
Levelized cost of CO_2 for synthesized methane

(*Case of CO_2 Capture from LNG-Fired Power Plants / Cross-Country Comparison*)



1. Environmental Value Assessment

Evaluate environmental value using metrics such as levelized CO_2 cost and product cost to support credit price forecasting.

2. Business Design & Screening

Identify cost-optimal conditions from CO_2 sources, technologies, energy, and partner countries to enable efficient project design.

3. Standardized Evaluation

Enable consistent comparison of technologies using internationally standardized LCA/TEA methods.

Capabilities of AIST Assessment Tool

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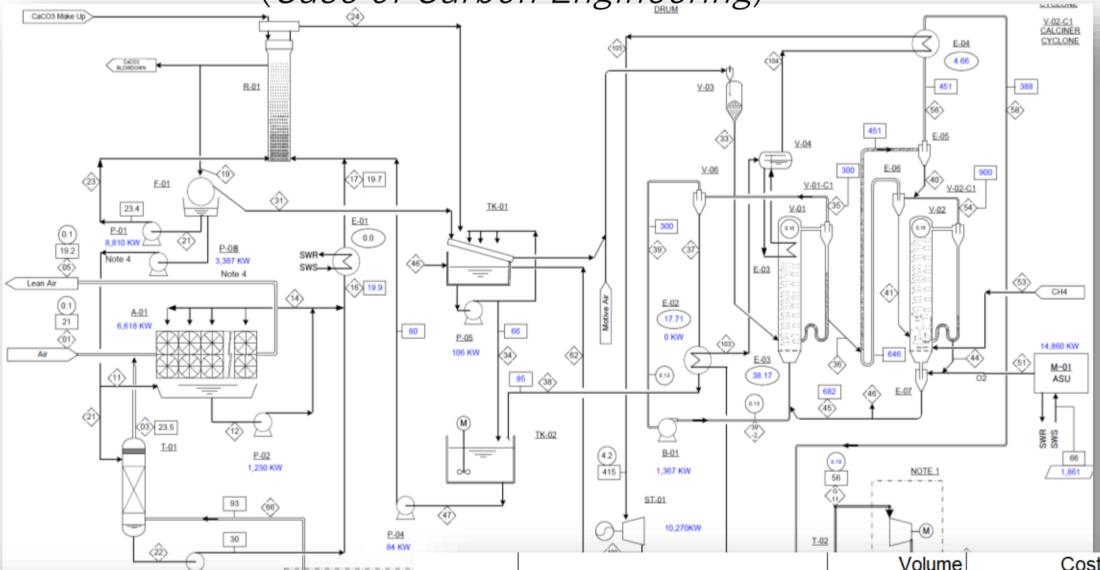
Process simulation data of direct air capture

(*Case of Carbon Engineering*)



Equipment		電力	
ITEM No.	SERVICE	Elec MW	Elec MW
A-01	Air Conatctor	+6.61	
F-01	Fines Filter	+0.61	
P-01	Filtrate Transfer Pump	+8.81	
P-02	Circulation Liquid Pump	+1.23	
P-03	CO2 Absorber Bottoms Pump	+0.31	
P-04	Ca(OH)2 Feed Pump	+0.08	
P-05	CaCO3 Wash Pump	+0.11	
P-06	Condensate Recovery Pump	+0.21	
P-07	Fresh Water Make Up Pump	+0.13	
P-08	Absorber Supply Pump	+3.39	
C-02-P1	GTG BOILER FEED PUMP	+0.18	
C-01-P1	CO2 Transfer Pump	+1.29	
ST-01	Steam Turbine		-10.67
C-02	GAS TURBINE UNIT		-43.82
C-02-ST1	GTG STEAM TURBINE		-10.27
C-01	CO2 Compressor	+21.35	
B-01	SLAKER BLOWER	+1.37	
M-01	ASU	+14.89	
E-01	Cooling Water Exchanger		
E-08	Steam Turbine Condenser		

	Equipment Item	Volume (item)	Cost (10^3 yen)	Cost (USD)
1	Direct construction cost			
1.1	Equipment cost			
1)	Special equipment			
	Air contractor	1600	22,100,000	145,098,812
	FINES FILTER	200	8,000,000	52,524,457
	ASU	1	4,441,667	29,162,016
2)	Tower	5	326,650	2,144,639
3)	Tank	12	231,800	1,521,896
4)	Heating furnace	20	374,400	2,458,145
5)	Reactor	20	3,244,160	21,299,718
6)	Heat exchanger	60	3,308,100	21,719,519
7)	Pump	74	[illegible]	[illegible]

1. Access to Process Information

Access detailed data on the processes within the tool, including process flows, equipment cost lists, and utilities.

2. Identification of Cost Reduction Opportunities

Analyze cost structures—such as equipment and fuel costs—based on detailed data to identify reduction opportunities.

3. Evaluation of R&D Impact

Quantitatively assess the impact of technological development on cost and efficiency to support R&D efforts.

Capabilities of AIST Assessment Tool

DAC + Diesel Cost Reduction

Cost breakdown and reduction potential

Feature of the output:

To ensure cost transparency, both total cost and its breakdown into CAPEX and OPEX are visualized, enabling bottleneck identification and better investment decisions.

1. Quantified R&D Impact

Evaluate cost and CO_2 impact of technology improvements and process optimization across DAC-to-fuel chains. Support R&D decision-making with quantitative assessment.

2. Marketability via SWOT

Assess technology options from multiple perspectives and derive market positioning with structured SWOT analysis for different CO_2 separation technologies.

3. Additional Advantages

Enables evaluation of carbon taxes imposed by mechanisms such as GX-ETS, as well as the mitigation effects achieved through R&D.

Toward a Globally Unified LCA/TEA Methodology

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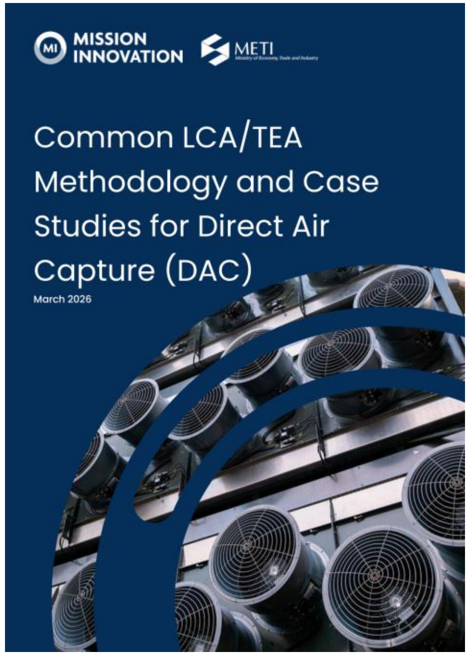
AIST participates in and leads multiple international frameworks to harmonize assessment methods, conditions, and datasets. Unification is the key to trusted international carbon markets.

Framework / Body	AIST Role	Scope of Harmonization	Status
Mission Innovation CDR Mission	**Leader (AIST)**	Unify CO_2 removal quantification, system boundary, functional unit, TEA conditions for DAC & Enhanced Weathering	Active (Leading)
Global CO_2 Initiative (GCI)	Member	Guidelines for CCU (incl. DAC) GHG reduction assessment; cross-boundary accounting methods	Active
Cascade (Voluntary CDR NPO)	Member	Enhanced Weathering CO_2 removal quantification, evaluation scope, MRV protocol standardization	Active
CONCAWE / NEDO (EU Petroleum)	NEDO Partner	Align LCA/TEA methodology for synthetic fuels between Japan and Europe — joint framework development	Active
ERIA (East Asia-ASEAN)	**Leader (AIST)**	Unify CCU emission reduction and economic assessment across East Asian nations	Submitting (Leading)
IMO MEPC	Active/Future	LCA for marine fuels; CI value framework alignment with AIST synthetic methane submission (MEPC 80)	Active / Future



* Mission Innovation: Government-level multilateral initiative (23 countries/regions) to accelerate clean energy R&D. AIST leads the CDR Mission LCA/TEA subgroup.

Status of International LCA/TEA Harmonization

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Key methodological divergences that AIST is driving toward convergence across international frameworks

Dimension	Current Inconsistency (Problem)	AIST Approach (Solution)
System Boundary	⚠ Wide variation: gate-to-gate, cradle-to-gate, cradle-to-grave, well-to-wake. Non-comparable results.	✓ **Unified Default:** Uses cradle-to-gate as default with optional cradle-to-grave extension, aligned with Mission Innovation CDR Mission.
Functional Unit	⚠ Inconsistent: per t CO_2 stored, per MJ energy, per kg product. Comparison is impossible without conversion.	✓ **Standardized:** Allows user-defined units; default follows ISO 14040 and Global CO_2 Initiative (GCI) guidance.
Background Data	⚠ Organization-specific/proprietary databases used without disclosure. Prevents third-party verification.	✓ **Transparent & Localized:** Uses national energy mix data (16 countries); transitioning to Ecoinvent for global auditability.
Counterfactual / Baseline	⚠ No consensus on reference systems for credit calculation, leading to inflated or deflated credit claims.	✓ **Rigorous Methodology:** Applies a transparent, documented baseline consistent with ISO 14064-2 and GCI guidelines.

Collaboration between CONCAWE and AIST

AIST Scope

Countries
Supply chains centered on Japan with overseas partners

Supply Chain
Multi-country pathways with Japan as demand market

Products
10 products including concrete, chemicals, and e-fuels

Focus
CCUS/CDR environmental value assessment

CONCAWE-AIST Joint LCA/TEA Tool

AIST-CMT
Unified Assessment Platform

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CONCAWE
European Standards

Evaluation Scope	Data Quality	Methodology
16 Countries	**Simulation**	**ISO 14040/44**

Joint Tool Scope

Countries
16 countries including EU, Japan, and energy-exporting nations

Supply Chain
Multi-country e-fuels pathways with EU as demand market

Products
10 products including concrete, chemicals, and e-fuels

Metrics
Life cycle CO_2, fuel cost, Levelized CO_2 cost, NPV

Joint Development: **CONCAWE × AIST** Standardization: **LCA/TEA Harmonized** Coverage: **16 Countries**

Collaboration between CONCAWE and AIST

Country A: CO_2 Capture & Production

CO_2 source and e-fuel production

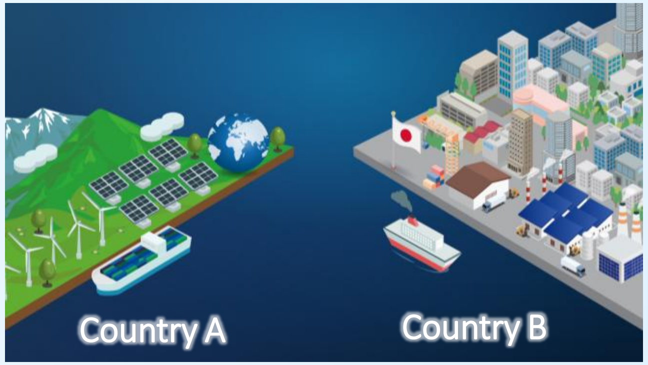
CO_2 Capture
Capture from LNG power plant or DAC

E-fuel Production
Synthesis of synthetic fuels

Export/Transport
Shipping to Country B

Cross-Border Flow

Shipping → Delivery



Country B: E-fuel Utilization

Import and consumption

Import/Receipt
Receive and store e-fuels

E-fuel Utilization
Transport, power generation, etc.

CO_2 Emissions
Accounting and reporting

The IPCC Guidelines do not clearly define how to handle CO_2 in cross-border carbon recycling.
(Source: Subcommittee on Carbon Management, METI)

Summary & Future Collaboration

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AIST-CMT Tool Development & Licensing

AIST has developed **AIST-CMT**, a unified Excel-based LCA/TEA tool that integrates process simulation with simulation data to simultaneously evaluate environmental and economic value. The tool is now available for **licensing to companies** and supports joint tool development initiatives.

CONCAWE-AIST Joint Tool Development

Collaborating with **CONCAWE** (European oil industry association) to develop a shared LCA/TEA tool that harmonizes methodologies for e-fuels across Japan and Europe, covering 16 countries with ISO 14040/44 compliance.

Harmonized Methodologies for International Markets

Standardizing **system boundaries, datasets, and evaluation methods** internationally to build trust in carbon markets, enable cross-border comparison, and reduce investment risks for CCUS/CDR technologies.

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