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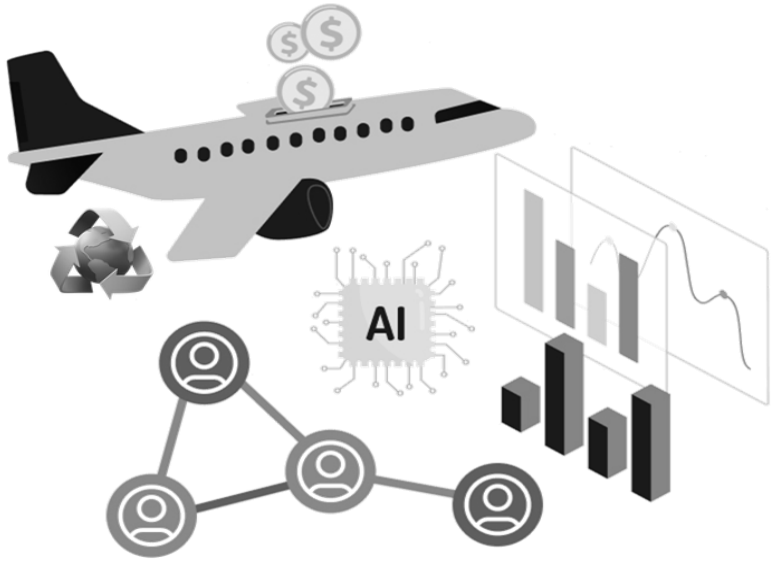
Collaborative actions to bring novel **BIO**fuels **THE**rmochemical **RO**utes into industrial **S**cale



Workshop: Advancing the Sustainability of Aviation and Maritime Biofuels through Digital Innovation and Stakeholder Engagement

8th Central European Biomass Conference (CEBC)

Angeliki Sagani, CERTH

January 21st, 2026
Graz, Austria

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

From Decarbonization Goals to a Digitalized Sustainability Framework

Decarbonization Transportation

Biofuels as a key solution for aviation & maritime

Driving Innovation

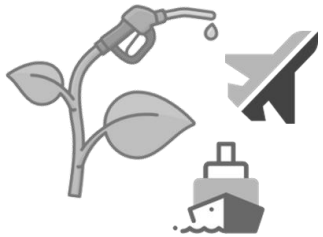
Leveraging digital technologies to accelerate sustainable biofuel deployment

Collaborating Approach

Cross-industry collaboration to enable scalable solutions

Focus on the presentation

Digitalized Life Cycle Sustainability Assessment (LCSA) Framework for biofuels



Setting the stage for a sustainable future in aviation and maritime sector !!

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Sustainability Challenges & Digital Innovation

Biofuels are significant to achieving net-zero emissions. Despite recent advances, significant barriers still limit their sustainable scale-up.

Sustainability Challenges

Environmental

- Feedstock availability
- Land-use concerns
- Life cycle impacts accounting

Economic

- High production cost
- Price volatility
- Limited infrastructure

Operational

- Supply chain complexity
- Certification and traceability
- Scaling production

Digital Tools

Big Data & AI | IoT | Blockchain

LCSA & Digital Innovation

- Real-time monitoring
- Integrated Analysis
- Informed Decision

Efficient; Transparent; Sustainable

→ *Addressing these challenges requires a life cycle, multi-dimensional perspective (LCSA)*

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Life Cycle Sustainability Assessment (LCSA) for biofuels

A holistic LCSA approach integrating environmental, economic, and social impacts across the full life cycle

1. Goal & Scope Definition

- Define system boundaries & functional unit
- Align with ISO 14040/14044 standards
- Establish assessment objectives
- Identify key stakeholders

Life Cycle Inventory Analysis

- Compile inventory data across life cycle stages
- Map material and energy flows
- Document emissions, waste and by-products
- Ensure data quality and completeness

Life Cycle Analysis (LCA)

- Environmental performance evaluation, e.g.,
  - GHG emissions
  - Non-renewable energy use
  - Land use & Biodiversity
- Hotspots evaluation

Life Cycle Costing (LCC)

- Economic performance evaluation, e.g.,
  - CAPEX & OPEX
  - Logistics
  - Environmental externalities
- Risks & opportunities analysis

Social Life Cycle Analysis (sLCA)

- Social performance indicators, e.g.,
  - Heath aspects
  - Safety aspects
  - Energy supply aspects
- Impacts on labor, community

Interpretation

- Trade-offs / Synergies
- Pathways comparison
- Sensitivity analysis
- Recommendations

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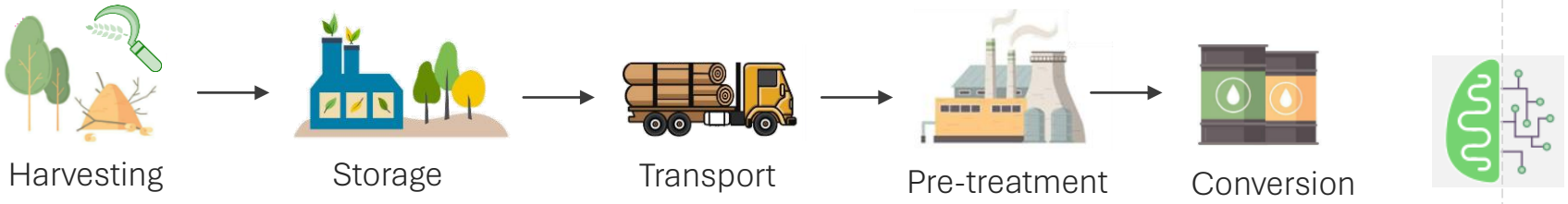
Digitalized Biomass Supply Chain Optimization

Five-Stage Supply Chain



Upstream Optimization

- IoT monitoring of land use
- ML for crop yield forecasting
- Waste & residue tracking
- Multi-objective Optimization

Improving environmental (LCA) & economic (LCC) impacts !!

Smarter Biorefineries

- Digital Twins for process optimization
- Energy and water efficiency monitoring
- Demand forecasting / market alignment
- Predictive Maintenance

Real-time, dynamic LCA & LCC

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Supply Chain Transparency & Traceability

Blockchain, LCSA & Digital Platforms

Blockchain

- Supply chain traceability & transparency
- Real-time data collection
- Insights for supply chains analytics

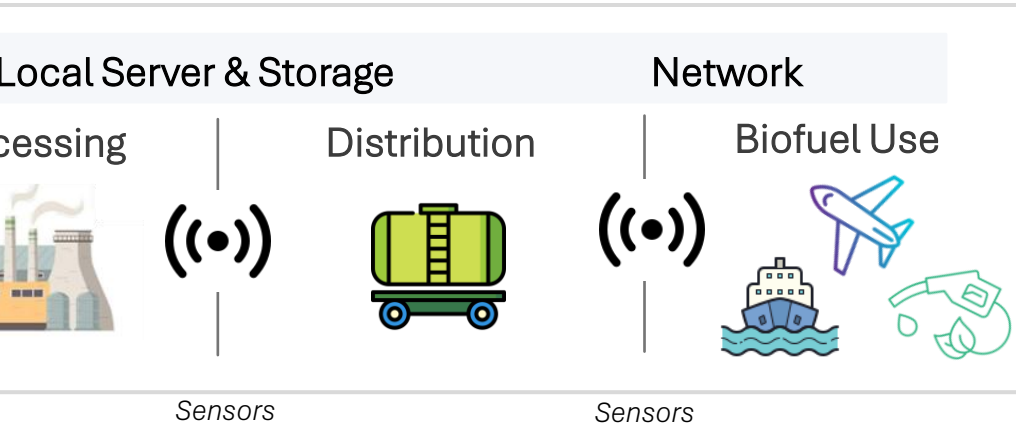
Traceable, Verified Data

LCSA

Input:
Resources; Energy; Materials; Cost

Output:
GHG emissions, production cost, fossil energy use, etc.

Traceable, Verified Data



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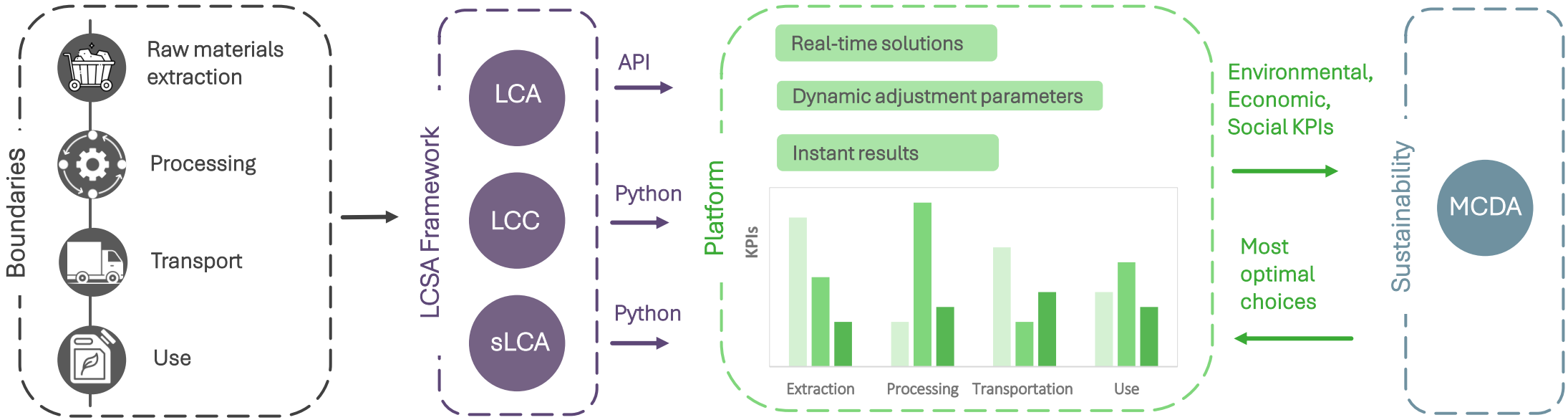
Our Integrated Decision Support System for Sustainability Assessment

Platform Design and Architecture

- Bridges high-fidelity sustainability models and stakeholder decisions
- Hosts expert-validated models in an accessible web interface
- Enables real-time sensitivity analysis and multi-criteria optimization
- No specialized software expertise required



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Methodological Integration: LCA and LCC Modules

Intelligent decision-making tool that empowers industries to assess sustainability, optimize costs, and choose the most eco-efficient biofuel production pathways.

LCA Dashboard

Assess Environmental Impact

Evaluate environmental KPIs (e.g., GHG emissions, fossil energy use

Customize Input Parameters

Energy Mix Composition
Utility Sources
Transportation Logistics

Visual Analysis

Interactive graphs for optimization insights

LCC Dashboard

Assess Environmental Impact

Evaluate environmental KPIs (e.g., GHG emissions, fossil energy use

Customize Input Parameters

Energy Mix Composition
Utility Sources
Transportation Logistics

Visual Analysis

Interactive graphs for optimization insights

Comparison Dashboard

Analyze LCA and LCC results side-by-side to assess environmental and economic trade-offs

Decision Support Dashboard

User Configuration

Selection of value chains, adjustment of dynamic parameters

Parallel Processing

Input + API Call + LCA Software + Environmental Indicators
Input + Python Microservice + Economic Indicators

Decision Output

Ranking of value chains, charts, spreadsheet exports

Stakeholders Preferences (weights) → Multi-Criteria Decision Analysis Engine

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Key Takeaways

Strategic Value for Stakeholders

- Industrial Manufacturers
  - LCC module supports policy-proofing (e.g., carbon tax scenarios, biofuel subsidies)
  - LCA module provides quantitative metrics for verified sustainability and renewable fuel certifications
- Policy Makers
  - Unified framework ensures regulatory incentives and standards are grounded in robust data
  - Facilitates compliance monitoring for renewable energy targets
- Researchers
  - Enables hypothesis testing for alternative biofuel production pathways
  - Real-time benchmarking between conventional vs. novel feedstocks

Unlocking Strategic Value & Sustainable Growth

- Scalable Across Industries:
  - Platform extends to diverse biofuel processes (pyrolysis & gasification)
- Business Impact:
  - Achieve real-time sustainability tracking, cost savings, and stronger compliance
- Future-Ready Innovation:
  - Simplified tools drive data-based decisions and sustainable growth

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Thank you!

Angeliki Sagani, CERTH
Senior Research Engineer
sagani@certh.gr

Dr. Dimitrios Kourkoumpas, CERTH
Senior Collaborating Researcher
kourkoumpas@certh.gr

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