CERESiS Project Overview

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CERESiS Final Event 22/4/2024

CERESiS

ContaminatEd land Remediation through Energy crops for Soil improvement to liquid biofuel Strategies

Our partners

ABE, CERTH Centre for Research & Technology Hellas, STEMS, National Technical University of Athens, KIT Karlsruhe Institute of Technology, Kokkalis Foundation, University of Strathclyde Engineering, UFG Universidade Federal de Goiás, eXergia Climate Change Consultants, netcompany intrasoft, Università degli Studi della Tuscia, Université de Sherbrooke

This project leading has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006717

FAPEG Fundação de Amparo à Pesquisa do Estado de Goiás

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Fonds Nouvelles frontières en recherche
New Frontiers in Research Fund

Fonds de recherche Société et culture Québec

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CERESiS Aim & Objectives

- **Aim**: CERESiS aims to develop, assess and validate **integrated biofuel production pathways linking land decontamination to appropriate bioenergy crops** and environmentally & economically efficient **advanced biofuel production** → WIN WIN
- **Objective 1**: Demonstrate the **suitability and effectiveness of various conventional and novel species of energy crops for phytomanagement & phytoremediation purposes in contaminated land**, against a variety of the most common contaminants globally
- **Objective 2**: **Demonstrate the potential of two novel thermochemical processes**, i.e. Supercritical Water Gasification (SCWG) and Fast Pyrolysis (FP), **for the production of biofuels and key biofuel precursors**
- **Objective 3:** Provide **decision support to stakeholders and policy makers in order to achieve optimal win-win solutions** for site-specific land decontamination through phytoremediation while simultaneously producing clean liquid biofuels

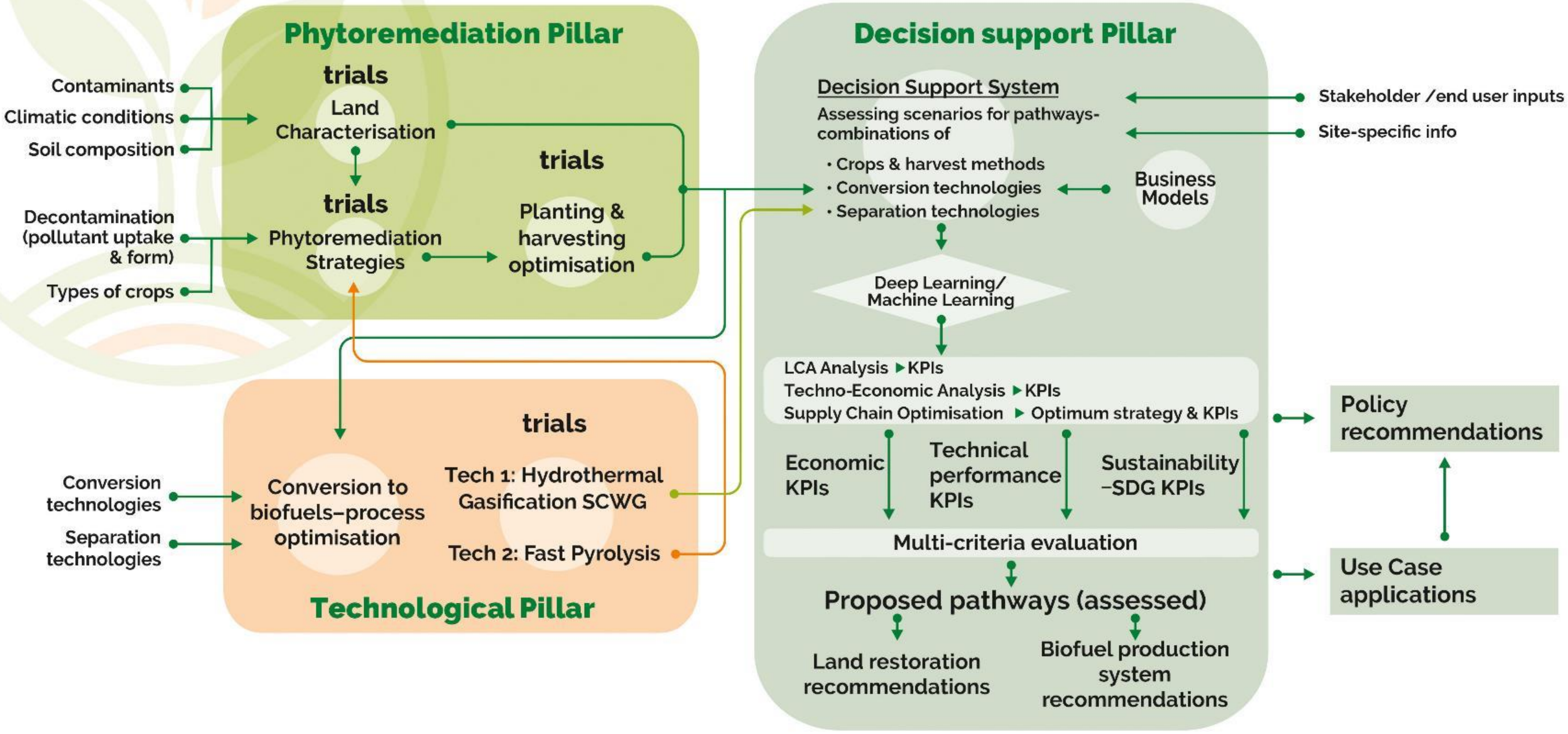
CERESiS partners

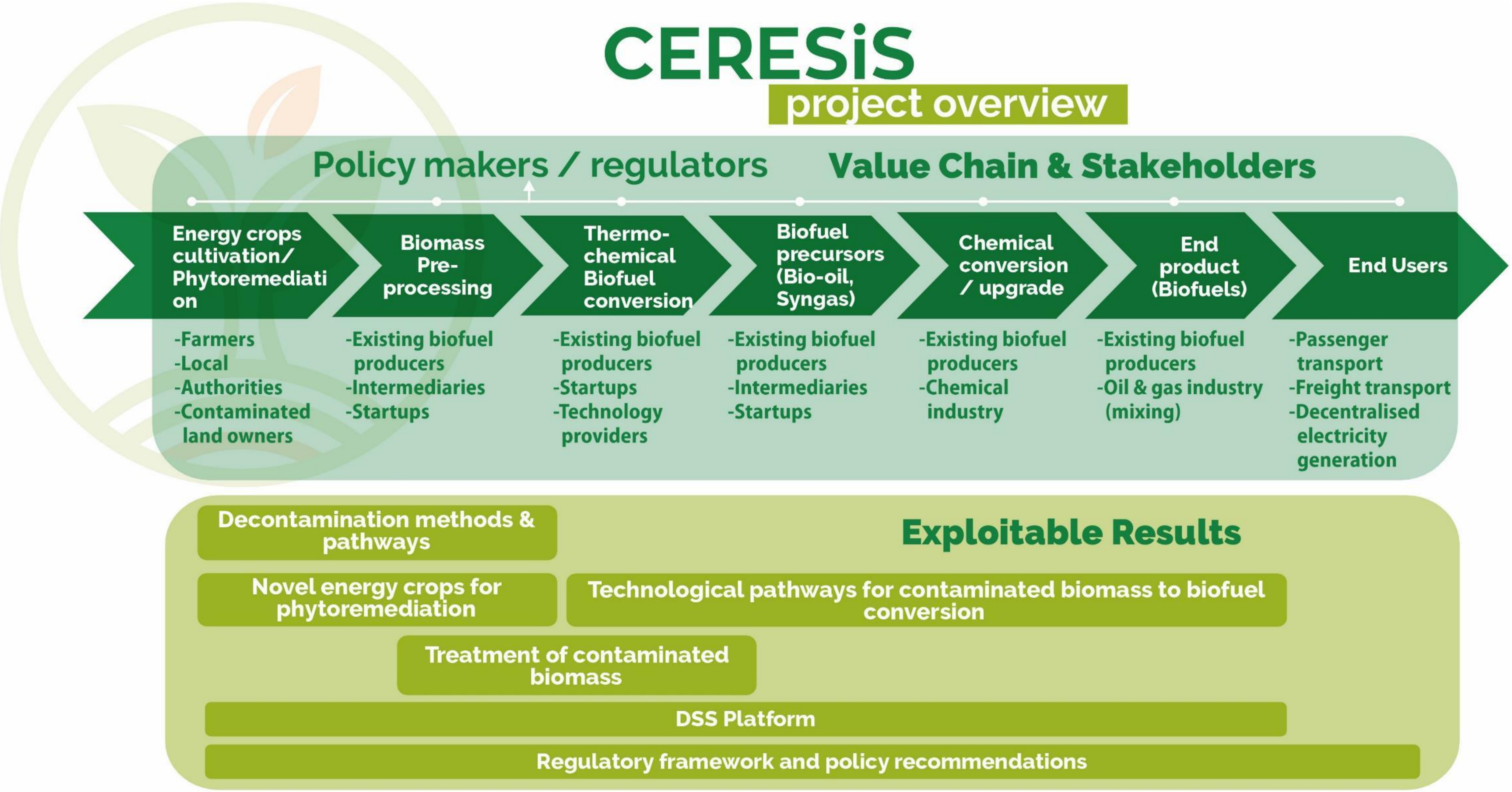
8 Countries

12 partners

- 6 Universities
- 2 Research Institutes
- 2 Companies/Industry
- 2 NGOs

CERESiS project overview




CERESiS
project overview
Policy makers / regulators
Value Chain & Stakeholders
Energy crops cultivation/ Phytoremediation
Biomass Pre-processing
Thermo-chemical Biofuel conversion
Biofuel precursors (Bio-oil, Syngas)
Chemical conversion / upgrade
End product (Biofuels)
End Users
-Farmers -Local -Authorities -Contaminated land owners
-Existing biofuel producers -Intermediaries -Startups
-Existing biofuel producers -Startups -Technology providers
-Existing biofuel producers -Intermediaries -Startups
-Existing biofuel producers -Chemical industry
-Existing biofuel producers -Oil & gas industry (mixing)
-Passenger transport -Freight transport -Decentralised electricity generation
Exploitable Results
Decontamination methods & pathways
Novel energy crops for phytoremediation
Technological pathways for contaminated biomass to biofuel conversion
Treatment of contaminated biomass
DSS Platform
Regulatory framework and policy recommendations

CERESiS phytoremediation strategy

Plant perennial grasses for phyto-stabilisation to:

- Maximise biomass yield (maximize energy production + income)
- Minimize contaminant uptake (minimise downstream issues)
- Maximise contaminant offtake (phyto-management during beneficial use of contaminated sites)

CERESiS trial sites

University of Strathclyde Glasgow

ABE

UFG
UNIVERSIDADE FEDERAL DE GOIÁS

UNIVERSITÀ DEGLI STUDI DELLA TUSCIA

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Supercritical Water Gasification and Downstream Gas-Upgrading

SCWG

Initial Drawbacks

- Relatively low gasification efficiencies (CE < 75 %)
- Salt separation not sufficient to remove precipitating inorganics, leading to blockages
- Some formation of coke in reactors

Systematic Investigation and Development

*(Lab-plant redesigned several times, **103 experiments** carried out)*

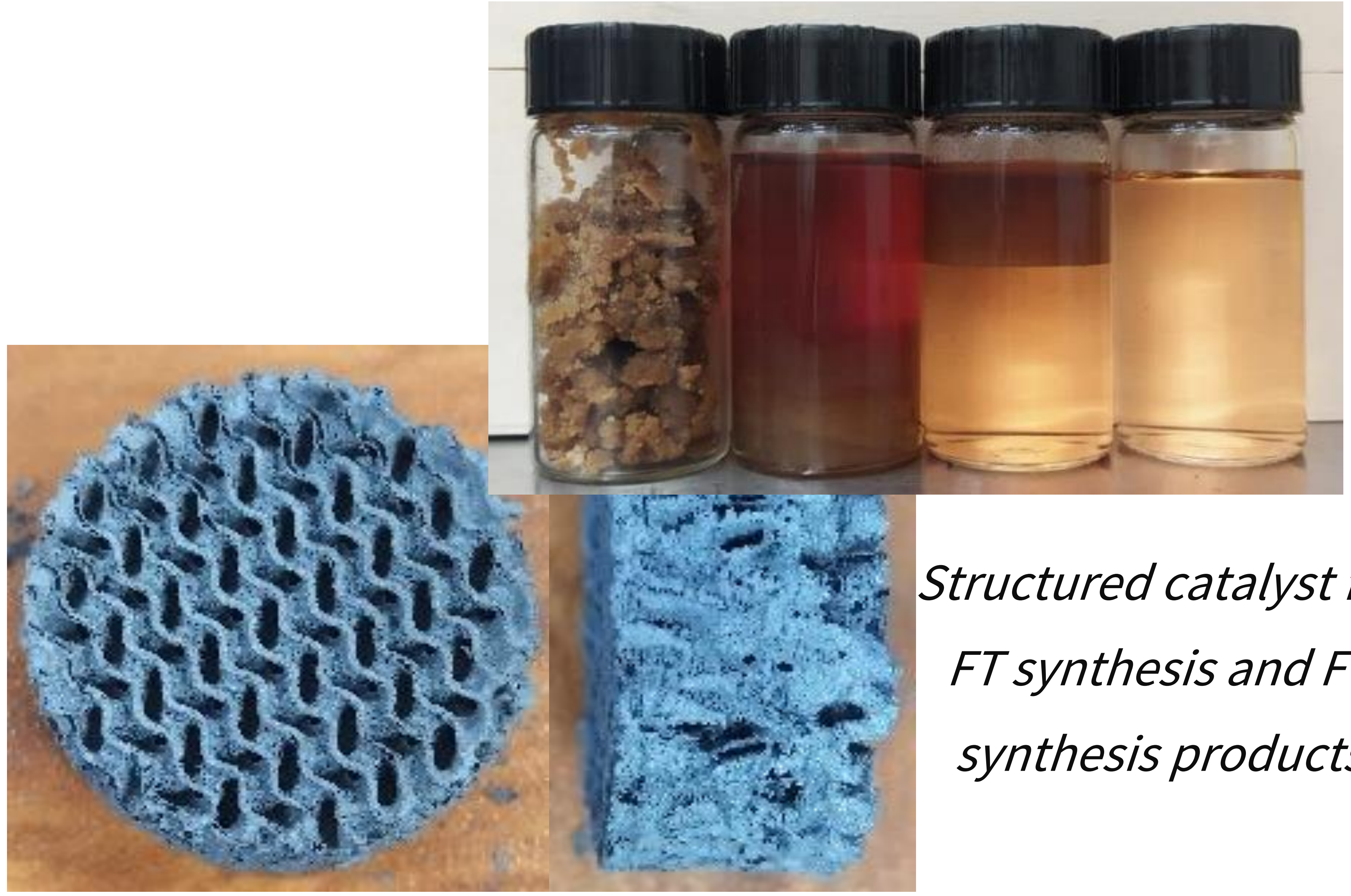
Final Results

- Lab-plant was developed which enables
  - High gasification efficiencies (CE > 90%)
  - Long time operation without solid formation
- Optimal operational parameters determined

Hydrocarbon Reforming and Fischer-Tropsch Synthesis

Main achievements

- Optimal reactor material (Inconel 625) and process conditions for the **dry reforming** of the SCWG product gas determined → **complete CH_4 conversion achieved**
- Production of structured Fe-catalysts using 3D printing methods for **FT synthesis**
  → different promotors tested in the catalyst
- Successful **FT synthesis for 100 h** → hydrocarbons produced in the diesel range

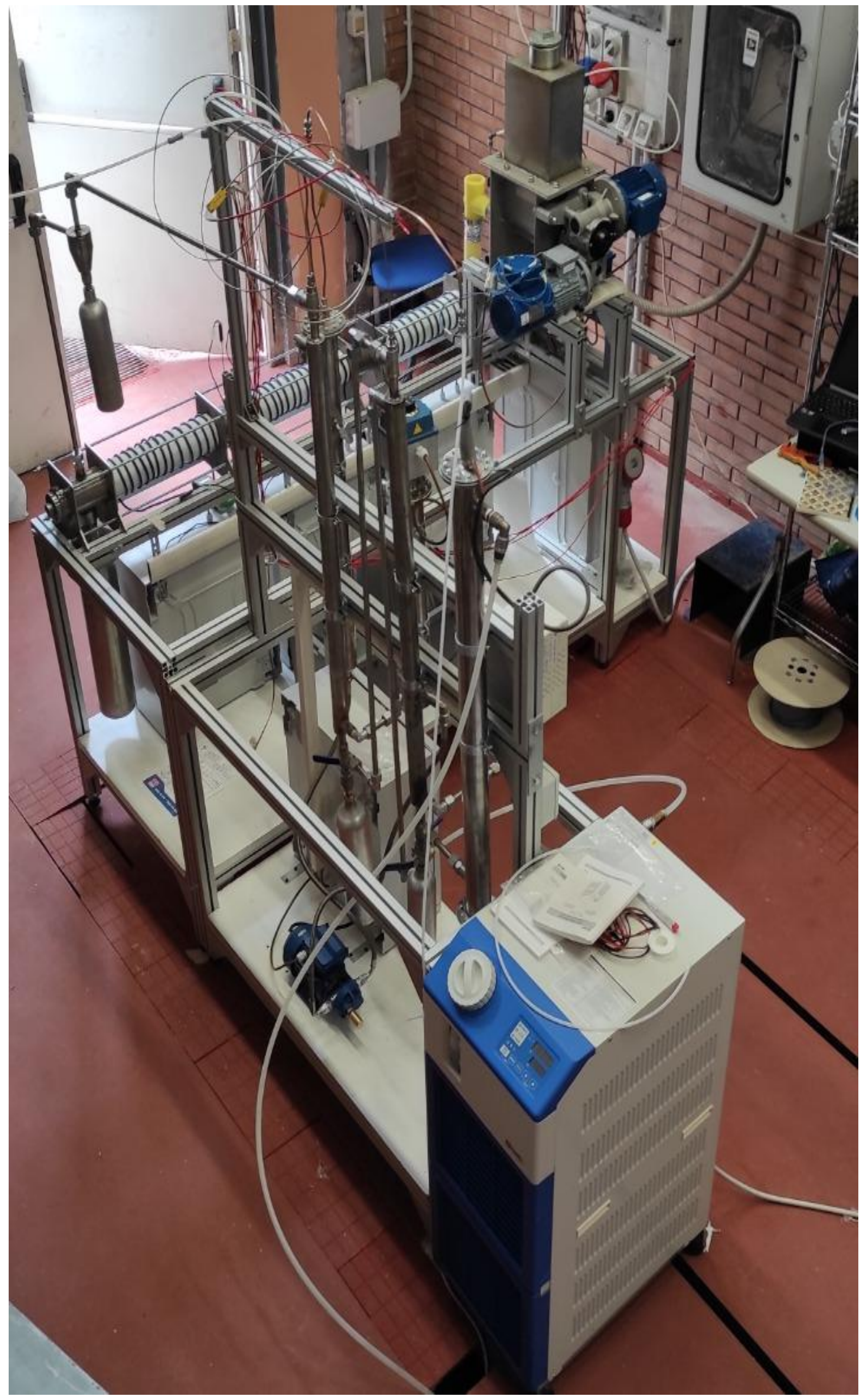


Structured catalyst for FT synthesis and FT synthesis products

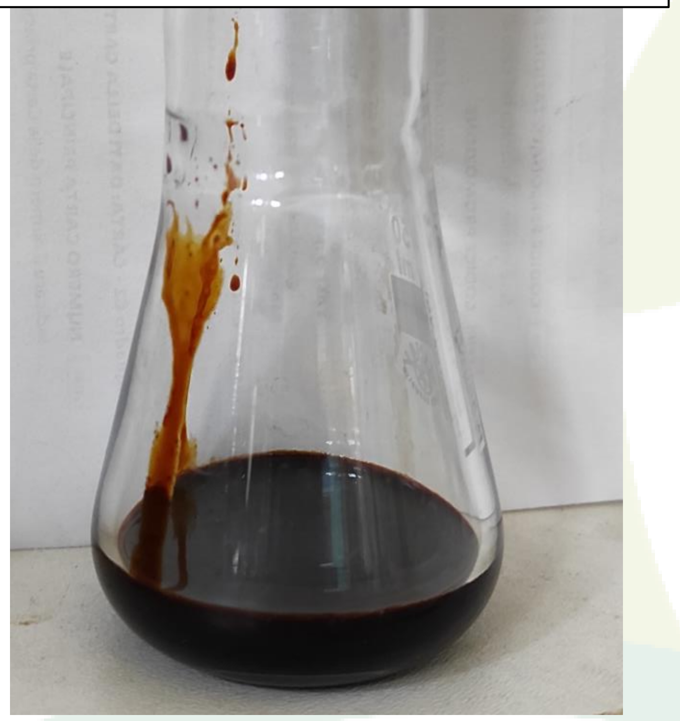
Pyrolysis technology pathway

Optimization of the plant operating conditions

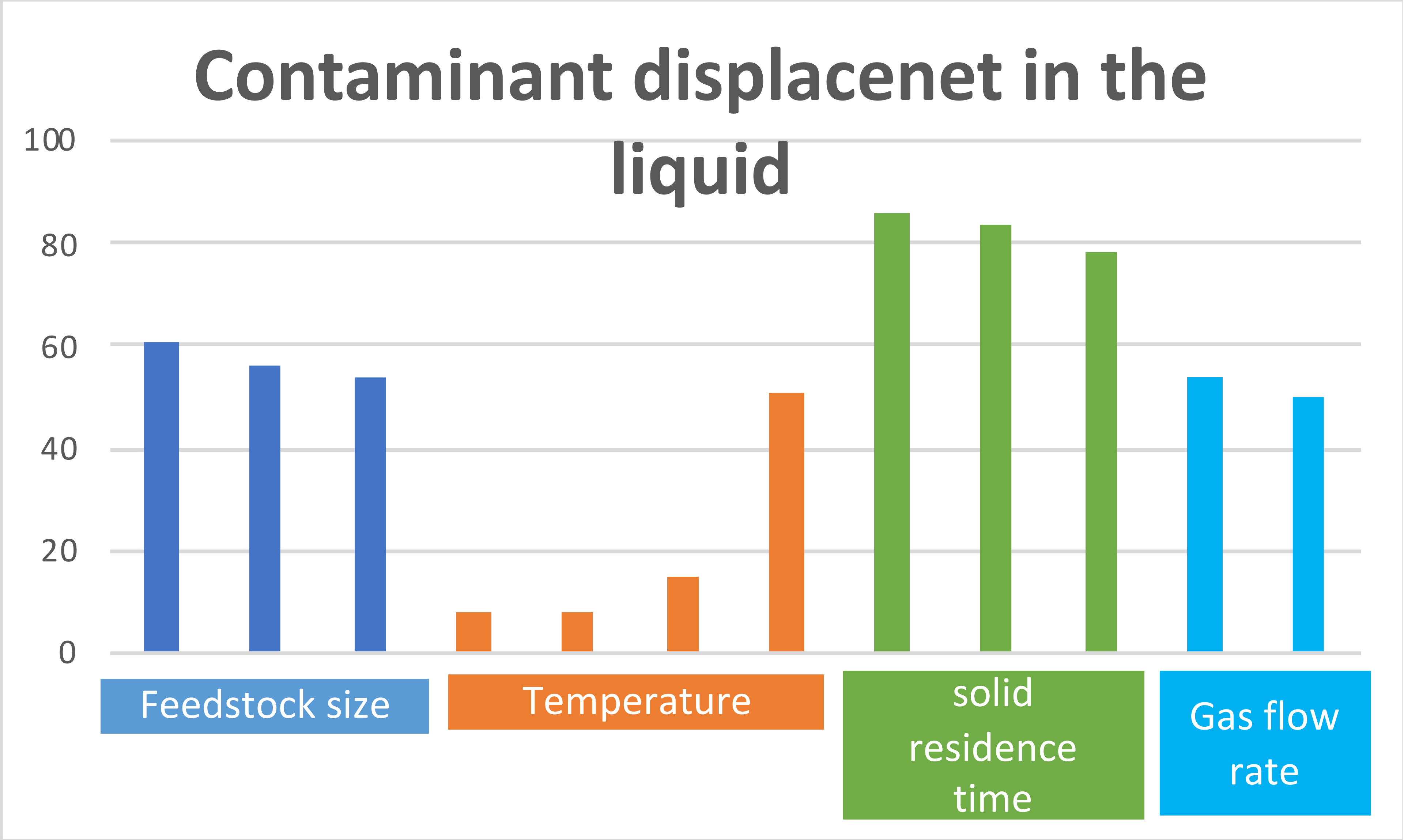
- 15 experiments varying three key influential parameters: temperature, carrier gas flow rate, solid residence time
- Novelty: optimization taking into account both liquid yield/quality and contamination



Oily fraction



Aqueous fraction



Performance of the pyrolysis plant

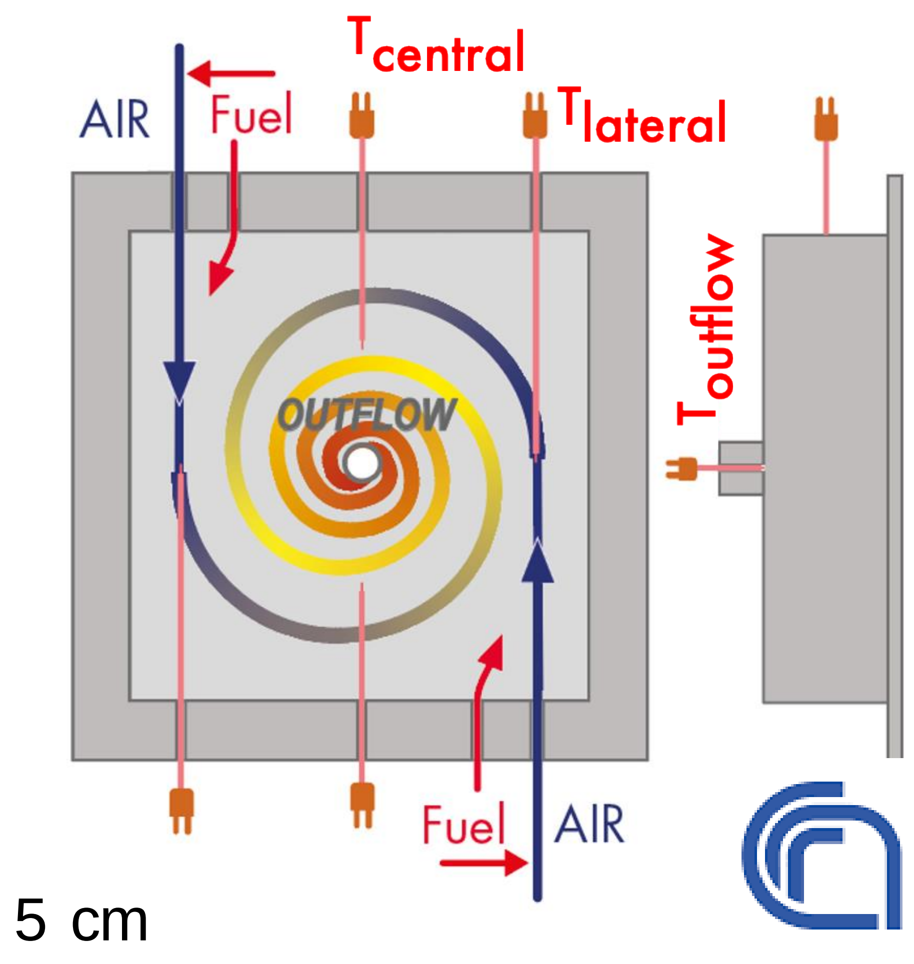
- 8 Experiments to evaluate the performance with different biomasses (herbaceous and woody).
- **Main achievements:** Liquid yield between **30-40 wt%,** very low average solid content (**0.13 wt%**), contaminant content (**100-600 ppm**)

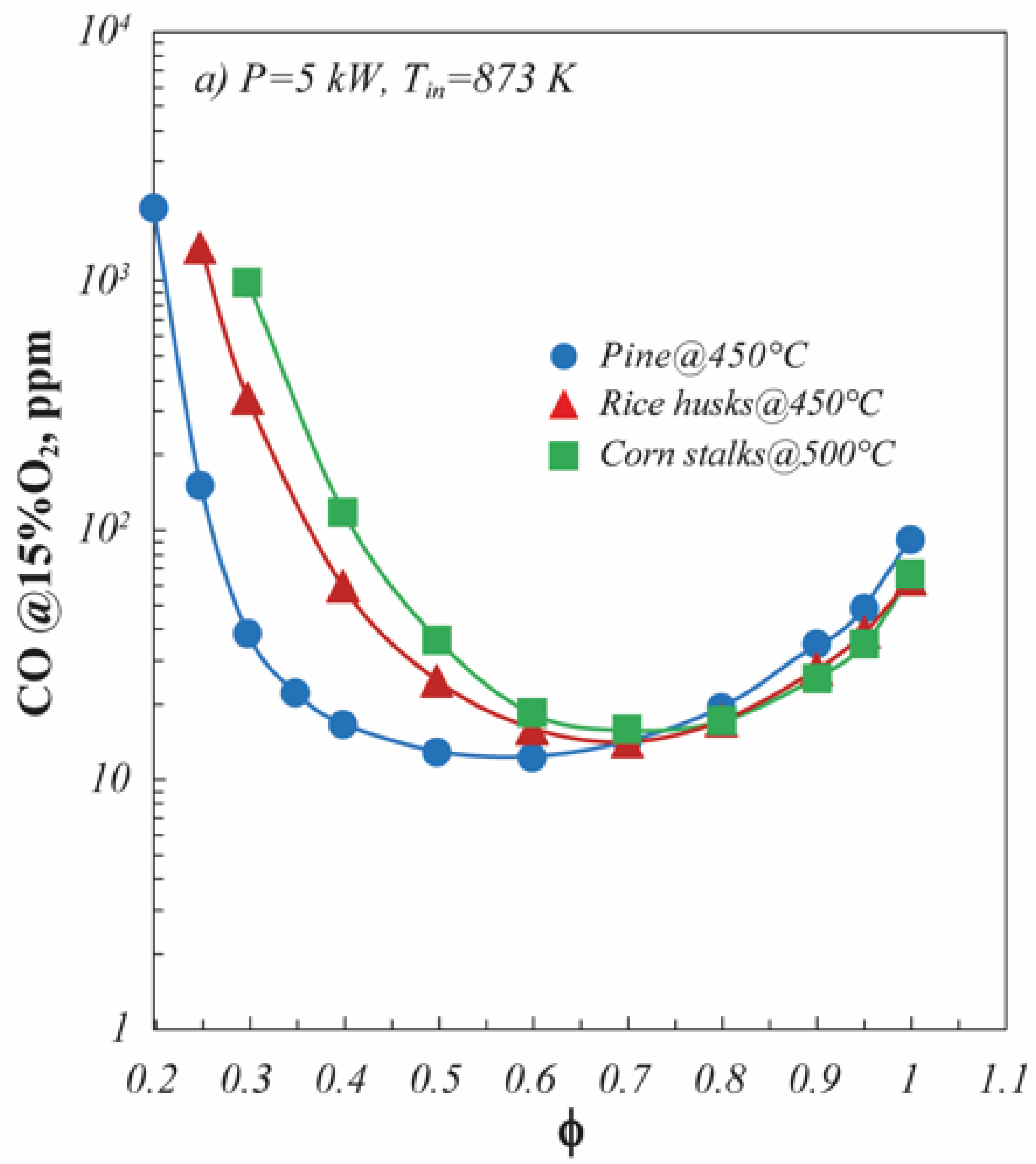
Pyrolysis technology pathway

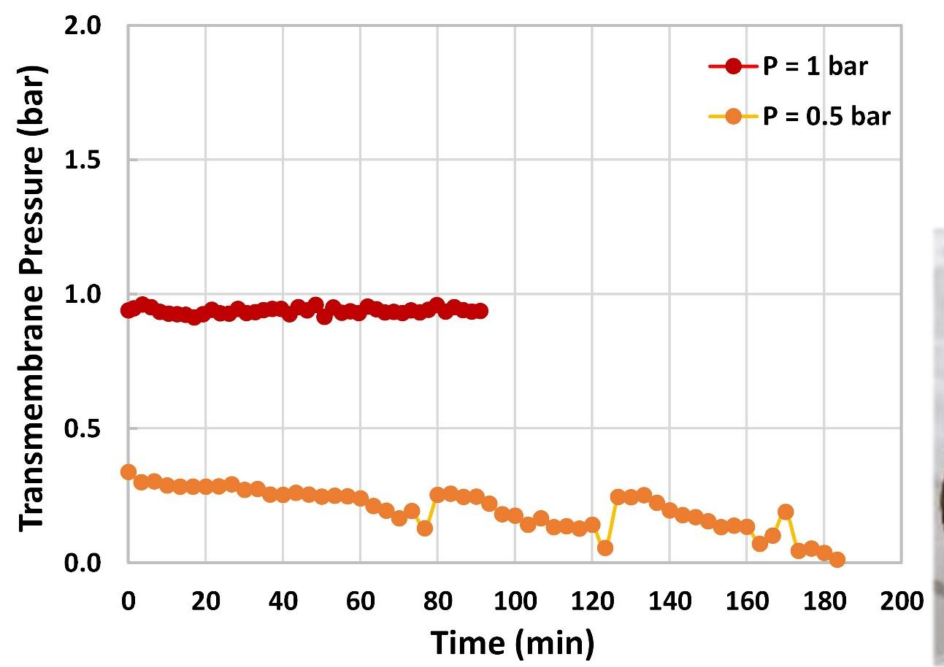
Combustion of the pyrolysis gas

- More then **50 experiments** to demonstrate the possibility to **valorize pyrolysis gas** (LHV from 2 to 11 MJ/kg) through **MILD combustion** conditions.
- Pyrolysis gas oxidation can be effectively stabilized under MILD conditions for **LHVs> 3MJ/kg**; **NOx** emissions < 10 ppm, **CO** emissions < 100 ppm.
- Mild Combustion is very **flexible** and **resilient** to **pyrolysis gas composition,** along with composition fluctuation over the time.

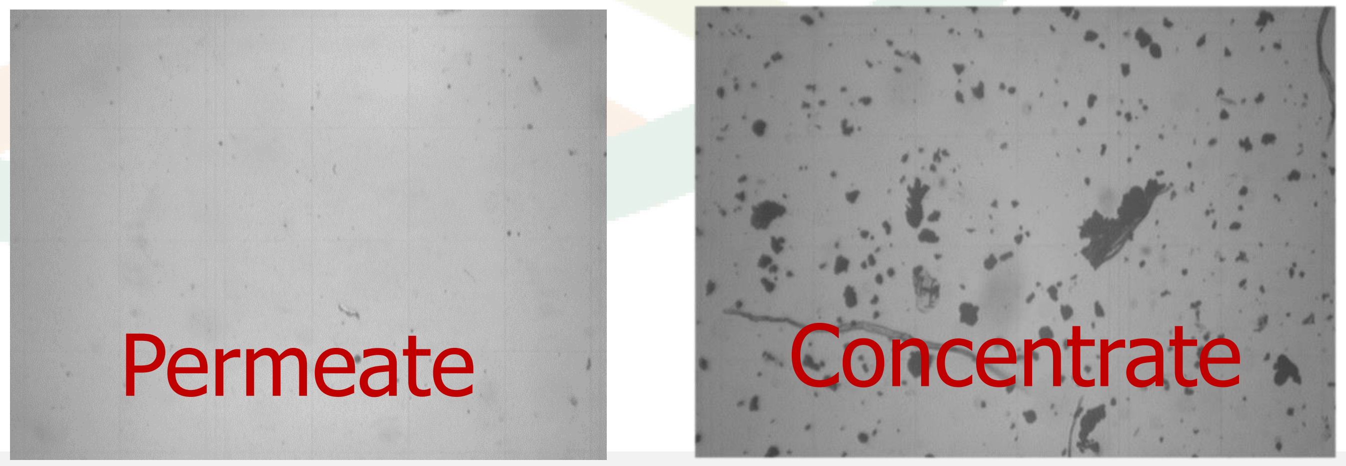
Cyclonic flow burner







Atech membranes before and after cleaning with NaOH

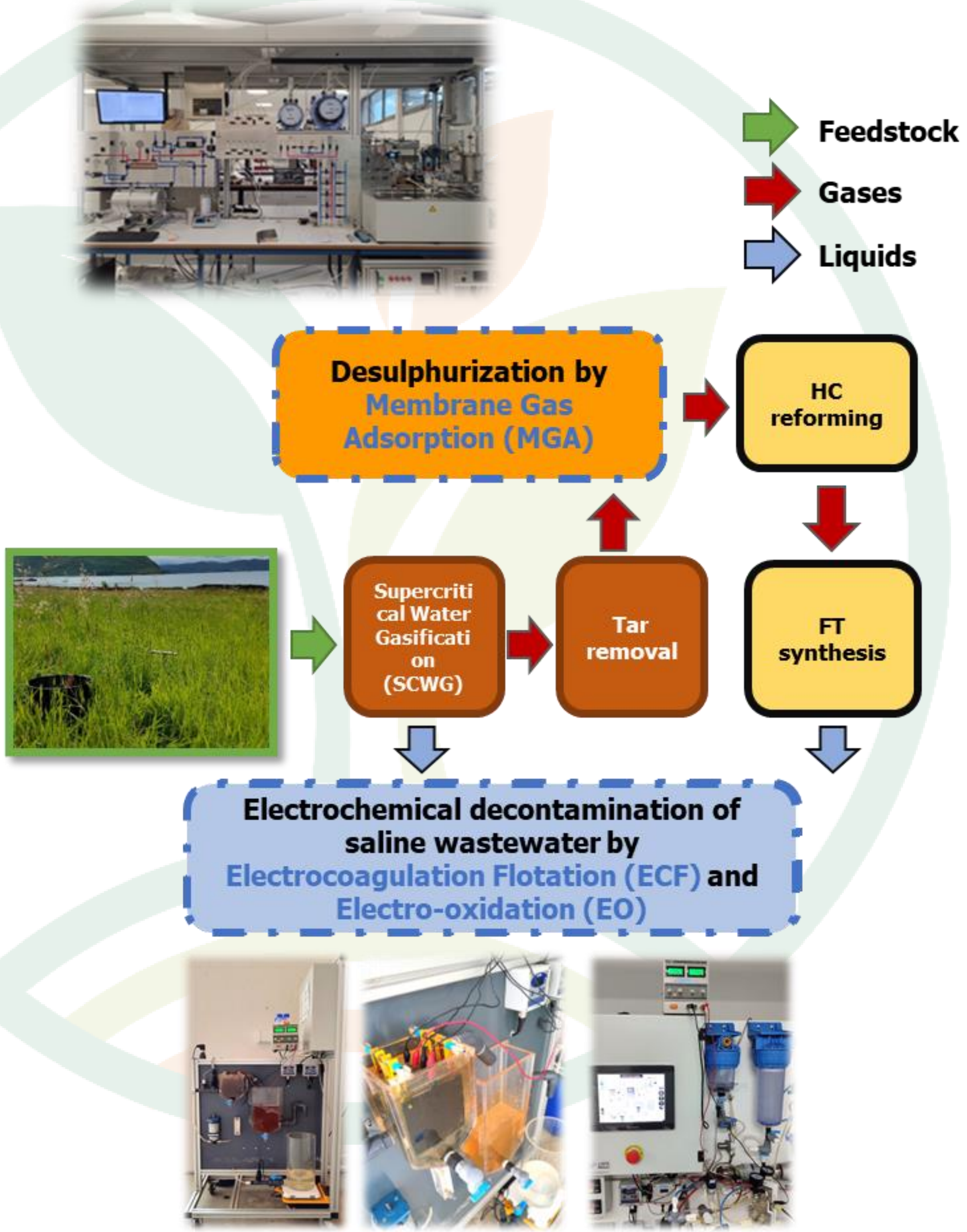


Microfiltration of the pyrolysis liquid

- Experiments to demonstrate the possibility to remove undesirable heavy metal-laden char particles (less than 1 micron in size) from bio-oils by ceramic MF
- Main achievements:
  - No fouling is indicated by the TMP profile during the MF of the FP bio-oil. In any case fouling was reversible!
  - Total retention of carbon particles in real bio-oil samples.

Decontamination technologies

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS
CPERI
Chemical Process and Energy Resources Institute



Development of MGA process for SCWG gaseous product upgrade

- Experiments with ***bench-scale dedicated test rigs*** in order to parametrize the process and identify the optimal operating conditions on technoeconomic basis.
- Use of hydrophobic polymeric membranes and dedicated solvents, achieving ***maximized H_2S capturing efficiency*** coupled with ***significant CO_2 removal***.
- Assessment of the process in ***laboratory pilot scale in relevant environment***.
- Recommended operating Treating Gas Capacity (TGC): **2.53 lpm/m^2** and acid gas amine loading: **0.28 molacid_gases/molDEA**.

Development of a hybrid ECF –EO process for effective removal of organics and heavy metals (HMs) from SCWG brine / wastewater

- Experiments with ***novel ECF / EO laboratory units constructed in-house***
- Validation of the ECF / EO processes in laboratory (***simulated SCWG saline wastewater using Pb and phenol*** as model heavy metal and organic contaminant, respectively) (TRL 4) and relevant environment (TRL 5) (***real SCWG saline wastewater***)
- The hybrid ECF / EO process in a single setup with 2 pairs of metal electrodes (**BDD/SS and Fe/Fe**) proved to be very efficient for the combined removal of **phenol (37%)**, **TOC (61%)**, **Pb and Ni ions (approx. 75%)** under optimum operating conditions (64 mA/cm^2, electrolysis time 134 min)
- **Low energy requirements** (1 kWh/m^3 for Pb removal by ECF, 37 kWh/m^3 for Pb/phenol removal by ECF/EO).

The CERESiS Decision Support System

What type of decisions can the CERESiS DSS support?

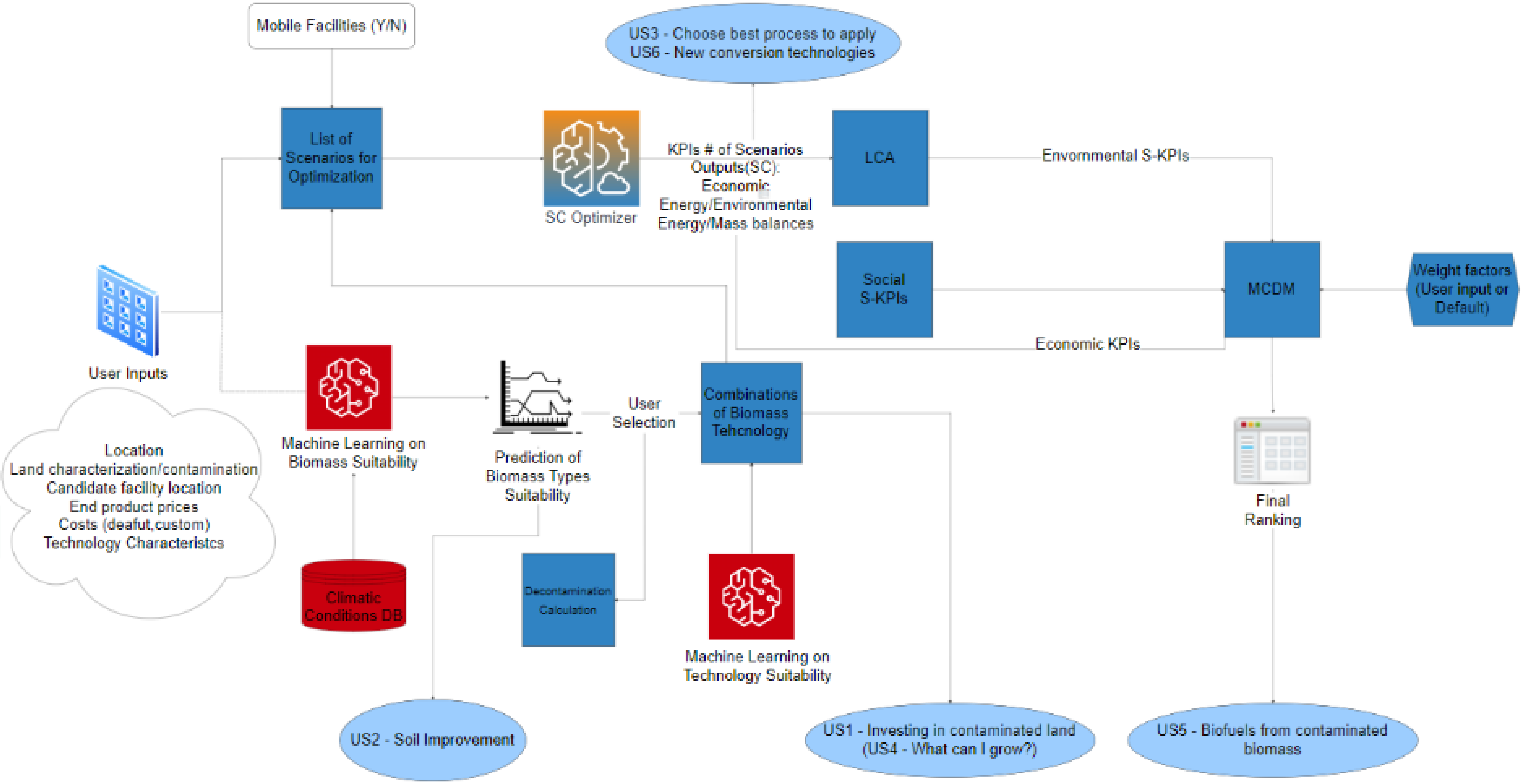
1. Which biomass types are suitable for particular contaminated land conditions?
2. What are the expected yields and contaminant uptake?
3. Which combinations of technologies - biomass types are suitable?
4. Which is the optimal supply chain design (facilities location, capacities, structure)?
5. Which is the optimal value chain configuration considering the specific case study conditions (i.e. selection of biomass type – technology – supply chain structure)?
6. What is the performance of the value chain against economic – environmental – social KPIs?

The CERESiS Decision Support System

Development and implementation of a dedicated DSS platform providing critical information to decision makers on the suitability of pathways consisting of combinations of energy crops and biofuel conversion technologies for specific applications

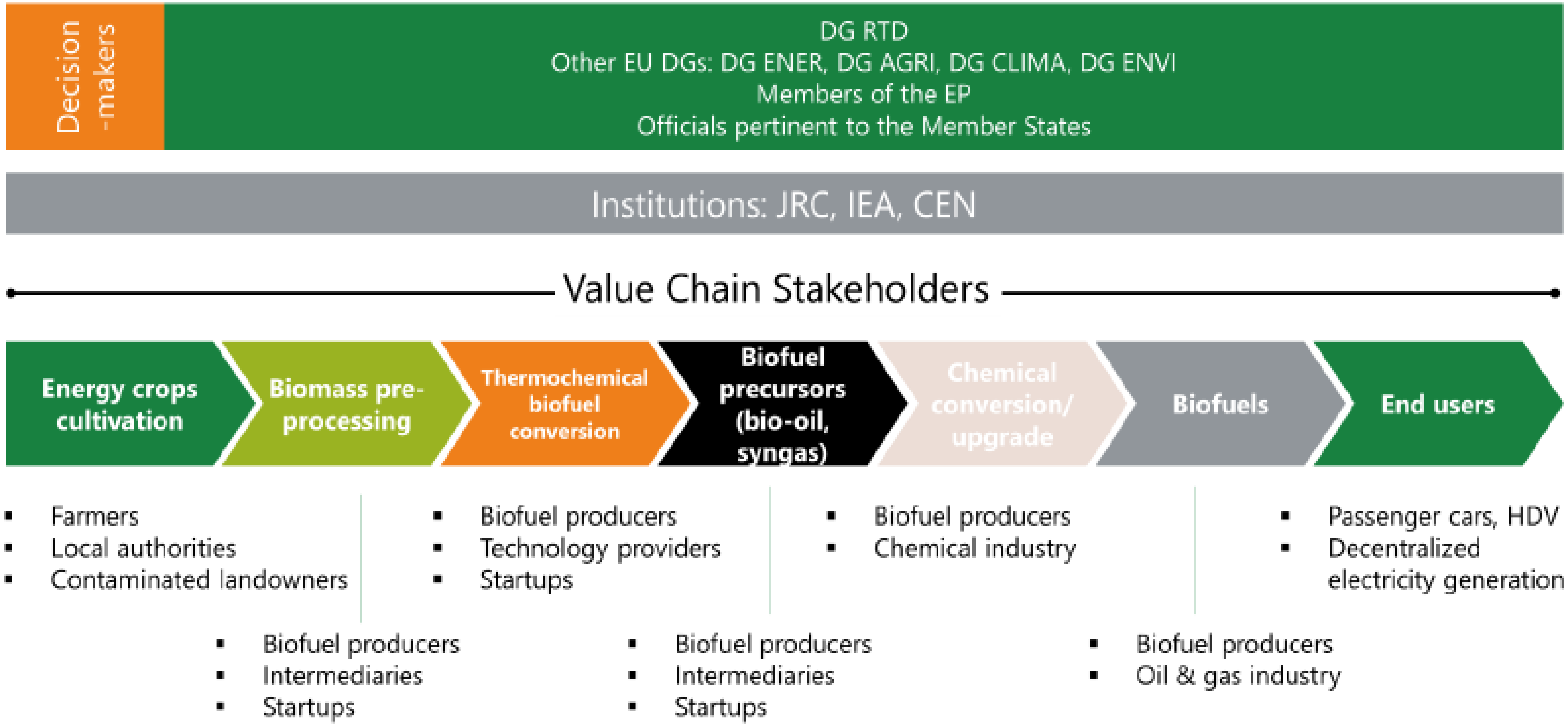
Key elements included

→Machine Learning for Biomass Suitability
→Technology suitability assessment
→Supply Chain optimization
→ Life Cycle Analysis
→ Social impact
→ Multi-criteria analysis



Policy Recommendations and Stakeholders' Engagement

Stakeholder engagement throughout project implementation served in several ways and mainly in introducing and communicating the CERESiS concept to a wide range of audiences.



Policy Recommendations and Stakeholders' Engagement

- Policy analysis outcomes: **there is not in place a unified overarching legislative framework** under which the two sectors (contaminated land and biofuels) can "communicate" on a solid basis.

  →A **specified policy and legislative framework should be adopted** for bridging the gap between phytoremediation strategies and clean biofuel production in a sustainable and optimum manner that will overcome the indirect land use change (iLUC) issue for biofuels and restore lands for agricultural uses.

- The Proposal for a Directive on Soil Monitoring and Resilience COM(2023)/416 **provides a unique opportunity** for EU Member States, that will ensure a solid policy and regulatory background for contaminated land management, land decontamination and phytoremediation.

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Our partners

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National Technical University of Athens

KIT Karlsruhe Institute of Technology

KOKKALIS FOUNDATION

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UNIVERSITÉ DE SHERBROOKE

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