# Recycling Carbon Dioxide in the Cement Industry to Produce Added-Value Additives: a Step Towards a $CO_2$ Circular Economy


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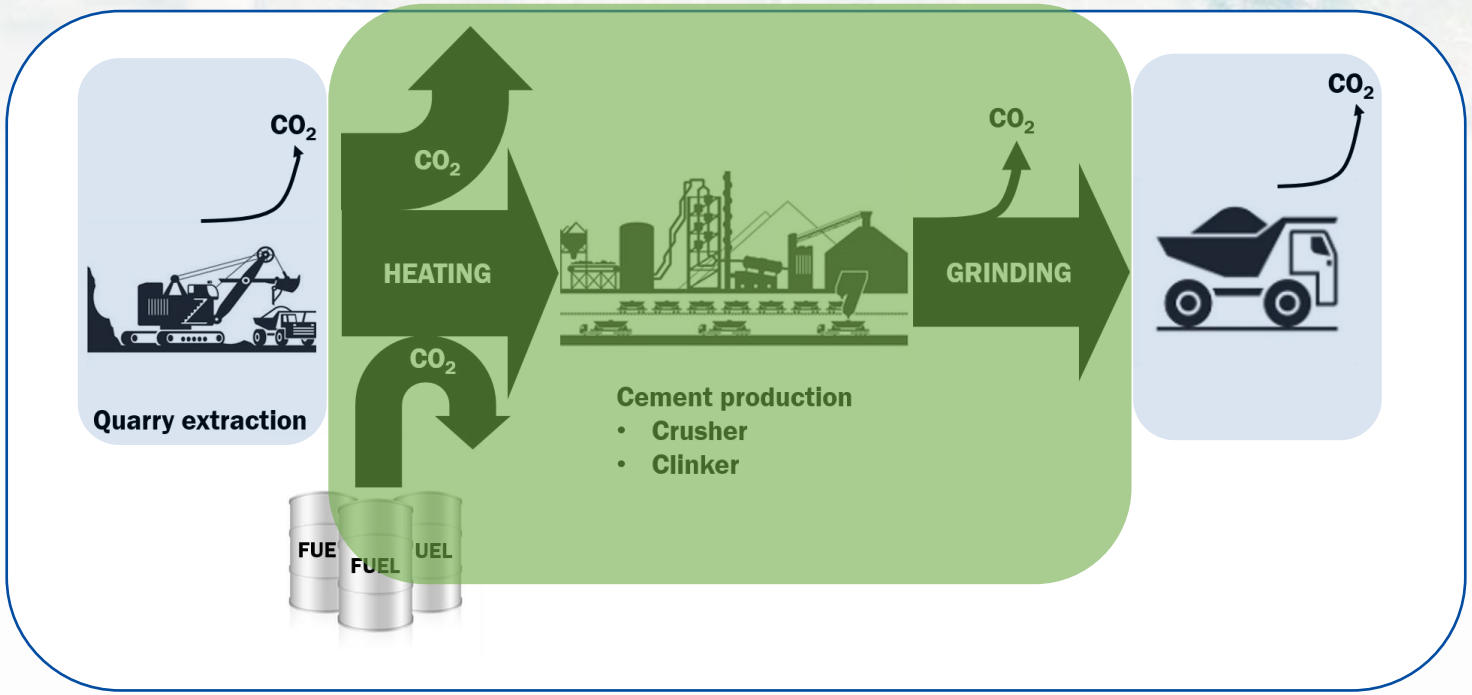
**4th June 2021**

**#EUGreenWeek**

**2021 PARTNER EVENT**

# Carbon Foot-print of the Cement Industry

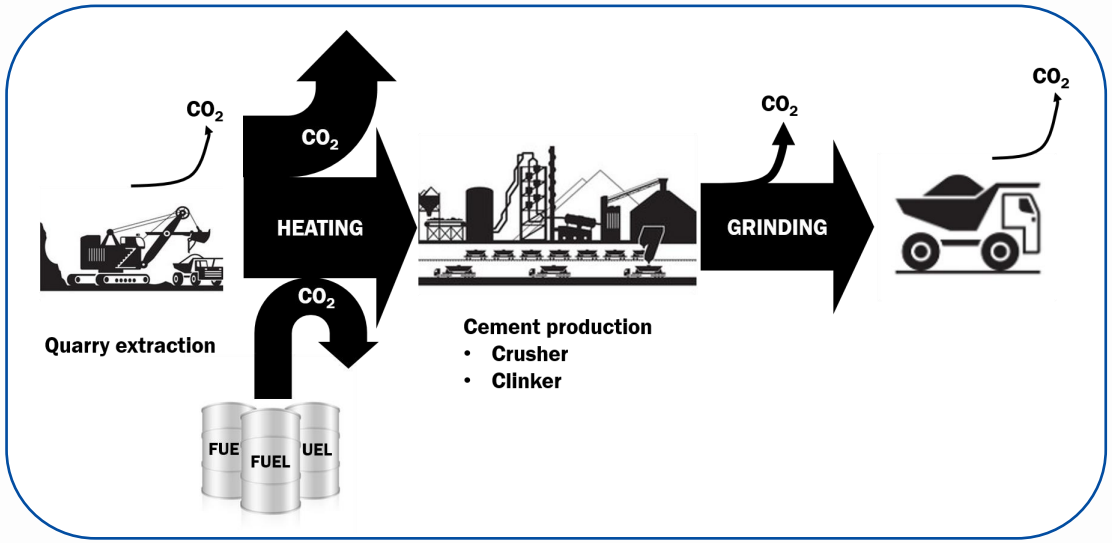



The cement industry produces
< 5% of global anthropogenic $CO_2$ emissions
and has a carbon foot-print of

**~ 1 kg $CO_2$ eq per kg of cement**

# How to Reduce the Carbon Foot-print of Cement Industry

Main $CO_2$ emissions from clinker




1st approach:
Clinker intensity reduction

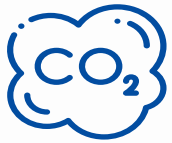

Reduction of cement quality

Improvement of cement quality

ReCO2DE

Carbon Capture Utilization (CCU) technologies to produce cement additives combining both approaches

Challenge:
High energy demand of additives production




2nd approach:
Carbon Capture Storage (CCS) technologies

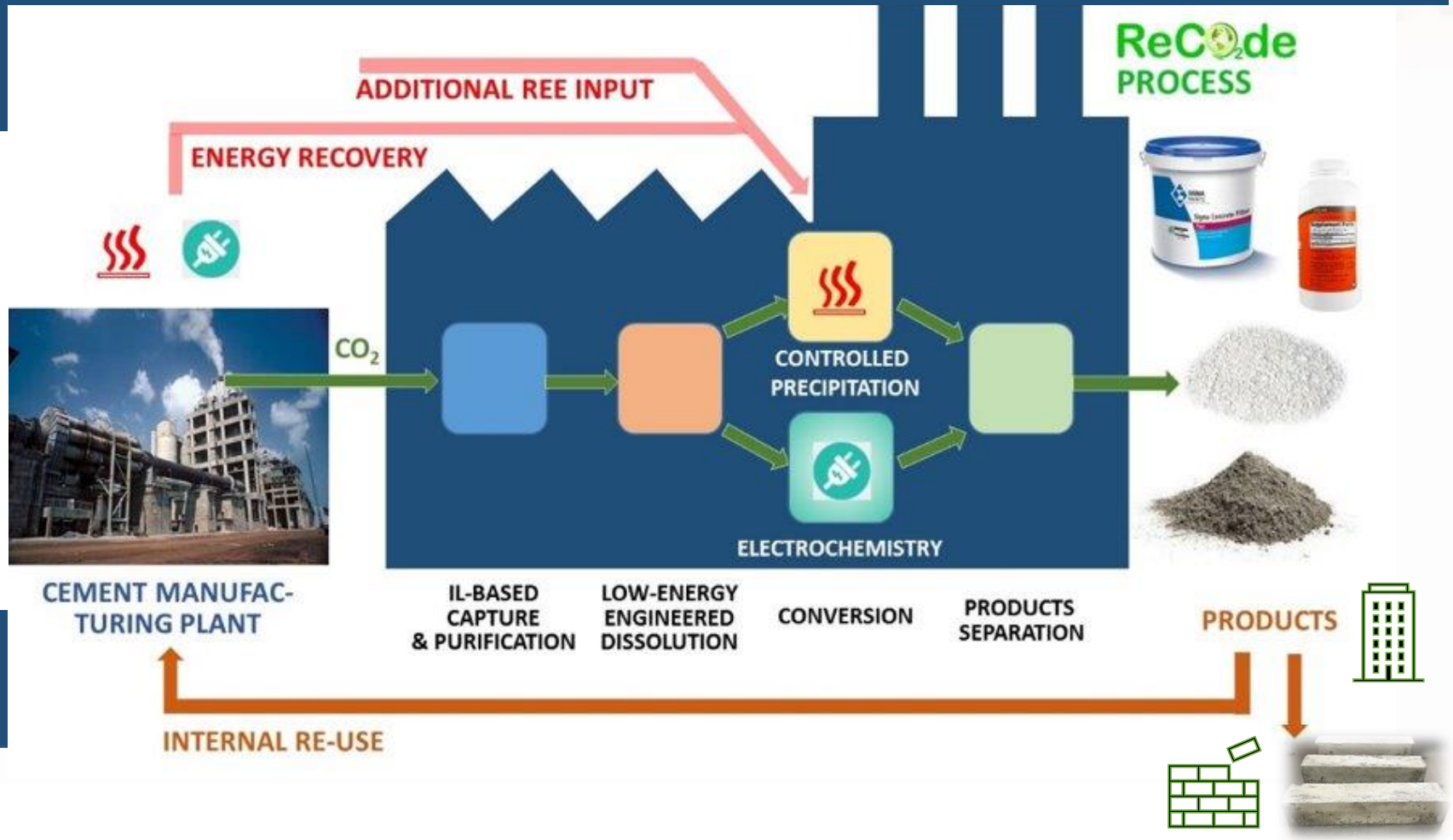
This project has received funding from EU's Horizon 2020 and innovation programme under grant agreement No. 768583

# Concept

Recycling carbon dioxide in the cement industry to produce added-value chemicals & materials to enhance cement quality: a step towards a $CO_2$ circular economy

August 2017 - January 2022

## A NEW IMPACTFULL TECHNOLOGY

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# ReCO2DE Towards zero pollution

SPIRE PROJECT

## Goal

To make cement industry able to contribute to at least 20% reduction of $CO_2$ emissions in the medium to long term.

**Overall budget:**
€ 7.904.415


## Partners

**1** Large industrial partner

TITAN

**5** Small Medium Enterprises

avantium, io·li·tec Ionic Liquids Technologies, HYSYTECH, CUBOGAS, met

**7** Research Centers & Univ.

iit ISTITUTO ITALIANO DI TECNOLOGIA, CERTH, ERIC, DVGW, Politecnico di Torino, KIT Karlsruhe Institute of Technology, university of groningen

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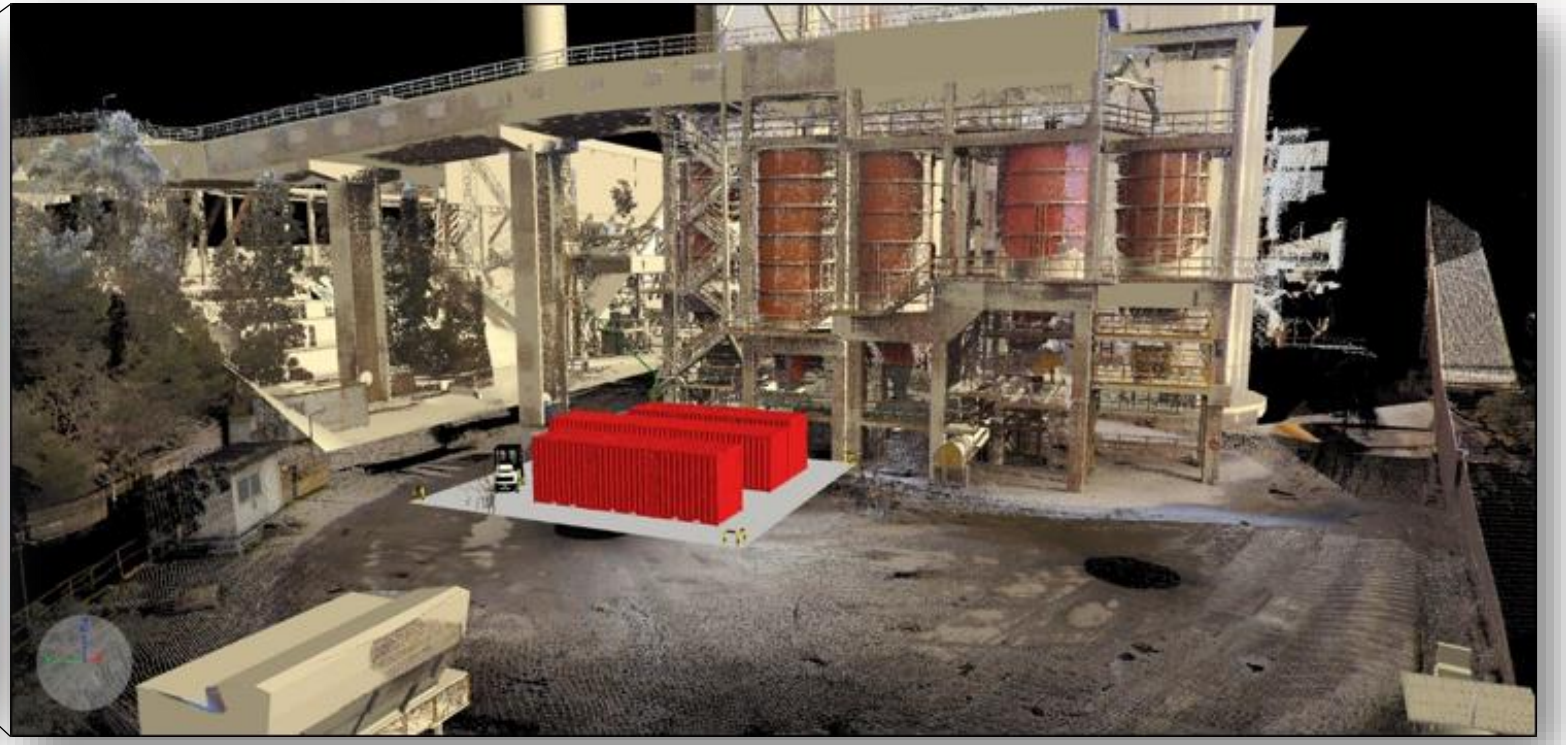
# Towards zero pollution

## Kamari Cement Plant


Athens, Greece

## RECODE TRL6 Integrated Demo Plant



In operation: From October 2021

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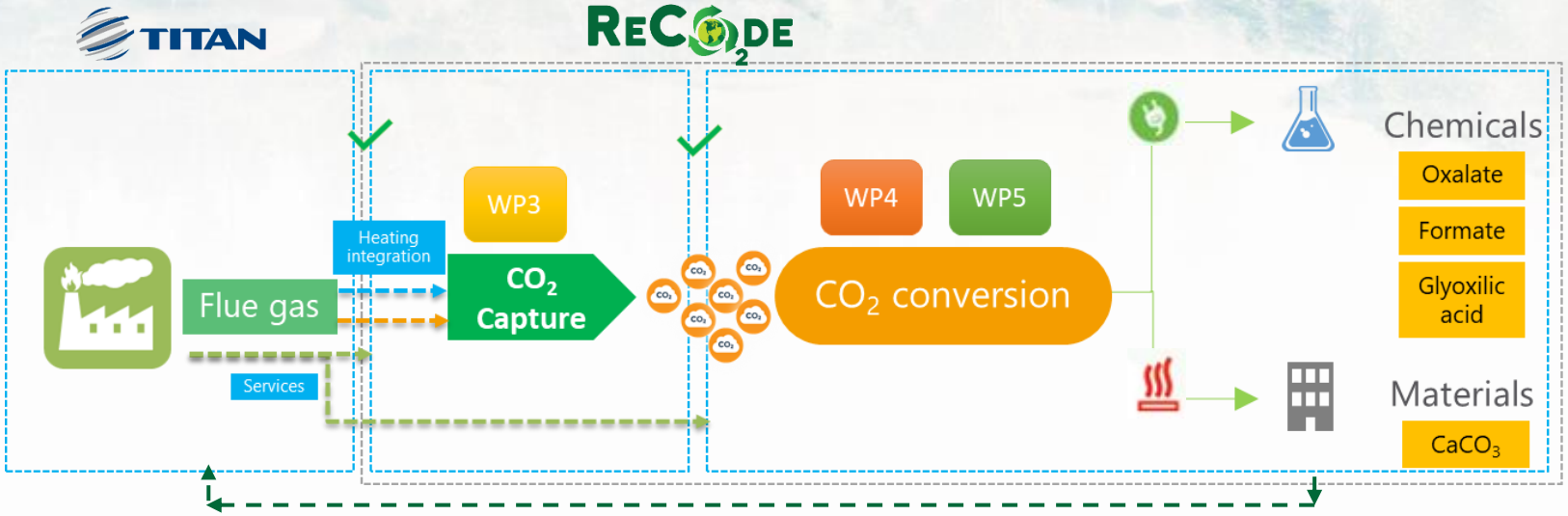
# TRL6 Demo Plant

## Demonstration

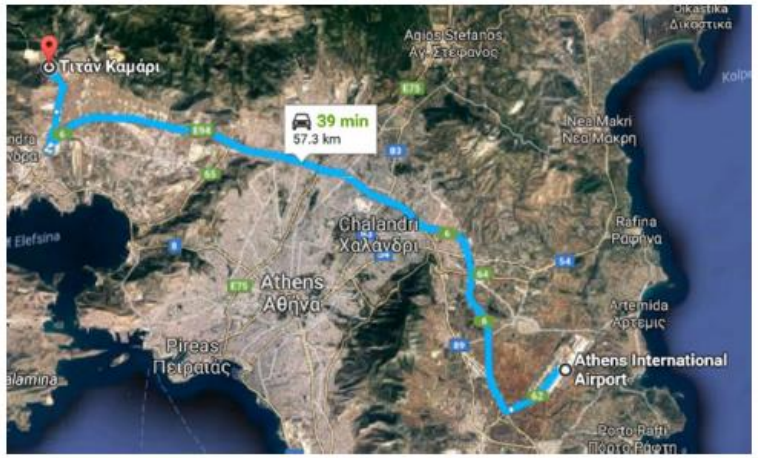
50m³/h flue gas treatment

- $CO_2$ Capture & Purification Unit (IL)
- Nano-$CaCO_3$ production
- Oxalate & Formate production
- Glyoxylic acid production




## Location: TITAN Kamari Plant

- 57 km from Athens Int. Airport
- 12 km from Port of Elefsis
- TITAN Research & Innovation facilities

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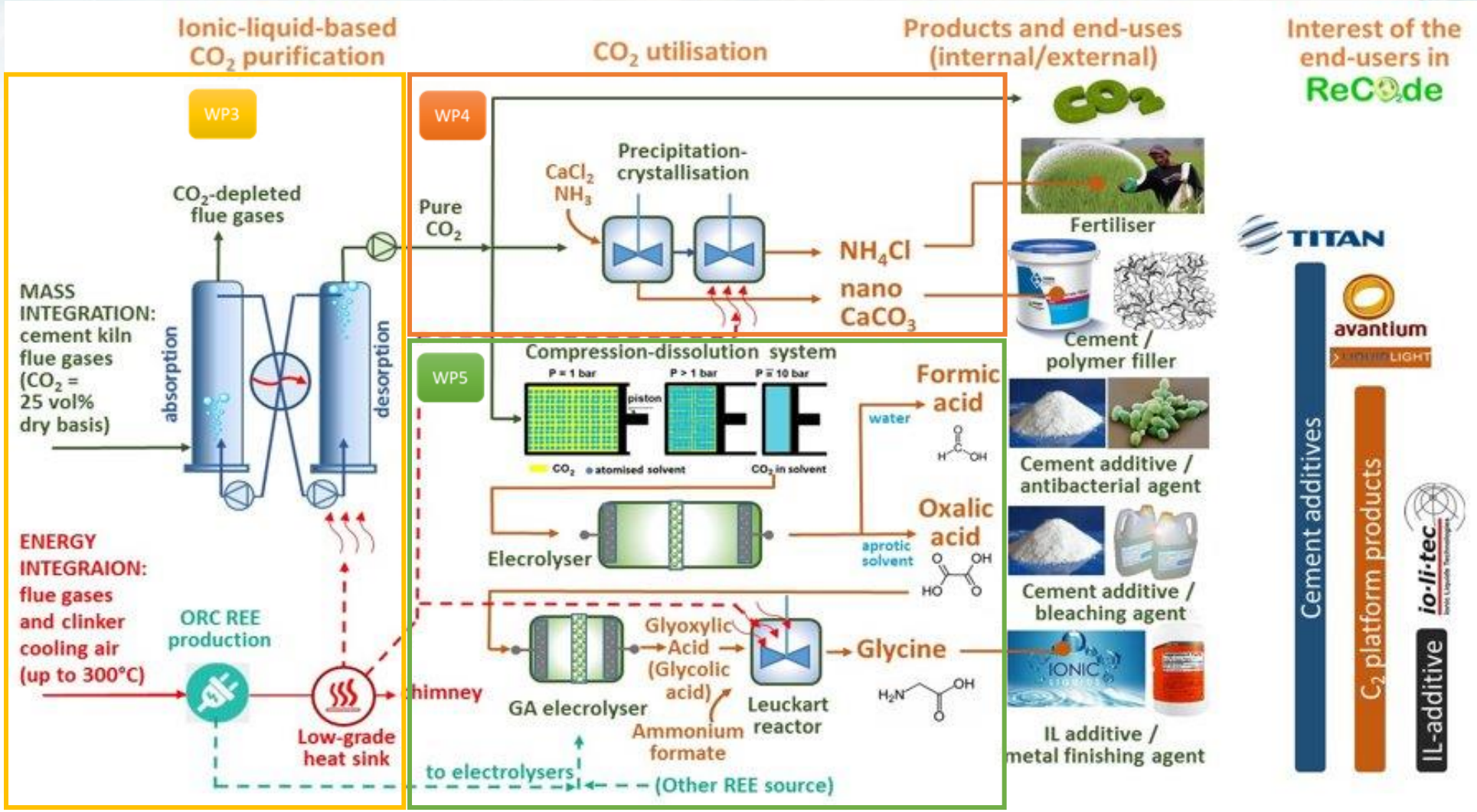
# TRL6 Demo Plant

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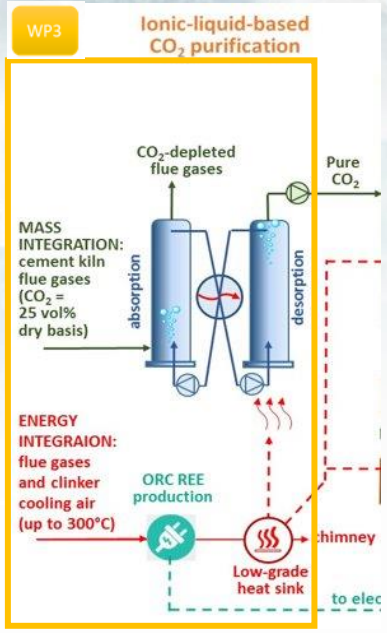


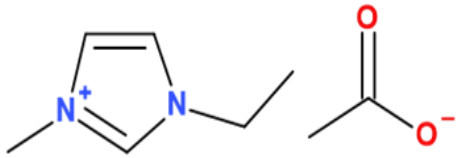

# ReCO2DE IL-based $CO_2$ purification

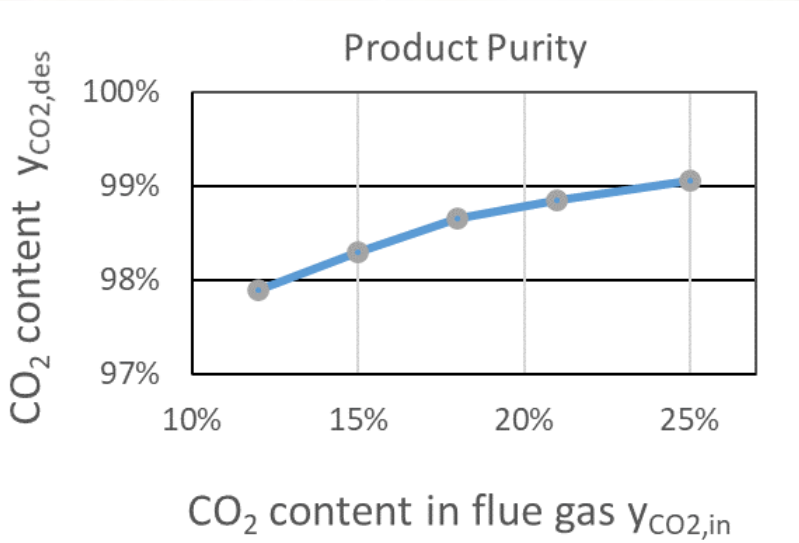
## Proof-of-concept: TRL 4 mini-plant

IL: [EMIM][OAc]

ISTITUTO ITALIANO DI TECNOLOGIA

io·li·tec Ionic Liquids Technologies




- $CO_2$ purity of > 99 vol-%
- Separation efficiency of 75 %
- No deactivation after > 220 h under air atmosphere

DVGW

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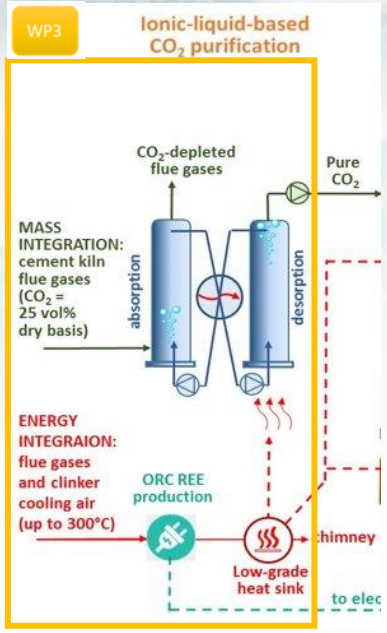
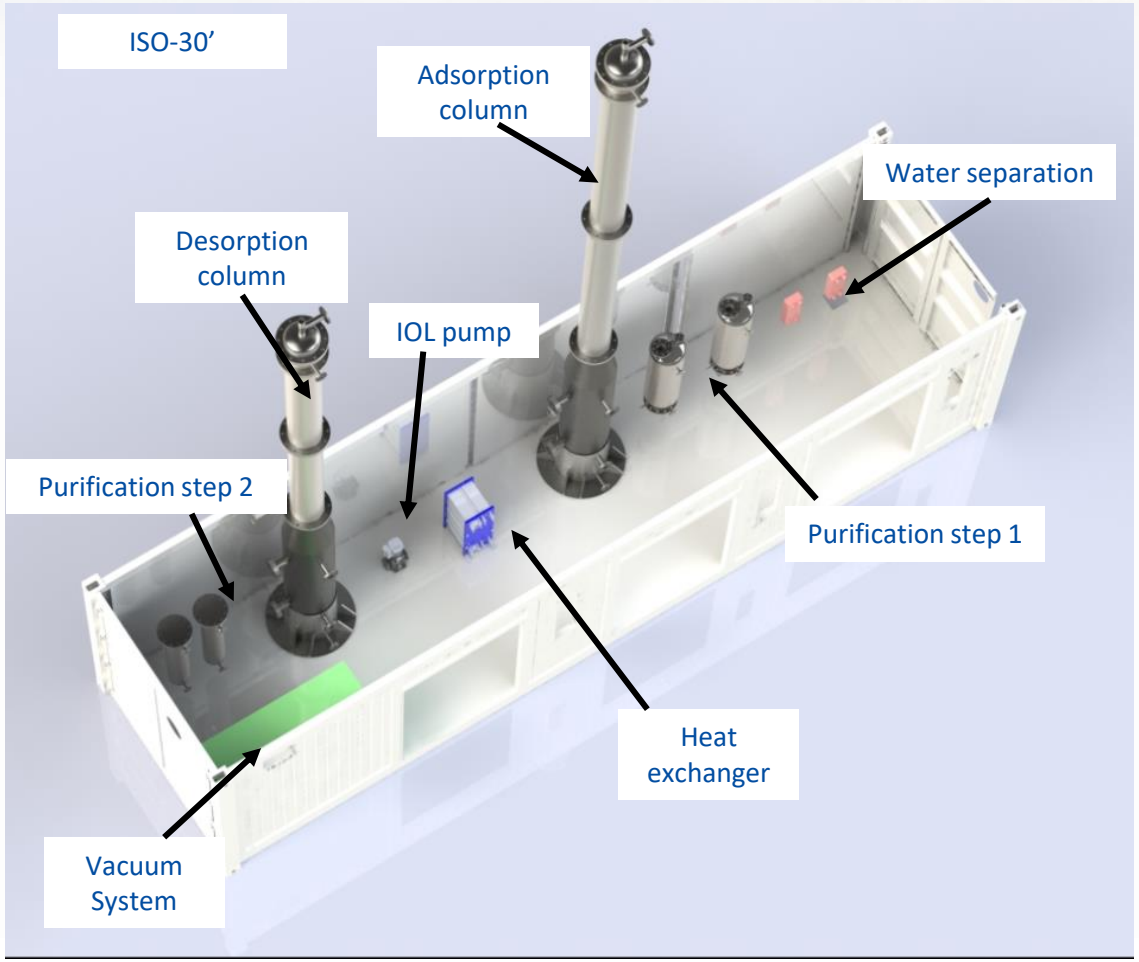



# IL-based $CO_2$ purification

## TRL 6 Demo-plant




## Feed gas:

- Flue gas from
- 100 m³/h (NTP)
- 120 °C
- > 10 vol-% of oxygen

## Product:

- 8 Nm³/h of purified $CO_2$
- Purity of 99 vol-%

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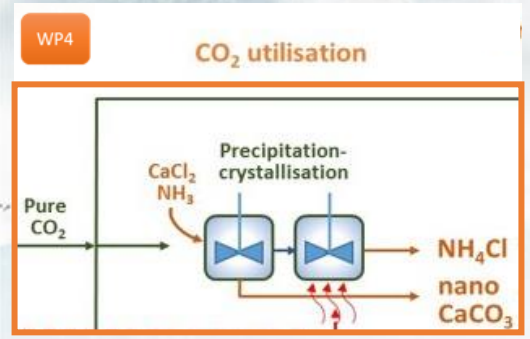


# ReCO2DE NanoCaCO3 fillers production

## TRL 3 & TRL 4 Process Optimization

Politecnico di Torino

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS


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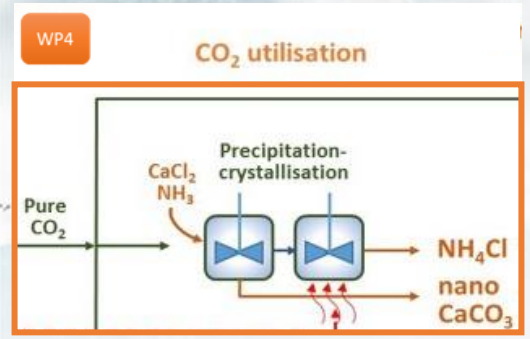


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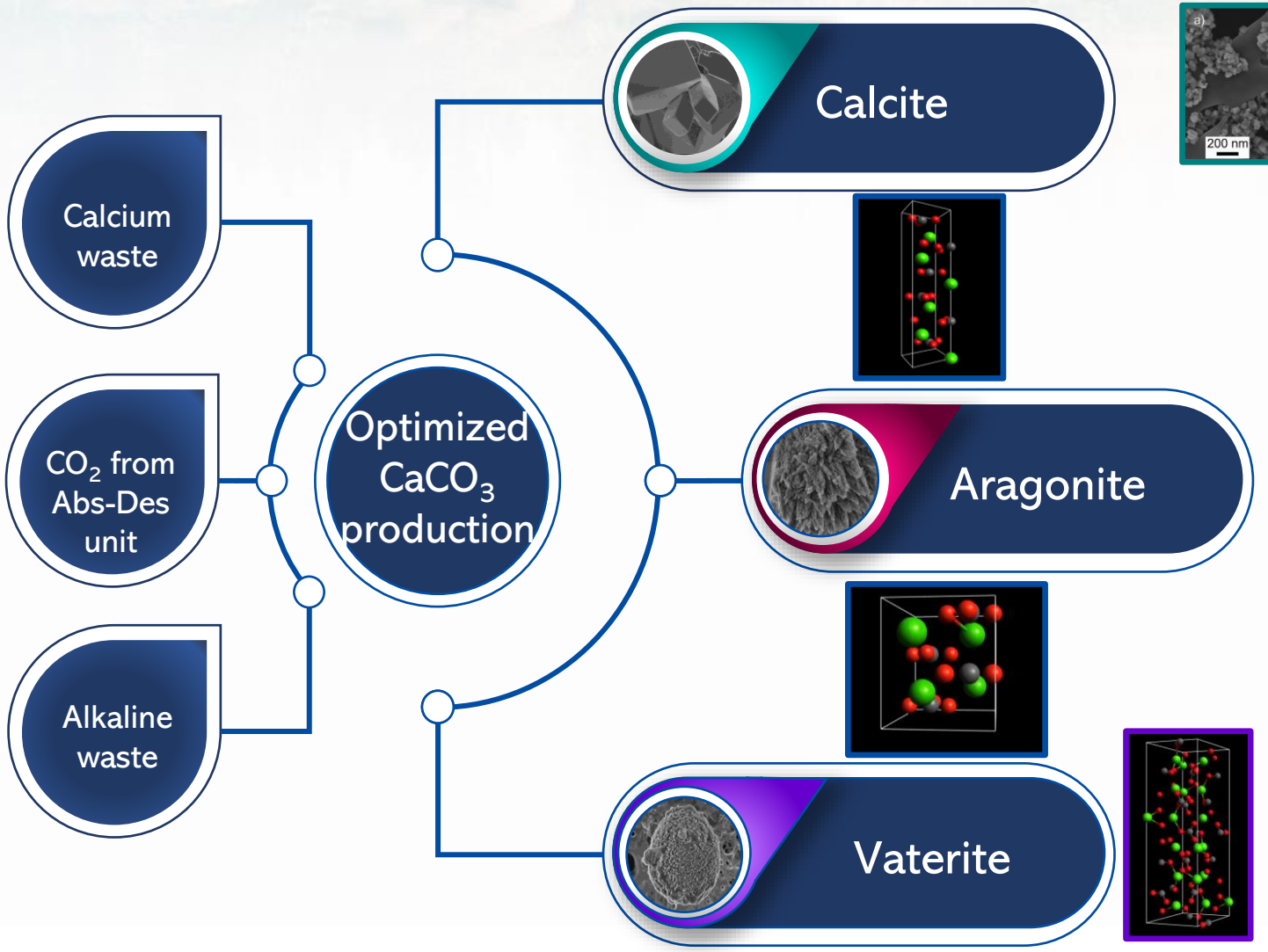
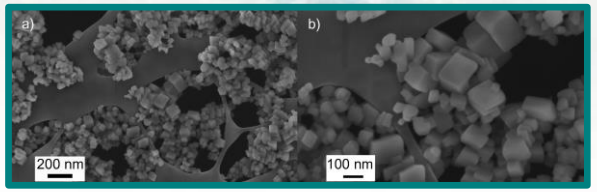
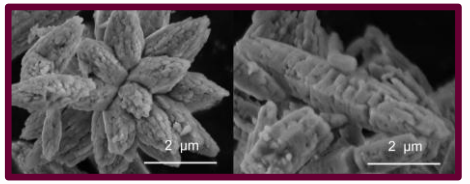
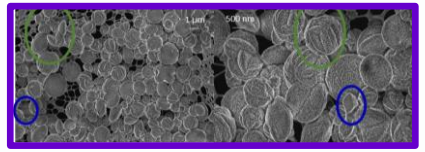



Calcite
Rhombohedral structure
$CO_2$ conversion = 35%




Aragonite
Orthorhombic structure
$CO_2$ conversion = 18%



Vaterite
Hexagonal structure
$CO_2$ conversion = 21%

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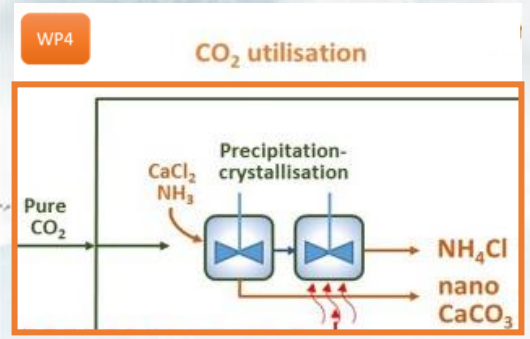
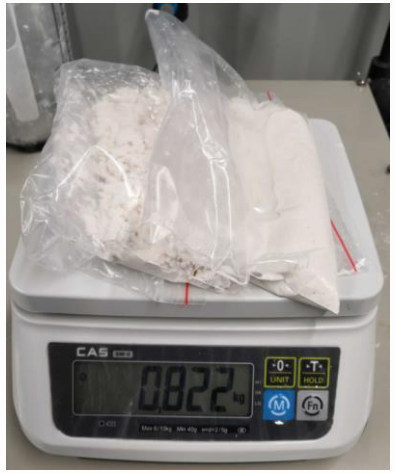



# NanoCaCO$_3$ fillers production

## TRL 5/6 Demo-plant

met. Politecnico di Torino CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS



1 kg/batch of $CaCO_3$

$CO_2$ conversion >20%.

Production of 1kg/batch of $NH_4Cl$ as by-product

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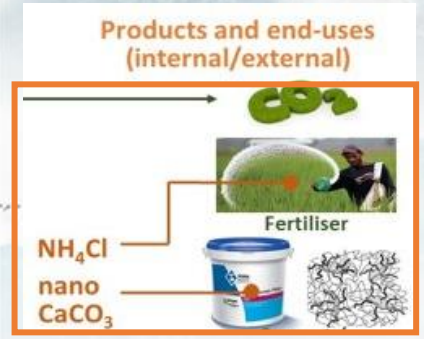
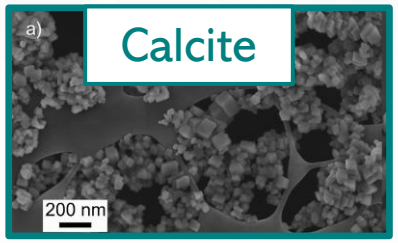
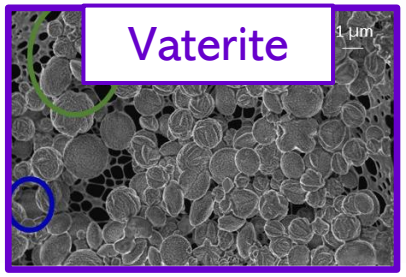


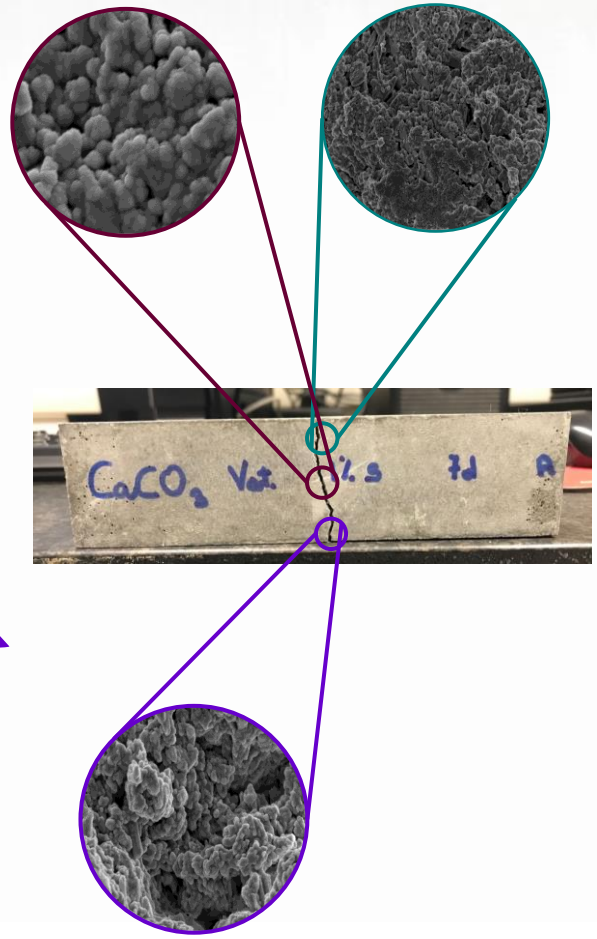

# Impact Analysis

## Evaluation Nano$CaCO_3$ product quality as cement filler

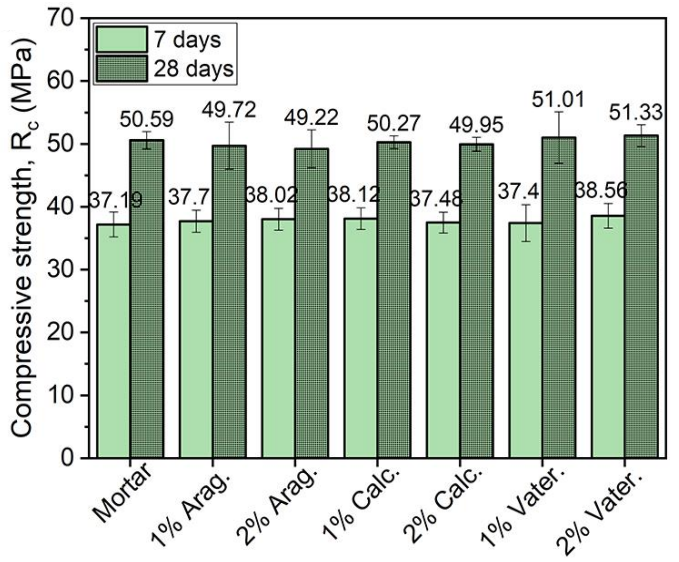







Substitution of cement with 1% - 2% of nano $CaCO_3$ crystals led to 1.5% - 3% improvement of the **mechanical properties** of the cementitious materials.

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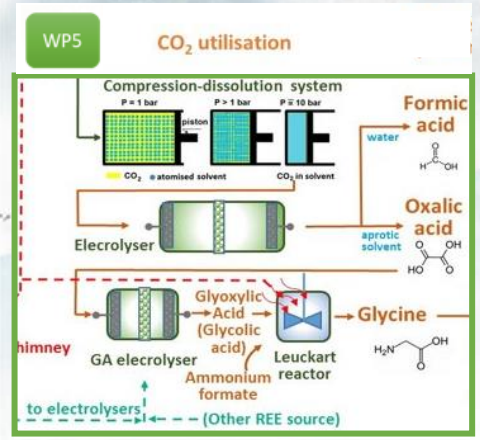


# ReCO2DE Electrocatalytic $CO_2$conversion

## Process Optimization & Upscaling

avantium · university of groningen · ERIC European Research Institute of Catalysis · iit istituto italiano di tecnologia · CUBOGAS · KIT Karlsruhe Institute of Technology · HYSYTECH Developing Solutions

**Process design** → **Catalyst development** → **Upscale catalyst synthesis** → **Designing and manufacturing the reactors** → **Testing and certification**

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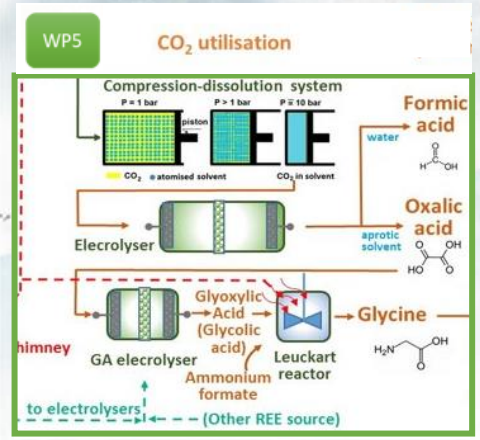


# RECODE $CO_2$ Electrocatalytic $CO_2$ conversion

## Process Optimization (TRL3 to TRL4)

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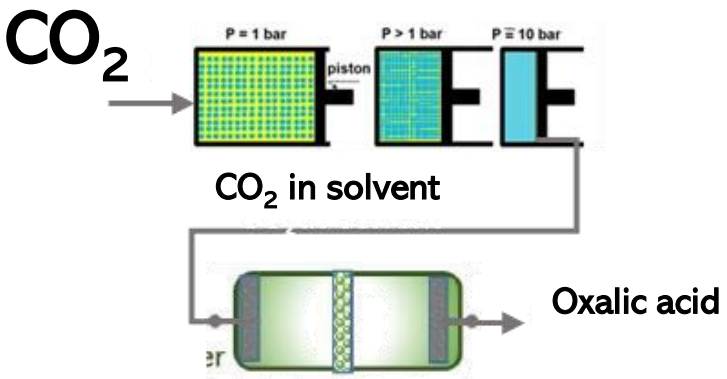
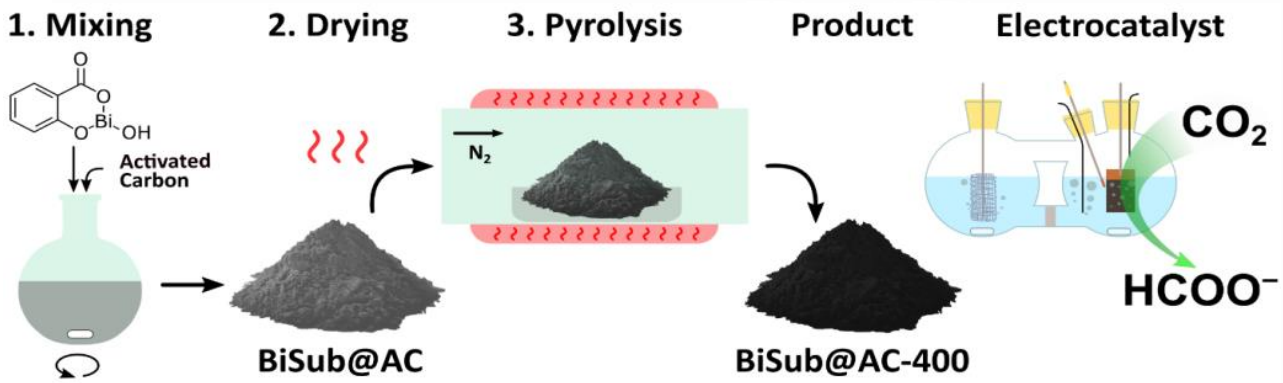
Process design → Catalyst development → Upscale catalyst synthesis → Designing and manufacturing the reactors → Testing and certification




Simultaneous $CO_2$ compression & dissolution: 46% reduction of overall energy consumption.

$CO_2$ conversion to Formate: > 99% of Faradaic efficiency

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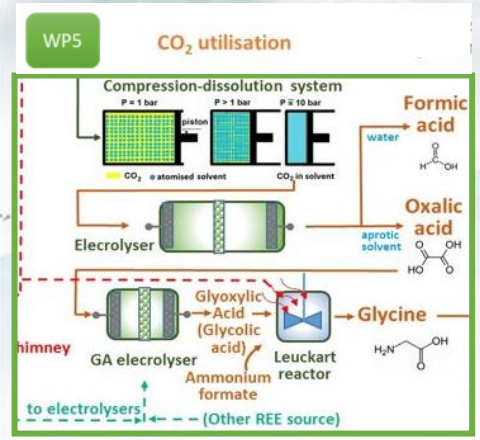


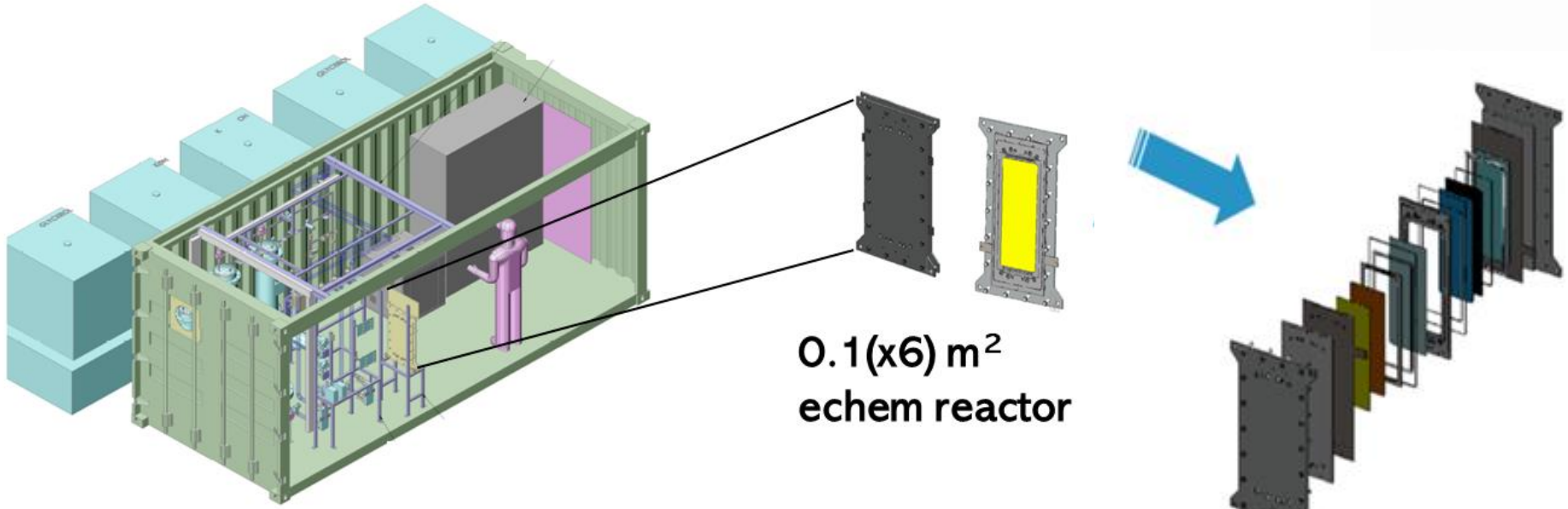

# RECODE $CO_2$ Electrocatalytic $CO_2$conversion

## Process Upscaling to TRL6

avantium

HYSYTECH Developing Solutions

Process design → Catalyst development → Upscale catalyst synthesis → Designing and manufacturing the reactors → Testing and certification




Layout of the electrochemical unit for formate production.

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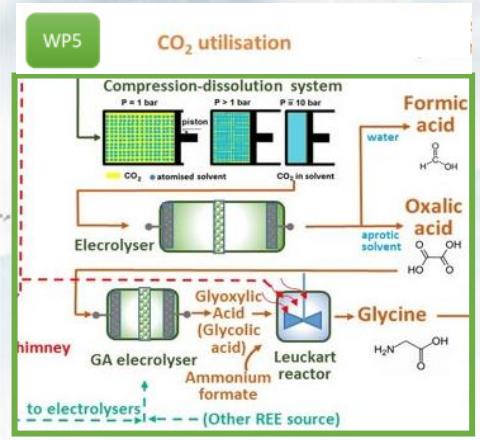
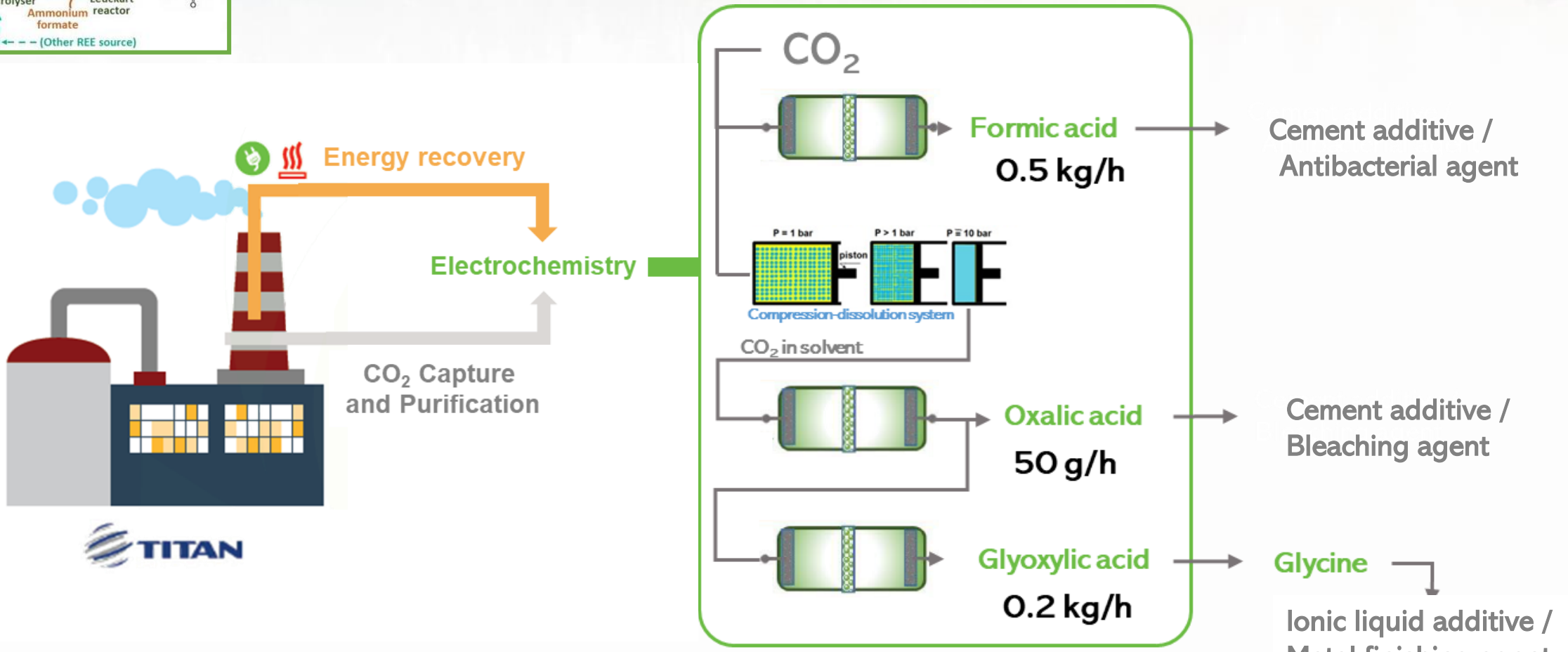



# ReCO2DE Electrocatalytic $CO_2$ conversion

## TRL 6 Demo-plant units

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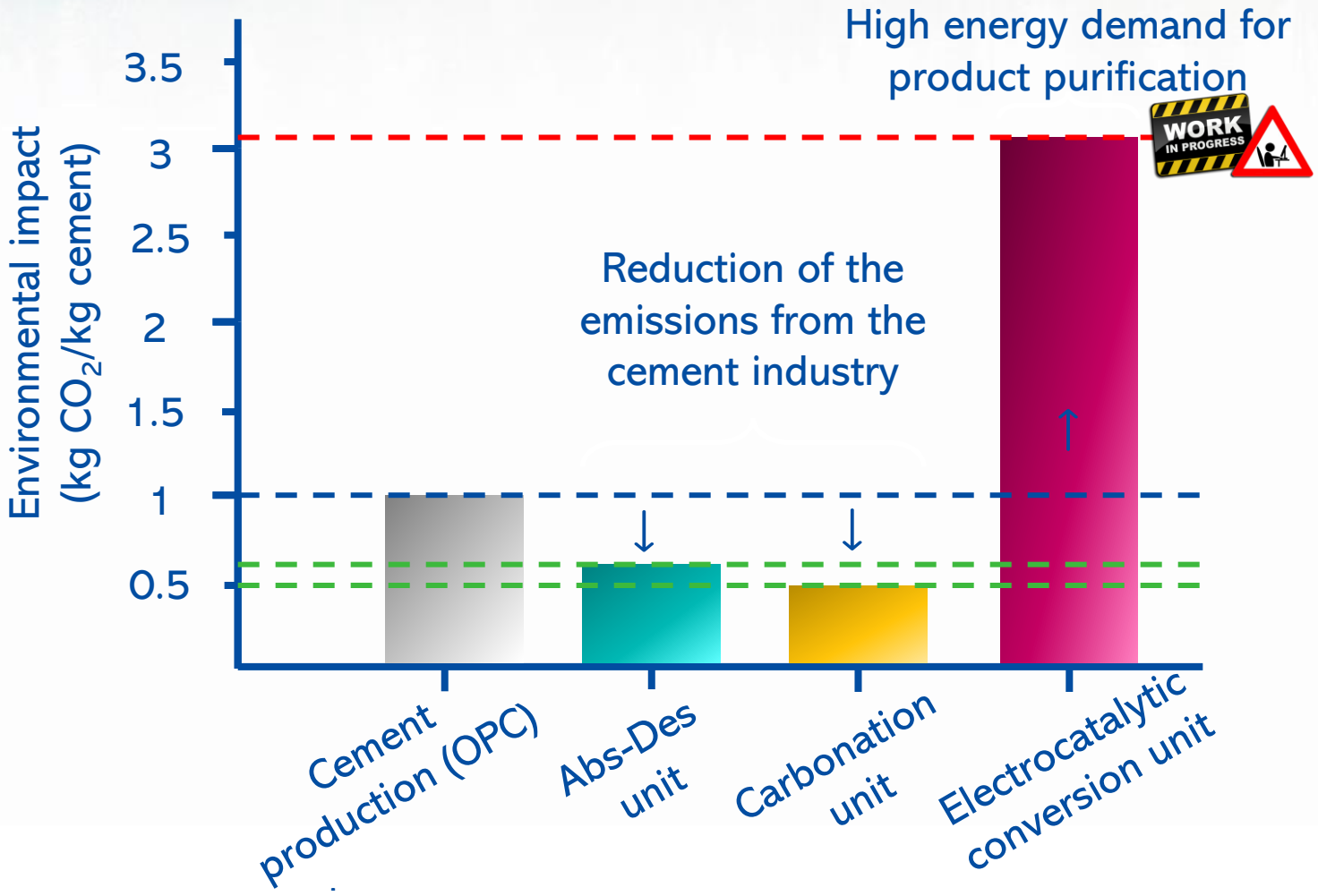
# Impact Analysis

## (Preliminary) Environmental & Techno-economic Feasibility




**Cement production (OPC)**

Production cost
81.65 €/t cement

**Cement production (OPC) – Recode integration**

Additives

Production cost
87.12 €/t
reinforced cement

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# Contacts & Links

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www.slideshare.net/recodeh2020

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