

EMPHATICaL Project

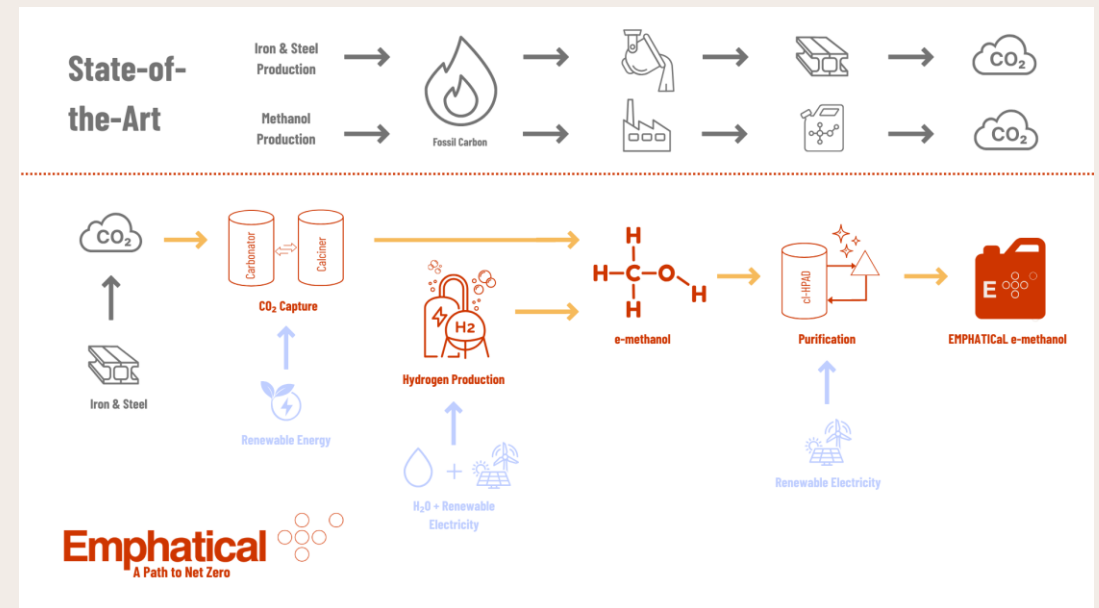
EMPHATICaL background



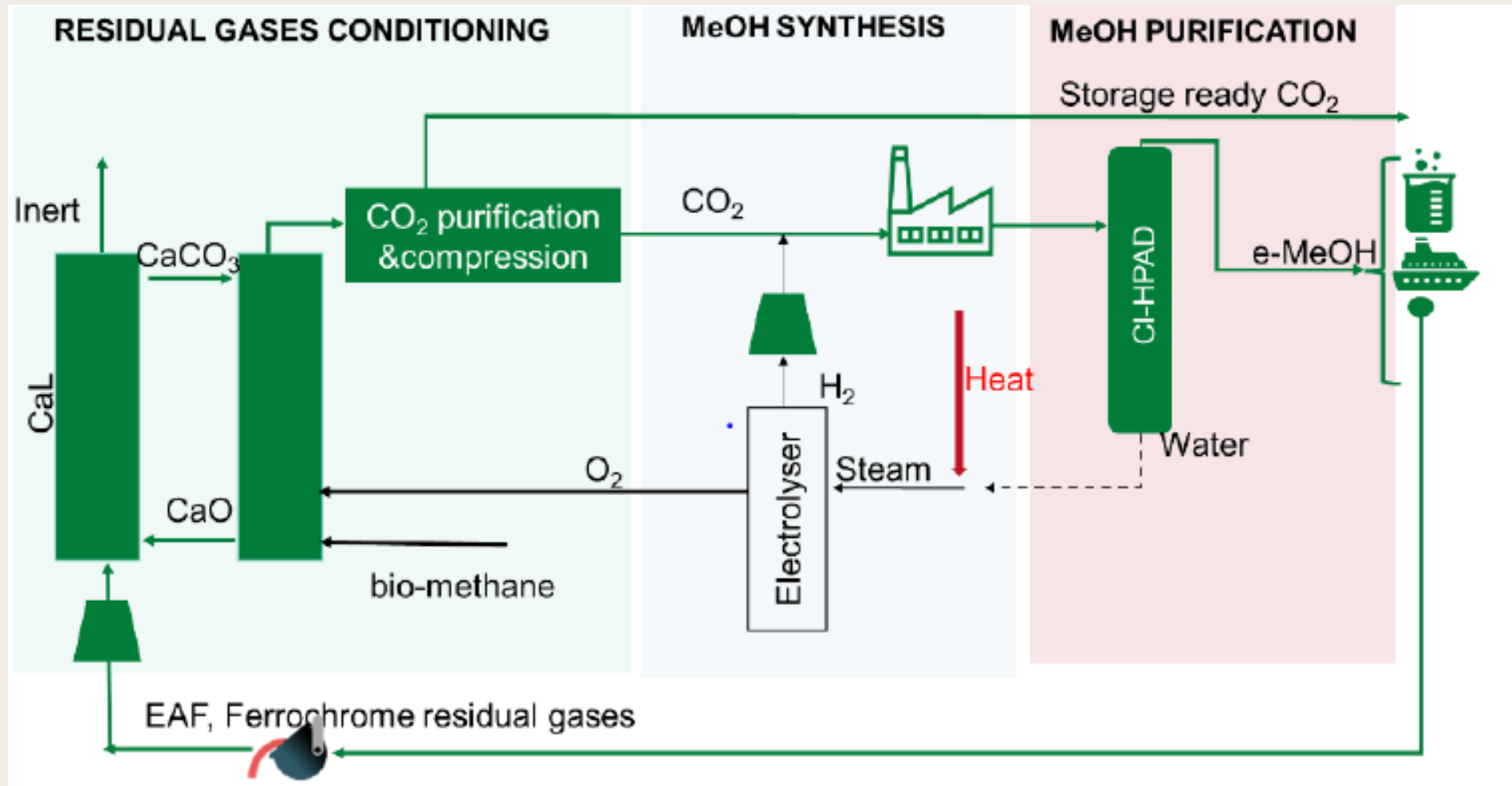
The EMPHATICaL (Efficient Methanol from Pumped Heat and Calcium Looping) is 4.5 year project focusing on the energy efficient integration of innovative oxy-blown calcium-looping capture technology, purification and conversion of CO₂ to e-methanol with green H₂ as a feedstock.

This project will:

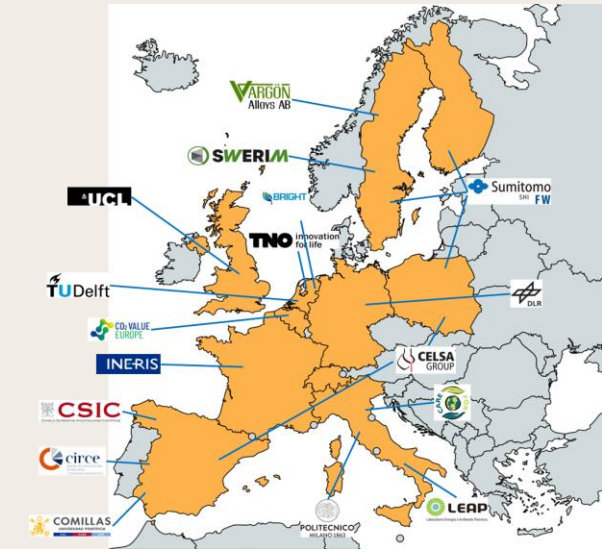
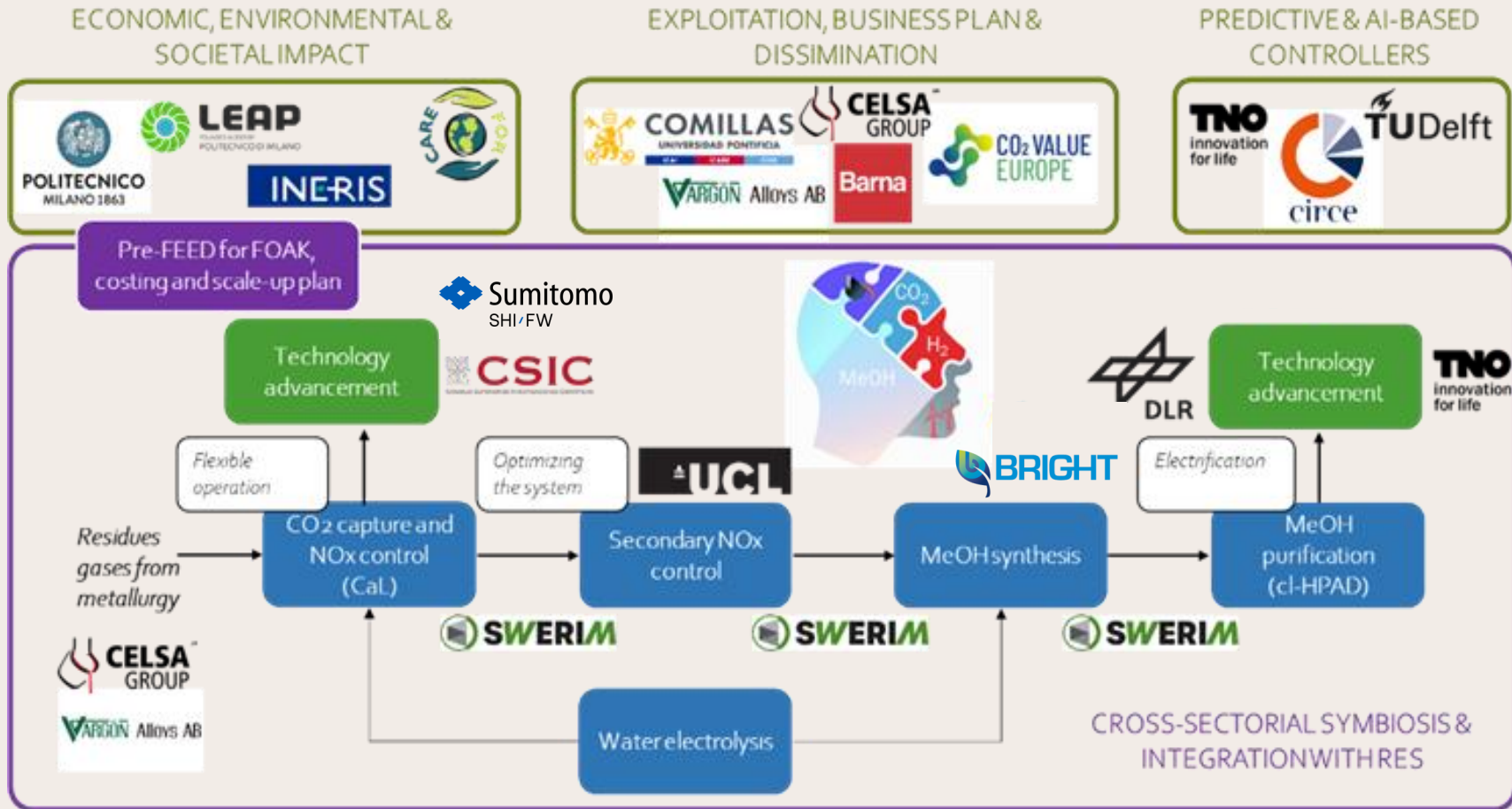
- Demonstrate at TRL7 continuous production of 1 t/d of Methanol from EAF and Ferrochrome Alloy residual gases
- Proof specific energy consumption reduction $\geq 25\%$ and e-methanol production cost reduction $\geq 15\%$, while achieving breakeven net zero CO₂ emissions.
- Deliver the preliminary Front End Engineering Design (pre-FEED) of a modular FOAK EMPHATICAL plant for 100 kt/year MeOH production, with proven economic feasibility (target IRR $> 12\%$)



EMPHATICaL Concept



EMPHATICaL Partnership



17 partners
 4.5 years
 Nov. 2024 – April 2029
 17.3 M€ EU funding
 101177725
 HORIZON-CL4-2024
 -TWIN-TRANSITION-01

EMPHATICaL Objectives within TNO Scope



Achieve a 25% reduction in the Specific Energy Consumption along with the possibility of reaching carbon neutrality through the replacement of fossil energy with biogenic energy.

TRL7 demonstration

- Design, procure, construct cl-HPAD and integrate EMPHATICaL principal components
- Demonstrate a consistent e-methanol product quality (> 99 w% purity (fuel grade4) and <1 w% losses in the top product) with a production rate up to 1 t/d in two test campaigns of 6 weeks each.
- Demonstrate gas-to-methanol energy yield (LHV based) $\geq 70\%$ from two defined feedstocks and H₂.
- Demonstrate flexible operation of structure packing cl-HPAD on variable crude methanol feed to prove >60% energy savings compared to conventional distillation process with a mass transfer and pressure drops comparable to the conventional packing (Height Equivalent to Theoretical Plate (HETP) = 0.3-0.4 m and pressure drop of 0.3-1 mbar/HETP).

EMPHATICAL process and system evaluation

- Mitigate the impact of fluctuating feedstock flow and intermittent renewable power, by numerical demonstration of AI-based controllers gaining at least 5% in overall system energy efficiency

Bankable design for the First-Of-A-Kind (FOAK)

- Contribute to the preliminary Front End Engineering Design (pre-FEED) of a modular FOAK EMPHATICaL for a 100 kt/y MeOH reference plant.

A long-term implementation plan and future exploitation of EMPHATICAL

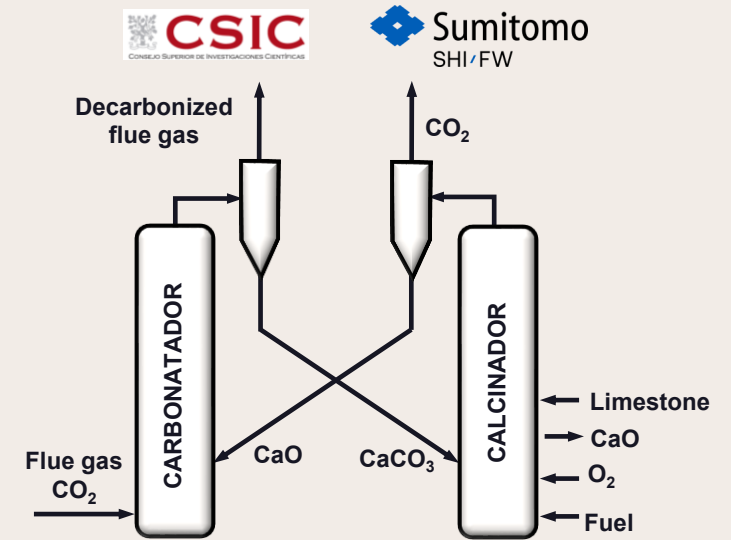
- Conduct a market analysis to identify: (i) market segments, trends, and key players with market share; (ii) target customers and segmentation; (iii) competing solutions and business models; (iv) specific customer needs that novel solutions can meet.

Enabling technologies



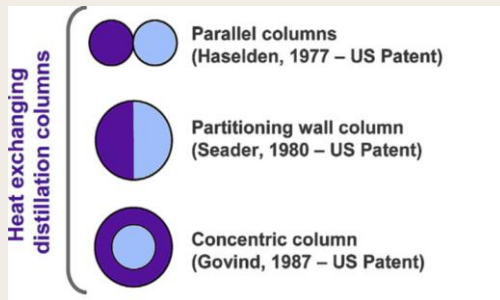
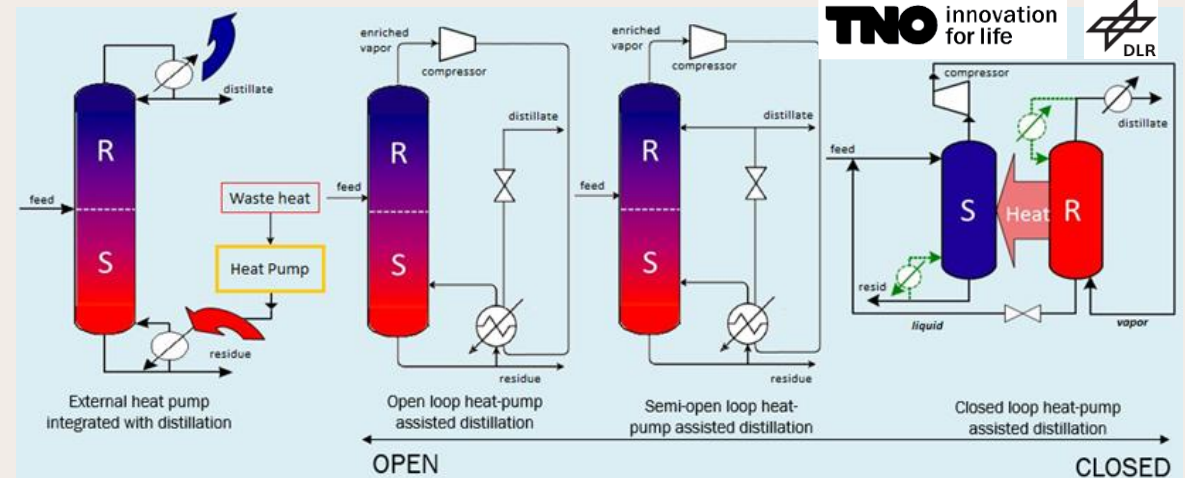
CALCIUM LOOPING TECHNOLOGY (CaL)

- CaL efficiently manage gases with intermittent CO₂ content and flow, ensuring a steady flow of high-purity CO₂.
- CaL pilot upgraded for oxy-fuel calcination to optimize CO₂ capture for MeOH synthesis
- Efficiently deals with SO₂ impurities: lower efficiency penalties (5-8%) for deep removal
- CaL acts as a NO_x control method. Virtual sensors for off-gas monitoring, optimizing CaL conditions, and reducing NO_x formation.



CLOSED LOOP ASSISTED DISTILLATION COLUMN (CL-HPAD)

- Electrification of the distillation
- Potential specific energy savings in distillation >60%
- Different integration options, depending on separation demand



Roadmap CaL



2004

2008

2009

2012

2018

2025

Proof of concept



Reactions kinetics, deactivation studies, reactivation methods

Small pilot plant (10's kWt)



Twin CFB reactor concept validation in lab scale. Basic reactor and process modeling

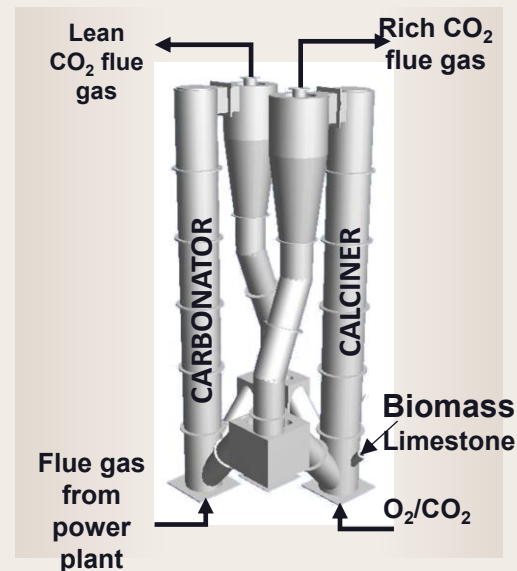
TRL 7 pilot plant (1.7MW_t)



Demonstration of Calcium looping systems at large scale

CaOling
(FP6 2009-2013)

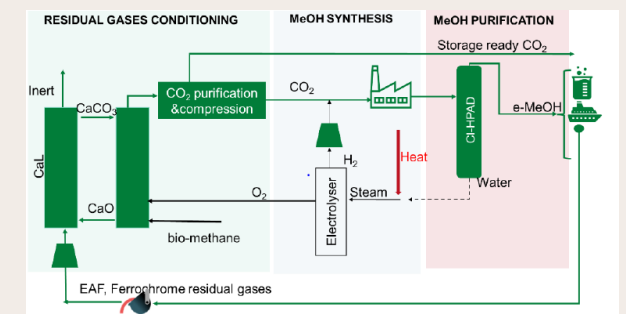
Improvements CaL systems & Industrial processes



- ✓ Variants of Calcium looping processes (recarbonation, combustion under rich-O₂ conditions, flexible flue gas loads)
- ✓ Industrial process (bio CHP & waste to energy plants)

ReCaL (RFCS 2012-2015)
CaO₂ (RFCS 2014/2017)
FlexiCal (RFCS 2016-2019)
Calby2030 (Horizon Europe 2023-2026)

EMPHATiCaL
(Horizon Europe 2024-2029)



EMPHATICAL Objectives for Calcium Looping

- ✓ Design, procure and construct EMPHATiCaL principal components integrated with a full CaL CO₂ capture system including oxy-calcliner.
- ✓ Achieve a constant captured CO₂ flow using advanced conditioning of two types of residual gases by CaL
- ✓ Alternative reactor design for dynamic capture (i.e. moving bed)

Roadmap ci-HPAD (TRL4 to First of a kind plant)



C₂ splitter application is not feasible.

- Promising alternative in MeOH-H₂O
- Possibility for 200% increase in productivity identified.

HEADLINES

TEA and LCA to confirm benefits.

Basic engineering of TRL7 pilot.

Build consortium for TRL7 pilot project (HEU)

REMAP²

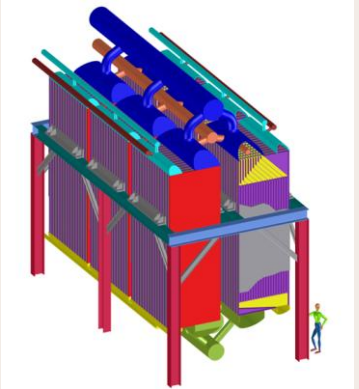
HPAD integrated with compressor.

MeOH integrated with Electrolyser (1 MW_{el})

TRL7 EMPHATICAL

Fully value chain integrated. Including: CO₂ Capture, Electrolysis, Methanol Production & Purification and Use.

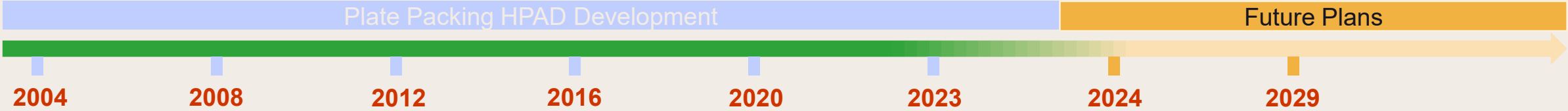
First of kind demo



Historical Development
Proof of concept done at ECN (TNO) & TU Delft

Model development and first application identified in the C₂-Splitter

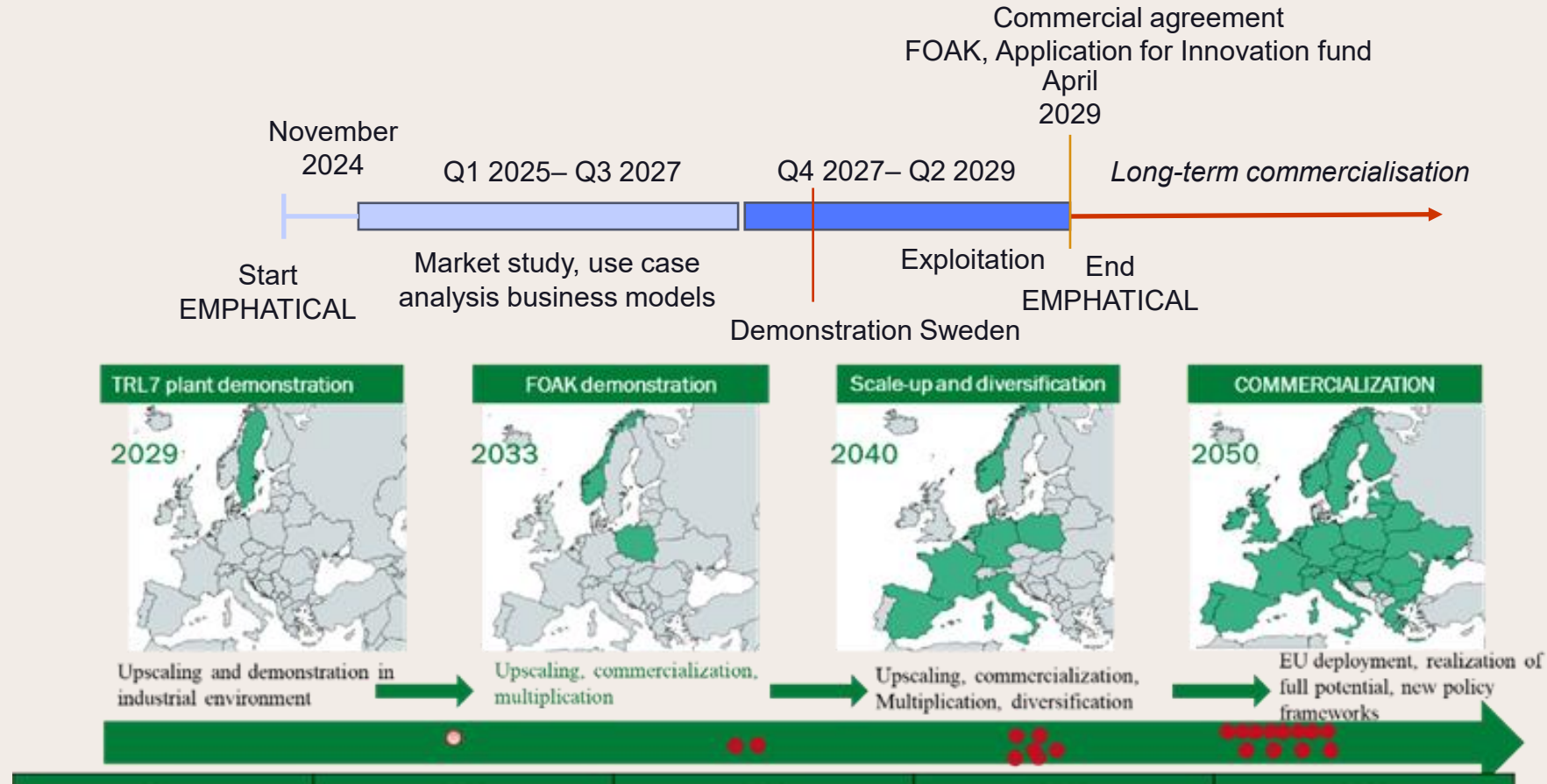
50 kg/hr test bench constructed and operated (TRL4). Stripping (S) mode or rectifying (R) mode only



Commercial implementation plan



Focus: Long-term implementation plan including a collaborative strategy to align stakeholders' needs
Through the definition of the FOAK and the long-term vision



EMPHATICAL project concept and vision



CONCEPT

- Carbon capture from **metallurgical** sector and utilization for **methanol** production

VISION

- Create bankable case for a first commercial size demonstrator at a scale of 100 kt/y methanol production capacity from EAF or ferrochrome alloy residual gases

ROUTE

- The EMPHATICaL project takes **all the steps required to develop the FOAK plant**
 - Demonstration of continuous production of MeOH from EAF or ferrochrome alloy residual gases at 1t_{meoh}/d scale
 - Site identification
 - Business plan development
 - IP&R, ownership, collaboration

EMPHATICAL Partners



KNOWLEDGE CONTRIBUTORS



SERVICE EXPERTS



END-USERS



TECHNOLOGY INNOVATORS



Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or [name of the granting authority]. Neither the European Union nor the granting authority can be held responsible for them.

Thank you for your attention!



**Funded by
the European Union**

The EMPHATICaL project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101177725.