HERCCULES

full CCUS chain demonstration

TALLINN 13/06/2024

Introduction to Horizon Europe HERCCULES project

DISSEMINATION EVENT ON CO_2 CAPTURE, TRANSPORT, USE AND STORAGE TECHNOLOGY (CCUS)

HORIZON EUROPE PROJECTS HERCCULES & CCUS ZEN

Speaker: Dr. Maurizio Spinelli
LEAP – Project Coordinator

Funded by the European Union

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HERCCULES project

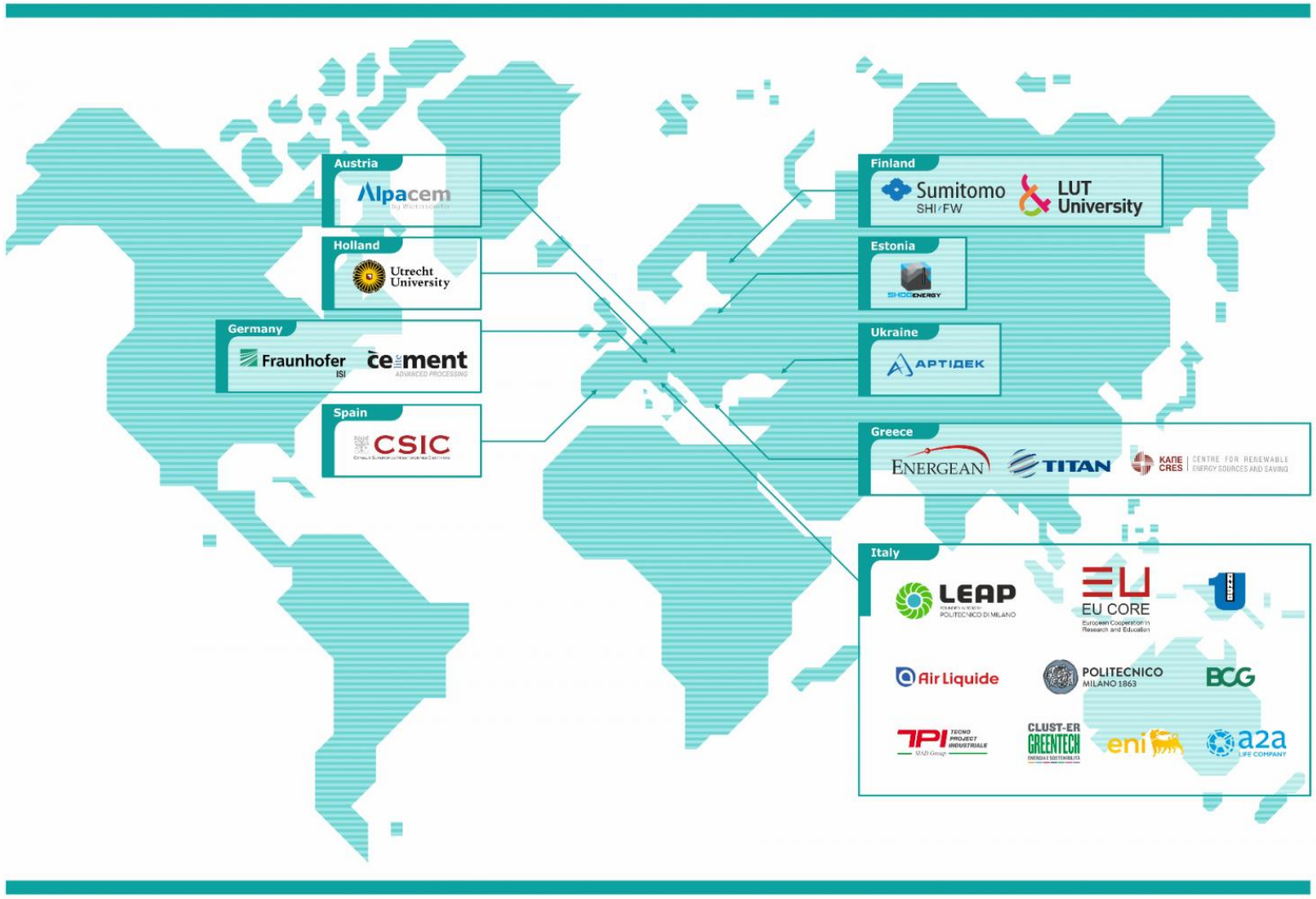
HERCCULES
full CCUS chain demonstration

HEROES IN SOUTHERN EUROPE TO DECARBONIZE INDUSTRY WITH CCUS

Demonstration of the **full CCUS chain** for the decarbonization of hard-to-abate industries in southern Europe, focusing on **cement and energy from waste sectors in Northern Italy and Greek clusters**

9 Research Organizations

14 Industrial Partners



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1. The numbers of HERCCULES

> HERCCULES: HEROES IN SOUTHERN EUROPE TO DECARBONIZE INDUSTRY WITH CCUS

> Demonstration of the full CCUS chain for the decarbonization of hard-to-abate industries in Southern Europe, focusing on cement and energy from waste sectors in Northern Italy and Greek clusters

- **Coordinator:** LEAP
- **Parternship:**
- 23 partners + 4 affiliated
- **Topic:** HORIZON-CL5-2022-D3-01
- **Start date:** 1 January, 2023
- **Duration:** 60 months
- **Budget total:** € 39.627.208,00
- **UE Contribution:** € 29.632.076,48

HERCCULES NUMBERS

- 3 CO_2 capture pilot plants
- 3 CO_2 use pilot plants
- 2 Storage sites
- >10.000 test hours
- >3500 ton CO_2 captured
- >1000 ton CO_2 stored
- >8000 ton of low-carbon concrete
- 7 Pre-feed and Hazop studies

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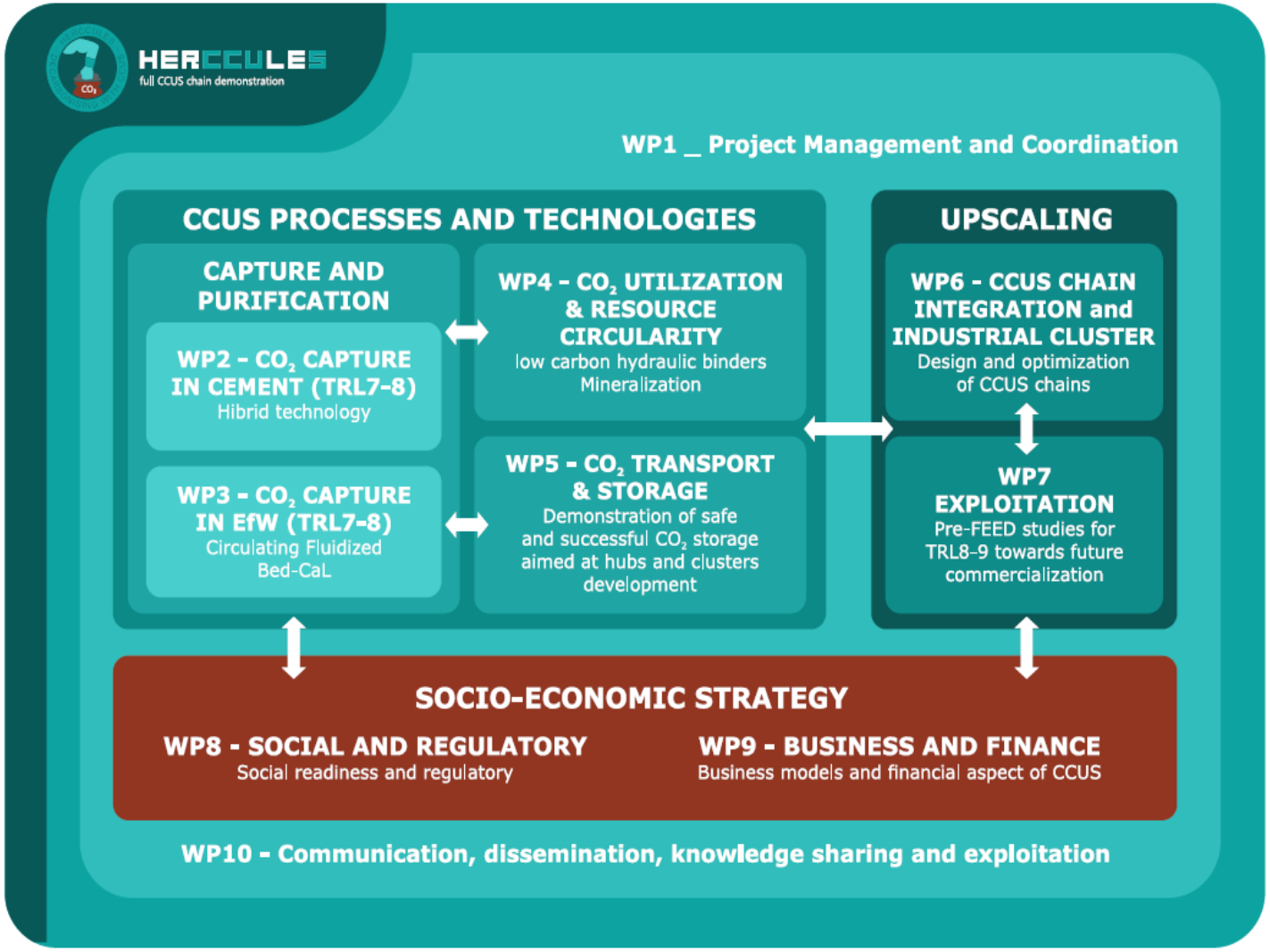
2. Structure & Work Packages



- Innovation Action – Budget ≈ **40 M€**
- **10** Work Packages
- **56** Deliverables,
- **18** Milestones
- Duration : **5 years**

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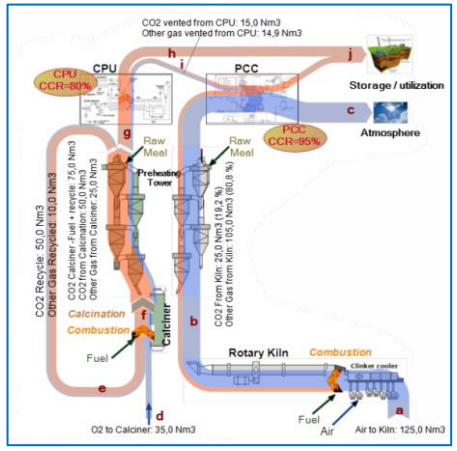
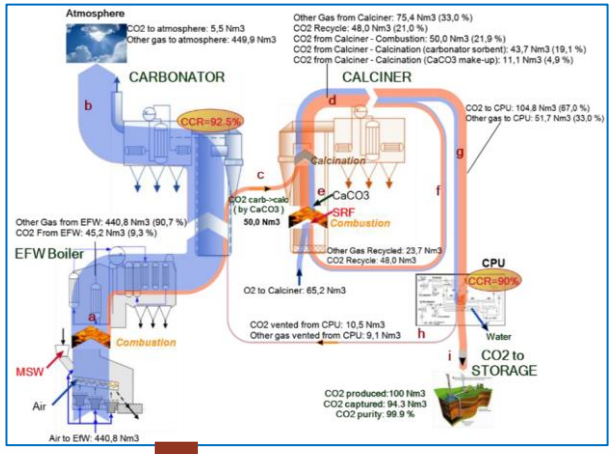
3. Timeline (I)





***Process modeling, design and construction** of the pilot units*

2023 2024 2025 2026 2027

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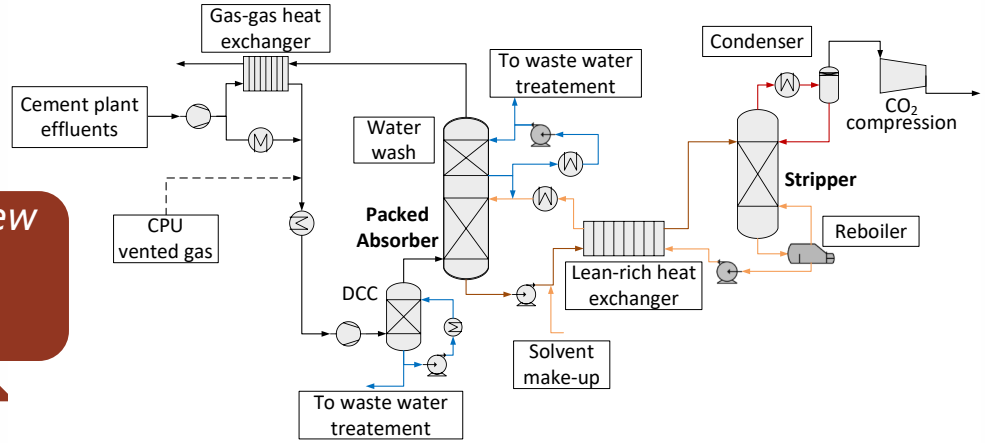
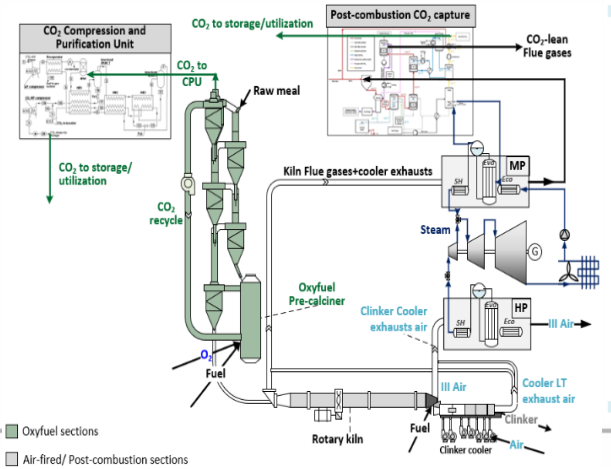
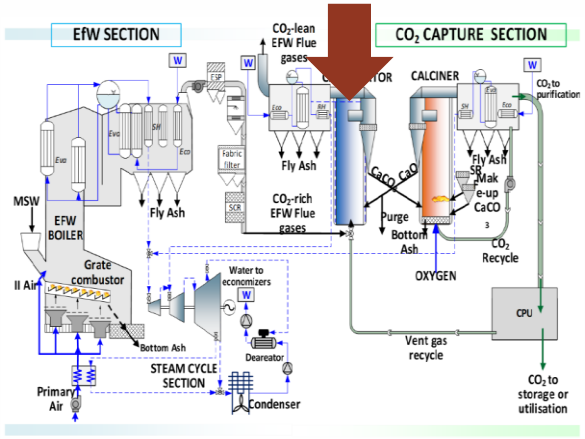
3. Timeline (II)

***Experimental testing** of the new generation **PCC pilot** at the Vernasca plant (BUZZI)*



2023 → 2024 → 2025 → 2026 → 2027





*Demonstration **at TRL7-8 of the hybrid demo plant** on cement flue gases and of the **EfW-CaL system***

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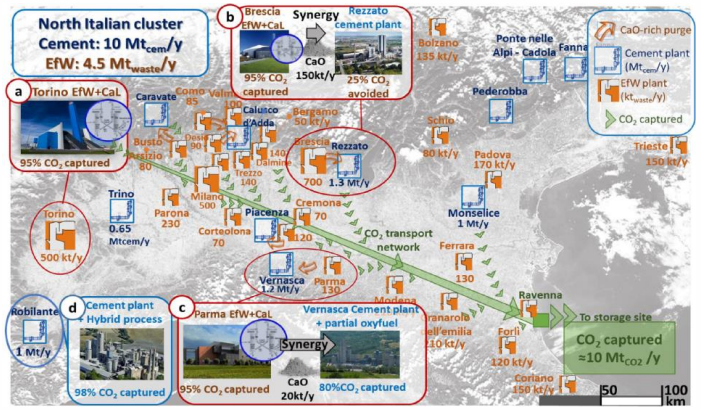
3. Timeline (III)

Testing and demonstration of ***demolished-concrete CO_2 mineralization*** *and production of* ***low carbon concrete***

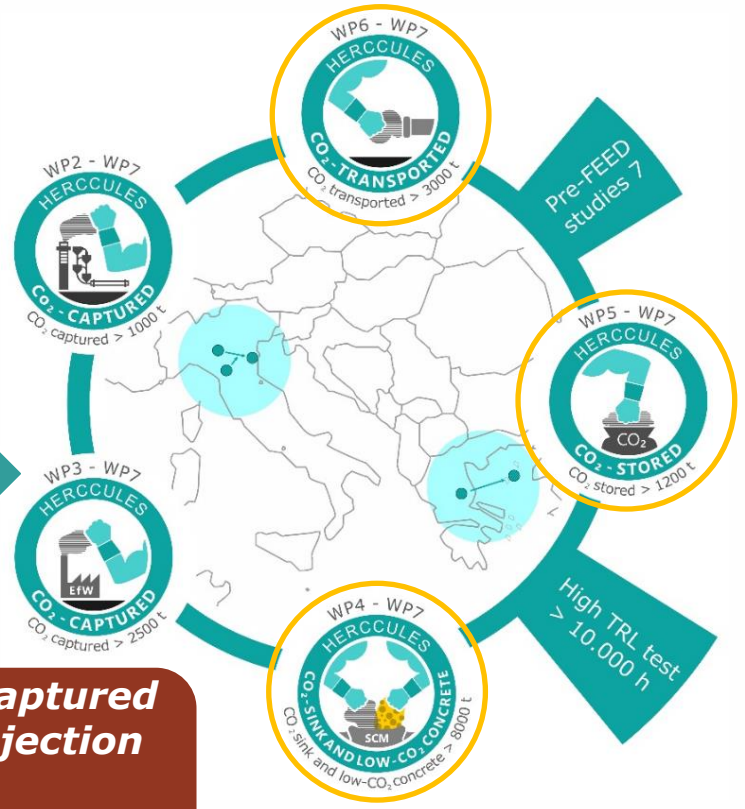
	A	1)	2)	3)	4)
	Reference concrete	TITAN and BUZZI - HERCCULES concrete with CCUS (5.000 m^3)	CELITEMENT - HERCCULES Concrete (5-10 m^3)	TITAN - HERCCULES Concrete (4000 m^3)	BUZZI - Zeolite HERCCULES Concrete (50 m^3)
Cement type	CEM II A-LL 42.5 R	CEM II A LL 42.5 CO_2 capture and geological storage (****)	HERCCULES CELITEMENT	CEM II A LL 42.5 CO_2 capture and geological storage (****)	
Cement content:	320 kg/m^3	320 kg/m^3	340 kg/m^3 *	280 kg/m^3	280 kg/m^3
Technology		CO_2 capture technology in cement making (WP2)	CELITEMENT production from carbon neutral CaO rich CaL purge (WP4)	CO_2 use by demolished concrete mineral carbonation (WP4)	CO_2 use by Natural zeolite (clinoptilolite) CO_2 uptake (WP4)
Additions				40 kg/m^3 CO_2 treated C&D waste	40 kg/m^3 CO_2 treated Zeolite
CO_2 emission	240 kg/m^3	50 kg/m^3 (negative with biomass firing)	100 kg/m^3	negative emission	negative CO_2 emission
OPEX	80 €/m^3***	125 €/m^3	70 €/m^3 (**)	110 €/m^3	110 €/m^3
Approach	ETS	CO_2 storage	Innovation cement relat	CO_2 storage and SCMs	CO_2 storage and SCMs
Scale factor:	Mass production	Mass Production		Mass production	Mass production

2023 2024 2025 2026 2027



Design and optimization *study of* ***CO_2 transportation*** *in Northern Italy*

Demonstration of ***captured CO_2 transport, injection and permanent storage*** *in Ravenna and Prinos sites*



HERCCULES full CCUS chain demonstration

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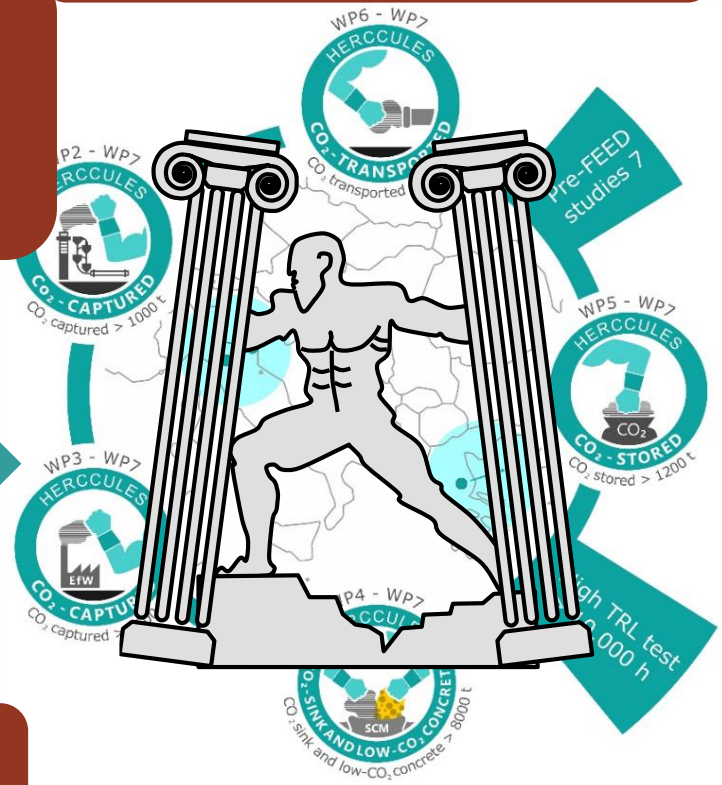
3. Timeline (IV)

BEYOND HERCCULES

- ***Exploitation & Business plan***
- ***Guidelines for citizen engagement***
- ***Definition of high-level economics***
- ***LCA and CBA of CCUS chain***

2023 → 2024 → 2025 → 2026 → 2027



WP10: Communication, dissemination and knowledge sharing
WP8: Social perception and community engagement

Full scale FOAK industrial project

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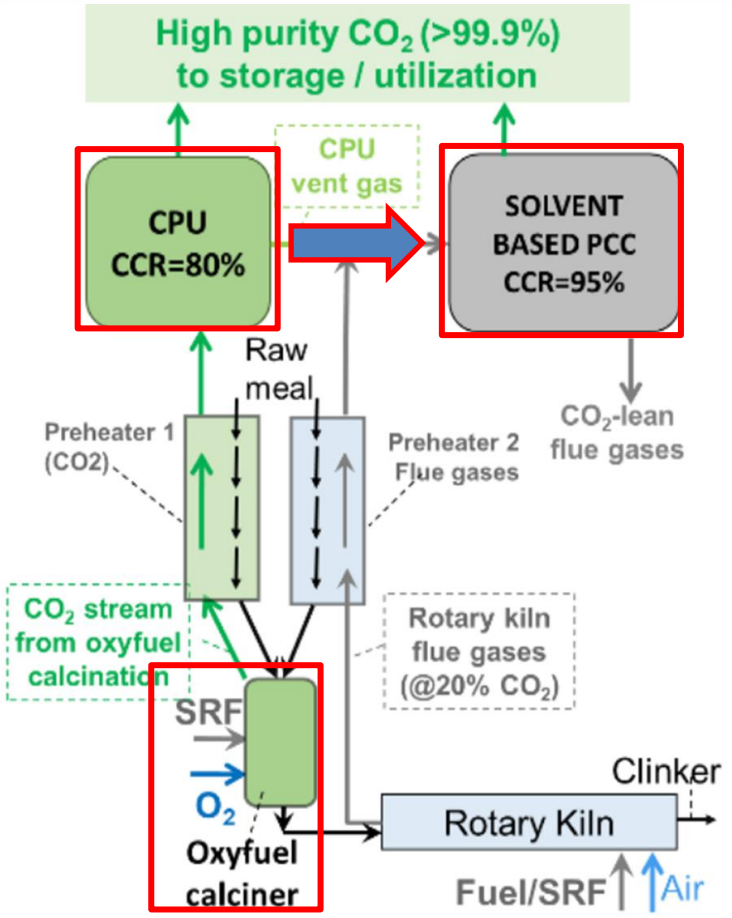
4. CCUS: Application in Cement sector (WP2-WP7)



HERCCULES Hybrid CO_2 capture configuration

1-Oxyfuel calcination with CPU

+

2- novel solvent-based post-combustion capture (PCC)

+

3- Integration CPU-PCC → Hybrid

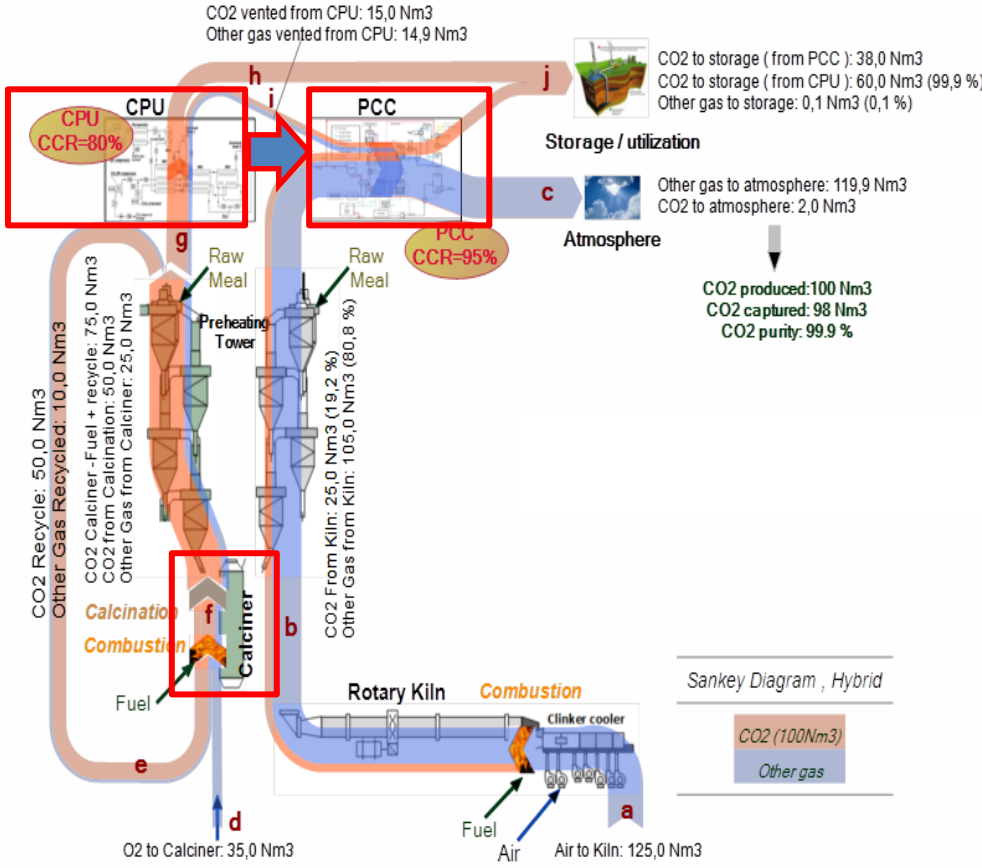
TRL 7-8 tests and scale-up studies for three configurations. KPIs:

i. **Ultra-high CO_2 capture rates (up to 98%) and purity (>99.9%)**

ii. **SPECCA<2.2 MJ_{LHV}/kg_{CO2}**

iii. **CO_2 emissions <-150 $kg_{CO2}/t_{clinker}$**

iv. **Cost of CO_2 avoided <50 €/t_{CO2}**



HERCCULES full CCUS chain demonstration

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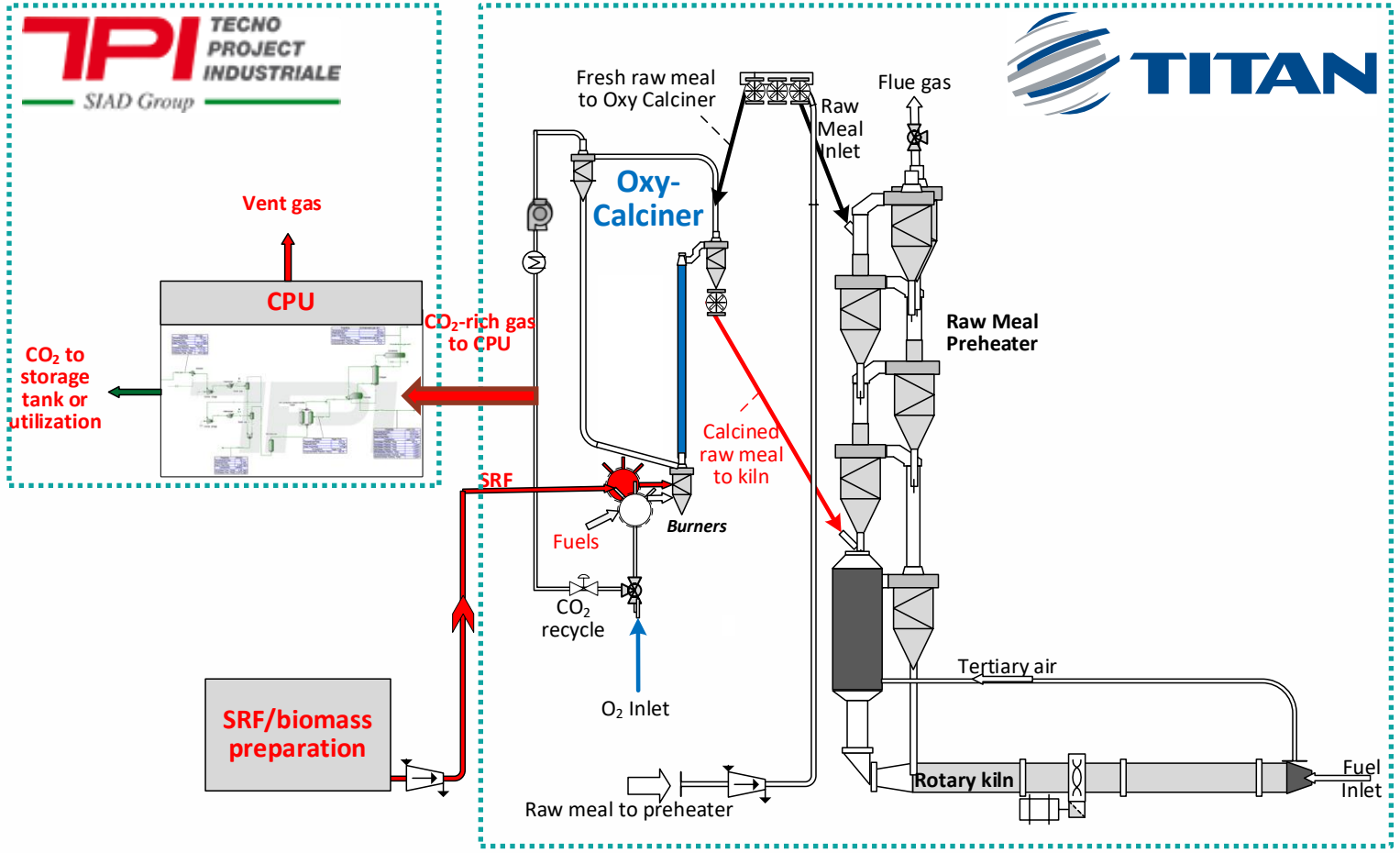
4. CCUS: Application in Cement sector (WP2-WP7)

1- Oxyfuel calcination with CPU

➢ **Oxyfuel pilot plant characteristics**

- Goal of this demonstration: partial oxyfuel technology benchmarking with conventional and alternative fuels, including biomass and waste
- **1.5 MW_{th}** oxyfuel demo plant + CO_2 Purification and liquefaction Unit (CPU)
- **Capture rate oxyfuel + CPU 80%**
- **4.5-5 ton_{CO2}/day** of high-purity (**>99.9%$_{vol}$**) liquid CO_2 produced



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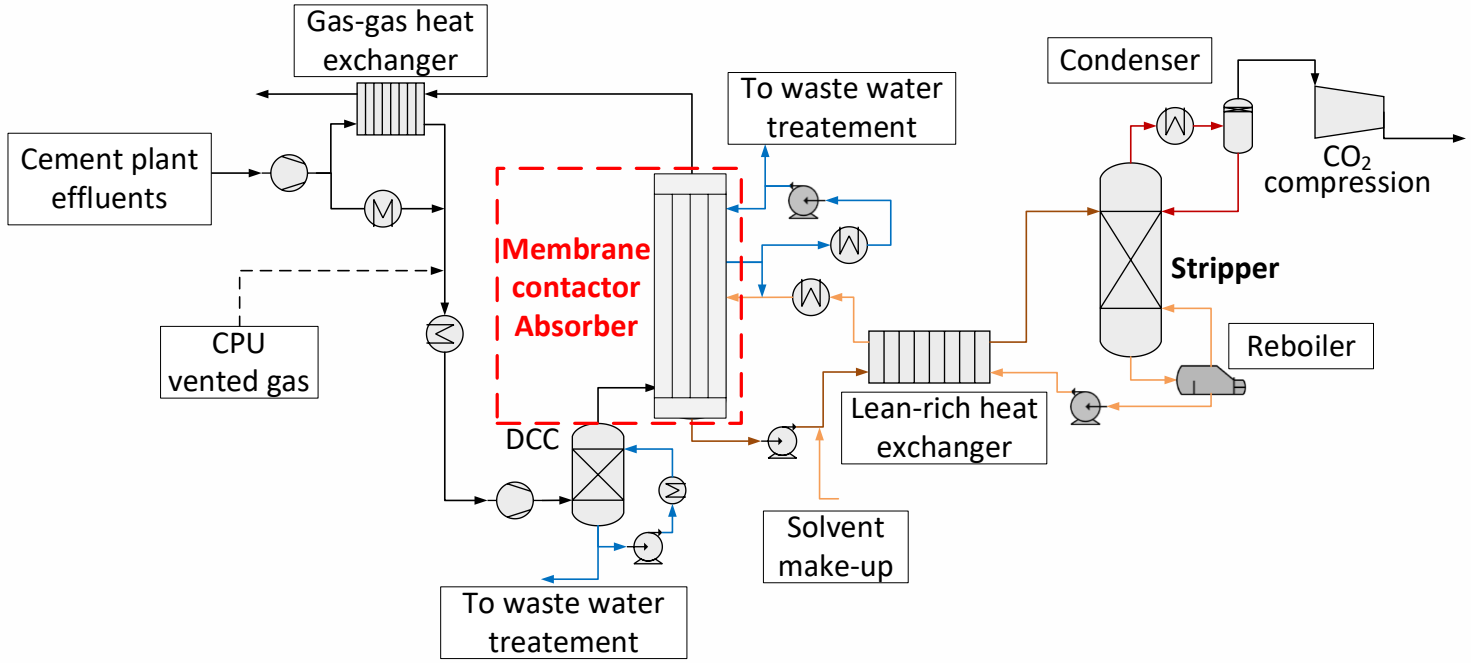
4. CCUS: Application in Cement sector (WP2-WP7)

2- Novel solvent-based post-combustion capture (PCC)

➢ **PCC pilot plant characteristics**

- Design to treat at least 250-300 Nm^3/h of cement flue gases
- **Capture rate >95%**
- 2.5-3 ton_{CO2}/day of Liquid CO_2 produced
- Solvents targeted: **MEA** (validation), improved **solvent**
- **Innovative design**, considering:
  - ➢ **Lean-vapor compression**
  - ➢ **Membrane contactor**



➢ **PCC pilot plant testing**

- The unit will be design as a movable skid-mounted system, to be **tested in Vernasca in the standalone PCC mode** (flue gas at the stack), or **flue gas from rotary kiln mixed with CPU off-gas in the hybrid mode (Greece)**

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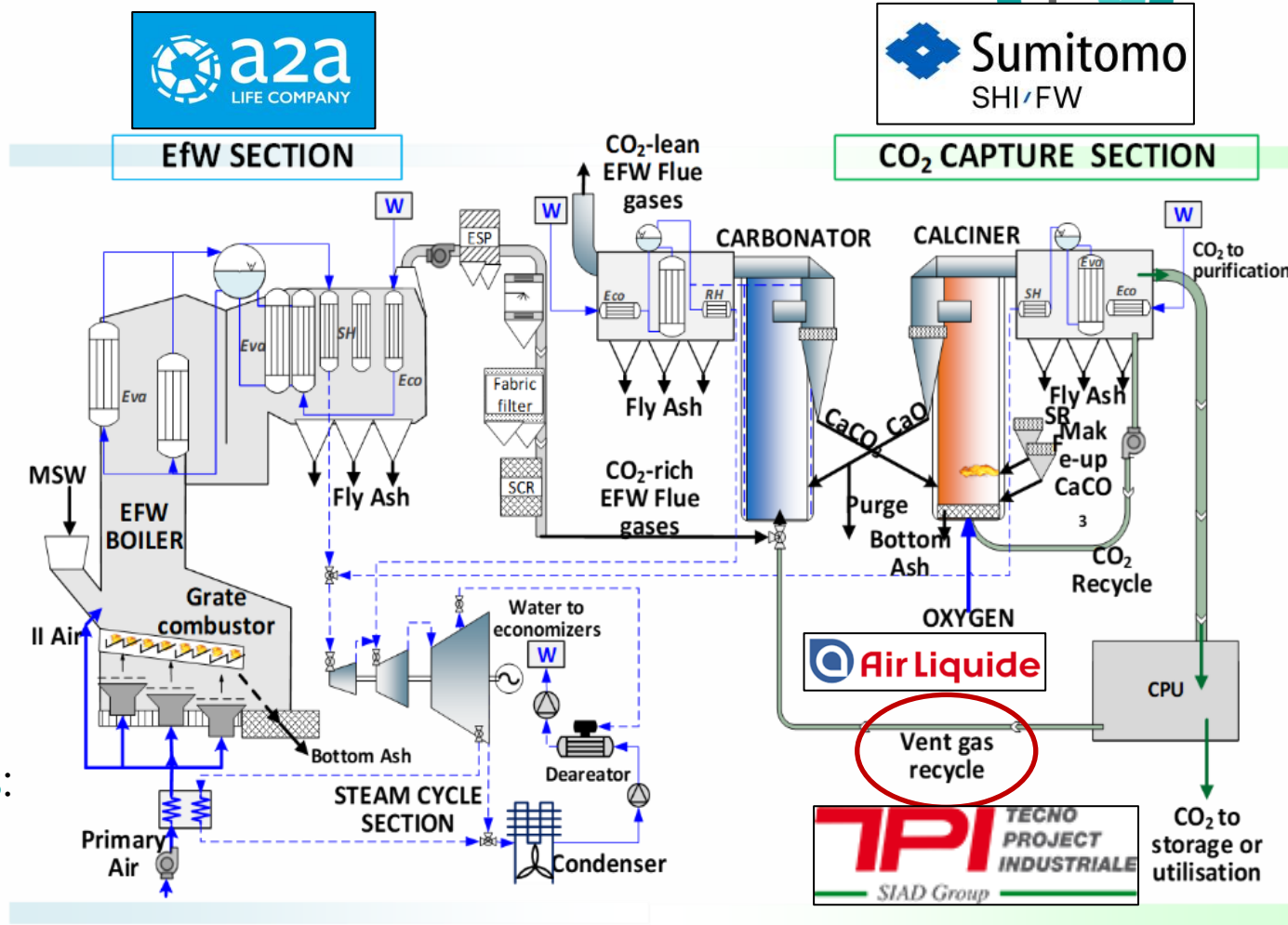
4. CCUS: Application in Energy from Waste sector (WP3-WP7)

- **HERCCULES** will demonstrate at **TRL 7-8** for the first time the **CFB CaL process coupled with CPU**
- Preliminary lab experiments will characterize the **Ca-based sorbent** exposed to EfW flue gases
- The demo plant will be installed and operated at the **EfW Silla 2 plant** owned by A2A Ambiente (A2AAMB)
- The CFB CaL pilot will be operated with **SRF** and **sewage sludge**, targeting the following KPIs:
  - i. CO_2 Capture efficiency **95%**
  - ii. Ultra-high CO_2 purity (**>99.9%**)
- **Scale-up studies** and techno-economic analyses:
  - i. Negative CO_2 emissions (**<-400 kg_{CO2}/t_{waste}**)
  - ii. Net electric efficiency improvement of 3% compared to MEA



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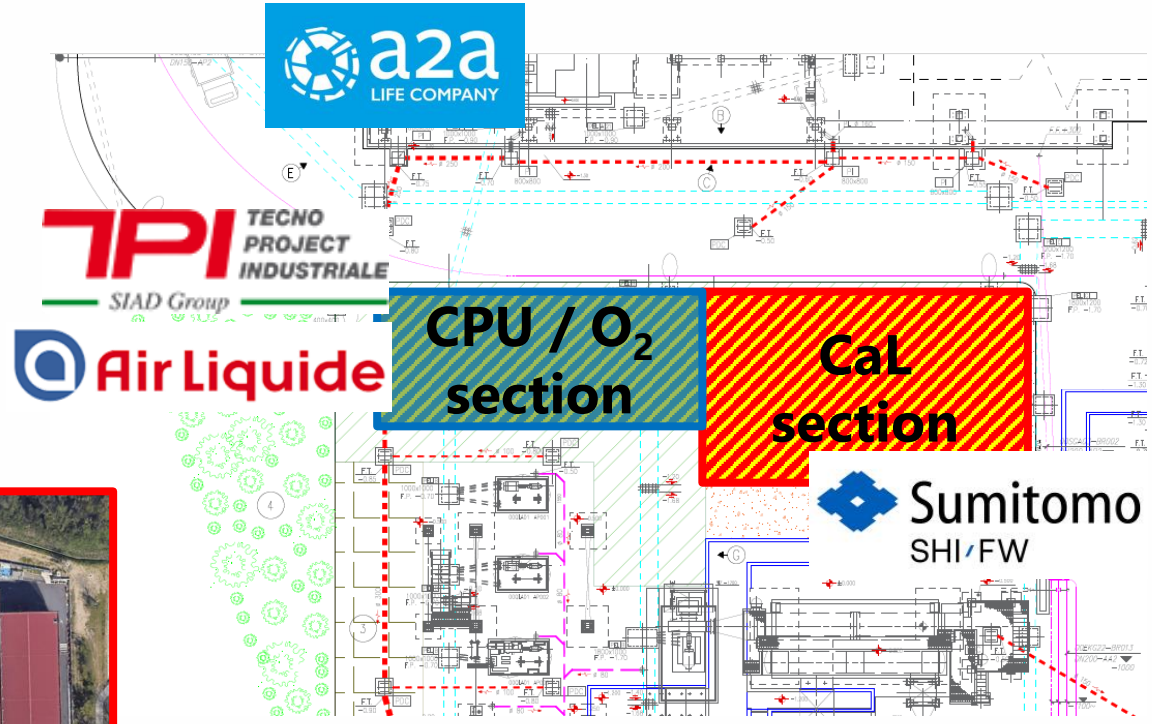
4. CCUS: Application in Energy from Waste sector (WP3-WP7)

➢ Calcium Looping + CPU configuration

The design of the CaL and CPU units are underway, based on:

- **Characteristics of WtE** host plant (Silla2 in **Milan, Italy**)
- Chemical-physical characteristics of the **flow gas entering** the Carbonator (**~1500 Nm³/h**)
- Properties of the **fuel derived from waste (1 MW_{th})**, as input to Calciner

Area selected for the installation of the systems



Division of areas between CaL and CPU / O_2 storage sections

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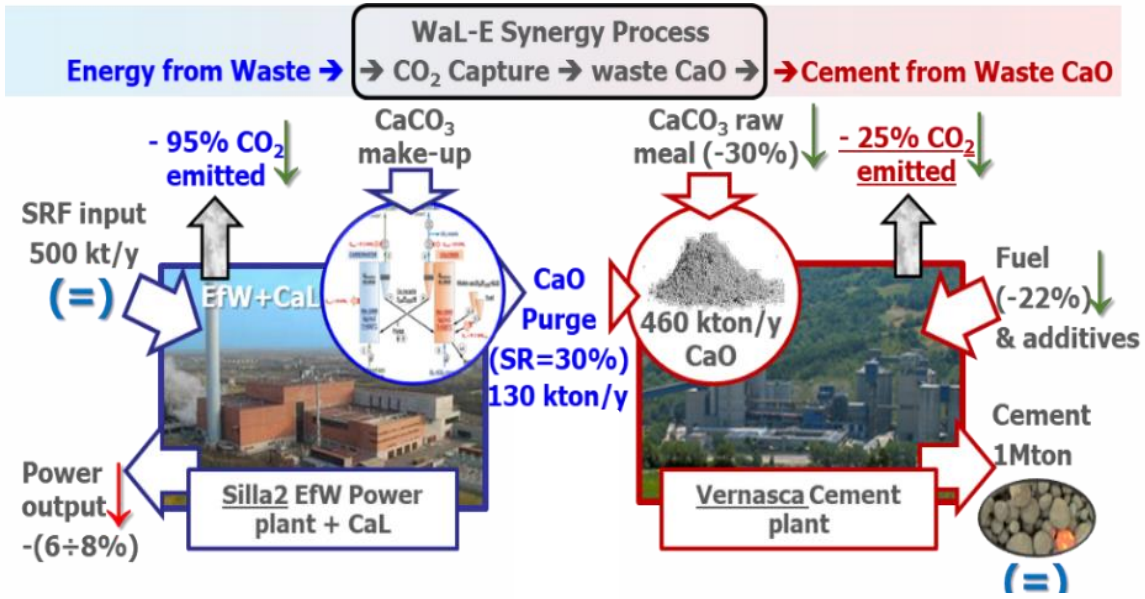
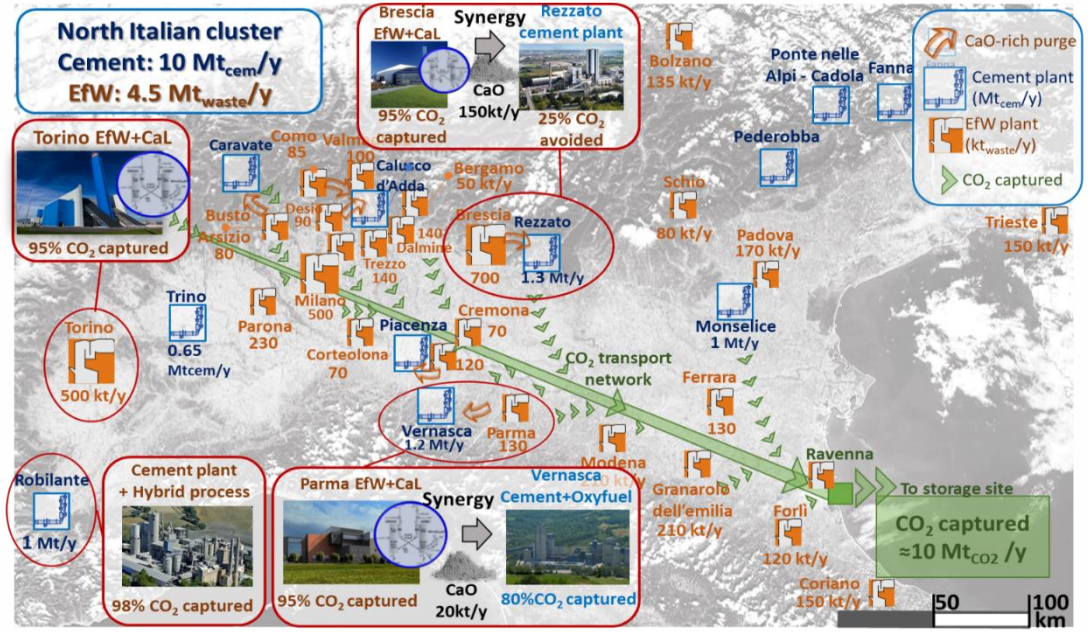
5. CCUS: CO_2 utilization and resource circularity (WP4-WP7)

Cement and concrete carbon footprint reduction:

i. **by-product materials recycle processes** exploiting the **CaO sorbent** (purged from the **CaL pilot plant**)





The carbon-sink materials produced via by-products circularity include the **low carbon CELITEMENT® hydraulic binder**, and the **low carbon sulfo-alluminate clinker**

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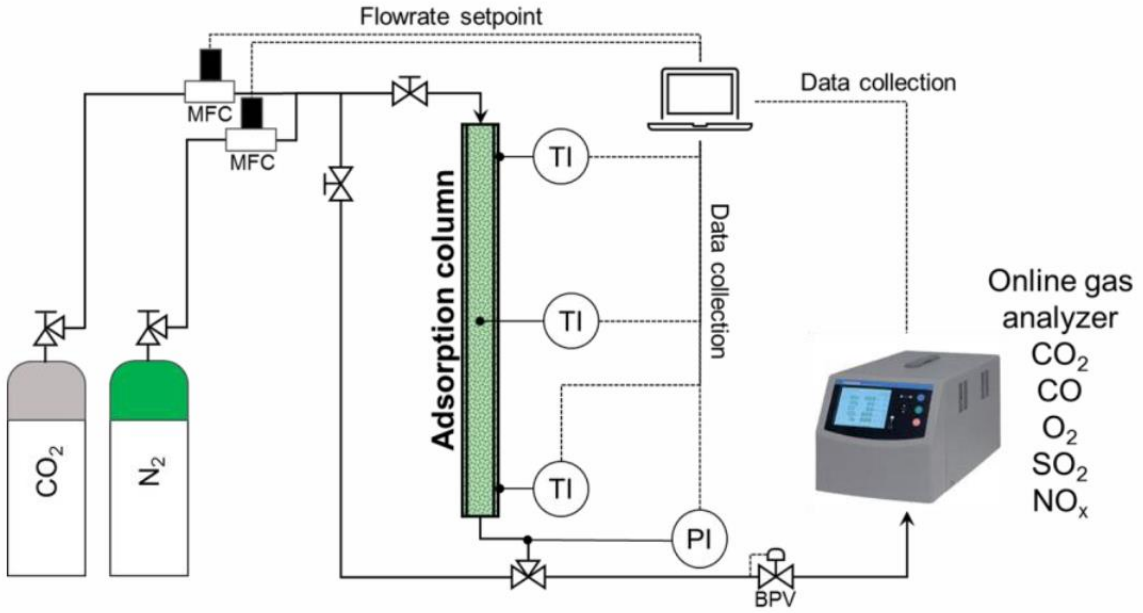
5. CCUS: CO_2 utilization and resource circularity (WP4-WP7)

Cement and concrete carbon footprint reduction:

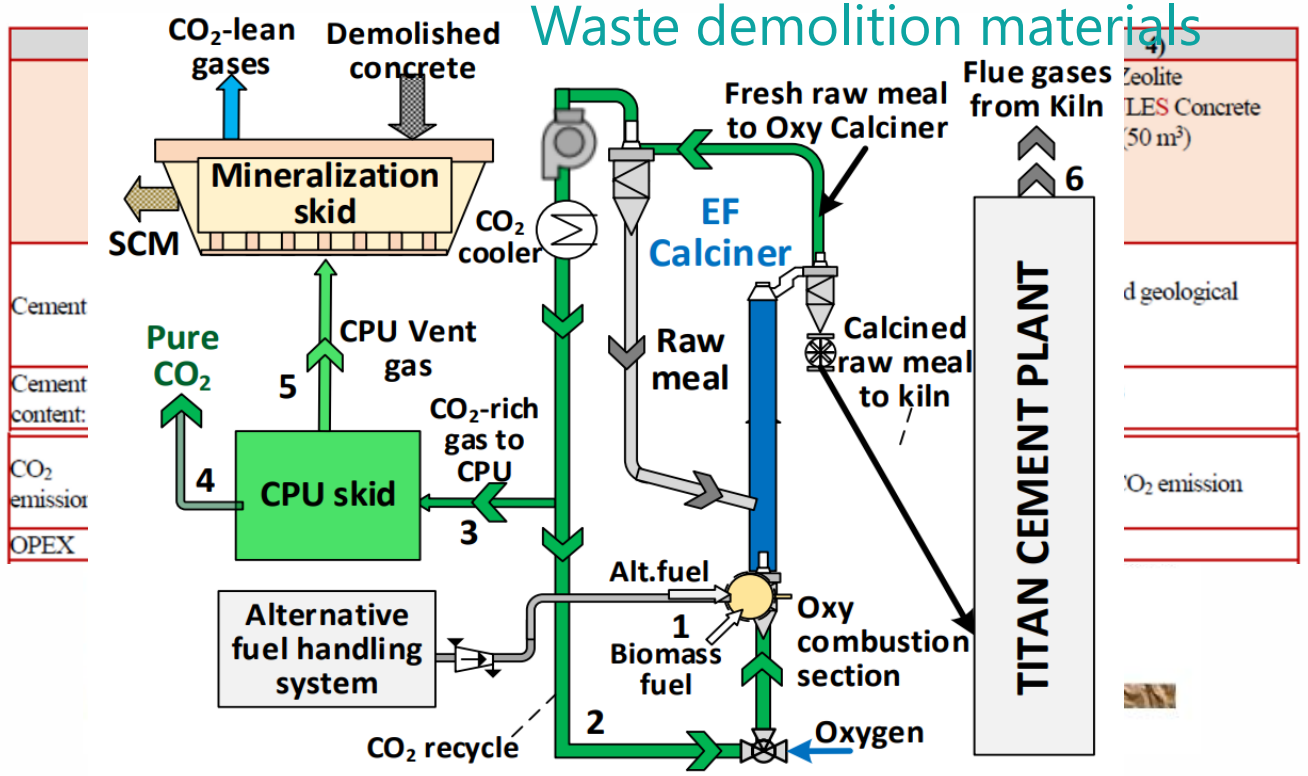
i. by-product materials recycle processes exploiting the CaO sorbent (purged from the CaL pilot plant)

ii. **two CO_2 mineralization skid integrated to CC demo plants (waste demolition & zeolite-based materials)**



Zeolite-based materials

Waste demolition materials



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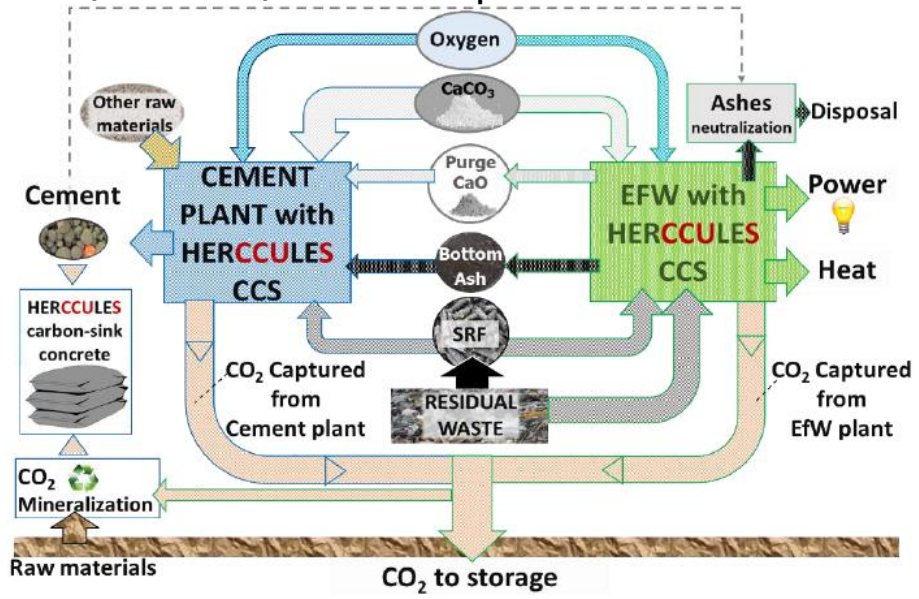
5. CCUS: CO_2 utilization and resource circularity (WP4-WP7)

Cement and concrete carbon footprint reduction:

i. **two CO_2 mineralization skid integrated to CC demo plants (waste demolition & zeolite-based materials)**

→ Four **novel, low carbon concrete formulation** will be produced (>8000 t) and compared with standard concrete

	A	1)	2)	3)	4)
	Reference concrete	TITAN and BUZZI - HERCCULES concrete with CCUS (5.000 m³)	CELITEMENT - HERCCULES Concrete (5-10 m³)	TITAN - HERCCULES Concrete (4000 m³)	BUZZI - Zeolite HERCCULES Concrete (50 m³)
Cement type	CEM II A-LL 42.5 R	CEM II A LL 42.5 CO_2 capture and geological storage (****)	HERCCULES CELITEMENT	CEM II A LL 42.5 CO_2 capture and geological storage (****)	
Cement content:	320 kg/m³	320 kg/m³	340 kg/m³ *	280 kg/m³	280 kg/m³
CO_2 emission	240 kg/m³	50 kg/m³ (negative with biomass firing)	100 kg/m³	negative emission	negative CO_2 emission
OPEX	80 €/m³***	125 €/m³	70 €/m³ (**)	110 €/m³	110 €/m³



Other circularities and synergies between cement and EfW sectors

- **SRF valorization** as fuel for both the cement and EfW capture technologies
- **Sharing and optimizing the infrastructure** for CO_2 transportation

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6. CCUS: storage and CO_2 chain optimization (WP5-WP6)

- **HERCCULES** will **safe and effective permanent CO_2 storage of more than 1000 ton of captured CO_2** in the most advanced CO_2 storage sites in Southern Europe: **Ravenna (ENI) and Prinos (ENERGEAN)**

  - **High storage capacity** and cost-effective potential, good connection with **clusters** of emitters and possibility to repurpose **existing infrastructures**

Ravenna CCS

Ph 1 - 2024
25 KTPA of CO_2

Ph 2 – 2027
4 MTPA of CO_2

Exp – after 2030
16 MTPA of CO_2

- Important CCS Hub in Southern Europe and Mediterranean
- Supports decarbonization of industrial clusters in Italy & Mediterranean – storage site for the PCI Callisto
- Transportation network being developed to receive CO_2 both via pipeline and shipping
- Strong interest from nearby and international emitters, including beneficiaries from Innovation Fund
- Over 20 feasibility studies in collaboration with national and international industrial emitters
- Over 500 MTON of CO_2 total capacity
- Phased expansion of injection up to 16Mtpa after 2030

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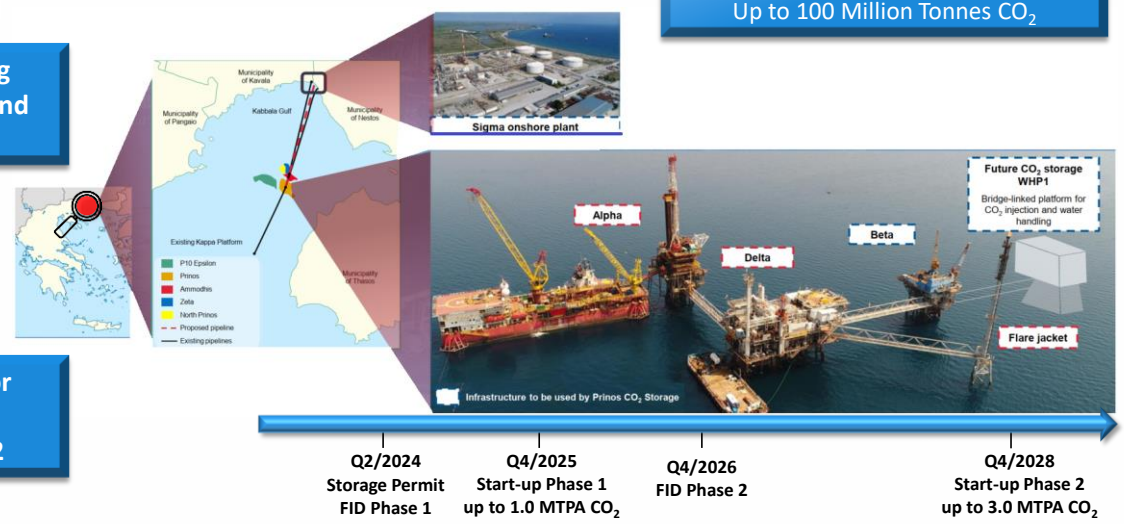
ENERGEAN

Qualified to receive funding through Greece's Recovery and Resilience Facility

8 MOU's signed by International Emitters

Greek Exploration Permit for Prinos Storage site granted @September 2022

TOTAL STORAGE CAPACITY
Up to 100 Million Tonnes CO_2



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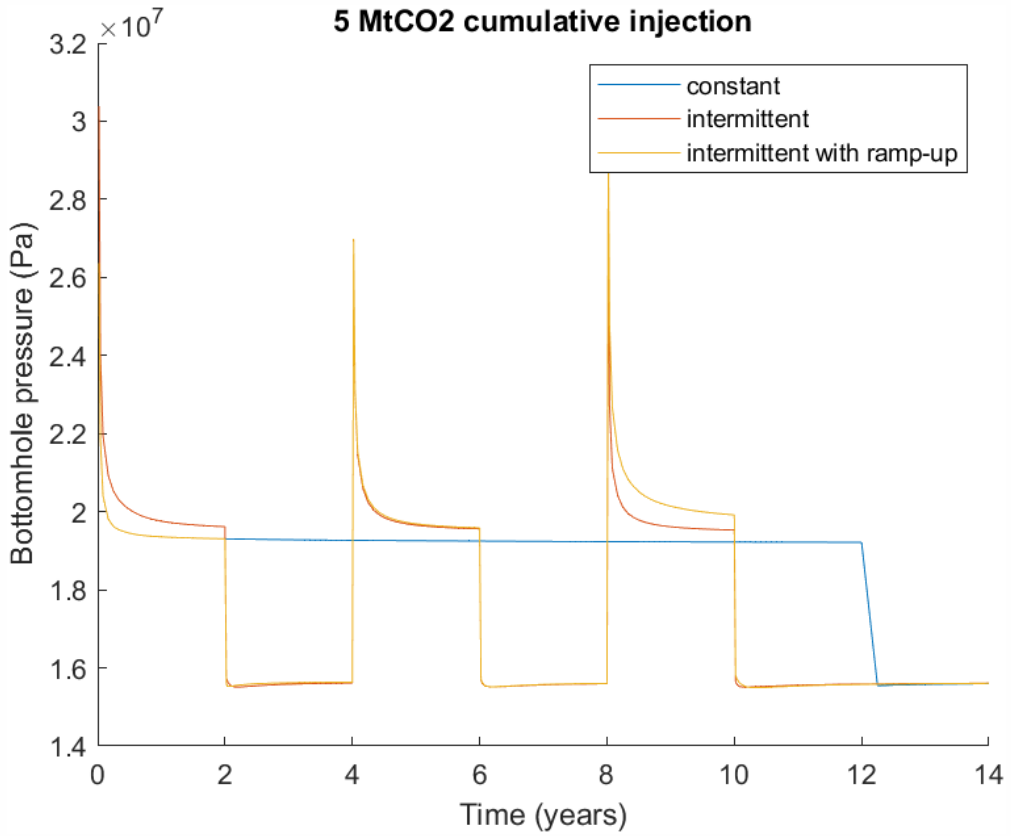
  - **High storage capacity** and cost-effective potential, good connection with **clusters** of emitters and possibility to repurpose **existing infrastructures**
  - **Monitoring** strategies, **modelling** of the storage reservoirs, development of guidelines for future storage site permitting and **authorization procedures**.



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6. CCUS: storage and CO_2 chain optimization (WP5-WP6)

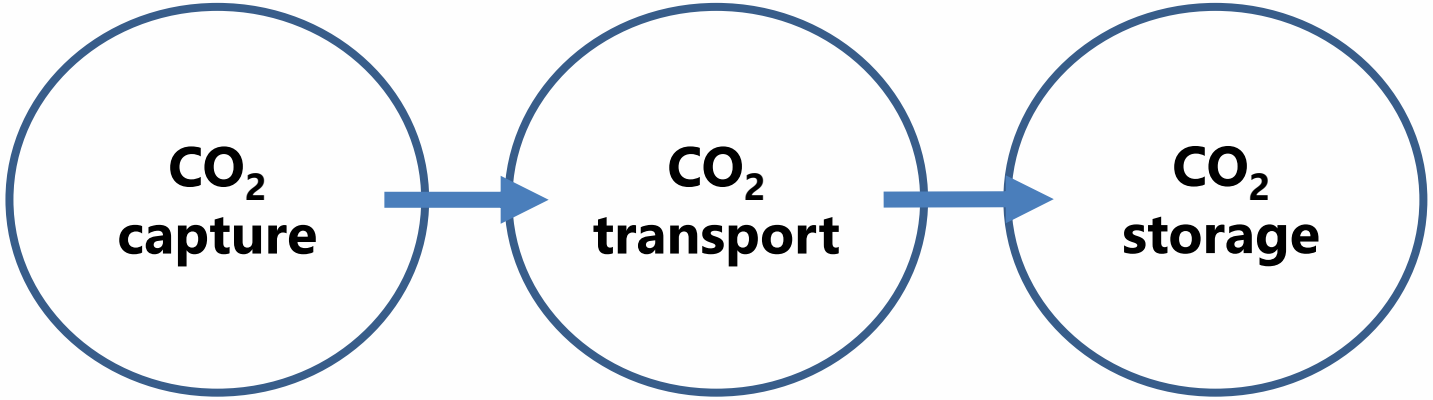
- **HERCCULES** will **safe and effective permanent CO_2 storage of more than 1000 ton of captured CO_2** in the most advanced CO_2 storage sites in Southern Europe: **Ravenna (ENI) and Prinos (ENERGEAN)**

  - **High storage capacity** and cost-effective potential, good connection with **clusters** of emitters and possibility to repurpose **existing infrastructures**
  - **Monitoring** strategies, **modelling** of the storage reservoirs, development of guidelines for future storage site permitting and **authorization procedures**.

  - **Multi-criteria optimization methods** for the **design of the optimal CO_2 transport network for utilization and storage** under different infrastructural evolution scenarios

Optimization framework: **Mixed Integer Linear Programming**

Overall optimization considering the 3 main components of the CCS chain



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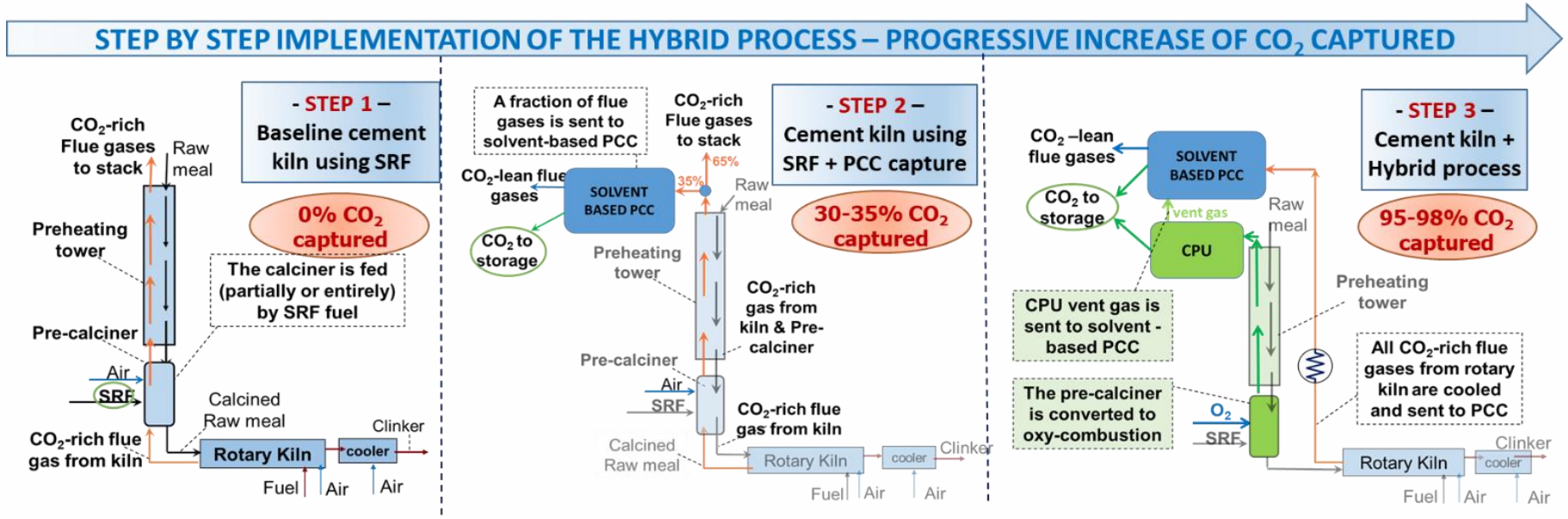
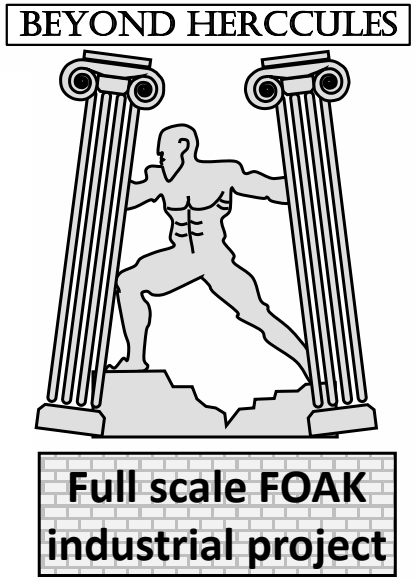
7. HERCCULES: Scale-up and Dissemination

- In the short term, pre-commercial demonstration at TRL 8-9 of a complete CCUS value chain (**scale-up HERCCULES demo plants, WP7 scale-up** studies)
- In the medium term, the results in **HERCCULES** can facilitate large-scale CCS implementation in cement (need of modernization) and EfW (increase of non-recyclable waste)





- Identification of **business models** and financial mechanisms tailored to CCUS, **LCA** and **CBA** in **WP9**
- Assessment of the **societal readiness** of the integrated CCUS chain; analysis of socio-economic and political barriers, policies and regulations to facilitate the development of regulatory framework **(WP8)**

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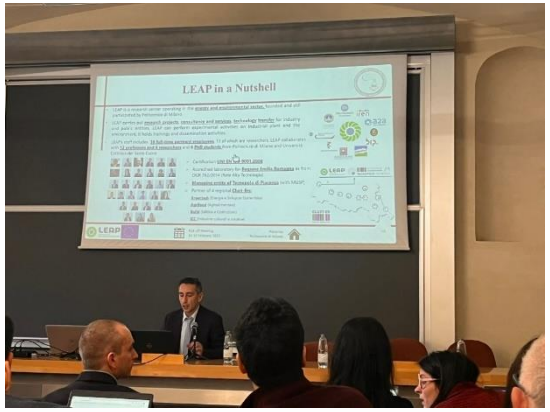
7. HERCCULES: Scale-up and Dissemination

Kick-off meeting – Piacenza, Italy 15-16th February 2023



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7. HERCCULES: Scale-up and Dissemination

First Regional stakeholder committee – Bologna, Italy 16th January 2024

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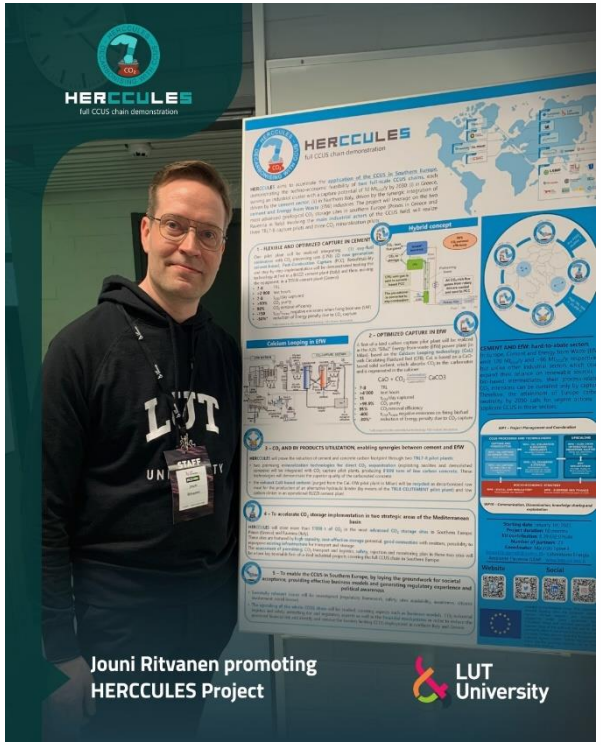
7. HERCCULES: Scale-up and Dissemination

Disseminations on social medias



HERCCULES project
May 2024

Carbon capture and storage (#CCS) technologies are pivotal in achieving current carbon emission reduction goals. Stepping up investments in CCS projects is imperative to achieve global net zero CO2 emissions by 2050.

HERCCULES project is a European project aimed at expediting this process, capitalizing on existing transport and storage endeavors in Italy and Greece while pioneering novel #capturetechnologies.

Drawing on its extensive engineering expertise, Tecno Project Industriale (TPI) part of The SIAD Group will play a crucial role in the project.

TPI will develop cutting-edge technologies for decarbonizing high-emission sites, designing and constructing CO2 capture and purification plants to be integrated into two cement

75

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HERCCULES
full CCUS chain demonstration

> THANKS FOR YOUR ATTENTION

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