

METAWAVE

High-temperature heating processes with breakthrough microwave and digital technologies for increased energy efficiency

1 Jan. 2024 - 31 Dec. 2027

HORIZON-CL4-2023-TWIN-TRANSITION-01-31

Project Coordinator: María Herrando
INSTITUTO TECNOLOGICO DE ARAGON (mherrando@ita.es)

Presenter: Valia Iliopoulou
CORE (viliopoulou@core-innovation.com)

ASPIRE

PROCESSES4PLANET

Project Overview

METAWAVE aims to revolutionize high-temperature heating industrial processes, using microwave-based heating systems.

METAWAVE's goals are intimately related to the Strategic Objectives (SO), with the 6th one associated with demonstrating the integrated microwave-based heating systems in 3 different industrial sectors.

SO1: Develop new design methods and consolidate a process for the introduction of microwave technologies as a replacement for fossil-based heating systems	→ **[KER1 METAWAVE simulation-driven design]**
SO2: Optimize the industrial heating processes and reduce the energy demand by integrating novel digital technologies	→ **[KER2 Microwave digitalisation process]**
SO3: Fully capture the potential of RES integration and energy flexibility by powering the micro-wave-based heating system from a digital virtual power plant	→ **[KER3 Flexible energy operation DSS]**
SO4: Deploy and validate an integrated and modular microwave-based heating system combining highly energy-efficient breakthroughs targeting increased productivity	→ **[KER4 Microwave heating integration kit]**
SO5: Ensure the techno-economic feasibility of the METAWAVE system and pave the way towards its wide acceptance, technological adoption and upscale	→ **[KER5 Sustainability and adoption strategy]**
SO6: Convincingly demonstrate the METAWAVE system in distinct industrial environments towards the acceleration of the approach to market readiness	→ **[KER6 METAWAVE demonstrations]**

ASPIRE

METAWAVE

PROCESSES4PLANET

Consortium

Instituto Tecnológico de Aragón

Project Coordinator

aimen TECHNOLOGY CENTRE

avanzare inventing the future

crit

COPHA

core|IC

EUROCORE CONSULTING

:fm Fricke und Mallah Microwave Technology GmbH

GRES ARAGÓN

idener.ai

imec

IRES Innovation in Research & Engineering Solutions

kmop

Metlen Energy & Metals

core

R&D Carbon

SYXIS innovate together

Tampere University

UNIVERSITAS STUDIORUM MUTINENSIS ET REGIENSIS 1175

UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

Project Case Study

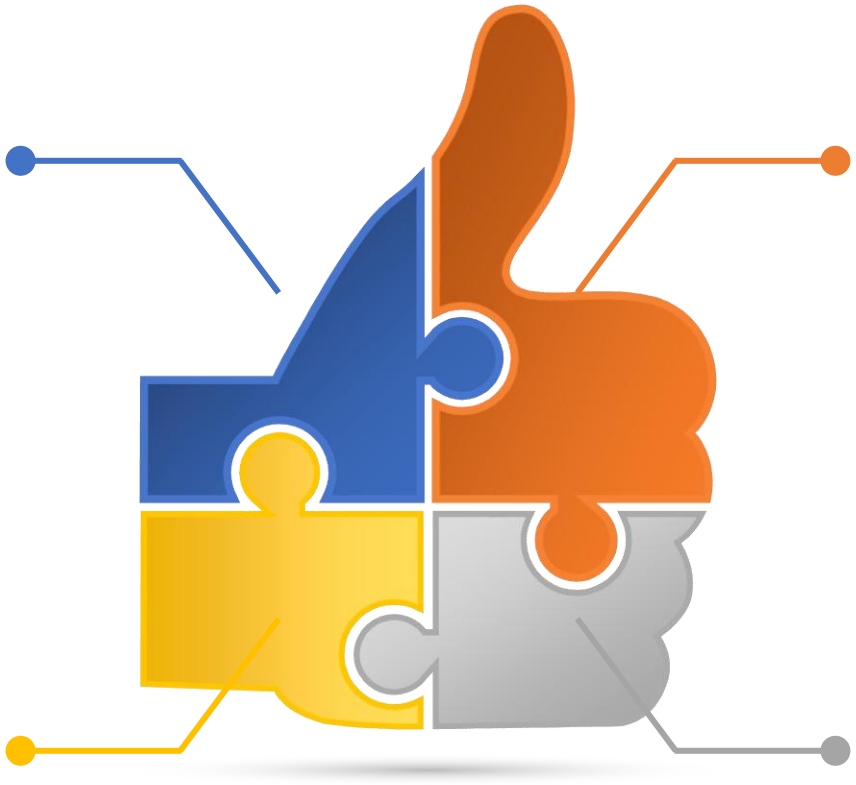
1. The EU/ P4P Needs

Process industries are characterized by a high energy-intensive demand and strongly rely on fossil re-sources to satisfy their energy needs, releasing a vast amount of greenhouse gas (GHG) emissions.

2. The Project Solution

METAWAVE proposes the introduction of advanced microwave-based heating systems in high-temperature heating processes (conventionally conducted at T>400°C) which opens significant opportunities for impactful, breakthrough research.

19 Partners
9 Countries



Budget: 9,487,573.87 €
(LUMP SUM)

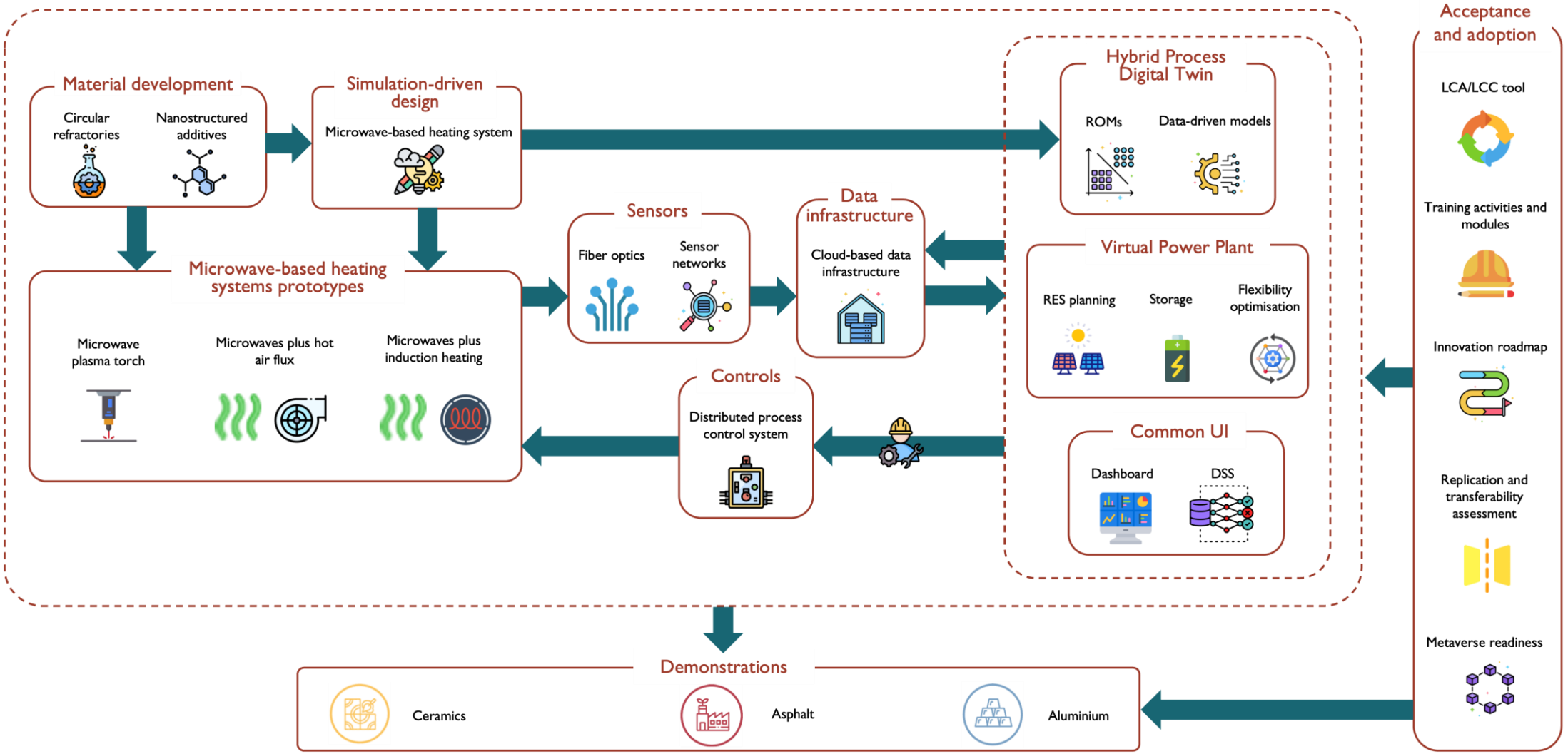
4. Demonstrators

Sector	Process	Prototypes
Ceramics GRES	Firing porcelain tiles	Microwave plasma torch
Asphalt COPHA	Heating aggregates	Direct microwave heating + hot air flux
Aluminium MYTIL	Carbon anode baking	Direct microwave + induction heating

3. Added Value

Demonstration of high-performance microwave-based heating systems. Key metrics include process efficiency, energy use, GHG emissions, and productivity. Enhanced system efficiency, faster processing, and better controllability can significantly advance the twin-transition and strengthen the project's industrial innovation impact.

Key Technologies and Significant Innovations



Key Technologies and Significant Innovations

METAWAVE systems and technologies	Starting TRL	Target TRL
Geopolymeric microwave refractories/susceptors (UMORE)	**4**	**6**
Selection charts for the design of successful microwave processing and applicators (UMORE)	**4**	**6**
Metaverse-ready common User Interface for the process DT and the energy management system (CORE)	**4**	**6**
Plasma-based heating system powered by microwave generators (FUM)	**4**	**6**
Hybrid heating system combining direct microwave heating and induction heating (UMORE)	**4**	**6**
Heating system combining direct microwave heating and hot air flux (FUM)	**4**	**6**
Reduced Order Models for microwave-based high-temperature heating process (ITA)	**4**	**6**
Multiparametric and multipoint FOS monitoring and control system (AIMEN)	**4**	**6**
Thermography using SWIR multispectral cameras for microwave-based heating	**4**	**6**
Distributed process control (NXT)	**5**	**6**
Graphene-based additives for improved microwave absorption (AVANZ)	**4**	**6**
Data-driven optimization for high-temperature microwave-based heating (IMEC)	**4**	**6**

Demonstrations

3 INDUSTRIAL USE CASES



GRES de Aragón (Spain)

Process: porcelain tiles firing (ceramic production)

Conventional heating process:

- **Continuous**
- **Process temperature (1000-1300 °C)**
- **Energy source: natural gas**

Technological Benefits: Microwave heating increases energy efficiency, reduces emissions, and boosts productivity, making the process more sustainable.





COPHA (Spain)

Process: aggregate heating (asphalt production)

Conventional heating process:

- **Continuous**
- **Process temperature (1400 °C)**
- **Energy source: low-sulfur heating oil**

Technological Benefits: Energy-efficient technologies improve productivity and significantly reduce emissions, enhancing overall sustainability.

METLEN (Greece)

Process: anode baking (aluminium production)

Conventional heating process:

- **Batch**
- **Process temperature (800-1000 °C)**
- **Energy source: natural gas + hydrocarbon volatiles**

Technological Benefits: Advanced heating systems increase productivity, lower energy use, and reduce emissions, supporting a greener production process.

Key Exploitable Results and project KPIs

- **KER1 METAWAVE simulation-driven design (SO1)**

  KPIs: *Use of recycled materials for refractories; >5 additives investigated and analysed; Energy reduction of >30%*

- **KER2 Microwave digitalisation process (SO2)**

  KPIs: *Maximize the process manufacturing efficiency by 30%; decrease the process energy consumption by at least 5%*

- **KER3 Flexible energy operation DSS (SO3)**

  KPIs: *Reduction of cost by >5% and CO2eq by 20-25% achieved through the EMS*

- **KER4 Microwave heating integration kit (SO4)**

  KPIs: *Maximum use refractories' temperature and productivity increase by 3-10%; 2D materials addition presenting <10% weight reduction at 1,000ºC; Power absorbed per unit volume increased up to 25-30%*

- **KER5 Sustainability and adoption strategy (SO5)**

  KPIs: *For each IUC (1-3): TEA, LCA, LCC, financing roadmap to TRL9; replication and transferability roadmaps to at least 3 different industries*

- **KER6 METAWAVE demonstrations (SO6): 3 ambitious and unique demonstrators at TRL-6**

Sector	Process	Prototypes	KPIs
Ceramics GRES	Firing porcelain tiles	Microwave plasma torch	Density and porosity of tiles similar to the conventionally fired ones with a maximum 5% deviation; productivity rate improvement by >6%; reduction of thermal losses > 30%; reduction in energy use by > 35%
Asphalt COPHA	Heating aggregates	Direct microwave heating + hot air flux	Final temperature of aggregates similar to the targeted one with less than 3% difference; productivity rate improvement by >7%; reduction of thermal losses by > 44%; reduction in energy use by > 50%
Aluminium MYTIL	Carbon anode baking	Direct microwave + induction heating	Density and porosity similar to the conventionally baked anodes with a maximum 2% difference; electrical conductivity, determined by resistance measurements, equal or higher than conventionally fired electrodes; productivity rate improvement by > 20%; reduction of thermal losses >36%; reduction in energy use by > 42%

Implementation Plans

KER6 METAWAVE demonstrations

- **TRL6 - Project Duration (4 years – 48 months):** Validation and demonstration activities in METAWAVE for the last 12 months at a relevant environment (lab and/or industrial pilot line) simulating same operating conditions of heating processes.
- **TRL7 – Prototype upscaling (+2 years):** The modular and scalable prototypes will be set on the path for larger demonstrations in the same P4P sectors and potentially to new industries.
- **TRL8 – Product Development and Initial Exploitation (+1 year):** Industrial partners will use the demonstrated prototypes to deploy the technology to early adopters, and other potential customers. Extensive in-field performance tests will be conducted, resulting in more detailed case study material to consolidate a pre-market ready solution. A fully commercial version of the system will also be developed during this time. The project's members established network will provide an instant commercial route for initial exploitation.
- **TRL9 – Product to European Market (+1 year):** Final preparations to the established channels for METAWAVE to hit the wider European market: ceramics, asphalt and aluminium process industries. The plan for strategic collaborations with stakeholders will be fully implemented.
- **TRL9 - Rest of the Developing World (+4 years):** The technology will be disseminated and exploited outside Europe. In addition, the effort will be directed towards the penetration of the technology in other P4P sectors via technology transfer channels and plans

Impacts of METAWAVE until 2033

	Replicability (#cases)	Transferability (#cases)	Energy Savings (GWh/y)	CO_2 averted (ktCO2)	CO2 credits (M€/y)	Productivity gain* (M€/y)	Total revenues (M€/y)	Jobs created	Investment leveraged (M€/y)
+1y	3	0	39.6	9.2	0.5	21.8	22.3	89	10.0
+2y	4	1	108.1	24.6	1.2	61.8	63.0	252	28.4
+5y	14	5	273.5	63.9	3.2	150.2	153.4	614	69.0
Cumulative (+5y)	21	6	421.3	97.7	4.9	233.8	238.7	954	107.4

*CO2€/t estimated at 50€

Contribution to KPIs

P4P KPIs		METAWAVE Contribution
	001.- Develop new electrified processes and Energy efficiency, ensuring process flexibility and capturing the full potential of renewable energies	Contribution to realizing the 100% total CO2eq emission reduction potential demonstrated at TRL6 through VPP interfaces (R3.1), EMS (R3.2). Replacement of fossil fuels through microwave system powered by plasma, direct microwave and hot air, direct microwave and induction prototypes (R4.5).
	005.- Design processes for maximum resource efficiency, including the development of materials for circularity	Novel refractories will be developed and produced by secondary raw materials, like glass and ceramic waste, copper slag, carbides of metals (R1.1), (R4.1) and demonstrated at TRL6.
	006.- Develop new processes for circularity of secondary materials from wastes/residues for all industrial processes	
	008.- Seed H4C's to foster circularity within and beyond process industries	Each of the 3 demonstrators will be treated as a H4C seed through a dedicated roadmap for each IUC (R5.8).
	0010.- Foster new framework conditions to generate a market for climate neutral and circular solutions	3 demonstrators, indicative representatives of the respective SPIRE sectors. LCA/LCC assessment will be performed (R5.1) and green financing plan will be elaborated (R5.6). Policy updates will be made to TG4.
	0011- Foster new skills and types of jobs and business development, including SMEs, through P4Planet programs and H4Cs	More than 900 new jobs and 20 job profiles: 20 new types of skills and jobs for operators and high-skilled profiles, of which at least 10 integrated in specific academic curricula and 10 integrated company training programs.

Barriers to Implementation and Investment Needs

Barriers identified	Means to overcome the barriers
Hesitation for data sharing and ownership as well as cybersecurity concerns	METAWAVE uses a robust and secure data management infrastructure for routing of time-series data and real-time data processing and analysis based on well-established industry tools and frameworks
Lack of techno-economic information regarding microwave-based heating systems	The project demonstrators will offer credible information on the potential of the solution. Dedicated TEA feasibility report and 3 LCAs, to contribute to the common understanding of microwave potential.
Lack of technical knowledge among engineers and operators, safety concerns and lack of digitalisation experience	Mitigating safety concerns can be achieved through proper system design, including the use of suitable refractories and monitoring to prevent hazardous situations. Training activities, dedicated safety guidelines and standards will ensure up-skilling, re-skilling and safety of workforce.
High investment cost especially for SMEs and major incurring costs for the industry to transition from fossil fuels to electricity	METAWAVE will deliver a sustainability and adoption strategy with a strong financial component. Enabling access to green finance should steer the landscape towards more favorable conditions for SMEs. Moreover, the simulation-driven design and the PDTs will facilitate the design of electrification systems.
Transition to electrification burdens the grid with additional loads, which will be ultimately covered by fossil-fuel power if there is no interfacing between industry and grid supply	The VPP offers prediction and dispatch capabilities for RES and aggregated storage systems that can meet the additional demand while increasing industry and grid flexibility. Coupled with the EMS for energy cost and GHG minimization and policy incentives, the VPP can catalyze the transition to fossil-free and competitive process industries.

Clustering with R&I initiatives

Cluster with other HEU related projects

Creation of an International Advisory Board (IAB)

to advise on:

- **scientific progress** of the project
- **potential dissemination routes**
- what could be achieved on the **pilot sites**
- **potential exploitation strategies** and **routes to market** which could be employed.

Are you interested in joining?
Please get in touch with us:

Mara Corbella
Exploitation Manager
Email: corbella.m@crit-research.**it**

María Herrando
Project Coordinator
E-Mail: mherrando@ita.es

Mara Corbella
Exploitation Manager
Email: corbella.m@crit-research.it

Project Website:
https://www.aspire2050.eu/metawave

Thank You!

Time for Questions

ASPIRE

PROCESSES4PLANET