

D1.4

Project Progress Report (M18)

CIRCE

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Project Information

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PROJECT OVERVIEW	The JOULIA project is focused on transforming energy-intensive industries by replacing traditional fossil fuel-based heating methods with advanced electric technologies. These industries rely on high-heat processes, which are critical for manufacturing products like rubber, ceramics, and plastics. By focusing on specific, high-heat applications, JOULIA seeks to showcase the potential of electrification to decarbonise operations, enhance efficiency, and drive sustainable industrial transformation.

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Abbreviations

Acronym	Definition
<i>EU</i>	<i>European Union</i>
<i>LCA</i>	<i>Life Cycle Assessment</i>
<i>MW</i>	<i>Microwave</i>
<i>PV</i>	<i>Photovoltaic</i>
<i>RRI</i>	<i>Responsible Research and Innovation</i>
<i>RTO</i>	<i>Research and Technology Organisation</i>
<i>RTO</i>	<i>Research and Technology Organisation</i>
<i>SME</i>	<i>Small and Medium Enterprise</i>
<i>TRL</i>	<i>Technology Readiness Level</i>
<i>WP</i>	<i>Work Package</i>

Table 1: Abbreviations

Executive Summary

JOULIA is a four-year Horizon Europe Innovation Action (December 2024 – November 2028) addressing one of the most pressing challenges of European industry: the decarbonisation of high-temperature industrial heat. Many manufacturing processes still rely on fossil-fuel-based heating, and JOULIA demonstrates how two **advanced contactless electric heating technologies**, induction and microwave, can replace these conventional methods in real industrial settings.

This Progress Report summarises the achievements of the project's first eighteen months (M1–M18). During this period, JOULIA has moved from the initial characterisation of its two industrial demonstration sites to the conceptual and engineering design of both heating technologies, while developing the digital tools that will optimise their operation and deploying a comprehensive dissemination and communication strategy.

Notably, the project has confirmed the feasibility of two technically demanding concepts: heating the two steel components of the rubber-curing machine simultaneously by **induction**, and using the aluminium layer of the insulation pipe as an active element to concentrate **microwave** energy

The project is progressing in line with its objectives. The foundations for the manufacturing, integration and demonstration phases that begin in the second period are now in place.

1. Introduction

1.1 The challenge: decarbonising industrial heat

Industrial heat accounts for a large share of European energy consumption and carbon emissions. A significant part of this heat is generated by burning fossil fuels, often natural gas, in processes that are difficult to electrify with conventional technologies. Replacing these heating methods with efficient, contactless, flexible and fully electric alternatives is essential to meet the European Union's climate neutrality goals.

1.2 The JOULIA approach

JOULIA develops, engineers and demonstrates two complementary electric heating technologies applied to two real industrial processes at medium-temperature range (100-500°C).

The first is **induction heating** applied to the rubber vulcanisation process at Artigo (ART) in Italy. The current process heats a rotocure machine using a high-temperature thermal-oil circuit, with associated energy losses and limited controllability. JOULIA introduces an induction-based heating system that delivers energy directly and electrically to the relevant parts of the machine, with finer temperature control.

The second is **microwave heating** applied to the production of multilayer insulation pipes at K-FLEX in Poland. These pipes combine polyethylene layers bonded to an intermediate aluminium barrier, and the bonding step currently relies on conventional thermal activation. JOULIA introduces a microwave-based system for the adhesive activation stage, improving energy efficiency and process flexibility.

Both demonstrations aim to reach an industrially relevant maturity level, supported by digital tools for process optimisation, predictive maintenance and environmental impact assessment, and accompanied by replication studies that extend the results to other sectors such as ceramics and food.

1.3 JOULIA Consortium

JOULIA brings together 15 partners and one associated entity from seven European countries, combining research and technology organisations, universities, technology providers and industrial end-users. The project is coordinated by CIRCE (Spain). This multidisciplinary partnership provides the complementary expertise required to take the technologies from concept to industrial demonstration.

The consortium incorporates:

- Four European **SMEs** (STAM, CEI, WR, CORE)
- Six **Large Enterprises**, representing the role of the end-users (ART, SIMIC, K-FLEX, FNC, EDP, TCID)
- Three well-known **RTOs** with large expertise in EU projects (CIRCE, CERTH, ISQ)
- Two **universities** (KTH, UNIGE)

2. Progress by technical area (M1–M18)

2.1 Characterisation of the demonstration sites and requirements

The first phase of the project established a solid baseline for both industrial processes. Working closely with the two demonstration sites, the consortium characterised the energy and material flows, the working temperatures and the operating parameters of each process. This work also defined the set of performance indicators that will be used to evaluate JOULIA's technical, environmental, economic and social impact, and produced a preliminary assessment of the health and safety requirements associated with the new heating technologies.

The two demonstration sites in figures. The ARTIGO facility in Italy produces around 1.3 million m² of rubber flooring per year. Its rubber vulcanisation process currently relies on a diathermic-oil circuit fed by natural gas, with the main components operating between roughly 100 °C and 220 °C. The site consumes approximately 6.5 GWh of electricity and 300,000 Sm³ of natural gas per year, and hosts an on-site photovoltaic plant of about 1.6 MW.

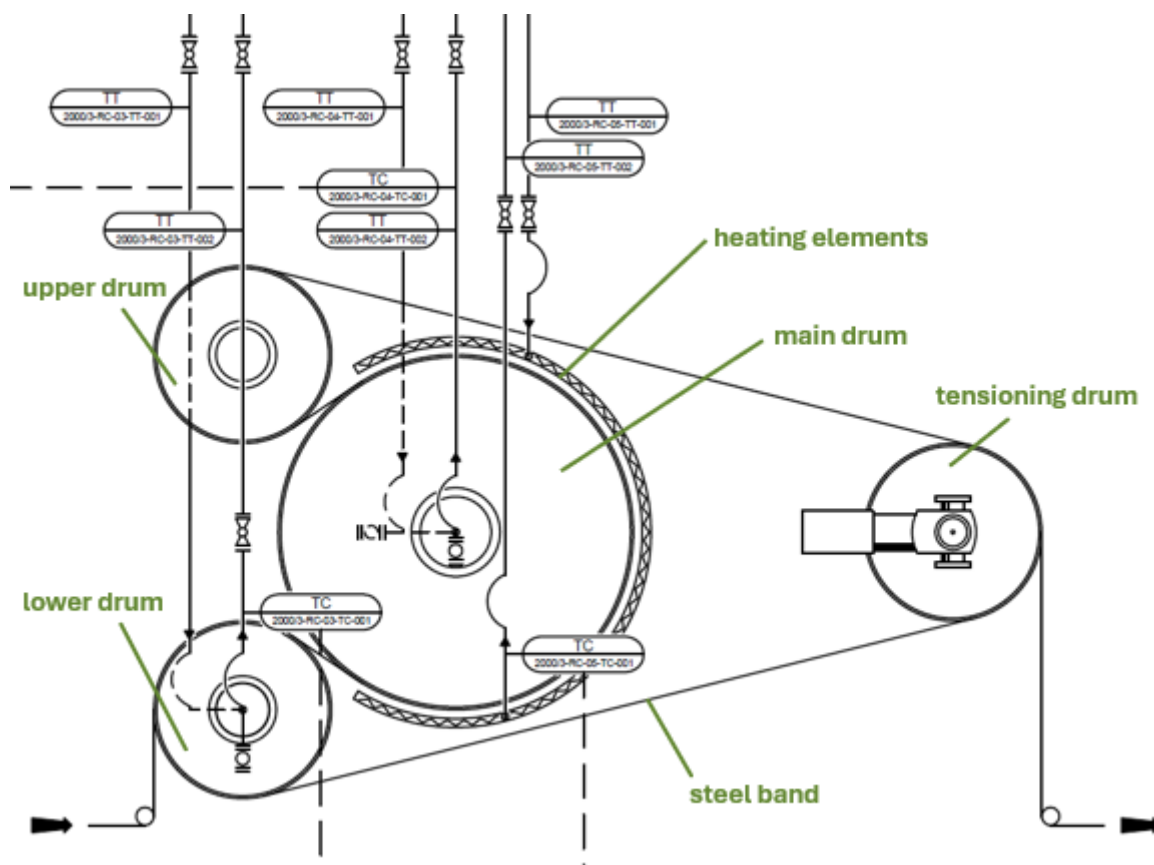


Figure 1: Scheme of the rotocure

At the **ARTIGO site**, the product is **rubber flooring**, manufactured as a continuous sheet. The key step is vulcanisation, the curing process that gives the rubber its final mechanical properties. This takes place in a machine called a rotocure: the rubber sheet passes continuously around a large heated rotating steel drum, pressed against it by a steel belt, so that the combination of heat and pressure cures the

rubber as it moves through. Today the drum is heated by a circuit of hot diathermic oil; JOULIA replaces that heat source with induction, while keeping the same heat-and-pressure curing principle.

The **K-FLEX** facility in Poland produces **multilayer insulation pipes** in a continuous process whose adhesive-activation stage operates around 100 °C, 24 hours a day. The site has an annual electricity demand of around 26 GWh and a natural gas demand of around 15 GWh, with 1.5 MW of installed photovoltaic capacity and further renewable plants under construction. JOULIA's induction and microwave technologies target medium-temperature heating, replacing fossil-based heat at the core of these two processes.

At the K-FLEX site, the product is multilayer insulation pipe. During manufacturing, several layers are assembled around the pipe, including an intermediate aluminium barrier and an outer polymer layer, bonded together with an adhesive. The step JOULIA focuses on is the activation of that adhesive: as the pipe — already fitted with its aluminium layer and with the adhesive applied — moves continuously along the production line, heat must be applied to activate the bond. JOULIA delivers this heat by microwave, applied to the moving pipe, replacing the conventional thermal activation

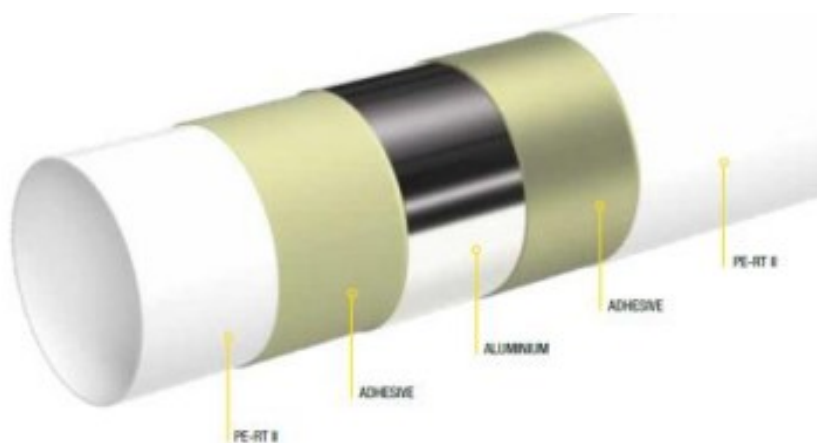


Figure 2: Structure of multilayered plastic insulation pipes PERT II

In parallel, the project mapped the needs and expectations of stakeholders through a series of interviews, ensuring that the technologies under development are aligned with real industrial priorities. This phase is now complete and is documented in the public deliverables on the characterisation of the demo sites (D4.1), the evaluation methodology (D4.2), the preliminary health and safety requirements (D4.3) and the report on stakeholder needs (D4.4).

From baseline to impact. The figures above describe the starting point. JOULIA's goal is to demonstrate that electrifying these heating stages can substantially cut the fossil-fuel consumption and emissions of both processes while improving energy efficiency — the project targets an energy-efficiency improvement in the range of 25–40% for the electrified processes, with an estimated energy saving of the order of 800 MWh of primary energy per year across the two demonstrations. The actual savings, emission reductions and electrification levels will be quantified during the manufacturing and demonstration phases, using the project's environmental impact assessment tool and data from the operating prototypes, and reported in the deliverables of the next periods.

2.2 Design of the induction heating system

The work on the induction system produced a concrete and non-obvious design outcome developed by **CIRCE** and **SIML**.

Heating the rotocure by induction is challenging because the machine's heat must reach both the rotating steel cylinder and the surrounding steel belt simultaneously, and conventional induction approaches — placing coils inside or directly around a moving drum — run into serious limitations of moving electrical connections, coil overheating and uneven temperature distribution.

The consortium analysed the requirements of the rotocure process and developed a heating concept capable of delivering uniform, controllable heat directly to the relevant metallic surfaces of the machine through electromagnetic induction, rather than through the conventional external heat source. The solution achieved is one of the most innovative technical challenges since two different metals are being heated at the same time from the same coil.

This work included the **conceptual design of the induction system**, the design of the power electronics and control approach required to drive it, and extensive modelling and simulation to confirm that the selected configuration meets the demanding requirements of the process. The result is a consolidated design baseline that is now ready to move into the prototype manufacturing and integration phases.

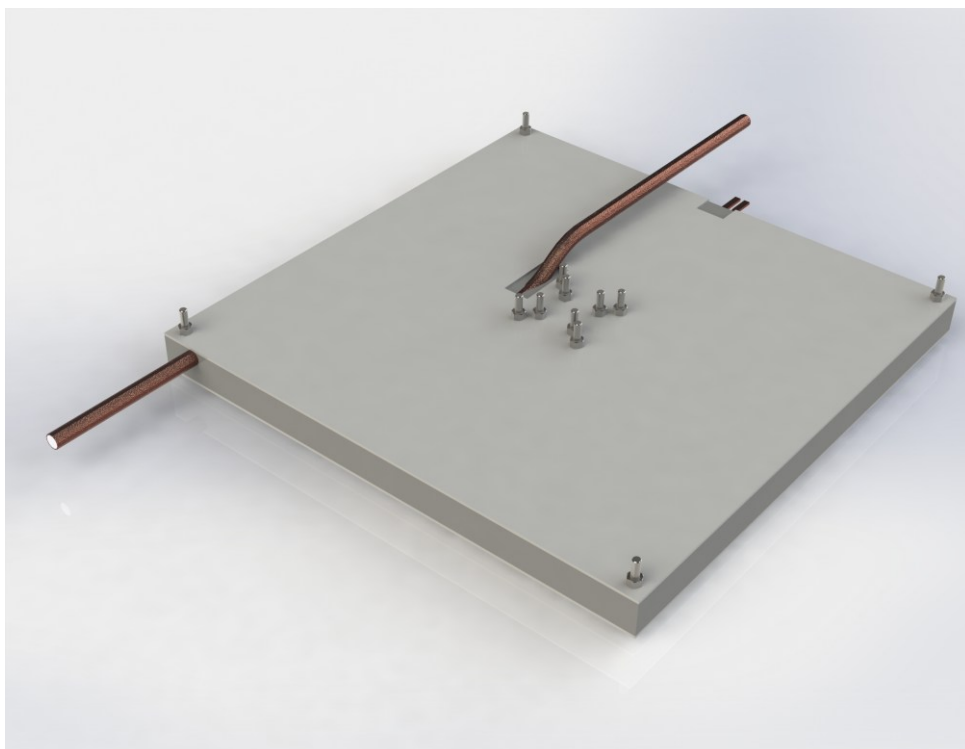


Figure 3 General view for the coil module of the JOULIA induction heating system

2.3 Design of the microwave heating system

The microwave work delivered its central result: confirmation that a continuous aluminium layer, normally considered incompatible with microwave heating, can be turned from an obstacle into an active part of the solution. Metallic structures reflect and distort microwave fields, which is precisely why applying microwaves to a product built around an aluminium barrier was the project's boldest technical bet.

CEI developed a microwave processing concept in which the aluminium layer itself helps guide and concentrate the microwave energy towards the adhesive interface that must be activated. The design combines resonant cavities, specialised applicators, dynamic tuning systems and dedicated filtering — the latter essential both to confine the microwave energy safely as the pipe moves continuously through the system, and to adapt the absorbed power to the line speed. A key design feature is that the heating unit can flexibly **modulate its power from 30% to 100%** of the available range to follow the production rate, making it fully compatible with continuous industrial operation.

Validating this concept required significant experimental effort, particularly to guarantee safe electromagnetic confinement. That validation confirmed the feasibility of the approach and now underpins the detailed engineering of the industrial prototype.

2.4 Digital tools for process optimisation

Electrifying a heating process is only worthwhile if the electricity is used intelligently. Once heat is delivered electrically, the process can be shifted in time to use cheaper or greener electricity, its equipment can be monitored to prevent downtime, and its true environmental footprint can be measured. JOULIA develops three digital tools to capture exactly these benefits:

The **process flexibility analysis** produced clear, differentiated conclusions for each site. At ART, the main opportunity lies in maximising self-consumption of the on-site photovoltaic generation — particularly at weekends, when production patterns leave room to align electricity use with solar availability — and the analysis indicated that operating an additional fully electrified rotocure line could open further flexibility opportunities. At K-FLEX, where the target process itself has little intrinsic flexibility, the study found that flexibility is better pursued at the level of the whole plant, for example through power-to-heat solutions operating alongside existing generation. These findings are supported by a first version of simulation tools that let each site explore its own flexibility potential.

The **predictive maintenance platform** was designed around infrared thermography to detect abnormal behaviour and anticipate failures, and preliminary thermal measurements were already carried out at both demonstration sites to confirm the feasibility of the approach (public deliverable D7.2).

The **environmental impact assessment tool**, based on a recognised life-cycle assessment platform (VERIFY), is being extended to capture the specific characteristics of JOULIA's heating technologies, so that the environmental benefits of electrification can be quantified rigorously once demonstration data are available.

2.5 Skills, Dissemination and exploitation

JOULIA recognises that electrifying industrial heat is not only a technical challenge but also a workforce one. A dedicated skills-needs assessment, carried out through an international questionnaire to sector experts and professionals, found that the transition to electrified processes requires new **"hybrid" professional profiles** that combine technical expertise in areas such as power electronics and energy integration with digital, environmental and transversal skills. To address this, the project developed a structured training plan organised into five modules and thirteen submodules, spanning professional profiles from operators and technicians to engineers and managers. This work sets JOULIA's technology development within the wider European context, where industry represents around a quarter of EU energy consumption but only a small fraction of industrial heat is currently electrified.

On dissemination and exploitation, a communication strategy was established at the start of the project (public deliverable D14.1) and is being actively implemented through the project website, social media and promotional materials, while the consortium has begun mapping its exploitable results and the routes to bring them towards the market.

3. Next Steps

With the design foundations now in place, the second period of the project shifts focus from design to construction and validation. The main activities foreseen in the coming period, in line with the project plan, are:

The detailed engineering of both heating systems will be completed, translating the consolidated designs into final specifications and manufacturing files. On this basis, the consortium will move into the **manufacturing of prototypes** for both the induction and the microwave heating systems, followed by **pre-industrial trials** in controlled environments to validate the technologies at an industrially relevant maturity level.

The digital tools will evolve from their initial versions towards their final form, refined and validated using data from the demonstration activities. The project will also advance its **replication and exploitation studies**, assessing how JOULIA's solutions can be transferred to other industrial sectors and preparing the ground for their wider market uptake.

These activities will pave the way for the full industrial demonstration campaigns that represent the culmination of the project.

4. Public deliverables of the first reporting period

Readers interested in the detailed results behind this report are invited to consult the project's public deliverables, available through the **JOULIA website** (<https://jouliaproject.eu/deliverables/>). The following public deliverables were produced during the first reporting period (M1–M18):

Deliverable	Title	Lead
D1.5	RRI First Report and Progress Report	CIRCE
D4.1	Characterisation of demo sites	STAM
D4.2	Evaluation methodology	CERTH
D4.3	Health and safety requirements – Preliminary report	ISQ
D4.4	Report on stakeholder needs	WR
D4.5	Health and safety requirements (update M18)	ISQ
D7.2	Predictive maintenance platform	CERTH
D14.1	Dissemination and Communication Plan	WR
D14.2	Dissemination and Communication report	WR
D14.3	Project synergies report	WR
D14.5	Skills Needs Assessment Report	ISQ
D14.6	Dissemination, Exploitation & Communication Plan (update M18)	WR

Table 2: JOULIA RP1 Public Deliverables

Conclusions

The first eighteen months of JOULIA have turned an ambitious concept into engineering-ready designs, backed by concrete technical results at both demonstration sites.

The two industrial baselines are now fully characterised. On the induction side, the project solved a problem that conventional induction heating does not address: **heating the two steel components of the rubber-curing machine — the rotating drum and the steel belt — simultaneously and from a single coil arrangement** placed behind the machine's back-plate, avoiding the moving electrical connections and overheating that ruled out classical approaches.

On the microwave side, the project confirmed experimentally that **the continuous aluminium layer of the insulation pipe, normally an obstacle to microwave heating, can be used as an active element that concentrates the energy onto the adhesive**, with a heating unit able to follow the production line by modulating its power between 30% and 100%.

These technologies are designed to deliver an **energy-efficiency improvement of 25–40%** in the targeted processes, with an estimated saving of the order of 800 MWh of primary energy per year across the two demonstrations — targets that the project will now verify experimentally.

The first versions of the **digital tools** that will support this verification are already in place, including site-specific flexibility analyses, a thermography-based predictive maintenance platform tested at both sites, and an environmental impact assessment tool.

With these foundations consolidated, JOULIA enters its second period — **manufacturing, integration and pre-industrial trials** — well positioned to demonstrate that energy-intensive industries can decarbonise their heating processes through efficient, flexible and fully electric technologies.



Electrification of industrial processes using induction and microwaves technologies



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