

INtegrating Cybernated Innovation to Raise the scale of Circular Units Looping Allied Regions

Project INCIRCULAR (I3-2021-INV2a-MANU)
ID 101114988

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1.0	18/09/2026	1 st Draft
1.1	28/09/2026	Review internally by TECOS
2.0	30/09/2026	Finally approved by Partners

R = Report, P = Prototype, D = Demonstrator, O = Other PU = Public PP = Restricted to other programme participants (including the Commission Services) RE = Restricted to a group specified by the consortium (including the Commission Services) CO = Confidential, only for members of the consortium (including the Commission Services) Restraint UE = Classified with the classification level "Restraint UE" according to Commission Decision 2001/844 and amendments Confidential UE = Classified with the mention of the classification level "Confidential UE" according to Commission Decision 2001/844 and amendments Secret UE = Classified with the mention of the classification level "Secret UE" according to Commission Decision 2001/844 and amendments

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Executive summary

From circular ambition to industrial evidence

INCIRCULAR demonstrated a practical and transferable pathway for turning industrial and post-consumer plastic waste into trusted resources for new manufacturing applications. The project connected recycling, material engineering, extrusion compounding, injection moulding, digital process intelligence, industrial validation, interregional replication and investment-oriented support. GORENJE-based secondary polymer streams were qualified and used to develop fifteen composite formulations, from which the most promising route was scaled to 545 kg and validated in a full-scale industrial demonstrator. The approach was then replicated across 13 cross-sector industrial cases in Slovenia and Andalusia and reinforced by six cascade-funded innovation projects involving seven SMEs. The project also created reusable digital tools, material and equipment information resources, scientific publications and an open-access Toolkit. The central lesson is that circular manufacturing scales when technical evidence, access to trial material, digital insight, replication support and investment logic are combined. INCIRCULAR therefore leaves behind not only a validated material and demonstrator, but a repeatable pathway that other companies and regions can adapt.



THE INCIRCULAR STORY AT A GLANCE

From waste streams to industrial confidence

INCIRCULAR investigated one central question: how can industrial plastic waste move from being a production residue to becoming a trusted resource for new manufacturing applications?

To answer it, the project connected material science, recycling, processing technologies, digital twinning, industrial validation and interregional cooperation in one integrated circular pathway. Over the course of the project, industrial and post-consumer waste streams were qualified, new recycled polymer formulations were developed and optimized, the most promising composite material was scaled up and validated in a real industrial demonstrator, and the approach was replicated in seven different sectors and two European regions.

Beyond the technical results, INCIRCULAR delivered practical tools, industrial evidence, SME innovations, replication methods and investment-oriented guidance that help companies to reduce the risk of adopting recycled composite materials and support the transition from circular concepts to industrial reality.

Project in a nutshell

2023 – 2026	9	3	I3
36-month project	European Partners	European Regions	Interregional Innovation Investments
€4.285 M	€2.999 M	101114988	TECOS
Total project budget	EU contribution	Project ID	Coordinator

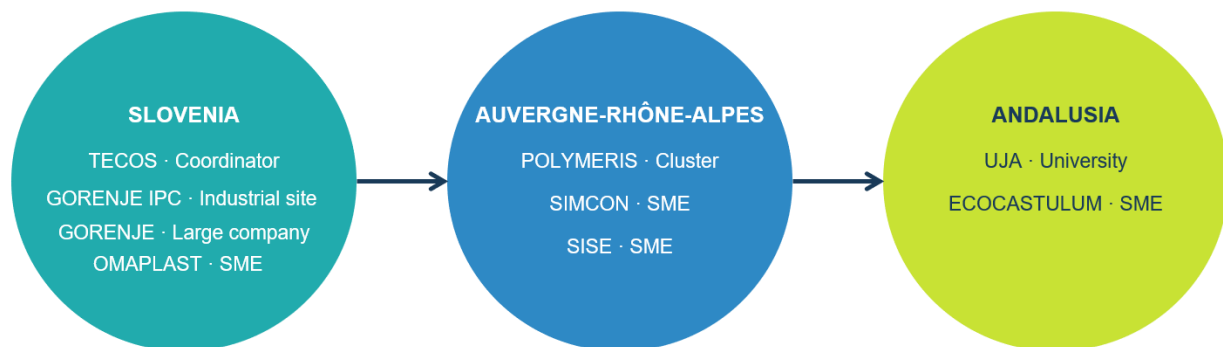
**ONE CONNECTED PATHWAY: WASTE → COMPOSITE MATERIAL → INDUSTRIAL PROOF →
REPLICATION → MARKET UPTAKE**

A EUROPEAN PARTNERSHIP

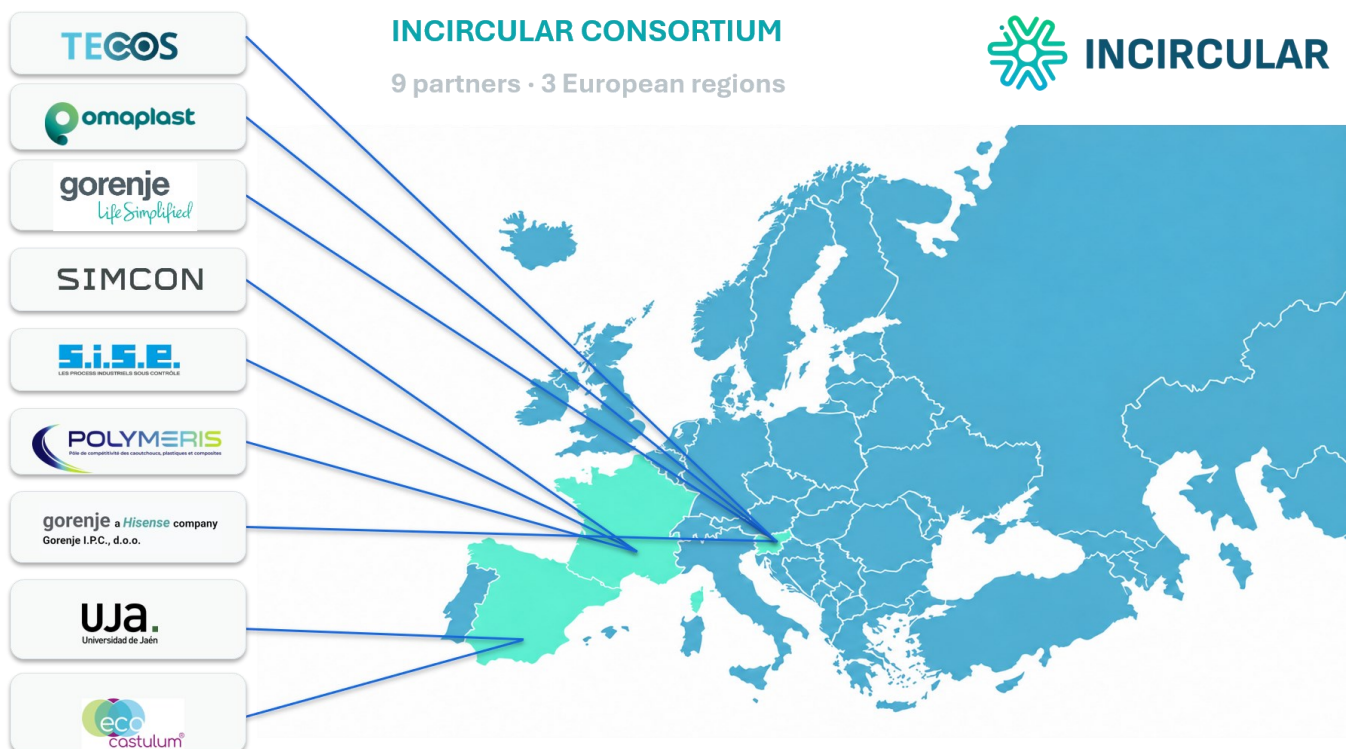
Nine partners combining industry, research, clusters university and SMEs

The consortium was built around the circular plastics value chain and brought together complementary capabilities from Slovenia, Auvergne-Rhône-Alpes and Andalusia.

9 PARTNERS · 3 EUROPEAN REGIONS · ONE CIRCULAR VALUE CHAIN



Complementary expertise: recycling · material engineering · industrial production · digital twins · testing · clustering · replication



Who contributed what?

Partner	Profile	Key contribution
TECOS	Coordinator / RTO & industrial association	Project coordination; material development; processing; technology transfer; replication.
POLYMERIS	Cluster	Interregional ecosystem building; cascade funding; mentoring; dissemination and replication.
SIMCON	SME	Simulation and digital-twin technologies, supporting injection-moulding process optimization.
SISE	SME	Industrial digitalisation, sensing and control solutions for injection-moulding processes.
ECOCASTULUM	SME	Material/environmental testing expertise and support to circular-material validation.
OMAPLAST	SME / recycler	Collection, sorting, recycling, scale-up compounding and high-quality recycled polymer supply.
GORENJE	Large company	Industrial investments, manufacturing environment, validation and integration into household-appliance production.
GORENJE IPC	Large-company industrial site	Industrial pilot and demonstration site for recycling, injection moulding and production validation.
UJA	University	Chemical Engineering, environmental and materials expertise; testing and validation; leadership and support for dissemination and communication; mirror stakeholder and replication support.

1 • PROJECT MOTIVATION

Why Circular Plastics need more than recycling

The core challenge was not simply to recycle plastic, but to make recycled material reliable enough for industry to trust, process and adopt.

Industrial uptake of recycled plastics is often limited by variability in feedstock composition, impurities, rheology, mechanical performance, colour, dimensional stability and long-term behaviour. Manufacturers also need evidence that a new material can run on existing equipment, meet product requirements, and fit an economically viable supply chain.

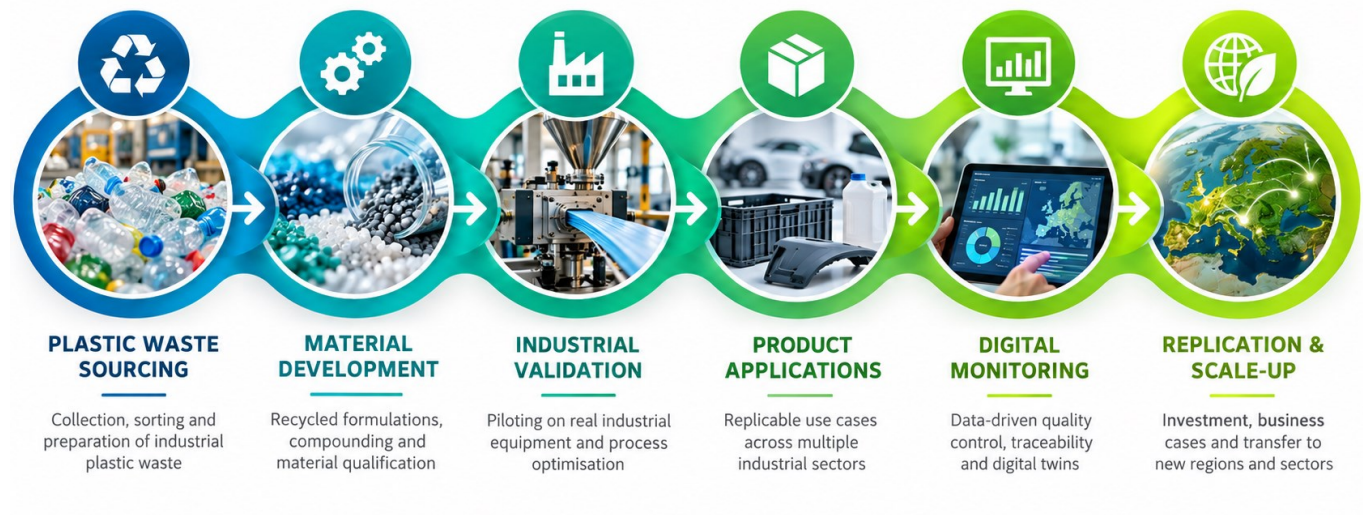
WASTE STREAM	COMPOSITE MATERIAL	PROCESS	MARKET
Stable and clean enough?	Properties fit the application?	Can it run repeatably?	Who will adopt and invest?

“INCIRCULAR focused on the whole journey from waste qualification to industrial uptake.”

2 · THE INCIRCULAR APPROACH

A connected pathway from waste to adoption

The project de-risked circular manufacturing step by step rather than jumping directly from recycled feedstock to a final product.



Replicate the pathway, not the product.

The approach combined six linked stages: qualifying the waste stream, engineering candidate materials, scaling the selected formulation, validating it in a real industrial environment, replicating the solution across additional applications, and transferring the evidence into practical guidance, tools and investment pathways.

3 · RESEARCH & MATERIAL DEVELOPMENT

Turning heterogeneous waste into a controlled material platform

INCIRCULAR investigated how post-industrial plastic streams could be transformed into a repeatable recycled-polymer base and then engineered for demanding manufacturing use.

1,570 kg	15	15 → 1	545 kg
GORENJE feedstock processed	Composite material formulations screened	Screening to one selected processing route	Upscaled composite produced

The technical route began with qualification and processing of GORENJE post-industrial plastics. Multiple composite formulations based on GORENJE feedstock and natural lignocellulosic fibers from post-consumer waste stream were developed and characterized to understand the balance between processability, mechanical performance and industrial repeatability. The selected formulation, ZZC500-20, was then produced at larger scale to supply industrial demonstration and replication activities.



Different types of lignocellulosic fibers screened



Selected INCIRCULAR material components



Final INCIRCULAR composite formulation: 77% rPP + 20% ZCC500 PC fibres + 3% MAPP compatibilizer

What was delivered

- ❖ A documented recycled-material baseline and qualification route.
- ❖ Fifteen screened formulations and an optimised transfer formulation.
- ❖ Upscaled material quantities sufficient for pilot, validation and external industrial trials.
- ❖ Material and process evidence that could be reused in replication decisions.

4 • FROM LABORATORY EVIDENCE TO INDUSTRIAL PROOF

A real product, real loads and real production conditions

The selected material was injection moulded in a real industrial environment and validated as a functional demonstrator.

1	25 kg	8	3,000 N
demonstrator	full-load validation	stacked boxes	compression load

GORENJE integrated the material into an industrial injection-moulding route and produced the project demonstrator. Product-level testing provided tangible evidence that the material route could move beyond laboratory specimens and into a real manufacturing context.



Industrial investments

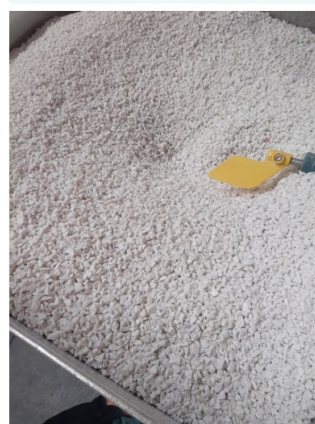
The project also supported industrial transformation at GORENJE through investments in recycling equipment, production-line upgrades and digital technologies. This physical capacity building was complemented by SME-driven innovation projects, creating a wider circular-manufacturing ecosystem.



Waste feeding & metal detection



Shredding / granulation



Mixing silo



Extrusion & pelletising

FROM EU SUPPORT TO INDUSTRIAL CAPACITY

INDUSTRIAL INVESTMENTS

4 pilot units

GORENJE investments
recycling · line upgrades · digital twin

CASCADE FUNDING

6 projects / 7 SMEs

sorting · sensing · AI · tooling · metallisation

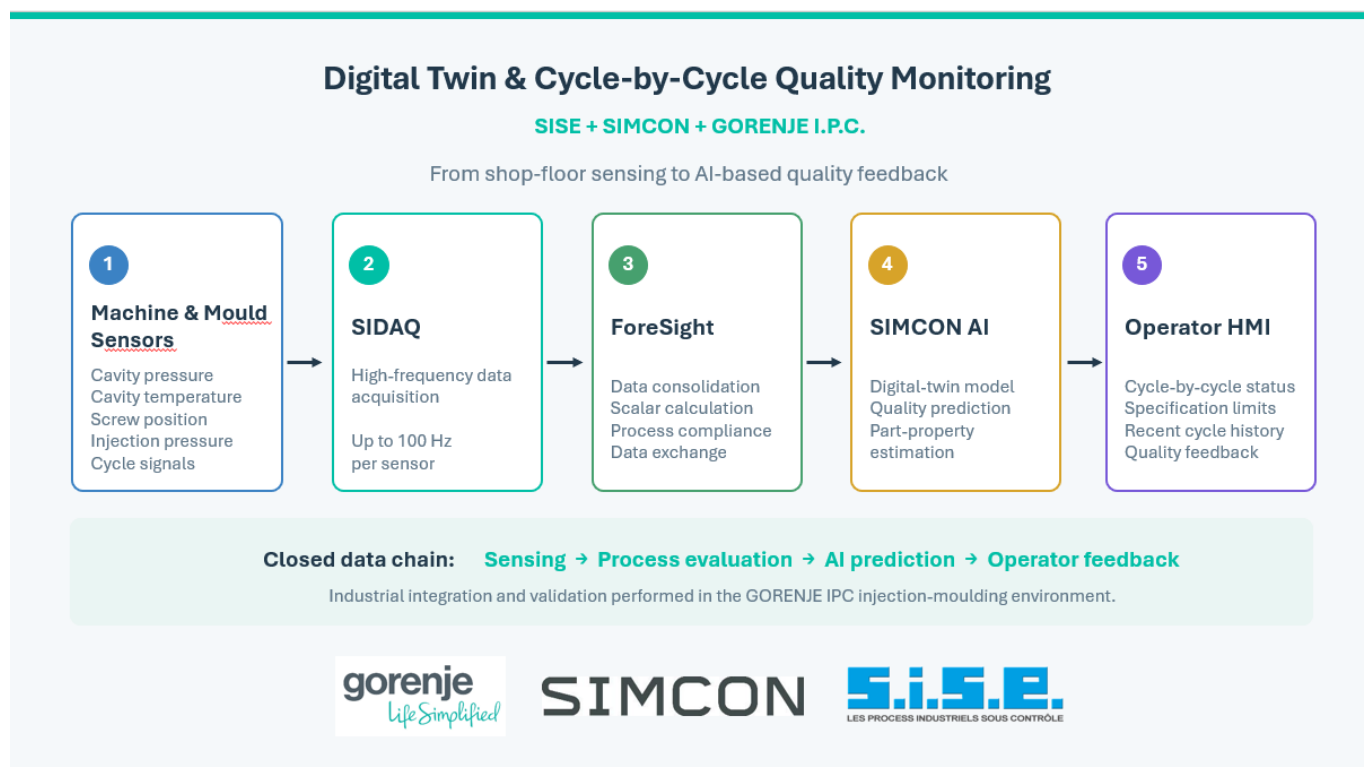
€6.75 million investment portfolio · €4.725 million public contribution

Making recycled-material processing visible cycle by cycle

Digital monitoring and process intelligence were used to reduce uncertainty and improve confidence in recycled-material processing.

Recycled materials can vary from batch to batch. INCIRCULAR therefore linked material development with process monitoring and digital-twin approaches, helping manufacturers understand how material variability interacts with injection-moulding conditions.

500 Hz	Digital Twin	Cycle-by-Cycle	Data → Decisions
sensor acquisition per channel	process understanding and qualitative monitoring	Quality transparency and operators feedback reporting	replication support & validated model



PHYSICAL VALIDATION + DIGITAL PROCESS EVIDENCE = STRONGER ADOPTION CONFIDENCE

Proving that the pathway can travel

Replication was treated as industrial qualification: the material left the original pilot and was tested across different products, sectors, machines and manufacturing routines.



APPLICATION SECTORS



13	9	4	Multiple
cross-sector replication cases	cases in Slovenia	cases in Andalusia	machines, moulds & sectors

Validated material was distributed to industrial stakeholders so they could test it on existing equipment with minimal first-adoption risk. Applications covered agriculture and irrigation, furniture, rail interiors, automotive components, recreational vehicles, electronics housings, household appliances, consumer products and RTO demonstration items.

“Replicate the pathway, not the product.”

From one demonstrator to 13 cross-sector applications

ID 101114988

13 cross-sector replication cases

Scaling INCIRCULAR circular polymer solutions into real industrial applications.


Train-seat trim piece


Car-headlight component


INCIRCULAR DEMO BOX
gorenje | i.p.c. **Hisense**

Motorhome cup holder


Furniture fixation joint


Water-pump housing


Shoehorn
TEGOS

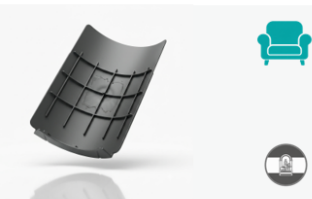
Screw-storage box
TEGOS

Washing-machine cable clips
gorenje **Hisense**

Washing machine pulley
gorenje **Hisense**

PEMF brain stimulator
OmniPEMF

Irrigation valve connector


Bed-base corner fitting


Double-floor distance holder


Cascade funding expanded the solution space

Six innovation projects involving seven SMEs added new technology bricks around the core material and manufacturing pathway.

6	7	≤ €60k	€359,040
innovation projects	SMEs supported	support per project	cascade funding budget

The supported projects addressed complementary challenges including plastic identification and sorting, sensing, machine learning and anomaly detection, recycling improvements, tooling life, metallisation and hyperspectral AI.

Cascade funding: 7 SMEs supported through 6 innovation projects

1
WR KNIVES

Wear-resistant industrial knives
Mentoring + industrial integration

2
CLARA

Classification & recognition automation
Mentoring + industrial integration

3
MOIK

Metallisation of industrial knives
Mentoring + industrial integration

4
PLASTNIR

NIR / multispectral process detection
Mentoring + industrial integration

5
SMART-MOLD

Machine anomaly recognition & telemetry
Mentoring + industrial integration

6
PITS

Hyperspectral plastic identification & AI
Mentoring + industrial integration

SEE	DECIDE	ACT
Better sorting & sensing	Data-driven decisions	Smarter processing & tooling

Why the I3 instrument mattered

INCIRCULAR connected complementary regional strengths instead of expecting one region to provide the entire circular solution.

COMPLEMENTARY CAPABILITIES

Recycling, materials science, industrial production, simulation, digital control, clusters and testing were connected across regions.

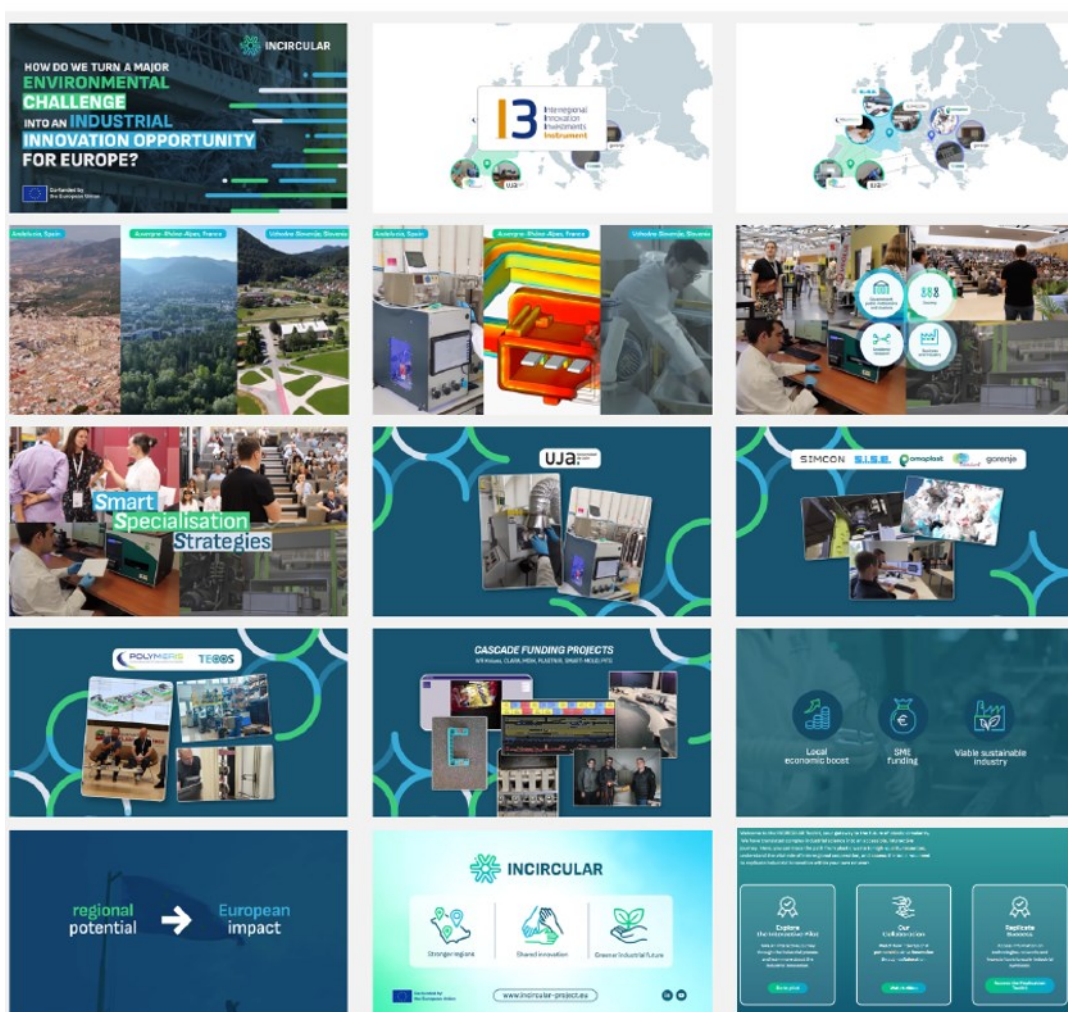
SMART SPECIALISATION

Regional strengths were linked to concrete industrial needs and investment opportunities.

CROSS-BORDER CONFIDENCE

Shared evidence, replication and SME participation shortened the distance between regional innovation and European uptake.

The I3 logic was therefore not an add-on to the technical work: it was the mechanism that connected the pilot, external trials, cascade-funded SMEs and replication networks into one European innovation pathway.



What remains after the project

INCIRCULAR leaves reusable physical and digital resources designed to help other organizations understand, evaluate and replicate circular-manufacturing solutions.

3	6	9	12+
exhibition panels	material info sheets	equipment info sheets	replicator samples
1	6	13	450+
full-scale demonstrator	interactive tools	validated technologies	mapped European actors

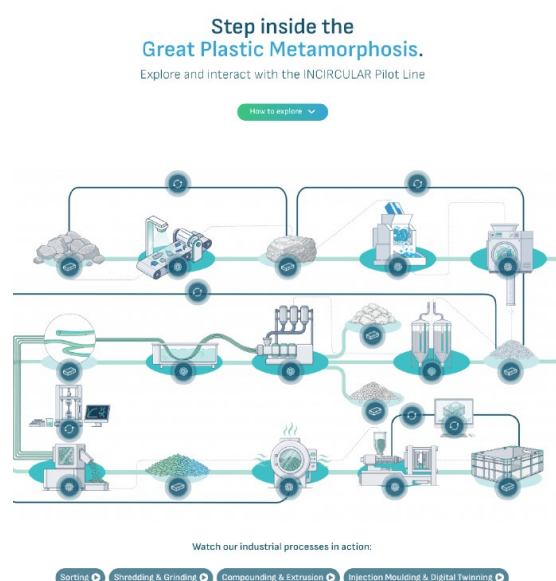
Scientific publications

INCIRCULAR generated three scientific publication outputs that preserve and extend the project's technical knowledge beyond the formal project period.

- **Recycled Sisal Fiber-Reinforced Polypropylene Derived from Industrial Waste Stream** — Detritus, Volume 34, March 2026 — peer-reviewed publication.
- **Industrial-Scale Injection Moulding Validation of Recycled Fiber-Reinforced Polypropylene: Processability and Manufacturing Feasibility** — Materials, 2026 — peer-reviewed scientific article on multi-site industrial processing and manufacturing feasibility.
- **Circular Polypropylene Composites Reinforced with Virgin and Recycled Cellulosic Fibres: Thermal Characterisation and Dimensional Stability** — Scientific manuscript developed within INCIRCULAR, addressing thermal behaviour and dimensional stability of circular rPP–cellulose composites.

The INCIRCULAR Toolkit

The open-access Toolkit transforms project knowledge into decision support. It allows users to explore the pilot line, technologies, networks, funding opportunities, replication examples & industrial-readiness tools.



UNDERSTAND · NAVIGATE · REPLICATE · COLLABORATE · ADOPT · UPSCALE · FUND

<https://incircular-project.eu/toolkit>

De-risk first, invest second

INCIRCULAR showed that industrial adoption works best as a staged decision process rather than a single leap from interest to capital investment.

Stage	Typical question	Evidence needed
1 • Interest	Could this material fit our product?	Material data + application screening
2 • Trial	Can we process it on our equipment?	Trial material + process guidance
3 • Qualification	Is performance repeatable?	Testing + product/process evidence
4 • Business case	Does the economics make sense?	Cost, logistics, CAPEX/OPEX + market uptake

The replication experience confirmed that supplying validated trial material and independent industrial evidence can substantially lower the risk of first adoption. Only after technical and operational uncertainty is reduced should companies decide on dedicated equipment, tooling, logistics or long-term supply arrangements.

“The first investment is often not a machine. It is evidence.”

What future circular-manufacturing projects should repeat

FIVE LESSONS FOR SCALING CIRCULAR INNOVATION

1**START FROM THE APPLICATION**

Geometry, tolerances, loading, aesthetics, ageing and regulation determine material fit.

2**REDUCE THE FIRST-ADOPTION BARRIER**

Let companies test validated material on existing equipment before major CAPEX.

3**INDUSTRIAL TRIALS BEAT ASSUMPTIONS**

Different machines, moulds and process routines provide the strongest transfer evidence.

4**REPLICATION = QUALIFICATION**

A successful first trial starts optimisation, repeatability checks and business planning.

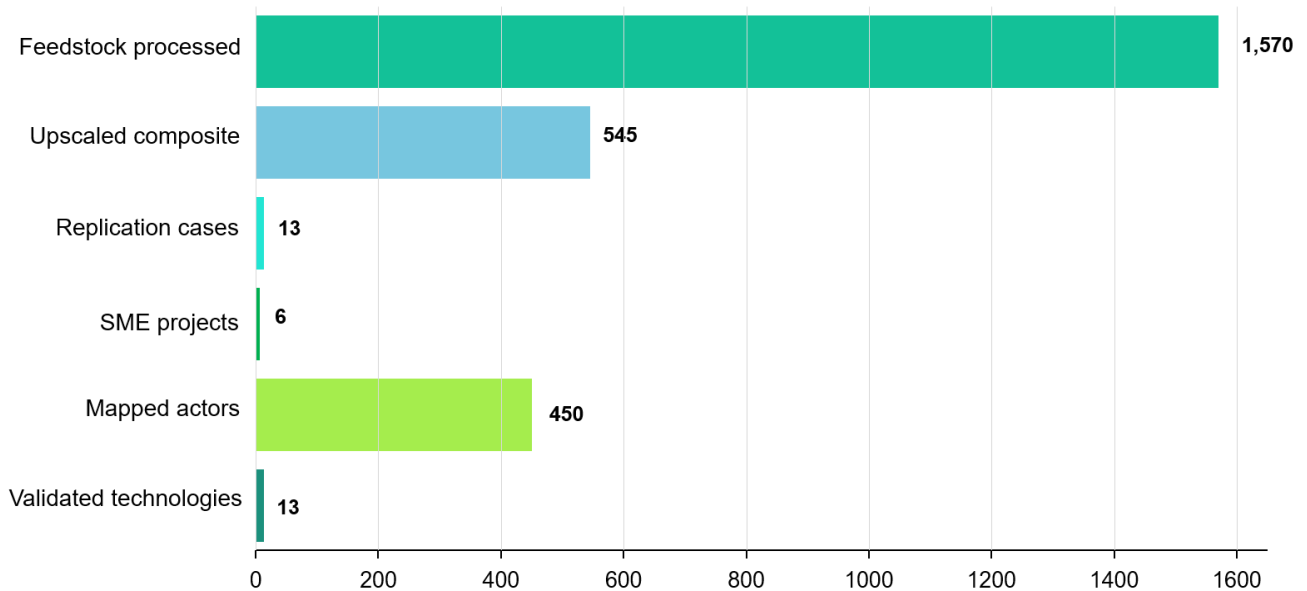
5**LEAVE REUSABLE KNOWLEDGE**

Material passports, process guidance and digital tools turn one pilot into a method.

The common denominator: confidence grows when evidence, access and support arrive together.

A pilot that became a wider innovation system

Selected final project metrics



1.570 kg	545 kg	15	1
industrial feedstock processed	upscaled composite produced	Composite formulations developed	industrial demonstrator validated
13	6	7	6
replication cases implemented	SME projects	SMEs supported	interactive tools created

The most important impact is the new methodology: INCIRCULAR demonstrated a repeatable route that connects material qualification, industrial evidence, external replication, digital support and investment logic.

From project results to post-project use

The formal project period ends, but the evidence, tools and partner networks were designed to continue supporting new applications and investment decisions.

- ❖ Use the validated material and process evidence as a baseline for new product families.
- ❖ Continue qualification of promising replication cases toward commercial applications.
- ❖ Use the Toolkit to identify technologies, partners, networks and funding opportunities.
- ❖ Develop business cases after technical and operational uncertainty has been reduced.
- ❖ Keep interregional clusters and RTOs active as trusted intermediaries for technology transfer.
- ❖ Exploit partner-specific results through the agreed post-project exploitation framework.

“INCIRCULAR leaves behind more than a demonstrator. It leaves a validated pathway for turning circular innovation into industrial reality.”

CONCLUSION

A validated pathway for circular manufacturing

INCIRCULAR showed that the transition from plastic waste to industrial circularity is not achieved by recycling alone. Industry needs a controlled secondary material, reliable processing evidence, product-level validation, digital insight, external replication and a credible route toward investment. By connecting these elements across three European regions, the project demonstrated that recycled polymer composites can move from laboratory development into real production and then into multiple sectors. The project's lasting value is therefore the combined method, evidence base, partner network and open tools that allow future users to replicate the pathway rather than copy one product. This provides a practical foundation for further market uptake, follow-on investments and new circular-material applications after the project ends.

INCIRCULAR in one view

01.10.2023	30.09.2026	€4,284,875.99	€2,999,413.19
Start date	End date	Project budget	EU contribution
9	3	70%	I3
European partners	European regions	EU funding rate	EU instrument

Consortium



Public resources

<https://incircular-project.eu/>

<https://incircular-project.eu/toolkit>

<https://incircular-project.eu/incircular-final-conference>

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