IRION Project Presentation

SUSTAINABLE AND EFFICIENT SOLUTIONS FOR SIMULTANEOUS AND CIRCULAR IRIDIUM AND MEMBRANE RECYCLING IN PROTON EXCHANGE MEMBRANE WATER ELECTROLYSERS

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AIMPLAS

Clean Hydrogen Partnership

The project is supported by the Clean Hydrogen Partnership and its members.

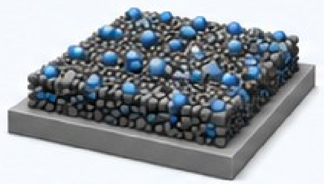
Co-funded by the European Union

IRION Consortium

Why IRION is needed: CRMs & PFAS challenge

Key barriers for sustainable PEM water electrolysers

Critical Raw Materials (CRMs)

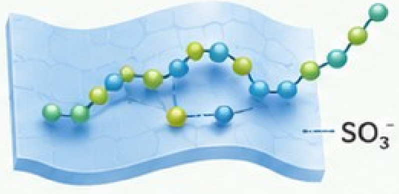


Iridium catalyst layer
(PEMWE)

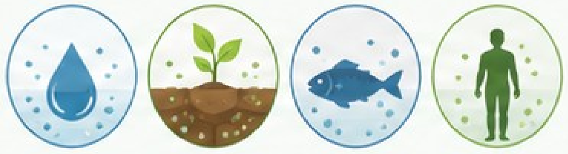
- Iridium is one of the rarest metals on Earth
- ~93.5% of global supply comes from South Africa
- Global production is only ~7–8 t/year
- Ir can represent ~20–25% of PEMWE stack cost

Low availability + high cost = major scale-up bottleneck

PFAS-containing ionomers



Fluorinated ionomer
(Nafion-type)



- Nafion-type ionomers are fluorinated PFAS materials
- They are highly persistent and difficult to degrade
- They can accumulate in soil, water and living organisms
- Lack of recycling routes increases environmental impact

Persistence + toxicity concerns = urgent circular solution needed

IRION addresses both challenges by recovering iridium and recycling fluorinated ionomer into new value chains.

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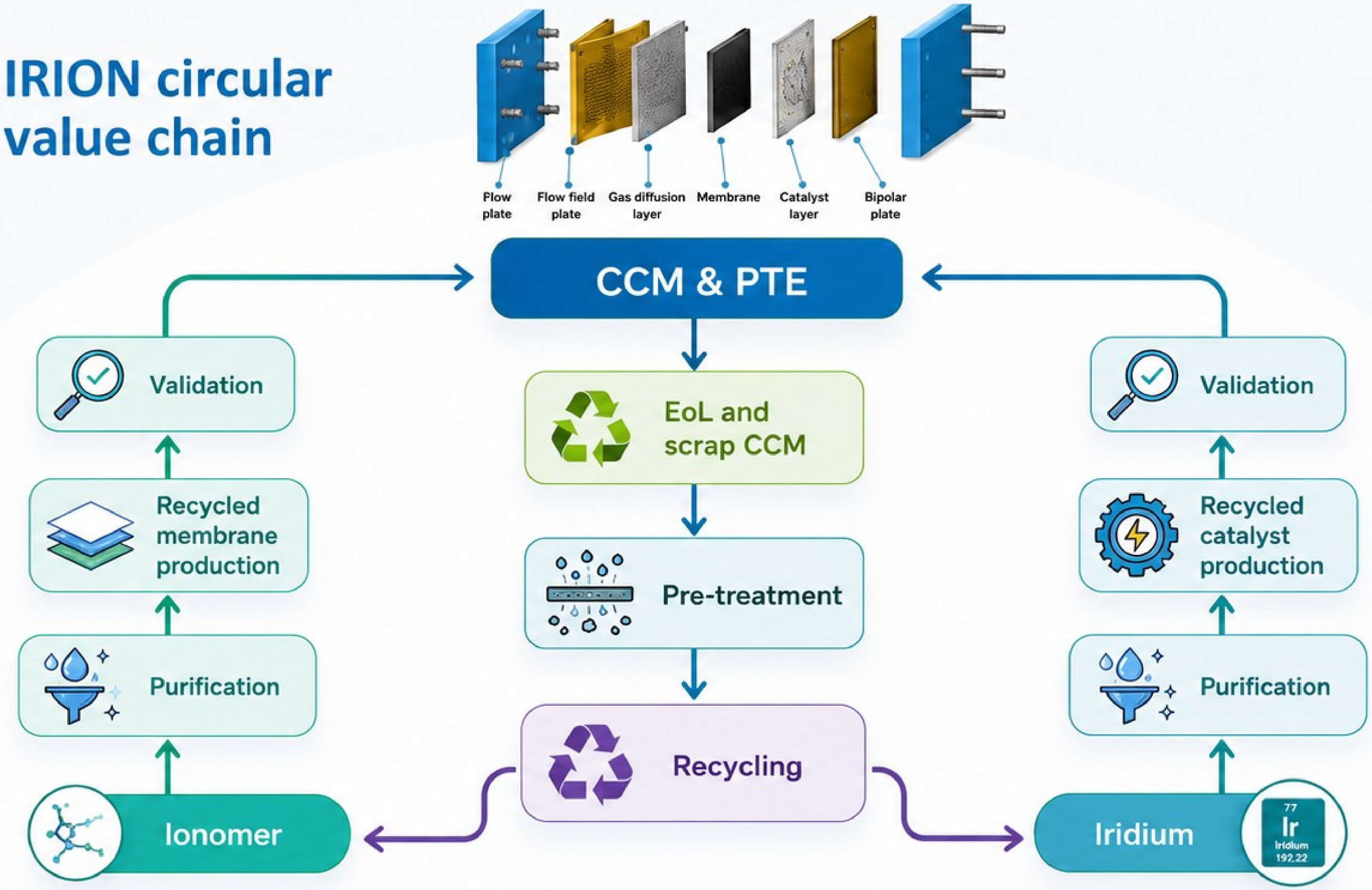
IRION circular value chain



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Target outputs: what IRION must deliver

Clear material, process and performance targets across the full circular chain

Input control

- Degradation test with **≥70%** accuracy
- Pre-processing guidelines: **≥20%** efficiency/time improvement

Recovery

- **≥70% Ir** and **≥70% Ionomer** extraction as minimum development target
- Best routes combined for higher recovery and lower downstream burden

Purity

- Ir **≥99.9%**
- Ionomer **≥99.5%**; Fenton metals **<15** ppm; other impurities **<500** ppm

Recycled materials

- Membranes with **≥80%** recycled ionomer and **≥90%** performance
- Catalyst with **≥50%** recycled Ir and high OER activity

Low-Ir manufacturing

- Inkjet gradient coating: target **<0.8 mg Ir cm^{-2}**
- PVD coating: target **<0.5 mg Ir cm^{-2}** and fluorine-free catalyst layer

Validation

- Single-cell and short-stack tests up to **1000 h**
- Performance close to virgin references; durability and stability verified

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Innovation · Feedstock diagnosis and pre-treatment

Building a reliable starting point for all recovery routes

Real CCM/PTE complexity

The available material is not a neat laboratory powder. Catalyst is distributed across the membrane/PTL interface and includes Ir, Pt and other metals.

Representative sampling

Pre-treatment will define how to cut, separate, grind or condition samples while preserving material balance and comparability between routes.

Degradation information

New tests will assess ionomer and electrocatalytic-layer degradation, supporting both recycling decisions and future eco-design recommendations.

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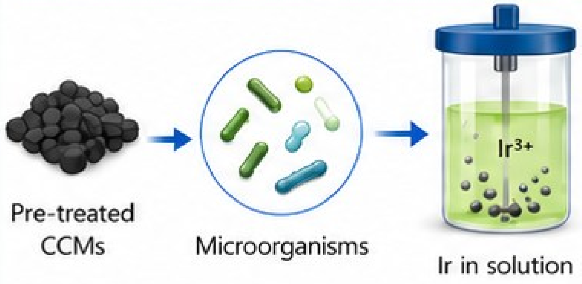
Innovative metal extraction & recovery routes

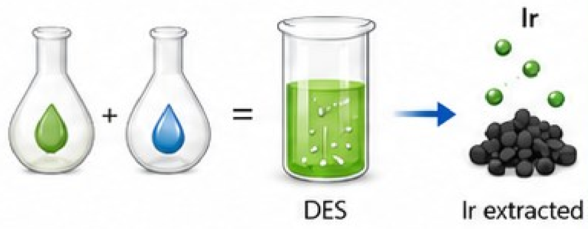
Four complementary pathways to recover iridium from end-of-life CCMs

1. Bioleaching



- Microorganisms solubilise iridium from recycled CCMs
- Acidophilic and cyanogenic routes explored
- Mild conditions, lower chemical demand

2. Deep eutectic solvents (DES)

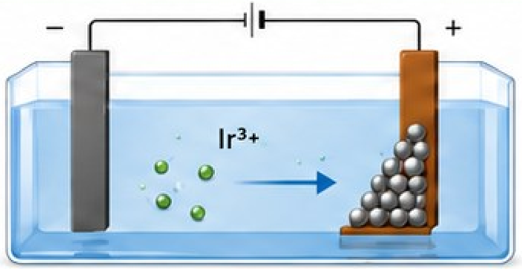


- Tailored green solvents for selective Ir dissolution
- Lower volatility and reduced hazardous reagents
- Recovery route designed for scalability

3. Ionic liquids (ILs)

- Tunable extraction media for complex Ir-containing streams
- High selectivity potential for platinum-group metals
- Supports cleaner separation and downstream recovery

4. Electrowinning



- Recovers dissolved iridium directly from solution
- High-purity metal deposition on conductive substrates
- Key parameters: pH and current density

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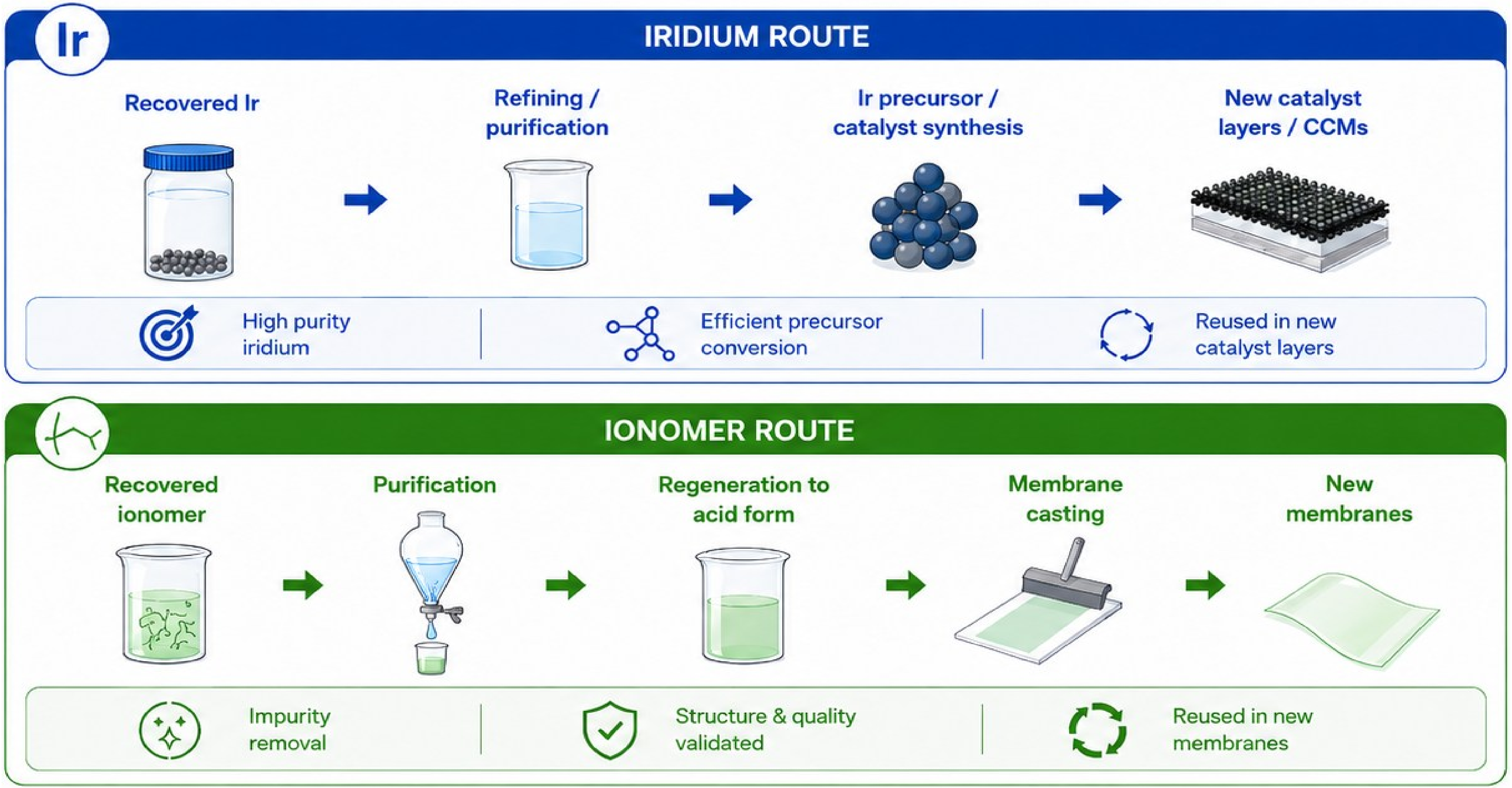
Iridium recovery and catalyst pathway

From Ir-containing CCM residues to reusable catalyst materials



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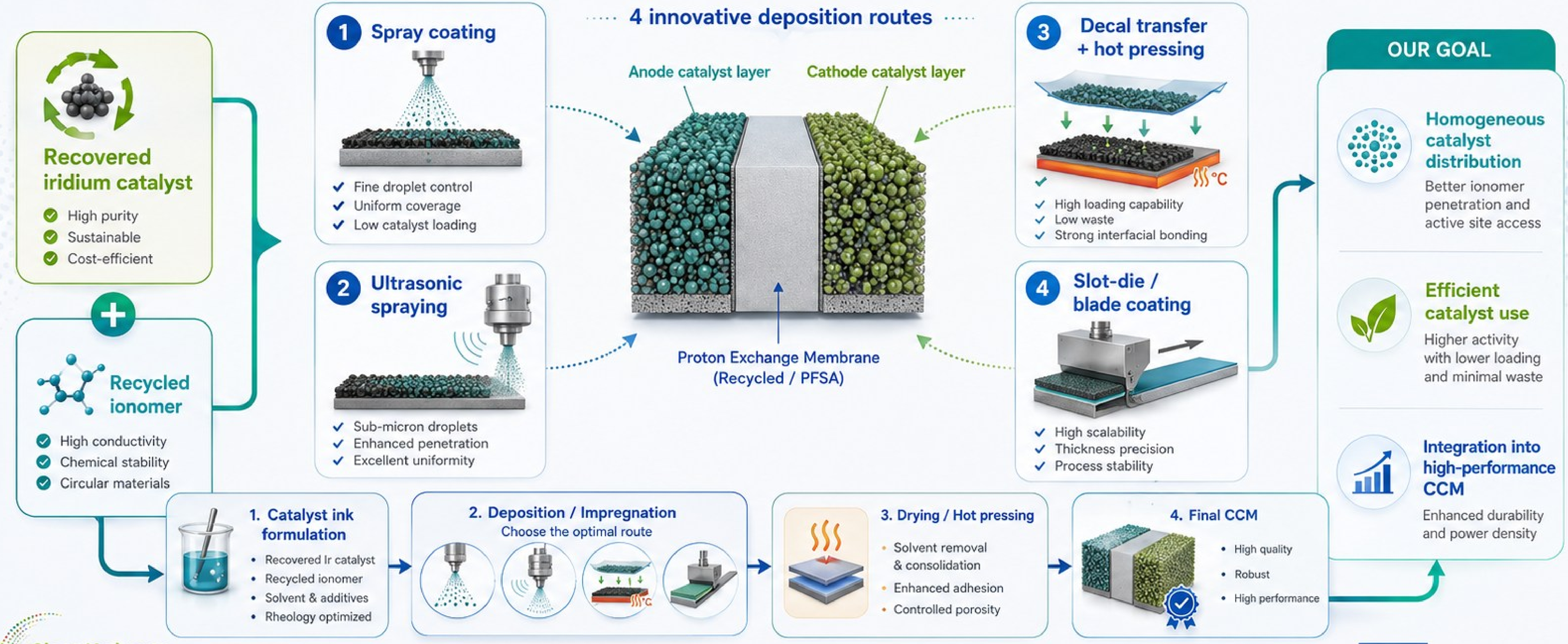
Advanced catalyst deposition and CCM fabrication

New deposition technologies for next-generation CCM performance



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IRION

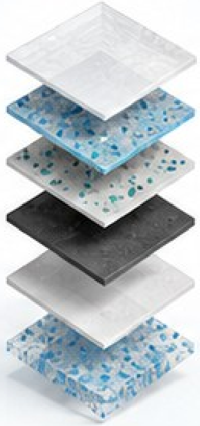
Validation, performance and sustainability

From recycled materials to validated PEM water electrolysis performance

Recycled materials

- Recycled membranes
- Recycled catalyst materials
- Recycled carbon supports

Membrane / Catalyst / CCM



- ✓ High quality integration
- ✓ Controlled composition
- ✓ Reproducible manufacture

Single-cell PEM water electrolysis testing

Technical validation

Cyclic voltammetry
Active area & ECSA

EIS
Ohmic & charge transfer resistance

Stability up to 1000 h
Long-term performance and durability

Performance comparable to state of the art
High current density at low cell voltage

Assessment of degradation effects
Efficiency retention and component durability

Sustainability assessment

LCA
Life Cycle Assessment

- Environmental impacts
- Hotspots identification
- Comparative assessment

TEA
Techno-Economic Assessment

- Capital & operating costs
- Cost of hydrogen
- Competitiveness analysis

SSbD / Sustainability
Safe-and-Sustainable-by-Design

- Material selection & safety
- Circularity & resource efficiency
- Responsible innovation

Driving a sustainable hydrogen future

High performance.
Low impact.
Responsible by design.

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IRION in a nutshell

Circular recovery and re-use of iridium and PFSA ionomer from PEMWE catalyst-coated membranes

Why it matters

- PEMWE needs iridium, one of the scarcest and most expensive CRMs.
- PFSA/Nafion-type ionomers create an end-of-life challenge due to persistence and future regulatory pressure.
- Current CCM recycling routes are still limited, especially when both metal and ionomer must be recovered together.

What IRION delivers

- New input-control methods for ionomer degradation and material pre-processing.
- Four Ir recovery routes: bioleaching, DES, ionic liquids and electrowinning.
- Purified Ir for catalysts/PVD targets and regenerated ionomer for new membranes.

Industrial relevance

- Recycled materials are integrated into new membranes, catalyst layers, CCMs and PTEs.
- Inkjet printing and PVD coatings target lower iridium loading, reduced fluorinated binder use and easier future recycling.
- Performance is verified through material characterisation, electrochemical testing, PEMWE validation and sustainability assessment.

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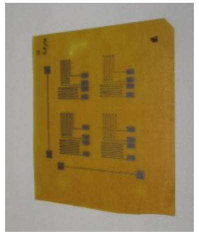
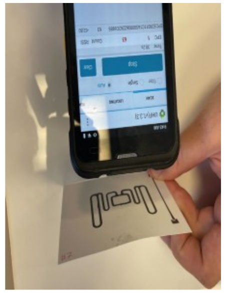
REFORM

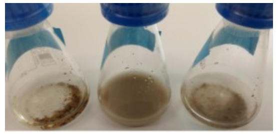
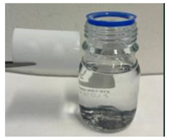
Building Blocks
- Adhesives
- Inks
- Substrates

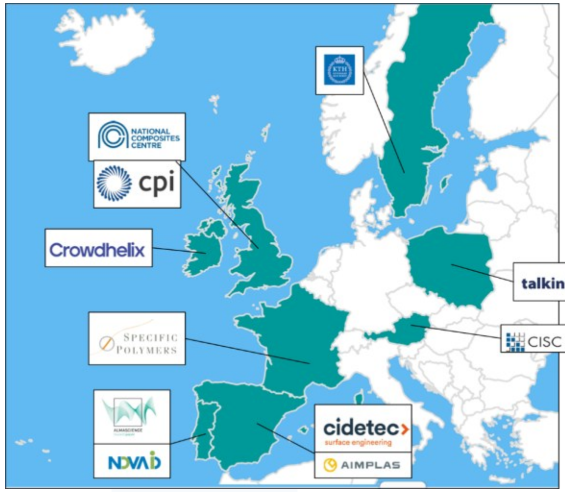
System Prototyping & Validation



Material Recovery & Sustainability

- AIMPLAS is leading End of Life studies for novel Printed Electronics
- Study of recyclability of printed electronics thorugh mechanical, chemical and biological routes
- Silver recovery from conductive adhesives



Metal recovery (Silver)

Conductive adhesives formulated with silver

↓

Pretreatment (adhesive detachment / swelling)

↓

Bioleaching / chemical leaching

↓

Silver precipitation

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Thank you

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