



Flexible, predictive and **R**enewable
Electricity powered electrochemical
toolbox **F**or a sustainable transition of
the catalyst-based European chemical **L**
industr**Y**

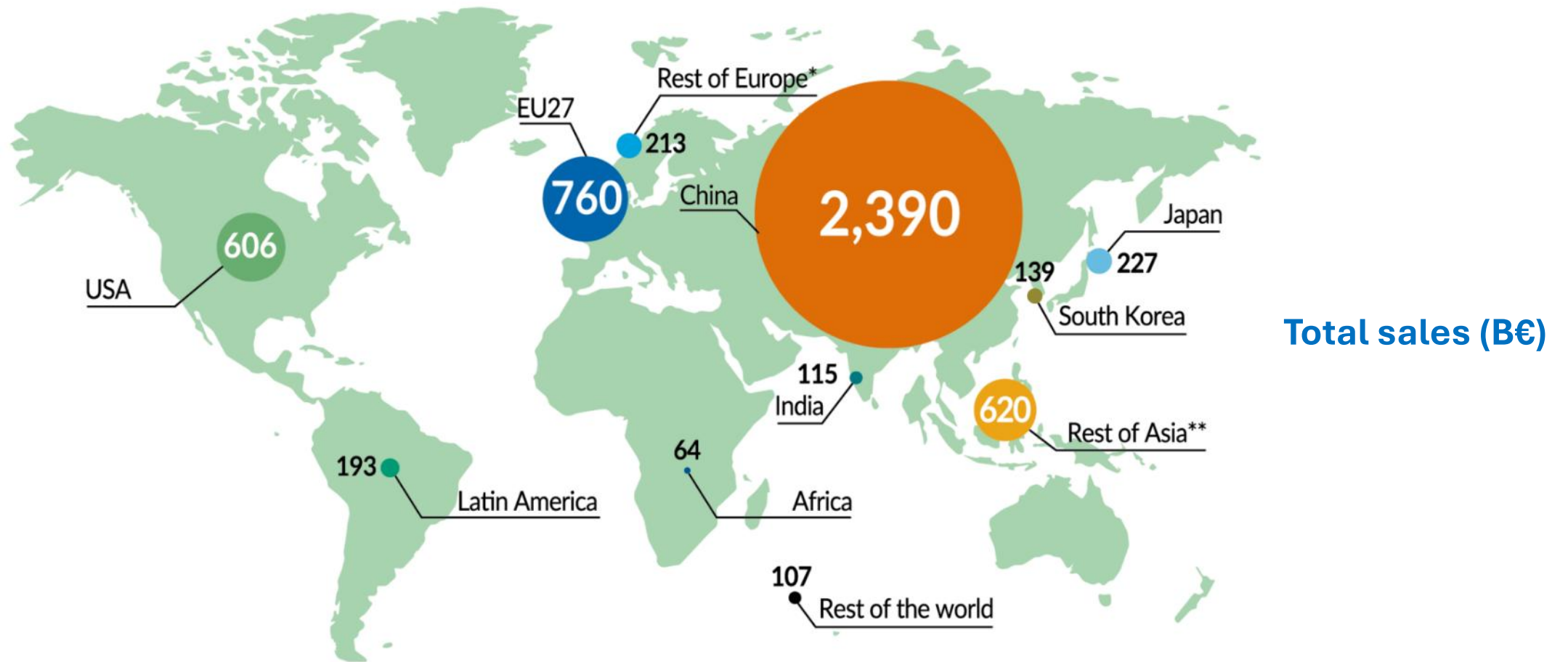
Savitha Thayumanasundaram
Coordinator



Funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency. Neither the European Union nor the granting authority can be held responsible for them. Grant Agreement N° 101091715.

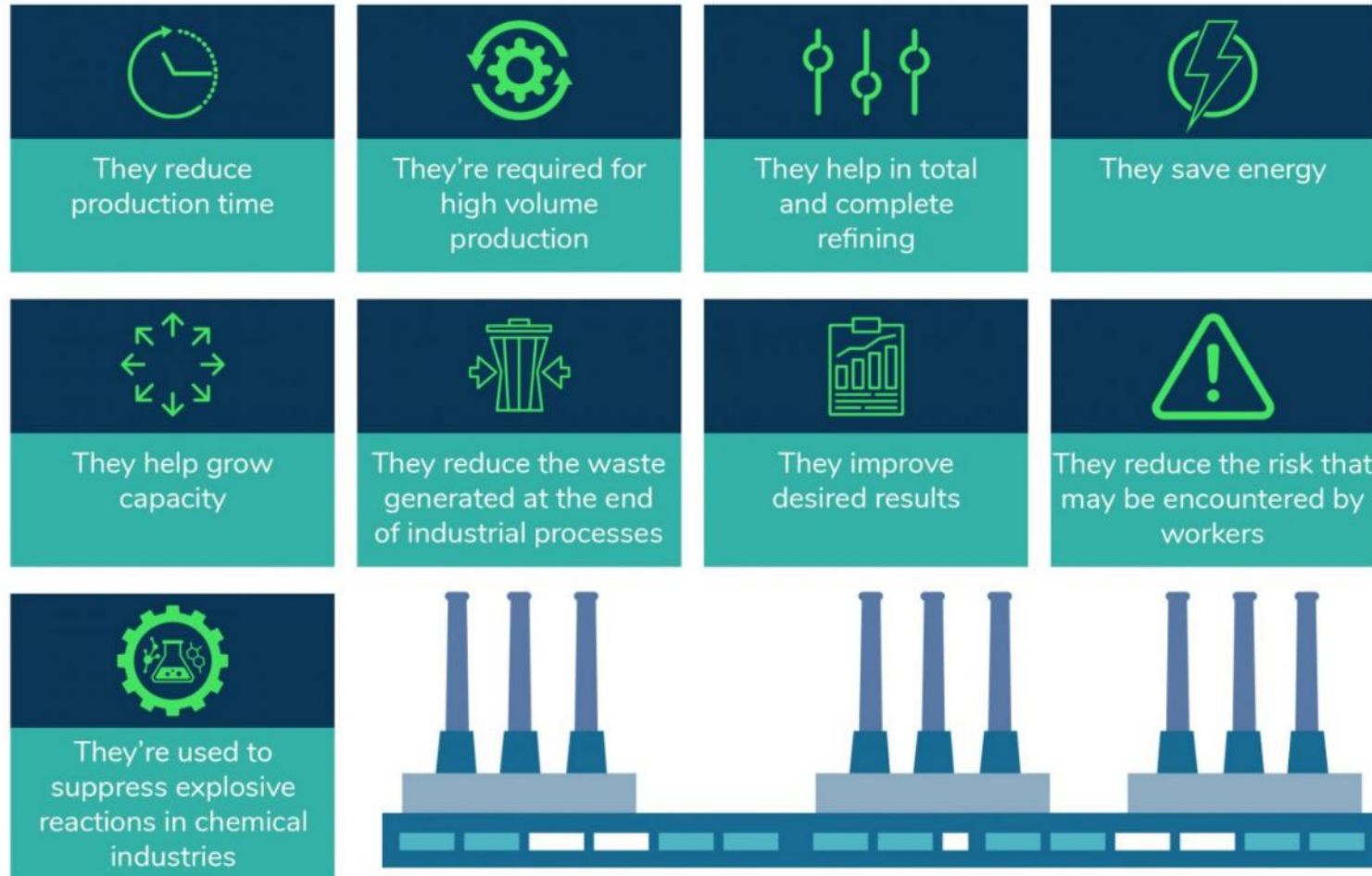
Motivation



■ **WORLD MARKET SHARE OF EU27 DROPPED 13% IN 20 YEARS.**

Motivation

Catalysts in the chemical industry



Recognized Trading & Shipping ([URL](#))

- EU catalyst market share (~25%), expected to reach ~10 B€ by 2030 (CAGR 4.4%).
- Used in ~90% of chemical processes.
- Industrial products (~60%) made using catalysts.
- Market growth hindered by socio-political issues: Critical Raw Materials (CRMs) & strategic foreign dependencies (SFDs).

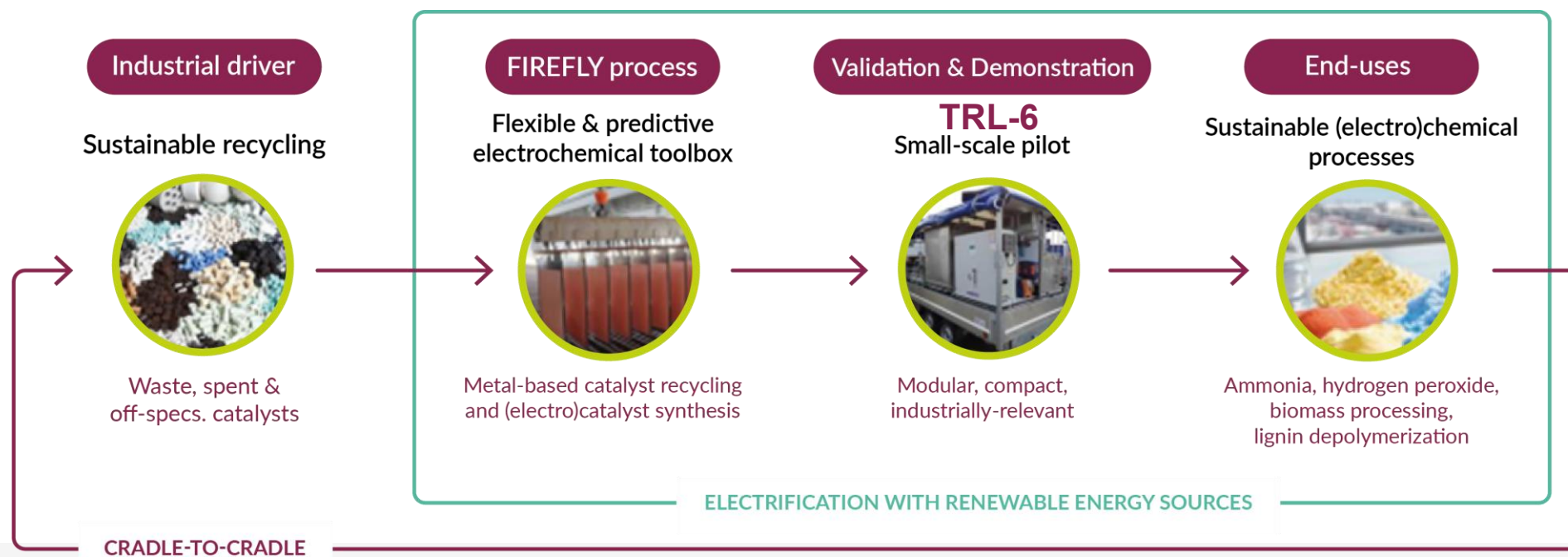
Platinum Group Metals (PGMs)

78 Pt PLATINUM 195.08	46 Pd PALLADIUM 106.42	45 Rh RHODIUM 102.91	77 Ir IRIDIUM 192.22	79 Au GOLD 196.97	47 Ag SILVER 107.87	
27 Co COBALT 58.933	22 Ti TITANIUM 47.867	74 W TUNGSTEN 183.84	42 Mo MOLYBDENUM 95.95	29 Cu COPPER 63.546	28 Ni NICKEL 58.6934	30 Zn ZINC 65.38

Vision

The FIREFLY project aims to electrify a large part of the chemicals value chain (environmental, economic, social)

- Power-to-catalysts and chemicals
- (Electro)catalyst recycling routes (spotlight: metal recovery)
- Electrification and decarbonization of selected chemical processes
- More sustainable and circular chemical industry (cradle-to-cradle)

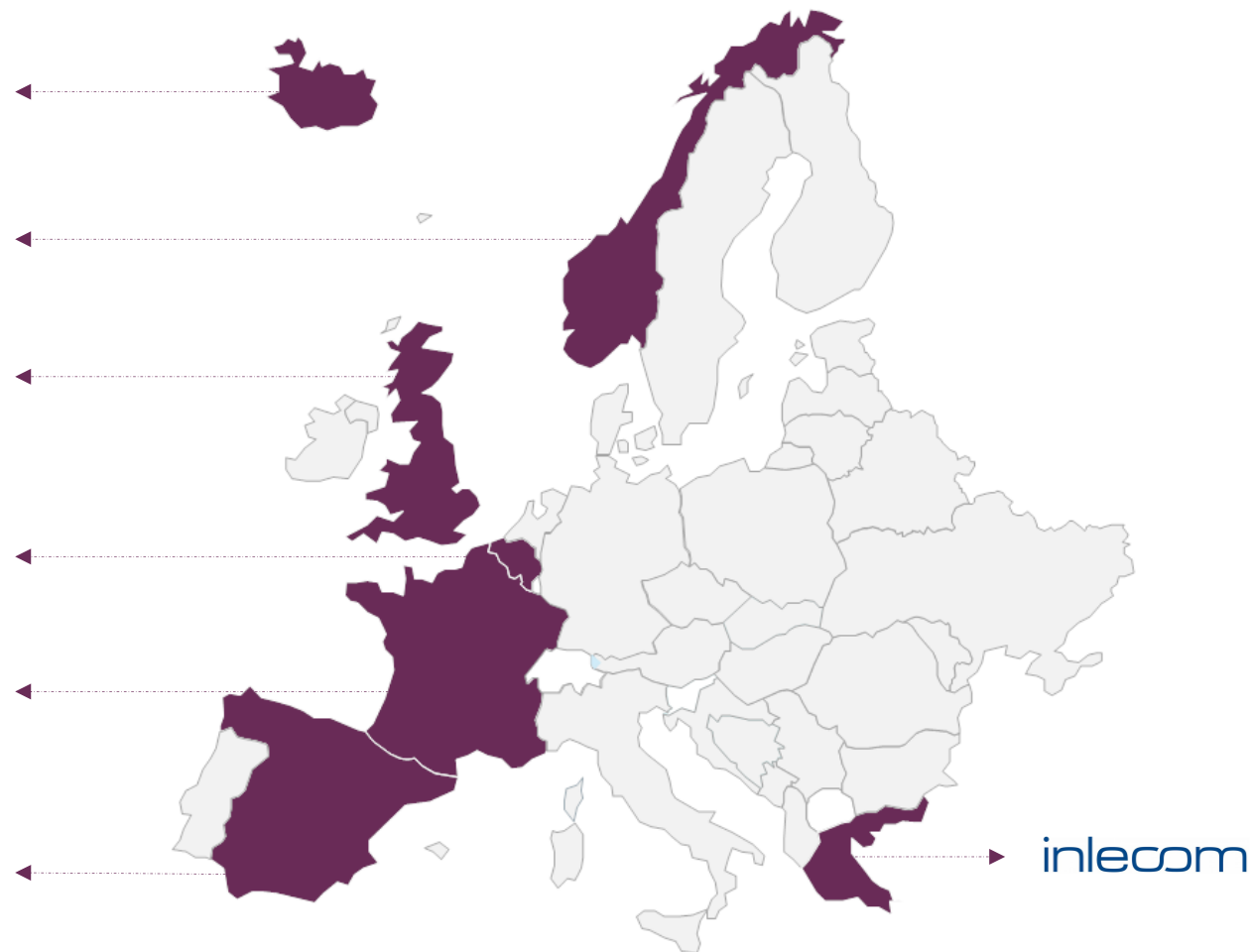


 **16 partners**
from **7 countries**

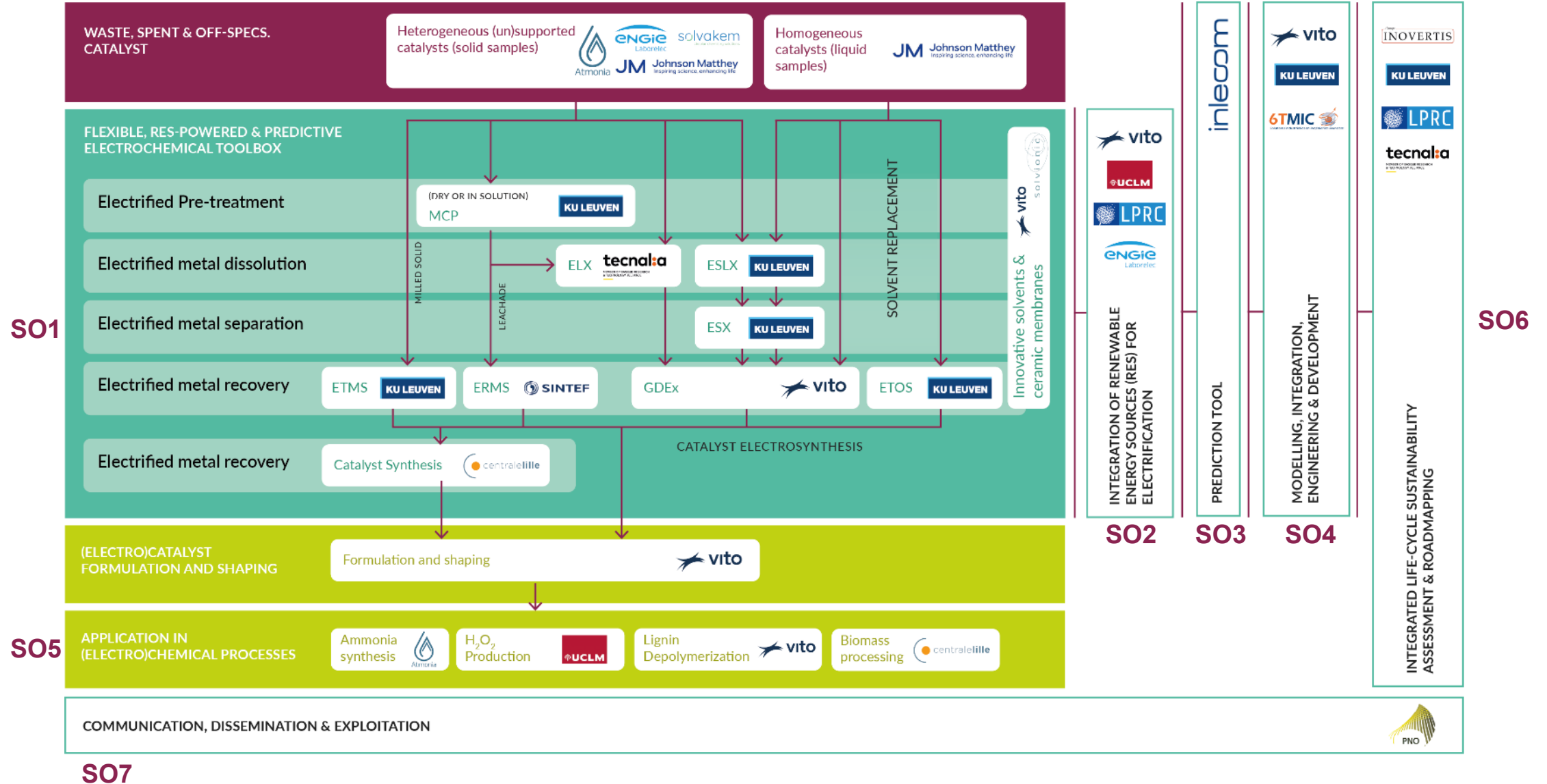
- 8 research centres
- 6 SMEs
- 2 large enterprises



Consortium

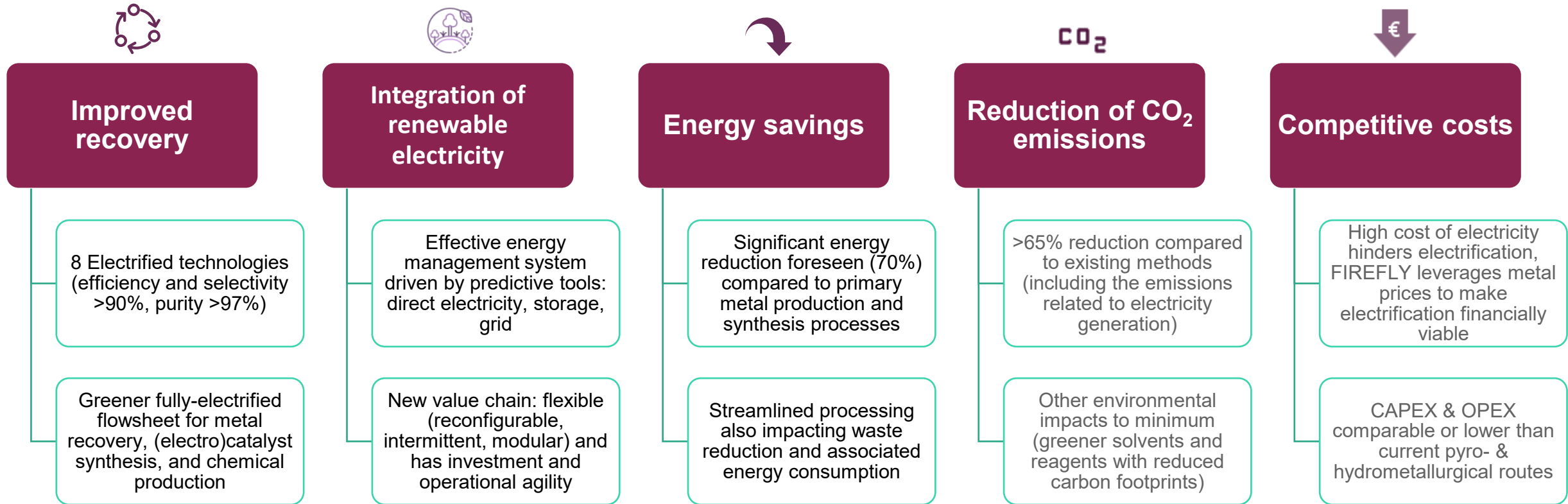


Technological developments



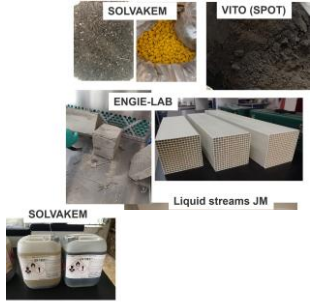
Expected impacts

- The main expected result of the FIREFLY project is a sustainable TRL-6 process for the flexible, predictive and RES-powered electro-driven recycling of metals, with the concurrent downstream synthesis of strategic metal-based (electro)catalysts, able to perform and unlock more-sustainable (electro)chemical processes.

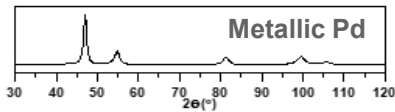


Process flow

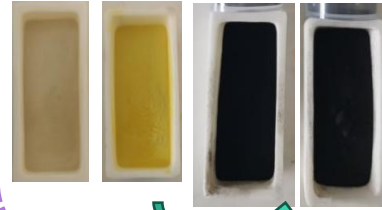
Industrial waste streams containing spent catalysts



Individual electrified technologies
MCP, GDEx, ESLX, ETMS, ERMS
- recovery of metals from waste streams



(electro)catalyst synthesis using recovered metals

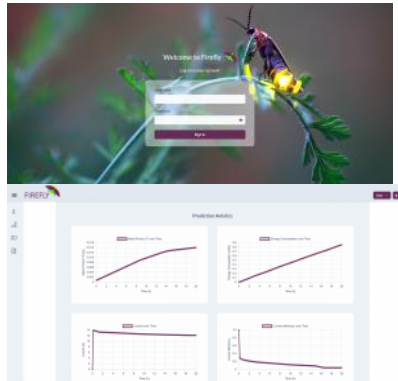
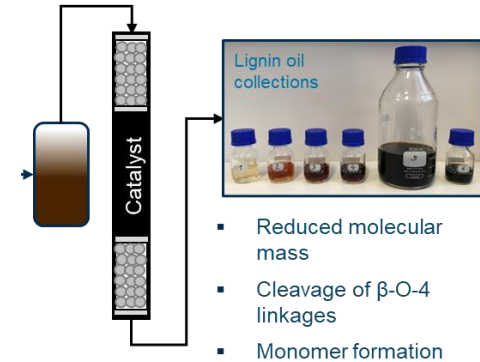


Synthesized Catalysts

Electrochemical toolbox to upscale the recovery of metals and production of (electro)catalyst (TRL 6)

AI predictive tool
RES integration

Demonstration of the catalysts in specific demo cases



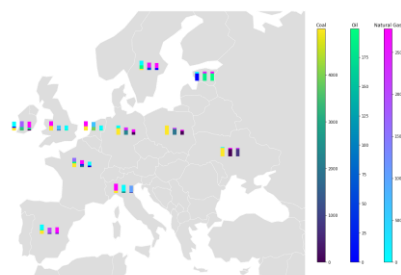
AI/ML tool to predict individual technologies, flowsheet optimization

Modelling of individual technologies, including energy consumption, RES compatibility

Results highlights (until M30)

Electrified technologies

DeNOx spent catalysts outflows

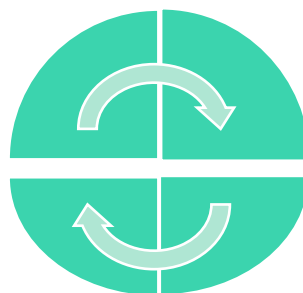


Mapping of resources

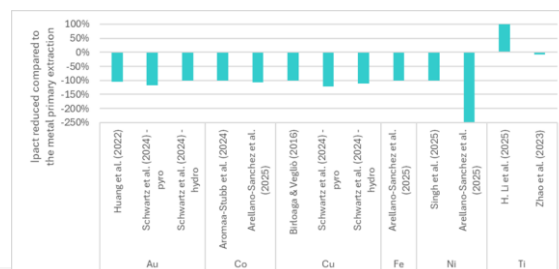
- Supply of industrial waste streams
- Mapping of available sources – MFA and GIS inventory
- Characterization of waste streams

Testing in demo cases

- Lignin depolymerization – better results with recycled catalyst ($\text{Pd}/\text{Al}_2\text{O}_3$)
- Recycled catalysts Pd/TiO_2 tested for biomass conversion.



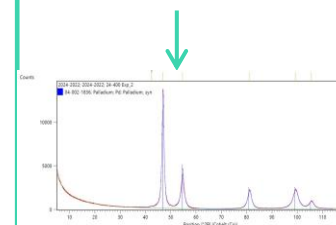
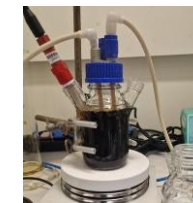
Sustainability assessment



Environmental impact

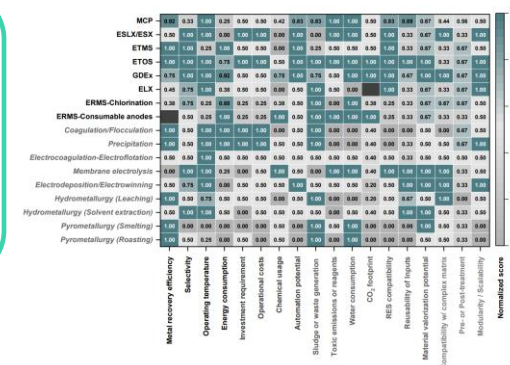
- Tertiary extraction leads to lower environmental impact
- Neutralizing chemicals results in lower impact

- 100% Pd and 99% V & W extraction using MCP
- >80% Pd extraction by ESLX
- 80% V and 77% Mo, 22% W from spent DeNOx by ELX
- 99% Pd removal from leachates and liquid waste streams by GDEx
- 60% W and 40% V extraction from spent DeNOx by ERMS
- 99.7% Pd recovery from waste stream by ETOS

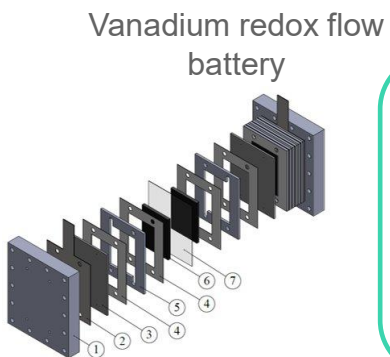


Benchmarking vs. SoA

- High recovery yield, selectivity
- Electrification leads to sustainable power-to-chemicals



Results highlights (until M30)

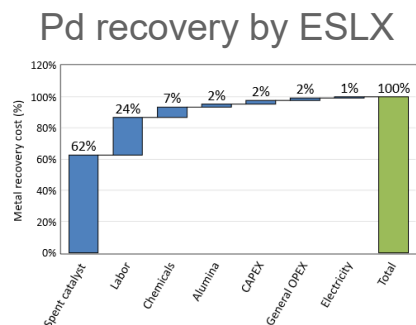


Energy requirements

- Powering by RES
- Energy consumption, scalability process integration potential of individual technologies
- VRFB – integrated RES system
- Lab-scale stacks 2-6 VRFB cells

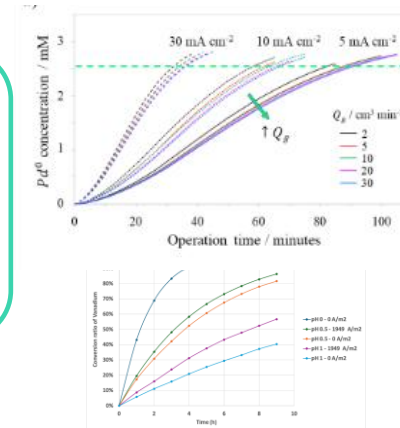
Economic analysis

- Techno-economic analysis for individual technologies
- Feedstock pricing – critical factor
- 1.1 tonnes of CO2-equivalent per kilogram of recovered Pd



Modelling

- GDEx – aligns with experimental results – extraction from trimetallic mixture – 2600 simulations
- ETMs – reduction of TiO2 – 735 simulations for AI/ML training.



AI Predictive tool

- Prediction of individual technologies
- Flowsheet optimization
- Interactive map

Interactive map



Exploitation

- Stakeholder analysis completed
- Internal exploitation workshop – 17 KERs
- Clustering events to steer the project towards industrial demonstration and exploitation

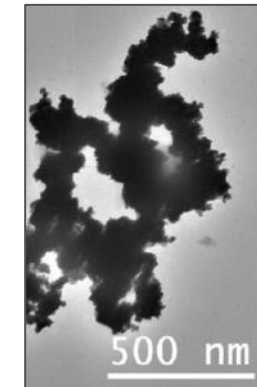
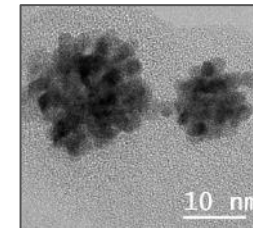
Scalability

- Not yet there, but vast experience by project partners. Example: PEACOC project.



TRL-7 GdEx pilot to demonstrate PGMs recovery & upcycling from EoL products

100 L h⁻¹, 2 kg PGMs per week – from automotive catalytic converters

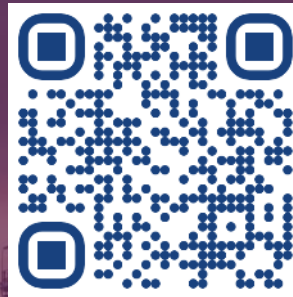


Barriers to implementation

- EU framework and political scenario very favorable to bring FIREFLY technologies to market, yet new environmental regulations and pressure towards electrification are essential
- FIREFLY technologies must compete with established routes
- Actions required
 - Engagement of stakeholders - high industrial involvement
 - Integration of FIREFLY individual technologies in current flowsheets where industry has difficulties
 - Testing of the small-scale pilot plant with several industrial waste streams to explore its flexibility
 - Scale-up beyond TRL-6 and commercial deployment
 - Industry-supporting infrastructure (eg., test benches with additional and optimized technologies)



FIREFLY Horizon Europe



www.firefly-project.eu



@FIREFLY_HEU
#FIREFLY

Thank you

Savitha Thayumanasundaram

Savitha.Thayumanasundaram@vito.be

firefly@vito.be



Funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency. Neither the European Union nor the granting authority can be held responsible for them. Grant Agreement N° 101091715.