

# Pioneering Sustainable Recycling

Cheap. Innovative. Efficient.





**CRUSADE**

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# Detailed project description

CRUSADE upscales environmental friendly technologies merging a combination of 23 technologies for sorting and a universal near-zero waste hydrometallurgical method to recycle up to 500 tn/year of spent automotive components (autocatalysts, fuel cells, batteries and printed circuit boards) from end-of-life vehicles and recover up to 40 tn/year of critical raw materials (Cu, Co, Mn, Ni, Pt, Pd, Rh, Li, Ru) at commercial specifications. The project leverages predeveloped technologies to establish a market ready pilot unit utilising novel concepts for material tracing using blockchain (AK.KA ITALIA, SAISLAB, ENTE) and pan European collection network establishment from the pioneers of the automotive components manufacturers (SUN, ADVENT, CRF, MONO, ACC) which guarantee the long term sustainable operation of the unit.

The material processing covers the whole chain from pre-treatment using validated technologies from the experts on the CRMs recovery (MONO, TUBAF, KUL) and upstream processing using a microwave assisted leaching methodology enabling lower CO<sub>2</sub> emission process (depending on the feed, reaching up to 80% reduction), compared to commercial processing. High specification market ready materials are prepared as outputs of the project undergoing a downstream purification and recovery process using solvent extraction and electrowinning, guided by industrial standards for end-use applications, while validated and benchmarked during the course of the project in new automotive products.

The processing is automated aiming to a 15% time reduction compared to current processes with the use of an industrial robot and artificial technology guiding the digitalised and automated sorting and the hydrometallurgical treatment (Industry 4.0 concept).

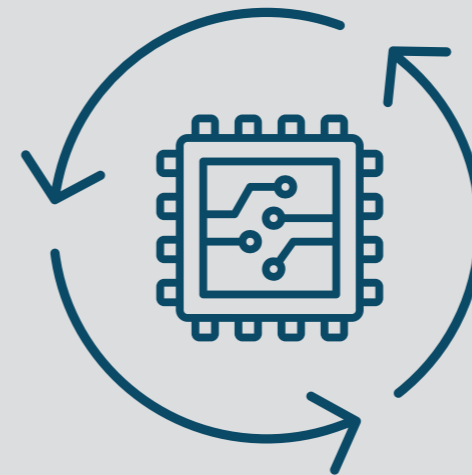
The materials are commercialised at 15% lower price compared to market standards due to the automated innovative cost efficient processing, CAPEX/OPEX reaching max 70% of product cost (average 30% gross profit margin depending on feed). ADVENT and SUN will be the first adopters of the outputs for validation in their long term business plans-ADVENT secured 850 million EUR funding for gigafactory development for fuel cells production, and SUN secured 150 million EUR for gigafactory development for production of LFP batteries. Both companies aim to adopt CRUSADE as raw material supplier.



The core activity of the CRUSADE solution is the digital sorting combined with recycling of CRMs from EoL components. As mentioned above, this relies on the blockchain/AI technologies followed with LIBS equipment for the sorting part providing accurate feedstock for a universal environmental friendly hydrometallurgical processes based on the improved operational conditions of the novel refining stages, compared to state-of-the-art for the recycling of metals from valuable components of EoL vehicles (EL VS).

The CRUSADE concept will be demonstrated in a pre-commercial pilot at TRL 7 (i.e., treating 1.5 tn of components per week) at the industrial facilities of the catalysts recycler MON.

6% increase in waste recovery



## SORTING PROCESSES

Sorting technologies of EoL products: All the automotive components to be recycled contain critical metals as it has already been mentioned while at the same time the applied process for recycling should be adjusted accordingly for each different waste stream. Through the application of sorting technologies the material inflow to the hydroprocesses will be increased by 2.5 times per hour and overall 6% overall recovery increase. According to data coming from Veolia, technological innovations developed on the waste sorting area can handle 2.5 times more waste per hour and recover 6% more waste.

The principle developed by Veolia is based on sequential selfadaptive sorting (TSA2) which automatically sorts the different plastics according to their compositions on a conveyor belt. The subsequent technology is the remotely operated sorting (TTO), which via a touch screen allow operators to sort the waste without touching it.

The combination is highly relevant to CRUSADE sorting technology which utilises the LIBS smart sorting based on composition and automation based on AI (remote monitoring). Therefore the 2.5 times increase is a realistic estimation.



# Information about partners



AIMEN Technology Centre, with more than 55 years of history, is currently a national and European benchmark in research, development and technological innovation in the areas of advanced manufacturing and laser manufacturing, digital technologies for manufacturing, smart materials, smart systems and recycling; as well as in the provision of differentiating technological services to the industry in the areas of manufacturing with advanced joining technologies, robotics and process digitization, a flexible cross-engineering service highly specialised in welding, corrosion, equipment calculation, product simulation and material tests.

Within CRUSADE project, AIMEN develops an object identification and material analysis module for automated sorting of EoL vehicle parts that will be implemented in the pilot line. The module is based on a vision and laser-induced breakdown spectroscopy (LIBS) system and applies machine learning algorithms for automated data analysis.



ACCUREC is a German SME company, founded in 1995 with its primary target to constitute the consumer battery recycling market in Germany. Within this project, ACCUREC is focus on battery recycling from the end-of-life vehicles, especially for the dismantling and pre-processing of battery packs in order to maximize the recyclabilities and circular economy impact.



Advent Technologies develops, manufactures, and assembles complete next-generation fuel cell systems, and the critical components for fuel cells in the renewable energy sector.

Advent has created highly efficient fuel cells that operate under extreme temperatures, humidity, and air quality performing in places no other energy solution can. More importantly, Advent's fuel cells are multi-fuel capable (hydrogen, e-methanol, e-fuels, natural gas), meaning they work on hydrogen as it comes in many different forms eliminating the need for complex hydrogen infrastructures. Because of this, it allows our fuel cells to be placed anywhere in the world and makes it possible to decarbonize the world today.

Advent is headquartered in Boston, Massachusetts, with offices in California, Greece, Denmark and the Philippines.

In CRUSADE, Advent will provide end-of-life HT-PEM MEAs into the recycling blockchain and will be responsible for the validation of the recycled HT-PEM MEAs.



BFC is an EPC company mainly involved in the construction of pilot and industrial plant in the saving energy sector and in the development of hydrometallurgical processes for the Critical Raw Material recovery (CRM). For this last activity process engineering is carried out by an affiliated and controlled company, Smart Waste Engineering srl (an Innovative SME) that it is owner of several innovative patents in the recovery of base and precious metals from e-wastes (printed circuit boards from WEEE and automotive sectors - PCB, dismantled solar panels, LCD, spent batteries, permanent magnets and industrial wastes).

BFC has already realized some hydrometallurgical plants in pilot and industrial scale with experience in the definition of CAPEX and OPEX of the developed processes. In the CRUSADE project the role of BFC is mainly related to the development of hydrometallurgical pre-treatment of PCB coming from the automotive sectors in order to recover base and precious metals. In particular the main activities in the project are related to WP4 (components pretreatment), WP5 (powder upstream processing) and WP 8 (Material validation for end-use applications and sustainability).

Consiglio Nazionale delle Ricerche (National Council of Research-Italy), is a public research organization; its duties are to carry out, promote, spread and transfer research activities in the main sectors of knowledge growth and use this research for the scientific, technological, economic and social development of the Country. CNR is composed of 7 main departments covering different fields. The total number of CNR employees amounts to about 8000.

The Institute for Advanced Energy Technologies „Nicola Giordano” (ITAE), located in Messina (Italy), is one Institutes of the Engineering, ICT, Energy and Transportation Department (DIITET) of Italian National Research Council (CNR). Within the Department, ITAE's strategic mission is mainly aimed at promoting and developing innovative energy processes and technologies with high efficiency and low environmental impact. The research activity of CNR-ITAE is based on a mixture of basic and applied research, carried out through a multidisciplinary approach. CNR-ITAE is focused on innovating electrochemical energy conversion technologies through up-to-date knowledge in materials science, micro- and nano-technologies, polymer science, and system engineering.

In CRUSADE, CNR is the lead partner for Task 8.1- Catalytic activity benchmarking of PGM based catalysts for autocatalysts and fuel cells.

In particular, the activity will address the following points:

- Benchmarking the catalytic activities of PGM-based catalysts for fuel cells
- Manufacturing new electrocatalysts using recycled PGMs materials
- Physicochemical and electrochemical characterization of the prepared catalysts
- Provide input to inventory of LCA activities in task 8.4.

