

# ECO Recycling

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## 1. COMPANY

Eco Recycling is a company (President Prof. Luigi Toro) that has been created in 2008 by the cooperation of university researchers, “La Sapienza” University and two SMEs operating in the field of environmental technologies and in the IT sector.

The initial objective of this company was the technology transfer of a new patent developed to recycle alkaline spent batteries (European patent application EP1684369 A1).

This activity was then extended to the valorization of other wastes such as spent catalysts, WEEE (Wastes from Electronic and Electrical Equipments) and other spent batteries (Li-ion and Ni-MeH).

It is also currently involved in the recovery of metal value from mining waste.

Eco Recycling has been responsible of the design, construction, and startup of a multipurpose pilot plant in Northern Italy (2009) which has been used not only for alkaline batteries but also for other kind of wastes. Based on Pilot activities an industrial plant with large potentiality (4000 t/y) has been designed by Eco Recycling and the plant is now operating at S.E.Val s.r.l. of Colico (LC).

Eco Recycling has been responsible of the design, construction, and startup of a new mobile pilot plant (2011-2012), including all the necessary facilities to recover metals from pretreated wastes. Reduced dimensions, mobility and flexibility of the included facilities made this apparatus economical and flexible allowing solving on-site the different needs of SMEs involved in the treatment and valorization of solid wastes containing metals.

Eco Recycling was responsible of the design, construction and start up of two demonstrative plants (2013-2014): one fixed and the other one mobile localized in two containers. They were finalized to recovery of rare earths (Yttrium, Terbium, Gadolinium, Lanthanum) from fluorescent powders of lamps and Co from Li batteries.

The company was responsible for the design, construction, and start-up of a pilot plant (2014-2015) in which an innovative hydrometallurgical process was used that allowed the recovery of both the support and precious metals present in the Palladium/Silver-based membranes used to produce hydrogen.

Furthermore, the company was responsible for the design, construction, and start-up of a mobile pilot plant (2014-2017) which employs an innovative hydrometallurgical process for the recycling of the components that make up PVPs. Using this pilot plant, it was possible to treat all types of panels currently marketed.

Over the past three years has deigned:

- a pilot plant for the treatment of lithium zero batteries (LIFE LIBAT project)
- one Demonstrative plant for treatment of black mass from battery, the aim of the plant was recovery pure cobalt (CROCODILE project), for this plant Eco Recycling also took care of its construction.
- two new prototypes in the context of two life projects (LIFE DRONE and LIFE BIOAS), one prototype is devoted to recycling of lithium-ion batteries and the other for the synthesis of bio chart for decontamination of drinking water from arsenic (for these two plants Eco Recycling also took care of its construction).

As part of the RHINOCEROS Project, the Company is working on the design of another plant that will be built at a Belgian company, again concerning the treatment of lithium-ion batteries.

The company owns several patents mainly relating to the treatment of end-of-life batteries and photovoltaic panels.

The company has also realized a technological platform (equipped with all the main services) in Civita Castellana where all the prototype and demonstration are located.

## 2. MISSION AND ACTIVITIES

- Innovative Process and technology development;
- Scale-up from laboratory to prototype scale;
- Environmental analysis;
- Technical and economical feasibility analysis;
- Basic and detailed design of prototype/full scale plant;
- Turnkey plant construction;
- Experimental campaigns on plants;
- Licensing of know-how;
- Assistance for full scale plant construction;
- Assistance for startup, management and personnel training;
- Chemical analysis for environmental control and process optimization.

In Research & Development activities, Eco Recycling usually collaborates with High Tech Recycling Research Centre (HTR) an Interuniversity Research including different universities: “La Sapienza” University of Rome, University of L’Aquila, University of Genoa, University of Bologna, University of Cagliari, Polytechnic University of Marche and IGAG Institute of CNR.

## 3. PROJECTS AND FINANCING

### 3.1. RHINOCEROUS

*“Batteries reuse and direct production of high performances cathodic and anodic materials and other raw materials from batteries recycling using low cost and environmentally friendly technologies”.*

Rhinoceros is a project funded by the European Commission (GA n.101069685) under the Horizon program (Call: HORIZON-CL5-2021-D2-01) and aims to facilitate access to the materials that make up the battery, developing a chain of innovative, circular and highly performing procurement able to recycle batteries and reuse the products obtained at high purity and at competitive prices for the remanufacturing of new batteries. In this project, therefore, the aim is to demonstrate a recycling path for batteries deriving from the automotive sector that have reached the end of their life, thus contributing to reducing Europe's dependence on the import of CRM (Li, Co, graphite). This project is currently ongoing (start date: September 2022 - end date: August 2026).

Eco Recycling, as project partner, is responsible for the following activities:

- basic and detailed design of the prototype concerning the hydrometallurgical treatment;
- support in construction and commissioning.
- support during the demonstration phase.

### 3.2. “LIFE DRONE” Project

“Direct pROduction of New Electrode materials from battery recycling” (co-financed by European Commission LIFE19 programme)

Life DRONE (LIFE19 ENV / IT / 000520) is a project co-funded under the LIFE + program and aims to demonstrate a new recycling route for different types of lithium-ion batteries (LIBs) that have reached the end of their life. The main idea is to demonstrate an innovative recycling process to recover high-value materials (graphite, Ni, Co and Mn) and employ these materials to synthesize high-quality cathode material for new NMC lithium-ion batteries. The project will be focused on

the scale-up of the hydrometallurgical treatment with mineral acids of the electrode powder currently delivered by the physical pretreatment of LIBs manually separated from the collected batteries. This treatment will yield a mixed hydroxide of Ni, Co and Mn, which will be successively employed to synthesize the NMC cathode material. The impact of the inaccurate LIBs manual sorting and of the consequent difficulties of pre-physical treatment control will be evaluated by quantifying the deviations of the operating conditions (Ni, Co and Mn concentrations) from the optimal values required for the mixed hydroxide synthesis. These deviations will be corrected in the process by the controlled addition of Ni, Co and Mn salts. The project will finally include the testing of produced materials by the production of new lithium-ion cells. To demonstrate the process, the mobile plant realized during the HYDROWEEE Project (FP7 n. 231962) will be operated along with a new unit designed and constructed to synthesize the NMC cathode oxide. The consortium is composed of four partners from the Italian market. Technosind srl is the leader of the project while the other project partners are the following: Eco Recycling, FAAM RESEARCH CENTER, S.EVal srl and Sapienza University Department of Chemistry. The Life DRONE project started in September 2020 and ends in December 2023 and has the following objectives:

- Process demonstration by treatment of 3 tons of Li-ion batteries (about 1350 kg of electrodic powder) producing 660 kg of NMC oxide;
- Validation of produced materials by preparation of 10 Li-ion cells;
- Evaluation of the process economic feasibility;
- Life cycle assessment of the proposed recycling route;
- Elaboration of a replicability plan evaluating the implementation in a different EU member state;
- Elaboration of a business plan to drive the large-scale industrial application of the proposed process.

### 3.3. “LIFE BIOAS” Project

“Removal of As from water using innovative BIO-adsorbents produced from by-products of the agro-industrial” (co-financed by European Commission LIFE19 program)

Life BIOAs (LIFE19 ENV / IT / 000512) is a project co-financed under the LIFE + program and aims to demonstrate the environmental and economic feasibility of a process to produce an innovative bio-adsorbent and, simultaneously, its use for the purification of drinking water from arsenic. The project will highlight the advantages related to environmental impacts (related to water purification) and the economic advantages related to a lower use of expensive raw materials and less energy consumption compared to the adsorbents currently produced). Within the project, three prototypes will be built, and experimental campaigns will be carried out for the production of bio adsorbents and for the decontamination of the waters. Eco Recycling srl is the leader of the project while the other project partners are as follows: ALFO ENERGIA srl, HTR center (High Tech Recycling, Department of Chemistry of the University "La Sapienza" of Rome), TALETE SpA, Technosind Srl, Universidade de Évora.

The Life BIOAs project starts in September 2020 and ends in August 2023 and has the following objectives:

- Design and construction of the prototype for the production of bio-adsorbents;
- Design and construction of the prototype for the treatment of the water that uses the bioadsorbents produced in the project;
- Design and construction of a portable prototype for the treatment of water that uses the bioadsorbents produced in the project;

- Demonstration of the use of innovative bioadsorbents in prototypes for removing arsenic from water;
- Technical-economic feasibility study of the proposed technology;
- Study of the environmental impacts associated with the proposed technology considering both the production of bi-adsorbents and their use for water treatment.

### 3.4. “CUSTOM-ART” Project

CUSTOM-ART is an H2020 funded project that stands for “Disruptive kesterites-based thin-film technologies customised for challenging architectural and active urban furniture applications “. The project has a total budget of 8M€ and will run for 42 months (start date: September 2020 - end date: February 2024). It involves 17 partners across Europe that includes the world-leading groups and main European actors involved in the development of kesterite technologies and Alejandro Pérez-Rodríguez from IREC is the coordinator of the project. Custom-Art consortium leads an ambitious and disruptive EC funded project for the development and demonstration of the next generation of BIPV and PIPV modules based on abundant thin-film materials.

Building- and product-integrated photovoltaics (BIPV and PIPV) are identified as key enabling technologies to make "near-zero energy buildings" and "net-zero energy districts" a reality. The mass adoption of BIPV and PIPV solutions can only be achieved by developing cost-efficient and sustainable thin-film technologies with unbeatable aesthetic functionalities, mechanical flexibility and optical tunability.

The EU-funded CUSTOM-ART project aims to develop the next generation of BIPV and PIPV modules based on abundant thin-film materials such as kesterites. The project will bring flexible and semi-transparent solar modules to a higher level of maturity (TRL 7), demonstrating very competitive conversion efficiencies (20% at cell and 16% at module levels) and increased durability (over 35 years), at a reduced production cost (less than EUR 75/m<sup>2</sup>).

By combining advanced strategies for materials properties management, with customized modules design in a circular economy approach, two types of products will be developed including flexible PV modules and semi-transparent PV devices. CUSTOM-ART will bring these technologies from TRL4-5 up to TRL7, demonstrating very competitive conversion efficiencies and durability (over 35 years), at a reduced production cost. They will exclusively use abundant elements and contributing to ensure the full sustainability and competitiveness of the European BIPV and PIPV Industry.

Eco Recycling as a project partner, is responsible for the following activities:

Definition of an innovative process for the recycling of this new type of thin film panels;  
Revamping of its existing mobile plant built within a previous project, identification of the changes necessary for the validation of the innovative process for the recycling of this type of panels;  
Realization of a technical-economic feasibility study for the construction of a full-scale plant, with the annexed drafting of a business plan.

### 3.5. “CROCODILE” Project

Crocodile (2018-2022) *"First of a kind commercial Compact system for the efficient Recovery Of CObalt Designed with novel Integrated LEading technologies"* (H2020-SC5-2016-2017) is a project co-funded by the European Commission inside the Horizon 2020 program. It aims to recovery Cobalt from a series of WEEE wastes and to demonstrate on a large scale the innovative

metallurgical process integrated, which uses different specific technologies to maximize the recovery of Cobalt.

Eco Recycling, as project partner, is responsible for the following activities:

- Revamping of the pre-existing mobile plant realized within the European HydroWEEE DEMO project, in order to identify the changes necessary for the realization of the proposed innovative process;
- Demonstration of the proposed process by integrating a new L-L extraction and electrodeposition sections to the previously developed plant (HydroWEEE DEMO);
- Support for the realization of the business plan.

### 3.6. “MEMBER” Project

MEMBER (2018-2022) “Advanced MEMBranes and membrane assisted procEsses for pre- and post-combustion CO<sub>2</sub> captuRe” (Call: H2020-NMBP-2016-2017) is a project co-financed by European Commission inside the Horizon 2020 program. The key objective of the project is the production and replicability of both advanced materials and new technologies (membranes and sorbents) to be used in power plants for the relative capture of CO<sub>2</sub> and to produce H<sub>2</sub> during the pre- and post-combustion phases. Based on the experience of Eco Recycling on the life of Pd/Ag membranes treatment in frame of a national project (HYRPAM), it will focus on the recyclability and sustainability of the membranes advanced materials constituent. An experimental activity will be done on a prototypal scale to determine the ideal technology for recycling and regenerating of membranes. The project objectives for which Eco Recycling is responsible are:

- Carry out a thorough research on the different methods for the recovery of Pd (and other metallic element) in solution as well as the reuse of the support for the manufacturing of new Pd-based membranes;
- Test the optimal techniques found and study the recovered support, which will be analyzed after this treatment in perspective of their reuse/recycling. New membranes will be manufactured on these supports and their properties will be measured and compared with the original membranes.



**Fig. 1** Member's prototype

## 3.7. “LIFE LIBAT” Project

LiBat (2017-2020) “*Recycling of primary Lithium Battery by mechanical and hydrometallurgical operations*” (LIFE16 ENV/IT/000389) is a project co-funded by the European Union within the LIFE+ program and it aims to demonstrate an innovative process for the recycling of end-of life primary Lithium batteries. The only plants currently operated in Europe use pyrometallurgical processes, while the proposed process integrates a mechanical pre-treatment section with a hydrometallurgical treatment section. This process derives from the collaboration between Eco Recycling and the HTR center (High Tech Recycling, Department of Chemistry of the “La Sapienza” University of Rome).

This solution allows achieving, in line with the EU Directive 2006/66/EC, a recycling efficiency of primary lithium batteries larger than 50% and ensures energy consumption and environmental pollution impact significantly lower than those achieved by implementation of pyrometallurgical processes.

The LiBat project aims at the following objectives:

- Demonstration of the new innovative process for recycling primary Li batteries (Li(O)/MnO<sub>2</sub>);
- Recovery of plastics, ferrous and non-ferrous materials through the integration of a mechanical pre-treatment with a hydrometallurgical treatment;
- Demonstrate the possibility of separately recovering Lithium and Manganese products, unlike alternative recycling technologies to date;
- Design and construction of a pilot plant capable of processing 50 kg of batteries/day.



Fig. 2 LIFE LIBAT’s prototype (constructed in SEVal and designed by Eco Recycling)

## 3.8. “e.THROUGH” Project

e.THROUGH project (2018-2022) “*Thinking rough towards sustainability*” (H2020-MSCA-RISE-2017) has the ambitious vision of turning the challenge of CRMs dependence into a strategic strength for Europe, contributing towards declassifying some CRMs (critical raw materials), as tungsten, indium, gallium and chromium, by: 1) Promoting new trends in the characterization and exploration of mineral deposits; 2) Mapping CRMs between EU mining regions; 3) Gaining

knowledge on innovative processes for recovery secondary CRMs; 4) Redesign construction materials using secondary materials, closing loops, strongly supporting waste minimization; 5) Life Cycle Assessment (LCA) for the evaluation of global environmental impacts; 6) Transferring newly generated knowledge to stakeholders, both for policy development and standardization, and for shaping responsible behaviors. e.THROUGH is an intersectoral and interdisciplinary consortium of EU & Third Country partners of leading institutions that see waste as a resource to recover CRMs, influencing the whole value chain. By training human resources in CRMs' value chain, their recovery, recycling, further reuse and LCA, they become the much needed young and senior scientists and engineers for the growing EU CRM industry. The consortium comprises 40% industry and 60% research partners.

### **3.9. "PHOTOLIFE" Project LIFE+ 2013**

Photolife (2013-2017) *"Process and automated pilot plant for simultaneous and integral recycling of different kinds of photovoltaic panels"* (LIFE13 ENV/IT/001033) was a project co-funded by the European Union within the LIFE+ program. The project aimed at the development and optimization of an innovative hydrometallurgical process able to treat different kinds of PVP and to the realization of a pilot plant (Fig.1). It consisted of a mechanical, physical and chemical section, which were integrated together to recover the various panel's components:

- High quality glass and suitable to reuse it in glass or ceramic industry;
- Recyclable polymeric materials;
- Al to be re-entered directly on the market;
- Glass powder for cement factory.

Furthermore, Photolife project have been aimed both to demonstrate in pilot scale the technical feasibility of an innovative process (developed on the base of laboratory scale experiments) for the automated and simultaneous treatment of the three main kinds of photovoltaic panels (Si-based, Cd-Te based and innovative panels as the CIGS) and to determine the overall economic feasibility of the pilot plant process accounting also for the recovery of electronic equipment (printed circuit boards and other electronic equipment) and plastics.

Eco Recycling was the coordinator of the project, the designer, and the builder of the pilot plant.





*Fig. 3 Photolife's prototype: pre-mechanical and physical sections.*

### 3.10. “HydroWEEE Demo” Project

Eco Recycling participated as SME to the HydroWEEE Demo project (2012-2017) “Innovative Hydrometallurgical Processes to recover Metals from WEEE including lamps and batteries - Demonstration” (Grant agreement n° 308549). This project was the continuation of the activity already co-financed by the EU financed within the FP7 calls (Seventh Framework Program of the EU). The processes previously developed for the recovery of base and precious metals from WEEE have been further optimized to increase the purity yield of the recovered metals (cathode ray tubes, lamps, printed circuits, LCDs, batteries).

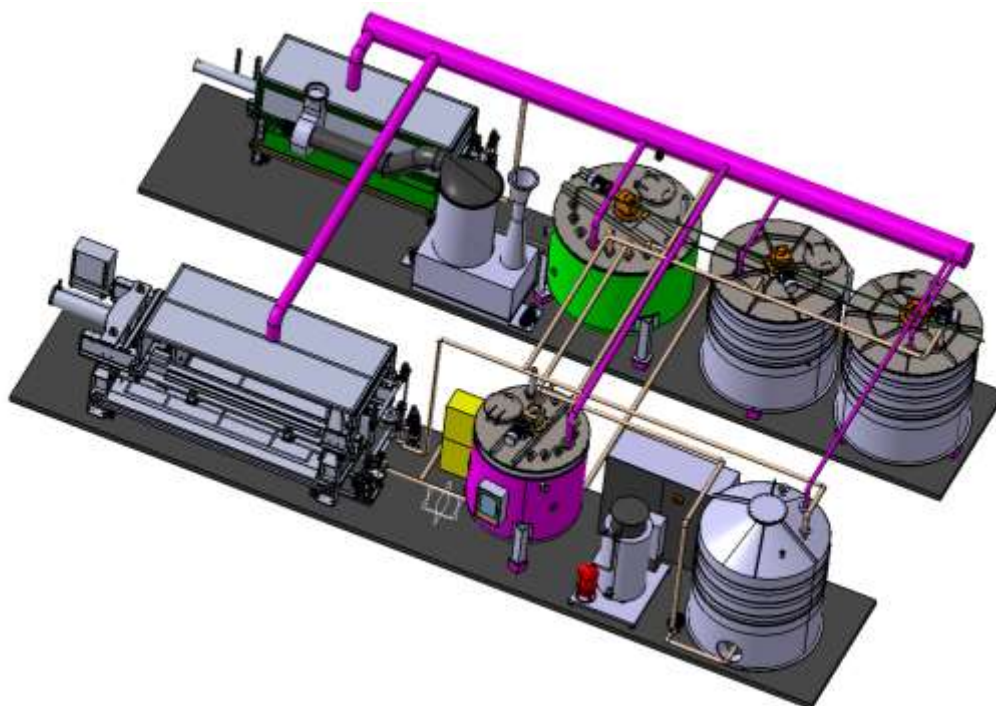
The main objective of the HydroWEEEDEMO project was to build two demonstration plants in an industrial scale: a fixed one installed at Relight s.r.l. in Rho (MI) (Fig. 2) and one mobile (Fig. 3) shared out in two containers have been installed at the industrial site of Eco Recycling s.r.l. (Civita Castellana, Viterbo). The project aimed at testing the processes already developed, to verify their performance and demonstrating feasibility from an integrated (technical, economic, operational,

social) point of view, also considering the risk assessment (including health) and the benefits for society and the environment, favoring then a wide diffusion on the market.

The demonstration objectives were successfully achieved when the fixed plant worked continuously for at least 18 months; in the same way, the mobile plant has been transported through at least 5 locations in at least 3 countries in Europe (Italy, Romania, Serbia).



*Fig. 4 Fixed plant under construction from Hydroweee Demo Project.*



*Fig. 5 3D design of the two containers mobile plant.*

### **3.11. “HydroWEEE” Project**

Eco Recycling participated as SME to the HYDROWEEE project (2008-2012): *“Innovative HYDROmetallurgical processes to recover metals from WEEE including lamps and batteries”* (Grant

agreement n° 231962) financed by the FP7 Calls in the contest of Research and Development (Call ID "FP7-SME-2008-1). The project aimed to develop innovative processes for the recovery of metal values present in WEEE (cathode ray tubes, LCD screens and circuit boards) fluorescent lamps, and Li-ion batteries.

In particular, Eco Recycling along with the HTR center (High Tech Recycling, Department of Chemistry of the "La Sapienza" University of Rome) was involved in the recovery of Co and Li from Li-ion batteries.

In the ambit of the activities of this project, Eco Recycling was responsible of the design and the construction of a new mobile pilot plant (Fig. 4) fully contained in a container loaded on trucks.

This mobile pilot plant was built comprising a chemical section and the unit operations necessary to treat all types of wastes addressed in the project (cathode ray tubes, LCD screens, circuit boards, fluorescent lamps and Li-ion batteries). Processes developed to treat the different waste categories (Li-ion batteries; fluorescent lamps; LCD; circuit boards) and the mobile pilot plant were registered as patents of which Eco Recycling is a co-owner.



**Fig. 6** Mobile plant from Hydroweee Project.

### 3.12. “O.RI.FO” National Project

O.RI.FO “*Optimization of a zero-waste treatment for the recycling of photovoltaic modules at the end of life*” is a project co-funded by the Ministry of the Environment and Protection of the Territory and the Sea within the “Call for the co-financing of research projects aimed at developing new technologies for the recovery, recycling and treatment of waste electrical and electronic equipment (WEEE)”.

It was born after a project co-funded by the EU (PHOTOLIFE, Life+ project) during this project a process for the treatment of photovoltaic modules at the end of life was developed and a prototype-scale plant was built.

During the O.RI.FO project, a new physical treatment unit will be designed, realized and tested for the treating of the fine fraction of the glass and will realized an experimental campaign to increase the recovery of the plastics; the purpose of this project is carry out a drafting of a complete business plan suitable for a full scale plant construction.

Within the Photolife project, the fine fraction of the glass has been treated using chemical processes. In the present project an alternative treatment is proposed: a physical treatment realized through an iron separation unit and an eddy current system, this new prototype line will be used to clean the glass and separate it from metals, this alternative treatment will provide significant economic and environmental advantages.

In the following project another aspect concerning plastics and their final destination will be explored, the fractions of plastics soaked in solvent can be valorized by:

- 1) Chemical treatment
- 2) Heat treatment / gasification

In this regard, a large experimental laboratory campaign will be carried out by the HTR research center. The experimental campaign will also aim to perform tests to remove the solvent in order to allow the design of the solvent recovery unit indispensable on a full-scale plant.

The project involves three partners: HTR (Inter University research center), Eco Recycling and GA Energy; will have a duration of 24 months, starting from 01/03/2018.

### 3.13. “HYRPAM” National Project

Eco Recycling (in collaboration with other partners, project leader: KT KINETICS TECHNOLOGY SPA) participated at the HYRPAM project (2014-2015). It was a project co-funded by the European Commission within the PFOR calls (Operational Program of the Lazio Region European Funds) and aimed at the development and optimization of a hydrometallurgical process aimed at recovering both the support and precious metals present in the membranes based on Palladio/Silver. This process was developed following a technical-economic evaluation of the entire life cycle of the same membranes and a pilot scale plant was realized (Fig. 5).

The results obtained from this project were the following:

- Development of a process for the treatment and enhancement of membranes at the end of life;
- The design and construction of a pilot plant suitable for treatment.

A patent was registered for the process of recovery and recycling of materials that make up the membranes for hydrogen separation (102015000039958).



*Fig. 7 Hyrpam's prototype.*

### **3.14. "NANOHYDRO" National Project**

Eco Recycling (in collaboration with Nova Systems Roma s.r.l.) participated in one Italian national project financed by Filas: "Nanohydro"(2012-2014). The aim of this project was the development of a process for the production, through electrochemical techniques, of nano metal materials based on Copper and Cobalt starting from leaches from the hydrometallurgical treatment of special waste such as WEEE and / or batteries. The main aims of the project were the identification of the operating conditions for the production of materials in a structured nano form, the scale-up of the process and the realization of a suitable pilot experimental system with advanced monitoring systems for the control of process parameters. To implement an efficient data analysis monitoring, a specific on-line survey system has been integrated to improve the expected objectives. This system consisted of both HW components for data collection and collection, as well as software for processing and analysis. The system has provided the possibility to automate the phases of control and management of complex electrochemical processes in full scale. In recent years the nano materials market has undergone strong expansion due to the interest of pharmaceutical industries, catalyst producers and technology companies.

The potential associated with the innovative project has been significant, both from an environmental and economic point of view, due to the production of high added value materials (Co and Cu structured nano) from waste. The structured nano-metallic cobalt can in fact be used in digital recording devices and in electromechanical microsystems (MEMS). The nano metallic cobalt particles are also used for the manufacture of high mechanical strength materials such as tungsten carbide of industrial mills and shredders. As far as metallic cobalt is concerned, it is also a catalyst widely used by oil companies; more generally, the structured nano can be used, with better performances, in all the applications in which its analogous micro structured is used.

A similar argument is associated with the production of nano-structured copper, a material that can be widely used wherever formidable conductive capacities are required, from printed circuits to the latest generation photovoltaic modules.

### **3.15. “Tecnotiberis” National Project**

Eco Recycling in collaboration with the HTR center (High Tech Recycling, Department of Chemistry of the "La Sapienza" University of Rome) participated in a technology transfer project co-financed by Regione Lazio and named Photorec (2010-2012), for the development of an innovative process to treat the end-of-life photovoltaic panels. This process has been developed on experience gained by researchers and technicians on studying of hydrometallurgical techniques (leaching, precipitation and recovery through electrolysis or calcination) and mechanical, physical, chemical operations, to obtain the PVP materials recovery. This recovery is possible through a series of operations (grinding, sieving, magnetic separation, eddy current separation, gravimetric separation) that prepare the feed for hydrometallurgical section and allow the physical separation of valuable materials. The most important aspect of innovative hydrometallurgical process was the dissolution of III and IV periodic system groups' oxide by acid or basic leaching, and the electrolytic recovery of Ga, In, Te. As an alternative to electrolytic process, the metals are recovered in the form of oxide, through precipitation or calcination.

A series of laboratory scale tests and the process simulations have been done to assess the recovery way cheaper than between the possible ones (electrochemistry or precipitation).

A patent was registered for the process for the treating of spent photovoltaic panels (WO2014184816 A1).

### **3.16. “Green Batteries” National Project**

Research Team of Professor Toro (University of Rome “La Sapienza”) and Prof. Vegliò (University of L’Aquila) working from 1980 in the field of hydrometallurgical treatment of ores to recover metals, redirected more recently (2000) their activities towards wastes as secondary raw materials. In the ambit of Green Batteries project, the team developed a hydrometallurgical process to separate zinc and manganese from spent alkaline batteries (wastes as source of metals). The process is conceived as “zero-waste” because a waste is treated to obtain new products recovering all the materials with potential application and using environmentally friendly conditions and chemicals. Both the process and the system to realize it are protected by a European patent (EP1684369 A1).

The MIUR (Italian Ministry of Education, University and Research) financed Eco Recycling to design and realize a demonstration pilot plant (Fig. 6) to recover zinc and manganese batteries. Based on Pilot activities a plant with large potentiality (4000 t/y) has been designed by Eco Recycling and is now operating at S.E.Val s.r.l. of Colico (LC). The pilot plant is now used for the validation of different process of treatment of other WEEE.

A patent was registered for the process and the plant for the treatment of all the kinds of batteries and accumulators excluding alkaline batteries and Lead accumulators (EP 2450991 A1).



*Fig. 8 Pilot plant for alkaline cells.*

## 4. Private contracts

The company S.E.val. srl commissioned Eco Recycling srl to design and build a full-scale plant for the treatment of Zn-Mn batteries.

S.E.val.srl is an Italian company involved in the overhead power line construction and maintenance. Its Ecology Division, with the specific objective of operating in the field of disposal, is focused on treatment and recovery of WEEE.

The company expressed interest in the process developed by Eco Recycling and commissioned company to carry out the engineering of a full-scale plant (4000 t/y).

DANIELI CENTRO RECYCLING commissioned Eco Recycling srl to provide technical support for the creation of various offers for end-of-life car battery treatment plants.

Danieli Centro Recycling is the division of the company DANIELI SpA, specialized in the design and construction of advanced technological recycling plants, with the aim of giving added value to waste and focusing on the needs and requirements to aim for zero environmental impact.

The company requested technical support from Eco Recycling for the realization of various offers to customers such as TESLA and AUDI for the construction of industrial plants for the recycling of lithium batteries deriving from the automotive sector.

It signed a contract with an English company for the construction of a plant for the treatment of lithium-based batteries.

It has agreements for the marketing of plants and prototypes in India.

It has projects with Morocco on strategic topics: recovery of metallic values and rare earth from residues from phosphoric acid processing and mining waste.

Negotiations are currently underway with a big player in the field of environmental protection for the realization by Eco Recycling of the basic and detailed design of a full-scale plant for the treatment of end-of-life panels.

## 5. PATENTS

<b>Title</b>	<b>N° patent</b>	<b>Type of waste</b>	<b>Recovered materials</b>
<i>PROCESS AND PLANT FOR THE TREATMENT OF RUN-DOWN BATTERIES</i>	<i>EP1684369 (A1)</i>	<i>Alkaline Zinc-Manganese batteries</i> 	<i>Manganese and zinc</i>
<i>PLANT AND PROCESS FOR THE TREATMENT OF EXHAUSTED ACCUMULATORS AND BATTERIES</i>	<i>EP2450991 (A1)</i>	<i>Li (0), Li-ion and NiMH batteries</i> 	<i>Lithium, cobalt, manganese, nickel and rare earths</i>
<i>PROCESS FOR TREATING SPENT PHOTOVOLTAIC PANELS</i>	<i>EP2997169A1</i>	<i>Photovoltaic panels</i> 	<i>Glass, aluminium and plastics</i>
<i>RECUPERO DI PLASTICHE E VETRO DAI PANNELLI FOTOVOLTAICI A FINE VITA (PCT phase, registered on 09/12/2020)</i>	<i>N. 102020000030176</i>		<i>Focalizzato sul recupero delle plastiche per un processo zero Waste</i>
<i>PROCESS FOR RECOVERY AND RECYCLING OF MATERIALS CONSTITUTING MEMBRANES FOR SEPARATION OF HYDROGEN</i>	<i>PCT/IB2016/054546</i>	<i>Pd / Ag membranes</i> 	<i>Metallic support and silver</i>



## 6. NEW ECO RECYCLING PILOT-OPERATIVE SITE

Eco Recycling has built an equipped platform in which all the pilot plants constructed during these years are hosted. The platform will be fully operational at the end of 2019 (obtaining all environmental permit) and will become a suitable site for testing different hydrometallurgical recycling processes.



## **Eco Recycling srl**

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