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LIFE17 ENV/ES/000216

LAYMAN'S REPORT

BIOLEACHING OF WEEE WASTES FOR THE RECOVERY OF VALUABLE METALS

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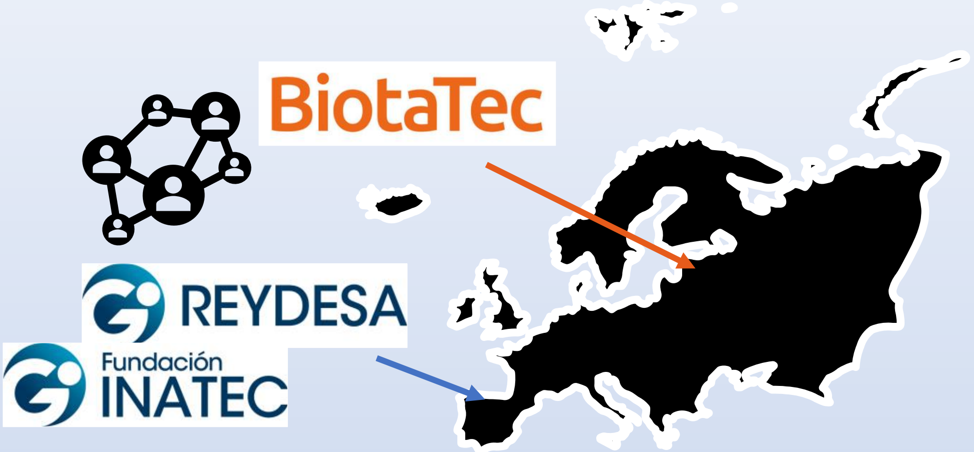

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Project Duration 01/07/18 31/07/22	Total Budget 932,377 €
Total Elegible Budget 907,377 €	EU contribution 60%

LIFE BIOTAWEE is a project co-financed by the European Commission through the LIFE Programme

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LIFE BIOTAWEE Project - an overview

Abbreviations:

Printed Circuit Board: PCB
Electric and electronic Equipment: EEE
Waste electric and electronic Equipment: WEEE
Non-metallic fraction: NMF
Copper: Cu
Gold: Au

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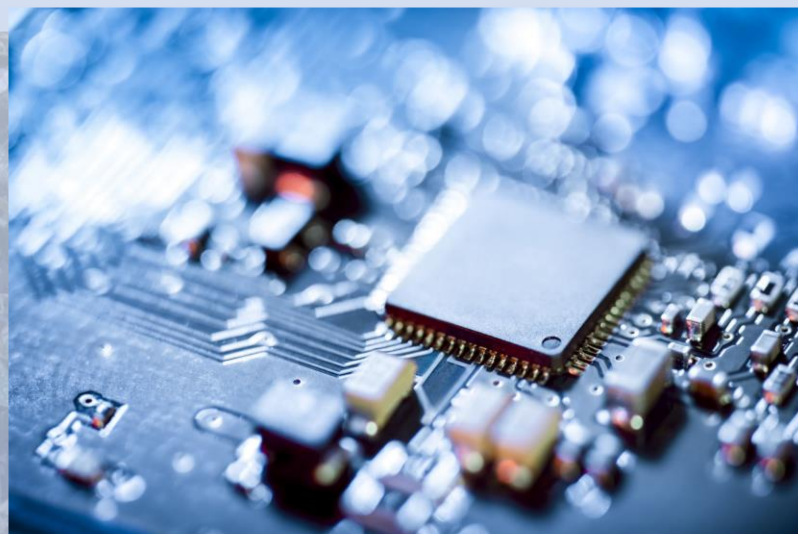
Summary of the project scope

Recovery of valuable metals from the NMF of PCBs from WEEE by the application of an innovative 2-step bioleaching technology

29	Cu	63.54
79	Au	196.97
47	Ag	107.87



Objectives

- Increasing recovery degree of PCB of WEEE contributing also to reduce European dependence of some high-valued metals with very low EU supply (mainly Au but also Cu and Ag).
- Promoting de use of biotechnology in the recycling processes of PCB of WEEE, contributing to make recycling sector a "bio-based industry".
- Reducing the processing cost, CO_2 and waste generation respect to hydrometallurgical process.
- Evaluate the technological and economic possibilities in widening the usage of the innovative technology on other complex wastes in order to reduce the processing cost (e.g. ELV or batteries).
- Ensuring the efficient communication and dissemination of LIFE BIOTAWEE project activities and results to the general public and relevant stakeholders at European level.

Non-metallic fraction of Printed Circuit Boards of WEEE

PCBs can be found in any piece of EEE: nearly all electronic items, including computers, calculators and remote-control units, contain large circuit boards; an increasing number of white goods, as washing machines contains circuit boards for example in electronic timers.

PCBs contain metals, polymers, ceramics and are manufactured by sophisticated technologies.

The main metals in PCBs are copper used as an electric current conductor (paths on laminate and parts of electric connectors and electronic elements), and tin used in solder for connections between elements and tracks on the board. The precious metals are also found in PCBs, mostly in electronic ones. The silver is mainly used in solder and contacts, whereas gold is in electronic components and is a protective later on contacts. Also, palladium is being used in contacts and multilayer ceramic capacitors.

In PCB waste management practice, the PCB waste is categorized into three groups based on precious metals concentrations:

Grade	Description	EEE Product
Grade 1/A/High	Generally, these will contain processors, semiconductors, gold pins and connectors containing precious metals which can be recovered	IT base units, hard drives & laptops, Display screen equipment, including flexible PCBs
Grade 2/B/Medium	Whilst not as valuable as Grade 1 type boards, these will still contain some semiconductors, gold pins and connectors containing precious metals which can be recovered	IT equipment, set top boxes, Display screen equipment, Small mixed WEEE
Grade 3/C/Low	These will generally only contain little, if any precious metals and are mostly valuable for their copper content	Small mixed WEEE, CRT TVs, Large domestic appliances

Disposal of PCBs in landfill is no longer accepted in developed countries because of environmental impact and loss of resources. So far, recycling of waste PCBs is an important subject in terms of potential recovering of valuable products. However, several difficulties still exist due to environmental problems involved in the end-of life of WEEE management. Due to its complex composition, PCBs recycling requires a multidisciplinary approach intended to valorised metals and plastic fractions and reduce environmental pollution.

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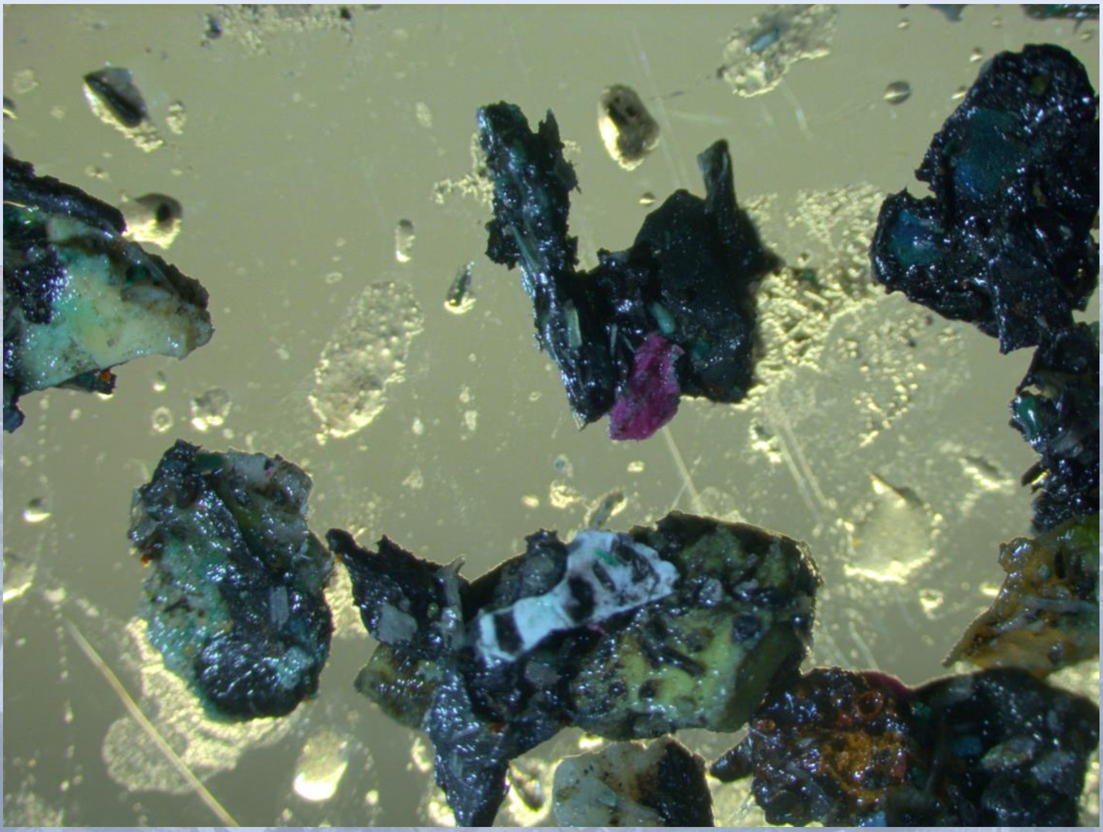
Bioleaching (or Biomining) technology



Bioleaching or biomining is the technique of extracting metals from ores and other solid materials typically using micro-organisms (bacteria, archae, fungi or plants).

Uses direct metabolism or byproducts of microbial processes to solubilize a metal sulfidic ore or waste into an aqueous solution, and it is used at commercial scale for the extraction of base and precious metals.

Anaerobic (ARGCON5) **In process of patentability by BIOTATEC**

Aerobic (At. ferroxidans) Cu extraction demonstrated

Aerobic (Ch. violaceum) Au extraction demonstrated

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LIFE BIOTAWEE process

Stage 1
- Mechanical treatment and separation step

Stage 2
- Aerobic Bioleaching with At. ferroxidans

Stage 3
- Aerobic Bioleaching with Ch. violaceum

Stage 4
- Cementation for metal extraction

LIFE BIOTAWEE intermediates

Stage 1
- Filter dust (metallic content)
- Impurities

Stage 2
- Leachate (Fe, Cu, Al)

Stage 3
- Leachate (Au, Ag)

LIFE BIOTAWEE products

Stage 1
- Cu concentrate
- Ferric

Stage 4
- Metallic concéntrate (>95% Cu)
- Metallic concéntrate (>95% Au)
- Al2O3
- FeO

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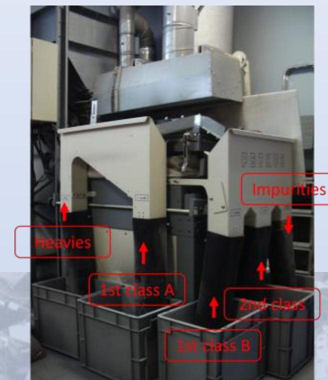
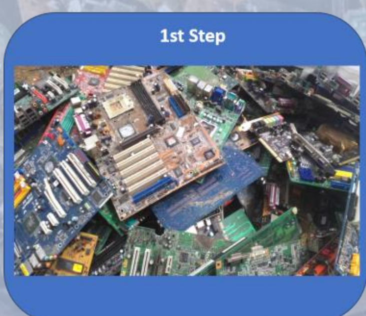
LIFE BIOTAWEE process

Stage 1: Mechanical treatment and separation step:







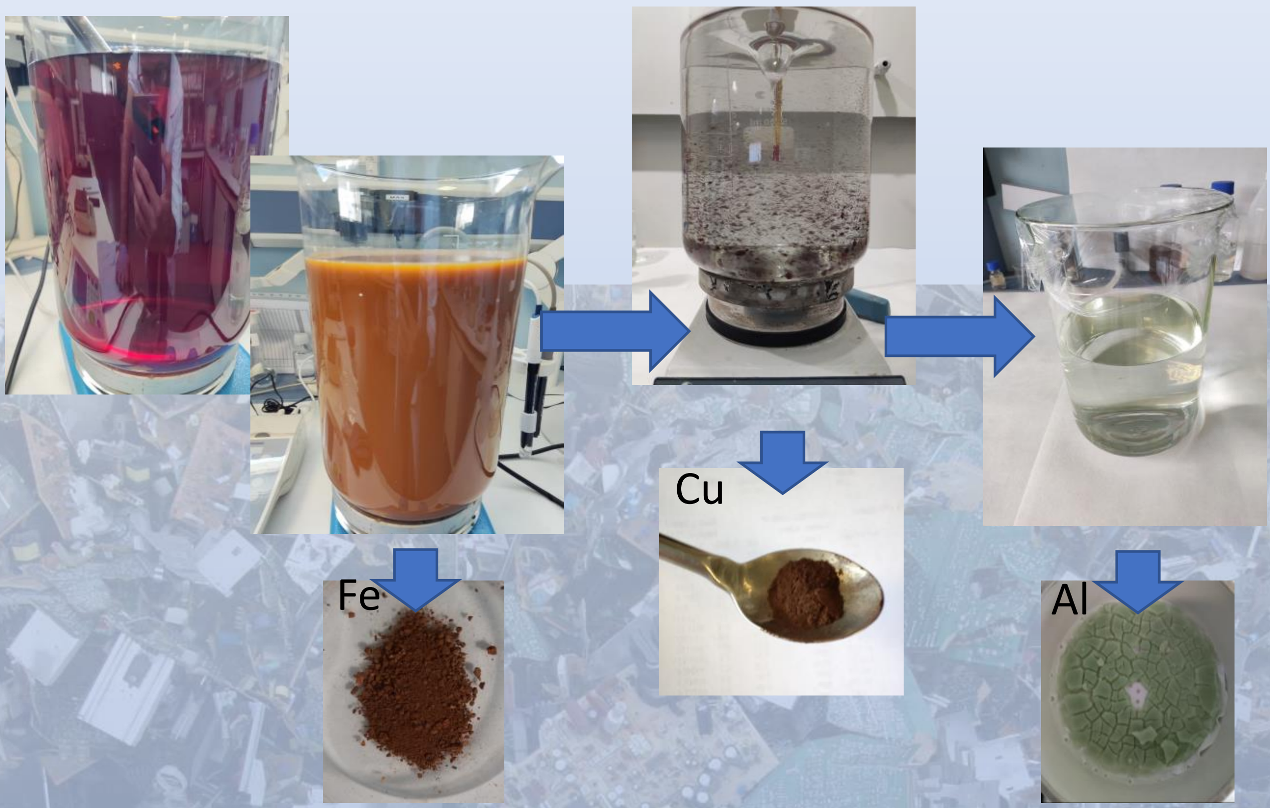
Stage 2 and 3: Aerobic Bioleaching with At. ferroxidans or Ch. violaceum

20 L reactor

50 L reactor

LIFE BIOTAWEE process

Stage 4: Cementation for metal extraction from stage 2:



Technical results achieved

The aerobic process performed in 50L pilot plant with At. ferroxidans, showed a **recovery of 86 - 95% Cu and 1-4% Ag**. Other metals contained in the waste in very low quantity have been also extracted with a recovery, around 76-88.5 % Al, 98% Zn or 53- 55% Ni.

Cyanogenic bioleaching with Chromobacterium violaceum culture in aerobic bioleaching was performed in 20L reactor obtaining a **gold extraction of 45** %

Reduce 38 % the processing cost of 2 aerobic step bioleachings compared to hydrometallurgical process.

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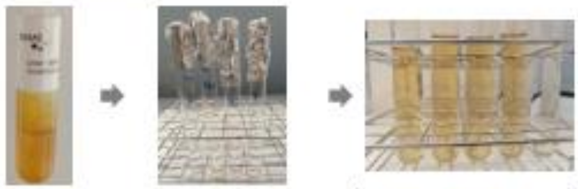
Scaling up the technology

Step 0

Microorganisms' reception

Inoculation in test tubes



(6 days in tests tubes)

Step 1

Without PCBs volume adaptation

(≈ 11 days)

Inoculation in 250 mL flasks

(5 days in 250 ml)

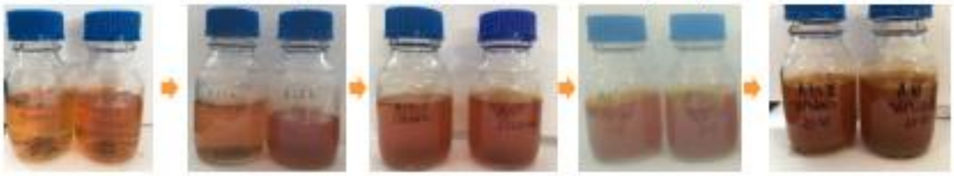
Step 2

With PCBs progressive adaptation

(≈ 63 days)

Adaptation to rejected fraction from PCB treatment previously cleaned

Step 3a	Step 3b	Step 3c	Step 3d	Step 3e
1.5 g PCB /L	2.5 g PCB /L	5 g PCB /L	7.5 g PCB/L	10 g PCB /L



Step 3a	Step 3b	Step 3c	Step 3d	Step 3e
(10 days)	(11 days)	(16 days)	(13 days)	(13 days)

Step 3

With PCBs increasing volume till 50 L

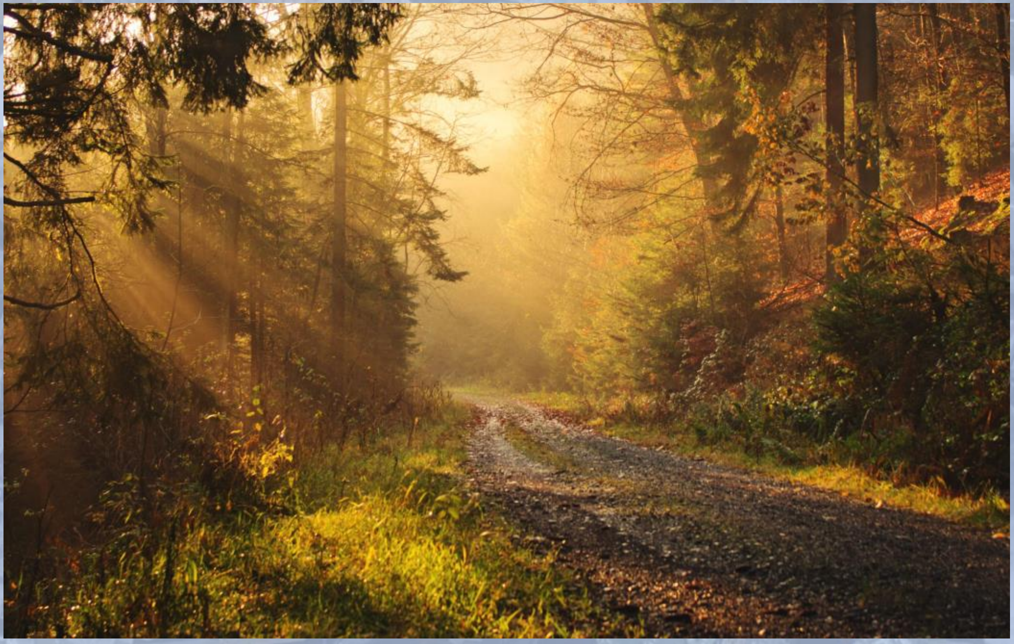
(≈ 55 days)

Adaptation to rejected fraction from PCB treatment previously cleaned

(25 days) → (20 days) → **Prepared for Test in 50 L**

Environmental impact of the project

- ✓ Avoid the incineration of almost 300 Tn/ year of PCB only from the REYDESA's process.
- ✓ Reduce the volume of unused fractions of PCB. From 1 Tn, 10 % is NMF (impurities) of PCB but there is also another NMF, the suction dust from the mechanical treatment which may be the 30 % of PCB.
- ✓ Reduction in hazardous effluents waste generation of 3.88 Tn/Tn PCB respect a complete hydrometallurgical process.
- ✓ LIFE BIOTAWEE process can reduce 42 % CO_2 eq. compared with the hydrometallurgical process
- ✓ Replicability: LIFE- BIOTAWEE process may treat the filter dust obtained from the mechanical treatment of other WEEE in REYDESA and in other companies of the recycling sector
- ✓ Promoting the use of biotechnology in the recycling process, contributing to make the recycling sector a "bio-based industry".
- ✓ Recovery per Tn of PCBs:
  - 182 Kg Cu
  - 0.24 Kg Ag
  - 0,021 Kg Au



Cost-effectiveness analysis

Is it feasible to process PCB in LIFE-BIOTAWEE process?

- PCB mixture used for the definition of LIFE-BIOTAWEE process is 20% Type1 + 80% Type3. Gold and Silver content is very low and platinum content is impossible to detect
- The high quantity of reagents necessary to carry out the bioleaching process and the long processing times entail a high cost and a low production capacity for a very high infrastructure investment

Processing this PCB mixture is not feasible in LIFE-BIOTAWEE process. But, in a Hydrometallurgy process?

- In Hydrometallurgical process, the investment cost is lower and the productive capacity is higher but the cost in reagents is much higher than in a bio-process
- The waste generated in a hydrometallurgy process is not reusable and more dangerous than the waste generated in a bio-process

When is LIFE-BIOTAWEE process to treat PCB economically feasible?

When the non-metallic fraction of PCB contains a **percentage of Cu greater than 17%**

When the non-metallic fraction of PCB **contains Au greater than 50ppm**

Under these conditions, the return of capital to the company is achieve in 2,7 years from the third year in operation. At that time, the process generates an added value of 412k€ per year for the company

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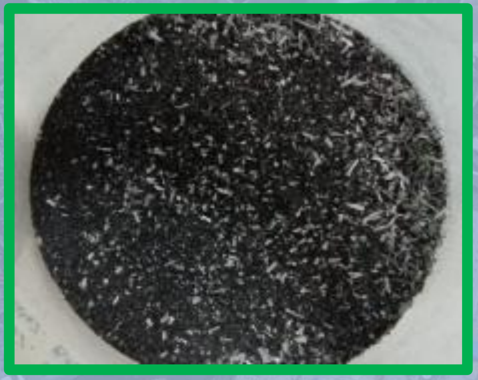
Replicability

Demonstration of a **2-step bioleaching technology (anaerobic + aerobic)** in the recovery process of valuable metals from the **filter dust** of a mechanical treatment. For this kind of waste, **biogas generation in the anaerobic step with 1% suspension of zig-zag dust in the 20 L reactor was confirmed (62% CH4 in gas phase)**

Also, aerobic bioleaching in the 50 L reactor was performed by At. ferroxidans. A extraction of 84% of iron, 88% of copper, and 48% of aluminium is possible for this waste. Conditions would need an optimization in order to improve results obtained, but in case of copper, the results are even better than the ones obtained for the NMF of PCB

Treatment of black-mass generated from mechanical treatment of the Lithium-ion batteries



Batteries extracted during WEEE decontamination and dismantling processes must be discharged and mechanically treated to release plastics and parts in a metallic state (aluminium, steel, copper…). After removing them to be recycled by more conventional methods, a sludgy mixture of lithium, manganese and cobalt is left behind in what is known as a "black mass".

Reydesa has opted to a new project where the main objective is to investigate, apply and validate a sustainable and innovative bioprocess to recover embedded Lithium with advanced and intelligent digitalization that, given its high value in the market, allows adding value to the entire chain in the bioleaching process for the recovery of lithium from the metal concentrate obtained from the mechanical treatment of LIBs from the LFP type (with LiFePO4 cathode), which is the future in the short/medium term in the battery manufacturing sector.

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