The processes to be carried on

- Recovery of rare earth elements (e.g. Eu, Tb, Y, Gd) from powder of CRTs and fluorescent lamps.
- Recovery of cobalt and lithium from powder of LIBs.
- Recovery of Indium from powder derived from LCDs.
- Recovery of high value metals (e.g. Au) from powder of PCBs.
Stationary vs. mobile

- **Stationary plant**
  - Fixed hydrometallurgical plant (installed at Relight srl in Rho (MI), Italy) originally designed to carry on the recovery of REE from lamps and CRT powders.
  - Possibility to extend plant operation to the treatment of LIBs, LCDs.

- **Mobile plant**
  - Hydrometallurgical plant entirely loaded on transportable containers carrying on the treatment of lamps, CRT, LCDs, LIBs.
  - Possibility to transport the plant to customers interested into processing and thus getting added value from the target WEEEs.

Conceptual plant design

- **Steps to be carried on**
  - *Leaching* of powders with acid
  - *Selective precipitation*
  - *Water treatment* by addition of calcium hydroxide
  - *Filtration* of solid suspensions from leaching
  - Removal of *acid vapours and dust* forming during plant operation.
### Main operation stages (Lamps process)

- **Reactants** ($H_2O$, $H_2SO_4$)
- **Solid waste**
- **Leaching** ($PH<1$, $T>70\,^\circ C$)
- **Solid-liquid suspension**
- **Filtration**
- **Filtrated liquid**
- **Selective precipitation**
- **Recovered product** (REE oxalates)
- **Filtration**
- **Filtrated liquid**
- **Oxalic acid**
- **to wastewater treatment**

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### Conceptual plant design

- **Selected process solutions**
  - Agitated chemical reactors for leaching, selective precipitation and water treatment.
  - Filter presses
  - Scrubber tower for purification of acid vapours
  - Filter for the abatement of dusts

- **Plant operation mode**
  - Batch operation was selected because of the possibility of large variations in characteristics and availability of powders.
  - Continuous mode would impose to frequently modify operating conditions to attain target yield and purity values.
Plant design - Optimization

- **Stationary plant**
  
  **Operational context:** reduced space limits to the possibility of installing plant equipment
  
  **Objective:** Maximizing the net economic income (accounting for costs of operation and equipment)
  
  **Constraints:** fitting the available budget.

- **Mobile plant**
  
  **Operational context:** severe space limits imposed by the need to load the entire plant to commercial containers
  
  **Objective:** Maximizing the net economic income (accounting for costs of operation and equipment)
  
  **Constraints:** Ensuring the possibility of *loading the plant on two containers* and fitting the prescribed budget.

Design procedure - Stationary plant

- **Input data**
  
  - Mass and energy balances
  
  - Kinetic data
  
  - Tendering - Information from suppliers

- **Optimization**
  
  - Admissible plant structure (number of units)
  
  - Optimal operating strategy (max n.batches/day)

- **Detailed design**
  
  - Detailed design (max processing capacity fitting available budget)

- **Economic balance**
Stationary plant P&I diagram

Stationary plant – 3D
Mobile plant - Equipment specifications

- **Specifications of main equipment could be fixed by the solution of the following problem:**
  - Maximizing plant productivity with the largest admissible container size (and with the available budget, of course!).

- **Maximum admissible container size not requiring “special transport”**

  L=13.716 m
  H=3.140 m
  W=2.55 m
Mobile plant – Design procedure

- Input data:
  - Mass and energy balances
  - Kinetic data
  - Information from suppliers

- Optimization:
  - Admissible plant structure
  - Optimal operating strategy (max n.batches/day)
  - Preliminary design (max processing fitting available space)
  - Detailed design
  - Checking for available space (Yes/Not)
  - Economic balance

Mobile plant design

- **Main plant units:**
  - 1 Reactor unit for powder leaching
  - 1 Filter press for filtration of leaching suspension
  - 1 Reactor section for selective precipitation.
  - 1 Filter press for separation of the desired product (e.g. REE oxalates for lamps process).
  - 1 Reactor section for waste-water treatment.

- **Additional equipments required for plant operation:**
  - 1 Scrubber for abatement of acid gas emissions
  - 1 Compressor for generation of high pressure air required for pneumatic actuators.
  - 1 Boiler for the generation of hot water.
Mobile Plant - P&I diagram

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Mobile plant layout – Container 1

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Mobile plant layout – Container 2

Mobile plant – 3D
Main equipment description

• Jacketed leaching reactor – R1 (n. of items 1)
  Volume: 4.5 m³.
  Material: steel internally covered with halar to ensure resistance to large temperature and acidic PH values.
  Weight: 3500 kg.
  Power agitation motor: 4 kW

Main equipment description

• Jacketed precipitation reactor – R2 (n. of items 1)
  Volume: 6 m³.
  Material: steel internally covered with ebanite to ensure resistance to large temperature and acidic PH values;
  Weight: 5000 kg.
  Power agitation motor: 7 kW
Main equipment description

- **Reactor for waste water treatment – R3 (n. of items 2)**
  
  **Volume:** 6 m³
  
  **Material:** polipropilene
  
  **Weight:** 1000 kg.
  
  **Power agitation motor:** 4 kW.

- **Filter press – FP1 (n. of items 1)**
  
  **Amount of sludge filtered per cycle:** 3200 l with 10 % dry solid content.
  
  **Cycle working time:** 1 hour
  
  **Material:** polypropylene plates
  
  **Filter press weight:** 6000 kg
Main equipment description

- **Filter press – FP2 (n. of items 1)**
  Amount of sludge filtered per cycle: 3800 l with 2 % dry solid content.
  Cycle working time: 1 hour
  Material: polypropylene plates
  Filter press weight: 1700 kg

Structuring containers

- Realization of structures allowing for the distribution of concentrated weights.
- Construction of a system enabling the introduction and placement of main equipment inside the container.
- Realization of additional lateral entrances allowing personnel to reach any point of the plant.
- Realization of holes for the passage of pipes, gas collectors and removal of minor equipment in case of damage.
**Structuring containers**

Man holes giving access to the back of the container

External structures enforcing stability

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**Structuring containers**

Structures for the distribution of weights

Internal beams enforcing stability

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**Structuring containers**

- Insulating panels
- Crane
- Tracks

**Mobile plant**
Mobile plant

Mobile plant

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Mobile plant

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Mobile plant

Stationary plant was constructed and is currently being operated to recover rare earth elements from lamps and CRTs. Performed tests demonstrated technical feasibility of processes for recovery of rare earth elements from lamps and CRTs.

Mobile plant was designed and constructed to simultaneously accommodate performance requirements imposed by four different hydrometallurgical processes. The plant is currently in Romania.

Conclusions