



# PhD in INGEGNERIA DEI MATERIALI / MATERIALS ENGINEERING - 39th cycle

**PNRR 117 Research Field: WASTE OF ELECTRIC AND ELECTRONIC EQUIPMENTS AS  
OPPORTUNITY: RECOVERY OF PRECIOUS METALS (PM) AND CRITICAL RAW  
MATERIALS (CRM) (WE-REC)**

**Monthly net income of PhDscholarship (max 36 months)**

**€ 1400.0**

In case of a change of the welfare rates during the three-year period, the amount could be modified.

## Context of the research activity

**Motivation and objectives of the research  
in this field**

Pressure on resources will increase, due to increasing global population, industrialization, digitalisation, increasing demand from developing Countries and the transition to climate neutrality and raw materials required in low-emission technologies and products. OECD forecasts global materials demand will more than double from 79 billion tonnes today to 167 billion tonnes in 2060. Global competition for resources will become fierce in the coming decade. Dependence of critical raw materials may soon replace today's dependence on oil. They are essential for products in strategic areas such as renewable energy, digital, aerospace and defence technologies. Well-known examples are rare earths elements found in the permanent magnets used to manufacture wind turbines motors, lithium used for batteries, and silicon used for semiconductors. In 2020, 10.5 kg of electrical and electronic equipment waste were collected per inhabitant in the EU. Moreover, annual waste generation is projected to increase by 70% by 2050, while half of total greenhouse gas emissions and more than 90% of biodiversity loss and water stress come from resource extraction and processing. In the coming decade, there is a need to accelerate the transition towards a regenerative growth model where the Planet resource consumption are within planetary boundaries, This progressive, yet irreversible transition to a sustainable economic system is part of a new industrial



	<p>strategy to reduce waste and ensure a well-functioning internal market for high quality secondary raw materials. Therefore, scaling up the circular economy from front-runners to the mainstream economic players is a decisive action for EU. These challenges represent priority objectives for EU, aiming to achieve a "zero waste" regime, as outlined in the EU Raw Materials Initiative (EC/2008/699) directive. In this contest, Italian PNNR gives the roadmap to address this challenge, and the advancement of knowledge is considered essential to consolidate the strengths and overcome the weaknesses of the Italian innovation system. WE-REC purses the advancement of the technological development knowledge for new utilization, reuse, recycling of valuable materials, mainly metals, present in end of life electric and electronic equipments. Accordingly, the project can be placed in the Thematic Objectives (OT), OT3 "Mobilizing industry for a clean and circular economy" and OT8 "zero pollution for an environment free of toxic substances".</p>
<p><b>Methods and techniques that will be developed and used to carry out the research</b></p>	<p>In EU in 2020, 12.4 million tons of e-equipments were put on the market, while 10.5 kg of e-waste were collected per inhabitant. This huge amount of e-waste still contains a considerable amount of CRMs and PMs; thus, opening rooms for recovery and exploitation of the resources therein. Metal recovery from WEEE implies: disassembly, upgrading and refining, where hydrometallurgy (HM) can be applied for the last step. In case of HM, solid-liquid adsorption, using solid phases for metal recovery, shows many advantages such as: high efficiency, short time, high enrichment factor, low cost, and low or no consumption of organic solvents. However, sorbent solids have still open points for their in-fields application. Therefore, WE-REC activity, performed in close connection with OSAI, the Company supporting this PhD project, will be focused on the selection and study of solid sorbents suitable for metal ions removal from e-scrap, and their re-marketing as secondary raw materials. A bibliographic analysis on ongoing hydrometallurgical processes, their limitations and benefits, the analysis of the form of re-marketing of the extracted secondary RMs, and the identification of key players in the process will be</p>



	<p>first performed. Then, starting from already available materials, a selection of different solid matrixes will be done, and the study of their application in the metal recovery process will be performed to evaluate sorption capability and mechanisms. The optimization of the sorption experimental parameters will be considered to maximize both recovery efficiency and metal selectivity. In case of unsatisfactory results, proper sorbent modifications will be explored. Solid reusability and regenerating system will be also assessed. First simplified model solutions, then the more complex ones, coming from different e-scrapes will be tested for adsorption onto the studied materials. The replacing of the natural or commercial sorbents with materials in turn produced by waste will also be pursued. Asustainability analysis about the of the global process is also. As required for a such challenge research, a multidisciplinary approach is considered fundamental for success. Therefore, chemical analysis of the solutions and physico-chemical of the sorbents before and after the use are planned. Last but not the least for the industrial application, the possibility to shape the sorbent powders in a formed object (pellets, cartridge, foams, monoliths) will also be explored.</p>
<b>Educational objectives</b>	<ol style="list-style-type: none"> <li>1. Ability to manage projects in circular economy</li> <li>2. Skill in developing a sustainable Secondary Raw Materials supply chain</li> <li>3. Capability to support processes for innovation and technology transfer in new sectors</li> <li>4. Capability to foster Circular Communities development</li> <li>5. Capability to answer to environmental topics and challenges</li> </ol>
<b>Job opportunities</b>	<p>There is an increasing request of highly specialized technicians and professional figures in fields such as:</p> <ol style="list-style-type: none"> <li>1. Revalorization of End Of Life materials</li> <li>2. Secondary Raw Materials supply chain</li> <li>3. Environmental technologies</li> </ol>



<b>Composition of the research group</b>	1 Full Professors 2 Associated Professors 3 Assistant Professors 5 PhD Students
<b>Name of the research directors</b>	Prof.ssa C. Cristiani

<b>Contacts</b>
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<b>Additional support - Financial aid per PhD student per year (gross amount)</b>	
<b>Housing - Foreign Students</b>	--
<b>Housing - Out-of-town residents (more than 80Km out of Milano)</b>	--

<b>Scholarship Increase for a period abroad</b>	
<b>Amount monthly</b>	700.0 €
<b>By number of months</b>	6

<b>National Operational Program for Research and Innovation</b>	
<b>Company where the candidate will attend the stage (name and brief description)</b>	OSAI AUTOMATION SYSTEM SOCIETA BENEFIT VIA CARTIERA 4, 10010 PARELLA (TO) <a href="http://www.osai-as.com">www.osai-as.com</a>
<b>By number of months at the company</b>	6
<b>Institution or company where the candidate will spend the period abroad (name and brief description)</b>	Witold Kurylak, &#321;ukaszewicz Research Network-Institute of Non-Ferrous Metals, Gliwice, Poland e-mail: <a href="mailto:imn@imn.gliwice.pl">imn@imn.gliwice.pl</a>
<b>By number of months abroad</b>	6

**Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information**

**Confidentiality Agreement with company:** since this is a thematic scholarship, Confidential Information, Results and their publication is subordinate to the restrictions agreed upon with the funding company. Upon acceptance of the scholarship, the beneficiary must sign a specific commitment.

**Individual budget for research:** 1. year: 1.900 euro; 2. year: 1.900 euro; 3. year: 1.900 euro  
**Teaching assistantship, availability of funding in recognition of supporting teaching activities:** there are various forms of financial for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities within the limits allowed by the regulation. Hewill operate under the supervision, but in autonomy, of the academic research director and the research director of OSAI, the Company involved in the project. Materials for Energy and Environment (MAT4En2) group has a long experience in training PhD researchers. Its laboratories host undergraduate and graduate students, carrying out research work for their



thesis, as well as postdoctoral fellows from abroad, participating in research programs funded by the UE and by other international agencies. The group cooperates with Italian and foreign universities and research centers. For the duration time of the PhD, the student will be trained to make him to develop decisional and coordinating capacities on research approach, time compliance, capacity to quickly answer to changes if required. He will be encouraged to submit results to the scientific community with presentation of the research in both National and International meetings, and publications in International peer-reviewed and open-access journals. At the best of his/her experience, he actively will contribute to communication/dissemination actions; therefore, he will attend local meetings, for training in the presentation of news of scientific character to learn the professional attitude for divulging scientific concepts to a large audience. The direct experience of dissemination with the not-peered social communities will constitute a valuable training in communication science and environmental problems at a not-academic level. He will be asked to collaborate and participate to financed projects to develop decisional and coordinating capacities regarding, for instance, research approach, time compliance, capacity to answer to changes required by feedback from the experimental results. The PhD student will coordinate the work of 1-2 level degree students to be trained to work in team and to be a team leader as required in a future employment. The PhD student will be involved in relation with Companies. At the end of the carrier he should be a deeply trained researcher with a strong scientific background, able to interact with both Academia and Industry. These are capacity required to managers of high quality and high-tech enterprises.