



PhD in SCIENZE E TECNOLOGIE ENERGETICHE E NUCLEARI / ENERGY AND NUCLEAR SCIENCE AND TECHNOLOGY - 39th cycle

THEMATIC Research Field: COMPARATIVE ANALYSIS OF DECARBONIZATION OPTIONS FOR ENERGY-INTENSIVE INDUSTRIES

Monthly net income of PhDscholarship (max 36 months)

€ 1500.0

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

Medium-scale energy-intensive industry such as paper, ceramic, glass, food, metals manufacturing will be required to reduce CO₂ emissions in the transition to net-zero emission economy. Different options are available for this class of industries, including direct electrification, hydrogen, and CO₂ capture, with different technical and economic implications. The overall objective of this PhD project is the comparative analysis among the different options for the reduction of CO₂ emission from energy-intensive industries and the understanding of the techno-economic trade-offs related to the geographic location (e.g., availability of solar and wind energy) and to the access to proper infrastructures (e.g., hydrogen transport, CO₂ transport, ...). The project will be developed through the following work packages (WPs)

- WP1 (months 1-18): Definition of the mass and energy balances of energy-intensive industrial processes (paper, ceramic, glass, food, metals) through simulation software (Aspen Plus). Comparative analysis of conventional processes based on fossil fuels and novel low-carbon processes based on heat pumps, electric heating, hydrogen, and CO₂ capture. Development of models for economic analysis and techno-economic comparative analysis.
- WP2 (months 18-30): Development of models for the



	calculation of balances of electrified plant configurations through year-long simulations with hourly resolution. Optimization of the size of the systems for energy and material storage, possibly exploiting energy storage opportunities embedded in the industrial process (e.g., storage of steam or other high-temperature fluids) and flexibility opportunities in response to the variability of renewable electricity supply. •WP3 (months 24-36): Identification of the best options for the decarbonization of industrial clusters, where hydrogen and/or CO₂ transport and storage infrastructures may be shared, through the analysis of case studies in southern and northern Europe.
Methods and techniques that will be developed and used to carry out the research	The research program requires the use of the following computational tools: •Aspen Plus software, for the calculation of mass and energy balances of state-of-the art industrial processes and of their possible future low-carbon variants. •Optimization software (e.g., using Matlab, Python, or GAMS) for the year-long assessment of industrial plants integrated with intermittent renewable energy supply.
Educational objectives	The PhD candidate will: • Become expert of energy-intensive industrial processes such as paper, ceramic, glass, food, metals manufacturing. • Become expert in critically analysing the performance of energy conversion processes from energy, environmental, and economic points of view. • Acquire specific modelling experience on the optimization of energy systems dominated by intermittent renewables. • Become proficient user of software for process simulations (Aspen Plus) and for optimization (Matlab, GAMS).



Job opportunities	Apart from academia and research institutes, the main expected job opportunities after the PhD will be in consultancy and in industry (both technology providers and end users), which in the next decade will implement innovative processes and technologies to reduce their carbon footprint.
Composition of the research group	5 Full Professors 7 Associated Professors 7 Assistant Professors 40 PhD Students
Name of the research directors	Matteo Carmelo Romano, Paolo Colbertaldo

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

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Educational activities: Financial aid per PhD student is available for purchase of study books and material, funding for participation in courses, summer schools, workshops and conferences, instrumentations and computer, etc. This amount is equal to 10% of the annual gross amount, for 3 years. Teaching assistantship: Availability of funding in recognition of supporting teaching activities by the PhD student. There are various forms of financial aid 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 regulations. Computer availability: individual use. Desk availability: individual use. Awards: Awards will be recognized to the PhD candidate up to Euro 4000 (gross amount) per year, in case of exceptional achievements in the research project, subject to the evaluation of the



research director.