Ph.D. in Physical and Engineering Sciences for Innovation and sustainability

Design of the PhD Course

Summary

1 Premise

The Ph.D. aims to promote the preparation of professionals capable of being a fulcrum of innovation for industry and society, of contributing to the development of new knowledge, of managing original research and development projects, autonomously carrying out programs of strategic importance. To achieve this goal, the course promotes and supports a strong integration between basic and applied research with a high degree of interdisciplinarity, with particular attention to both the production realities active in this sector (see the various collaborations in the various research projects of the members of the board such as the Marie Tecnimont group, coordinator of the AIRE project, the companies SOLIDpower, Walter Tosto, HyGear partner of the BLAZE project, the companies ICI Caldaie, Calida Technologies, Marion Technologies partner of the GICO project, the companies SNAM and Rampini partners of the LIFE3H project, etc.) and towards the search for possible spin-offs that can be developed within the PhD itself, thus creating new production realities that do not currently exist (using not only the Marconi laboratory, as the operational structure of this PhD, but also the Marconi centers (e.g. Innovation Hub, CERITED "Research Center for Ecological and Digital Transition", CARe "Center for Automotive Research and evolution") and the structures of other bodies with which USGM or directly the DSI have agreements). This multidisciplinary approach is conceived as an inevitable integration and synergy between engineering, design, energy and IT skills with those of a physical and mathematical nature and those of civil engineering and architecture, in order to promote a path capable of training people who are as self-sufficient as possible, both in the use of tools and methods for research, and in the ability to transfer these high skills in the field of business innovation.

2 Learning objectives

The Ph.D. in PHYSICAL AND ENGINEERING SCIENCES FOR INNOVATION AND SUSTAINABILITY aims to to promote the preparation of researchers and professionals capable of being a fulcrum of innovation for industry and society, of contributing to the development of new knowledge, of managing original research and development projects, autonomously carrying out programmes of strategic importance. To achieve this goal, the Course promotes and supports a strong integration between basic and applied research with a high degree of interdisciplinarity, with particular attention to both the production realities active in this sector (see the various collaborations in the various research projects of the members of the board such as the Maire Tecnimont group, coordinator of the AIRE project, the companies SOLIDpower, Walter Tosto, ENERECO and HyGear partners of the BLAZE project, the companies ICI Caldaie, Calida Technologies, Marion Technologies partners of the GICO project, the companies SNAM and Rampini partners of the LIFE3H project, etc.) and towards research by means of possible spin-offs that can be developed within the scope of the PhD itself, thus creating new production realities that do not currently exist (using not only the Marconi laboratory, as the operational structure of this PhD, but also the recent Marconi Innovation Hub and CERITED - Center for Ecological and Digital Transition and the structures of other bodies with which USGM or directly the Department of Engineering Sciences have already agreements). This multidisciplinarity is conceived as an inevitable integration and synergy between engineering, design, energy and IT skills with those of a physical and mathematical nature and those of civil engineering and architecture, in order to promote a path capable of training self-sufficient people, both in the use of tools and methods for research, and in the ability to transfer these high skills in the field of business innovation.

In particular, the PhD aims to be the tool for the advanced training of professionals able to move within the future technological scenarios in the various contexts (Systems for energy and the environment; Environmental Technical Physics; fluid machines; Mechanical and Thermal Measurements; Mechanical Design and Machine Construction; Telecommunications; Information Processing Systems; Geotechnics; Construction Techniques; Urban Planning and Technology; Experimental Physics; Mathematical Physics; Mathematical Analysis) with a multidisciplinary preparation able to manage from all points of view a technologically advanced industrial and service production, where product and process innovation is achieved in an integrated way also with the territory and the environment, with big data management and with a careful look at sustainability and basic science, engine of innovation. Furthermore, knowledge of product development methodologies, management and analysis of processes, materials, energy systems for the production, storage and use of energy, including advanced mobility systems, will facilitate the implementation of advanced engineering approaches required by the labor market today. The territory and urban transformations (including the regeneration of existing ones) will be the right context of reference. All this explains the innovative potential in terms of patent possibilities associated with this activity and the personal growth of the eventual winner of this doctorate.

3 Areas of research

The Ph.D. in PHYSICAL AND ENGINEERING SCIENCES FOR INNOVATION AND SUSTAINABILITY carries out of higher education and scientific research related to 3 areas: INDUSTRIAL AND INFORMATION ENGINEERING, CIVIL ENGINEERING AND ARCHITECTURE and PHYSICAL AND MATHEMATICAL SCIENCES which

They involve the following scientific fields: Energy, Thermomechanical and Nuclear Engineering, Mechanical, Aerospace and Naval Engineering, Electrical Engineering, Electronics and Measurements, Telecommunications Engineering and Electromagnetic Fields, Physics and Mathematics, Urban and Territorial Planning and Design, Structural and Geotechnical Engineering. In fact, research in industrial and information engineering requires more and more advanced skills in physical and mathematical sciences and, as far as the application in the territory is concerned, in Civil Engineering and Architecture. An example of this is the research on the development and integration of renewable energy systems, hydrogen and fuel cells, measurement, control, automation and management systems, advanced geotechnical and structural analysis, urban and landscape analyses and in general the planning/design/management of innovative and sustainable systems, which can be found in the publications, projects, patents and awards of the members of the PhD board and in the related activities carried out by the Department of Engineering Sciences (DSI, department of this PhD) and by the Guglielmo Marconi University, both experimentally, through the laboratory with the test rig of electrochemical processes (e.g. batteries/supercapacitors/fuel cells/electrolyzers) and thermochemical processes (e.g. air conditioning, pyrolysis, gasification), and simulatively, through the DSI server to which teachers, researchers and students have access equipped with various programs (e.g. ASPEN, SIMAPRO). Therefore, the PhD Course has training and research contents in strategic issues for high-level innovation such as:

- Evaluation, design, measurement, control, implementation, optimization, management and decommissioning (through simulation of behavior and performance at steady state and in transient and experimental tests) of innovative materials, processes, components, machines, plants and systems for the production, conversion/transformation, storage, transport, distribution and use of energy in the civil and industrial sectors, with particular reference to production from local and renewable resources, distributed generation, innovative energy carriers, industrial and agricultural buildings and production, and environmental protection such as renewable energy plants with the use of fuel cells (e.g. the European projects UNIFHY, BLAZE, GICO, SO-FREE, LIFE3H focused on production from waste or renewables, storage and distribution of hydrogen and its use in stationary systems and for mobility with fuel cells) especially through the development of models (black box, one, two and three-dimensional), theoretical (matter and energy balances, thermodynamic, kinetic, fluid dynamic models and their mixes) and/or experimental (and theoretical-experimental mixes) using software (e.g. MATLAB, ASPEN, SIMAPRO, FLUENT) and test-rigs and pilot plants (e.g. batteries/supercapacitors/fuel cells/electrolyzers, sorbents/catalysts, combustion/pyrolysis/gasification through programmable resistive feeders and banks, EIS, GC, MS, TGA/DSC, furnaces, etc. present in the Marconi laboratory and other laboratory instruments and pilot plants present in the institutions with which Marconi has collaboration agreements) and the study of the physical, chemical and thermal properties of materials including additive manufacturing techniques; eco-design and green design and biomaterials and nanomaterials;
- Energy systems for mobility: innovative power trains, HEV (Hybrid Electric Vehicle), BEV (Battery Electric Vehicle), FCEV (Fuel Cell Electric Vehicle); Driving cycles and energy-emission analysis of the use of vehicles in real conditions (on the road); Research and development of technologies (including power electronic systems) and innovative solutions (including those related to the management of

electricity grid) for motor vehicles and for industrial mobility, communication and energy systems; Self-Driving Cars, V2I (Vehicle to Infrastructure) and V2V (Vehicle to Vehicle); smart mobility;

- Energy and environmental certification of innovative materials, processes, components, machines, plants and systems including buildings; Study of lighting and acoustic problems in confined and non-confined environments; Research and development of new methodologies for the thermo-hygrometric well-being of confined spaces;
- Energy and environmental planning, efficient use of energy in the industrial, tertiary and residential sectors and analysis of needs, local production from renewables, import/export of energy and related emissions in different atmospheres with particular reference to the application of the technologies and systems described in the previous points and to the environmental impact of energy systems including LCA (Life Cycle Assessment), LCC (Life Cycle Cost), S-LCA (Social Life Cycle Analysis);
- Reverse engineering, rapid prototyping, integrated design techniques (Design for X, DESS), Lean Six Sigma, accelerated testing for decay prediction; predictive maintenance; industrial automation and home automation; quality and safety;
- Evaluation, design, measurement, control, implementation, optimization, management and decommissioning of IT systems and networks; Next-generation IT architectures; Cloud and distributed systems; Software Engineering; Reliability and safety; Databases and knowledge bases; Innovative architectures for the web; Natural Language Processing; Machine learning; Distributed databases; Artificial intelligence; Wireless telecommunication systems and next-generation networks; Satellite systems; advanced land, air and satellite traffic control systems;
- Smart Grids, Smart Cities and Social Innovation;
- Land governance, urban planning and land consumption; Mitigation of seismic risk of the territory and of the built-up area, Basic concepts and approaches related to the identification of seismic risk for the territory and the built-up area, Consolidation and support of soils, Detection techniques for monitoring the territory, Seismic vulnerability of buildings and intervention techniques, Regulatory tools regarding the assessment and design of interventions for the mitigation of seismic risk of the territory and the built-up area.
- Theoretical and applicative aspects of physics and mathematics such as High Energy Physics and related experimental apparatuses; Mathematical Physics and applications of energy and engineering interest; Theoretical physics of fundamental interactions and applications to the development of new technologies.
- Innovative and sustainable technologies for face-to-face and distance education systems.

The research areas listed above are directly and indirectly reflected in almost all policies
strategic objectives of the PNRR. In particular, the research scope of the doctorate for projects carried out with a scholarship ex D.M.
No. 351 of 9 April 2022 is mainly related to Mission 2 Green Revolution and Ecological Transition (covering all the components of this measure: M2C1: sustainable agriculture and circular economy; M2C2: renewable energy, hydrogen, grid and sustainable mobility; M2C3: energy efficiency and renovation of buildings; M2C4: protection of land and water resources); but also in mission 1 digitalization, innovation, competitiveness, culture and tourism (main focus is on the M1C2 component: digitalization, innovation and competitiveness in the production system), in mission 3 infrastructures for sustainable mobility (covering all the components of this measure M3C1: investments in the M3C2 rail network: intermodality and integrated logistics), in mission 4 Education and Research (covering the M4C1 for example with the development of the laboratory Marconi remotely and for long-term testing, see European project RE-OPEN and M4C2 for example with the development of patents and spin-offs). In addition, some strong connection points

are found in the overarching themes of "Smart Growth. Sustainable and inclusive" of "Social and Territorial Cohesion", of "Health and economic, social and institutional resilience and of the "Green Transaction". Particular attention will be given in the PhD (in full coherence with the objectives of the PNRR which dedicates numerous investments to the sector) to the theme of "urban regeneration", understood as a tool aimed at "reducing situations of marginalization and social degradation as well as improving the quality of urban decorum as well as the social and environmental context", and that of the definition of tools (such as Integrated Urban Plans) that can provide for "urban planning invested, with the aim of transforming vulnerable territories into smart and sustainable cities, limiting the consumption of building land" (cit. PNRR). In general, the PhD is perfectly in line with the Italian, European and international objectives for 2030 and 2050 for a progressive and complete decarbonization. These objectives require the development of innovative and sustainable materials, processes, components, machines, plants and systems, particularly in the energy sector, both from the point of view of environmental compatibility, energy security and competitiveness. Hence the need, and the enormous potential, to invest in the development of the entire value chain of new technologies and new vectors such as hydrogen; processes that start from research, innovation, technology transfer and higher education, and embrace the entire field of production (e.g. green hydrogen, electrolysers, fuel cells), infrastructures (e.g. multi-platform stations, hydrogen pipelines, purification and pressurisation and storage sites) and uses (e.g. sustainable mobility, "hard to abate" sectors and power plants, grid stabilisation, civil and industrial uses).

3.1 Scientific disciplinary sectors involved

In line with the research areas illustrated, the scientific disciplinary sectors involved are the following:

- ING-IND/09
- ING-IND/08
- ING-IND/11
- ING-IND/14
- ING-IND/05
- ING-IND/12
- ING-INF/03
- ICAR/20
- ICAR/09
- ICAR/07
- FIS/01
- MAT/07
- MAT/05

3.2 National and international partnership

The training and research activities of the doctorate in the areas illustrated may make use of the collaboration of universities, research institutions and companies with which the Guglielmo Marconi University has institutionalized relationships. These partners are as follows:

- National partners
    - ENEA (Casaccia and Trisaia Research Centres)
    - CNR (INFN, ITAE, etc.)
    - Sapienza University (DIAEE and SBAI departments)
    - University of L'Aquila (DIIE department)

    - Tor Vegata University (DII Department)
    - Campus Biomedical University (Department of DIC)
    - University of Rome 3 (DII department)
    - University of Genoa (DICCA Department)
    - Politecnico di Milano (DE Department)
    - Institute of Information Science and Technology (ISTI)
    - FERRARI SpA – Maranello (MO)
    - FIAT RESEARCH CENTRE – Orbassano (TO)
    - GE OIL & GAS – NUOVO PIGNONE – Firenze (FI)
    - BONFIGLIOLI RIDUTTORI S.p.A. (BO)
    - PIAGGIO & C. SpA – Pontedera (PI)
    - Ashoknolage – Roma (RM)
    - TOYOTA MOTOR ITALIA S.p.A – Roma (RM)
    - SOLIDPOWER SpA – Trento (TN)
    - WALTER TOSTO SpA – Chieti (CH)
    - ENERE SpA –Fano (PU)
    - ICI CALDAIE SpA – Verona (VR)
    - SNAM SpA – San Donato Milanese (MI)
    - RAMPINI SpA – Passignano sul Trasimeno (PG)
- International partners
    - Imperial College London - UK
    - Ohio State University Columbus - USA
    - Fermilab – USA
    - CERN – SWITZERLAND
    - MIT - Massachusetts Institute Of Technology - USA
    - FZJ – Germania
    - University of California (Computer Science Department) - USA
    - Stanford University (Electrical Engineering Department) - USA
    - Universitè de Strasbourg - Francia
    - Huelva University - Spagna
    - Eindhoven University of Technology – Paesi Bassi
    - Vienna University of Technology - Austria
    - MARIE TECNIMONT SpA - France
    - IDIADA SpA - Spain
    - BALLARD Spa - Sweden
    - MARION TECHNOLOGIES SpA - Francia
    - CALIDA CLEANTECH Srl - Germany
    - MAYHTEC – France
    - HYGEAR - Olanda

4 Expected employment and professional opportunities

The aim of the PhD is to train experts who, thanks to the skills acquired, are able to guide the development of process and product innovation in the various industrial, civil and research fields, such as the development of efficient and sustainable energy systems from renewable sources and fuel cells. In this sense, future PhDs, in possession of both specialized technical skills and operational skills to manage the development of innovation, can be inserted, for example, as Innovation Manager, Energy Manager, Fleet Manager, Product Manager or within Research and Development, Design, Production, Application and Management departments of public and/or private bodies, for, for example, the design or operation of energy production, distribution, storage and use facilities; control of the safety of the plants and analysis and monitoring of their environmental impact; rationalization and optimization of the use of resources, assessment of the seismic risk of the territory and the built environment and the design of specific interventions. In addition, thanks to the disciplines related to the governance of the territory, future Doctors will have skills able to guarantee the possession of the cognitive and cognitive foundations of a decision-maker in the Public Sector and, in general, in the management of urban transformations. They will be able to design and implement, in compliance with the existing regulatory framework, the administrative and management systems that best meet the needs of its positive functionality. In order to provide a multidisciplinary preparation, and thanks to the combination of applied research and basic science, future PhDs will have the opportunity to learn the most advanced techniques of data processing and process analysis, thus expanding the possibilities of employment in different sectors. Future Doctors will therefore be able to find employment at universities, public or private research centers, mechanical, energy, automotive and information industries, companies and institutions for the production and conversion of energy and for the mobility of people and goods, plant engineering companies, automation and robotics industries, manufacturing companies in general and in the context of services, in the Public Administration and Local Authorities. Particular employment development can also be given to the transactional and service sector, both for public and private bodies, as well as in the field of Applied Biotechnology in the field of technological innovation in Industrial and Information Engineering, Civil Engineering and Architecture and Physical and Mathematical Sciences. In addition, in the event that the results obtained during the PhD lead to the development of original products/processes that can be used on the market, it will be possible to participate as protagonists in the creation of patents, new companies and academic spin-offs, especially through the Marconi Innovation hub center

5 Formation

5.1 Educational and research methodology

The PhD is structured on training processes characterized by the use of a combination of disciplinary and interdisciplinary methodological approaches aimed at ensuring the development of research in the areas described in the previous point, keeping in mind the State of the Art and innovations at national, European and international level.

The working methodology is characterized by a strong interaction between professors and students/doctoral students and also involves figures, laboratories and plants belonging to the institutions with which Marconi has joint research projects or collaboration agreements.

In order to increase the skills of doctoral students, the course provides an offer of training programs that, based on the specific scientific skills of the members of the college, aims to define an engineering profile characterized by a high degree of specialization and a critical understanding of current and innovative technologies both in the national context and in the European and international context.

The related educational offer, divided into common activities and activities of a specialized nature, therefore provides
1) specific training activities with interdisciplinary content and in particular several ad hoc teaching modules structured in cycles of lectures and interactive lectures progressively open to the direct participation of doctoral students with final examination (e.g. Linguistic and IT specialization, Management, enhancement and ethics of research, Physics, Chemistry and Mathematics Laboratory) and 2) specialization courses on topics related to the educational objectives of the individual Ph.D. student (e.g. Laboratory of Innovative Technologies for Sustainable Energy Systems, Urban Design, Industry 4.0, Modern Physics Meetings, Use of test rigs and equipment present at Marconi such as test rigs of batteries/supercapacitors/fuel cells/electrolyzers, sorbents/catalysts, combustion/pyrolysis/gasification, use of programmable resistive power supplies and banks, EIS, GC, MS, TGA/DSC, ovens, etc.). These activities are complemented by participation in the main seminars, conventions, conferences and study days in the sector.

5.2 Planned courses

In line with the educational objectives of the PhD course, the following courses are provided:

- Laboratory of Physics, Chemistry and Mathematics: reference professors Matteo Martini, Sabino Meola, Donatella Barisano, Stefano Stendardo, Fabio Happacher, Giovannella Simona, Fabio Rinaldi, Stefano Viaggiu
- Laboratory of Innovative Technologies for Sustainable Energy Systems: reference professors Fabio Orecchini, Enrico Bocci, Romeo Giuliano, Umberto di Matteo, Stefania Proietti, Alberto Garinei, Arcidiacono Gabriele, De Luca Ernesto William, Garinei Alberto, Citti Paolo
- Urban Design Laboratory: reference teachers Cinzia Bellone, Stefania Lirer, Ernesto Grande
- Meetings of Physics and Modern Physics: reference professors Matteo Martini, Sabino Meola, Donatella Barisano, Stefano Stendardo, Fabio Happacher, Giovannella Simona, Fabio Rinaldi, Stefano Viaggiu Carlo Iazzeolla
- Industry 4.0: reference teachers Proff. Fabio Orecchini, Enrico Bocci, Romeo Giuliano, Umberto di Matteo, Stefania Proietti, Alberto Garinei, Arcidiacono Gabriele, De Luca Ernesto William, Garinei Alberto, Citti Paolo

5.2.1 Laboratory of Physics, Chemistry and Mathematics

The aim of this workshop is to teach students to reason in a scientific way by interpreting the behavior of some very simple natural phenomena. Normally, the experiences that are part of an educational laboratory are based on activities that are carried out mechanically to verify a law, confirm hypotheses, etc. In this workshop we want to ask ourselves questions whose answers will come only after careful reasoning. Tomorrow, when we are faced with a new problem, there will not be a manual to follow slavishly but we will have to respond ourselves.

The course includes a minimum laboratory experience of about 3 hours for 7 days. This experience, to be agreed with the teacher, can be carried out by the student in his/her home or in available institutions/companies or in the Marconi laboratory, located in via Paolo Emilio 29. The tests must then be supported by a technical report to be delivered during the exam. In addition to these approximately 21 hours, there are 10 hours of individual study activities (study, laboratory regulations, teaching materials and texts) and 10 hours for the drafting of the paper.

For the final exam, the student will have to prepare and deliver a report for each experience. This documentation will then be discussed during an oral exam. The test lasts an average of 30 minutes.

5.2.2 Laboratory of Innovative Technologies for Sustainable Energy Systems

The aim of this workshop is to provide students with the techniques of design, use and analysis of the main industrial applications, through direct contact with software and machinery. The student carries out simulation and/or experimental experiences in the laboratory in order to directly apply the notions learned during the degree courses and verify his/her skills on these techniques (simulative/experimental) of industrial applications increasingly required by the world of work. Compatibly with the planning of research activities, the student will also be able to participate in laboratory experiences integrated into the research projects in which the university participates.

The course includes a minimum laboratory experience of about 3 hours for 7 days. This experience, to be agreed with the teacher, can be carried out by the student in his/her home or in available institutions/companies or in the Marconi laboratory, located in via Paolo Emilio 29. The tests must then be supported by a technical report to be delivered during the exam. In addition to these approximately 21 hours, there are 10 hours of individual study activities (study, laboratory regulations, teaching materials and texts) and 10 hours for the drafting of the paper.

For the final exam, the student will have to prepare and deliver a report for each experience. This documentation will then be discussed in person at the headquarters in Via Paolo Emilio 29. The test lasts an average of 30 minutes.

5.2.3 Urban Design Laboratory

The aim of this workshop is to provide students with the techniques of design, use and analysis of the main urban design tools. The student carries out simulation and/or experimental experiences in order to directly apply the notions learned during the degree courses and verify his/her skills on these techniques (simulative/experimental). Compatibly with the planning of research activities,

The student will also be able to participate in laboratory experiences integrated into the research projects to which
The university participates.

The course includes a minimum laboratory experience of about 3 hours for 7 days. This experience, to be agreed with the teacher, can be carried out by the student in his/her home or in available institutions/companies or in the Marconi laboratory, located in via Paolo Emilio 29. The tests must then be supported by a technical report to be delivered during the exam. In addition to these approximately 21 hours, there are 10 hours of individual study activities (study, laboratory regulations, teaching materials and texts) and 10 hours for the drafting of the paper.

For the final exam, the student must write and deliver a minimum of 5 graphic papers and a short report (30 pages). This documentation will then be discussed in person at the headquarters in Via Paolo Emilio 29. The test lasts an average of 30 minutes.

5.2.4 Meetings of Physics and Modern Physics

The course allows you to acquire a greater mastery of the mathematical-physical sector. The topics of study are divided into lessons on:

- pedagogy
- Mathematics and Statistics
- Modern Physics
- cosmology
- radiation protection
- Didactics of the laboratory
- Physics Laboratory
- Quantum Mechanics
- Special Relativity

5.3 Other didactic activities

In line with the objectives of the PhD course, the courses presented will be accompanied by other training activities:

- Seminars
- In-person and remote laboratory activities
- Activities at research infrastructures
- Language improvement
- Further information technology
- Research and knowledge management of European and international research systems
- Exploitation and dissemination of results, intellectual property and open access to research data and products
- Fundamental Principles of Ethics, Gender Equality and Integrity

5.3.1 Seminars

The courses presented in the curricular teaching offer are associated with a wide range of seminars, both specialized and multidisciplinary, in order to offer doctoral students opportunities for in-depth study

in the individual disciplinary areas but also in exchange and fruitful interaction between them. Therefore, training activities are planned that will address issues related to the research process or to the scientific questions on which studies can be developed by merging approaches of different specialized matrix and following them with round tables of experts that favor a fruitful exchange between disciplines as well as the interaction between teachers and students such as, for example, participation in meetings of international projects. The seminar activities will also be aimed at training aimed at the acquisition of transversal skills, which concern scientific communication, the use of the most suitable technologies for the acquisition of the results that are the objective of one's research, teaching skills and knowledge regarding national and international research systems such as those developed during European research projects (think of the European Research Area, horizon result buster, etc). The seminar activities will be structured in multiple forms (seminar, workshop, webinar, conference, ...) and will involve the participation of professors belonging to the Doctoral Board, but also of other scientific experts (other professors within the University, professors belonging to other Italian or foreign universities, scientific experts belonging to research institutions and Italian and foreign companies).

5.3.2 In-person and remote laboratory activities

The planned teaching activities will be accompanied by practical experiences according to the acquisition of application skills. Research activities will be able to benefit from qualified and specific operational and scientific structures, including laboratories equipped for research such as the laboratory described above in which to carry out experiments both in presence and remotely (e.g. for long term tests) on electrical, electronic, computer and energy systems (capacitors, batteries, cells/electrolyzers, conditioning with catalysts and/or sorbents).

5.3.3 Activities at research infrastructures

Research activities will be able to benefit from qualified and specific operational and scientific structures, including laboratories equipped for research. This will take place at the administrative and operational offices of the University, but also at institutions with which the University and the Department of affiliation have established agreements for research activities. Among these, it is possible to mention in particular national and international research infrastructures such as CNR/INFN, ENEA, CERN, FERMILAB, etc.

5.3.4 Language improvement

As part of the PhD course, the increase in competence in expression and comprehension in English, with reference to both written and spoken language, will be promoted at several levels. PhD students will be offered the opportunity to have access to the English language courses that are part of the University's educational offer. The use of spoken and written English will also be encouraged, both in oral communication involving international interlocutors and in the use of international scientific articles. This will take place both in the context of the teaching offer and in that of the research activity. Periods of study and research abroad will also be encouraged.

5.3.5 Further information technology

As part of the PhD course, the increase in computer skills will be promoted at several levels. PhD students will be offered the opportunity to have access to computer science courses that are part of the University's educational offer. The use of IT tools in the context of the

research activities. In particular, the competence of PhD students in the use of databases and software functional to specific research paths will be promoted. In particular, the skills useful for carrying out research of scientific literature in the Databases will be increased; data management and analysis; the drafting of written and graphic scientific communication products. This will take place both in the context of the teaching offer and in that of the research activity, therefore including the use of software such as ASPEN and SIMAPRO.

5.3.6 Research and knowledge management of European and international research systems

As part of the PhD course, particular attention will be paid to training PhD students in the management of the research process in all its phases. In addition, knowledge regarding national and international research systems will be promoted, as a function of the activation of scientific exchanges and the acquisition of expertise in attracting funds aimed at research. To this end, PhD students will be able to avail themselves of the support of the University's Research and Development Area. This structure provides managerial, financial, administrative and, in specific cases, technical-scientific support in the formulation and implementation of proposals in response to national and international funding calls.

5.3.7 Exploitation and dissemination of results, intellectual property and open access to research data and products

PhD students will be supported in the enhancement and dissemination of the results achieved through the research carried out. To this end, specific teaching activities will be aimed at training in scientific communication, both written and oral, also in a foreign language, referring in a transversal way to the standards of the various disciplinary areas. Oral and written communication of the interim results of the research to peers, the rest of the scientific community and society will also be supported and encouraged, already during the course of the PhD. Open access to data and research results will be promoted, ensuring the protection of intellectual property.

5.3.8 Fundamental Principles of Ethics, Gender Equality and Integrity

In the Doctoral Course, specific attention will be paid to training in compliance with the principles of ethics and the rules of conduct that are essential for the scholar. Both in teaching and research activities, the transmission of fundamental principles will be promoted, such as integrity, respect for the dignity of the person, competence, social responsibility and the protection of well-being. A part of the curricular and seminar teaching activity will be dedicated to these topics, providing PhD students with references to the available ethical codification and expanding its application in a transversal sense to the disciplines. In the management of the PhD, compliance with principles such as gender equality, the enhancement of young people and the reduction of territorial gaps will be guaranteed.

6 Consistency with the objectives of the NRRP

The topics of Industrial and Information Engineering, Civil Engineering and Architecture and Physical and Mathematical Sciences are directly and indirectly reflected in almost all the strategic policies of the PNRR. In particular, they are mainly reflected in mission 2 green revolution and ecological transition (covering all the components of this measure: M2C1: sustainable agriculture and circular economy; M2C2: renewable energy, hydrogen, grid and sustainable mobility; M2C3: energy efficiency and renovation of buildings; M2C4: protection of land and water resources); but also in mission 1 digitalization, innovation, competitiveness, culture and tourism (main focus is on the M1C2 component: digitalization, innovation and competitiveness in the production system), in mission 3 infrastructures for sustainable mobility (covering all the components of this measure M3C1: investments in the rail network M3C2: intermodality and integrated logistics), in mission 4 Education and Research (covering all M4C1 components for example with the development of the PhD laboratory also remotely and for long-term testing, see European project RE-OPEN and M4C2 for example with the development of patents and spin-offs). In addition, some strong points of connection can be found in the overarching themes of "Smart Growth. Sustainable and inclusive" of "Social and Territorial Cohesion", of "Health and economic, social and institutional resilience and of the "Green Transaction". Particular attention will be given in the PhD (in full coherence with the objectives of the PNRR which dedicates numerous investments to the sector) to the theme of "urban regeneration", understood as a tool aimed at "reducing situations of marginalization and social degradation as well as improving the quality of urban decorum as well as the social and environmental context", and that of the definition of tools (such as Integrated Urban Plans) that can provide for "urban planning invested, with the aim of transforming vulnerable territories into smart and sustainable cities, limiting the consumption of building land" (cit. PNRR).