DOCTORATE RESEARCH PROGRAMMES ON SUSTAINABILITY / INNOVATION-RELATED TOPICS
Attachment 5

PhD PROGRAMME IN INDUSTRY 4.0 XXXVII CYCLE
Inter-university course in collaboration with University of Bari "Aldo Moro"

Department: Department of Electrical Engineering and Information Technology

Coordinator: Prof. Mariagrazia Dotoli (mariagrazia.dotoli@poliba.it)

Places available:

- "Innovation" macro-area: 3 places
- "Sustainability" macro-area: 1 places

Candidates are advised that there are separate application calls for each macro-area. Candidates who intend to apply for both programmes must submit two different applications for each macro-area,

The current document includes attachments regarding specific details for research topic fields for each macro-area.

Admission Requirements

Applicants to the PhD programme in Industry 4.0 must hold a second level (specialized) degree as follows:

- Degree diploma awarded by an Italian university prior to Ministerial Decree 509/99;
- Specialist Degree (as per Ministerial Decree 509/99);
- Master's Degree (as per Ministerial Decree 270/04);
- Degree qualifications awarded by foreign universities officially recognised as equivalent to the above.

The Selection Board will decide upon the eligibility of qualifications as part of the assessment procedure.

Application Instructions:

Please note that the information provided in this paragraph **complements and does not substitute** that contained in arts. 2 and 3 of the Call for Applications document.

REQUIRED DOCUMENTATION

Candidates **must** upload the following documentation to their online application. **Failure to do so will result in their exclusion from the selection procedure**:

1. A **CV** following the layout of the **example** provided by Politecnico di Bari on the Politecnico website www.poliba.it in the *Ricerca/Dottorati di Ricerca* section. This file should be named "01.CV";

2. **A signed, valid identification document.** This file should be named ***"02.Documento riconoscimento".*** Only the following documents will be considered; failure to comply will result in exclusion from the selection process***;***

   - ID card, only if issued by an EU member state;
   - Driving licence, only if issued by an EU member state;
   - In all other cases, a fully valid passport (also non-EU citizens, including the UK);

DOCTORATE RESEARCH PROGRAMMES ON SUSTAINABILITY / INNOVATION-RELATED TOPICS
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3. **Degree qualification certification for first (Bachelor) degrees and second (specialization/Master's) degrees (or 5-year Single Cycle degrees)**. A list of all exams taken with their relative marks in both degree courses (or the Single Cycle course) should also be included, following the example provided by Politecnico di Bari which is available from the Politecnico website in the *Ricerca/Dottorati di Ricerca* section. This file should be named "03.Titoli di laurea";

   Candidates with **a degree qualification awarded by a non-Italian university** must attach the following documents to their application, prepared by the academic institute which issued them. This supersedes any form of self-declaration:
- Degree certificate or diploma showing relative final mark;
- Official transcript of exams taken during all university study programmes, showing relative results;
- Any other relevant documentation which demonstrates the equivalence of qualifications with those required in this application call (Supplementary Diploma, *Dichiarazione di Valore* (statement of value) issued locally).
  These documents must be in Italian, French or English or translated into Italian or English and verified by an official Italian diplomatic or consular representative under the responsibility of the candidate. These should follow the guidelines set out in the document "*PROCEDURES FOR ENTRY, RESIDENCY AND ENROLMENT OF INTERNATIONAL STUDENTS AND THE RESPECTIVE RECOGNITION OF QUALIFICATIONS, FOR HIGHER EDUCATION COURSES IN ITALY FOR THE ACADEMIC YEAR 2021/22*" available at the link www.studiare-in-italia.it/studentistranieri;

4. **An abstract / summary of the thesis topic for specialist/Master's degree (or five-year Single Cycle degree),** stating the title and name of thesis supervisor(s) (max 3,000 characters); this file should be named "04.Abstract tesi";

5. **The candidate's thesis for specialist/Master's degree (or five-year Single Cycle degree);** for graduating students whose thesis is not yet complete (see art.2), a draft version of the thesis which has been completed up to the time of application; (N.B. *draft version* implies a version of the thesis text written by the graduating candidate up to the date of application, which, in terms of chapters and pages, allows the Selection Committee to evaluate its relative content and subject area. The abstract is uploaded as a separate file and is not accepted as a *draft version of the thesis* under any circumstances. This file should be named "05.Tesi";

6. **Research project proposal,** which must be completed in the format provided by the Politecnico di Bari; this is available at www.poliba.it/it/dottorati-di-ricerca. The proposal must include:
   - research project criteria in line with art.3 of Ministerial Decree 16061/2021 and art.5 of the call for applications document;
   - research topics in accordance with the PhD programme selected and relevant macro-area topic (Sustainability/Innovation, refer to attached macro-area details).

   Proposals are assessed purely as part of the selection procedure and are not necessarily those which candidates will develop during the programme. This file should be named "06.Proposta di Ricerca".

OPTIONAL DOCUMENTATION

7. **A self-certification declaration for any other qualification deemed suitable for evaluation** which must be signed and dated and follow the layout of the example provided by Politecnico di Bari on the Politecnico website www.poliba.it in the *Ricerca/Dottorati di Ricerca* section. In accordance with art. 46 (Statements in lieu of Certification) and art. 47 (Self-Drafted Affidavits) of Presidential Decree 445/2000 (pursuant to art. 15 of Stability Law 183/2011, candidates may not submit certificates and affidavits issued by public administrations or providers of public services for qualifications that are to be assessed. These certificates should be replaced by statements as per arts. 46 and 47 of Presidential Decree n. 445/2000). This file should be named *"*07. Dichiarazione altri titoli*";*

8. (additional, optional) **Two letters of presentation from teaching staff** who have supervised the candidate throughout their university studies. These files should be named "08.Lettere presentazione 1" , "08.Lettere presentazione 2";
9. **Language certification** demonstrating a knowledge of English which corresponds to at least B2 level. Only non-Italian citizens can attach certification which demonstrates knowledge of the Italian language. This file should be named "09.Certificazione linguistica 1" (2, 3 etc);
10. **Any publications** related to activity carried out and shown on the candidate's CV. This file should be named "10.Pubblicazione 1" (2, 3 etc).

All of the aforementioned documents must be in either Italian or English or translated into Italian or English, under the responsibility of the candidate.

In cases of large documents unavailable as electronic files or which exceed the number of MB permitted for documents, applicants may submit these separately (in paper format or as a CD or DVD-ROM), accompanied by a detailed list of contents, by 2 p.m. of the deadline date for admission applications.

Any publications submitted on paper or digital support must be sent in a closed envelope, signed along the seal, to the following address:

Magnifico Rettore del Politecnico di Bari – Direzione Gestione Risorse e Servizi Istituzionali-Settore Ricerca, Relazioni Internazionali e Post-Lauream - Ufficio Protocollo – Via Amendola 126/B, 70126 BARI (Italy)

Envelopes must display the name and surname of the candidate together with the following text: "*Concorso di Ammissione al Corso di Dottorato in*… (name of the PhD programme)". The delivery of the envelope containing publications to Politecnico di Bari - by postal service, private courier or shipping agency – is at the exclusive risk of the candidate.

Admission examination

The admission examination is based on:

1. **an assessment of qualifications held** (average exam marks, final degree mark, theses, Master's degrees, post-graduate courses, language certification, publications, etc.);

2. **an interview** to ensure a complete evaluation of the candidate and to verify the applicant's aptitude for research and willingness to undertake experience abroad, as well as areas of research interest.

The Selection Board will assess candidates' qualifications and interview with a mark out of 100 (maximum mark for qualifications 40 and interview 60). Candidates obtaining less than 10 marks for the qualification evaluation will not be admitted to the interview.

The results of the Board's assessment for qualifications and project proposals will be published on the ESSE3 portal in the private area of each candidate.

No other notification will be sent directly to candidates.

At the end of the examination procedure, the Board will carry out an overall assessment and draw up an admission rankings list on the basis of the marks obtained by candidates in each part of the examination.

The assessment criteria for qualifications will be established by each Selection Board.

SCHOLARSHIP N. 7

National Operational Programme 2014-2020

PhD programmes for sustainability and innovation-related subjects

Ministerial DECREE N. 1061 (10 Aug 2021)

Academic Year 2021/2022 – XXXVII CYCLE

INNOVATION-BASED TOPICS (ACTION IV.4)

SCHOLARSHIP N. 7

A. RESEARCH PROJECT PROPOSAL	
a. Relevance of doctorate research project in creating high added value in terms of scientific, social and economic impact on Italy, fostering appropriate research models and the formation of professional profiles as a response to the requirements of the business sector for innovation and competitiveness. **A development of research on topics of innovation, digital advancement and enabling technology while supporting the enhancement of human capital, determining factors in the progress of research and innovation in Italy.**	According to recent studies, the robotics market has been valued 40 billion USD in 2019 and the forecasts project a CAGR of around 25% on a temporal horizon going from 2020 to 2025. Such a growth is mainly driven by the profound changes occurring in the robotics market, among which we cite the increasing adoption of products in new domains such as surgical robotics, autonomous vehicles, vehicles for transportation of goods, exoscheletons, unmanned aerial vehicles. This transformation will inevitably lead to both the adopion of robotics products in non-industrial markets and, consequently, a remarkable decrease of the average product costs. At the same time, new methodologies pertaining to the Artificial Intelligence (AI) field allow the development of new robotics applications that, until very recently, were hardly to be imagined.

	Thus, an important challenge that the Italian productive system has to tackle is the introduction in robotics produtcs of innovative control paradigms based on artificial intelligence and, more precisely, on Deep Reinforcement Learning techniques. Despite the fact that such methodologies with application to robotics are attracting the attention of the Automatica and AI scientific communities and producing a plethora of interesting solutions, their usage in products is yet limited. The adoption of those new control techniques is mainly hindered by the fact that it is hard to guarantee that the trained agents are sufficiently robust and safe to operate. Another limitation stems from the fact that complex tasks solved with Reinforcement Learning tools often require consistent requirements in terms of computational power to be run. To solve this issue, recently the scientific community is studying techniques to allow the deployment of RL agents on devices characterized by low computing and memory capacity such as, for instance, low cost and low power microcontrollers. Consequently, the doctoral programme herein proposed has the goal to study and propose novel and innovative Deep Reinforcement Learning algorithms that are able to 1) improve their robustness so that they can be employed in mission critical applications 2) be deployable on embedded devices.
b. Adherence of doctorate research project to National Strategies of Intelligent Specialisations (SNSI) and PNR and applicability to Law 240/2010 and Ministerial Decree 45/2013 regarding PhD students, with the aim of fostering innovation and exchange between the field of research and world of manufacturing and the certification of research project contributions within the sector of innovation (Law 240/2010, art. 24, section 3 and subsequent modifications and additions).	The proposed research is placed at the intersection of Robotics and Artificial Intelligence fields. More in details, the doctoral programme proposes to study novel Reinforcement Learning techniques with a particular focus on robotics that guarantee that the agent constantly keeps in a safe state during all training phases. As specified below in the *point c),* another goal of this proposal is to allow the deployment of the trained Safe Reinforcement Learning agents on devices characterized by reduced computational and memory capacity. The PNR identifies Robotics as a research area with repercussions in multiple fields. In particular, Section 5.4.4 focuses the attention on the importance of Robotics technologies in the context of Industry 4.0 scenarios (articulation 2), health (articulation 5) and the application of robotics in hostile environments (articulation 1). The research topics dealt in this

	doctorate programme will have an important impact on all the aforementioned articulations as they will allow the development of techniques to improve the security of agents for mission critical applications. Furthermore, the project will impact on the field of Artificial Intelligence (Section 5.4.3 of the PNR) and, more specifically, on the articulation 6 "Artificial Intelligence for industrial production" with reference to the research priority identified therein as Edge-AI that allows integrating intelligence into factories and products. The SNSI outlines, among the technological development trajectories with national priority, the line "5.5.6 Digital Agenda, Smart Communities, intelligent mobility systems" that relates to "Embedded" electronic systems, intelligent sensor networks, internet of things. The research on Edge-AI carried out by the PhD student in collaboration with the company will allow to obtain important advances on the state of the art with reference to the incorporation of artificial intelligence in electronic devices and sensors. The collaboration will allow a virtuous exchange of knowledge between our Polytechnic and the production world in a highly innovative sector.
c. Research activity proposal, methods and contents	The research activity developed by the graduate student is set to accomplish the three main objectives described in the following. *Objective n.1* To bring advances to the current state of the art of the Reinforcement Learning (RL) paradigm applied to robotics, known as Safe Reinforcement Learning (SRL). This technique differs from classical RL by avoiding, already in the training phase, that neither the environment with which the agent interacts, nor the agent itself, will be subject to any type of damage. The literature in this topic is still narrow and the first contributions in the field of automation date back to just the 2018. While RL algorithms solve sequential non-deterministic decision-making in the framework of the so-called Markov Decision Problems (MDP), Safe-RL algorithms leverage the Constrained Markov Decision Problems (CMDP). The latter differs from the MDP by including some constraints in order to directly integrate the idea of *safety* in the RL process. The graduate student will identify, in accordance with the involved company, the real case scenarios on top of which the

	developed solutions will be tested. The tests will be conducted through simulations carried out with tools such as OpenAI Gym or MuJoCo. *Objective n.2* Regarding this objective, the proposed research is set to study solutions for the Edge-AI that will help the integration of the proposed Safe-RL algorithms on electronic devices whose computational power and memory are limited. To the purpose, the student will study techniques for the compression and partitioning of neural networks so that those partitions can be distributed among a given number of devices. The results will be compared with benchmarks and metrics defined by the TinyML foundation. *Objective n.3* The third goal concerns the development of SRL algorithms on embedded devices such as microcontrollers applied to the topic of interest of the company involved in this doctoral programme. The graduate student will apply compression and quantization of the resulting neural networks in order to deploy the SRL agent on the robot. The robotic system produced will be tested to evaluate the performances of the outputs of objective n.1 and objective n.2 in real case scenarios.
B. COMPANY-BASED ACTIVITIES within the Italian territory	
a. Research activity to carry out with the company	The company is committed, aside from development of cutting-edge microcontrollers and electrical devices, to research and development of embedded products that integrate Artificial Intelligence technologies. The graduate student will accomplish all the research activities, in the research plan briefly described above, that fall in the objective n.2 and part of the objective n.3. The company's expertise in the field of Edge-AI is testified by numerous publications appeared in journals and international conferences related to the field.
b. Period of company-based study and research	12 months
c. Measurable nature of expected results and potential impact of	The proposed PhD plan is set to develop enabling technologies in the fields of robotics and artificial intelligence bringing a disruptive impact in all the

implemented actions with reference to the aims of the Recovery Assistance for Cohesion and the Territories of Europe programme (REACT-EU): quantifiable and measurable targets in doctoral research project in line with indicators set out in NOP reference of actions.	productive sectors concerned by robotics technologies. The project's results are in accordance witht one of the main goals of REACT EU, namely the support to digital transition of our nation. The research will be carried out together with the company. The project proposal is perfectly aligned with the research and development themes of the company in connection with the Industry 4.0 and Industrial Robotic topics. This will allow a fruitful exchange of knowledge and the realization of a strong and long-lasting synergy between our Polytechnic University and a company leader in the productive sector, reaching one of the objectives cited in the PNNR ("M4C2 - dalla Ricerca all'Impresa"), The research plan will allow to train a PhD student specialised in a high-tech area with interdisciplinary knowledge in the fields of robotics, artificial intelligence and embedded systems. The results obtained by the graduate student will be quantified by evaluating the proposed algorithms through state-of-art benchamrks in the fields of robotics and neural network compression. The applicability of the obtained results in real case scenarios will be verified thanks to the collaboration with company. The graduate student has to produce at least one paper accepted by an international journal and will present the research activities in at least three international conferences. The PhD student will disseminate the results through specialized seminars in the master courses of "Mobile and Field Robotics", "Embedded Control" carried out in the context of the Master Degree in Automation Engineering. Moreover, the PhD student will employ social media such as LinkedIn and Twitter to further disseminate the results to a non-spcialized audience. Thanks to the collaboration with the company the PhD student will be able to demonstrate the proposed solutions at a TRL at least equal to 4.
C. ACTIVITIES ABROAD	
a. Research activity abroad	Not programmed.

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National Operational Programme 2014-2020

PhD programmes for sustainability and innovation-related subjects

Ministerial DECREE N. 1061 (10 Aug 2021)

Academic Year 2021/2022 – XXXVII CYCLE

SUSTAINABILITY-BASED TOPICS (ACTION IV.5)

SCHOLARSHIP N. 8

A. RESEARCH PROJECT PROPOSAL	
a. Relevance of doctorate research project in creating high added value in terms of scientific, social and economic impact on Italy, fostering appropriate research models and overlap of knowledge and skills to promote the development of innovative products and services with reduced environmental impact, focusing on topics such as; **- protection of the ecosystem;** **- biodiversity;** **- reduction of climate change impact;** **- enhancement of sustainable development**	The project: "Innovative and sustainable photovoltaic devices based on perovskite composites / colloidal nanocrystals integrated in bio-based polymers" intends to design, develop and manufacture photovoltaic devices based on hybrid halide (HP) perovskite composites and colloidal nanocrystals (NC), suitably combined and integrated in matrices consisting of biopolymers (polyhydroxalkanoates - PHA), 100% biodegradable and bio-derivatives. This research project intrinsically combines the development of innovative technological solutions to the need for energy with the paradigms of sustainability and environmental protection. In fact, the project intends to provide technologically advanced solutions to produce

in order to promote green recovery and overcome the effects of the Covid-19 pandemic crisis.	green energy, being aimed at the creation of high-performance photovoltaic devices capable of efficiently exploiting sunlight and appropriately designed to allow sustainability and eco-compatibility, both in terms of materials and process technologies, using completely bio-derived materials. The future use of potentially flexible photovoltaic devices that use environmentally friendly materials favors the integration of solar cells into portable and wearable technologies. The involvement of the company will ensure the exposure of the PhD student to a reality that, specifically in his corporate vision, is inspired by the principles of the blue economy, the closed cycle, zero waste for obtaining intelligent and sustainable products. This project will prepare the doctoral student so that he can become, at the end of the training course, a highly qualified researcher and professional, with high employment opportunities in numerous research and production chains. In fact, various and complementary skills will be acquired in the field of chemistry of materials, chemical-physical investigation, development of biobased products, engineering of materials and devices, resulting in a truly interdisciplinary curriculum, significantly completed by the experience in the group.
b. Adherence of doctorate research project to National Strategies of Intelligent Specialisations (SNSI) and PNR and applicability to Law 240/2010 and Ministerial Decree 45/2013 regarding PhD students and grant funding to Sustainability-based research projects	The proposed research aims the development of advanced devices for the conversion of solar energy, using an ecological, environmentally friendly and sustainable approach, which combines green photovoltaic technology with the use of bio-based products. In addition, the development of devices on a potentially flexible polymer substrate is in line with the goal of developing wearable solar cells that can be integrated into portable technologies. Metal halide perovskite (HPSC) solar cells represent an extremely valid and promising technology to produce renewable energy, given their high photoconversion efficiency, low cost, and low impact of manufacturing methods. For the realization of the devices it will be necessary to design and develop HP materials with an appropriate composition to ensure

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	high performance in the processes of absorbing sunlight, as well as NC of TiO2, NiO and SnO2 as constituents of electron and hole transporting layer (ETL and HTL) and NCs of inorganic perovskites (CsSnI3, CsAgBiI3) for the functionalization of HP films, to optimize charge transport at the interface. The environmental compatibility and sustainability of the production processes of materials and the manufacture of devices will also be assessed. These devices will have to compete with the current state of the art of photovoltaic technology, in terms of energy efficiency, robustness and durability. The combination of these functional materials with biopolymers obtained with recovery and recycling technologies will make it possible to explore original and technologically advanced solutions capable of responding in a sustainable and efficient way to the need to reduce the carbon footprint.
c. Research activity proposal, methods and contents	The research aims the development of eco-sustainable and economical materials and processes for the realization of new generation photovoltaic devices based on inorganic HP and NC polycrystalline films deposited on transparent biopolymer substrates. Main objectives of the proposed research activity are: i) the application of innovative procedures for the synthesis of perovskite NC (CsSnI3, CsAgBiI3) to be integrated into HP and NC oxide films (TiO2, NiO, SnO2) to be used such as ETL and HTL, ii) the study of preparation procedures for light harvesting layers based on polycrystalline films of HP or their composites, iii) development of procedures for the production of thin films of PHA (and / or mixtures and composites) with excellent mechanical and optical properties iv) development of deposition / functionalization techniques to make the biopolymer conductive which, together with the other engineering strategies, allow to increase the performances of the device. The methodologies will be, about objective i) low cost potentially scalable colloidal synthesis techniques of nanocrystalline semiconductor oxides (TiO2, NiO and SnO2) starting from low dangerous reagents, using moderate

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	temperatures, resulting in colloidal solutions that can be manipulated towards the realization of thin films. About the objective ii) deposition methodologies, suitably developed, starting from a solution of HP polycrystalline films. In a first phase of the project, lead-based HPs (CH3NH3PbI3 and with mixed cations / anions) will be used, the chemical composition of which will be varied to modulate its optical properties to ensure high performances and stability, and then gradually reduce and replace lead. with eco-sustainable alternatives (Sn, Bi). To further limit the presence of toxic constituents, different mixtures of non-toxic solvents and the use of adjuvant additives for the growth of HP will be explored. The properties of the HP polycrystalline films will be improved by adding NCs of synthetic inorganic perovskites to the film or deposition at the interface with the other active layers. With this combination it will be possible to obtain a greater stability of the constituents of the device thanks to the passivation of the electronic defects and a better functioning of the same induced by the control of the processes of generation and transport of the charges. To achieve objective iii) changes will be implemented to the biosynthesis process developed by the company to biopolymer to improve processability and transparency. The achievement of this goal will also make use of the development of deposition conditions (solvent, temperature, film thickness). Regarding objective iv), engineering strategies of metallic, semimetallic or semiconductive layers on the polymeric substrate (ie graphene; MoS2) will be developed to make this support conductive, NC deposition processes and NC / hybrid perovskite halide composites, verifying the applicability of large-scale industrial deposition procedures, such as roll-to-roll deposition adopted by most of the packaging industries and for which the use of high environmental impact solvents is limited.
B. COMPANY-BASED ACTIVITIES within the Italian territory	
a. Research activity to carry out with the company	The company has developed innovative technologies for the realization of biosynthesis

	processes for the production of biopolymers starting from waste materials, such as waste water. Furthermore, the same company owns a previous know-how regarding PHAs. As part of the project, the PhD student at will deal with the preparation of the biobased polymer, belonging to the class of PHA, bio-derived polyesters obtained by fermentation. Thermoplastic polymers, biodegradable and biocompatible, PHAs, among the many characteristics, also present insolubility in water and resistance to degradation. However, PHAs have low plasticity, poor flexibility and limited optical transparency, which are instead essential characteristics to make it suitable for use for optoelectronic applications, and within the project, for integration into the photovoltaic device. To this end we will proceed according to two approaches: i. trying to implement the characteristics and parameters of the biopolymer production process to obtain it with the characteristics required for the specific class of applications; ii. applying alternative strategies such as the addition of plasticizers and copolymerization with suitable polymers or the use of solvents that make the material processable and suitable for the applications. In this perspective, a complete characterization of the optical, mechanical, and rheological properties of the polymer will be carried out and the effect of the addition of additives, copolymers and solvents, suitably selected in consideration of their safety characteristics for humans and l environment, on the plasticity, optical transparency and filmability of the product obtained. The results of the activity carried out in the company will be essential for the realization of the polymeric support.
b. Period of company-based study and research	6 months
c. Measurable nature of expected results and potential impact of implemented actions with reference to the aims of the Recovery Assistance	The monitoring of the student's progress will make use of a regular meetings, including: a weekly progress report, a monthly overview of the progress of the project with colleagues in

for Cohesion and the Territories of Europe programme (REACT-EU): quantifiable and measurable targets in doctoral research project in line with indicators set out in NOP reference of actions.	the research group and a monthly direct comparison with supervisors. This scheme guarantees constant contact between the student, the team, and the supervisors to share the difficulties of the project, thus allowing a fruitful discussion to overcome the critical issues in pursuing the project objectives. The supervisors will follow the development of the activities also during the periods spent at the company and abroad, supporting the company tutor and the tutor at the foreign research group, and will jointly evaluate the progress made and the goals achieved, to integrate the paths training and enhance the skills acquired in business and academia. The validation of the approaches, such as the development of polymer modification protocols for the control of its optical properties, or even modification of the polymer production process, will allow the doctoral student to acquire, through an effective training through process research, interdisciplinary and intersectoral knowledge in the field of production and modification of biobased polymers, and of the optical, rheological and mechanical characterization of such materials. This know-how is of great value for the PhD student, which can be usefully spent in various fields, from research, public and private, to specific production sectors in the field of green chemistry. The experience of staying at the company will also represent a unique opportunity for privileged exposure and experimentation in the field, in a reality that in its corporate vision is inspired by the principles of the blue economy, the closed cycle and zero waste for obtaining intelligent and sustainable products. The aims of the project proposal are in line with what is defined by the REACT-EU package which aims to support initiatives in the context of the European Green Deal, both with a view of developing knowledge and technologies capable of responding effectively to the needs of renewable energy, with a real impact on the environmental implications that the use of these technologies is destined to have, both in the perspective that the development of new technologies can be translated into their

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	industrial up-scale, with a potential impact in terms of economic and thermal jobs, both for specialized and non-specialized personnel.
C. ACTIVITIES ABROAD	6 months
a. Research activity abroad	The research period abroad will be carried out with a group that has a strong expertise in the development of devices based on thin films and 2D materials. The research activity of the project will be aimed at the creation of conductive circuits on the biopolymer film capable of tolerating its flexibility. The target will be realized through different deposition strategies of conductive materials and functionalization of the biopolymer. In the laboratories of the J. Heyrovsky Institute of Physical Chemistry in Prague, the doctoral student will create electrically conductive surfaces by depositing metallic, semimetallic or semiconductive layers on the polymer substrate with layer-by-layer transfer methods, ultra-high vacuum evaporation techniques (UHV) or direct growth on the surface of the required material. In particular, the PhD student will be trained in the oriented transfer of 2D materials (such as graphene and MoS2), thermal evaporation techniques, plasma sputtering and chemical synthesis of (semi) conductive materials on pre-functionalized substrates. The team has solid and recognized expertise in the field of low-dimensional systems and has an advanced research infrastructure. The doctoral student will have direct access (subject to adequate training) to all the equipment that could prove useful for carrying out the project. In particular, the laboratory is equipped with spin-resolved ARPES, XPS (UPS), a multitude of SPM techniques, Raman spectroscopy operating at 11 wavelengths, photoluminescence spectroscopy from deep UV to medium IR, spectroscopic ellipsometry, spectroelectrochemical configuration available for any spectroscopic instrumentation, class 1 clean room, photolithographic techniques, electrical characterization laboratory working up to the fA and nV regimes, magnetron deposition or evaporation techniques, fully equipped synthesis laboratories. The assistance of technical personnel is

	guaranteed in any case. The complex of instrumental facilities, together with highly qualified operators, represents an exceptional opportunity for the acquisition of technological, as well as scientific know-how for the PhD student. The PhD student will be actively involved in the life of the laboratory, experimenting, together with the research aspects, also the management aspects of the project activities, which will thus contribute to effectively complete his training.

SCHOLARSHIP N. 9

National Operational Programme 2014-2020
PhD programmes for sustainability and innovation-related subjects

Ministerial DECREE N. 1061 (10 Aug 2021)
Academic Year 2021/2022 – XXXVII CYCLE

INNOVATION-BASED TOPICS (ACTION IV.4)

SCHOLARSHIP N. 9

A. RESEARCH PROPOSAL

THE ENERGY FLEXIBILITY OF BUILDINGS THROUGH THE STORAGE AND CONTROL OF LATENT THERMAL ENERGY

a. Relevance of doctorate research project in creating high added value in terms of scientific, social and economic impact on Italy, fostering appropriate research models and the formation of professional profiles as a response to the requirements of the business sector for innovation and competitiveness. **A development of research on topics of innovation, digital advancement and enabling technology while supporting the enhancement of human capital, determining factors in the progress of research and innovation in Italy.**	The building air conditioning sector has long been engaged in the search for technologies capable of ensuring energy efficiency and energy flexibility. Direct electrification and thermal-electrical cogeneration are among the most pursued approaches to obtain a significant reduction in the environmental impact of the building energy demands. However, the seasonality of the heat demand, the increasing loads for refrigerant, the variability and limited capacity of the renewable electricity supply, often due to the limits of our electrical grids, are significant limits and have slowed down the replacement of traditional heating/cooling building systems based on methane combustion. In this context, there is growing attention to the electrification of buildings in conjunction with the use of energy storage and with the coupling of thermal solar energy storage to reduce the building energy demand. This is evident in cluster 5 "Climate, Energy and Mobility" of the European Horizon program which is dedicated to the development of solutions for the production, use and sustainable storage of energy.

SCHOLARSHIP N. 9

	With the electricity demand of buildings becoming more dynamic and an increasing percentage of intermittent generation of renewable energy from urban solar photovoltaics, the energy grid faces increasing challenges to manage the real-time balance between supply and demand. In this scenario, a smart response to energy demands that is able to promote thermal energy storage to promote the flexibility of energy demand, is receiving growing attention. This project focuses on different modalities of latent thermal storage through thermal batteries with phase change materials whose operation will be implemented through the use of IoT systems and the networking of different energy production and use systems. In fact, energy storage technologies promise a flexible management of energy demand, and therefore promote reliable and resilient electricity grid through the "smart" energy storage. Indeed, buildings can help the grid improve stability by optimizing flexible loads and promoting thermal storage without electric batteries. This research proposal will develop systems with phase change materials, both micro-encapsulated and macro-encapsulated, produced from animal and vegetable waste, in order to increase the sustainability of the raw materials adopted while promoting the circularity of materials between different sectors. The project will also include strong mathematical formulation to quantify energy flexibility, and therefore both coding and simulation skills will be required. This project is expected to unveil research opportunities to establish a common definition and performance metrics for the energy flexibility of buildings with thermal batteries and then develop energy flexibility systems by coupling air conditioning machines with latent thermal storage. The ultimate goal is the development of value chains for the production and use of both microscale (up to 50 kW) and medium scale (up to 500 kW) latent thermal accumulations in an urban environment.
b. Adherence of doctorate research project to National Strategies of Intelligent Specialisations (SNSI) and PNR and applicability to Law 240/2010 and Ministerial Decree 45/2013 regarding PhD students, with the aim of fostering	The challenge of the ecological transition requires the concurrence of transdisciplinary skills in order to face the different problems of an overall transition in a comprehensive way. In this case, the energy management in the urban environment requires an understanding of the implications of

innovation and exchange between the field of research and world of manufacturing and the certification of research project contributions within the sector of innovation (Law 240/2010, art. 24, section 3 and subsequent modifications and additions).	the growing penetration of renewable energy production and the exploitation of solar energy. This must be associated with energy storage systems capable of operating with automated algorithms to optimize its control. Such storage systems increasingly consider latent forms as a privileged solution to reduce volumes and increase the density of the energy charge. The present research proposal aims to study the possibility of promoting latent thermal accumulations in coupling with traditional air conditioning systems that could exploit the variability of renewable energy sources or the underuse of smart electricity grids in different periods (thus preferring operation in off periods-peak). This research proposal allows for the achievement of some of the objectives of the European Green Deal relating to the challenge of sustainability by transforming climate problems and environmental challenges into opportunities. Through dynamic simulations of the most common types of thermal plants, the optimal dimensions of latent thermal accumulations of different geometry and functioning will be evaluated. The project will also be carried out by collaborating with a company engaged in the development of innovative systems for air conditioning. The research proposal is consistent with the National Strategy of Intelligent Specialization approved by the European Commission. Specifically, the proposed project falls within the national thematic area "Smart and sustainable industry, energy and environment" which provides for development trajectories based on production processes combined with environmental sustainability and technological innovation. Furthermore, the proposed research complies with the "Climate, Energy, Sustainable Mobility" section of the PNR, and specifically the intervention areas "Climate change, mitigation and adaptation" and "Environmental energy".
c. Research activity proposal, methods and contents	The research activity, over the three years, extends ongoing researches and will focus on the following aspects: • Energy evaluations, also through dynamic numerical modeling, of small thermal storage systems with organic phase change materials. Energy demand control strategies will be developed and compared to promote energy flexibility through

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	energy demand control methodologies (ie demand-side management, DSM), including optimal controls; • Experimental evaluation campaigns in the laboratory on storage tanks with PCM of animal and vegetable origin, of which "smart" algorithms, characteristic of industry 4.0, will be implemented, through the use of IoT systems and the networking of the various production systems and use of energy.
B. COMPANY-BASED ACTIVITIES within the Italian territory	
a. Research activity to carry out with the company	The research proposal includes a 6-months research activity with the partner company.
b. Period of company-based study and research	6
c. Measurable nature of expected results and potential impact of implemented actions with reference to the aims of the Recovery Assistance for Cohesion and the Territories of Europe programme (REACT-EU): **quantifiable and measurable targets in doctoral research project in line with indicators set out in NOP reference of actions.**	Given the research outlined above, the project appears to be centered on the creation of innovative knowledge with significant scientific, social and economic repercussions on the national territory. In particular, in the choice of the research program, the formation of a professional energy management profile is anticipated. The scope is to be able to respond to the needs for innovation and competitiveness expressed by the entrepreneurial system, assimilating specialized technical knowledge concerning both the management of energy that the peculiarities of the built heritage. As seen in section A.b, the project complies with the PNR, and it is consistent with the L.240 / 2010 and the Ministerial Decree 45/2013 about PhD programs, given the growing need to encourage innovation and interchange between the world of research and the world of production and the contribution of research projects in the innovation sectors (Law 240/2010, art. 24, co. 3). The solution proposed in this project promotes green recovery oriented towards energy conservation as desired by REACT-EU which aims to finance interventions aimed at the circular economy and energy saving.
C. ACTIVITIES ABROAD	

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a. Research activity abroad	The research proposal includes six months of research activity. The research activities will concern study of the methods for identifying homogeneous types of users, the modeling of the related energy requests and the evaluation of algorithms that can predict, also through multidisciplinary approaches, the behavior of hybrid systems and multi-system type “Smart” in buildings.

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National Operational Programme 2014-2020

PhD programmes for sustainability and innovation-related subjects

Ministerial DECREE N. 1061 (10 Aug 2021)

Academic Year 2021/2022 – XXXVII CYCLE

INNOVATION-BASED TOPICS (ACTION IV.4)

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A. RESEARCH PROPOSAL **INNOVATIVE AUGMENTED REALITY INTERACTION TECHNIQUES FOR HEALTH CARE IN INDUSTRY 4.0: HUMAN CENTRED APPROACH**	
a. Relevance of doctorate research project in creating high added value in terms of scientific, social and economic impact on Italy, fostering appropriate research models and the formation of professional profiles as a response to the requirements of the business sector for innovation and competitiveness. **A development of research on topics of innovation, digital advancement and enabling technology while supporting the enhancement of human capital, determining factors in the progress of research and innovation in Italy.**	The healthcare sector is evolving with the Industry 4.0 logic towards the digitization of processes and information (e.g. digital diagnostics and electronic medical records). The growing complexity of systems and data represents an important challenge for healthcare professionals that already overburdened by the terms of work shifts, psychophysical stress, bureaucracies and responsibilities. Augmented Reality (AR) is one of the most promising solutions to this problem because it can provide a direct interface between technological systems, procedures and data, through personalized information and instructions in the visual field of the operator in the right place at the right moment. [1] This research aims to innovate in the field of the operator interface of the medical instrument by focusing on precision manual activities (milling, drilling, insertion of needles,

	etc.). The expected result is to improve performance and reduce the stress of the doctor and patient appropriately measured with laboratory and field experimentation. Moreover creating the impact on the sustainability of the process, by reducing resources plates, paper, diagnostics and disposable templates. In addition, the multidisciplinary strategic area that integrates engineering, medicine and industrial design, offers an enhancement of human life by developing innovative professional profiles that are in great demand in the digital transition of the national health system.
b. Adherence of doctorate research project to National Strategies of Intelligent Specialisations (SNSI) and PNR and applicability to Law 240/2010 and Ministerial Decree 45/2013 regarding PhD students, with the aim of fostering innovation and exchange between the field of research and world of manufacturing and the certification of research project contributions within the sector of innovation (Law 240/2010, art. 24, section 3 and subsequent modifications and additions).	Robotics is not yet able to replace the human hand, but there are areas in which even a minimal human error can have serious consequences on the patient (eg the destruction of bundles of nerves). The AR and with its recent evolutions in terms of resolution and tracking accuracy, can provide guides and visual aids that are able to reduce the risk of error and the stress of the surgeon that potentially reduce the postoperative recovery time of patient, with considerable impact in economic, environmental, human and society. The literature has already demonstrated the efficacy of AR in various medical fields [2], [3], [4], however, the current literature is focused more on technology and functionality, often leaving out both physical and cognitive ergonomic factors of medical operator. Therefore, the research topic, in line with the multidisciplinary doctoral path of Industry 4.0, is to study new methods of representing medical information in AR in the implementation of high-risk precision manual operations [5]. The innovative contribution is to apply human-centered methodologies borrowed from the world of industrial design and integrate them with those of information technology, automatic controls and engineering of the electromechanical tools used (eg torque control and milling speed). The close interaction with the medical world, from and research centers of great prestige in the sector can create synergies of interchange in the production world with medical systems suppliers present in the area. This issue is fully part of the research underway at international level [6DF], and offers important implications in terms of

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	scientific publications, but also in economic terms of patentability and commercialization in strategic sectors for the country. The expected results are publication in conferences and scientific journals and / or patenting and / or integration with existing tools. Given their generality, the methodologies can be extended to other related sectors such as the industrial one (eg precision mechanical industry, watchmaking, crafts, micro-assemblies, etc.).
c. Research activity proposal, methods and contents	A first activity is market analysis and carry out an in-depth review of the literature, and identify the most interesting medical areas in which to bring high-impact innovation. Once these have been identified, an activity will be carried out to identify the functional requirements and identify the criticalities. Questionnaires will be administered, for a holistic understanding and to collect qualitative and quantitative data. The next activity is designing the innovative interface with a human centered design approach. This phase will make use of prototyping systems, theoretically with the modeling of scenarios, storyboards, personas (virtual users), and evaluated in Virtual Reality (using Unity 3D or similar) and subsequently in the field in AR. Experimental protocols will be defined capable of acquiring user feedback directly and indirectly, the user will be fully involved in the solution of the implementation. The final phase will be to publish the results and the systemization of the added value through patenting or agreements with the biomedical industry in international scientific fields.
B. COMPANY-BASED ACTIVITIES within the Italian territory	
a. Research activity to carry out with the company	The main activities within the company are aimed at understanding the needs of the medical operator and the collection of data with interviews and surveys, focus groups with experts for the definition of scenarios and spaces for innovation. The company can provide case studies and the related quantitative data acquisition phase: digital twin modeling of existing environments and operating tools in 3D, acquisition of poses in the users' space, operational scenarios (room, devices, etc.), the

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	operating room staff acting to operate on the patient in a realistic way. Finally, the company can provide commercial channels for the creation of innovative products and systems.
b. Period of company-based study and research	6 months
c. Measurable nature of expected results and potential impact of implemented actions with reference to the aims of the Recovery Assistance for Cohesion and the Territories of Europe programme (REACT-EU): **quantifiable and measurable targets in doctoral research project in line with indicators set out in NOP reference of actions.**	This research aims to create interactive graphical information and guidelines for controlling the function of medical instruments (e.g. position in space, avoiding danger zones, milling torque control) and tools that limit the effort on the part of the operations team, exploring the effects and new methods of interaction of augmented reality for surgical processes. This research has the potential to improve the surgical success, safety and general well-being of surgeons and patients. In addition, in the long run, it can have a positive impact on society, increase the productivity and effectiveness of the surgeon, give a higher quality of treatments to patients and provide a mutual profit. The effectiveness of the methodologies will be assessed qualitatively and quantitatively through preliminary simulations in virtual reality and subsequently in the augmented reality. Protocols and metrics (error rate, execution times, operator fatigue) will be defined for the experiments including questionnaires and / or interviews (SUS test, NASA TLX). The impact will be providing better medical processes, lower error rates, and an improved quality of life for patients and doctors. From the point of view of scientific performance, the expected result is at least one international publication per year, with preference in a journal.
C. ACTIVITIES ABROAD	
a. Research activity abroad	The main activities are to use the availability of having the latest generation medical technologies directly on site, as well as a very important scientific background of reference worldwide. The company can provide the latest generation AR technologies in terms of viewers and tracking, as well as create alternative case studies.

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