Università degli Studi di Napoli "Parthenope"

Department of Engineering

PhD PROGRAM

in

ENERGY SCIENCE AND ENGINEERING

Program Organization

ESE-PhD Programme

Objectives

The doctoral program in Energy Science and Engineering (ESE), established since 2013, is a 3 years full-time study and research degree, totalling 180 credits. The research areas of the ESE include, but are not limited to: renewable energy sources; energy saving, storage, conversion and engineering, and environment engineering including technologies for waste management and process efficiency improvement.

The Ph.D. program involves several scientific fields (applied mathematics, thermodynamics and thermal science, fluid machinery and energy conversion systems, chemistry and material science, management and engineering) to give Ph.D. students a multidisciplinary stimulating environment in which to develop highly-specialised research skills.

In particular, the ESE Ph.D. program focuses on:

- Energy sources and energy conversion systems
- Energy management, simulation and modelling
- Renewable Energy Sources
- Heating, ventilation and air conditioning systems
- Energy consumption and planning
- Fuel cells
- Energy Efficiency for Buildings and Industry
- Distributed Generation and Grid Integration of Renewable Energy Sources
- Materials for sustainable energy production, storage and conversion
- Thermo-fluid-dynamic in bio-engineering
- Fundamentals of chemical processes for energy

The basic scientific skills developed in program to tackle the above mentioned topics are:

- Fluid mechanics
- Heat and mass transport
- Multiphase flows
- Computer methods for energy simulations

At the end of the PhD course, candidates will be able to:

- Use fundamental knowledge of physics, chemistry and engineering to find new, better and more sustainable ways to convert, distribute, use and manage energy.
- Write and review scientific papers in which the results of research are presented in a proper scientific manner.
- Propose research and development projects for demonstration of energy efficient products, as well as for development of such products for the market.
- Work with Small Medium Enterprises (SMEs) to bring research results to the market and/or make it available to the public.
- Work with public institutions to evaluate new technological developments, fund and spread technological knowledge to the general public.

Program organization

The overall organization of the ESE Ph.D. program is given in Figure 1.

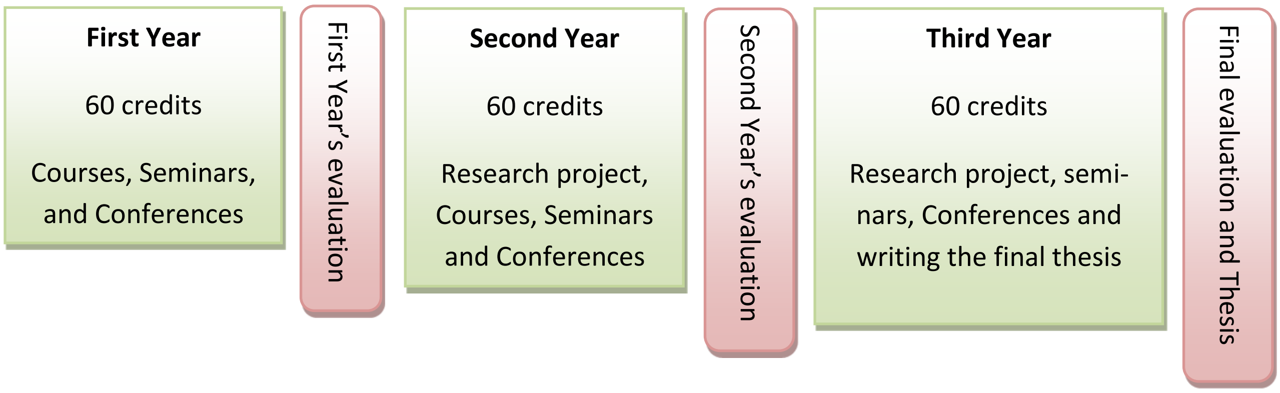

Figure 1 - Organization of the ESE-PhD program

The PhD program officially starts on November 1 of each year, however students can be evolved later during the first year.

During the first year, students must attend courses and seminars organized for the ESE-PhD program, take the related exams, and start carrying out their research under the supervision of members of the Scientific Committee of the PhD program.

Within 10 days from the end of the first year, students submit a report on the activities carried out, and the courses attended during the year, as well as the main results of their research. Students present their yearly work to the Scientific Committee, who, on the basis of their report and of the presentation, propose admission of each student to the second year of the program.

During the second year, students can still attend courses and seminars, and carry out their research project under the supervision of members of the Scientific Committee of the PhD program. Students are invited to present results of their research to conferences and to scientific journals for possible publication.

Within 10 days from the end of the second year, students submit a yearly report on the activities carried out courses or Conferences that they attended, with the main scientific results achieved during that year, and a title for the PhD thesis. Students present their activities to the Scientific Committee, who, on the basis of the report and of the presentation, admits each student to the third year.

During the third year, students complete their research project under the supervision of members of the Scientific Committee of the PhD program and write their final thesis. During the third year students must present their results to conferences and to scientific journals for possible publication.

Within 10 days from the end of the third year of their PhD program, students present the activities carried out, and the main scientific results achieved during their Ph.D. program year to the Scientific Committee. Students submit their final thesis to Committee of three external reviewers (Review Committee), proposed by the Scientific Committee and nominated by the Rector.

The Review Committee is asked to write a report on the final thesis within a month, recommending the thesis for acceptance, or acceptance with minor/major revision, or rejection.

If the final thesis is accepted with major revision, the Review Committee can ask propose up for a maximum of six months to submit a revised version of the thesis, that the Review will evaluate again. After the six months, the thesis is admitted for final discussion.

By mid-January of the year following last year the PhD program the Scientific Committee admits students to their final discussion based the activities carried out by the student and on the review of the thesis obtained from the external Review Committee. Based on these evaluations, the Scientific Committee admits students to the final presentation of their doctoral thesis.

By the same time (2 and ½ months from the end of the third year of the PhD program) the Scientific Committee proposes to the Rector the names of three experts for the final Examination Committee of the doctorate defence, who cannot be from Review Committee, and cannot have participated in the work of any of students of the ESE PhD program under evaluation.

Within three months form the end of the third year of their PhD program, students must submit to the scientific committee, and to the University Rector, final version of their thesis, which takes into account all comments received from their thesis review.

All students are required to spend at least 2 months, and up to a maximum of 18 months, in a research institution/company, during the three years of their PhD program. During this period of time, students are entitled to an reimbursement of 50% of their grant.

In order to start their research abroad, students must present an invitation letter from a tutor from a foreign institution who intends to host the student. With the invitation letter, the student must also submit to the Scientific Committee a formal request for authorization of their research activities to be carried out abroad, and for the extra grant to be paid for the period of time abroad.

The application must be signed also by the tutor of the student, indicating the months that he/she intends to spend abroad.

Upon arrival at the foreign Institutes, The tutor of the foreign Institutes sends a letter confirming the arrival of the student and the beginning of the activities at the foreign Institutes.

Teaching organization and description

The basic scientific areas of interest for the ESE-PhD program are listed below, and represent the multidisciplinarity of the program, that is needed in today's energy research and development, and are related to the main objectives of the program:

A. Thermo- fluid Dynamics and Thermal Science
B. Energy Systems
C. Chemistry and Material Science
D. Electrical, Automation, and Management Engineering

Basic courses on the above subjects are offered to PhD students from Master modules organised by the Department of Engineering at the Università degli Studi di Napoli "Parthenope".

The PhD program also offers specific courses, developed as integrated courses, taught by members of the Scientific Committee in the above areas and the specific courses, that are listed in Table 1, as well as well-known scientists from all over the world.

The specific courses are organised courses offered by the Department of Engineering the course can be taken during the following years of the program courses in modules of 12/24 hours. Each specific courses can be taught by two members of the Scientific Committee and should be taken during the first year of the course.

Specific Before getting involved with the specific courses, that provide them with the "instruments" and knowledge to develop their own research in the field of energy, PhD students are introduced to the Energy problem from different points of view, highlighted by world known scientists during seminars specifically given for the PhD program.

The modules are taught by the members of the Scientific Committee as listed in Table 2.

At least 10 credits will be gained by students through participation in seminars specifically organised for the ESE-PhD program and in Conferences that are of interest for the PhD program.

A list of events of interest for the ESE-PhD Program will be posted on the ESE-PhD website: **www.esephd.it**.

During the first year, students will also receive above training courses, that will be organised in conjunction with other PhD programs of the Università degli Studi di Napoli "Parthenope", on:

- Advanced Computer Methods for Engineering - 9 credits (course from Numerical Methods for Engineering taught to MSc students)
- Data Acquisition and Measurement - 6 credits (can be equivalent to the Energy measurement for industry taught to MSc students)
- Management of intellectual property and research projects, European funding - 1 credit
- Scientific English and writing - 6 credits (over two years – offered online)

English writing can be offered individually by qualified instructors.

The courses calendar for the year is planned at the beginning of each year.

Each course includes at least 12 hours of teaching, specific hours for individual and group study and a final examination.

The main contents of each specific course are described at the end of this document.

Instructors provide students with a course syllabus a week before the beginning of the course.

All courses are taught in English, which is official language of the PhD program.

Table 1- Scientific Committee of the ESE-PhD program

n.	Surname	Name	Institution	Position	Module
1	Arpino	Fausto	Università di Cassino e del Lazio Meridionale	Ass. Prof.	7
2	Beatrice	Carlo	Istituto Motori – CNR	First Res.	1
3	Bracale	Antonio	Università di Napoli Parthenope	Ass. Prof.	5
4	Caramia	Pierluigi	Università di Napoli Parthenope	Ass. Prof.	5
5	Carotenuto	Alberto	Università di Napoli Parthenope	Full Prof.	6
6	Chinesta	Francisco	ENSAM Paris Teach (France)	Full Prof.	14
7	Cioffi	Raffaele	Università di Napoli Parthenope	Full Prof.	9
8	Colangelo	Francesco	Università di Napoli Parthenope	Ass. Prof.	9
9	Di Donato	Camilla	Università di Napoli Parthenope	Ass. Prof.	
10	Dular	Matevž	University of Ljubljana	Full Prof.	
11	Ferone	Claudio	Università di Napoli Parthenope	Ass. Prof.	2
12	Forcina	Antonio	Università di Napoli Parthenope	Res.	13
13	Jannelli	Elio	Università di Napoli Parthenope	Full Prof.	8
14	Massarotti	Nicola	Università di Napoli Parthenope	Full Prof.	
15	Mauro	Alessandro	Università di Napoli Parthenope	Res.	
16	Kalin	Mijtan	University of Ljubljana (Slovenia)	Full Prof.	
17	Minutillo	Mariagiovanna	Università di Napoli Parthenope	Ass. Prof.	8
18	Nithiarasu	Perumal	Swansea University (U.K.)	Full Prof.	4
19	Nowak	Andrzej J.	Silesian University (Poland)	Full Prof.	12
20	Petrillo	Antonella	Università di Napoli Parthenope	Res.	13
21	Roviello	Giuseppina	Università di Napoli Parthenope	Res.	2
22	Sanchez	David	University of Seville (Spain)	Full Prof.	
23	Šarler	Božidar	University of Ljubljana (Slovenia)	Full Prof.	11
24	Sciubba	Enrico	Università di Roma"La Sapienza"	Full Prof.	9
25	Vaglieco	Bianca Maria	Istituto Motori - CNR	Dir. Res.	3
26	Vanoli	Laura	Università di Napoli Parthenope	Full Prof.	6

Table 2 –Special courses given by the Scientific Committee:

ID	Objectives	Course name	Credits
1	B	Advanced powertrain systems	3
2	C	Chemical energy conversion: combustion and electro-chemical processes.	3
3	A-C	Reactive flows and combustion	3
4	A	Computational fluid dynamics	3
5	D	Electrical power systems analysis	3
6	B	Energy Saving	3
7	A	Experimental validation of numerical models for fluid flow problems	3
8	B	Hydrogen and fuel cell systems	3
9	C	Advanced materials for energy systems	3
10	A-B	Numerical methods in energy science	3
11	A	Meshless methods	3
12	A	Inverse Thermal problems	3
13	D	Sustainability, life cycle assessment and strategic decision making	3
14		The era of "Twins" A new paradigm for simulation-and-data-based engineering as applied to materials, processes, structures, and systems.	3
		Total	**52**

Description of the specific courses contents

Advanced powertrain systems

The course will provide the fundamentals and the future trends of vehicle propulsion systems and components (fuel cell and electrical drive also in combination with internal combustion engines), powertrain configuration (ICE, Electric, CVT, Hybrid) under closed track conditions, driveline configurations, powertrain system control (including fuzzy logic, adaptive and torque based systems).

Chemical conversion of energy: combustion and electro-chemical processes.

The first part of this course will be focused on the kinetic, thermodynamic, and mechanistic principles of the combustion reaction. The chemistry of fuels, comburents, the effect of combustion on the environment and the formation of pollutants will be discussed.

The second part of the course deals with the direct conversion of chemical energy into electrical energy through electrochemical processes. The main topics will be the basics of electrochemistry, galvanic cells and batteries, principles of operation of fuel cells, basics of hydrogen production and storage. The course topics will be coordinated with the course on reactive flows and combustion.

Reactive flows and combustion

The course will address the fundamentals and the basic numerical models of chemically reactive flows and combustion processes occurring in energy conversion devices with applications to internal combustion engines and combustion systems. In particular, the students will study premixed premixed and non-premixed gaseous flames, liquid-fuel droplet combustion, ignition of gaseous mixtures combining phenomenological, chemical and thermo-fluid dynamics. The course topics will be coordinated with the course on chemical and electro-chemical processes.

Computational fluid dynamics

This course introduces an overview of the fundamental principles and the mathematical equations governing fluid flow and heat transfer phenomena, in conjunction with the course on numerical heat transfer. Moreover, the main issues of finite difference, finite volumes and finite elements methods will be given, and applications to engineering problems.

Experimental validation of numerical models for fluid flow problems

In the first part, the course describes the design and realization of experiments aimed at collecting data for the validation of Computational Fluid Dynamics (CFD) results. In the second part, the course describes numerical methods for the resolution of heat and mass transfer problems, alongside with post-processing and validation of obtained results.

Electrical power systems analysis

The course covers methods and techniques to analyse the steady state operating conditions of electrical power systems. A short introduction on the modelling of the main electrical components (line, transformers, etc.) is provided. Then, the power flow formulation problem and numerical resolution methods are illustrated.

Energy Saving

The course will address methods and techniques to reduce the need of energy in buildings and industry. Topics covered include energy balances, energy demands and consumption, HVAC and refrigeration systems, CHP systems, buildings and district heating, lighting systems, application of renewable energy systems, waste management. Particular emphasis will be given to energy consumption monitoring and control.

Hydrogen and fuel cell systems

The course provides a basic knowledge and understanding of the various types of fuel cells and their principles of operation, including developments and future trends. The balance of plant of fuel cell-based power systems will be addressed. Hydrogen production and storage will also be introduced.

Advanced materials for energy systems

This course is focused on novel organic and inorganic materials employed in energy systems, such as fuel cells, solar energy conversion, electrical energy storage devices, micro-gas turbines ecc. Basic knowledge on properties and technological manufacturing process will be discussed.

Numerical methods in energy sciences

The student will be given the basis issues in numerical modelling of power plants and energy systems, with particular emphasis on thermodynamic models. Application to energy systems and energy & buildings problems will be provided.

Meshless Methods

In the field of computational mechanics, meshless methods are those that do not require geometric connection between the nodes of the simulation domain, i.e. a mesh. They are defined on interaction of the nodes with its neighbors. The student will be given basic theoretical and coding concepts of this fast developing field that has many advantages over mesh based approaches. A spectra of practical applications of meshless methods in thermofluid sciences will be demonstrated.

Inverse Thermal Problems

The course will introduce the inverse thermal problems as an alternative to the direct thermal problems. Mathematical fundamentals and classification of the inverse thermal problems will lead one to the general method of solutions together with the discussion of specific algorithms. Students will receive also overview of typical inverse thermal problems available in the literature but as well as solved by the lecturer.

Sustainability, life cycle assessment and strategic decision making

The course has two main goals: (i) introduce to the use of environmental sustainability metrics as tools that measure the benefits achieved through a sustainability strategy, leading to informed environmental decisions and (ii) introduce the analytical solutions to improve the decision making process.

The era of "Twins" - A new paradigm for simulation-and-data-based engineering as applied to materials, processes, structures, and systems

In the previous industrial revolution, virtual twins emulating a physical system were considered as the major protagonists of simulation-based engineering. This type of twin was usually based on numerical, yet static, models that were used, often separately and independently, in designing, manufacturing and testing complex systems and their components. They were, however, not expected to accommodate or assimilate data. The reason is that the characteristic time of standard simulations was, and still is even today, not compatible with the real-time-response required to perform a meaningful intervention or control of an active process.

The next generation of twins, digital twin, allows real-time decision-making by using powerful data analytics, machine learning and artificial intelligence on the abundant collected data. Thus, predictive and operative maintenance, and data-based control can be possible. However, creating a data-based model from scratch is expensive and sometimes requires too much data that can be difficult or even impossible to collect. Hence, a hybrid paradigm seems more pertinent - a paradigm that allows also for predictions from a physics-based model, whose noticed deviations from the physical measurements provides an opportunity to learn on-the-fly. The latter can be defined as the "deviation data-based model", which represents identification issues or an epistemic ignorance inherent in the considered physics-based model. In other words, it is indeed a new paradigm of "data-based engineering and engineered data".

Though the hybrid approach, combining two models – one based on the physics and the other on the prediction/measurement deviation – seems the most appealing modeling framework. The challenge remains within the "computation time"!

In order to perform predictions in real time, models based on the physics must be calibrated and solved under the stringent real-time constraint, also the data-based model should be learned online in real-time. In both cases, Model Order Reduction (MOR) techniques open new possibilities for more efficient simulations and modeling enabling real-time feedbacks. The Proper Generalized Decomposition (PGD) method, is one of these well-established MOR techniques that consists of calculating offline a parametric model containing the solutions of all possible scenarios – while circumventing the combinatorial exposition. It enables real-time simulation, optimization, inverse and sensitivity analyses, uncertainty propagation and simulation-based control.

The Dynamic Data Driven Applications Systems (DDDAS) based on the hybrid paradigm outlined above constitutes a new era in simulation-based-and-data engineering sciences. It is applicable across materials, processes, structures, and complex systems – bridging design, manufacturing, and the systems in-operation throughout their lives, enhancing their performances and lifecycle.