DRIG

Course title	Empirical research on sustainable innovation and resilience
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY / GOAL	This module will deal with empirical research in the fields of sustainable innovation and consumer behavior, with a specific focus on surveys (questionnaire development, administration, and statistical data analysis) as well as main approaches and tools firms can consider in assessing and managing supply chain risks in order to achieve resilience in their supply chains.

DRISS

Course title	Dynamic identification and structural monitoring: fundamentals and applications to wind turbines
Scientific Discipline Sector	ICAR/08 – ICAR/09
CFU	2 (Modulo A: 1 ICAR/08 + Modulo B: 1 ICAR/09)
Year	Second
SUMMARY / GOAL	This course concerns experimental investigations of the structural response of wind turbines, in order to calibrate models for structural analysis under dynamic loads, like wind and seismic actions, and to investigate the structural health of those structures. Applicative issues will be introduced by theoretical and experimental fundamentals.

CTI

Course title	Contextual Design and Heritage: identity and material culture of the territories
Scientific Discipline Sector	SSD: ICAR/13
CFU	2 CFU
SUMMARY / GOAL	The course aims to explore the role of design in the enhancement of material culture as recommended by the 2003 UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, with a particular focus on Southern Contexts. The "intangible cultural heritage means the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage". The Heritage dimension proposed by the UNESCO Convention is a "phenomenal extension" of the field of knowledge, conservation, enhancement and re-activation of material culture in which contextual design is developing a prominent role. Contextual Design is an important field of contemporary research developed in North Europe, in the Design Academy of Eindhoven. The aim is to investigate the meaning of the material and immaterial artifacts of design in relation to the identities of the territories and to the historical and cultural stratification that distinguishes them. Contextual Design and Cultural Heritage thus become a strategic combination to face the modern challenges of enhancing territorial contexts against the current phenomena of globalization and spectacularization of culture.

CTI

Course title	Design for Historical and Contemporary Heritage Landscapes
Scientific Discipline Sector	SSD: ICAR/14
CFU	2 CFU
SUMMARY / GOAL	The Faro Convention extends the idea of heritage from the architectural dimension to the dimension of city and landscape, recognizing together with the value of the single artifact the value of the relationship between artifacts in urban or natural context. Furthermore, the Convention consider as heritage non only the “extraordinary” but also the “ordinary” architecture, not only the ancient but also the ‘modern’ architecture. The notion of heritage landscape results from this new idea of heritage. The course will deal with the themes of the project for the preservation and valorization of the heritage landscapes, both historical and contemporary, both extraordinary and ordinary. The heritage landscapes are not only the archaeological and historical landscapes but also, for example, the urban landscape of the ‘modern’ city, that of the social housing district as well as that of the disused industrial plants. In this perspective, the course will deal with theories and design techniques useful for the transformation of the heritage landscapes, necessary to preserve, valorize and resignify them.

CTI

Course title	Generative Algorithms: digital tools for parametric design and assessment of structures
Scientific Discipline Sector	SSD: ICAR/09
CFU	2 CFU
SUMMARY / GOAL	New technologies are changing the way engineers work within the construction sector. Newly developed software solutions have provided effective methods to explore the design space at the interface between Structural Engineering and Architecture, allowing more efficient design strategies. The course aims to explore the potentials of new digital tools based on generative algorisms. The course is organized into four main parts in which both theoretical and practical aspects will be illustrated: 1) Theoretical aspects of the Generative Scripting; 2) Introduction of the Python interpreter component for Grasshopper (Rhino 3D), which allows to execution of dynamic scripts; 3) Introduction to Structural Optimization; 4) Workshop: the students will be divided into groups, and they would be defining helpful generative algorithms in their research topic.

CTI

Course title	Theories and methods in structural design: modeling and experimental issues
Scientific Discipline Sector	SSD: ICAR/08
CFU	2 CFU
SUMMARY / GOAL	The shape of masonry constructions and the influence of the curvature in the load bearing capacity of arches, domes and vaults. Seismic actions and masonry constructions. Mechanical behavior of masonry: heterogeneity, different behavior in tension / compression, non-linear mechanical response, anisotropy, failure modes, damage. Modeling strategies: micromechanical models, FEM and DEM implementation of micromechanical models, macro-mechanical models, multiscale models, NT (No-Tension) and RNT (Rigid No Tension) models, macro-elements. Limit Analysis: static and kinematic approaches. From the static approach of Limit Analysis to the relation between shape and structures in masonry arches and vaults (and back to graphic statics).

DRIEI

Course title	Fundamentals of Information Security and Data Privacy
Scientific Discipline Sector	IINF 05/A
CFU	1
SUMMARY / GOAL	This course delves into the dynamic interplay between Artificial Intelligence (AI), Machine Learning (ML), and data security and privacy, highlighting both the challenges and opportunities these technologies present. The rapid advancements in Information and Communication Technologies (ICTs) are transforming society, delivering profound societal and economic benefits. This evolution is fueled by the vast availability of rich, heterogeneous data and the pervasive adoption of AI-ML approaches for data generation, analysis, and processing. However, this technological leap presents a double-edged sword in the realm of data protection. On one hand, AI-ML applications introduce new privacy and security risks, such as potential data exposure during the learning process or vulnerabilities like data poisoning attacks, which can compromise model accuracy and integrity. On the other hand, AI-ML techniques also offer transformative opportunities, enabling innovative solutions for cybersecurity and privacy-preserving data sharing. This course offers a comprehensive overview of the research issues, challenges, and opportunities at the intersection of AI-ML, data security, and privacy. Participants will explore the dual nature of AI-ML's impact, gaining insights into both the potential threats and the groundbreaking solutions it can provide for safeguarding information in the era of smart technologies. The course combines theoretical lectures with practical insights. Participants will engage with real-world case studies and hands-on sessions, enabling them to implement and evaluate interpretability techniques. A final project will require students to analyze a case study using the acquired knowledge and tools.

DRIEI

Course title	Machine learning
Scientific Discipline Sector	IINF-05/A
CFU	1
SUMMARY / GOAL	The course will provide a broad introduction to machine learning. The course will cover Supervised learning, Machine Learning systems design and evaluation, Unsupervised learning, including clustering and dimensionality reduction. By the end of the course, the course participants will be able to design and implement Machine Learning-based applications autonomously. The lessons alternate theoretical lectures and implementation examples.

DRIEI

Course title	Mechatronic Systems
Scientific Discipline Sector	IINF-04/A
CFU	2
SUMMARY / GOAL	This class provides the PhD students with analytical tools to model and simulate interconnected multi-physical dynamic systems, with a focus on mechatronic systems and actuator applications. A generalized modeling framework will be initially presented to describe engineering systems across different physical domains (e.g., mechanical, electrical, magnetic, fluidic, thermofluidic). A port-based modeling perspective will be introduced, which exploits the concept of energy to model the physical interconnection among various sub-systems in a universal and coherent way. Based on the derived framework, basic mathematical models of different types of electrostatic, electromagnetic, hydraulic, and pneumatic mechatronic systems will be derived. In parallel to model development, basic technological aspects of each class of mechatronic systems and actuators will be discussed, and the most common physical components and applications will be presented. At the end of the PhD class, the students will be able to model and simulate complex mechatronic systems consisting of the interconnection of several components with a unified thermodynamic framework, and will have a basic understanding of the operating principles of the most common types of mechatornic actuator technologies.

DRIG

Course title	A user-centered approach to Ergonomics assessment in the Industry 5.0 paradigm
Scientific Discipline Sector	ING-IND/15
CFU	2
SUMMARY / GOAL	The industry 4.0 program and the perspectives of the innovative I5.0 approach are significantly changing the role played by the operator on the smart factory shopfloor. The introduction of the mass-customization paradigm and the fast changes in the production cycle require new operators' capabilities. In particular, the I4.0 operator is requested to be a smart element in the production cycle, able to adapt to sudden changes by means of decisional capabilities. In order to strengthen such capabilities, it is necessary to optimize the working conditions so as to free operators from unnecessary tasks and allow them to use their physical and cognitive resources in an optimal manner. The Human Performance Envelope (HPE) constitutes the set of factors that define the conditions in which the operator acts and encompasses environmental, social, physical, and cognitive aspects. In order to optimize the operator's performance, it is essential to understand the processes that govern the definition of the HPE, thus allowing both designing efficient solutions and applying rigorous validation procedures. Thanks to technological innovations (e.g. low-cost tracking systems and physiological signals platforms), nowadays it is possible to apply an integrated approach for the HPE assessment using both traditional and novel methods. The course will be composed of 3 modules aiming at providing Ph.D. students with the necessary knowledge to validate in their scientific research the effectiveness of solutions designed in order to improve the operator's performance with particular attention to the HPE. Module I. Introduction and theoretical bases. The role of the Operator in the I4.0 smart factory. Introduction to the concept of HPE and its fundamental components —the physical and the cognitive workload. Basic principles of the Cognitive Load Theory. The ISO standard 11226 Ergonomics — Evaluation of static working postures. Module II. Assessment methods for physical ergonomics. Post-hoc measures (the Borg-CR 10 scale), direct methods, observational methods (the Rapid Upper Limb Assessment metrics), and innovative applications for the observational methods (the ErgoSentinel tool). Module III. Assessment tools for cognitive ergonomics. Post-hoc measures (the NASA Task Load Index, the Multiple Resource Questionnaire), task performance measures (Completion time, Error Rate, reaction Time, the dual-task design); direct methods (the electrocardiographic signal and the Heart Rate Variability Analysis approach). By the end of the course, Ph.D. students will have a broadened knowledge in the field of the Industry 4.0 paradigm through the awareness of the new role of the operator and the knowledge of the HPE concept. Furthermore, they will be able to handle tools for physical and cognitive workload assessment and for designing an experimental setup in order to validate innovative solutions for HPE improvement.

DRIG

Course title	Advanced Additive Manufacturing and Reverse Engineering design and processes for the twin transition
Scientific Discipline Sector	ING-IND/16
CFU	2
SUMMARY / GOAL	The course aim to provides PhD students with the knowledge about advanced Additive Manufacturing (AM) and Reverse Engineering (RE) processes mainly for new Repairing/Remanufacturing more sustainable solutions in circular industrial economy. In fact, the new Additive Manufacturing methods offer the best value-added, resource-efficient approach to end-of-life product recovery. The course project will be articulated in different topics: 1. Direct Energy Deposition (DED) solutions for repair and life extension. Among DED processes, Laser Powder Metal Deposition will be analysed in more detail because of its enormous capabilities, flexibility and efficiency.

DRIG

Course title	Design and management of research projects
Scientific Discipline Sector	ING-IND/17
CFU	2
SUMMARY / GOAL	This course provides essential knowledge, methodologies, and tools for designing and managing research projects. The main learning objectives are as follows: Guide participants in crafting successful proposals and developing comprehensive plans for research projects to capitalize on available funding opportunities. Focus on the objectives, methodologies, conditions, and best practices of major research programs. Familiarize students with the EU financial framework. Equip students with the principles and competencies of project cycle management. Develop the ability to precisely define the objectives, purpose, and requirements of a project. Introduce principles, techniques, and tools for the design and planning of research projects. Enhance competencies in key project monitoring and control techniques. Familiarize students with the successful dissemination principles of research projects.

DRIG

Course title	Metaverse Integration for Digital Transformation of industry
Scientific Discipline Sector	ING-IND/15
CFU	2
SUMMARY / GOAL	This course provides an in-depth exploration of the metaverse as a fundamental catalyst for digital transformation in an increasingly evolving industrial context. Balancing theory and practice, participants are guided through a series of modules designed to provide a comprehensive and applied understanding of key concepts. The introduction will outline the fundamental importance of the Metaverse in the context of the Digital Transition. The first module will explore the history and development of metaverse technologies. A clear distinction will be made between virtual reality, augmented reality and the metaverse concept itself. The second module, through the study of successful cases and the analysis of successful implementation strategies, will explore the practical applications of the metaverse in a business context. The third module will provide an overview of enabling technologies. It will examine how Artificial Intelligence and Blockchain can empower the Metaverse and accelerate the digital transition. The fourth module is highly practical. It will guide participants in designing immersive experiences and developing a strategic plan for integrating the metaverse into the corporate environment. Hands-on experience will be provided through practical sessions using virtual reality metaverse development platforms such as the Unity game engine. The course conclusions will summarise the acquired knowledge and prepare the participants for the final project. The aim of this assignment is to develop a practical project that applies the concepts of Digital Transition through the metaverse. After completing the course, the theoretical and practical learning will be reinforced by presenting and evaluating projects. The course aims to train participants as informed Digital Transition leaders, equipped with the skills to fully exploit the potential of the Metaverse in the business domain, through theoretical lectures and practical sessions.

DRIG

Course title	Smart sustainable manufacturing
Scientific Discipline Sector	ING-IND/16
CFU	2
SUMMARY / GOAL	The major issue of sustainable manufacturing activities is the management of useful information: the way we choose data to measure may strongly change the perception of its nature and influence. Thus sustainability, which is an emerging paradigm in manufacturing, is now leading the most of the scientific efforts in defining the assessment of sustainability and the collection of significant measures of transition toward actions that satisfies the economic, environmental, social and technological targets. Smartness paradigm in manufacturing, on the other hand, is deeply tied to the information management and use, provided the Digital Twins as well as Cyber Physical Systems are mostly based on data get from sensing systems and on their elaboration to predict the evolution of systems simulated. The class will bring the students to understand the main driving issues in assessing and managing sustainable manufacturing in the light of a smart transition. At the same time will put major issues to come in order to stimulate students in their scientific career to deepen open issues still remaining on the subject from a technological perspective. Contents 1CFU. Manufacturing processes and the main factors of production: material and energy. Manufacturing and sustainability. Production systems and their sustainable management. Smart manufacturing paradigms: I4.0 and 5.0. 1CFU Criteria for modeling manufacturing processes and their critical variables. Cyber Physical System and Cyber Physical Social System. Measurement of the ecological footprint of a process: carbon and water footprint. Sustainability Assessment of manufacturing processes based on 1 and 2nd law of thermodynamics.

DRIME

Course title	Acoustics and thermoacoustics
Scientific Discipline Sector	ING-IND/09
CFU	2
SUMMARY / GOAL	Coupling between acoustic waves and flames has become a central issue in the development of many modern combustion systems because of both environmental issues (noise) and the destructive interactions which acoustics can generate in combustors. Numerical tools are essential in many flames/acoustics studies but a theoretical background in acoustics and especially in acoustics for reacting flows is mandatory to tackle such problems. This course presents the fundamental concepts of acoustics and thermo-acoustic instabilities together with instability control strategies. Possibilities of data-driven approach for optimal design of stable combustion chamber will be also presented. The course is an alternation of theoretical presentations and practical work. It is divided into 5 lectures and a practical hands-on. 1) Fundamental of acoustics: theory, modelling and measurement techniques. 2) The thermo-acoustic combustion instabilities 3) Flames as acoustic element: Flame transfer functions/Flame describing functions 4) Controlling of thermoacoustic instabilities: passive and active control strategies 5) Data-driven methods for optimal design. 6) Simple hands-on.

DRIME

Course title	Hydraulic Turbomachines for Energy Recovery in Water Distribution Networks
Scientific Discipline Sector	ING-IND/09
CFU	2
SUMMARY / GOAL	Water Distribution Networks (WDNs) represent a noteworthy field for possible implementation of Small Hydropower (SHP). Indeed, WDNs experience considerable water leakages due to their age and water management authorities often divide the WDNs by inserting Pressure Reducing Valves (PRVs), which waste a potentially recoverable hydraulic head. The replacement of PRVs with turbomachines can be considered as an economically feasible solution to achieve both an effective pressure control and an energy recovery, otherwise wasted. In this framework, the course aims to provide criteria for selecting and predicting the performance of hydraulic turbomachines for energy recovery in water distribution networks. The course starts with an overview on the global scenario of renewable energy sources. In particular, hydropower sector will be deepened ranging from the large hydropower to the small/mini hydropower and its potential. Then, the available technologies to exploit hydraulic energy in water distribution networks will be illustrated (i.e., Pumps as Turbines (PaTs), Cross-flow turbines, Energy harvesting valves, etc.). Afterwards, PaTs will be investigated. After the analysis of the state of the art, the course will present performance prediction models (both theoretical and empirical). Cross-flow turbines and energy harvesting valves will be discussed in terms of performance curves and regulation techniques. Subsequently, the course will focus on methods for the selection of the proper machine for a specific WDN. Then, different case studies will be analyzed in terms of energy production and economic feasibility. The last part of the course will be focused on how to experimentally investigate a Pump as Turbine. In particular, the hydraulic turbomachinery lab (PoliBa) will be described. Then, the experimental characterization of a PaT selected for a WDN will be illustrated.

DRIME

Course title	Hydrogen for Sustainable Transportation Systems
Scientific Discipline Sector	ING-IND/08
CFU	2
SUMMARY / GOAL	Hydrogen can play a significant role in the decarbonization process of hard-to-abate transport sectors such as heavy and long-distance road transport and maritime mobility, where electrical transportation is not technically viable. Hydrogen may be used either to feed fuel cells (FCs) or burned inside ICE. The current state hydrogen FC technology is expensive and requires pure hydrogen. Furthermore, large batteries are needed to cope with the transient nature of power demands for vehicle applications, reducing the overall efficiency. ICEs can be fueled with non-purified hydrogen, resulting in significantly lower production cost of hydrogen fuel. Furthermore, they can take advantage of the existing advanced combustion and engine control technologies. The course proposes an overview of both technologies, considering their pros and cons. The course delves into the aspects related to the configuration of propulsion systems, power management systems, storage systems, as well as the problems of deterioration of fuel cells and hydrogen embrittlement.

DRIME

Course title	Introduction to fluid-structure interaction
Scientific Discipline Sector	ING- IND/06
CFU	2 CFU
SUMMARY / GOAL	The objective of this course is to deliver the key topics concerning Fluid-Structure Interaction (FSI) problems for biophysical and engineering applications. The students are expected to understand the mechanisms underlying the fluid-elastic effects in microscopic and human-scale applications, with the respective modelling approaches. The course will focus on simplified, low-dimensional models containing key aspects of real-world problems. Reference applications include bacterial locomotion, aeroelastic phenomena on airfoils, flow-induced vibrations of bridge decks, vibrations of conveying pipes. Numerical solutions will be addressed by means of a Matlab implementation.

DRIME

Course title	Offshore Wind Technologies
Scientific Discipline Sector	ING-IND/08
CFU	2
SUMMARY / GOAL	Offshore wind energy has the potential to integrate a large part of the renewable electric energy that will be produced in the coming years to meet the objectives of reducing global CO2 emissions. For Italy in particular, interest is focused on floating turbine technologies, which can play an important role in industrial development, with the integration of blue economy activities in ports and at sea. However, floating wind turbines still require fundamental research on platforms, turbines and mooring technologies to make them fully competitive for use in the Mediterranean, where wind speeds and sea states are lower than in northern Europe. The course provides an overview of floating turbine technologies, considering their advantages and disadvantages and their possible integration with other offshore power generation systems such as wave energy converters and floating photovoltaic platforms. The course covers aspects related to digital tools for identifying areas suitable for the development of marine renewable energy sources, tools for performance analysis and simulation, ranging from simplified models based on BEM to more accurate CFD simulations.

DRIME

Course title	OPTIMIZATION THEORY
Scientific Discipline Sector	MAT/05
CFU	2 CFU
SUMMARY / GOAL	Mathematical Formulation. Control of production and consumption. Reproductive strategies in Social Insects. Pendulum. Moon lander. Rocket railroad car. Controllability of Linear Systems. Observability. Bang-Bang Principle. Time Optimal Control. Calculus of Variations and Hamiltonian Dynamics. Pontryagin Maximum Principle. Control of production and consumption. Linear Quadratic Regulator. Maximum Principle with transversality conditions. Distance between two sets. Commodity trading. Hamilton-Jacobi-Bellmann equation. Dynamic programming. Connections between dynamic programming and the Pontryagin Maximum Principle. Differential games. Isaacs equations. Games and the Pontryagin Maximum Principle. War of attrition and attack.

DRISA

Course title	DoE and Robust Design applied to setup optimization for numerical and experimental testing
Scientific Discipline Sector	ING-IND/14
CFU	2 CFU
SUMMARY / GOAL	The aim of the course is to provide skills in the definition of statistically robust setup and analysis of experimental and/or numerical plans in order to reduce the impact of the noise.

DRSATE

Course title	Bio-residues and geomaterials for sustainable engineering: from multiscale characterisation to mechanical improvement
Scientific Discipline Sector	CEAR-05/A (ICAR/07)
CFU	2 CFU
SUMMARY / GOAL	The sustainable use of resources is a crucial aspect in a scenario of exponential increase in their consumption, driven by a growing global population and a continually accelerating global economy. It is therefore a duty for today's researchers to find out new strategies that enable such development while minimizing the consumption of the planet's primary resources. This approach, inspired by principles of circular economy and sustainability, can be applied to various fields of engineering. Specifically, scientific approaches will be presented to implement more sustainable management of different residues, mainly of marine origin, such as shells, dredged soils, algae, and seagrass. Dredged sediments, for example, are one of the most environmentally impactful natural materials to be managed nowadays due to the massive amounts that are dredged periodically in Europe (approximately 200 million m3 per year), both to ensure the effective functioning of activities in port areas and, when contaminated, for remediation of polluted sites. In this context, various studies anticipate their mechanical improvement using traditional binders, such as cement that is the source of about 8% of the world's carbon dioxide (CO2) emissions. The course will showcase recent approaches paving the way to transform these residues into new secondary raw materials useful for various industrial sectors. In detail, the geo-chemo-hydro-mechanical characterisation at multiple investigation scales of both the residues to be treated and the new geomaterials produced will be presented, in order to identify the reuse potential of the waste soils beforehand and the geo-mechanical performance of the new geomaterial afterward, depending on the intended use. Examples of products and applications in different industrial fields. Case studies and ongoing- EU projects related to the specific topic.

DRSATE

Course title	How to build an ontology that lasts for design matters: Theory.
Scientific Discipline Sector	ICAR/20
CFU	2 CFU
SUMMARY / GOAL	'Applied Ontology' is an approach developed within Artificial Intelligence and aimed to build symbolic representations of (a fragment of) reality. The use of applied ontology ensures that the result is conceptually coherent, semantically clear and computationally robust. In this course we introduce the motivations and methodology of applied ontology focusing on (a) the distinction between data and information; (b) the DOLCE ontology; (c) the conceptual analysis of simple scenarios of urban and social interest; (d) methodologies for ontology-based model construction; and (e) the use of software (e.g., Protege) for ontology construction.

DRSATE

Course title	How to build an ontology that lasts for design matters: Lab.
Scientific Discipline Sector	ICAR/20
CFU	1
Year	Second
SUMMARY / GOAL	The course aims to develop models to build ontological representations of knowledge, applied in particular to Town and Country Planning (PIanificazione urbanistica e territoriale) and Territory Engineering (Ingegneria del territorio). Lessons learned from recent Poliba research, such as the monastery as an architectonical type and urban square as a physical and social place, will be retrieved and discussed. As a whole, the program is focused on: (i) a brief introduction recalling basic aspects of theory; (ii) examples and exercises for application to each studied disciplines, particularly to Town and Country Planning and Territory Engineering. In this lab course each student will be asked to develop a work concerning the application of theoretical topics to a specific case, which can be identified at their choice among the topics of their doctoral course.

DRSATE

Course title	Sustainable Mobility and Shared Mobility in a Smart Cities framework: optimization models and applications
Scientific Discipline Sector	ICAR/05
CFU	1 CFU
SUMMARY / GOAL	Shared mobility is one of the possible solutions for reducing the traffic congestion problem following the sustainable mobility perspective. It offers the potential to enhance the efficiency, competitiveness, social equity, and quality of life in large cities. The goal of this course is to provide the Ph.D. students the theoretical background and knowledge necessary to manage optimization models for solving shared mobility problems considering environmental aspects. Moreover, basic knowledge in using IBM ILOG CPLEX and MATLAB software for solving Integer Linear Programming models is carried out. The lectures will be structured into two parts. The first part of the course will be focused on the introduction to shared mobility and recent technologies applied to reach the Mobility-as-a-Service concept. Furthermore, a short introduction about optimization models, e.g., Vehicle Routing Problem, for solving transportation issues. The second part of the course will deal with exercises of Integer Linear Programming models through the usage of IBM ILOG CPLEX and MATLAB software.

DCMCEI

Course title	Elements of digital transition in civil engineering
Scientific Discipline Sector	ICAR/02
CFU	2
Year	Second
SUMMARY / GOAL	The course aims to provide elements of digital transition tools in water engineering and the concept of Digital Twin and Digital Water Service. The students were introduced to advancements in data acquisition, storage and representation with the latest methodologies developed from technical-scientific research based on complex network theory, machine learning and multi-objective optimization. The final aim is to provide PhD students with effective and transferable products that implements efficient processes to face various technical issues. Advanced applications to Water Distribution Networks (WDNs) will be used as benchmarks, involving students in applying Digital Water Services to integrate the concept of Digital Twin, tailored for WDNs, with well-established algorithms and methodologies, to support solving WDN life-cycle management issues.

DCMCEI

Course title	Innovative evaluation techniques to support the implementation and management of civil constructions
Scientific Discipline Sector	ICAR/22
CFU	2
Year	Second
SUMMARY / GOAL	The course aims to provide an essential overview of the main evaluation techniques to support decisions in local interventions, also with reference to public-private partnership models. Contents in summary form: – Estimate and innovative tools for the construction of civil works; – Financial analysis and economic analysis (ACB) for the evaluation of investments and the estimate of the impact on the community; – Multi-Criteria Decision Analysis (MCDA) to support decisions in complex contexts: the construction of multidimensional indicators for the implementation and management of civil works.

DCMCEI

Course title	Low carbon structural design and retrofitting of concrete infrastructures using advanced composites
Scientific Discipline Sector	ICAR/09
CFU	2
Year	Second
SUMMARY / GOAL	The main contents of the course are: – Introduction to low-carbon structural design. – Fibre-Reinforced Materials in civil engineering construction. – Innovative reinforcement for resilient concrete structures. – Retrofitting concrete structures using advanced composites.

CTI

Course title	The architecture of construction
Scientific Discipline Sector	SSD: ICAR/12
CFU	2
Year	Second
SUMMARY / GOAL	The course includes a first part with focus on the Form of Construction, i.e. the formal codes that constitutes the basic topics of structural forms; the second part deals with the knowledge of structural elements and the corresponding compositional techniques. The formal fundamentals comprise essentially the masonry wall system, the trilith system and the frame system, which are declined in specific and possible variations, depending on the use of materials and production techniques. At the same time, other formal principles focus on covering systems: the flat roof, the pitched roof, the vault, the dome. The course starts with a historic excursus that explains the origins of these structural fundamentals, the consolidation processes and the development due to the strengthening of techniques. A special attention shall be given to the best practices of the 20th century, in circumstances where the structural conception assumes a particular relevance in meeting the needs of "the architecture of techniques", i.e. skyscrapers, factories, commercial warehouses, religious buildings etc.

CTI

Course title	The post-growth paradigm in planning research
Scientific Discipline Sector	SSD: ICAR/21
CFU	2
Year	Second
SUMMARY / GOAL	The educational objective of the course The post-growth paradigm in planning research is to offer PhD students the tools to understand the complexity of the contemporary world and acquire the ability to develop an autonomous and conscious thought with respect to the problematic issues and challenges that it arises. The course therefore aims to deepen the main phenomenologies of the post-growth paradigm in the city and in the territory, and at the same time discuss the lines of research that the disciplines of the territory, and in particular urban planning, have started in recent decades. There will be frontal lectures and exercises, closely integrated, that articulate the course in two parts. The first part of the course will be dedicated to thematic lectures, in which the themes of the post-growth paradigm, its causes and material manifestations will be deepened; moreover, the paths of the contemporary urban research will be outlined, in the directions of a renewed relationship with the existing, of the valorization of the territorial heritage, of the integration and contamination with the disciplines that deal with the themes of sustainability and climate change. The second part will be dedicated to exercises to be developed with reference to specific case studies representative of current research. These will take place in the form of interlocutions that, through comparison, will help doctoral students to acquire an autonomous ability to apply the knowledge acquired through analytical and critical tools useful to interpret the different theoretical positions and evaluate the operational consequences. The attribution of training credits will take place through an interview, aimed at verifying the acquisition of knowledge and skills by the doctoral student. In the evaluation will also take into account the participation in training activities carried out.

DAUSY

Course title	Linear and nonlinear Kalman filtering: theory and applications
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY / GOAL	This course aims to provide both theoretical and practical tools to tackle estimation problems encountered in several areas of engineering and science. In particular, it is shown how to formulate such estimation problems as instances of a general dynamical system state estimation problem and how to derive the mathematical solution of the latter problem. Then it is shown that, for a linear Gaussian system, such a solution yields the well known Kalman filter. Further, approximate techniques (e.g. extended and unscented Kalman filters, particle filter, etc.) are presented for the case of nonlinear and/or non-Gaussian systems, for which an exact closed-form solution cannot be found. To conclude the theoretical part, theoretical limitations (i.e. the Cramer-Rao lower bound) on the quality of estimation are discussed. In the final part of the course, we illustrate some applications of linear/nonlinear Kalman filtering (e.g., tracking, robotic navigation, environmental data assimilation).

DAUSY

Course title	Non-linear Control
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY / GOAL	The course introduces analytical tools for the analysis and design of nonlinear control systems. At the end of the course students will understand how to analyze the stability of nonlinear dynamic systems and knowledge of some of the main approaches for designing nonlinear controllers. Basic engineering examples and Matlab exercises are provided.

DRIEI

Course title	Electric power system markets and planning
Scientific Discipline Sector	ING-IND/33
CFU	1
Year	Second
SUMMARY / GOAL	The aim of the course is to provide information about the organization of electric power system planning and operation with different levels of electricity markets for the provision of energy and services. The classroom activities will deal with: • Power system evolution • Power system development planning and scenario approach • Power system regulation services and reserves • Structure of electricity markets, coupling, grid models, and new regulation services Scientific papers and books on the selected arguments will be used as reference The examination method is represented by a synthetic report on a chosen topic.

DRIEI

Course title	Matlab recipes for measurement signal processing
Scientific Discipline Sector	ING-INF/07
CFU	2
Year	Second
SUMMARY / GOAL	The aim of the course is to present, with a “hands on” approach, a number of useful techniques to acquire and process measurement data, with actual implementation in Matlab. The programme of the course is intended to be adjusted on-the-fly, according to the actual background of the students (in order to avoid too simple or too advanced topics), and to meet actual topics of interest for their Ph.D. work.

DRIEI

Course title	Numerical Methods for Multidimensional Differential Problems
Scientific Discipline Sector	MAT/08
CFU	1
Year	Second
SUMMARY / GOAL	This course will provide an advanced level overview on the numerical solution of partial differential equations and computational models for differential problems. Within a rigorous mathematical setting, the major classes of numerical methods will be analyzed and critically discussed. Consistency and stability will be also accounted providing essential guidelines for the choice and implementation of numerical methods for differential problems. The course syllabus follows: • Transport equations. Scalar transport problem, a priori estimation. System of hyperbolic linear equations. Finite difference technique, scalar equation discretization and discretization of a system of hyperbolic linear equations. Boundary conditions. • Equivalent models for transport equations. • Kinetic BGK-like models. Kinetic models for hydrodynamics and traffic laws. Convergence and Stability. Computational aspects. • Description of parallel computing structures and strategies. Shared memory VS distributed memory.

DRIEI

Course title	Supervision and monitoring of renewable energy systems
Scientific Discipline Sector	ING-IND/31
CFU	1
Year	Second
SUMMARY / GOAL	The course aims to introduce the fundamental concepts for the monitoring of the electrical and energy performance of plants/systems based on Renewable Energy Sources (RES), notably photovoltaic systems, and for the diagnostics of anomalies or failures. 1) Supervision and monitoring systems for RES 2) Statistical tools for performance analysis of RES 3) Infrared analysis for the fault detection of RES

DRIME

Course title	Adjoint methods for gradient-based optimisation and control of energy systems
Scientific Discipline Sector	ING- IND/08
CFU	2
Year	Second
SUMMARY / GOAL	The course then aims at providing PhD students with the fundamental knowledge and the main techniques for the optimization and control of energy systems using adjoint methods. Adjoint methods are powerful mathematical tools that play a crucial role in sensitivity analysis, gradient computation, and optimization of complex systems. In this course, we will focus on their application in energy systems, covering both theoretical foundations and practical implementation. The student will understand the fundamentals of adjoint methods and their relevance to optimization and control. He will be able to apply adjoint methods to: (a) perform sensitivity analyses on linear and nonlinear partial differential equation; (b) explore optimization techniques using adjoint methods for energy system design and control; (c) gain hands-on experience in implementing adjoint methods through practical examples and exercises; (d) investigate real-world applications of adjoint methods in propulsion systems, power systems, and other energy domains. Syllabus: 1. Introduction to adjoint methods a. Importance in optimization and control b. Historical context and development c. Mathematical Foundations 2. Review of calculus and differential equations a. Introduction to variational calculus b. Linear algebra and optimization concepts c. Sensitivity Analysis 3. Computing gradients using adjoint methods a. Numerical aspects and implementation b. Gradient-based optimization algorithms 4. Formulation of optimization problems in energy systems a. Constrained and unconstrained optimization b. Case studies in energy systems 5. Introduction to control theory a. Optimal control using adjoint methods b. Feedback control and stability analysis 6. Hands-on exercises with MATLAB a. Implementation of adjoint methods b. Simulation and analysis of real-world energy systems 7. Automatic differentiation and adjoint methods

DRIME

Course title	Contact Mechanics
Scientific Discipline Sector	ING-IND/13
CFU	2
Year	Second
SUMMARY /GOAL	The course focuses on the contact mechanics of smooth and rough deformable solids. The effects of interfacial interactions, such as adhesion and friction, on the contact behaviour are also studied. Probability theory for rough surface analysis is also briefly discussed.

DRIME

Course title	Digital Manufacturing for Biomedical Applications
Scientific Discipline Sector	ING- IND/16
CFU	2
Year	Second
SUMMARY / GOAL	The program introduces digital manufacturing with a focus on biomedical applications. It covers the basics of 3D printing technologies, materials, and processes specific to the biomedical field. The program also includes a practical component where students will work on a small project, applying what they have learned. The final assessment will concern the participation in class discussions and activities and the evaluation of the small project.

DRIME

Course title	Manufacturing modeling and simulation
Scientific Discipline Sector	ING- IND/16
CFU	2
Year	Second
SUMMARY / GOAL	This program provides a comprehensive introduction to manufacturing modeling and simulation. It covers the definition and importance of modeling, various modeling techniques, the role of data, and the interpretation of simulation outputs. The course also includes case studies and a hands-on project to apply the learned concepts. The final assessment will concern the participation in class discussions and activities and the evaluation of the hands-on project.

DRIME

Course title	Non-Destructive (NDT): Process, Types and Applications in Mechanical Engineering
Scientific Discipline Sector	ING- IND/14
CFU	2
Year	Second
SUMMARY / GOAL	The course aims to provide PhD students the basic principles of main methods of Non-Destructive Testing for structural diagnostics. PhD students will develop skills related to the use of techniques such as penetrant tests, eddy currents, magnetic particles, thermography, and ultrasound. The lab activities will be focused on Active and Passive Thermography techniques: Pulsed thermography, Lock-in Thermography, Step Heating thermography and Thermoelastic Stress Analysis.

DRISA

Course title	Hydraulics for Aircraft
Scientific Discipline Sector	ING-IND/08
CFU	2
Year	Second
SUMMARY / GOAL	The course will enable PhD students to gain knowledge about conventional and novel hydraulic systems employed in aircraft for fuel metering and for flight control. In addition, students will master Simulink simulations of these systems. The acquired knowledge can be transferred to the study and simulation of hydraulic components and systems employed in industry and in the transportation sector.

DRISA

Course title	Space Commercialization
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY / GOAL	The aim of the course is to develop knowledge about the market challenges and the business opportunities offered to the new generation of European space entrepreneurs by the emerging space economy.

DRISA

Course title	Spacecraft Structural Dynamics & Loads
Scientific Discipline Sector	ING-IND/04
CFU	2
Year	Second
SUMMARY / GOAL	The course aims to explain basic notions as well as some advanced concepts about structural dynamics and its importance in the development of the spacecraft structures (design, analysis, and test). Both numerical methods and experimental results will be presented.

DRISS

Course title	Bridges and critical infrastructures: seismic risk and wind-structure interaction
Scientific Discipline Sector	ICAR/09
CFU	2
Year	Second
SUMMARY / GOAL	This course aims to investigate the structural response of bridges and high-rise buildings under the simultaneous action of wind flow and seismic impulse. The main goal is to estimate the multi-hazard effects on flexible structures, the seismic and wind actions. The calculation of the induced vibration and the comfort limits for users and occupants will be discussed.

DRISS

Course title	Seismic risk of reinforced concrete buildings: innovative modeling, analysis, and mitigation strategies
Scientific Discipline Sector	ICAR/09
CFU	2
Year	Second
SUMMARY / GOAL	This course aims to investigate the reinforced concrete response of some cases study. The structural response of reinforced concrete buildings will predict through Machine Learning applications. In particular, Matlab algorithms and Straus software will be used and discussed in this course. This approach will be discussed.

DRSATE

Course title	Sustainable Technologies for Circular Economy in Waste Management
Scientific Discipline Sector	ING-IND/22
CFU	2
Year	Second
SUMMARY / GOAL	Today's linear economic model (take-make-dispose) is wasteful and unsustainable. In a circular economy, the maximum value is extracted from resources in use, then products and materials are recovered and regenerated at the end of each service life. The transition from a linear economy to a circular economy is currently one of the biggest challenges in the field of waste management. In this perspective, the aim of this course is to develop scientific and technical aspects on the closing the loop of both urban and industrial waste. The goal is to ensure PhD students obtain a solid background in environmental technologies, with competencies for designing and tailoring new waste management systems, and with a specific view to the sustainability of processes and technologies. The course is developed on principles of Circular Economy and Sustainable Development, on circularity as a tool for saving non-renewable raw materials and reducing the waste production. In particular, the lessons discuss basic scientific principles and recent technological advances in current strategies for resource recovery from waste (for example: recycling of dry waste and composting of organic waste). Also, the course presents solutions to pressing problems associated with waste management and treatment, as well as the health impacts created by improper waste disposal and pollution. The major topics covered by the course are: 1) circular economy and sustainability: basics and application; 2) closing the loop: the circularity as a tool for saving raw material and natural resources and to reduce waste production; 3) industrial symbiosis and urban mining definition; 4) recovery and recycling of industrial and urban waste; 5) innovative and sustainable technologies: pre-treatment and selection, mechanical-biological treatment, energy recovery, disposal in landfills; 6) use of secondary raw materials.

SSI

Course title	Energy storage
Scientific Discipline Sector	ING-IND/08
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	The course addresses the topic of energy storage with a multidisciplinary approach, analyzing the differences between thermal and electrical storage from a global perspective
Syllabus	This course examines different energy storage technologies, empowering the reader to make informed decisions on which system is best suited for their specific needs. Decarbonization is a crucial step towards a sustainable future, and renewable energy plays a vital role in making this transition possible. However, the intermittency of some sources such as wind and solar energy requires the use of energy storage systems. The course contains a detailed study of the fundamental principles of energy storage operation, a mathematical model for real-time state-of-charge analysis, and a technical analysis of the latest research trends, providing a comprehensive guide to energy storage systems. From battery storage systems to hydrogen storage systems, this course provides the tools to effectively manage energy and ensure that excess energy is utilized during times of deficit and signposts the likely future development and lines of research enquiry for each technology discussed.
Bibliography	Energy Storage Systems: Fundamentals, Classification and a Technical Comparative, José Manuel Andújar Márquez, Francisca Segura Manzano, Jesús Rey Luengo
Examination method	Written

SSI

Course title	Microgrid structures and operation
Scientific Discipline Sector	ING-IND/33
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	The aim of the course is to describe the methodologies and procedures for planning, managing and controlling multi-energy microgrids, in AC or DC configurations, in grid-connected and islanded modes. Control and supervision of an MG is carried out by a SCADA system that, through proper Energy Management System (EMS), can optimize operation and reliability.
Syllabus	Smart grids and microgrids Planning, management and operation of microgrids in the presence of electric and thermal demand The role of microgrids in markets and enhanced grid integration through ancillary services Design, programming and control of DC microgrid for supplying electric vehicles Experiences on experimental microgrid management and operation.
Bibliography	Scientific papers and books on the selected arguments.
Examination method	A synthetic report on a chosen topic.

SSI

Course title	NIR and MIR laser coupling with fibers
Scientific Discipline Sector	FIS/01 – FIS/03 - FIS/07
Hours of instruction	20
CFU	2
Year	Second
Goal	The goal of the course is to provide students with the basic concepts of how light is guided in optical fibers and how their structure can be optimized to guide near-infrared (NIR) and mid-infrared (MIR) sources.
Syllabus	1. **Step-Index Waveguides:** starting from the scalar Helmholtz equation, hybrid modes HE and EH will be derived in solid core waveguides. 2. **Hollow Core Waveguides:** the propagation of light in void structure will be analyzed, focusing on the several materials employed to realize hollow core waveguides. 3. **Simulation of Solid and Hollow Core Waveguides:** solid and hollow core waveguides will be simulated with COMSOL. 4. **Laboratory activity:** realization of an optical setup for alignment of laser sources with hollow core fibers and measurement of the beam profile of NIR and MIR-coupled sources.
Bibliography	Clifford R. Pollock, Michal Lipson - Integrated Photonics (2003, Springer) Xingcun Colin Tong - Advanced Materials for Integrated Optical Waveguides (2014, Springer)
Examination method	Report on laboratory activity