UNIVERSIDAD POLITÉCNICA DE MADRID

Escuela Técnica Superior de Ingeniería y Diseño Industrial

Master's Degree in
RENEWABLE ENERGIES AND ENVIRONMENT

DOSSIER

19th Edition **2024-25**

GENERAL DATA

Academic title: "Master's Degree in Renewable Energies and Environment"
Title type: "Permanent Learning MSc" of Universidad Politécnica de Madrid (UPM)
Centro responsable: Escuela Técnica Superior de Ingeniería y Diseño Industrial (ETSIDI) of UPM
Duration: 60 ECTS (European Credit Transfer System) along 2 semesters (~600 h formation)
Methodology: face-to-face with some on-line support
Location: ETSIDI, Ronda de Valencia 3, 28012 Madrid - SPAIN
Dates. Start: October 1st 2024. End: June 30th 2025. Final project (Master Thesis) submission: October 30th 2025
Schedule: 18:30 - 21:30 h from Monday to Friday
Available places: 25 students
Tuition fees: 6.480 €

The tuition fee includes, on the part of the ERMA Master:

- Face-to-face classes and practical activities
- Classroom materials on line
- Internet access to the Moodle platform with exclusive access for consulting/downloading documentation.
- Attention to doubts and queries outside class hours during the teachers' tutoring hours.
- Evaluation tests, realization, correction and revision
- Basic Personal Protective Equipment and transport for technical visits.
- Mentoring and defence of the Master's thesis.
- Dissemination of CV in collaborating companies, management of internships in companies.
- Certificate issued by the Master with the grades corresponding to each module.

and as a student of the UPM:

- Institutional email, private area in *Politécnica virtual* with e-mail manager, access to resources, etc.
- Wi-Fi and Remote Access Service UPM-VPN
- ONEDRIVE UPM with Microsoft Office 365, including 1 TB of storage capacity.
- Access to scientific journals and online databases, AENOR Standards.
- UPM student card and corresponding accident insurance

Scientific or technological field (UNESCO nomenclature):

Within the field "Energy Technology" (3322), the subfields: "Power Generation" (332202) and "Non-Conventional Energy Sources" (332205).

Academic requirements. The ERMA Master's Degree is aimed at participants with the following degrees:

- Degrees in Engineering, Architecture, Physical, Chemical and Environmental Sciences.
- Bachelor's and master levels in engineering and architecture degrees.
- Bachelor's Degrees in Physical, Chemical and Environmental Sciences.
- University Degrees in Engineering and Bachelor's Degrees from other countries.

Other requirements: have your own laptop with the following minimum characteristics:

- Windows 11, Processing speed: 1 GHz, RAM memory: 4 GB. Free hard disk space: 100 GB
- Minimum screen resolution: 1280 x 720. NET 4.8 framework. Graphics card supporting OpenGL 2.0

Administrative secretariat:

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BRIEF PRESENTATION

The ERMA Master was launched in 2006, being the 2024-25 academic year the 19th edition. So far, 450 students have graduated from the past editions. The degree of satisfaction of the participants in all the editions has been, and is being, very high and the interest it arouses is unquestionable, as the number of applications is more than twice the available places. In recent years, the ERMA Master's Degree has been at the top of the annual ranking of the newspaper El Mundo on the best postgraduate energy programmes offered in Spain, which is a recognition of the efforts made to offer this excellent training.

OBJECTIVES

The aim of the degree is to provide high-level technical training in clean energy production technologies and their implications for sustainable development, with a view to integration into the related business and institutional sector.

The ERMA Master contributes to the United Nations Sustainable Development Goal (SDG) 7: 'Clean and Sustainable Energy' in its targets: universal access to modern energy, increasing the global share of renewable energy and doubling the improvement of energy efficiency. It also contributes to the other SDGs related to energy for sustainable development, as specified in each module and, in particular, to SDG 13 Climate action, in its targets on reducing greenhouse gas emissions, climate resilience of energy infrastructure and sustainable energy strategies.

The focus of the ERMA Master's degree is on engineering applied to renewable energy and energy efficiency projects, technologies and processes, with direct integration in the professional sector. Using software, legislation, technical solutions, etc., from the business sector, including the analysis of the economic profitability of projects and their environmental viability.

The technical level of the contents, the experimental developments proposed and the methodology of the ERMA Master, provide participants with the ability to innovate, put into practice, develop and apply ideas in emerging environments such as those related to renewable energies and in broad contexts, usually multi-disciplinary.

METHODOLOGY

The Master's degree is taught face-to-face with online support. A variety of methods will be used for face-to-face classes:

- Participative lectures
- Sessions where case studies and projects are developed.
- Laboratory and field practice sessions
- Technical visits

Each module is taught by a large number of speakers, whose main contribution is their direct professional experience.

Each student will have at their disposal specific classroom material to follow each module through a Moodle web platform, with exclusive access, where they will be able to download various resources provided by the teaching staff: presentations, technical documentation, case studies, legislation, reports, etc. You will also have individual licences for the software used: WAsP, Windpro, PVsyst, Homer pro, T*Sol, HMH-SPV, etc. to install on your laptop. The delivery of assignments, reports, exercises, works, etc., as well as the news and discussion forums, are carried out through the Moodle platform.

EVALUATION

For each module: Continuous assessment, based on multiple-choice tests, questionnaires, preparation of practical case reports, pre-projects, presentations, assignments, portfolios, etc.
For the Master's Thesis: Report on the work carried out. Public presentation before an Assessment Committee made up of Master's specialists in the topic. The presentations will take place on the days set in July or October.
Follow-up: participants in the Master's programme will be monitored once they have completed it, in order to facilitate and evaluate their professional integration.

TEACHING STAFF

The ERMA Master is taught by around 120 lecturers with the following backgrounds:

- 65 % are **experts from companies** related to the energy, renewable and environmental sector.
- 30 % are **professors and researchers** of the Polytechnic University of Madrid from 7 Schools, University Institute of the Automobile 'INSIA', Institute of Solar Energy, etc.
- 5 % are **researchers** from research, development and innovation centres such as IMDEA ENERGÍA, CENER Foundation, Centre for Research and Environmental Studies CIEMAT, Higher Council for Scientific Research CSIC, etc.

MATERIAL RESOURCES

Máster Classroom. Dedicated classroom with WIFI, live broadcasting possibilities of the classes and state-of-the-art air purifiers with the capacity to remove all biological material from the air, renewing the air with a frequency similar to that of an operating theatre.

- **ETSIDI Photovoltaic laboratory-terrace.** It has several monitored photovoltaic systems with a total power of 82 kWp with more than 250 PV modules of all technologies. There are also several autonomous photovoltaic systems and various material for practice. There is an exhibition area showing the historical evolution of photovoltaic technology, materials & equipment. Recently, it´s been added a pilot system to produce green hydrogen.

- **Environmental Laboratory of the Department of Mechanical, Chemical Engineering and Industrial Design ETSIDI UPM.** Equipped with infrastructure for simulations, waste characterisation, obtaining bio-fuels from energy crops or waste oils, etc.

- **Laboratory of Fluid Mechanics and Hydraulic Machines of the Department of Mechanical, Chemical Engineering and Industrial Design ETSIDI UPM.** Consisting of a turbine test bench, a pump test bench and two hydraulic test benches with equipment for individual tests: head losses, Pelton turbine, etc.

- **"Workplace" ORMAZABAL del Departamento de Ingeniería Eléctrica Electrónica Automática y Física Aplicada ETSIDI UPM.** Classroom with company and subscriber transformer stations that allows visualizing the components and making maneuvers and measurements

FORMATION STRUCTURE

Students must complete 48 ECTS [1]of modules and 12 ECTS of Master's Thesis.

The modules are listed below, grouped by thematic blocks:

	BLOCK I GENERAL ASPECTS OF RENEWABLE ENERGIES	ECTS
1	Energy market	3
2	Energy storage	1,5
3	Renewable resources	1,5
	BLOCK II DISTRIBUTED RENEWABLE ENERGIES	
4	Low temperature renewable thermal energies	3
5	Stand-alone systems and microgrids	3
6	Photovoltaic self-consumption	5
7	Energy efficiency in buildings and industry	3
	BLOCK III RENEWABLE ENERGY PLANTS	
8	Photovoltaic power plants	3
9	Onshore wind power farms	3
10	Onshore wind power farms energy assessment	1,5
11	Offshore wind farms	2
12	Mini-hydro and marine power plants	1,5
13	Thermosolar energy and bioenergy	2
14	Grid integration of renewable energies	1,5
15	Hybrid and storage plants	3
	BLOCK IV OTHER VECTORS AND RENEWABLE APPLICATIONS	
16	Green hydrogen technologies	2
17	Renewable energies for transportation	3
18	Renewable energy sustainability	3
19	Universal access to energy	1,5
20	Conferences	1
	Master's Thesis	12
	TOTAL ECTS	**60**

[1] ECTS: European Credit Transfer and Accumulation System. 1ECTS C corresponds to approximately 20-25 hours of student work: 10-12 hours of lectures (including problems and lab sessions) and about 12 hours of personal study.

Module 1. Energy market 3 ECTS

OBJECTIVES: To understand the current situation of the energy sector and its future prospects, from a technical and environmental point of view. To understand the functioning of the electricity market and the electrical power system. Introduction to the regulation of the different subsectors: electricity, gas and renewables.
Analyze the viability of renewable energy projects and their impact on the country's economy. Training to assess environmental problems and develop solutions.

CONTENTS:
The regulatory framework of the energy sector.
The global energy system.
Operation of the electricity power system.
Functioning of the electricity market.
Mechanisms to support investment in generation.
Analysis of regulation, impact and economic viability of renewable projects.

Module 2. Energy storage 1,5 ECTS

OBJECTIVES:
Analysis of energy storage systems, their importance, typology, applications, functional strategies, as well as the criteria for evaluating technologies and the main challenges for their development, especially electrochemical systems.

CONTENTS:
Justification of energy storage systems.
Technical characteristics of energy storage.
Types and applications of energy storage systems: mechanical, electrical, chemical and thermal.
Compressed gas (CAES) and liquid air (LAES) systems.
Conventional and advanced electrochemical batteries: lithium, redox flow, etc.
Comparative and economic analysis of technologies: case studies.

Module 3. Renewable resources 1,5 ECTS

OBJECTIVES: Determination of the solar and wind energy potential of a site. Selection and management of solar radiation and wind resource databases.

CONTENTS
Solar radiation. Sun-earth movement. Shading length. Analysis of solar radiation: parameters, indices and correlations. Solar radiation modelling. Solar radiation databases. Solar resource assessment. Basic meteorology. Wind resource analysis: measurement, parameters, long term, vertical profile, wind roses and Weibull distribution. Sources of wind data. Mesoscale. Types of wind modelling. Wind resource assessment. Introduction to PVsyst and WAsP.

Módulo 4. Low temperature renewable thermal energies 3 ECTS

OBJECTIVES: provide the fundamentals and elements of analysis, design and sizing of installations for the use of low-temperature solar thermal energy in buildings and in applications to industrial processes. Learn about the main components of aerothermal and geothermal installations and study examples of harnessing projects. Use energy simulation programmes for low-temperature thermal installations.

CONTENTS:
Low temperature solar thermal energy. Collection and storage systems. Applications for DHW and heating. Spanish regulations on the use of low temperature solar thermal energy (CTE, RITE, IDAE). Solar thermal energy for industrial processes. Design and sizing of solar thermal installations with TSol. Aerothermal installations. Analysis of geothermal resources, low enthalpy geothermal applications. Valorization of the geothermal resource in thermal installations for heating, cooling and DHW production. Example of geothermal projects within the scope of the Spanish CTE. Simulation with EED.

Module 5. Stand-alone systems and microgrids 3 ECTS

OBJECTIVES: The main objective is to dimension autonomous renewable energy systems (photovoltaic, wind, hybrid and microgrids). This will require knowledge of both the characteristics and applications of these systems and their main components. At the end of the module, students will be able to size and choose the devices for a specific application (modules, batteries, wind turbines, inverters, regulation and control systems, etc.).

CONTENTS
Stand-alone photovoltaic systems: photovoltaic effect, photovoltaic cells and modules, batteries, regulators, inverters, sizing of devices and systems and application examples.
Photovoltaic pumping systems: fundamentals of pumping, type of pumps and control equipment, sizing of systems and application examples.
Hybrid systems: wiring diagrams, operating criteria, use of auxiliary generators and gensets, sizing and application examples.
Microgrids: Configuration, equipment and connection diagrams, operating criteria and sizing.

Module 6. Photovoltaic self-consumption 5 ECTS

OBJECTIVES: Project development of grid-connected photovoltaic systems on buildings for self-consumption applications with PVsyst

CONTENIDO: Concept and types of photovoltaic self-consumption. Building-Integrated Photovoltaic. Selection photovoltaic modules, inverters and batteries for self-consumption. Configurations, typologies and electrical schemes for self-consumption. Support systems for photovoltaic modules in buildings. Dimensioning and energy analysis of self-consumption photovoltaic systems with PVsyst. Regulation and processing. Rentability analysis. Photovoltaic self-consumption projects: examples, phases and documentation.

Module 7. Energy efficiency in buildings and industry 3 ECTS




OBJECTIVES: acquire knowledge to carry out '**Energy Audits**/Energy Management Systems' in buildings, industries and transport infrastructures. Simulation software for **Building Certification**, according to the actual EU Energy Efficiency Directive

CONTENTS

State of the art of 'Energy Management': new EU-regulation. Energy Saving Certificates (ESCs). Bioclimatism, passive systems and scope of the European nZEB standard: 'Nearly Zero Energy Buildings': energy sustainable systems. Active energy production and distribution systems. Distribution systems. Design of installations. Technical building regulations. Thermal simulation programmes for buildings. Analysis, procedure and methodology of an 'Energy audit'.

Module 8. Photovoltaic power plants 3 ECTS

OBJECTIVES: To know the market of photovoltaic plants and its current trends. Knowing the different phases of development: Promotion, preliminary technical evaluation, selection of components and their criteria (Module, Inverter, Tracker, Transformer) and finally the construction and interconnection. Use of tools for dimensioning, analysis and technical-economic evaluation of photovoltaic plants.

CONTENTS:

Main characteristics of a solar plant. Sizing and energy analysis of fixed and tracked plants. Solar tracking: types, characteristics and innovative commercial solutions. Central solar inverters for photovoltaic plants: main manufacturers; technical characteristics and selection criteria. Agri-voltaic plants. Floating Photovoltaic Plants. Electrical infrastructure of PV plants: transformation centres and medium-voltage grids: components, materials, technical requirements, legal requirements, current commercial solutions. Project planning, energy management, monitoring and control, commissioning and maintenance of PV plants. PV market. PV plant visit. Current trends in the PV Utility Scale market.

Module 9. Onshore wind farms 3 ECTS

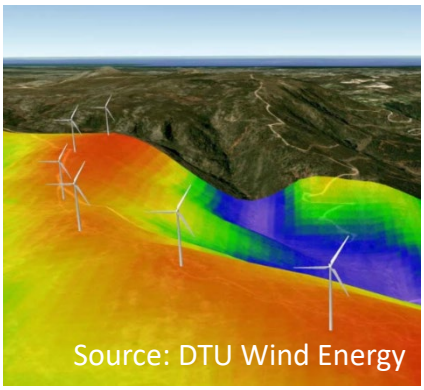
OBJECTIVES: to train specialists capable of analysing the operation and capacities of regulation and control of the different types of wind turbines on the market. To acquire the ability to configure, dimension, install and operate wind farms located on the mainland and connected to the electricity distribution and transmission grid.

CONTENTS:

Aerodynamic study of aero turbines. Wind turbine technology. Fixed speed electrical generation systems. Variable speed electrical generation systems. Regulation and control of synchronous generation systems. Regulation and control of doubly-fed generation systems. Direct-coupled multi-pole generators. Construction, assembly and operation of wind farms. Maintenance. Electrical design of a wind farm. Comprehensive management of wind farms. Wind farm life extension. Economic analysis of wind installations.

Módulo 10. Onshore wind farms energy assessment 1,5 ECTS

OBJECTIVES: Optimize wind potential of an onshore site by the selection of the most suitable wind turbine, tower height and locations. Determine the energy produced and analyze the economic viability of onshore wind farms.



CONTENTS: Wind resource. Wind characteristics, wakes and aerodynamic loads. WAsP software. CFD, WindSim and WindPro software. Anemometry. Short-term wind energy forecasting. Wind farm profitability analysis.

Module 11. Offshore wind farms 2 ECTS

OBJECTIVES: Knowledge and learning of the fundamentals of Offshore Wind Technology, as well as the main scopes that make up the design, construction and operation of offshore wind farms.

CONTENTS:
Introduction to Offshore Technology: fundamentals, main markets, project development and promotion. **Offshore Foundations**: structural typologies, main elements, design phases and conditions, fabrication. **Offshore Wind Turbines**: operation fundamentals, main components, turbine technologies, and control strategies. **Offshore Electrical Infrastructure**: electrical components from the turbines to the connection point. **Installation, Logistics and O&M**: planning and supply of logistic and installation means required for the construction of offshore farms. Assessment of the strategies and indicators to be considered for the optimal O&M of offshore wind assets. **Floating Offshore Technology**: designs according to stability, types of mooring trains, dynamic cables, substations, design, manufacturing, logistics and installation, O&M, main technologies, case studies, present and future of the sector: challenges and opportunities.

Module 12. Mini-hydro and marine power plants 1,5 ECTS

OBJECTIVES: Integral management of a mini-hydroelectric power plant project: design, execution and start-up. Knowing the technologies for the use of marine energy resources, analyzing their technical, economic and environmental viability.

CONTENNTS: **Mini-hydroelectric power plants**. Hydroelectric resource. Diversion, weir, intake, by-pass channel, load chamber, penstock, penstock, power plant with turbine-alternator groups. Technical aspects: nominal and ecological flow rates. Types of installations. Characteristics. Electromechanical equipment. Hydraulic turbines. Regulation and control. Economic aspects: profitability of the installation. Legal aspects: state of the Spanish legislation. Environmental aspects. Visit to mini-hydraulic power plant. **Marine energies**. Tidal power plants. Other havesting installations: wave energy, marine currents, ocean thermal energy.

Module 13. Thermosolar energy and bioenergy 3 ECTS

OBJECTIVES: To know the elements of high temperature solar thermal plants with energy storage for electricity and/or process heat generation applications. To know the different sources of bioenergy and the usual transformations necessary for its use. To know the technologies applicable in each case.

CONTENTS:
Introduction to concentrating solar power. Solar thermal power plants with parabolic trough (PTC) and Fresnel collectors for medium-high temperature applications, both for electricity generation and process heat for industry. Thermal energy storage in molten salts. A case study will be studied. The usual sources and transformation of biomass for its use (electricity generation or process heat) will also be discussed. Applications and technologies applicable to biomass and biogas will be discussed.

Module 14. Grid integration of renewable energies 1,5 ECTS

OBJECTIVES: To analyze the technical, legal and management problems of the integration of renewable energies into the national electrical grid. To learn about the characteristics and potential of distributed generation and its implications in the management and control of electricity grids. Analyze communications systems, large databases, smart grid management and new business models in smart grids.

CONTENTS:
Distributed generation and smart grids. Integration of renewable generation in electrical grids, system stability and security, quality of service. Grid integration of wind energy, experiences of Red Eléctrica de España. Grid codes. Communication technologies and protocols in distribution networks. New monitored and automated transformation centers. Smart homes and Smart Grids. Intelligent energy management: Smart Energy.

Module 15. Hybrid and storage plants 3 ECTS

OBJETIVOS: Development of evaluation projects for hybrid and storage grid-scale plants.

CONTENTS:
Hybrid and storage plants. Hybridization of renewable resources. Technical-economic feasibility analysis. Energy management. Regulatory aspects. Case studies. Virtual power plants. Reversible pumped storage. The role of inverters in hybrid plants with storage. Large-scale electrochemical storage. Sizing and energy analysis of hybrid and storage plants. Hybrid plant project with storage. WindPro and HOMER Pro software licenses. Visit of a Hybrid Plant.

Module 16. Green hydrogen technologies 2 ECTS

OBJECTIVES: Analysis of hydrogen as an energy vector, including its production from primary sources, its safe transmission and handling, and the applications, uses and markets of hydrogen and its derivatives.

CONTENTS:
Hydrogen and Power-to-X technologies as vectors of renewable energies, from a technical, environmental and economic point of view: sources, production processes, projects, infrastructures and markets. H_2 production from renewable sources. Storage, transport and safety of H2 as an energy vector. Hydrogen energy applications; fuel cells. Integration of H_2 and hybrid RE systems. Biomethane (SNG) and Power-to-X (ammonia, e-fuels). The new hydrogen society and economy

Module 17. Renewable energies for transportation 3 ECTS

OBJECTIVES: To understand the potential that biofuels and new hybrid and electric propulsion systems can have in the reduction of CO_2 emissions. To know the aspects that condition, limit and enhance their development, as well as their social impact. To know how biofuels interfere in the operation of reciprocating engines and how the new propulsion systems affect vehicle performance.

CONTENTS:
Overview of renewable energies (biofuels, electricity and hydrogen) used in the transportation sector and future perspectives. Fundamentals of reciprocating internal combustion engines (ICE) and their injection systems. Fuels and their combustion in ICE. Use of biofuels in spark ignition and diesel engines. Fundamentals of vehicle theory (driving and resistant efforts and characteristic curves) Hybrid vehicles (HV) and electric vehicles (EV) with batteries or fuel cell. Hydrogen in automotive: technologies.

Module 18. Renewable energies sustainability 3 ECTS

OBJECTIVES: to understand the technical concept of sustainability, the aspects it comprises and how it affects the renewable energy sector. The specific objectives are: i) to understand the use of indicators, tools and procedures to assess the sustainability of renewable projects and technologies; ii) to understand the application of sustainability concepts in the renewable energy sector: Agenda 2030, corporate social responsibility, sustainable finance, decision making, good practices; iii) end-of-life management in wind and photovoltaic installations.

CONTENTS: Theoretical bases of environmental, economic and social sustainability. Application in the renewables environment of tools to assess the sustainability of products, organizations and projects: life cycle analysis, environmental product declaration, environmental impact assessment, organizational and product carbon footprint, circularity indicators. International framework of the 2030 Agenda and Sustainable Development Goals applied to renewables. Corporate social responsibility and Non-Financial Information Statements (NFS). Sustainable finance, green bonds and the European green taxonomy. Operations of the sustainability department of an energy company. Example of good practices in the implementation of renewable projects. Recycling and waste management in wind and photovoltaic projects.

Module 19. Universal Access to energy 1,5 ECTS

OBJECTIVES: Approach to energy access in low- and middle-income countries. Appropriate technology systems for human development. Analysis of renewable energies application potential for developing countries.

CONTENTS:
Energy access situation worldwide. Potential of renewable energies. The cases of Latin America and Sub-Saharan Africa. Definitions and measurement of basic access to homes and public services. The Multi-Tier Framework: Capacity, availability, reliability, quality, affordability, legality and security. Prospective scenarios. International cooperation in the field of access to basic services. Cooperation policies, programs and projects. Modes of electrification: Grid connection, isolated mini-grids and home systems. Energy use systems applied to development projects: solar thermal, photovoltaic, wind and hydraulic systems. Energy for cooking: impacts and alternatives. Energy in settlements for refugees and their host communities.

Conferences 1 ECTS

OBJECTIVES: To present the most “hot” topics in renewable energies by the most relevant professional associations and entities in the sector.

CONTENTS:
The topics will be programmed on renewable energies and the environment that are relevant at that time

Master’s Thesis 12 ECTS

OBJECTIVES: To carry out an original, integrative or synthesis project or study that allows the application of the knowledge and skills acquired in the modules and that is current and of interest for the related professional sector.

SUBJECT AND IMPLEMENTATION The topic may be selected among those provided by the professors of the Master or proposed by the student. The TFM may be carried out within the framework of a curricular or extracurricular external academic internship that must comply with the regulations established by the UPM.

SPONSORS

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