2020/2021

EUREC Master in Renewable Energy:
Specialization in Ocean Energy
Instituto Superior Técnico – University of Lisbon

Module handbook

General learning outcomes of the Specialization Semester in Ocean Energy

The specialization semester in Ocean Energy is organized to provide the students with sufficient technical knowledge in marine renewable energy while also providing them with a good grounding in the role of marine renewables in the energy sector. It involves the following aspects:

- Sound understanding of the role of ocean renewable energy technologies in the energy sector;
- Basic technical knowledge on the different ocean renewable energy technologies that are and will be contributing to energy supply covering the following aspects:
    - evaluation of the resource;
    - conversion process;
    - performance of systems in operation;
    - tools for simulation and design.
- Ability to make an economic evaluation of the profitability and competitiveness of marine renewable energy projects.

General Prerequisites:

- 1st semester of the master course completed.
- Four-year undergraduate degree or the equivalent in any engineering or applied science branch.
- Fluency in spoken and written English language (applicants with limited skills in English language are advised to take additional courses).

Module name:	**Ocean Energy Resources**		
Section	Specialization		
Topics	• Introduction to the ocean environment • Ocean surface waves • Ocean tidal currents • Ocean thermal energy conversion • Ocean salinity gradient energy resource • Site selection and characterization for ocean energy systems		
Semester	2		
Module Co-ordinator	Luís Gato, Associate Professor, IST, University of Lisbon.		
Lecturers	José Cândido, PhD, WaveEC, Teresa Simas, PhD, WaveEC, Juan Portillo, PhD Student, IST, University of Lisbon.		
Language	English		
Classification within the curriculum	Module of the Ocean Energy Specialization of the Master of Renewable Energy		
Teaching format / class hours per week during the semester	30 hrs 20 hrs 118 hrs	Lectures Tutorial Self study	
Contact Hours/ Workload	50 hours (contact hours) 168 hours (total study load, equals 6 ECTS x 28 hours)		
ECTS credits	6		
Requirements under the examination regulations			
Recommended prerequisites	See general prerequisites		
Learning outcomes	At the completion of this module, the student will: • have an understanding of the physical mechanisms in the ocean which are on the basis of the generation of surface waves, tides and currents, and their effects, as well as the biological processes that may affect or be affected by ocean energy devices. • be familiar with the statistic description of waves and currents • use the statistical information to make evaluation of the energy resource • use of GIS in site selection characterization.		
Programme	Introduction to the ocean environment: ocean water and geology; ocean circulation and stratification; ocean habitat; ocean economy.		

	Ocean surface waves: linear wave theory (regular and random waves); wave spectrum; wave energy resource: parametrical characterization of ocean waves, nearshore wave transformation, wave measurement and modelling. Other sources of ocean energy: ocean tidal currents (current measurement; current turbulence; current energy resource); ocean thermal energy conversion; ocean salinity gradient energy resource. Site selection and characterization for ocean energy systems: criteria on energy resource, expected cost levels, water depth, seabed geology and ecology, distance to shore, ports, O&M bases and electrical grid, marine environmental issues.
Assessment/ exam	Exam (60%); Essay on a chosen topic (40%)
Equipment	State-of-the-art GIS tool
Literature	• Apel, J.R., 1987: Principles of Ocean Physics. Academic Press, 631 pp. • Bakus, G., 2007. Quantitative analysis of marine biological communities. Wiley. • Boon, J., 2004: Secrets of the tide: Tide and tidal current analysis and predictions, strom surges ans sea level trends. West Sussex, UK: Horwood Publishing, Ltd. 300 pp. • Cartwright, D. E. Oceanic tides. Rep. Prog. Phys., 1977, 40(6), 665–708. • Goda, Y., 1985: Random Seas and Design of Marine Structures. University of Tokyo Press, Japan. 323 pp. • Sarpkaya, T. and M. Isaacson, 1981: Mechanics of Wave Forces on Offshore Structures. Van Nostrand Reinhold Company, New York, U.S.A.. 651 pp. • Young, I.R., 1999: Wind Generated Ocean Waves. Elsevier Science Ltd, Oxford, UK. 288 pp. • Roberts, J., 2007. Marine Environment protection and biodiversity conservation. Springer-Verlag Berlin Heidelberg. 264 pp. • Lerman, M., 1999. Marine Biology: environment, diversity and ecology. Addison-Wesley.

Module name:	**Modelling and Control of Ocean Energy Systems**		
Section	Specialization		
Topics	• Wave energy systems • Marine current turbines • Other types of energy systems		
Semester	2		
Module Co-ordinator	Luis Gato, Associate Professor, IST, University of Lisbon		
Lecturers	António Falcão, Emeritus Professor, IST), José Falcão de Campos (Associate Professor, IST), Luís Gato (Associate Professor, IST), João Henriques (Assistant Professor, IST), Ricardo Pereira (Assistant Professor, IST), João Baltazar (PhD Researcher, IST), Duarte Valério (Associate Professor, IST), Rui Gomes (PhD Researcher, IST).		
Language	English		
Classification within the curriculum	Module of the Ocean Energy Specialization of the Master of Renewable Energy		
Teaching format / class hours per week during the semester	30 hrs 20 hrs 6 hrs 112 hrs	Lectures Tutorial Laboratory Self study	
Contact Hours/ Workload	56 hours (contact hours) 168 hours (total study load, equals 6 ECTS x 28 hours)		
ECTS credits	6		
Requirements under the examination regulations			
Recommended prerequisites (prior knowledge)	Basic courses on: • Fluid Mechanics • Thermodynamics • Applied Mathematical Analysis		
Learning outcomes	At the completion of this module, the student will: • become familiar with the linear hydrodynamic theory of wave energy systems • become familiar with the hydrodynamic theory of marine current turbines (BEM) • be introduced to advanced numerical hydrodynamic modelling of wave and current systems and control simulation		

	• be introduced to experimental testing and monitoring of OE systems • get a basic knowledge of other forms of ocean energy and their systems as OTEC and salinity gradients.
Programme	Wave energy systems: Types of wave energy converters. Linear wave-structure interactions. Frequency domain analysis. Hydrodynamic coefficients and their computation. Time domain analysis. Phase control. Arrays. Model testing techniques. Marine current turbines. Types of marine current turbines. Hydrodynamic models: Blade Element Momentum (BEM), Lifting line (LL), Integral Boundary Element Method (IBEM). Hydrofoil data and analysis. Cavitation and strength. Design criteria. Multiple turbine interaction. Other types of energy systems: Ocean Thermal Energy Conversion (OTEC). Energy from salinity gradients.
Assessment/ exam	2 Tests and/or exam
Equipment	Laboratory: Wave flume at the Civil Engineering Laboratory.
Literature	• J. Falnes, Ocean Waves and Oscillating Systems. Cambridge: Cambridge University Press, 2002. • G. Thomas, The theory behind the conversion of ocean wave energy: a review. In: (J. Cruz, editor) Ocean Wave Energy. Berlin: Springer, 2008, p. 41-91. • Numerical and experimental modelling of WECs. In: (J. Cruz, editor) Ocean Wave Energy. Berlin: Springer, 2008, p. 133-188. • A. A. Sayigh (Editor), Comprehensive Renewable Energy, vol. 8, Ocean Energy, Elsevier, in press, 2012. • A. F. O. Falcão, Wave energy utilization: a review of the technologies. Renewable and Sustainable Energy Reviews, vol. 14, p. 899-918, 2010. • Lecture Notes. To be produced. • Jack Hardisty, “The Analysis of Tidal Stream Power”, John Wiley & Sons, 2009, ISBN 978-0-470-72451-4. • Roger H. Charlier, Charles W. Finkl, “Ocean Energy: Tide and Tidal Power”, Springer, 2009, ISBN: 3540779310

Module name:	**Ocean Energy SystemsTechnologies**		
Section	Specialization		
Topics	• Power take-off systems • Mooring and anchoring systems. • Farm layout • Offshore electrical grid and connection systems • Operation and maintenance of ocean energy devices • Offshore operations • Maritime safety issues		
Semester	2		
Module Co-ordinator	Luís Gato, Associate Professor, IST, Technical University of Lisbon		
Lecturers	Luís Gato (Associate Professor, IST), Paulo Branco (Associate Professor, IST), Rui Castro (Associate Professor, IST), Ângelo Teixeira (Associate Professor, IST), João Henriques (Assistant Professor, IST), João Fernandes (Assistant Professor, IST), Ricardo Pereira (Assistant Professor, IST), Rui Gomes (PhD, Researcher, IST); Invited lecturers.		
Language	English		
Classification within the curriculum	Module of the Ocean Energy Specialization of the Master of Renewable Energy		
Teaching format / class hours per week during the semester	37.5 hrs 25 hrs 6 hrs 112 hrs	Lectures Tutorial Laboratory Self study	
Contact Hours/ Workload	68.5 hours (contact hours) 210 hours (total study load, equals 7.5 ECTS x 28 hours)		
ECTS credits	7.5		
Requirements under the examination regulations			
Recommended prerequisites (prior knowledge)	See general prerequisites		
Learning outcomes	At the completion of this module, the student will: • become familiar with the state of the art of electro-mechanical power take-off equipment used in wave energy converters and		

	marine current turbines; • be introduced to mooring and anchoring systems; • become familiar the design and configuration of farms; • being capable of distinguish the different components and designs of offshore electrical grids; • get basic knowledge on the requirements to deploy, operate and maintain the wave and current energy system; • become aware of maritime safety issues.
Programme	Principle of operation and components of air turbines, water turbines, high-pressure hydraulic systems, linear and rotating electrical generators, and energy storage in ocean energy. Classification of offshore structures; loads, cost and materials of mooring and anchoring systems; description of anchoring and foundations systems; taut and slack-mooring systems; and mooring configurations in arrays. Principles of interference of WEC arrays and layout optimization methods. Analysis of tidal turbines arrays. Offshore electrical grid structure and components, cable technologies, electrical designs (HVDC vs AC), interaction with the local electricity network, integration into the National grid, examples/case studies. Routine and non-routine offshore operations; management systems; maintenance procedures, risk assessment and inspection plans; and case studies. Introduction to offshore operations; vessels, equipment and personnel; method planning and permitting; principles, legislation and standards of safety management.
Assessment/ exam	Tests/Exam
Equipment	Laboratory: ■ a) Fluid Mechanics Laboratory of the Mechanical Engineering Department of IST. Air turbine test rig. ■ b) Electrical Machinery Laboratory of the Electrical and Computer Engineering Department of IST.
Literature	• A. Sayigh. Comprehensive Renewable Energy: Ocean Energy. Elsevier, 2012. • J. Cruz. Ocean Wave Energy: Current Status and Future Perspectives, 2008. • S. Chakrabarti. Handbook of offshore engineering. Elsevier, Vol. 2, 2005. • Carbon Trust . Guidelines on design and operation of wave energy converters, 2005. • EMEC. Guidelines for Health and Safety in the Marine Energy Industry, 2008. • R. E. Harris et al. Mooring systems for wave energy converters: A review of design issues and choices. • B. Child. On the configuration of arrays of floating wave energy converters. PhD thesis, University of Edinburgh, 2011. • I. Alegría et al. Transmission alternatives for offshore electrical power. Renewable and Sustainable Energy Reviews 13, 1027–1038, 2009. • K. Thorburn et al. Wave energy transmission system concepts for linear generator arrays. Ocean Engineering 31, 1339–1349, 2004.

Module name:	**Economics, Policy and Environment**		
Section	Specialization		
Topics	• Policy issues • Licensing & permitting • Economic analysis of marine farms • Environmental and socio-economic impact assessment and monitoring of marine farms		
Semester	2		
Module Co-ordinator	Luís Gato, Associate Professor, IST, University of Lisbon		
Lecturers	José Cândido (PhD, WavEC), Teresa Simas (PhD, WaveEC), Inês Machado (PhD Student, WavEC), Amorina Gonzalez, (MsC, WavEC)		
Language	English		
Classification within the curriculum	Module of the Ocean Energy Specialization of the Master of Renewable Energy		
Teaching format / class hours per week during the semester	22.5 hrs 15 hrs 88.5 hrs	Lectures Tutorial Self study	
Contact Hours/ Workload	37.5 hours (contact hours) 126 hours (total study load, equals 4.5 ECTS x 28 hours)		
ECTS credits	4.5		
Requirements under the examination regulations			
Recommended prerequisites (prior knowledge)	See general prerequisites		
Learning outcomes	At the completion of this module, the student will: • become familiar with the basic economic analysis of ocean energy systems including the cost, financing and economic evaluation • get basic knowledge on the general policy issues regarding ocean energy systems and more detailed knowledge on the licensing and permitting procedures for installation of OE systems and enabling mechanisms as funding, feed-in tariffs and tax incentives • Be able to perform simple environmental impact studies for OE systems.		
Programme	Marine spatial planning, concession regimes of marine areas; consenting		

	and licensing of marine farms; feed-tariffs, green certificates, tax incentives and other financial support mechanics. Economic analysis of a marine farm: present and future cost of energy (LCOE, externalities) – the role of offshore energy; characterization of offshore renewable costs (CAPEX and OPEX); project financing: principles (equity, debt ratio), parameters (discount rate, return period, NPV, IRR), tools (Retscreen, etc.) and risk assessment. Environmental and socio economic impact assessment and monitoring: EIA objectives, process and requirements; public consultation and conflict of uses management; environmental monitoring; life-cycle assessment.
Assessment/ exam	Exam (60%); Essay on a chosen topic (40%)
Equipment	-
Literature	• Paillard, M., Lacroix, D., Lamblin, V. (2009) Marine Energy Renewables – Prospective Foresight Study for 2030, Éditions Quae, ISBN 978-2-7592-0183-9. • Mendonça, M. (2007) Feed-In Tariffs – Accelerating the Deployment of Renewable Energy, Earthscan, ISBN 978-1-84407-788-5. • Soares, I., Moreira J., Pinho, C. e Couto J. (2007). Análise Financeira de Projectos, Edições Sílabo, Portugal. • Economics of wind Energy, EWEA, http://www.ewea.org/fileadmin/ewea_documents/documents/00_POLICY_document/Economics_of_Wind_Energy__March_2009_.pdf • Projected Costs of Generating Electricity. IEA, 2010. • "Accelerating marine energy", Carbon Trust, 2011. • Ernst & Young and DECC (UK). "Cost of and financial support for offshore wind", 2009.

Module name:	**Project**		
Section	Specialization		
Topics	• Resource characterization • Site selection • Conceptual system development • Licensing procedure • Environmental impact • Economic analysis		
Semester	2		
Module Co-ordinator	José Maria André, Assistant Professor, IST, University of Lisbon		
Lecturers			
Language	English		
Classification within the curriculum	Module of the Ocean Energy Specialization of the Master of Renewable Energy		
Teaching format / class hours per week during the semester	8 hrs 40 hrs 120 hrs	Lectures Tutorial Report work	
Contact Hours/ Workload	48 hours (contact hours) 168 hours (total study load, equals 6 ECTS x 28 hours)		
ECTS credits	6		
Requirements under the examination regulations			
Recommended prerequisites (prior knowledge)	The 4 courses of the Specialisation Modulus on Ocean Energy of the Master Course		
Learning outcomes	At the completion of this module, the student will: • bring into practice the knowledge acquired through a case study in the form of a specific small project.		
Programme	This course integrates the knowledge previously acquired by the students regarding the resource evaluation, and the conversion processes. At the end of the course each student should deliver an outline project to explore wave energy in a given site and with a		

	given technology.
Assessment/ exam	Presentation
Equipment	
Literature	Literature of the different courses

Laboratory

Module-2: Modelling and Control of Ocean Energy Systems:

- Wave Flume of the Civil Engineering Department of IST: Characterization of systems of regular and irregular 2D waves. Energy spectra: Duration 3 h.
- Wave Flume of the Civil Engineering Department of IST: Characterization of a floating body response RAO in a system of regular 2D waves: Duration 3 h.

Module-3: Mechanical and Electrical Equipment:

- a) Fluid Mechanics Laboratory of the Mechanical Engineering Department of IST: Testing of an air turbine for use in OWC systems: Duration 3 h.
- b) Electrical Machinery Laboratory of the Electrical and Computer Engineering Department of IST: laboratory practice on electrical generators: Duration 3 h.

Programme management:
Prof. Luis Gato: M.Sc. organization & Eurec master steering committee.