Diploma de Formação Avançada
em
Energias Renováveis Marítimas
Marine Renewable Energies

(Proposta de Criação)

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Diploma de Formação Avançada em Energias Renováveis Marítimas – *Marine Renewable Energies*

1. Enquadramento

A ideia de criar no Instituto Superior Técnico um curso de especialização em energias renováveis marítimas nasceu de uma solicitação da agência EUREC (European Renewable Energy Centres Agency) ao IST para formular uma proposta de um módulo de especialização em Energia do Oceano *("Ocean Energy")* a integrar no Mestrado Europeu de Energias Renováveis promovido por aquela agência. Esta solicitação veio fortalecer a convicção, no seio dos grupos de investigação activos no IST nas áreas da energia das ondas e correntes, de que haveria necessidade no mercado de trabalho de uma oferta de formação pós-graduada especializada em energias renováveis marítimas.

1.1. A especialização em Energia do Oceano no Mestrado EUREC em Energias Renováveis

A agência EUREC organiza um mestrado internacional em Energias Renováveis. O mestrado destina-se a detentores de um diploma universitário com duração mínima de 4 anos e tem a duração de 16 meses (Setembro a Dezembro do ano seguinte). O mestrado destina-se a formar técnicos para a indústria e serviços e tem um carácter profissionalizante. A estrutura do curso contém um semestre (5 meses) numa universidade de base (*core university)* onde é dada formação geral no espectro das energias renováveis, um semestre (5 meses) de especialização numa área específica de energia renovável numa universidade (*specialisation provider*) de um outro país e um semestre (5 meses) de projecto com tese. Uma descrição sucinta deste mestrado encontra-se no Anexo I.
Ao IST foi solicitado em 2009 que apresentasse uma proposta para o semestre de especialização em energia do oceano *("Ocean Energy")*. Uma proposta preliminar foi apresentada em duas reuniões da EUREC em 2009 e 2010. A candidatura do IST a membro da EUREC, com vista à realização do semestre de especialização, recebeu parecer favorável do Conselho Científico a 07/04/2010, foi formalizada em 27/05/2010, sendo o IST membro da Agência EUREC desde Janeiro de 2011. A proposta à EUREC para o semestre de especialização em Energia do Oceano foi formalizada em Junho de 2011 e aceite em Janeiro de 2012 com a assinatura do respectivo Memorando de Entendimento.

1.2. A formação especializada em Energias Renováveis Marítimas

O IST tem uma experiência de 30 anos na área do aproveitamento da energia das ondas em termos de I,D&D e, mais recentemente, também na energia de correntes e eólica "offshore". Neste percurso o IST tem uma invejável participação no desenvolvimento de centrais piloto e protótipos, sendo de salientar a construção da central de energia das ondas na ilha do Pico, nos Açores. Esta central, com 400 kW de potência instalada, foi a primeira no mundo a ser ligada à rede eléctrica. Embora tenha tido uma vida difícil no seu arranque, encontra-se hoje operacional em regime experimental. Para além da valia científica da actividade que a equipa do IST tem vindo a realizar, é particularmente importante a interacção que o IST tem sabido realizar com o governo e o tecido empresarial português relevante para esta área, bem como as fortes ligações internacionais e, mais do que isso, a relevância do seu impacte internacional, não só científico, mas também empresarial. A ligação do IST ao tecido empresarial português está bem patente na criação e dinamização do Centro de Energia das Ondas, que presentemente associa 15 empresas de diversos sectores e três instituições de I&D.

Por outro lado, para além da equipa do DEM que com mais tradição tem trabalhado nesta área, tem-se verificado um aumento significativo de colegas do DEM e de outros departamentos interessados nesta área.

O estado de desenvolvimento da tecnologia e o interesse crescente do tecido empresarial pela energia das ondas e o eólico "offshore", consubstancializado no teste em águas portuguesas de 4 tecnologias de aproveitamento de energia das ondas nos próximos 3 anos, no estado avançado dum projecto de demonstração de uma turbina eólica offshore flutuante nesse horizonte temporal, na legislação que cria a tarifa bonificada para a energia das ondas e uma zona piloto para a energia das ondas com um potencial de ligação à rede eléctrica de 250 MW e na vontade de criar um cluster nacional nesta área, adicionado à procura internacional por técnicos com formação nesta área, justificam claramente que se equacione a oferta de uma formação universitária na área da Tecnologia e Energia Oceânica. Essa formação deve focar nas energias renováveis marítimas (ondas, correntes e eólico "offshore"), mas ser aberta para aspectos mais abrangentes da tecnologia, economia, meio marinho e gestão empresarial, de modo a permitir aos formandos intervirem em áreas diferentes como a aquicultura e a exploração de hidrocarbonetos no oceano.

Por estes motivos o DEM tem vindo a preocupar-se com a oferta de um curso de pós-graduação, em ligação com outras unidades académicas do IST, que possa dar resposta imediata às necessidades futuras do mercado em energias renováveis marítimas.

Neste contexto, o DFA em Energias Renováveis Marítimas, que agora se propõe, constitui uma oferta de formação avançada única no panorama universitário nacional e internacional, conferindo ao IST um papel pioneiro no ensino desta área.

2. Objectivos

O objectivo do DFA em Energias Renováveis Marítimas é o de formar técnicos especializados com conhecimento aprofundado dos aspectos científicos, tecnológicos, económicos e ambientais envolvidos no aproveitamento das diferentes energias renováveis existentes no mar.
O foco do curso será nas energias das ondas e das correntes de maré e na energia eólica "offshore" que possuem elevado potencial energético e para as quais se prevê um papel muito relevante na produção de energia eléctrica de origem renovável no futuro.
Os técnicos especializados habilitados com este diploma de formação avançada terão seguramente oportunidade de vir a contribuir para o desenvolvimento de um sector emergente da indústria marítima associado às energias renováveis.

3. Estrutura curricular modular do DFA

3.1. Objectivos gerais da aprendizagem

O DFA em Energias Renováveis Marítimas - *Marine Renewable Energies* está organizado para dotar os alunos dos conhecimentos técnicos suficientes em energias renováveis marítimas e, simultaneamente, facultar-lhes a base para poder compreender o papel que as energias renováveis marítimas desempenham no sector da energia, envolvendo os seguintes aspectos:

- Compreensão aprofundada do papel das energias renováveis marítimas no sector da energia,
- Conhecimento técnico-científico fundamental nas diferentes energias renováveis marítimas que estão presentemente, e estarão no futuro, a contribuir para o fornecimento de energia, cobrindo os seguintes aspectos:
    - avaliação do recurso,
    - processos de conversão,
    - desempenho dos sistemas em operação,
    - ferramentas de simulação e análise.
- Capacidade para realizar a avaliação económica da rendibilidade e competitividade de projectos de sistemas de energias renováveis marítimas.

3.2. Estrutura modular

O DFA em Energias Renováveis Marítimas - *Marine Renewable Energies* compreende um total de 30 ECTS e tem uma estrutura modular organizada de acordo com a seguinte tabela:

<table>
<tr><td></td><td>6 ECTS</td><td>6 ECTS</td><td>6 ECTS (3+3)</td><td colspan="2"></td></tr>
<tr><td>Course/Modulus</td><td>Wave Energy</td><td>Tidal Energy</td><td>Wind Energy</td><td>OTEC</td><td>Salinity</td></tr>
<tr><td rowspan="2">Ocean Energy Resources 6 ECTS (*)</td><td colspan="5">OER 1 - Ocean Environment - 3 ECTS</td></tr>
<tr><td>OER 2 Wave Resource 1 ECTS</td><td>OER 2 Tidal Resource 1 ECTS</td><td>OER 2 Wind Resource 0.5 ECTS</td><td>OER 2 OTEC Resource Technology 0.5 ECTS</td><td>OER 2 Salinity Resource Technology 0.5 ECTS</td></tr>
<tr><td>Modelling and Control of Ocean Energy Systems 6 ECTS</td><td>MCOES 1 W Wave Energy Systems 3 ECTS</td><td colspan="2">MCOES 2 T Stream Energy Systems 3 ECTS</td><td></td><td></td></tr>
<tr><td rowspan="4">Ocean Energy Systems Technologies 7.5 ECTS (*)</td><td colspan="5">OEST 1 Mechanical and Electrical Equipment 3 ECTS</td></tr>
<tr><td>OEST 1 Wave 1 ECTS</td><td>OEST 1 Tidal 1 ECTS</td><td>OEST 1 Wind 2 ECTS</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>OEST 2 Wave Farms 1 ECTS</td><td>OEST 2 Tidal Farms 1 ECTS</td><td>OEST 2 Wind Farms 0.5 ECTS</td></tr>
<tr><td colspan="5">OEST 3 Offshore Operations 0.5 ECTS</td></tr>
<tr><td rowspan="3">Economics, Policy and Environment 4.5 ECTS</td><td colspan="5">EPE 1 Economic Analysis 2 ECTS</td></tr>
<tr><td colspan="5">EPE 2 Policy Isssues 1 ECTS</td></tr>
<tr><td>EPE 3 Wave Environmental Impact 0.75 ECTS</td><td>EPE 3 Tidal Environmental Impact 0.75 ECTS</td><td></td></tr>
<tr><td>Project 6 ECTS</td><td>P Wave</td><td>P Tidal</td><td></td></tr>
<tr><td>Project Wind 3 ECTS</td><td colspan="2"></td><td>P Wind 3 ECTS</td></tr>
</table>

(*) Without Wind

3.3. O Currículo

Os 30 ECTS do DFA em Energias Renováveis Marítimas - *Marine Renewable Energies* é oferecido em dois perfis: Energia do Oceano - *Ocean Energy*, coincidente com o semestre de especialização do EUREC Master in Renewable Energy, e Energias Renováveis Marítimas - *Marine Renewable Energies*, que inclui o eólico "offshore".

Curriculo:

Comum:

a. *Ocean Energy Resources* (6 ECTS)
b. *Modelling and Control of Ocean Energy Systems* (6 ECTS)
c. *Ocean System Technologies* (7.5 ECTS)
d. *Economics, Policy and Environment* (4.5 ECTS)

1. Perfil Energia do Oceano - *Ocean Energy*:
   e. *Project* (6 ECTS)
2. Perfil Energias Renováveis Marítimas - *Marine Renewable Energies*:
   f. *Offshore Wind Resource and Technology* (3 ECTS)
   g. *Analysis of Marine Renewable Energy Systems* (3 ECTS)

3.4. Unidades Curriculares Isoladas

A estrutura modular do DFA permite a criação de 3 novas unidades curriculares isoladas de nível M (Mestrado) de 6 ECTS. Estas unidades curriculares aglutinam os módulos de natureza científica e tecnológica de cada tipo de energia renovável marítima. Poderão ser oferecidas como unidades curriculares de opção nos programas de Mestrado e Mestrado Integrado do IST e como unidades curriculares isoladas no âmbito do DFA. São as seguintes:

h. Energia das Ondas - *Wave Energy* (6 ECTS)
i. Energia das Correntes - *Current & Tidal Energy* (6 ECTS)
j. Energia Eólica Marítima - *Offshore Wind Energy* (6 ECTS)

4. Unidades Curriculares

Instituto Superior Técnico
Departamento de Engenharia Mecânica
Energias Renováveis Marítimas
Marine Renewable Energies
Diploma de Formação Avançada
1º Ano/2º Semestre

Unidades Curriculares	Área Científica	Tipo	Horas de Trabalho		Créditos	Observações
			Total	Contacto		
Ocean Energy Resources	TTCE	Semestral	168	30 T 20 OT	6	Nível F
Modelling and Control of Ocean Energy Systems	TTCE	Semestral	168	30 T 20 OT 6 PL	6	Nível M
Ocean Energy System Technologies	TTCE	Semestral	210	37.5 T 25 OT 6 PL	7.5	Nível F
Economics, Policy and Environment of Ocean Energy Systems	TTCE	Semestral	126	22.5 T 15 OT	4.5	Nível F
Project	TTCE	Semestral	168		6	Nível F Projecto
Offshore Wind Resource and Technology	TTCE	Semestral	84	15 T 10 OT	3	Nível M
Analysis of Marine Renewable Energy Systems	TTCE	Semestral	84		3	Nível F Projecto
Wave Energy	TTCE	Semestral	168	30 T 20 OT 6 PL	6	Nível M
Current & Tidal Energy	TTCE	Semestral	168	30 T 20 OT	6	Nível M
Offshore Wind Energy	TTCE	Semestral	168	30 T 20 OT	6	Nível M

TTCE: Termofluidos e Tecnologias de Conversão de Energia

T – Ensino Teórico; OT: Orientação Tutorial; PL: Ensino Prático e Laboratorial

Os programas e a bibliografia das unidades curriculares encontram-se detalhados no Anexo II.

5. Viabilidade Financeira do DFA

A viabilidade financeira do DFA em Energias Renováveis Marítimas estará assegurada pelo financiamento do Semestre de Especialização em Energia do Oceano do Mestrado EUREC em energias Renováveis. A EUREC contribuirá para o financiamento anual do curso com 26000 euros acrescidos de 500 euros por aluno. O IST está comprometido a assegurar o curso no 2º semestre de cada ano lectivo durante um período de 3 anos desde que estejam inscritos pelo menos 3 alunos nesse ano lectivo. O financiamento mínimo de 27 500 euros garantirá o funcionamento do DFA. Uma previsão das despesas envolvidas no funcionamento do curso no período de 2013 a 2015 encontra-se no Anexo III.

Para os alunos do DFA que não estarão inscritos no Mestrado EUREC em Energias Renováveis aplicam-se as propinas a fixar pela Coordenação do Curso, sujeitas aos mínimos em vigor no IST (actualmente de 2500 euros por aluno, e de 85 euros por cada unidade ECTS para a inscrição em unidades curriculares isoladas).

6. Funcionamento do DFA

O DFA terá início no ano lectivo de 2012-2013. A programação do curso para o 2º semestre do ano lectivo de 2012-2013 encontra-se no Anexo IV.

A distribuição de horas lectivas pelos docentes prevista para o 2º semestre do ano lectivo de 2012-2013 encontra-se no Anexo V. O impacto no serviço docente das Áreas Científicas e dos Departamentos envolvidos encontra-se na Tabela:

Departamento		
DEM	Horas	h/semana
Termofluidos e Tecnologias de Conversão de Energia	37.5	2.7
Engenharia Naval	6	0.4
Total DEM	43.5	3.1
DEEC		
Energia	6	0.4
Total DEEC	6	0.4

7. Acreditação do Mestrado EUREC em Energias Renováveis.

O Diploma de Mestre em Energias Renováveis é concedido pelas universidades debBase em que o aluno se encontra inscrito. Algumas universidades de base (Hanze-Groningen, Países Baixos, e Oldenburgo, Alemanha) requerem processos de acreditação junto das instituições de acreditação de cursos de ensino superior dos respectivos países. A informação detalhada das unidades curriculares que o aluno de uma dessas universidades de base universidade frequentará no IST como unidades curriculares isoladas, que deverá informar os respectivos pedidos de acreditação, consta do Anexo VI.

Anexo I O Mestrado EUREC em Energias Renováveis

A EUREC Agency (European Renewable Energy Centres Agency) é uma Agência que representa junto da União Europeia os centros de investigação em energias renováveis europeus.

No âmbito das suas actividades, a EUREC Agency promove desde 2002 um curso de Mestrado em Energias Renováveis de dimensão europeia. Este curso inicia-se em Setembro e decorre ao longo de dezasseis meses e três semestres. No primeiro semestre, cujas aulas terminam em Dezembro, é dado um módulo genérico em energias renováveis no seio das chamadas universidades de base (*Core Universities*). O segundo semestre, cujas aulas decorrem entre Fevereiro e início de Junho, é de especialização numa das tecnologias renováveis, sendo esta formação obtida numa das universidades especialistas. Estas universidades são também responsáveis pelo terceiro semestre, que decorre entre Julho e Dezembro, no qual os alunos realizam uma tese de mestrado numa empresa ou numa instituição de I&D.

A formação base é obtida numa das 5 universidades de base seguintes:

- Ecole des Mines de Paris, França – Ensino em francês
- Universidade de Loughborough, RU – Ensino em inglês
- Universidade de Saragoça, Espanha – Ensino em espanhol
- Universidade de Oldenburg, Alemanha – Ensino em inglês
- Universidade de Hanze-Groningen, Países Baixos – Ensino em inglês

A formação especializada é obtida apenas numa única universidade conforme a especialidade seleccionada. Em 2012-2013 serão oferecidas as seguintes especialidades (em inglês):

- Universidade de Kassel, Alemanha: Sistemas Híbridos.
- Universidade Técnica de Atenas, Grécia: Energia Eólica.
- Universidade de Northumbria, RU: Energia Fotovoltaica.
- Universidade de Saragoça, Espanha: Bioenergia.
- Universidade de Perpignan, França: Energia Solar Térmica.
- IST Universidade Técnica de Lisboa, Portugal: Energia do Oceano.

Informação detalhada sobre o mestrado EUREC em energias renováveis pode ser obtida em http://www.master.eurec.be/en/.

Anexo II: Programas das Unidades Curriculares

Ocean Energy Resources (6 ECTS)

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, near-shore 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.

Bibliography:

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.

Modelling and Control of Energy Systems (6 ECTS)

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.

Bibliography:

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, 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

Ocean Energy Systems Technologies (7.5 ECTS)

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.

Bibliography:
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.

Economics, Policy and Environment of OE Systems (4.5 ECTS)

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.

Bibliography:
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.

Project (6 ECTS)

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.

Offshore Wind Resource and Technology (3 ECTS)

Programme:

Evaluation of wind energy resource: Wind modelling onshore. Wind modelling offshore. Ocean conditions. Offshore wind energy siting. Wind turbine aerodynamics: unsteady aerodynamics of aerofoils and dynamic stall. Turbine wakes. Aerodynamic loads on turbine blades. Types of support structures. Hydrodynamic loads on support structures. Structural analysis: Dynamic analysis of turbine and support structure. Fatigue analysis of turbine blades. Wind turbines control: Aerodynamic power control and electromagnetic torque control. Dynamic analysis and stability. Control strategies. Wind farm technology: Offshore wind farm design. Energy prediction and optimization. Grid connections.

Bibliography:
Wind Energy Handbook , T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi, John Wiley & Sons, 2001.
Wind Turbine Technology, David Spera (Editor), 2nd Edition, ASME, 2009.
Wind Turbine Aerodynamics, A State-of-the-Art, Lecture Series 2007-05, Von Kármán Institute for Fluid Dynamics, 2007.
Sathyajith Mathew and Geeta Susan Philip (Editors), *Advances in Wind Energy Conversion Technology,* Springer 2011
Peter Jamieson, "Innovation in Wind Turbine Design", Wiley 2011.

Analysis of Marine Renewable Energy Systems (3 ECTS)

Programme:

Students carry out a project on the technical, economical and environmental assessment of a marine renewable energy system. For a given technology and site characteristics the student performs a technical assessment, an evaluation of the annual energy production, an economic analysis and a simple environmental impact study.

Wave Energy (6 ECTS)

Programme:

Ocean surface waves: linear wave theory (regular and random waves); wave spectrum; wave energy resource: parametrical characterization of ocean waves, near-shore wave transformation, wave measurement and modelling. 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. Power take-off characteristics. 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.

Bibliography:

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, 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.

Current and Tidal Energy (6 ECTS)

Programme:

Ocean tidal currents: current measurement; current turbulence; current energy resource. 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. 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. Analysis of tidal turbines arrays.

Bibliography:

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

Lecture Notes. To be produced.

Offshore Wind Energy (6 ECTS)

Programme:

Types of wind turbines. Aerodynamic models: Blade Element Momentum (BEM), Lifting line (LL), Integral Boundary Element Method (IBEM). Foil data and analysis. Foil design criteria. Unsteady aerodynamics of aerofoils and dynamic stall. Turbine wakes. Aerodynamic loads on turbine blades. Evaluation of wind energy resource: Wind modelling onshore. Wind modelling offshore. Ocean conditions. Offshore wind energy siting. Types of support structures. Hydrodynamic loads on support structures. Structural analysis: Dynamic analysis of turbine and support structure. Fatigue analysis of turbine blades. Wind turbines control: Aerodynamic power control and electromagnetic torque control. Dynamic analysis and stability. Control strategies. Wind farm technology: Offshore wind farm design. Energy prediction and optimization. Grid connections.

Bibliography:

Wind Energy Handbook , T. Burton, D. Sharpe, N. Jenkins, E. Bossanyi, John Wiley & Sons, 2001.

Wind Turbine Technology, David Spera (Editor), 2nd Edition, ASME, 2009.

Wind Turbine Aerodynamics, A State-of-the-Art, Lecture Series 2007-05, Von Kármán Institute for Fluid Dynamics, 2007.

Sathyajith Mathew and Geeta Susan Philip (Editors), *Advances in Wind Energy Conversion Technology,* Springer 2011

Peter Jamieson, "Innovation in Wind Turbine Design", Wiley 2011.

Anexo III Previsão de orçamento para o Semestre de Especialização em Energia do Oceano do Mestrado EUREC

EUREC	Master	on	Renewable Energy				
Specialisation		Ocean Energy		2º Semester	IST	UTL	
EUREC	Funding		Specialisation	26000	per/student	500	
	2012-13	2013-14	2014-15				
Specialisation	26000	26000	26000				
Number students	3	3	3				

			2012-13			2013-14			2014-15	Total
Budget			27500			27500			27500	82500
Costs	mh	Cost/mh		mh	Cost/mh		mh	Cost/mh		
Lectures	150	30	4500	150	30	4500	150	30	4500	13500
Preparation	450	30	13500	250	30	7500	250	30	7500	28500
Invited lecturers			2500			7500			5000	15000
Fee EUREC			2500			2500			2500	7500
Meetings			3000			3000			3000	9000
Overhead			1500			1500			1500	4500
Total			27500			26500			24000	78000
Saldo			0			1000			3500	4500

Anexo IV

Programação do DFA em Energias Renováveis Marítimas
Marine Renewable Energies

2012-2013

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	11 Feb	18 Feb	25-Feb	04-Mar	11-Mar	18-Mar	25-Mar	1-Apr	8-Apr	15-Apr	22-Apr	29-Apr	6 May	13 May	20 May	27 May	03-Jun	10-Jun	17-Jun	24-Jun
Course/Modulus																				
Ocean Energy Resources 6 ECTS	OER 1 - Ocean Environment 3 ECTS					Eval OER 1			OER 2 Wave Resource 1ECTS		OER 2 Tidal Resource 1ECTS		OTEC	Salinity			Eval 2 Exam 1			Exam 2
Offshore Wind Resource and Technology 3 ECTS									Offshore Wind Resource and Technology 3 ECTS									Exam 1		Exam 2
Modelling and Control of Ocean Energy Systems 6 ECTS	MCOES 1 W Wave Energy Systems 3 ECTS					Eval MCOES 1 Lab 1 MCOES 1		Lab 2 MCOES 1									Eval 2 Exam 1			Exam 2
	MCOES 2 T Stream Energy Systems 3 ECTS							Eval MCOES 2												
Ocean Energy Systems Technologies 7.5 ECTS	OEST 1 Mechanical and Electrical Equipment 3 ECTS					Eval OEST 1			OEST 1 Tidal 1 ECTS		OEST 1 Wave 1 ECTS		OEST 2 Wave Farms 1 ECTS		OEST 3 Offshore Operations 0.5 ECTS			Eval 2 Exam 1		Exam 2
						Lab 1 OEST 1		Lab 2 OEST 1					OEST 2 Tidal Farms 1 ECTS							
Economics, Policy and Environment 4.5 ECTS	EPE 1 Economic Analysis 2 ECTS			EPE 2 Policy Issues 1 ECTS		Eval EPE 1		Eval EPE 2	EPE 3 Envir. Imp. Wave 0.75 ECTS		EPE 3 Envir. Imp Tidal 0.75 ECTS						Eval 2 Exam 1			Exam 2
Project 6 ECTS									Project 6 ECTS											
Analysis of Marine Renewable Energy Systems 3 ECTS													Project 3 ECTS							

Anexo V

Distribuição Lectiva do DFA em Energias Renováveis Marítimas

Marine Renewable Energies

2012-2013

Docente	António Dente	António Falcão	[redacted]	Nuno Fonseca	Teresa Pontes	João Henriques	João Baltazar	Rui Gomes	Pedro Vicente	Bolseiro	Tiago Duarte	Miguel Lopes	Teresa Simas	José Cândido	Alex Raventos	Nuno Matos	Convidado 1	Convidado 2	Total
Instituição	IST	IST	[redacted]	IST	IDMEC	IST	IST	IST	IST	IST	IST	WAVEC	WAVEC	WAVEC	WAVEC	WAVEC			
Departamento	DEEC	DEM	[redacted]	DEM		DEM	DEM	DEM	DEM	DEEC	DEM								
Área Científica	Energia	TFTCE	[redacted]	Eng Naval		TFTCE	TFTCE	TFTCE	TFTCE		TFTCE								
Unidade Curricular			[redacted]																
Ocean Energy Resources			[redacted]		18								10	20					50.0
Modeling and Control of Energy Systems		26	[redacted]				12	6											56.0
Ocean Energy Systems Technologies	6		[redacted]	6		14.5		10	10	3		3					4		68.5
Economics, Policy and Environment			[redacted]										11		15	10			37.5
Project			[redacted]																8.0
Offshore Wind Resource and Technology			[redacted]				10				9							4	25.0
			[redacted]																
Total	6	26	[redacted]	6	18	14.5	22	16	10	3	9	3	21	20	15	10	4	4	

Anexo VI: Course Description for Accreditation within EUREC Partner Universities

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 masters 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	Prof. Dr. António Sarmento, Associate Professor, IST, Technical University of Lisbon
Lecturers	Dr. Teresa Pontes (IDMEC), Dr. José Cândido (WaveEC), Dr. Teresa Simas (WaveEC)
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 Lectures 20 hrs Tutorial 118 hrs 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	Prof. José Falcão de Campos, Associate Professor, IST, Technical University of Lisbon
Lecturers	Prof. Dr. António Falcão (Professor Emeritus, IST), Prof. Dr. José Falcão de Campos (Associate Professor, IST), Dr. João Baltazar (Researcher, IST), Prof. Dr. João Teixeira Borges (Associate Professor, IST), Eng. Rui Gomes (MSc, 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 Lectures 20 hrs Tutorial 6 hrs Laboratory 112 hrs 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, 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	Prof. Luís Gato, Associate Professor, IST, Technical University of Lisbon
Lecturers	Prof. Dr. Luís Gato (Associate Professor, IST), Prof. Dr. António Dente (Professor, IST), Prof. Dr. Nuno Fonseca (Assistant Professor, IST), Dr. João Henriques (Researcher, IST), Dr. Miguel Lopes (Researcher, WaveEC), Mr. Pedro Vicente (MSc, Researcher, IST), Mr. Rui Gomes (MSc, 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 Lectures 25 hrs Tutorial 6 hrs Laboratory 112 hrs 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	Prof. Dr. António Sarmento, Associate Professor, IST, Technical University of Lisbon		
Lecturers	Mr. Nuno Matos (MSc, WavEC), Mr. Alex Raventós (MSc, WavEC), Dr. Teresa Simas (WaveEC)		
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	Prof. Dr. José Maria André, Assistant Professor, IST, Technical 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 — Lectures 40 hrs — Tutorial 120 hrs — Report work
Contact Hours/ Workload	8 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. José Alberto Falcão de Campos: M.Sc. organization & master steering committee.