University courses and opportunity for a European Master Program in Marine Renewable Energy

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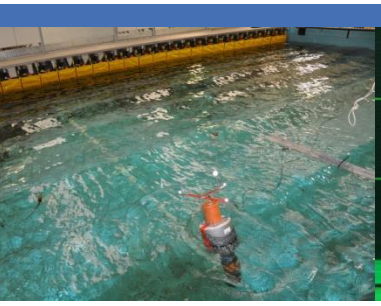
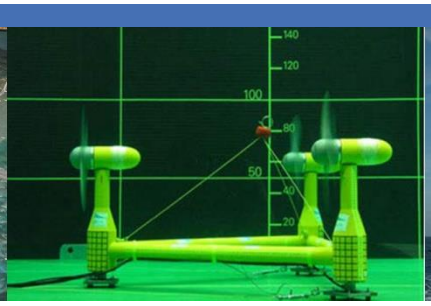
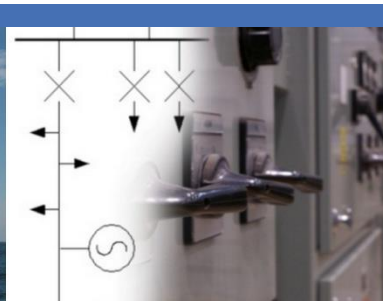
MARINET

Marine Renewables Infrastructure Network

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ABOUT MARINET

MARINET (Marine Renewables Infrastructure Network for emerging Energy Technologies) is an EC-funded network of research centres and organisations that are working together to accelerate the development of marine renewable energy - wave, tidal & offshore-wind. The initiative is funded through the EC's Seventh Framework Programme (FP7) and runs for four years until 2015. The network of 29 partners with 42 specialist marine research facilities is spread across 11 EU countries and 1 International Cooperation Partner Country (Brazil).

MARINET offers periods of free-of-charge access to test facilities at a range of world-class research centres. Companies and research groups can avail of this Transnational Access (TA) to test devices at any scale in areas such as wave energy, tidal energy, offshore-wind energy and environmental data or to conduct tests on cross-cutting areas such as power take-off systems, grid integration, materials or moorings. In total, over 700 weeks of access is available to an estimated 300 projects and 800 external users, with at least four calls for access applications over the 4-year initiative.

MARINET partners are also working to implement common standards for testing in order to streamline the development process, conducting research to improve testing capabilities across the network, providing training at various facilities in the network in order to enhance personnel expertise and organising industry networking events in order to facilitate partnerships and knowledge exchange.

The initiative consists of five main Work Package focus areas: Management & Administration, Standardisation & Best Practice, Transnational Access & Networking, Research, Training & Dissemination. The aim is to streamline the capabilities of test infrastructures in order to enhance their impact and accelerate the commercialisation of marine renewable energy. See www.fp7-marinet.eu for more details.

Partners

Ireland
University College Cork, HMRC (UCC_HMRC) *Coordinator*
Sustainable Energy Authority of Ireland (SEAI_OEDU)

Denmark
Aalborg Universitet (AAU)
Danmarks Tekniske Universitet (RISOE)

France
Ecole Centrale de Nantes (ECN)
Institut Français de Recherche Pour l'Exploitation de la Mer (IFREMER)

United Kingdom
National Renewable Energy Centre Ltd. (NAREC)
The University of Exeter (UNEXE)
European Marine Energy Centre Ltd. (EMEC)
University of Strathclyde (UNI_STRATH)
The University of Edinburgh (UEDIN)
Queen's University Belfast (QUB)
Plymouth University(PU)

Spain
Ente Vasco de la Energía (EVE)
Tecnalia Research & Innovation Foundation (TECNALIA)

Belgium
1-Tech (1_TECH)

Netherlands
Stichting Tidal Testing Centre (TTC)
Stichting Energieonderzoek Centrum Nederland (ECNeth)

Germany
Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V (Fh_IWES)
Gottfried Wilhelm Leibniz Universität Hannover (LUH)
Universitaet Stuttgart (USTUTT)

Portugal
Wave Energy Centre – Centro de Energia das Ondas (WavEC)

Italy
Università degli Studi di Firenze (UNIFI-CRIACIV)
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Università degli Studi della Tuscia (UNI_TUS)
Consiglio Nazionale delle Ricerche (CNR-INSEAN)

Brazil
Instituto de Pesquisas Tecnológicas do Estado de São Paulo S.A. (IPT)

Norway
Sintef Energi AS (SINTEF)
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LEGAL DISCLAIMER

EXECUTIVE SUMMARY

This document presents an overview of the existing European educational programmes in the field of marine renewable energy. It also includes suggestion for a transnational European master program in marine renewable energy.

CONTENTS

1 INTRODUCTION

The need to diversify our energy supplies supported by political instances has contributed to the significant growth in the field of marine renewable energy in the last decade. This rapid expansion has created a need for scientists with educational background in this field. Many universities throughout Europe are now proposing university courses and/or MSc programmes in order to fulfil this increasing demand. This report aims at summarising the existing possibilities for training in the field of marine renewable energy in Europe. Finally, a transnational European MSc programme in marine renewable energy is proposed.

2 LIST OF EUROPEAN MSC PROGRAMMES IN MARINE RENEWABLE ENERGY

A list of European MSc programmes in Marine Renewable Energy (MRE) has been compiled from inputs from the partners in the Marinet network (see Table 1). Several other universities across Europe proposes courses or lectures related to MRE, but only the ones having an established programme of 1 or more semester are listed in the table below.

Table 1. List of European university courses and MSc Programmes in Marine Renewable Energy

Programme	Host institution	Country	Duration	Link
MSc Offshore Renewable Energy	University of Scathclyde	UK	12 months	http://www.strath.ac.uk/courses/postgraduatetaught/sustainableengineeringoffshorerenewableenergy/
MSc Marine Renewable Energy	Heriot Watt University	UK	12 months	http://www.postgraduate.hw.ac.uk/prog/msc-marine-renewable-energy/?programme=375
MSc Marine Renewable Energies	Instituto Maritimo Español and Bureau Veritas Centro Universitario	Spain	12 months	http://ime.es/site/index.php/cursos-on-line/master-in-marine-renewable-energies.html
MSc Marine Renewable Energy	Plymouth University	UK	12 months	http://www1.plymouth.ac.uk/courses/postgraduate/4148/Pages/CourseOverview.aspx
MSc Renewable Energy Engineering	Cranfield University	UK	12 months	http://www.cranfield.ac.uk/courses/masters/renewable-energy-engineering.html
MEngSc Marine Renewable Energy	University College Cork	Ireland	12 months	http://www.ucc.ie/en/ckr51/
Advanced Master in Renewable Marine Energies	ENSTA Bretagne	France	2 semesters	http://www.ensta-bretagne.eu/index.php/advanced-master-in-renewable-marine-energies/
European Master in Renewable Energy - Module on Ocean energy	Technical University of Lisbon	Portugal	1 semester	http://www.master.eurec.be/en/Partnering-Universities/Spe-Ocean-Energy-IST-Lisbon-Portugal/

2.1 COURSES CONTENT

2.1.1 University of Strathclyde, UK

The University of Strathclyde is proposing a MSc in Offshore Renewable Energy developed with industrial partners. The duration of the programme is 12 months full time or 24 months part-time.

The programme includes instructional classes as well as elective classes. Students are required to complete eight classes, a group project consisting on producing sustainable solutions to real-life industry problems and an individual project in a selected topic including the submission of a thesis.

Course		Description
Instructional classes	Sustainability	This class aims to provide the student with an understanding of the concepts of sustainability and sustainable development. The social, environmental and economic impact of development strategies will be identified and the mitigation of negative impacts discussed.
	Energy Resources & Policy	Against the background of international commitments on atmospheric emissions, diminishing fossil fuel resources and the liberalisation of energy markets, this class examines sustainable options for energy production, supply and consumption.
	Electrical Power Systems	This class aims to provide the student with an understanding of the operation of modern electrical power systems along with the techniques to undertake a basic technical analysis of key electrical devices and systems.
	Finite Element Analysis of Floating Structures	This class aims to provide the student with a theoretical and practical knowledge of the finite element method and the skills required to analyse floating structures with ANSYS, a commercially available finite element analysis program. Particular emphasis will be given to ANSYS graphical user interface (GUI) and Workbench platform.
	Renewable Marine Energy Systems	This class provides the student with an understanding of the ways in which the maritime environment can offer a significant sustainable contribution, to global energy demands. Also you'll undertake aero/hydrodynamic and structural assessments of the design and operation of marine energy generating systems.
Elective classes	Design Management	This class provides a structured introduction to the design management process, issues and tools.
	Financial Engineering	The class aims to introduce elements of financial engineering that are applied to reduce risk of business insolvency and enhance the financial robustness of business enterprises.
	Information Management	This class aims to give the student an understanding of the types of different approaches, techniques and systems used in building information based systems. In particular to introduce the student to the software engineering process, identifying information requirements and visual modelling. Also the student will acquire a basic understanding of information storage, retrieval, and systems.

		In addition to this it will provide an appreciation and basic skills in the process of developing information systems. It will also familiarise the student with information technology, how to model and use information and an introduction into a way of representing information on a computer based system.
	Risk Management	Under Health and Safety legislation, and under the wider European Post-Seveso Directives, it is mandatory for many industries to carry out risk assessments with the aim of showing that risk is "As Low As Reasonably Practicable". This class aims to introduce the fundamental techniques of risk analysis and risk-informed decision making. The student will have the opportunity to learn the general principles of methods and their place in risk management, as well as the chance to develop skills in applying these methods to variety of engineering examples.

2.1.2 Heriot-Watt University, UK

Heriot Watt University is proposing a MSc in Marine Renewable Energy. The duration of the MSc degree course is 12 month full-time and is taught at the Orkney Campus. The same education can also be done part-time and/or by distance learning. It involves studying 8 taught courses listed in the table below.

Course	Description
Energy in the twenty first century	This course is designed to give the student a broad understanding of the environmental, political and socio-economic context for current developments in renewable energy. The course examines the extent of current energy resources and how energy markets function. It covers some energy basics you will need for the rest of the programme (e.g. thermodynamics, efficiency conversions) as well as environmental issues associated with energy use, climate change and the political and policy challenges involved in managing energy supply and achieving energy security.
Economics of renewable energy	This course gives an understanding of the economic principles and mechanisms which affect energy markets today. It covers price mechanisms, the economics of extracting energy and the cost-efficiency of renewable energy technologies. You will learn about economic instruments used by policy-makers to address environment and energy issues, economic incentives to stimulate renewable energy development and about environmental valuation.
Environmental policy and risk	This course explores the legal and policy context in which renewable energy is being exploited. The student will gain an understanding of international law, particularly the Law of the Sea, property rights and how these relate to different energy resources. The course also looks at regulatory issues at the international, European and UK level, which affect how energy developments are taken forward, as well as risk assessment and management in the context of renewable energy developments.
Oceanography & Marine Biology	This course is designed to give the student an understanding of the science of waves and tides, and how this affects efforts to exploit energy from these

	resources. The student will also learn about marine ecosystems and how these may be impacted by energy extraction and about the challenges and impacts associated with carrying out engineering operations in the marine environment.
Marine renewable technologies	The student will gain an understanding of renewable energy technologies which exploit wind, wave and tidal resources. The focus is on technical design issues which developers face operating in the marine environment, as well as the logistics of installation, operations and maintenance of marine energy converters.
Renewable technology: Integration	This course explores the technical aspects of generating renewable energy and integrating it into distribution networks. The student will learn about the electricity grid and how electrical power and distribution systems work. The student will find out about different renewable fuel sources and end uses, and the challenges of energy storage.
Development appraisal	Looking at what happens when renewable energy technologies are deployed, this course examines development constraints and opportunities: policy and regulatory issues (including strategic environmental assessment, environmental impact assessment, landscape assessment, capacity issues and the planning system). It also looks at the financial aspects (valuation of capital asses, financing projects and the costs of generating electricity) and at project management.
Development project	This is a team project, where students have the opportunity to apply what they have learned through the other courses in relation to a hypothetical project. The student has to look at a range of issues including resource assessment, site selection, development layout, consents, planning and economic appraisal, applying the knowledge and tools the student has studied.

2.1.3 Instituto Maritimo Español and Bureau Veritas Centro Universitario, Spain

Instituto Maritimo Español and Bureau Veritas Centro Universitario has worked together to create a MSc programme in Marine renewable energies. This is a 12 months MSc online programme for an equivalent of 60 ECTS. The course is structured in 7 academic modules focusing on offshore wind and students must also develop a Final Project and either develop an International Business Project, or work as an intern in a company from the sector.

Course	Description
Introduction	This introductory course includes the following topics: international energy context, role of renewable energies in the context of sustainable development, low carbon economy, marine energies versus conventional energies, adjusting renewable energy and climate change policies, and carbon footprint of electricity generation.
Technical Aspects of Marine Technologies: Offshore wind farms	The student will learn about the design, construction and installation of an offshore wind farm. This includes the project management require behind this, the foundations, grid connection and offshore wind turbines.
Projects Permitting Process	The student will learn about the process of applying for permit for offshore wind projects. This includes the project origination and early site appraisal, the environmental impact assessment, the

	development risk and the development execution risks and due diligence.
Shipping and Logistics	This course deals with shipping and logistics related to offshore wind farms project. This includes detailed business opportunities for the shipping industry in marine energies, specialized marine units for the offshore and marine energy industry, building and conversion of supply and service ships, the role of shipyards in the construction and installation of main components, the fleet operation and associated costs and the role of logistic centres for the marine energy industry.
Operation and maintenance of Offshore wind farms	The student will learn about the cost associated with the value chain activities, the main hurdles to delivering O&M, the health, safety and environment risk, the availability, the contingency plan and the commercial aspects of offshore wind operations & maintenance.
Economics	This course on economics will cover the following topics: international framework for marine energies, incentives to marine energies, offshore wind financing, marine energies costs, risks and financial modelling.
Technical Aspects of Marine Technologies II: wave, tidal, currents	This course introduces other types of marine renewable energies. The student will have an introduction to ocean energy (resource assessment, key markets, test sites,…), learn about wave and tidal energy conversion, salinity gradient, ocean thermal marine energy, deployment of marine energy system and key markets and future perspectives in these fields.

2.1.4 Plymouth University, UK

Plymouth University is offering a MSc in Marine Renewable Energy. The programme is divided into compulsory modules providing the student with a broad background on marine renewable, optional modules and research project and dissertation. The duration of the programme is 12 months full-time.

Course		Description
Core modules	Economics, Law and Policy for Marine Renewable Energy	This module provides an overview of key economic concepts and issues relevant to the development and exploitation of marine renewable energy (MRE). The module also provides an overview of the relevant legal regimes relevant to MRE, including property rights, climate change and energy, marine environmental protection and maritime safety and security.
	Introduction to Marine Renewable Energy	This module provides an introduction to the engineering, technological, environmental, socioeconomic and legal issues relevant to the development and exploitation of marine renewable energy. The relative influence of the various factors in determining the success of specific sites is assessed and the current barriers to future development identified.

	MSc Dissertation	The student will complete a research project that they have designed in the semester 1 research skills module. The project can be submitted in the format of a journal paper or dissertation. The write-up will communicate the project aims, methodology, data analysis, interpretation, synthesis and conclusions
	Research Skills and Methods	This module aims to equip students with the practical skills and contextual framework for conducting high quality research. Emphasis is placed on workshop opportunities to acquire and practice research planning, analysis, communication, writing and oral presentation skills.
Optional modules	Assessment of Coastal Resources and Impacts	This module reviews the dynamics of the coastal ocean and explores methods to assess MRE resource availability and potential environmental impacts. Observational methods for understanding coastal morphology, ecosystems and forcing mechanisms such as waves, tidal currents and tidal elevation are examined. Methods for impact mitigation and management are discussed. Case studies from around the world are utilized.
	Economics of the Marine Environment	This module will provide students with a clear overview of the problems associated with economic activity in marine environment and the potential solutions to these problems.
	Marine Planning	This module evaluates the emergence and practice of marine planning in UK waters. It will explore the techniques available for developing marine plans and demonstrate the role which may be played by geographic information systems and other tools. Through lectures, field visits and case studies, it will also develop the learner's knowledge of the marine environment as required for marine planning.
	Mechanics of MRE Structures	This module will cover engineering aspects of marine renewable energy conversion. The module comprises lectures and tutorials, invited industry lectures, a field trip visit to a marine engineering company and a wave energy converter performance experiment in the COAST lab.
	Modelling Coastal Processes	The modelling process is described and some simple modelling techniques are introduced. The application of these to continental shelf modelling, pollution modelling, wave and tidal modelling will be done using some simple, identified simulations with the aid of available software.

2.1.5 Cranfield University, UK

The MSc in renewable energy engineering at Cranfield University is made up of eight compulsory taught modules, a group project and an individual research project. The course comprises eight one-week assessed modules, a group project, and an individual thesis project. The duration is 12 months full-time or 3 years part-time.

Course	Description
Dynamics of Fluidic Energy Devices	To provide a theoretical and applied understanding of fluid mechanics and fluid loading on structures with an emphasis on the conceptual & preliminary design of wind, wave and tidal current renewable energy systems.
Structural Integrity of Renewable Energy Systems	To provide a general understanding of pertinent issues concerning the use of Engineering Materials and practical tools for solving structural integrity and structural fitness-for-service problems.
Computer Simulations for Engineering Design	To introduce the techniques and tools for modelling, simulating and analysing practical engineering problems. This course provides the basic theoretical and practical knowledge to allow an engineer to competently perform both Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) using commercial software packages used in industry.
Risk and Reliability Engineering	To introduce the principles of risk management and reliability engineering and solve relevant engineering problems through widely applied methods and tools.
Advanced Control Systems	To introduce methodologies for the design of control systems for industrial applications.
Renewable Energy Technologies, Policy and Markets	To provide an overview of the key aspects of the renewable energy industry: technology, finance, risk and certification, and basic legislation, to gain an understanding of the principles of operation, configuration, characteristics and key implementation issues of renewable-energy utilisation systems.
Power Electronics and Machines	To introduce and analyse electrical machines and power electronic systems for electric power conversion applications, including wind power generation and power controller for photovoltaic cells. To introduce electric power generation, transmission and distribution, and to examine the aspects of power management, load flow, and stability.
Testing and Routes to Certification	To provide a theoretical, applied and experimental understanding of the main engineering fields involved in the design and the operation of hydrodynamic testing facilities (such as wave tanks, towing tanks and water circulation channels) and aerodynamic testing facilities (ie wind tunnels).

2.1.6 University College Cork, Ireland

University College Cork is offering a MEngSc in Marine Renewable Energy covering a range of engineering and non-engineering topics relevant to the marine renewable energy industry. The duration of the programme is 12 months

full-time. The first part includes core and elective modules and 5 at choice elective modules for a total of 60 ECTS. The second part consists of a Marine Renewable Energy Research Project, to the value of 30 credits.

Course		Description
Core modules	Environmental Hydrodynamics	The students will be able to develop mathematical description of hydrodynamic behaviour, derive expressions for Stream Function and Potential Function, quantify flow patterns for fluid / structure interactions, calculate wave behaviour using the Airy linear wave theory and understand the limitations in the derivation, quantify the kinematics and dynamics of surface wave motions, quantify the propagation of a surface wave into the shoreline, describe the options for measurement and description of real sea waves, develop models for tides in the ocean and develop solutions for diffusion in one dimensional streams.
	Wind energy	The course covers wind characteristics and resources, measurement and instrumentation, data analysis and energy production estimates, weibull distribution, log and power laws, aerodynamics of wind turbines, characteristics of airfoils, momentum theory, wind turbine rotor dynamics, wind turbine design and components, blade pitch and stall control, principles of wind farm design and micro-siting, introduction to wind farm design software tools, civil works for wind farms, wind energy variability, wind energy storage technologies, requirements for and approaches to wind energy forecasting, and offshore wind energy.
	Ocean energy	This course covers the subjects of introduction to ocean energy, wave theory, tidal theory, wave and tidal energy resource- measurement and calculations, wave energy convertors, tidal energy convertors, practical systems modelling and design, output calculation methods, power take-offs and system integration issues.
	Advanced Topics in Marine Renewable Energy	The course covers the subjects of ICT and control engineering for marine renewable energy devices, wind and wave loading of offshore structures, offshore operations, maintenance and robotics, ocean energy device modelling using CFD techniques, design, manufacture, durability and test of materials for marine renewable energy devices, economics of marine renewable energy, environmental impacts of marine renewable energy with specific reference to tidal energy systems and marine governance and the regulatory regime.
	Tidal energy	The course covers the basics of ocean and coastal currents & water levels, measurement & analysis of tidal currents and elevation and principles of tidal prediction, the basics theory of current hydrodynamics, ocean tides, coastal tides, global and local currents and their drivers, principles of tidal energy, tidal stream devices and tidal barrages, the types of devices, the performance estimates using Betz limit & Blade Element Moment Theory, the tidal stream devices and CFD, the wake effects, turbulent boundary layers and shear flows wave current interaction, the marine ecology interactions with marine renewable energy, in particular tidal stream power, the modelling tidal resources and interaction of tidal turbine.

Elective modules	Innovation Finance	This course examines the finance of innovation, focusing on technology-based start-up ventures, and the early stages of company development. It addresses key questions which challenge all entrepreneurs: how much money can and should be raised; when should it be raised and from whom; what is a reasonable valuation of the company? The subject aims to prepare students, as innovators and entrepreneurs, for these decisions.
	Sustainable Energy	This course covers the subjects of sustainable energy, global and regional energy trends in terms of fuel supply and sectoral consumption, electrical, transport and thermal energy consumption, energy end use, pillars of sustainable energy policy, environmental impacts of energy, climate change, transboundary gas emissions, security of energy supply, cost competitiveness, policy instruments, energy efficiency indicators, socio-economic assessment of energy supply systems, renewable energy market development and fuel cells and the hydrogen economy.
	Harbour & Coastal Engineering	This course covers the subjects of coastal engineering principles, coastal erosion and deposition, coastal protection methods, harbour design, breakwater construction, port structures, data collection and hydrographic surveying.
	Finite Element Analysis	The student will learn about finite difference solution of continuum problems, weighted residual methods with continuous trial functions, piecewise defined trial functions and the finite element method (FEM), finite element shape functions, mapped elements; numerical integration (Quadrature), generalisation of the finite element method & variational principles, time dependent problems, derived response smoothing and error analysis. A series of continuous assessment exercises will lead up to the development of a primitive 2D FEA program from the principles covered in the lectures, using the students programming platform of choice.
	Power Electronics, Drives & Energy Conversion	The course covers the subjects of electric vehicle powertrain, isolated and non-Isolated converters, and modelling, characterization, operation and speed control of AC machines.
	Electrical Power Systems	The course covers the subjects of electrical power supply systems, energy sources, generation, transmission and distribution of electrical energy, three-phase ac circuit theory, network equations and power flow, unbalanced three-phase systems, symmetrical components and sequence networks, synchronous generators: torque equation and equivalent circuit, real and reactive power flow, power transformers: equivalent circuit, per-unit theory, three-phase and auto-transformers, transmission lines and faults: symmetrical and asymmetrical faults, utility/consumer interface: loads, wiring, protection, and system modelling.

Environmental Impact Assessments	The student will learn about EIA, its purpose and limitations, the legal background and statutory requirements, the approaches and methods, the standardisation and quality control, the preparation of EIA reports and recommendations, the preparation of environmental impact statements and some case studies.
Practical Offshore Geological Exploration	The student will learn about seabed mapping techniques and practice, seabed sampling techniques and practice, sub-seabed imaging techniques and practice, seabed monitoring techniques and practice, offshore survey planning, offshore geological data collection, evaluation and resource assessment.
Technology Business Planning	This course will utilise business cases and draw on the experience of Irish entrepreneurs. It will also give students practical experience of business start-up and entrepreneurial behaviour.
Intellectual Property Law for High-Tech Entrepreneurs	The intellectual property seminars will give students an opportunity to explore in detail this rapidly developing area of law. Topics covered will provide an opportunity for students to explore issues arising for the legal protection of research and innovation with specific focus upon copyright, patents and trademark law. Students will be afforded an opportunity, by way of weekly seminars, to explore and discuss topical issues, including copyright law in the digital age, the conflict between consumer and commercial interests in affording protection and exclusive use to trademark owners and the ongoing debate as to the patentability of computer programs and biotechnological inventions. Students will have an opportunity to develop an understanding of the legal framework surrounding the protection of inventive and original work and will do so with reference to their own research and development.
Energy Systems Modelling	The student will learn about technical, economic and market modelling of energy systems, modelling national energy demand and supply, macro-economic top-down modelling and techno-economic bottom up modelling, partial equilibrium and general equilibrium modelling, modelling renewable energy systems, and the student will have an introduction to MATLAB Simulink, LEAP, SAM, MARKAL - TIMES and PLEXOS modelling tools.
Control Systems	The course covers the subjects of control theory terminology, state-space modelling of physical systems, differential equations, discrete-time equations, Laplace transforms and transfer functions, simulation algorithms, classical control, discrete-time control basics, state-space control, and model predictive control.
Maintenance & Reliability	The student will learn about reliability of components, processes and systems, reliability in design and maintenance management.

2.1.7 ENSTA Bretagne, France

ENSTA Bretagne is offering an advanced Master programme in Renewable Marine Energies. The duration of the programme is two semesters where the first semester is an applied training of 501 hours (see table below) and the second semester is a final thesis in an industrial or academic environment.

Course	Description
Overview of energy resources	This course covers the subjects of waves: dynamics and resources, tides and coastal circulation, ocean circulation, numerical modelling, measurements in a coastal environment, and coastal meteorology.
Engineering sciences and technology	Design of energy extraction systems This course covers the subjects of elements of hydrodynamic design of mechanical energy collectors (wind turbine, underwater turbines, wave energy converters), design elements and review of exploitation system technologies of marine thermal energy, design elements of mechanical systems, material and structures in a marine environment, and design of facilities at sea.
	Design, analysis and management of energy chain This course covers the subjects of power transmission, analysis of the electricity chain and control, optimization and management of energy chains, capture and transmission systems, and diagnosis and management of weakened modes.
Coastal Environment and Impacts	The course covers the subjects of sedimentary dynamics, marine ecology and disturbance of ecosystems, coastal geology, and geomatics.
Marine Energy and Society	The course covers the subjects of legal instruments and stakes, spatial and social stakes, and the economic aspects of marine renewable energy.
Project	The student is introduced to the design of energy production systems, or does a case study of an installation.
Refresher course (as needed)	This course gives the student reminders in electrical engineering, electrical machines, mechanical technology, and fluid mechanics, and an introduction to Matlab.

2.1.8 Technical University of Lisbon, Portugal

The technical University of Lisbon is offering a specialisation semester on Ocean Energy as part of the European Master in Renewable Energy. The master specialisation features 30 ECTS spread over the modules below. The duration of the specialization is 1 semester.

Course	Description
Ocean Energy Resources	The student will learn about the physical mechanisms in the ocean which are on the basis of the generation of surface waves, tides and currents, and their effects and the statistic description of waves and currents. The student will learn how to use the statistical information to evaluate the energy resource and how to use the GIS in site selection characterisation.

Modelling and control of ocean energy systems	The course covers the linear hydrodynamic theory of wave energy systems, the hydrodynamic theory of marine current turbines (BEM), the advanced numerical hydrodynamic modelling of wave and current systems and control simulation, the experimental testing and monitoring of ocean energy systems and the basic knowledge of other forms of ocean energy and their systems as OTEC and salinity gradients.
Ocean energy systems technologies	The course covers the electro-mechanical equipment used in wave energy systems and marine current turbines, the offshore electrical grid and connection systems and the basic knowledge on the requirements to deploy, operate and maintain the wave and current energy systems both isolated and in arrays.
Economics, policy and environment	The course covers the basic economic analysis of ocean energy systems including the cost, financing and economic evaluation, the basic knowledge on the general policy issues regarding ocean energy systems and more detailed knowledge on the licensing and permitting procedures for installation of ocean energy systems and enabling mechanisms as funding, feed-in tariffs and tax incentives and the student will perform simple environmental impact studies for ocean energy systems.
Offshore wind resource and technology	The course covers the wind energy resource and the difference between onshore and offshore wind energy resource, the aerodynamics of offshore wind turbines, the loading on turbines and turbine structures, the control of turbine, and the problematic of designing offshore wind farms.
Project	The student will bring into practice the knowledge acquired through a case study in the form of a specific small project.

2.2 Analysis of the courses offered in MRE programmes within Europe

The courses offered in the different programmes described earlier have a similar structure. Most of them consist of a core module of general courses in marine renewable energy, including energy resource and policy, and a specialised module where more technical aspects are taught, such as design, modelling and power systems. The topics that are more recurring are, in order:

1) Energy resource and Policy
2) MRE technologies
3) Economics of RE
4) Electrical Power Systems
5) Risk, management and reliability
6) Design management
7) Permitting
8) Environmental impact

There is a good overlap among the different courses taught in MRE within the different European universities. Furthermore, many programmes include a project to apply the knowledge gained previously.

Some well know “hot topics” in the field seem not to have been yet considered in the education previously mentioned. For example,

a) in wave energy: mooring design and materials, wave to wire models, optimization of energy capture with control strategies, design issues related to survivability
b) in tidal energy: the issue of reversibility of the rotor, loads generated by vortex and turbulences, installation methods and logistics

The Instituto Maritimo Español has dedicated most of the MSc to offshore wind energy and the topic can be treated in greater details:

c) offshore wind: technical aspects, permitting, logistics and shipping, operation and maintenance of wind farms

In other words, it is important to allow time for specific topic to develop and these specific topics should try to address the specific requirements that the sector is presenting.

3 SUGGESTION FOR A EUROPEAN MASTER PROGRAM IN MRE

3.1 EUROPEAN MASTER PROGRAM IN MRE

The European Master Programme in MRE proposed in this document is divided in 3 modules. In the first module the students will receive core foundation in common aspects related to MRE and a technical introduction to all technologies. In the second module the students should travel to another university to receive the specialization that the student wishes to pursue. The following specializations are proposed:

1. Grid Integration
2. Offshore wind
3. Tidal Energy
4. Wave Energy
5. Shipping logistics, operations and maintenance of offshore MRE installations

During the third module, the student will develop a research project in a laboratory, test site or in a company in the area of her/his specialization.

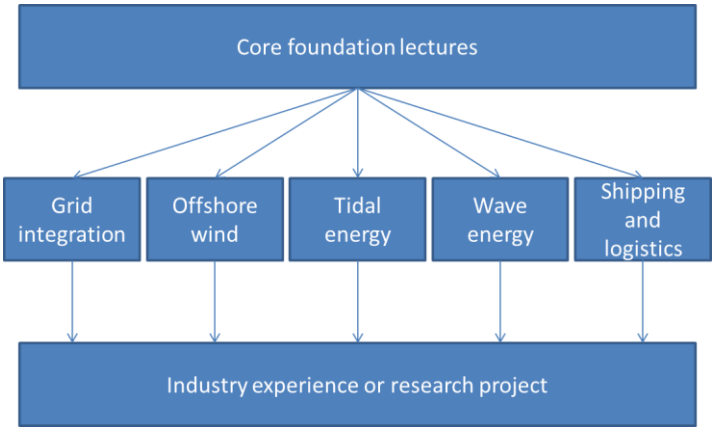

Figure 1. Outline of the suggested structure for the European Master in Marine Renewable Energy.

The requirement for admission to the programme should be a BSc degree of a high standard in an Engineering, Maths or Physics OR equivalent appropriate work experience.

The assessment of the taught modules (60 ECTS) will be done via a mixture of continuous assessment (assignments and mini design projects) and traditional examinations. The project module (30 ECTS) will be assessed by means of written dissertation and oral presentation.

In the following sub-chapter, the possible lectures and topics to be taught in the European Master Program in MRE will be described by section and possible universities partners will be included in the description.

3.1.1 First module: fundamental courses in MRE

During the first module, the students will gain knowledge on the different technologies in MRE, resource assessments, measuring techniques, logistics, economics, policy and licensing processes. The fundamental courses could be offered by all the universities involved and may be taught in other languages than English. All the universities should however have the same first module programme or a programme that will guarantee that the students acquire the same set of skills necessary for any of the specializations. The fundamental courses proposed are listed in the table below.

Course	Description
Resource assessment for wind, wave and tidal energy **5 ECTS**	The course covers the physical mechanisms in the ocean which are on the basis of the generation of wind, surface waves, tides and currents, and their effects and the statistic description of wind, waves and currents. The student will learn how to use the statistical information to evaluate the energy resource and how to use the GIS in site selection characterisation.
MRE technologies **5 ECTS**	The course covers the electro-mechanical equipment used in wave energy systems, marine current turbines and offshore wind turbines, the offshore electrical grid and connection systems and the basic knowledge on the requirements to deploy, operate and maintain the wave, current and offshore wind energy systems both isolated and in arrays.
Economics of RE **4 ECTS**	The course covers the basic economic analysis of ocean energy systems including the cost, financing and economic evaluation, enabling mechanisms as funding, feed-in tariffs and tax incentives.
Electrical Power Systems **4 ETCS**	The course covers the subjects of electrical power supply systems applied to MRE systems: energy sources, generation, transmission and distribution of electrical energy.
Risk and reliability **4 ETCS**	The course gives an overview of the key aspects of the renewable energy industry: technology, finance, risk and certification, and basic legislation, to gain an understanding of the principles of operation, configuration, characteristics and key implementation issues of renewable-energy utilisation systems.
Design management for MRE installations **4 ECTS**	This course covers the subjects of elements of hydrodynamic design of mechanical energy collectors, design elements and review of exploitation system technologies of marine thermal energy, design elements of mechanical systems, material and structures in a marine environment, and design of facilities at sea.
Policy and licencing/permitting **2 ECTS**	The course covers the basic knowledge on the general policy issues regarding ocean energy systems and more detailed knowledge on the licensing and permitting procedures for installation of ocean energy systems.
Environmental impact **2 ECTS**	The course covers the subjects of sedimentary dynamics, marine ecology and disturbance of ecosystems, coastal geology, and geomatics and the student will perform simple environmental impact studies for ocean energy systems.

The universities suitable for hosting the first module of the programme include the ones that already have a master program in marine renewable energy in place (Chapter 2):

- University of Scathclyde
- Heriot Watt University
- Instituto Maritimo Español
- Plymouth University
- Cranfield University
- University College Cork
- ENSTA Bretagne
- Instituto Superior Técnico

Many other universities/institutions, for example those member of the MaRINET consortium, could easily offer the first module of the programme. This includes for example Ecole Centrale de Nantes, Aalborg University, Università degli Studi di Firenze, and NTNU.

3.1.2 Second module: specialization

The second module corresponds to a specialization module in the field of MRE. Four specializations have been chosen. This module contains four to six courses for a total of 30 ECTS. The courses will include laboratory exercises, small projects, case studies, and field trips when possible.

3.1.2.1 Grid integration

The specialization "Grid integration" (30 ECTS) corresponds to the following courses:

Course	Description
Distributed generation **5 ECTS**	This course introduces the concept of distributed generation for the different MRE systems. It covers the subject of power system operation and distributed generation.
Generation and storage technologies **5 ECTS**	This course covers the energy generation for the different MRE technologies (offshore wind power, tidal power and wave energy power), hydrogen technologies ad power storage.
Control techniques and renewable energy integration systems **5 ECTS**	This course covers the subjects of AC/DC Drives Control, predictive direct power control of systems connected to the grid, technological aspects of power electronic systems connection to the grid, active network devices, control and FACTS technology, and micro-grids.
Power grid analysis **5 ECTS**	The course covers the subject of electric systems modelling, power supply quality and optimization and grid Planning.
Smart grids **5 ECTS**	The course covers the subject of smart grids programming, protective devices, and smart grid. A case of Study of distributed generation protection will also be part of the course.
Standards and electric markets **5 ECTS**	This course covers the subject of standards and electric market when dealing with MRE systems.

This specialisation is available at the University of Zaragoza and could easily be implemented at, for example, University College Cork.

3.1.2.2 Offshore Wind Energy

The specialization "Offshore Wind Energy" (30 ECTS) corresponds to the following courses:

Course	Description
Offshore wind energy resource **6 ECTS**	The course covers the subjects of offshore wind characteristics and resources, measurement and instrumentation, data analysis and energy production estimates, Weibull distribution, and Log and power laws.
Site selection and characterization for wind energy systems **6 ECTS**	This course covers the subject of design criteria for offshore wind energy systems, choice of material and foundation for offshore wind energy systems.
Modelling and Control of wind turbines **6 ECTS**	This course goes into details concerning the modelling and control of offshore wind turbines. This includes blade pitch and stall control and an introduction to wind farm design software tools.
Market of offshore wind **6 ECTS**	This course covers the subjects of international framework for offshore wind energies, offshore wind financing, marine energies costs, risks and financial modelling. Both bottom based and floating technologies will be studied.
Operation and maintenance **6 ECTS**	This course covers the operation and maintenance of offshore wind energy systems. It includes the cost associated with the value chain activities, the problematic to delivering O&M, the health, safety and environmental risk, the availability, the contingency plan and the commercial aspects of offshore wind operations & maintenance.

The universities or institutions suitable for this specialization are: DTU, Aalborg University, Delft University, Instituto Maritimo Español, University of Nottingham, and University of Manchester.

3.1.2.3 Tidal Energy

The specialization "Tidal Energy" (30 ECTS) corresponds to the following courses:

Course	Description
Tidal currents **6 ECTS**	This course covers the subjects of tidal energy resource characteristics, measurement campaigns and how the resource may be harnessed in a tidal energy system.
Site selection and characterization for tidal energy systems **6 ECTS**	This course covers the specifics of site selection and its characterisation, the design criteria for tidal energy system, including the choice of materials to be used.
Tidal turbine technologies **6 ECTS**	This course covers the different types of devices (free flow turbines, tidal barrage, ducked turbines) and power estimation using Betz limit and blade element moment

	theory.
Modelling and control of tidal turbines **6 ECTS**	This courses covers the different operation strategies for tidal turbines including the subjects of two flow directions, reverse turbines, ebb and tide modes, pumping etc…
Operation and maintenance **6 ECTS**	This course covers the operation and maintenance of tidal energy systems. It includes the cost associated with the value chain activities, the problematic to delivering O&M, the health, safety and environmental risk, the availability, the contingency plan and the commercial aspects of tidal energy system operations & maintenance.

The universities or institutions suitable for this specialization are: University of Strachlyde, Ecole Centrale de Nantes, Cambridge University, University of Edinburgh, and Oxford University.

3.1.2.4 Wave Energy

The specialization "Wave Energy" (30 ECTS) corresponds to the following courses:

Course	Description
Ocean surface waves **6 ECTS**	This course covers the theory of ocean surfaces waves. This includes wave theory, wave resource measurement and calculations and how the resource may be harnessed by wave energy systems.
Site selection and characterization for wave energy systems **6 ECTS**	This course covers the specifics of site selection and characterisation for wave energy systems. This includes design criteria, materials to be used, mooring design, and foundation design.
Wave energy technologies **6 ECTS**	This course covers the different type of devices for wave energy conversion (point absorbers, OWC, overtopping devices and others), including modelling of a simple point absorber device using boundary element method.
Modelling and control of wave energy devices **6 ECTS**	This course covers the subjects of modelling and control of wave energy devices, including the reliability and costs of the different control solutions.
Operation and maintenance **6 ECTS**	This course covers the operation and maintenance of wave energy systems. It includes the cost associated with the value chain activities, the problematic to delivering O&M, the health, safety and environmental risk, the availability, the contingency plan and the commercial aspects of wave energy system operations & maintenance.

The universities or institutions suitable for this specialization are: University College Cork, Plymouth University, Aalborg University, University of Edinburgh, and Ecole Centrale de Nantes.

3.1.2.5 Shipping logistics, operation and maintenance of offshore MRE installations

The specialization "Shipping logistics, operation and maintenance of offshore MRE installations" (30 ECTS) corresponds to the following courses:

Course	Description
Construction, deployment and decommissioning **7 ECTS**	This course covers the subject of construction of MRE system, technical management of installation operations and technical management of operation and maintenance.
Vessels and equipment specifications for installation and operation of MRE **8 ECTS**	This course covers the subjects of innovative solutions for current vessels for both installation and O&M phases of MRE systems taking into account the specifics of vessels for the specific component and/or operation to take place.
Logistics **8 ECTS**	The course covers the logistics behind shipping, operation and maintenance of MRE systems, including the concept of integrated logistics and operation and maintenance strategies, weather window for installation and O&M.
Economics and market assessment **7 ECTS**	This course covers the subject of cost analysis related to technical innovations and system optimisations, and assessment of market impacts of proposed innovations (job creation, development of commercialisation strategies).

This specialization could benefit from the outcome of the LEANWIND FP7 EU project for offshore wind and be extended to all MRE. The universities or institutions suitable for this specialization are: University of College Cork, The University of Edinburgh, Aalborg University and Fraunhofer IWES.

4 CONCLUSIONS AND RECOMMENDATIONS

The growing interest in marine renewable energy is easily noticed by the creation of master programmes in this field in the recent years. As presented in this report, eight universities or institutions are providing such courses in Europe, more specifically in France, Portugal, Spain, Ireland and UK. The different master programmes have noticeable similarities in their structure and the lectures offered. Furthermore, those programmes are extremely popular, reaching easily the attendance limit.

The MaRINET project has shown how transnational interactions can be beneficial. This transnational experience could easily be transferred into a transnational European Master in Marine Renewable Energy, taken the well-established network of the MaRINET project. The programme for such a Master has been outlined in this document. It consists of three modules, where the first contains fundamental courses in MRE, the second corresponds to a specialization also in the form of courses and the last is a research project in a laboratory, test site or in a company in the area of specialization. Suggested available specializations are: grid integration, offshore wind, tidal energy, wave energy, and shipping and logistics.

It is the hope of the MaRINET project that it will be possible, in the near future, to implement such kind of European master programme as this would further indicate the evolution of the MRE sector. It is nevertheless important to notice that coordination among the universities or institution that will be involved in the programme should be pursued at an early stage. The coordination experience gained through the MaRINET project could be of significant help in the process.