Wave power has great potential for contributing to international environmental and sustainable energy goals. WAVETRAIN RTN seeks to coordinate and facilitate the training and exchange of researchers within Europe in this field, say **Frank Neumann** and **António Sarmento**

Wave energy R&D gathers momentum

After more than 30 years of limited success, substantial progresses over the last decade put ocean wave energy conversion firmly on the path towards commercial-scale implementation. It is expected that waves can complement the European renewable energy mix and contribute towards the Kyoto objectives significantly. Long-term potential is estimated to be in the range of at least 2000 Terawatt-hours per year world-wide (ca. 10 per cent of present global electricity demand).

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To face the expected boom, industry requires well-trained engineering professionals with substantial understanding for the non-forgiving maritime environment and the necessity for low-cost solutions. WAVETRAIN has significantly contributed in closing the gap from existing education and training to the creation of highly competent 'wave energy engineers' with an international background. In the absence of existing educational paths for those seeking to become a 'wave energy engineer', a consortium of several European Universities, R&D entities and companies joined together in order to offer network-wide courses, complementary to the adjacent engineering disciplines, integrated in well-defined applied research profiles. The group of recruited researchers has rapidly grown together to a well-collaborating European cluster covering most of the wave-energy-relevant aspects. The collaboration effort, funded under the Marie Curie Actions in the 6th FP from 2004-2008, has been reinforcing Europe's leading position in wave energy developments, and led to a follow-up project Wavetrain2, which is presently being negotiated with the EC, after having successfully finished the evaluation rounds for funding within the FP7 PEOPLE-ITN programme.

Partners and network structure

The partnership of Wavetrain RTN arose from former collaboration within EC-funded R&D projects and was an initiative of the Wave Energy Centre (WavEC, Portugal), who elaborated the proposal and managed the project, which was formally co-ordinated by Instituto Superior Técnico (IST, Portugal).

The project consisted of a total of 383 researcher-months contracted from outside each host institutions' countries, and a substantial amount of network-wide training events with some focus on real sea testing.

The concluded R&D work programme

The project research, simultaneously delivering the substance of the hands-on training, has mainly been accomplished by the contracted researchers themselves, with relatively limited intervention by the supervisors and, in some cases, other team members. The research project's work programme is organised into five tasks, which are as follows:

Task 1: Pre-Normative Research; Task leader INETI

A comprehensive identification of wave-energy relevant resource parameters, and seasonal and geographic wave energy variability were the major outcome of this task, incorporating several network partners in this field. An extensive document was produced, leading to the conclusion of a PhD work at INETI. Further more, WAVETRAIN members participated in ongoing standards discussions on several levels.

Task 2: Device Modelling & Design and New Concepts; Task leader ECN

Hydrodynamic modelling, control strategies for floating wave energy converters, and their application in different deployment sites was conducted mainly at IST, including an extended analysis of point-absorber theory with reference to the concept of 'array' and

Wavetrain partners and their role within the project			
Instituto Superior Técnico	IST	Portugal	Co-ordinator
Teamwork Technology	TT	The Netherlands	Device developer (AWS)
Spok ApS	Spok	Denmark	Device developer (Wave Dragon)
Queens University Belfast	QUB	United Kingdom	Device developer (Oyster)
Wave Energy Centre	WavEC	Portugal	Manager; Device Monitoring (Pico OWC)
École Centrale de Nantes	ECN	France	Numerical Modelling
University College Cork	UCC_HMRC	Ireland	Experimental Modelling
University of Edinburgh	U of E	United Kingdom	Experimental Modelling
Instituto Nacional de Engenharia Tecn. e Inovação	INETI	Portugal	Resource Assessment
Delft University	TU Delft	The Netherlands	Linear Generator
Chalmers University	Chalmers	Sweden	Mooring Issues

'wave farm'. Dynamic analysis of the AWS device and developing an overall model including cost and energy production for the next prototype were the main activity lines at TT. Both profiles led to PhDs. At ECN, optimal control laws for possible control methods used in wave energy converters were investigated, leading to the modelling and control of systems with variable structure like the SEAREV device. At UCC_HMRC, experimental modelling on the OE Buoy device, and at QUB the development of the Oyster device was conducted, both in the context of a PhD work.

Task 3: Structure, Components & PTO (Power-Take-Off); Task leader U of E

The insufficient amount of representative data series, from the prototype devices, led to the substitution of evaluating PTO performance from real-scale test data series, with the development and hands-on testing of a new device. Activities were focused at U of E, and included a 6-degree-of-freedom (surge, heave, sway, pitch, roll, yaw) rig for a wave tank, the calibration of the curved tank in order to determine the transfer function and the conception, building and testing of a modified 'Salter's Duck' device for desalination purposes.

At TUDelft, the work focused on improvement of the linear generator concept for use as a PTO system (PM Linear generator) of the AWS device. At Chalmers, a Good Practice Guide for mooring isues of slack moored WECs was produced, leading to a PhD.

Task 4: Plant Monitoring and Evaluation; Task leader QUB

During the project period, monitoring activities on the AWS device, the OWC pilot plant on Pico/Azores (WavEC) and the Wave Dragon device (SPOK and UAA – University of Aalborg) were the baseline for some initial considerations on pilot plant performance and PTO improvements. Both AWS and Wave Dragon monitoring were integrated in PhD works at TT and SPOK, which further contributed substantial technical input for the development of next-generation AWS and the 7 MW Wave Dragon device.

Task 5: Ecological and Socio-economical Impacts; Task leader WavEC

The non-technical issues covered in WAVETRAIN comprised an in-depth investigation of wave energy economics for large-scale implementation and related instruments, as well as environmental issues of pilot plants, preparatory work for large-scale wave farms and licensing issues. Apart from some activities developed by SPOK, most of the work in this task was performed by WavEC, culminating in a proposal of an environmental monitoring strategy for the Portuguese Wave Energy Pilot Zone.

Training and networking activities

As opposed to the classical European collaborative projects, where specific tasks are to be achieved at each network node in order to yield a global joint R&D outcome, the primary objective of the Marie Curie RTN is the training and intra-European exchange of researchers and improving the networking capacities.

Within WAVETRAIN, the latter could be mainly achieved by creating

Training and exchange opportunities	
Introduction to Ocean Wave Energy *Chalmers, Spring 2005*	Ocean wave theories and applications; mathematical handling of moving bodies and body-sea interaction; wave harmonics and resonance effects; practical considerations for wave energy conversion (1 week)
Numerical Modelling Techniques *ECN, Summer 2005*	Introduction into numerical modelling techniques applied to wave energy conversion; adjacent to advanced numerical modelling course organised outside WAVETRAIN at the same location. (1 week + 1 week external)
Experimental modelling and plant monitoring *UCC_HMRC & QUB, Summer 2006*	Experimental modelling techniques, survival at sea; site visit to Galway test centre (first part, Cork); field trip to LIMPET OWC on Islay/Scotland and introduction into monitoring techniques (second part, QUB) (1 week)
Mechanical, Hydraulic and Electric PTO Issues *U of E, End 2006*	Hydraulic, pneumatic and direct drive PTO options, demonstration of the curved wave tank of the wave power group; hands-on training in the electrical machines laboratory (1 week)
Environmental Issues / Socio-Economics SPOK, Spring 2007	Environmental and socio-economic issues based on offshore wind experience; adjacent to the CA-OE Workshop on Environmental, Economics, Development Policy (1 week)
Wave Energy Realities ('wrap-up' course) *WavEC, Autumn 2007*	Operating of the real-scale Pico OWC (400kW), retrieving and evaluating data in small groups. Essentials in economics and finance, project management and soft skills (1 week)

a cohesive and independant group of fellows, forming the basis for the collaborative effort. A major catalyst for the creation of this critical mass was the implementation of short courses ('summer school' concept) on carefully chosen topics.

The existence of these short courses did on the one hand regularly concentrate the fellows in one location over several days, and on the other hand provide valuable training beyond the strict horizon of their work programme.

The short courses were generally very well received, also from members of the wider wave energy community. They further helped to establish topics on which study in the immediate future should be focused. Apart from these short courses, the vehicle for networking was the joint focus for a number of international conferences, and the recently created INORE group (International Network on Offshore Renewable Energy).

The success of the research network

The fundamental contribution of WAVETRAIN to the Ocean Wave Energy community has been the preparation of 15-20 young professionals that 'grew' together in the sector, building a critical mass for future collaborations.

Most have been absorbed by the emerging industry faster than WAVETRAIN could 'produce' them. The concept of local hands-on training mixed with joint network training events has shown to be a very successful tool to induce group dynamics in the young researchers from different countries. WAVETRAIN has by some being considered as "the best money the EC ever spent on wave energy". The follow-up project Wavetrain2 is expected to start in summer 2008.★

At a glance

Full Project Title

Research Training Network Towards Competitive Ocean Wave Energy

Key figures

Approximately 400 researchers have been contracted from countries outside the scope of the project partnership. Furthermore, there have also been six intensive network-wide short course periods and several secondments to other team members, while the project has also put forward a strong presence at international wave energy events.

Project objectives

The Wavetrain project aim to encounter and address the multiple scientific and technological challenges that areclosely associated with the pre-commercial phase of ocean wave energy utilisation. The project will offer grants or contracts to both Early Stage and Experienced Researchers from other countries.

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