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HERIOT WATT INSTITUTE OF PETROLEUMENGINEERING

MREDS

Marine Renewable Development In Scotland

A RESEARCH PROPOSAL ISSUED SEEKING INDUSTRY SUPPORT BY

HERIOT-WATT INSTITUTE OF PETROLEUM ENGINEERING

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Summary

Heriot-Watt University and partners seek Industry support for an integrated project in Marine Renewable Energy with particular emphasis for opening up the potential in the North Sea around Scotland's Coast. The consortium that has been assembled (Universities, Research Laboratories, SME and Local Government) is of sufficient scale and breadth to tackle the many restrictions in bringing the technology to the market place.

Background and Rationale

Scotland has the greatest marine renewable energy resource in the world. Despite the substantial progress made and enormous optimism surrounding the emergence of the marine renewables sector in Scotland it is still a fledgling industry, and when viewed by observers often rightly seen as a particularly vulnerable sector. This vulnerability is a consequence of many factors, foremost among which are:

1) The fragility of the infrastructure in Northern Scotland notably the grid and its further development, the latter being subject to significant influence by national (Westminster driven) decisions;
2) Under-investment, with many designs and project initiatives being led by SMEs without substantial capital investment capacity, and with less attractive returns to investors than comparable onshore renewables projects;
3) The capacity of the economy of the Highlands and Islands to support the R&D activity necessary for the region to be a world-leader in this technology with expertise and resources capable of supporting its development, rather than simply relying on imported technologies to exploit these resources;

MREDS takes as its prime objective the goal of strengthening this emergent sector, and seeks to achieve this in four ways, elements of which are also significant factors in the (non-marine) renewables sectors:

- Seeking innovative short, medium and long term solutions to possible constraints to the conventional export infrastructure; developments which are in themselves and whose demonstration is desirable regardless of future changes in grid export capacities;
- Attempting a broad-scale cross fertilisation between the marine petroleum and marine renewables sectors, including exchanges and sharing of approaches to best practice and innovation, such as:
  - Petroleum industry innovation in projects and marine operations;
  - Encouraging petroleum industry engagement in marine renewables projects;
  - General exchanges of engineering practice in harsh/extreme environments;
- Seeking to identify and propose solutions to the management of issues associated with development risk, and in particular investment and insurance risks;
- Seeking to ensure that environmental and social issues (which have dogged onshore wind developments and other licensed marine activities, such as salmon farming) are tackled proactively and to the satisfaction of stakeholder interests.

MREDS has already led to a key strategic involvement between Heriot-Watt University and the UHI network in terms of developing research capacities; and with EMEC in terms of optimising opportunities for further development of research capacity, linked to its unique wave and tidal test facilities.

Core funding is in place (£0.5m) and secures the engagement on the Steering Group of SMEs in the Scottish marine renewables sector. A springboard proposal from Workpackage 5 (WP5) has led to £1m funding from the Scottish Funding Council. Other workpackages, notably WP4 and WP6 are already developing new proposals. Joint Industry Project Funding (JIP), where we are

seeking £30k per sponsor per year, will enable the development of a number of key research strands within the workpackages, further research proposals, and will draw in other key researchers from the University sector.

All JIP sponsors will be represented on the Steering Group for MREDS, and sponsorship provides the opportunity to shape the research programme as it develops. All research will be for open publication, but available in advance to all Steering Group members.

The following pages provide a summary of the proposal seeking ticket sponsorship and an outline of the contents of the workpackages and brief details of the lead investigators at this time.

WORKPACKAGE 1: EXPORT CONSTRAINTS, EXTERNALITIES AND OPPORTUNITIES

Leaders: Dr Jim Chalmers (UHI Millennium Institute) and Dr Gareth Davies (OREF)

Staff wishing to collaborate and contribute to this workpackage include staff from the HWU Energy Academy, Professor Marcus Newborough, Dr John Fletcher (Strathclyde University), and members of the Orkney Renewable Energy Forum (OREF).

Overall Goal: To define precisely the short, medium and long-term implications of grid constraints and other externalities, identifying and determining which opportunities offer the greatest prospects for overcoming such constraints in these timescales.

Introduction: The marine renewable resources of the North and West of Scotland have been identified as offering unique opportunities for economic development, yet externalities and export constraints will increasingly militate against these. The delivery of an estimated 35-84TWh of power annually from this region will require enlightened decision-making based on a sound understanding of the constraints and their solution. A significant amount of knowledge is held by OREF and other specialists on these and related topics.

Strands:

1. **Impacts of present grid arrangements and the short/medium/long term implications of constraints** - the aim is to produce the Definitive Grid Repercussions Study for the Highlands and Islands region with clear recommendations – led by OREF Chair, Dr Gareth Davies and Dr Jim Chalmers, with input from other OREF members/HIE and OIC.
   [Report of this study incorporating the findings of Strand 2 to have widespread circulation]

2. **Grid management** – to examine the technical mechanisms and limits to which these may relax present grid constraints – led by Dr John Fletcher (Strathclyde) and Professor Marcus Newborough (HWU)
   [Output: report of this study and publications]

3. **Other opportunities for overcoming externalities and constraints** – to include local substitution of power and fuel, and other means of securing an overhead capacity for marine renewables projects from, for example, a gas/hydrogen powered electricity generating plant - to be an exhaustive study of the range of such possible alternatives – led by Dr Sandy Kerr and Professor Patrick Corbett.
   [Output: structured workshop and iteration of findings among participants to produce report and recommendations for further studies]

4. **Alternative energy storage and transport as means of overcoming externalities and constraints** - what are the options and feasibility (production/storage/transport/ domestic/industrial) and existing pilot project experiences – led by Dr Jim Chalmers, Dr Robin Goodhand and Professor Frank Rennie (UHI Millennium Institute).
   [Output: major seminar organised by UHI to synthesise findings in report form]

5. **The role of gas hydrates in the medium to long term** – seeking to encapsulate the findings of work conducted by the gas hydrates group in the Institute of Petroleum Engineering in determining the feasibility and practicability of the use of hydrates for the storage and transport of hydrogen, as a means of overcoming export constraints - led by Professor Bahman Tohidi (IPE/HWU).
   [Output: report of this study]

6. **Examination of mechanisms necessary for market stimulation to overcome constraints** – what are the necessary mechanisms, which would be pre-requisites to market solutions to overcoming externalities and constraints – led by Dr Sandy Kerr
   [Output: report of this study and publications]

Resourcing Estimate: Support required for the input of staff time and springboard proposals arising from any strand to be considered as funds arise by the Steering Group.

WORKPACKAGE 2: PETROLEUM AND RENEWABLES

Leader: Professor Patrick Corbett (HWU/IPE)
Industrial Liaison: Dr Olivier Dubrule (Total E&P Aberdeen)

In addition to the named investigators HWU staff wishing to collaborate and contribute to this workpackage include many staff from the Energy Academy at HWU and partners in the Energy JRI within the Edinburgh Research Partnership.

Overall Goal: To explore and enable a greater exploitation of the synergies between the offshore petroleum and the marine renewables sector.

Introduction: Both sectors face similar challenges and problems in working in extreme environments, but there are significant differences in scale. Little formal exchange has apparently taken place between the two industry sectors. The increasing innovation in the petroleum sector may have an important role to play in the development of renewables and marine renewables in particular. The petroleum industry has a track record of participating in the development of renewables technology and this is expected to grow as petroleum companies diversify into broader energy companies (Corbett *et al*., 2007[1]).

Strands:

1. **Facilitation of "petroleum and renewables" exchanges** initially explored in a series of themed workshops concerning the marine renewables sector, formal and informal networking, involving both sectors and invited participants. MREDS aims to be a forum bringing together marine renewable SME's and potential petroleum industry interests. A wide range of topics from engineering design and standards, availability of support services, to lessons learned in regulatory compliance will be explored in this way – Professor Patrick Corbett with Dr Olivier Dubrule acting as industrial liaison.
   [Outputs: Reports from workshops and from informal networking]

2. **Issues of magnitude and scale in applying the offshore industry experience and lessons to be learned.** Developing as a study but incorporating the experiences and exchanges in Strand 1 this output will document those areas where greater exchange may assist the development of the marine renewables sector, and define the constraints to this in terms of differences in magnitude and scale. For example, in the cost of projects and differing operating environments. North Sea experience will be disseminated across international operators (Brazilian and Japanese petroleum majors have indicated interest in the marine renewables sector) – Dr Rob Harris, Professor Patrick Corbett with Dr Olivier Dubrule acting as industrial liaison.
   [Outputs: Report of this study and publications]

3. **Renewables synergies with petroleum industry innovation** seeking to elaborate present and possible future innovation within the petroleum industry and the potential for sharing the experiences to the benefit of both sectors. This includes investigation of the greater use of renewables technologies in offshore petroleum - Professor Patrick Corbett
   [Outputs: Report of this study and publications

4. **Major international conference "Petroleum and Renewables"** with a focus on marine renewables will form the principal vehicle for disseminating the results of this workpackage and providing a platform for key players in both sectors to elaborate on case studies and on sharing experiences and developing synergies – to be organised by Professor Patrick Corbett and Dr Olivier Dubrule with support from ICIT staff.
   [Output: Published conference proceedings]

Resourcing Estimate: Some support to be provided by ICIT from core funding but strands 2 and 3 in particular best supported by additional RA input.

[1] Corbett, Kerr, Richards, Side and Davies, 2006, Petroleum Industry and Renewables, *First Break*, Jan 2007, 53-59.

WORKPACKAGE 3: MITIGATION, MINIMISATION AND MANAGEMENT OF RISK

Leaders: George Mermiris (Strathclyde/Glasgow) and Dr Phil Clark (HWU)

In addition, HWU staff: Dr Rob Harris, Dr Karl Stephen, Colin Bullen, Professor Jonathan Side, Dr Sandy Kerr; Professor Nigel Barltrop (Strathclyde/Glasgow); with Dr Gareth Davies (Aquatera).

Overall Goal: To explore and determine means for investment risk and insurance risk mitigation, minimisation and management, and appropriate roles for EMEC and other organisations in mechanisms for risk reduction and management.

Introduction: Developers, insurers and investors face initial uncertainties and risks associated with the development of marine energy device deployment and operation. Little formal categorisation or estimation of these has been undertaken. The proposed work strands have no overlaps, but rather a synergy, with the Supergen Marine Renewal workstream on risk and reliability which has as its focus the determination of failures within the internal marine energy convertor (MEC) systems, and means of extrapolation of industry data to these unusual operating environments. The following strands are complimentary to this, and additional ones are already emerging.

General Strands which may be elaborated further in response to sponsor input:

- **Insurance risk and its management/minimisation,** *strands proposed:* suspended debris and biota in tidal streams, surface collision risk, other third party risk and liability, HSE data; *strands that may be further developed:* material and component selection, site marking, buoy design for tidal sites, all linked to valorisation in design suite; and means of capturing perceptions and approaches adopted by insurers (workshop) to contrast against known data.
- **Investment risk and its management,** e.g. commissioning / decommissioning, certification etc. requirements, maintenance routines and marine operations planning (access), promulgation of knowledge on systems and system reliability - linked to insurance, underwriting the risk, financial sector perceptions against known data analyses; reputation risk and opportunity management.

Specific Strands proposed at this time:

1. **Risks from marine debris** including acquisition of data from propellor fouling incidents and size frequency analyses of the significance of beach debris likely to be in suspension, oil industry structures trap data, methods for the monitoring of suspended debris/biota, and of impacts with structures – led by Dr Phil Clark, Professor Jonathan Side and Dr Sandy Kerr. [Outputs: report of this study and publications]

2. **Surface collision risk** focussing principally on surface navigation, both for isolated development and examination of VTMS approaches for larger array development (e.g. Pentland Firth) – led by George Mermiris (Strathclyde/Glasgow), Colin Bullen and Dr Phil Clark.
   [Outputs: report of this study and publications]

3. **Other third party risk and liability** (e.g. moorings/foundation failure, consequences) using Monte Carlo modelling and Bayesian Networks / Influence diagrams, and spectral analysis of non-linear responses– led by George Mermiris (Strathclyde/Glasgow) and Dr Phil Clark.

4. **Maintenance accessibility and associated risks** e.g. intervention constraints and safety issues – led by Professor Nigel Barltrop (Strathclyde/Glasgow).

5. **HSE database** - requirements for industry sector data, and analyses, end uses and data acquisition by regulatory authorities. Developing experiences from the offshore petroleum sector, commercial sensitivities etc. – led by Dr Gareth Davies (Aquatera) and Colin Bullen. [Output: workshop/seminar for discussion of data, and means of acquistion]

Resourcing Estimate: Support required for input of staff time and springboard proposals from any strand to be considered as funds arise by the Steering Group.

WORKPACKAGE 4: HYDRODYNAMICS, MOORINGS AND FOUNDATIONS

Leaders: Dr Rob Harris (HWU) and Dr Karl Stephen (HWU)

In addition HWU staff wishing to collaborate: Colin Bullen (HWU), Dr Melissa Bowen (formerly of Stanford University, IPE), Dr Phil Clark (HWU), Professor Jonathan Side (HWU) and Professor Nigel Barltrop (Strathclyde/Glasgow)

Overall Goal: To provide design expertise and guidelines for the analysis of MEC systems resulting from the investigation and assessment of the hydrodynamics associated with MEC devices. Focus of the work aimed at wave and current loading, mooring dynamics, environmental and system modelling.

Introduction: The design and development of marine renewable devices requires a clear understanding of the environment and its resulting imposed loading on such structures. MECs require to withstand specific environmental loadings and their moorings and foundations in turn require unique characteristics. The combination of wave and current loading is of particular importance, especially for moored tidal energy convertors (TECs) where such combinations can impose high cyclic loading. The understanding of the interactions of waves and currents, are already part of a Total PhD study and further studies of the hydrodynamic implications of rotors for moored TECs are currently being addressed. The long-term environmental assessment is to be addressed through wide spatial-scale measurement of wave and currents as well as storm surge modelling. A springboard proposal (RASCAL PF) is currently being finalised to undertake studies of wave and current monitoring for the Pentland Firth.

Strands:

1. **Effects of wave and currents (particle kinematics) on MEC efficiency**, *strand underway*: Total funded PhD 'Long-term data time series analysis of waves, tides and currents at a MEC site', study involves the hydrodynamics of wave current interaction, the effects on wave spectra, the energy distribution, fluid particle kinematics, non-linear wave analysis, field data monitoring and analysis with emphasis on evaluation for TEC developer needs.

2. **Wide spatial-scale measurement of wave and currents:** springboard proposal (RASCAL PF for the Pentland Firth), study aims to improve on conventional ADCP methods (and wave data buoys in strong currents) which are impractical on the scale of our study area, the Pentland Firth. Instead, dedicated HF radar systems will provide data for site assessment and appraisal prior to tidal device installation, and subsequently continuous data for use by developers and for more general use in oceanographic and modelling studies. *A further strand,* the application of the Stanford University 3D wave and tidal modelling software, SUNTANS, is seen as an integral part of this study.

3. **Storm surge modelling:** theoretical simulations, again utilising the SUNTANS software, to determine long term estimates of storm surge effects at Orkney sites, with associated implications for MEC mooring design.

4. **Mooring requirements and options** *strands proposed and underway*: studies relating to TEC device design, mooring systems, conventional catenary, hybrid (material), semi-taut and mooring mechanisms. Navigational buoy/mooring design for TEC sites. Studies to date include DTI and Carbon Trust work on dynamic assessment for TEC devices and collaborative work with Supergen II mooring arrays for MEC devices involving Brian Linfoot (HWU).

5. **Foundations requirements and options:** the application of anchoring techniques applicable to MEC systems requires consideration of cost, environmental effects and performance with specialist knowledge of seabed geotechnics, piling, anchoring and dynamic performance. Dr Peter Woodward (HWU)

Outputs: Reports and publications

Resourcing: 1 RA at HWU/ICIT

WORKPACKAGE 5: ENVIRONMENTAL AND ECOLOGICAL IMPACTS

Leaders: Professor Jonathan Side (ICIT/HWU) and Dr Stuart Gibb (ERI/UHI Millenium Institute)

In addition to the named investigators HWU staff collaborating and contributing to this workpackage include Dr Karl Stephen, Dr Melissa Bowen and Dr Rob Harris; and Dr David Woolfe (ERI/UHI MIllenium Institute)

Overall Goal: To determine the likely environmental impacts from marine energy convertors and propose mitigative measures, and methods of measurement/monitoring, for these.

Introduction: Initial SRDG funding of £1m has enabled the development of collaboration between ICIT/HWU and ERI/UHI in a study that will focus on developing an understanding of impacts on, and building research capacity in:

- coastal physical processes (led by Dr Rob Harris)
- hydrodynamics and water column processes (led by Dr David Woolfe)
- pelagic and benthic dynamics (led by Dr Stuart Gibb)
- ecosystem considerations and consequences (led by Professor Jonathan Side)

Further linked studies include the Total (Fondation and E&P Aberdeen) funded research on passive remote monitoring of diving birds and the Supergen Plus project (jointly with Queens University Belfast) to determine the "what, why and how" for environmental monitoring purposes. Ongoing work in this area includes the 2 PhD studentships in the SEAMEX programme (funded by HIE and EPSRC Supergen Marine). Full details of all of these studies are available on request.

Additional Strands:

1. **Collation and presentation of all findings from completed studies and those presently underway.** There is already a significant amount of research being undertaken on the environmental effects of marine energy convertors (MECs). The above studies have sought for example not to duplicate relevant work undertaken in the COWRIE programme for offshore wind, or in the EMEC monitoring programme – led by Dr Stuart Gibb and Professor Jonathan Side
   [Output: Workpackage report which is updated regularly to reflect new work]

2. **Consideration of regime change in the coastal waters of the North of Scotland.** Regime shift in these ecosystems has been postulated. Certainly recent years have seen ecosystem impacts of climate change and dramatic fluctuations in the fortunes for example of the sandeel fishery and of the breeding success in nesting seabirds. Clarity and a comprehensive understanding is required in all considerations relating to the monitoring of environmental and ecosystem impacts of MEC deployment. For example the loss of high-energy sentinel species (such as *Fucus distichus*) may be a result of increases in coastal sea temperatures rather than simply a consequence of the extraction of energy – led by Dr Melissa Bowen, Professor Jonathan Side, and Dr David Woolfe, with invited contributors
   [Output: Workpackage report which is updated regularly to reflect new work, and publications]

3. **New PhD scholarships** designed to support outstanding students in one or more of the following themes: water column ecological effects, ecological/environmental models of change in energy regime, marine protected areas (MPA)/fishery impact modelling (e.g. effects on commercial fisheries/marine conservation), acoustic and remote sensing methods and monitoring, cost effective technologies and methods for detecting ecological change, wave energy convertors (WEC) effects on coastal processes. – Host insitution and surpevisors selected as appropriate.

Resourcing Estimate: Allowance for investigator time and for PhD studentships for Strand 3.

WORKPACKAGE 6: SOCIO-ECONOMIC VALUES AND RESPONSES

Leaders: Dr Sandy Kerr (HWU/ICIT) and Professor Frank Rennie (LCC/UHI)

HWU staff wishing to collaborate: Professor Jonathan Side (ICIT); Professor Paul Jowitt (SISTech)

External staff wishing to engage: Professor Climis Davos (UCLA, USA), Dr Hance Smith (Cardiff, University of Wales), Professor David Whitmarsh (University of Portsmouth)

Overall Goal: To understand the potential socio-economic hurdles to the development of marine renewables and identify pathways to overcome these difficulties.

Introduction: One of the major challenges facing onshore renewable energy is public resistance, particularly in the case of large-scale onshore wind. This is manifest in challenges through the planning system, conflict with other land uses and discontent over the distribution of financial benefits. Marine energy development will be introduced into an environment with existing claims on space and resources (fisheries, navigation conservation etc). This WP seeks to explore these socio-economic issues in the marine sector before they become impediments to development.

Strands:

1. **Value conflict assessment using AGORA**[2]: using the AGORA methodology capture the values of marine stakeholders and identify where these values are likely to conflict in the context of marine energy development. This technique identifies the underlying conflict of values that is present in any stakeholder dispute. It will identify the root concerns about renewable energy development in the marine environment - Dr Sandy Kerr, Professor Frank Rennie, Professor Jonathan Side, and Professor Climis Davos
   [Outputs: Report of this study and publications]

2. **Assessment of the economic impact on fisheries** – Closed areas for marine energy converters will reduce the sea area available for fishers. At the same time closed areas may act as sanctuaries (No Take Zones) for commercial species. The economic and social impacts of this are likely to be complex and uneven depending on location, the nature of the fishery and fish species involved. This strand shall model these impacts and examine how costs and benefits will be disputed amongst fishing communities - Dr Sandy Kerr, Professor Jonathan Side, Professor David Whitmarsh
   [Outputs: Report of this study and publications]

3. **Community Involvement:** Community involvement in renewable energy project (through ownership or payments) is recognised as having two benefits (i) overcoming public resistance to renewable energy development and (ii) a potential economic development opportunity for rural economies. This strand shall examine both the mechanisms to achieve this and the capacity of communities[3] to engage with marine projects - Dr Sandy Kerr and Professor Frank Rennie
   [Outputs: Report of this study and publications. Seminar to disseminate findings]

4. **Marine planning and allocation of resource**: this strand will examine how different licensing arrangements would impact upon the development of marine renewables. In particular it will draw on recent experience from onshore wind energy and the expansion of aquaculture, where planning mechanism, arguably, failed to accommodate the rapid expansion in development leading to stakeholder conflict; and developments in marine spatial planning, including legislation in Scotland/UK and Europe - Dr Sandy Kerr and Dr Hance Smith
   [Outputs: Report of this study and publications. Seminar to disseminate findings]

Resourcing Estimate: Staff time plus 2 RAs (LCC and ICIT).

[2] AGORA – Agreement of Group Options with Reasonable Accord

[3] A spring board proposal has been submitted to HICEC (Highlands and islands Community Energy Company). The study will examine hurdles to community participation in renewable energy projects

MREDS Resources Sought

The MREDS consortium seeks 6 industrial partners committing 3years funding with options to extend to 5years. Funding is sought at £30,000 per company per year.

MREDS Key Personnel - brief details

MREDS Steering Group Chairman

The Rt Hon Professor Jim Wallace is an honorary professor at Heriot-Watt University, who has a close association with the work of ICIT on the University's Orkney Campus. Since retiring from the Scottish Parliament in May 2007, Jim has been actively involved in raising the profile of the Scottish renewables sector and in championing the opportunities for marine renewables research and development in the North of Scotland. He will chair the MREDS Steering Group.

MREDS Oil Industry Advisor

Dr Olivier Dubrule of Total E&P Aberdeen has agreed to act as the industrial liaison for workpackage 2. He is Manager of the Geoscience Research Centre in Aberdeen and former president of EAGE (European Association of Geoscientistst and Engineers).

Heriot-Watt University

Professor Patrick Corbett is Head of the Institute of Petorleum Engineering. He has a PhD in Petroleum Engineering and a DSc "Petroleum Geoengineering". Patrick has 11 years of industry experience as a geoscientist for Unocal in the UK, Netherlands and Indonesia. Since then he has followed an active research career investigating many aspects of permeability, anisotropy modelling, well test interpretation, dynamic upscaling, and genetic petrophysics. He was SPE EUROPEC convenor for a Special Session of "Petroleum plus Renewables" at the EAGE/SPE Forum in Vienna in 2006.

Professor Jonathan Side is Director of ICIT and Professor of Sustainable Development at Heriot-Watt University. He is an honorary professor at the University of Edinburgh, and is a fellow of the RICS. He is a long-term champion of marine renewables in Scotland, and has served several terms as Chair of OREF. He has been involved in numerous marine science research programmes, and has project managed several of these, including 3 EU framework research projects.

Dr Rob Harris, previously a Lecturer in the School of Life Sciences at Heriot-Watt, has relocated to the University's Orkney campus, joining the ICIT / IPE research and teaching group. His main research interests lie in the fields of hydrodynamics, oceanography and more recently marine renewable energy systems, he has over 29 years experience in hydrodynamic model testing, and in offshore / marine structures.

Dr Sandy Kerr teaches on a number of energy related MSc courses and supervises doctoral students. His research interests include the sustainable management of coastal and island resources particularly renewable energy, fisheries, and conservation. Recent research articles have appeared in journals such as *Ocean and Coastal Management*, and *Fisheries Research and Town Planning Review*.

Dr Phil Clark has been a Lecturer at Heriot Watt University since 1993, currently in the School of the Built Environment involved in teaching and research in Reliability Engineering and Offshore Hydrodynamics, particularly the effect of nonlinear wave loading. Previous employment includes British Maritime Technology, Wallsend, and Institut Francais du Petrole in Rueil-Malmaison, France.

Dr Karl Stephen is a physicist and has been carrying out research and consultancy for the oil and gas industry at the Institute of Petroleum Engineering since 1996. He has worked on several projects, which have focussed on improving the modelling and prediction of hydrocarbon recovery from reservoirs. Karl is also applying these interests in modelling tidal behaviour on the north coast of Scotland to ensure that energy converters can be appropriately located and operated.

UHI Millenium Institute

Professor Frank Rennie is Head of Research at Lews Castle College, UHI Millenium Institute. His main research interest is the relationships between the natural environment and community development. Recent work has focussed on the use of new technologies to promote rural development; involving collaborations with partners in Europe, Amazonia, New Zealand, Bhutan and Nepal. Professor Rennie has published widely, including more than 20 books.

Dr Stuart Gibb is Director of the Environmental Research Institute (ERI) at North Highland College, UHI Millennium Institute. His research has been in the fields of marine bio-geochemistry, including biogenic gases, air-sea exchange processes and atmospheric chemistry, phytoplankton dynamics and climatic and environmental change.

Dr Jim Chalmers has a background in agricultural research and practice. He joined Orkney College, UHI Millennium Institute in 1999 to lead the development in collaboration with ICIT of an undergraduate programme in sustainable development and environmental management. He is involved in renewable energy, waste minimisation, biotechnology and sustainable development relevant to UHI programmes.

Universities of Strathclyde/Glasgow

George Ap. Mermiris is a Research Fellow in the department of Naval Architecture and Marine Engineering (Universities of Glasgow and Strathclyde) with primary interest in risk-based design and risk modelling. He has participated in a number of research and commercial projects and he has authored and co-authored 5 journal and conference papers

Orkney Renewable Energy Forum

Dr Gareth Davies is the current Chair of the Orkney Renewable Energy Forum (OREF). He has a PhD in marine biology, and has worked as an environmental consultant for most of his career. His work in the North of Scotland on renewable energy resources is well known and forms part of the 350 projects covering a wide range of environmental and operational energy studies he has completed.