Institution: University of Strathclyde

Unit of Assessment: 12

Title of case study: Economic benefits from spin out company, Nautricity Ltd, and adoption of new technology to extract energy from tidal flows.

1. Summary of the impact (indicative maximum 100 words)

A step change reduction in tidal energy costs has been achieved through the development of the novel Contra Rotating Marine Turbine 'CoRMaT' tidal energy technology. The internationally patent-protected CoRMaT system reduces capital, operational and maintenance costs while increasing the extractable tidal energy resource by harnessing flows in deeper waters and from less energetic sites, which were previously considered to be uneconomic. A University spin-out company, Nautricity Ltd, was formed in 2010 to commercialise this technology. The development of this technology has changed both Scottish and UK Government policy via their introduction of programmes which demonstrate a step change reduction in the costs of marine renewables.

2. Underpinning research (indicative maximum 500 words)

Context: The economic potential of the commercial exploitation of marine power is vast, with global business opportunities estimated at £60billion per annum. The UK is leading the international development of a marine renewable industry, which is contributing to the realisation of 2020 targets for renewable energy capture. The research described here investigated and established a more efficient and cost effective engineering solution to extracting energy from tidal flows. The forces generated by the gravitational attraction of the moon and the sun's movements relative to the earth produce strong marine tidal flows, which are locally concentrated by landmasses. These strong tidal currents represent a vast renewable energy resource.

Key findings: The outcomes from the research identified a novel, more efficient tidal turbine configuration consisting of dual-contra-rotating rotors with a dissimilar number of fixed pitched blades per rotor. On the back of this, a Scottish Enterprise Proof of Concept (PoC) award was secured by Clarke, Grant and Johnstone in 2004 - 2008 to investigate whether this new approach was physically viable and delivered the expectations of the initial research. The PoC award enabled prototypes of the turbine to be built, tested and proven in both laboratory and real-sea test conditions at 1/30th and 1/10th scale respectively. The results confirmed this new engineering approach to tidal turbine technology delivered class leading performance via:

- an enhanced coefficient of performance (Cp) approaching 42%;
- reactive torque minimisation, providing the ability of the turbine to be held on station using a lower cost, tensioned mooring system, and for the turbine to passively align with the tidal stream direction under all anticipated operating conditions of the tidal diamond;
- reduced wake development and propagation delivering a reduction in downstream swirl (this has beneficial implications for reducing inter-device spacing within a tidal array);
- a significant reduction in the dynamic forces on each blade unit delivering beneficial implications for robustness; and
- confirmation of device stability throughout the duration of the tidal cycle.

The prototype delivered higher efficiencies of tidal power capture to delivered electrical power output through its more efficient rotor system directly driving a ground breaking sea-water flooded/ cooled, contra-rotating generator. These, together with the use of a tensioned mooring system incorporating passive yaw control, delivered step-change cost reductions in hardware when compared with current best practice.

The successful outcomes from the initial research has led to further research funding being secured from RCUK in 2010 by Johnstone, and in 2013 by Stack and Johnstone; and from EC Framework 7 in 2011 by Johnstone to investigate improving the durability of tidal energy technology sub-components through the development of apposite advance structural materials for the marine environment.

Key Researchers: This research was undertaken between 2000 – 2004 by a team in the Energy Systems Research Unit, Department of Mechanical and Aerospace Engineering, University of

Strathclyde. The key researchers were - J A Clarke (academic member of staff 1977 – present, currently Professor), A D Grant (Research Fellow 1972 to 2010, now retired), C M Johnstone (Senior Lecturer 1991 to present).

3. References to the research (indicative maximum of six references)

References 1, 2 and 3 best exemplify the quality of the underpinning research. References 1 and 2 are also included in the UoA 12 REF2 submission

1. Johnstone C.M., Pratt D., Clarke J.A. and Grant A.D. 'A techno-economic analysis of tidal energy technology' Renewable Energy an International Journal Vol. 49, pp101-106, January 2013, UK, ISSN 0960-1481

2. Clarke J A, Connor G, Grant A D, Johnstone C M and Ordonez-Sanchez S 'Analysis of a single point tensioned mooring system for station keeping of a contra-rotating marine current turbine', Nov-2010 In : IET Renewable Power Generation. 4, 6, p. 473-487, 15 p.

3. Clarke J A, Connor G, Grant A D, and Johnstone C M 'Design and testing of a contra-rotating tidal current turbine', Power and Energy, V221(A2), pp171-179, May 2007, ISSN: 0957-6509.

4. Johnstone C M, Pratt D, Clarke J A and Grant A D 'The need for tidal energy to be cost competitive with off-shore wind power', Proc. 3rd Int. Conf. on Ocean Energy, Bilbao, Spain, 6-8 October 2010.

5. Clarke J A, Connor G, Grant A D, Johnstone C M and Ordonez-Sanchez S 'Contra-rotating marine turbines: single point tethered floating system – stability and performance', Proc. 8th European Wave and Tidal Energy Conf., Uppsala, Sweden, 2009.

6. Clarke J A, Connor G, Grant A D, Johnstone C M 'Development and in-sea performance testing of a single point mooring supported contra-rotating tidal turbine', Proc. 28th Int. Conf. on Ocean, Offshore and Arctic Engineering, Hawaii, USA, 2009.

Evidence for quality of research (grants, patents etc.).

- International Patent No. GB2005/ 0516149.2 "Contra-rotating tidal current turbine" Clarke, Conner, Grant and Johnstone 2005-2012
- European Patent No. GB2010 /1104524.2 "Hydro-Buoy tidal energy mooring system" Johnstone and Pratt 2012
- 2010-13 Knowledge Transfer: Secondment of an ESRU academic to lead Nautricity and ensure technical continuity with the commercialisation of the CoRMaT tidal turbine, £210,000.
- 2011-12 Knowledge Transfer: REP Award to second an ESRU researcher into Nautricity to inform of hydrodynamic design processes associated with rotor development, £25,000.
- 2011-15, EC FP7, Marinet - Implementation of best practice testing procedures for wave and tidal energy converters, €555,000.
- 2012-12, Nautricity: EC FP7, Tidal Sense Demo - Development and demonstration at full scale of condition monitoring capabilities on large scale commercial tidal rotors and foils. €240,000.
- 2012-13 Nautricity: Waters II grant for the deployment of a commercial CoRMaT device under the Waters II competition, Scottish Government, £1.4 million.
- 2010-13, BIS, UK/Korean research collaboration: tidal energy flow mapping and fluid-structure interaction study of tidal stream turbines, £69,500.
- 2011-12, UK SI-TI, UK-Asia tidal energy scoping meeting: agglomeration of UK-Asia tidal energy developers to develop a tidal energy industry in Asia while learning from UK experiences.
- 2012-13 Nautricity: Smart Scotland award to demonstrate a full scale Hydro-buoy mooring system to facilitate the station keeping of tidal turbines. Scottish Government £250,000
- 2013-2016, RC UK – Research award to develop robust large tidal rotors through development of advanced structural materials. £1.1million

4. Details of the impact (indicative maximum 750 words)

Process from research to impact

Research outputs have been disseminated by Clarke, Connor, Grant and Johnstone through extensive publishing of journal and conference papers. New IP has been generated and secured via UK and international patent applications. This new technology has been the recipient of awards from professional institutions and industry bodies. To realise the commercial benefits, a University spin out company has been formed to bring the Contra Rotating Marine Turbine (CoRMaT) technology to market, creating the following types of impact:

New spin out created: Nautricity Limited was registered in 2009, and secured £5M industrial investment from First Tech, the investment arm of First Oil, in 2010 (Source A). To provide continuity in the development and commercialisation of the CoRMaT technology, Nautricity has seconded Johnstone as its CEO to lead the development of both the company and the CoRMaT technology within UK, North American and South Korean markets. In 2012/13 Nautricity built pre-commercial full scale systems for deployment in UK and International waters and to demonstrate economic viability.

Adoption of new renewable energy technology

The CoRMaT technology is considered unique and pioneering in that it can be deployed at mid water column, in deeper water, and where the flow velocities are faster. Due to the reduced complexity and inherent passive control integrated into the CoRMaT technology, this has delivered 'step changing' cost reductions in harnessing tidal energy. These reduced costs make it economically viable to harness power from less 'energetic' tidal sites and sites located in deeper waters, neither of which were previously considered feasible. This substantively increases the exploitable tidal resource.

CoRMaT is a proven, next generation, tidal stream turbine. The technology is regarded by the Carbon Trust, Scottish Enterprise and both UK and Scottish Governments as being a next generation technology which is 'disruptive' to the industry. This 'disruptive' nature is associated with the delivery of necessary step changes to make it more cost competitive with other forms of renewable energy. The capital cost has been assessed by the Carbon Trust, UK (Source B) and the Scottish Government to deliver £3,240/kW for a 500 kW device, approximately 40% of the costs quoted for competing 1st generation technologies. The projected electricity generating cost, 14p/kWh, is currently within the predicted 2020 band (12 to 18p/kWh) for tidal stream turbines operating in a velocity between 2.5 m/s and 3.5 m/s. The costs for CoRMaT are expected to be profitable. Operational costs have been calculated at £160/ MWh while existing Government incentives of 5 Renewable Obligation Certificates (ROC's) will provide a revenue of approximately £230/ MWh. The university spin-out company, Nautricity, is in the process of demonstrating the commercial viability of CoRMaT when deployed at full scale to capitalise on this.

In 2011 Nautricity secured an agreement to lease for the development of a 3MW test array from The Crown Estates. This led to the development of the first small array at the Mull of Kintyre off the south-west coast of Scotland, with the potential to build out to a 30MW tidal array. Nautricity has secured outline consent for a tidal site together with grid connection approval to facilitate the development of the site in 2014 (Source C). In February 2012 Nautricity secured a £250k SmartScotland award from the Scottish government for a £900k project developing and proving a novel tidal energy mooring system to augment the performance of the CoRMaT system. The prototype mooring system with a full scale CoRMaT turbine was deployed at the European Marine Energy Centre, Orkney in February 2013. In July 2012, Nautricity secured a Scottish Government WATERS II award of £1.4M against a £5.5M project to deploy and demonstrate a commercial system in deeper waters off the west coast of Scotland, to be deployed and commissioned during the summer of 2014.

Influence on Government Policy: The delivery of the CoRMaT technology has changed both UK and Scottish Government marine renewable policy. The realisation of next generation technology being available has scoped the development of the Scottish Government's Waters II competition in 2012 to specifically support the delivery of next generation wave and tidal energy technologies

which promise to deliver 'step-change' cost reductions (Source D). Subsequently, the Carbon Trust is using the cost benefits of the CoRMaT technology as a bench mark for the capital and operational costs of tidal technologies (Source B). Nautricity personnel have been invited (January 2012) to sit on the Scottish Government's reconvened Marine Energy Group (Source E), and Scottish Renewables: Marine Energy Working Group (Source F). Both these groups have a remit to inform both the Scottish and UK Government of necessary policy development in order to deliver a marine renewable industry. These groups informed the recent Waters II, Wave Energy Acceleration, and Marine Renewable Consolidation Fund calls, which are managed by the Scottish Government and the Carbon Trust.

Commercial benefit to utility companies and other organisations: Nautricity have demonstrated the commercial viability of marine power extraction to the energy utilities. This is bringing commercial benefit to the European Marine Energy Centre (EMEC) and its supply chain in the Orkney Islands and the Kintyre peninsula, where the commercial deployment of the technology at the Mull of Kintyre is taking place. The CoRMaT design is protected internationally by Patents GB2005/161492 and GB2010/ 1104524.2 and once an indigenous UK market is developed an International market will be exploited. In overseas market development, Nautricity's CoRMaT technology has been shortlisted as a preferred technology by Fundy Tidal Inc. for a 3MW project it is developing in the Bay of Fundy, Nova Scotia Canada, and by Haida Gwaii Tidal, British Columbia Canada for a 1.5MW community tidal energy project. With the growth in electricity supplies from renewables, especially in Asia, Nautricity has been invited to develop and deploy its CoRMaT technology in these emerging markets. The recent Memorandum of Understanding between the Scottish Government and the Incheon Authority, South Korea (in May 2013) to collaborate in the development of tidal energy in the Incheon region provides the delivery vehicle for the tidal energy technology. The Director of Incheon Metropolitan City Green Energy Policy Division said: "*The MoU gives momentum to encourage joint studies and knowledge sharing, thus helping to establish Incheon as a "mecca" for tidal energy*." (Source G).

Wider implications: To summarise, currently the impact is in terms of the adoption of the new technology and its influence on Government policy on renewable energy companies. The wider implementation of the technology will lead to benefits to the local economy through job creation within Nautricity, and its strategic supply chain partners, and commercial expenditure within communities where the technology is being deployed. The eventual cost reduction and environmental benefits will be to the consumer.

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. http://www.nautricity.com/docs/014_001_files_Sep10_firsttech_funding_1283276898.pdf spin out company secures significant investment
B. Marine Technology Accelerator Manager, Carbon Trust, London UK can be contacted to support the claim(s) that the application of the CoRMaT tidal technology is a cost benchmark for next generation tidal energy systems.
C. http://www.nautricity.com/news/mull-of-kintrye-tidal-array/ Nautricity development at Mull of Kintyre
D. Scottish Enterprise/ Scottish Government WATERS II Program Manager can be contacted to support the claim(s) that CoRMaT technology is changing Scottish and UK government policy on supporting next generation wave and tidal technology to deliver the necessary 'step-change' cost reductions.
E. http://www.scotland.gov.uk/Resource/0039/00395516.pdf Report from marine Energy Group
F. http://www.scottishrenewables.com/technologies/marine/ Report from Scottish Renewables: Marine Energy Working Group
G. http://www.scotland.gov.uk/News/Releases/2013/05/marine-energyu06052013 Scottish Government Press release 'Scotland makes waves in South Korea'