ENERGY

MARINE ENERGY
MORE THAN JUST A DROP IN THE OCEAN?

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

This report focuses on barriers for commercialising the marine energy market in Scotland along with the current and future funding of marine energy projects. It makes recommendations on how this important renewable energy resource can best be developed and supported to provide for Scotland's energy future. This report has been produced in the context of the Institution's strategic themes of Energy, Environment, Education and Transport and its vision of 'Improving the world through engineering'.

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MARINE ENERGY— TAKING SCOTLAND'S REPUTATION FOR ENGINEERING INNOVATION INTO THE 21ST CENTURY

Today the marine energy sector is approaching a 'make or break' point. Nowhere else is this truer than in Scotland. Abundant resources mean that there is enormous potential for Scotland to become a world leader in this emerging renewable energy sector. Put simply, decisions taken now will determine whether Scotland has the potential to go on to pioneer commercial marine energy generation.

In light of the position facing the marine energy sector, the Institution of Mechanical Engineers undertook a report to offer recommendations on how the sector can best deliver on its potential. This report:

- Provides a brief overview of the energy challenge and the political response to this;
- Provides an overview of the renewable industry in Scotland, with particular focus on the opportunity that marine energy presents;
- Outlines the public funding available to the marine energy sector;
- Presents the findings of cross-enterprise stakeholder consultation on barriers to commercialisation, the effectiveness of policy and public funding, and the enterprise requirements for skills and education.

Marine energy has a part to play in society's energy challenge. People's concerns about climate change and the security, sustainability and cost of oil and gas supplies have made energy one of our most pressing political priorities. With this in mind, ambitious targets have been set, with the UK agreeing to source 15% of its energy from renewable sources by 2020.

Further, both Holyrood and Westminster have recently agreed to target an 80% reduction in CO_2 emissions by 2050 (compared to 1990 levels). Changes in electricity generation are expected to play a leading role in meeting these targets. Westminster is proposing that approximately a third of the UK's electricity is generated from renewable sources by 2020. Holyrood has more ambitious targets of 31% by 2011 and 50% by 2020.

Scotland has always led the UK in renewable energy; its hydro-electric power stations have been producing ~10% of Scotland's electricity for decades. More recently, wind farms have played an increasing role and will be the dominant contributor to Scotland's 2011 target.

However, new technologies will be required to meet the 2020 target of 50% of electricity to be sourced from renewable technologies. It is on this timescale that marine energy can contribute. Previous studies have estimated that wave and tidal energy could provide 10% of Scotland's electricity by 2020.

The marine energy sector is on the cusp of success. Wave and tidal energy prototypes are being deployed in the ocean for the first time, many of them in Scotland. The durability, maintainability and performance of a range of technologies will be tested, and the results will dictate whether the marine energy sector has a commercial future. Although there are no guarantees, the opportunity is too great to allow it to simply pass by.

It is in no-one's interest if the sector were to fail. Extensive research and consultation with marine energy device developers, investors and governmental organisations highlighted the following key challenges to successful commercialisation:

- **Technology**. The challenges of installing wave and tidal devices in energetic seas;
- **Funding**. Capital support to design, manufacture and install first generation prototypes in the real ocean environment;
- **Skills**. Transferring subsea and marine experience from the North Sea oil and gas industry;
- **Grid Capacity**. Delivering grid capacity in regions of marine energy potential.

In response to these challenges, the Institution of Mechanical Engineers has developed the following recommendations for the Scottish Government and other stakeholders:

1. Political Leadership. Maintain sector momentum through strong, courageous and consistent political leadership. Marine energy enjoys cross-party support and continually emphasising this reduces the perception of political risk amongst potential investors;

2. Funding. To provide a solution to these challenges, the Institution is proposing the formation of a £40M fund to ensure that a sufficient range of well-engineered wave and tidal energy technology can be tested in the ocean environment. Such a scheme would invite applications for projects that included:

- Both technology demonstration via a first-generation prototype and a subsequent first commercial array;
- A combination of skills in marine energy technology, marine and subsea manufacture and installation, and electrical power engineering;
- A single lead contractor.

Such a scheme would be complementary to existing capital support mechanisms. The proposed scheme would complement the Saltire Prize by providing predictable support and playing to the strengths of Scotland's existing enterprise, whilst the Saltire Prize would act to advocate these strengths on the global stage.

3. Infrastructure. Work with Westminster to find grid infrastructure solutions that will allow marine energy in Scotland to play its part in meeting the UK's renewable energy targets.

The potential prize is the positioning of Scotland at the forefront of the marine energy sector, creating sustainable wealth from technology, manufacturing and engineering support, and contributing to climate change targets.

The resources are abundant. Scotland's waters could potentially produce 25% of Europe's tidal power and 10% of its wave power. Furthermore, the North Sea oil and gas industry means that there is a pre existing concentration of subsea and marine engineering skills and infrastructure in place, while Scottish academic institutions are at the vanguard of research in marine energy. Finally, there is a significant cluster of technology developers based in Scotland.

To secure the prize, Scotland must act now to ensure that a sufficient range of well-engineered wave and tidal energy technology is tested in the ocean environment. The Institution looks forward to working with the Scottish Parliament and Government to take forward the recommendations of this report.

Openhydro Open-Centre Turbine test structure at EMEC

INTRODUCTION

Mechanical engineers have been innovating to support the world's energy needs for over a century. Today, the need for innovation is greater than ever, with climate change and fears over the security, sustainability and cost of oil and gas supplies leading to a radical rethinking of energy policy. The UK Government has committed to source 15% of all energy used from renewable sources by 2020, a ten-fold increase from 2006 levels. The proposed response to this challenge is laid out in the UK renewable energy strategy[1]. To meet this target, nearly a third of UK electricity generation is likely to come from renewable sources by 2020, equivalent to 7,000 new wind turbines.

Scotland is particularly well placed to respond to this challenge, having world-leading natural resources and a long tradition of engineering innovation. Scotland's resources have the potential to provide 25% of Europe's wind power, 25% of Europe's tidal power and 10% of Europe's wave power[2]. The Scottish Government has recognised this potential and has set ambitious targets of 50% of Scottish electricity demand to be met from renewable sources by 2020, with 31% achieved by 2011[3].

Marine energy is derived from wave and tidal power. It is a resource that is particularly plentiful in the seas surrounding Scotland. Encouraged by Government incentives, the technology has developed to the point that the first machines are producing electricity. The aim of this paper is to combine research on the current state of the marine energy enterprise in Scotland with consultation with key players, to provide impartial policy recommendations to the Scottish Government. Specifically, the objectives are to:

- Provide a brief overview of the energy challenge and the political response to this;
- Provide an overview of the renewable industry in Scotland, with particular focus on the opportunity that marine energy presents;
- Outline the public funding available for marine energy enterprise;
- Undertake cross-enterprise stakeholder consultation on barriers to commercialisation, the effectiveness of policy and public funding, and the enterprise requirements for skills and education.

The focus of this paper is the marine energy enterprise in Scotland. The scope is restricted to wave and tidal stream technologies; tidal range technology is more applicable elsewhere in the UK, most notably the proposed barrage across Severn Estuary.

The research undertaken involved desktop study and interviews with industry stakeholders, listed in Annex A. The views expressed in Section 3 (funding) and Section 4 (barriers) are based on these interviews.

1.1 SOCIETAL CONCERNS RELATING TO ENERGY

The issues behind the current focus on energy policy are widely understood. They relate to climate change concerns and the security, sustainability and cost of oil and gas supplies.

The Stern Report[4] concluded that climate change is the greatest market failure ever seen. Average temperatures could rise by 5°C if climate change goes unchecked, leading to massive disruption costing ~5% of global GDP. The benefits of strong, early action considerably outweigh the costs, estimated to be ~1% of global GDP. The report recommended that global support for low-carbon technologies be increased five-fold. Within the UK, energy supply currently accounts for about 40% of CO_2 emissions[5].

Security of supply concerns relate to a predicted electrical generation capacity gap and predictions of increased reliance on imported gas. By 2015 there is a predicted 14GW gap, equivalent to 18% of required UK capacity[6]. Furthermore, the UK currently imports ~10% of its gas needs, but this could grow to ~90% by 2020[7], much of this sourced from potentially politically unstable areas.

The sustainability of oil and gas supplies has been the subject of intense scrutiny as crude oil prices have been extremely volatile, reaching $145/barrel in July 2008 and subsequently falling to ~$60/barrel. Opinions on whether we are approaching peak oil vary dependent on what are considered to be technically extractable oil reserves. Regardless, high prices for oil and gas supplies fundamentally change energy policy.

Taken together, these issues explain why energy policy is a priority for Government.

1.2 THE UK POLITICAL RESPONSE

Current UK energy policy is set out in the Energy White Paper [May 2007[8]], which outlines four key goals, viz:

- Put the UK on a path to cutting CO_2 emissions by 60% by about 2050, with real progress by 2020. This has recently been increased to 80%[9];
- Maintain the reliability of energy supplies;
- Promote competitive markets in the UK and beyond;
- Ensure that every home is adequately and affordably heated.

The White Paper confirmed a target of 10% of UK electricity to be produced from renewable sources by 2010, with an aspiration to double this by 2020. The main policy instrument to achieve this remains the Renewables Obligation (RO, a green tax on electricity consumers, discussed further in section 3.1). However, the RO was extended to support up to 20% of electricity being produced from renewables (previously 15%). The White Paper also concluded that nuclear power should be part of the future energy mix and a consultation on how to facilitate new nuclear build was announced.

Associated UK legislation includes:

- **Nuclear Power White Paper** [January 2008[10]], which built on the nuclear consultation and put in place the enablers for building new nuclear power stations. This paper also committed to strengthening the EU Emissions Trading Scheme (ETS) to set a clear price for carbon emissions and hence improve the economics of all low-carbon energy technologies, including nuclear;
- **Climate Change Bill**[11], will set a target for a 80% reduction in CO_2 emissions by 2050 compared to 1990 levels. It also creates the Committee on Climate Change that will advise the Government on setting incremental carbon budgets to achieve this reduction;
- **Planning Bill**[12], which introduces the Infrastructure Planning Commission (IPC) in England and Wales. This will have the responsibility for deciding on major projects of strategic importance, such as new power plants;
- **Marine Bill**[13], which aims to streamline the administrative process for consenting offshore energy projects and considers a strategic framework for the development of renewable energy projects in UK coastal waters.

In spring 2007, the EU Heads of Government agreed to source 20% of the EU's energy from renewable sources by 2020. In January 2008 the European Commission published a draft directive on how the 20% target would be shared amongst member states, setting the UK target at 15%[14].

Subsequently, the UK Government has issued its renewable energy strategy[1], laying out its proposed response to this target. This includes proposals to further increase the proportion of renewable electricity supported under the RO and the provision of extra support to newer technologies, such as marine energy.

1.3 THE SCOTTISH POLITICAL RESPONSE

Although energy policy is largely reserved to Westminster, the Scottish Government has introduced a unique range of enabling policies to promote the uptake of renewable energy in Scotland. This includes:

- Leading Westminster in proposing an 80% reduction in CO_2 emissions by 2050 compared to 1990 levels[14];
- Ruling out new nuclear power stations, with the result that Scotland is dependent on renewables to meet CO_2 targets;
- Setting ambitious targets of 31% of electricity to be produced from renewable sources by 2011 and 50% by 2020 [3];
- Modernising the planning system[15], including the introduction of a National Planning Framework, under which projects of strategic importance (including projects to contribute to renewable energy) would be decided;
- Undertaking a Strategic Environmental Assessment (SEA)[16] to inform the development of strategy for marine energy and planning permission for marine energy projects;
- Proposals to manage the consenting process for marine renewables through a single new marine management organisation[17];
- Substantial funding for the European Marine Energy Centre (EMEC), a globally unique test centre for wave and tidal stream devices;
- Provision of extra revenue support to marine energy projects, discussed further in section 4;
- Introducing the Saltire Prize to award innovation in clean energy.

MARINE RENEWABLE ENERGY IN SCOTLAND— A SMALL NATION'S UNIQUE ADVANTAGE

2.1 A SNAPSHOT OF RENEWABLE ENERGY IN SCOTLAND TODAY

The latest statistics for renewable energy consumption in Scotland are given below in **Figure 1**. It can be seen that in 2006 16% of electricity consumed came from renewable sources. The equivalent UK-wide figure was 4.5%.

The dominant contributors to renewable energy in Scotland today are hydro-power and onshore wind (the latter is the only real contributor to the 'wind, wave & solar' category). Hydro-power is dominated by schemes built in the 1960s; the only significant current project is the 100MW Glendoe scheme which is close to completion.

Conversely, the latest figures for wind projects in Scotland show that wind generation will soon be the dominant renewable energy source in Scotland. In 2006 there was 947MW of wind capacity in operation. By October 2008 this had risen to 1,400MW. There is also a further 780MW in construction, 2,215MW with planning permission and 2,684MW going through the planning system, giving a potential capacity of over 7,000MW[18]. These projects should deliver the capacity for Scotland to meet the target of 31% of electricity to be produced from renewable sources by 2011.

Looking ahead to the 2020 target of 50%, new sources of renewable energy will be required. Marine energy is an ideal candidate. The Forum for Renewable Energy Development in Scotland (FREDS) estimates that 1,300MW of marine power could be installed by 2020, creating 7,000 direct jobs and leading to a substantial export market for Scottish marine companies[19]. Marine energy would also introduce valuable diversity to the portfolio of renewable generation technologies and is largely decoupled from the intermittency of wind.

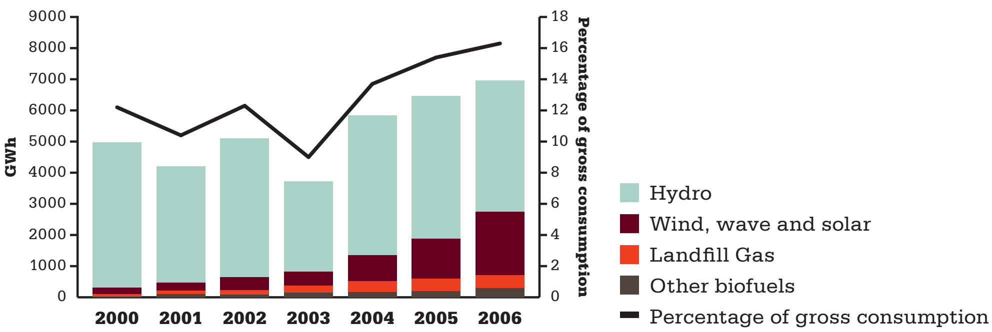
2.2 THE POTENTIAL FOR MARINE ENERGY IN SCOTLAND

The Carbon Trust has estimated that the practically achievable UK resource could equate to ~20GW from wave and ~6GW from tidal generation[20], assuming a 33% capacity factor. Scotland has the overwhelming share of this resource; FREDS estimated that Scottish resource could equate to ~14GW from wave and ~7GW from tide[19], enough to supply all of Scotland's electricity. The tidal resource is mainly located off Orkney and Islay. The wave resource is mainly located off the west coast of the Hebrides, Orkney and Shetland. Clearly, Scotland enjoys world-leading marine energy resources that can contribute at scale to renewable energy and CO_2 emission targets.

Over the years there has been some doubt that the industry could deliver on its potential and many within the industry would agree that they were guilty of over-optimism on timescale. However, the marine energy sector has recently demonstrated that it can deliver power onto the electricity grid. Wavegen's shoreline wave device in Islay has been operational since 2000 and three further technologies have recently achieved this milestone, namely:

- OpenHydro's 250kW tidal device, located at EMEC in Orkney, in May 2008;
- Marine Current Turbines' 1.2MW tidal device, located in Strangford Lough, Northern Ireland, in July 2008;
- Pelamis Wave Power's Aguçadoura project, located off the Portuguese coast, in July 2008.

Figure 1: Electricity Generated by Renewables in Scotland 2006 (Source BERR)



Scotland also has world-leading marine and subsea engineering skills, born of its heritage in ship-building and North Sea oil and gas development. These are transferable to marine energy, but the challenge is to make them available at a time of high demand from both oil and gas and the emerging offshore wind industry. Scotland also has some of the leading marine energy academic institutions. For instance, Edinburgh, Heriot Watt and Strathclyde universities are three of the five universities making up the Supergen consortium, which leads research into marine energy in the UK.

Scotland also has much of the necessary infrastructure. Another legacy of the North Sea oil and gas industry is the manufacturing and port facilities necessary to construct and transport large marine structures. This is complemented by EMEC, a globally unique test centre for wave and tidal devices. The weakness in Scotland's infrastructure is the grid system, which has limited capacity in regions of marine resource, discussed further in section 4.4.

This combination of resource, skills and infrastructure, coupled with political support from Holyrood and Westminster, has led many marine energy developers to base themselves in Scotland. This technology cluster includes:

- **Aquamarine Power**. Based in Edinburgh, Aquamarine is developing a near-shore wave device (Oyster) and a tidal device (Neptune). It has raised about £10M of funding, including investments by Scottish & Southern Energy and Sigma Capital;
- **AWS Ocean Energy**. Based near Inverness, AWS is a deep-water wave device and is undertaking R&D on further marine energy technologies. Its investors include Shell Technology Ventures Fund, Tudor BVI Global and RAB Capital;
- **Hammerfest UK**. Hammerfest Strom is based in Norway where it has had a tidal turbine in operation for four years. Following investment by Scottish Power Renewables, it has set up a Glasgow-based subsidiary (Hammerfest UK) to deploy the technology in UK waters. Scottish Power Renewables has recently announced its intention to develop 60MW of tidal capacity deploying the Hammerfest technology at three sites in the Pentland Firth, Islay and Antrim;
- **Pelamis Wave Power.** The world's leading wave power company, based in Edinburgh, has recently achieved a world first with the grid connection of three Pelamis units off the coast of Portugal. Future projects include four units at EMEC and up to seven units at Wavehub off the Cornwall coast. To date, the company has raised almost £40M of investment;
- **Scotrenewables**. Based in Orkney, Scotrenewables is developing a floating tidal turbine. It has have secured nearly £10M of funding, including investments from Fred Olsen and Total;
- **Wavegen**. Based in Inverness, Wavegen has had an operational shoreline-based wave device installed on Islay since 2000. It is are currently pursuing two similar projects, one nearing completion at Mutriku in the Basque country and one in development with nPower at Siadar in Lewis.

Scotland's utilities (Scottish Power Renewables, Scottish and Southern Energy through its purchase of Airtricity) are working closely with marine energy developers to deliver projects. The working relationship between the utilities and developers is much closer than that found in the wind industry. A beneficial delivery model has emerged in which the developer is responsible for the technology and the utility is responsible for any projects (including site identification, consenting and grid connection), allowing each to play to their strengths.

It is clear that Scotland is uniquely placed to take advantage of the opportunity presented by marine energy. To take full advantage of this opportunity the Scottish Government must play a leadership role in growing the enterprise.

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WE NEED TO GET THE DEVICES OUT OF ACADEMIA AND INTO THE SEA.


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GROWING THE ENTERPRISE— PUBLIC SECTOR FUNDING FOR MARINE RENEWABLE ENERGY

3.1 MARKET PULL— REVENUE SUPPORT AND EMISSIONS TRADING

The Renewables Obligation (RO) is the predominant source of subsidy for renewable technologies. It is a 'green tax', paid for by electricity consumers via higher bills. The RO places a mandatory requirement for UK electricity suppliers to source a growing percentage of renewable electricity (currently at 9.1% and increasing each year). Suppliers are required to produce evidence of their compliance with this obligation by purchasing Renewable Obligation Certificates (ROCs).

The obligation is set higher than the available capacity. If a supplier cannot source the required renewable generation then they must pay a 'buy-out' price. ROCs are traded as a commodity, with the market price being the buy-out price, supplemented by a market factor set by the difference between the renewable obligation and available capacity. Average wholesale electricity prices vary, but typically are ~£45/MWhr. Currently, the average ROC price is ~£50/MWhr[21] and hence represents a significant subsidy payment on top of the wholesale price to the operator of a qualifying renewable energy project.

Currently one ROC is awarded for each MWhr of electricity generated from eligible renewable sources. However, the UK Energy White Paper[8] has proposed banding ROCs to provide greater market pull for newer technologies. Under this proposal, onshore wind would receive one ROC, offshore wind 1.5 ROCs and wave/tidal two ROCs. This is expected to come into effect from April 2009. In recognition of Scotland's unique marine resource, the Scottish Government has gone further and is proposing three ROCs for tidal energy and five ROCs for wave energy[22], replacing its extant Marine Supply Obligation. These significant multipliers have been chosen to make early tidal and wave projects competitive with other technologies.

Other forms of market mechanism that favour renewables include the climate change levy (CCL) and the EU Emissions Trading Scheme (ETS). The CCL is a tax on large energy consumers. However, energy from renewable sources is exempt from the levy. The effect of the CCL is small compared to the RO, favouring renewables to the tune of ~£4/MWhr. The ETS applies to large emitters of CO_2 across the EU, who must monitor their emissions and apply for an equivalent tradable permit from their national government. This places a price on CO_2 emissions and increasingly will favour low-carbon energy sources such as renewables and nuclear.

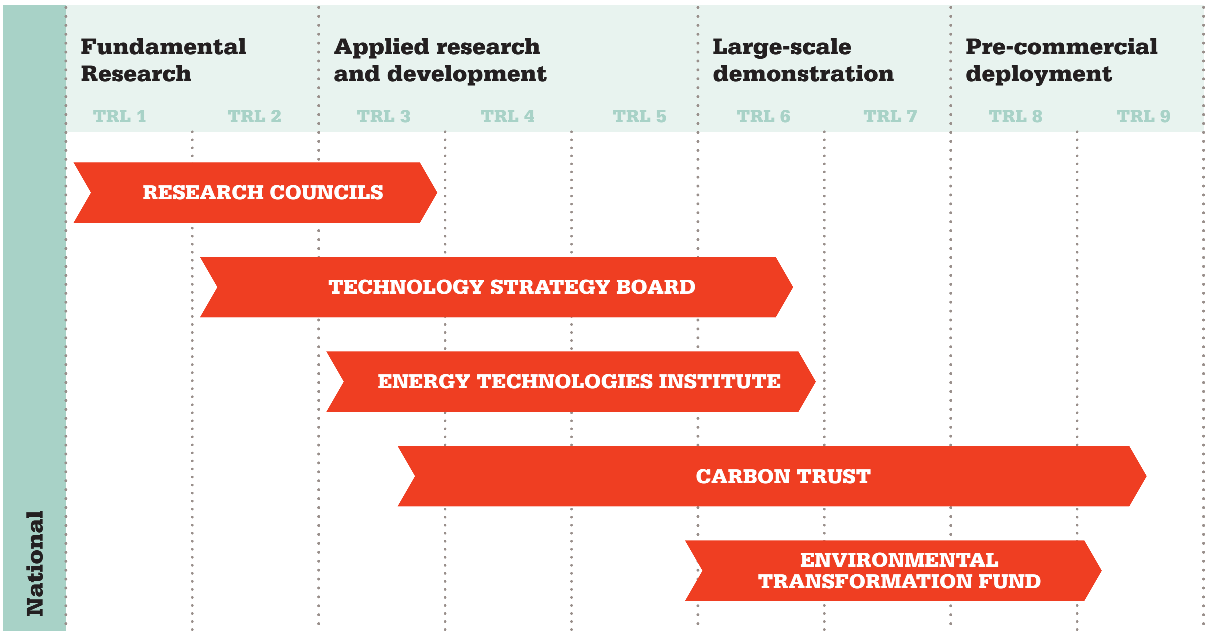
3.2 CAPITAL— THE UK FUNDING LANDSCAPE

The funding landscape in the UK for all renewables is given in **Figure 2** opposite. This section identifies the funds available to marine renewables and provides comment on each, drawn from discussion with stakeholders.

- **Research Councils**. Research into marine energy is funded by the EPSRC and partners through the Supergen marine consortium. The research seeks to increase understanding of the interactions between devices and the ocean, from model-scale in the laboratory to full size in the open sea. The research undertaken is broadly viewed as relevant to industry needs, but there is widespread industry criticism of the dissemination of results;
- **Technology Strategy Board** [TSB]. The TSB promotes innovation through investing in projects and sharing knowledge. It has historically supported early-stage marine energy projects with grants of the order of £100K. Currently the TSB has no call for marine energy proposals. The decision-making process for receiving funding is widely viewed as cumbersome and slow. This can lead to small teams being distracted from their core business of technology innovation, and the stop-start nature of such funding does not provide a stable platform to allow recruitment.
- **Energy Technologies Institute** [ETI]. The ETI is a public-private partnership. Private sector organisations EdF, Shell, BP, E.On, Rolls-Royce and Caterpillar have each committed £50M over the next ten years and this has been match-funded by the UK Government, giving current funding of £600M. Its role is to leverage the skills of its members to accelerate the deployment of low carbon energy systems. It will provide significant funding to vertical consortia that together have the capability to deploy developing energy systems. It has a marine energy programme that is expected to provide ~£10M each to a small number of projects. ETI has caused much controversy within the industry because of a perceived lack of transparency, intellectual property (IP) requirements and a view that the scale of funding available means that the ETI will 'pick' winners. Some of this controversy can be attributed to poor communication, with the funding package proving acceptable to some developers;

- **Carbon Trust**. The Carbon Trust seeks to accelerate the move to a low-carbon economy by working with organisations to reduce carbon emissions and develop commercial low-carbon technologies. It is running a £3.5M marine energy accelerator, investing in projects to develop lower-cost concept designs, to reduce component costs and to reduce the cost of installation and O&M. The industry finds the Carbon Trust to have a better understanding of marine requirements than the TSB and less onerous IP requirements than the ETI, but the application process does give rise to expensive transaction costs;
- **Environmental Transformation Fund** (ETF). The ETF provides funds for low-carbon energy and energy-efficiency technologies. It provides the funding for the Marine Renewables Deployment Fund (MRDF), which includes a £42M wave and tidal energy demonstration scheme. This will fund up to 25% of capital costs to a maximum of £5M per project and also provides revenue support at £100/MWhr (on top of ROCs) to a maximum of £9M per project. Crucially, the scheme has an entry requirement that devices must be grid-connected and demonstrated in representative sea states for three months continuously or six months in a 12 month period. The MRDF is widely described as the "right scheme at the wrong time", as no developer has met the entry criteria since it was set up in 2004 and hence it has not helped with the costs of installing first prototypes. Nonetheless, with recent grid-connection of the OpenHydro, Pelamis and MCT devices, the MRDF is likely to be accessed to fund second generation prototypes or first small arrays.

Figure 2: UK Funding for Renewable Technologies (from BERR)



3.3 ADDITIONAL FUNDING FOR MARINE ENERGY IN SCOTLAND

The Scottish Government has put in place further funding mechanisms that support the unique nature of Scotland's marine energy resource. This section identifies these and provides comment on each, drawn from discussion with stakeholders.

- **Wave and Tidal Energy Scheme** [WATES]. WATES was launched in October 2006 and distributed £13.5M in funding to nine developers, including Scottish-based Scottish Power Renewables (for a Pelamis array), AWS Ocean Energy, Scotrenewables, Aquamarine Power and Wavegen[23]. The scheme is universally praised for being well targeted, flexible and non-bureaucratic. It has accelerated the deployment of several prototypes at EMEC and levered significant private sector funding. To many interviewed it "put right the wrongs of the MRDF". However, the developers have not drawn down the funding as quickly as anticipated because of technical challenges with their devices. No further funds are currently available;
- **The Saltire Prize**[24]. The Saltire Prize was announced in April 2008 and offers £10M for an advance in clean energy. The prize is open globally, but the winning team must deliver an advance that is relevant to Scotland and can be deployed within a two to five year timeframe. The industry has mixed views; the prize is supported for advocating Scotland's renewable energy potential on the global stage, but there are concerns over the lack of objective criteria against which the prize will be awarded;
- **European Marine Energy Centre** [EMEC]. EMEC is a test centre for wave and tidal devices located in Orkney. It provides at-sea berths and infrastructure to grid-connect and test devices in the real ocean environment and is globally unique. It was established with £15M of funding from Holyrood, Westminster and the EU. The industry is united in recognising EMEC as a visionary establishment. There is a view that industry over-optimism led to EMEC being quickly established before it was needed and that a more considered approach may have led to berths and infrastructure better suited to developers' eventual requirements. Nonetheless, EMEC remains the test site of choice for most developers. Some have found EMEC's contractual requirements demanding (for instance, with regards to liability and insurance), but this could be considered a learning process for developers as they first face the commercial challenges associated with deploying large structures at sea.

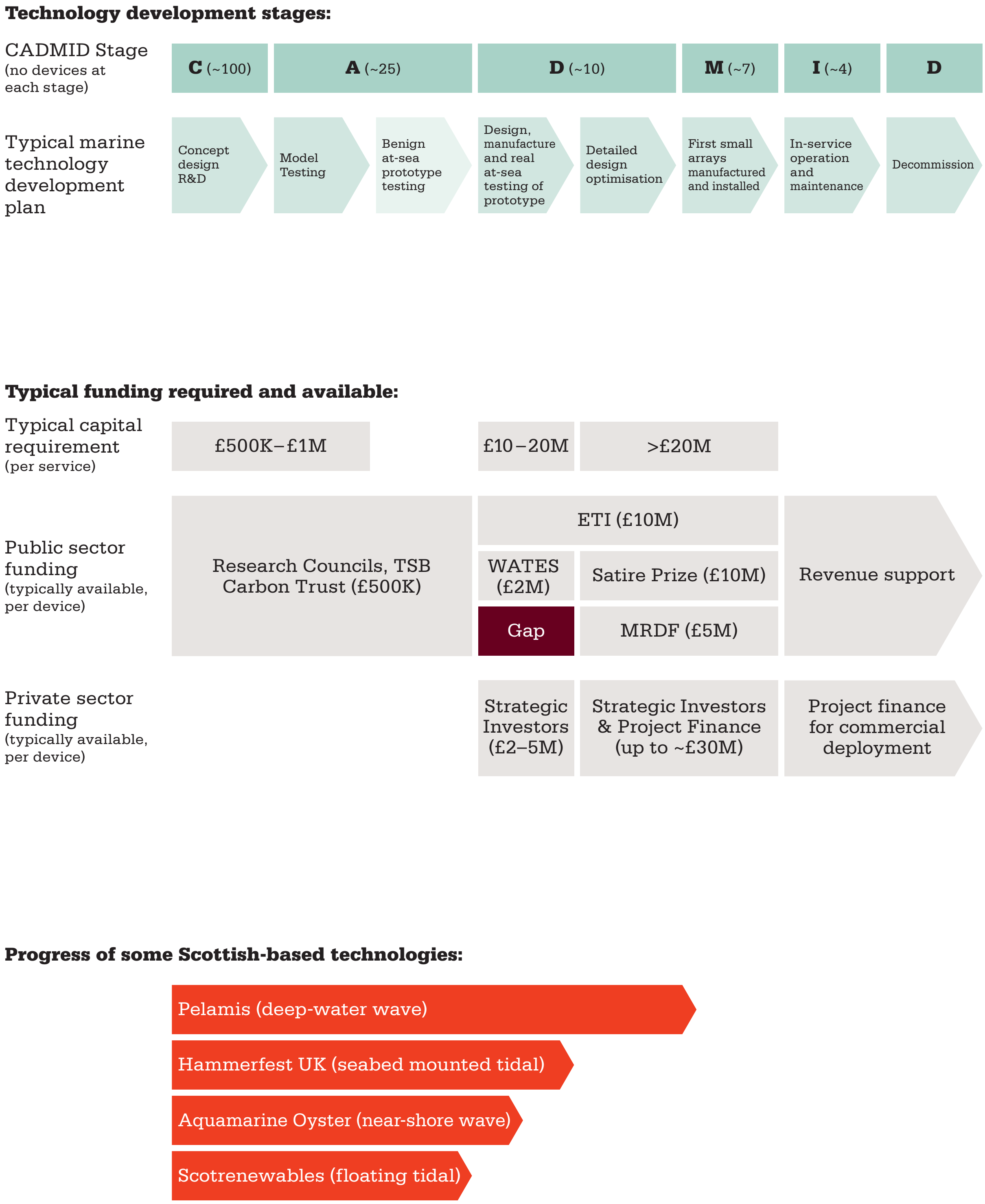
3.4 THE BIG PICTURE— A FUNDING GAP EMERGES

Figure 3 opposite presents a typical wave or tidal technology development plan against the generic CADMID product lifecycle (concept, assessment, demonstration, manufacture, in-service and disposal). Approximate numbers of devices at each stage are given. Latter stages are projections; assuming two tidal and two wave winning technologies emerge, this suggests that around seven devices should be supported as small arrays and around ten devices supported through at-sea prototype testing. Typical capital requirements per device at each stage are given, based on industry discussion and known prototype costs, and are contrasted with the available public sector funding. Typical private sector funding is also given, based on known investments. Finally, the progress of some leading Scottish-based technologies is represented.

Consideration of this picture leads to the following conclusions.

- Early-stage concept and assessment development has historically attracted sufficient funding per device. However, if further concepts are to be brought forward then new TSB funding is required;
- The industry is currently at the demonstration stage of designing, manufacturing and installing full-scale prototypes, mostly at EMEC. Typical project costs are £10–20M per device and MRDF funds cannot be accessed because such projects do not meet the scheme's entry criteria. WATES has been extremely successful at progressing several projects, but even to complete these projects, developers will need to raise further capital. Furthermore, if ~ten devices are to progress to this stage then additional projects will need to be funded. Resolution of this funding gap is pressing if momentum is to be maintained. ETI may assist in this regard, but only for a small number of developers and there is no guarantee that these will be Scottish-based. Initial analysis suggests that the size of the funding gap is £40M;
- Although it is too early to be sure, a combination of ETI, Saltire Prize and MRDF funding is likely to lever enough private sector funding to progress an appropriate number of devices to small arrays. Significant private sector funding is to be expected, because such projects will generate appreciable electricity and hence attract revenue support.

Figure 3: Available and required capital throughout the product lifecycle



THE CHALLENGES— VIEWPOINTS FROM STAKEHOLDER CONSULTATION

4.1 TECHNOLOGY

"We need to get the devices out of academia and into the sea."

Views on technology maturity vary across the industry. Some think that the current generation of devices contain winning designs that simply need to prove themselves. Others think that transformational change will be needed to produce cost-competitive technology. Either way, there is consensus that the technology still presents significant risks, for instance:

- The practical engineering challenges of deploying devices at sea. WATES and EMEC have moved the enterprise from the drawing board to deployment of prototype devices in the ocean environment. The challenges of installation, operation and maintenance are now being faced. Experience to date is that installation is very challenging; OpenHydro, MCT and Pelamis all experienced significant difficulties before achieving successful grid connection;
- Prices of steel, installation vessels and subsea components have all risen significantly in recent years, driven in part by demand from oil and gas and the wind industry. This has driven up the cost of delivering the first at-sea prototypes. Significant cost reduction needs to be achieved by a combination of economies of scale, learning by doing and value engineering.

The marine energy sector is at a crucial stage. Devices are being deployed in the ocean environment for the first time. The survivability, maintainability and performance of a range of marine energy technologies will be tested and the results will dictate whether the enterprise has a commercial future – there are no guarantees. Given the urgency of climate change action, reflected in renewable energy and CO_2 targets, it is the right time to resolve these technology issues. However, sufficient funding needs to be made available so that the best technology is put to the test by the best teams.

4.2 FUNDING

"People over-estimate where marine power is and hence believe that funding should predominantly come from revenue support schemes."

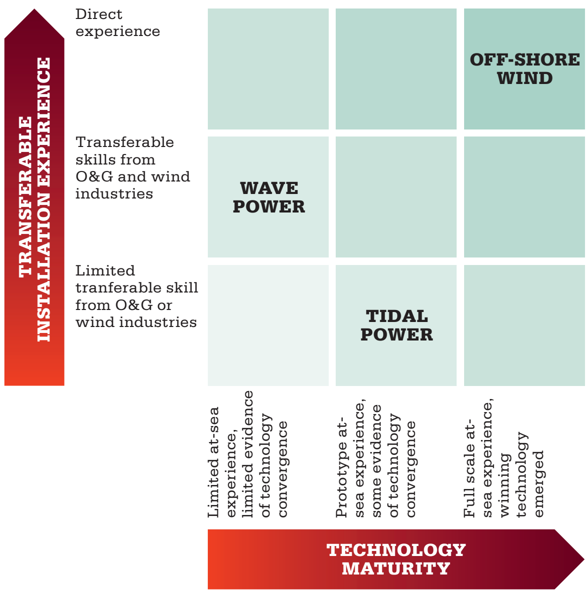
Technology risk and funding are closely related. With technology challenges still to be overcome, funding should be available at appropriate scale and as a mix of capital and revenue support. The Scottish Government's proposal for banded ROCs is generally viewed as providing the right level of revenue support. However, the technology challenge necessitates further capital support. Section 3.4 identified a capital funding gap of £40M.

4.3 SKILLS

"Tidal in the main is about subsea engineering and wave is about marine engineering."

The limited transference of marine and subsea engineering experience from the North Sea oil and gas sector and offshore wind industries to the marine energy enterprise is seen to be a significant barrier to the development of reliable, affordable technology and installation solutions. **Figure 4** qualitatively compares tidal, wave and offshore wind in terms of technology maturity and installation experience. This illustrates that there is very little experience in any industry of installation, operation and recovery in high-energy tidal waters. Wave device installation is likely to rely on weather windows of days, whereas tidal installation is likely to depend on slack water windows of under an hour. Hence, bringing in experience of rapid subsea installation would go a considerable way to addressing the technical risks of deploying devices at sea. More generally, bringing in North Sea design and manufacture experience is likely to improve operational reliability and hence improve the affordability of the enterprise. The requisite skill sets are more likely to reside in the large North Sea contracting companies than the oil and gas majors. A lack of experienced electrical power engineers is also a significant shared challenge across the industry.

Figure 4: Transferable design and installation experience



4.4 GRID CAPACITY

"The grid will be the No.1 constraint to marine energy in Scotland."

Grid capacity in areas of high marine energy resource is limited, both for connection to the local distribution networks and for the onward transmission from areas of high resource to areas of high demand.

Ofgem regulates investment in distribution and transmission assets and only considers projects that have applied for a grid connection, with no contingency for future projects. This raises two main issues:

- A small developer applying for a connection must carry the commercial risk that the project may not be consented. This means that [it carries] a disproportionate share of risk for developments of national strategic importance;
- There is no route for incorporating a strategic view of future generation scenarios, such as the emergence of marine energy.

As an example of the pressing importance of this issue, upgrades to the subsea cables connecting Shetland and Lewis to the Scottish mainland are currently being sized based on known projects only, with no allowance for future wave and tidal projects.

Policy relating to the transmission system is reserved to Westminster, but marine resources are predominantly located in Scotland. Without a solution the potential for the marine energy enterprise in Scotland is limited. This may lead technology developers and the associated supply chain to move to countries where grid infrastructure does not constrain the development of marine energy projects.

MAKING MARINE ENERGY A REALITY— POLICY RECOMMENDATIONS TO THE SCOTTISH GOVERNMENT

Material policy recommendations should address the barriers identified in section 5 in an integrated fashion, whilst drawing on the strengths of Scotland's national advantage. They should be distinctive to Scotland, additional to existing policy and complementary to existing initiatives. With this in mind, the following policy recommendations are offered to the Scottish Government and other stakeholders.

MAINTAIN THE MOMENTUM THROUGH STRONG, COURAGEOUS AND CONSISTENT POLITICAL LEADERSHIP

"Political will is vital."

Developing a world-leading marine energy sector is a long game and sustained support, consistency and foresight are required. All agree that the political will and cross-party support of the industry over the past few years catalysed the considerable progress achieved and has contributed to a sense of belief. This needs to be developed in step with the emerging needs of the industry. Political leadership needs to be evident in rhetoric, action, engagement and foresight.

- **Word**. Political rhetoric is supportive, but would benefit from formal cross-party endorsement, to reduce perceived long-term risk associated with the political cycle. A sense of partnership with Westminster on issues such as revenue support and grid reforms would also strengthen belief in the home market;
- **Action**. The benefits of action to date can be seen through the progress achieved by WATES funding and the EMEC facility. It is essential that this continues – the recommendations of this report guide the priority for action;
- **Engagement**. Energy utilities and technology developers are engaged with the opportunity, but involvement from Scotland's subsea, marine and manufacturing base is limited and not characterised by the same sense of belief. With the enterprise moving into a phase of subsea design, manufacture and installation, this needs to be addressed. These industries need to be roused to the benefits of supporting initial prototypes and projects as a way of securing the know-how to take leading positions in the long term;
- **Foresight**. A realistic projection of the future skills and infrastructure required to deliver the competing global demands of marine energy, offshore wind and oil and gas needs to be made and acted on.

PROVIDE FURTHER CAPITAL SUPPORT, TARGETED AT BRINGING THE REQUISITE SKILLS TO OVERCOME CURRENT TECHNOLOGY CHALLENGES

"It's about the money."

The marine energy sector is at a crucial stage where the technology is being tested in the real ocean environment. The results will dictate whether the industry has a commercial future. Extra capital funding is required to ensure that a sufficient range of well-engineered technology is tested. The initial funding is required immediately and the total sum is likely to be drawn down over the next two to three years. **Figure 3** provides an overview of this funding gap.

The MRDF provides for capital support, but its entrance requirements preclude the funding of first-generation prototypes, due to the requirement to demonstrate grid-connected operation in order to access this fund. The ETI's marine programme attempts to address this gap by making substantial investment in vertical consortia, but has drawn criticism about transparency, IP requirements and "picking winners". Conversely, WATES was widely admired for its simplicity, flexibility and lack of "strings attached". However, WATES has not brought significant subsea experience into the enterprise. Hence, it is recommended that any new funding from the Scottish Government should:

- Be administratively and contractually simple;
- Allow the market to guide investment targets;
- Address known challenges with the technology and the skill base, most notably bringing in subsea and marine engineering expertise;
- Provide support to first-generation prototypes that are unlikely to generate much revenue (but will provide know-how to develop first small arrays, which will be revenue-generating);
- Provide clarity of ownership of risk;
- Provide a return to the Scottish economy, through the creation of jobs and export of both manufactured goods and IP.

The simplest way to create interest from the oil and gas sector is to make an investment in marine energy comparable to a North Sea investment. This requires comparable return and comparable risk. Achieving comparable return would require the Scottish Government to provide sufficient public capital to allow a 15 to 20% return on the private capital. Achieving comparable risk would require the Scottish Government to underwrite the following risks:

- Long-term political uncertainty over revenue support, by writing banded ROC support into legislation as a priority;
- Consenting, by pre-consenting sites or insuring investment against delay in the consenting process;
- Grid-connection, by guaranteeing income for an operational project.

Such a scheme would invite applications for projects that included:

- Both technology demonstration via a first-generation prototype and a subsequent first commercial array;
- A combination of skill in marine energy technology; marine and subsea manufacture and installation; and electrical power engineering;
- A single lead contractor.

Focused consultation with the marine energy enterprise and the North Sea contracting industry would be required to develop the details of such a scheme. Detailed financial analysis is beyond the scope of this report, but initial analysis suggests that the size of such a scheme would be £40M of public funds, supporting of the order of four projects, each advancing different technologies. Such a scheme would complement the Saltire Prize, by providing bankable support playing to the strengths of Scotland's existing enterprise, whilst the Saltire Prize acts to advocate these strengths on the global stage.

WORK WITH WESTMINSTER TO FIND COMMON INFRASTRUCTURE SOLUTIONS FOR THE RENEWABLE ENERGY CHALLENGE

"Transmission must be a UK solution."

Collaborative working between the Westminster and Holyrood administrations is required to find win-win solutions. Westminster's renewable energy strategy[1] does not foresee a significant role for marine energy by 2020, but Holyrood does. However, the UK is likely to rely heavily on Scotland to meet its 2020 15% renewable energy target and hence a significant portion of the infrastructure investment is likely to fall in Scotland.

It is recommended that Scotland's contribution to the UK's 2020 renewable energy target is defined and a commensurate proportion of transmission system infrastructure investment devolved. It would then be for Holyrood to agree the nature of that investment to support its vision of how Scotland will achieve its contribution to the UK target.

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IMAGES

Oyster Hydro Electric Wave Energy Convertor
Image courtesy of Aquamarine Power

Openhydro Open-Centre Turbine test structure
All commercial installations are deployed below the ocean surface with no obstruction to shipping. Image courtesy of Openhydro and Michael Brookes Roper Photography

GLOSSARY

Banding (of ROCs) Proposed division of ROCs into bands of differing value, dependant upon the origin of the renewable generation. Increases revenue subsidy to less developed technologies such as wave and tidal.

(Installed) Capacity The theoretical maximum power which a generating asset could produce.

Capacity factor The ratio of the actual output of a power plant over a period of time and its output if it had operated at full capacity over the same period of time.

CCL Climate Change Levy.

Deepwater Describes devices designed to be located a considerable distance offshore, in deep water.

EMEC European Marine Energy Centre.

EPSRC Engineering and Physical Sciences Research Council.

ETF Environmental Transformation Fund.

ETI Energy Technologies Institute.

ETS (The EU) Emissions Trading Scheme.

FREDS Forum for Renewable Energy Development in Scotland.

GDP Gross Domestic Product.

GW Giga-Watt – unit of electrical power equal to 1000MW. Appropriate in discussions of national power requirements.

IP Intellectual Property

IPC Infrastructure Planning Commission.

KW Kilo-Watt – unit of electrical power useful at the domestic scale. A domestic kettle consumes of the order of 1kW.

kWhr Unit by which electrical energy is purchased at the domestic scale.

Marine Energy Energy, most usually in the form of electricity, generated from wave or tidal motion.

Marine Energy Enterprise The industry associated with the development and deployment of marine energy projects and technology.

MRDF Marine Renewables Deployment Fund.

MW Mega-Watt. Unit of electrical power equal to 1000 kW, and hence appropriate in discussion of generating capacity.

Near shore Describes devices designed to be located in relatively shallow water, near to land.

Peak oil Refers to the point in time when the maximum rate of global petroleum extraction is reached, after which the rate of production enters terminal decline.

RO (The) Renewables Obligation.

ROC Renewables Obligation Certificate.

Shoreline Describes devices designed to be mounted at the boundary between land and sea.

Supergen Research consortium of UK Universities formed to lead research into renewable energy in the UK. Has a marine consortium, which leads research into wave and tidal energy.

Tidal range Technology which extracts energy principally from the difference in water height between high and low tide.

Tidal stream Technology which extracts energy from the moving flow of water caused by an incoming or outgoing tide.

Tidal turbine A rotating device which generates electricity from the energy of the tides.

TSB (The) Technology Strategy Board.

TWhr Unit by which electrical energy is measured at the national scale. Equal to 1×10^9 kWhr.

WATES Wave and Tidal Energy Scheme.

ANNEX A— STAKEHOLDERS INTERVIEWED

Device Developers
David Gibb, Chief Financial Officer, Wavegen
Simon Grey, Chief Executive Officer, AWS Ocean Energy
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Robin Burnett, Marine Project Engineer, Airtricity / Scottish and Southern Energy

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