CARBON TRUST

CARBON TRUST

Marine Renewables Green Growth Paper

EXECUTIVE SUMMARY

Climate change and the need to decarbonise the economy require a comprehensive and ambitious development of renewable energy sources. Marine energy has the potential to be a key renewable energy source given the substantial energy resources present in the globe's oceans. This paper discusses the potential business value benefits arising to the UK from the involvement of UK-based businesses in the marine energy sector. In the context of this report, marine energy sources considered are wave and tidal stream.

Given the relative infancy of marine technologies, there is still considerable uncertainty as to whether wave and tidal systems will play a meaningful role in meeting global energy needs. Deployment scenarios suggest a broad range of potential outcomes, and marine energy should be seen as an "option play" whose value is particularly high if we believe they can achieve strong cost reductions and/or other low carbon generation technologies like Nuclear and CCS face particular deployment constraints. Our analysis of energy system development suggests that up to c.240GW of marine capacity could be deployed globally by 2050, with roughly 75% coming from wave, and the remainder from tidal. Modest deployment would take place by 2020 (led relatively more by tidal stream technologies which are closer to commercial deployment), with deployment only ramping up in the 2020s. To reflect the high degree of uncertainty, we have also presented a more cautious medium scenario, and highlighted the risk of "near zero" deployment even in the long term.

Our analysis of deployment of the global market would suggest that the total market for marine energy in a high scenario is worth up to c.£460bn (cumulative, undiscounted) in the period 2010-2050, with the market reaching up to c.£40bn per annum by 2050.

In terms of the potential for the UK, we estimate that the tradable[1] market accessible to UK-based business is up to c.£340bn, peaking at c.£29bn per annum. Breaking this down into the respective technologies, the accessible global market for wave in the 2010-2050 period amounts to nearly **£250bn** (cumulative, undiscounted) (peak of c.£23bn p.a.). Similarly the accessible global market for tidal stream energies is estimated at **c.£93bn** (cumulative, undiscounted), peaking in the late 2040s at c.£6bn p.a.

Given the UK's present, and likely future strengths in this technology area, we consider that the UK could capture **c.£76bn** of the global marine market or around 22% of the accessible global market (cumulative, undiscounted to 2050 in our high scenario). This would suggest a gross contribution to UK GDP of **c.£15bn** over the forecasted period (c.£10bn for wave, and c.£5bn for tidal, and not accounting for any displacement effects). Our analysis concludes that this level of contribution could mean the generation of over 68,000 UK jobs from marine energy by 2050[2].

---

[1] An estimate of the total market that is effectively addressable to the UK based on CT analysis of the levels of regional resource and deployment

[2] Gross benefits assume that UK policy is committed to meeting climate change targets, despite the potential economic cost (covered in other studies). Hence, our assessment of gross contribution to GDP from business creation does not take into

1. SECTOR DESCRIPTION

We have taken the marine sector to consist of electricity generated by capturing the power of **tidal streams** and **waves.**

Wave energy: Waves are caused by wind blowing over the sea. The longer the water distance over which the wind blows, the greater the transfer of energy to waves. Waves are contained in the water nearest the surface. Wave energy devices convert wave energy into electricity. The deployment location is the primary defining characteristic of wave devices, which spans onshore (shoreline), near-shore or offshore locations. The deployment location gives an indication of how much energy there will be available to the device, with more energy available in environments further from shore. There are several basic different types of wave energy converters including: oscillating wave surge converters, attenuators, overtopping devices, oscillating water columns, point absorbers and submerged pressure differential devices. Some devices attempt to combine several of these types into one.

Tidal stream energy: Tidal streams are caused by the movement of large bodies of water under the influence of the moon's gravitational pull. The amount of energy it is possible to extract depends on the speed of the flowing stream, which is higher in locations where the water is funneled such as between islands and the mainland The majority of tidal stream devices are horizontal access 2 or 3 bladed concepts, similar in appearance (but not size) to those devices used for wind power extraction..

2. ROLE OF MARINE RENEWABLES IN THE UK's LOW CARBON TRANSITION

Marine energy systems are still in development. While a handful of examples are at full demonstration stage, most are in the early demonstration or applied research phase. Both wave and tidal energy still require considerable development to play a meaningful role in the supply of renewable energy.

We have used energy system models[3] to assess the potential of marine renewables in meeting the UK's electricity needs through to 2050 across various scenarios. Given the relative early stage of marine renewables technology, there is some uncertainty about its eventual role.

To explore the maximum potential economic value of wave and tidal steam energy, we have analysed the scenario in which marine energy deployment is the highest. This occurs when substantial innovation takes place in marine technologies, and where significant constraints limit the deployability of other, non-renewable energy sources. In this "high" scenario, meaningful commercial deployment does occur, with marine technologies supplying the UK with up to c.1.0GW by 2020, rising to 27.5GW by 2050, of which approximately 18.5 GW is wave energy and 9GW is tidal stream. Our assessment also recognises a "medium" scenario with significant but less aggressive deployment of c.13GW by 2050, as well as scenarios where little marine energy deployment occurs.

---

account the economic costs to society (e.g. revenue support or carbon price) inherent in meeting climate change targets overall.

[3] Including the Markal model used as input to the Committee on Climate Change's Fourth Budget Report

This technology potential has a high level of uncertainty associated with it, and there is a large risk that it is not deployed at all, or in very small quantities. The conditions required for marine energy to reach large deployments are the following:

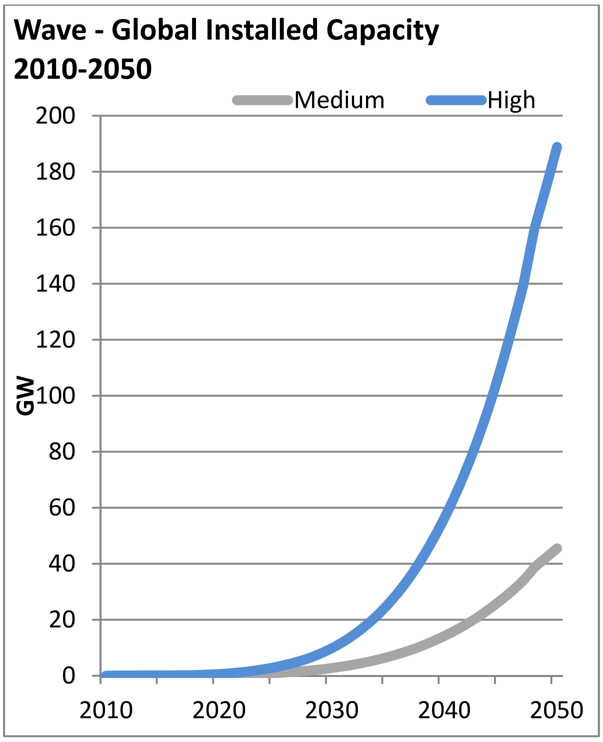
- The technology is successfully 'proven'. To date only a handful of examples have progressed to full demonstration stage. Considerable innovation is required to bring technologies to commercial deployment. Further full scale demonstration of wave and tidal devices is required to prove the technical viability of the technology, followed by deployment of initial arrays and first farms to prove commercial viability. These stages are capital intensive and the private sector will most likely require some form of public sector support. In the longer term, innovation will also be required to allow the technologies to move further off-shore (wave) or into deeper water (tidal) to harness greater energy resource.
- The technology is able to reduce its costs enough to compete with other low carbon technologies. This ultimately depends on the degree of targeted R&D that takes place and the degree to which it can drive accelerated cost reduction, and how this compares to cost reduction in other technologies e.g. CCS.
- Other peripheral barriers to deployment are overcome, including public acceptance regarding environmental impact and sufficient development of the manufacturing supply chain. At present the most substantial barrier is the development of the electrical grid to accommodate the deployment marine resources. Much of the deployment is expected to take place in remote locations (e.g. west coast of Scotland) where grid infrastructure is at present relatively limited.
- Under less aggressive cost improvement scenarios, significant marine energy deployment could still result if other energy supply options (especially non-renewables like nuclear power and fossil fuels with carbon capture and storage) face technical or public acceptability problems OR energy efficiency and demand response measures prove less successful than expected.

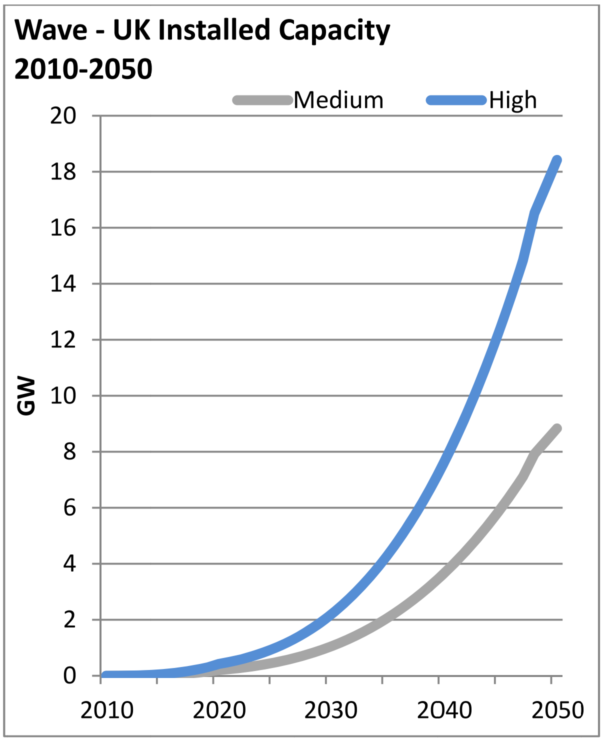
3. MARKET OPPORTUNITY

Wave Market Opportunity

Scenarios suggest that the deployment of wave energy worldwide could be substantial by 2050. Based on IEA scenarios we estimate global wave deployment of up to 189GW by 2050[4]. As with our UK deployment scenarios, we believe this depends on significant technological developments, and (to some extent) on limits to the success of other low GHG supply and demand-reduction measures. Hence there is considerable uncertainty around the ultimate levels of deployment and the risk of much smaller levels of deployment (e.g. our medium scenario) or even "zero" deployment remains high.

[4] IEA Blue MAP scenario projects ocean energy generation. We have assumed that wave energy is 75% of ocean energy generation with a capacity factor of 25%.





Source: Carbon Trust analysis

In the high scenario, the total global market for wave energy technology is estimated to be worth around £31bn/year by 2050.

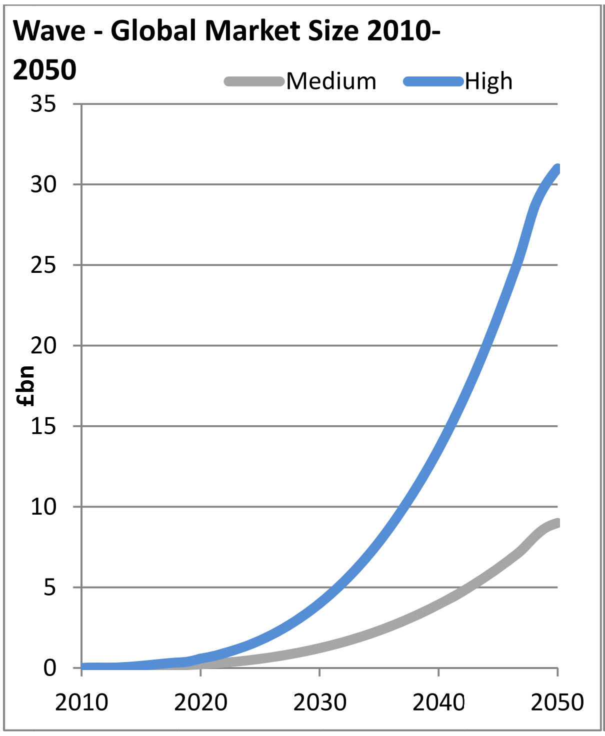
The cumulative global market size (turnover) from 2010-2050 could be c.£335bn (undiscounted) taking into account that higher uptake of the technology will mean that the unit cost will go down by up to a factor of three[5]. Based on our estimates on the location of available resource globally, and the rate at which deployment takes place in these regions, we have been able to estimate the UK's likely tradable market (i.e. the market which it can access and in which it can compete) to be nearly **£250bn** (cumulative, undiscounted), or c.75% of the global market, translating into a peak annual figure of c.£23bn.

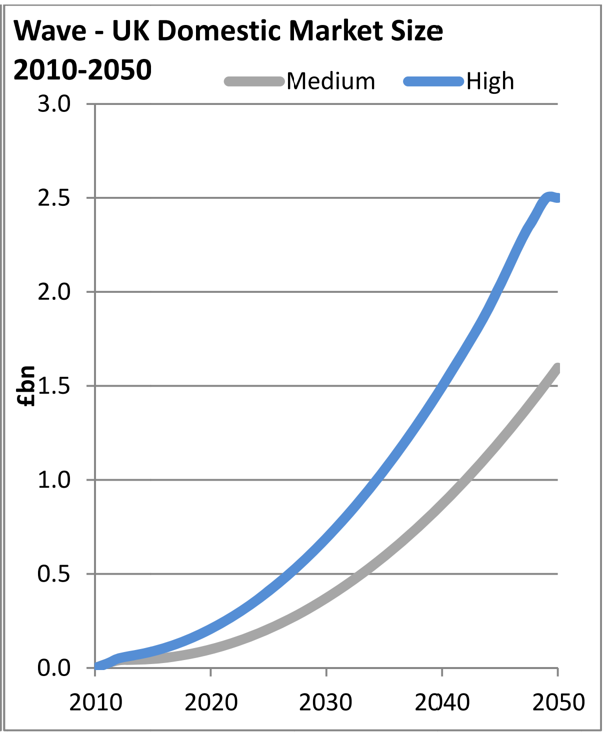
In terms of a present value contribution to GDP[6], this accessible market translates into **c.£48bn** in value.

---

[5] Levelized costs in 2050 compared to those of the initial commercial deployment

[6] This is a key metric for policy makers considering the value of investing in technology development. It represents cumulative value from 2010-2050, applying a discount rate of 3.5% p.a., a GVA/turnover estimate of c.55%, and assuming no displacement effect





Note: The market value in any year includes the installed costs of wave energy devices deployed in the year and the operating and maintenance costs of all wave energy devices operating in the year
Source: Carbon Trust analysis

The market value is expected to peak only in the 2050s as the technology saturates, with overall wave capacity expected to level off leading to lower sales of new and replacement capacity.

The deployment of wave technology is assumed to be low before 2020 (as the technology is being proved), with significant capacity coming on-stream after 2020. This leads to rapid annual growth in the market for wave energy devices between 2020 and 2050 for the UK and worldwide of 9%/year and 14%/year respectively.

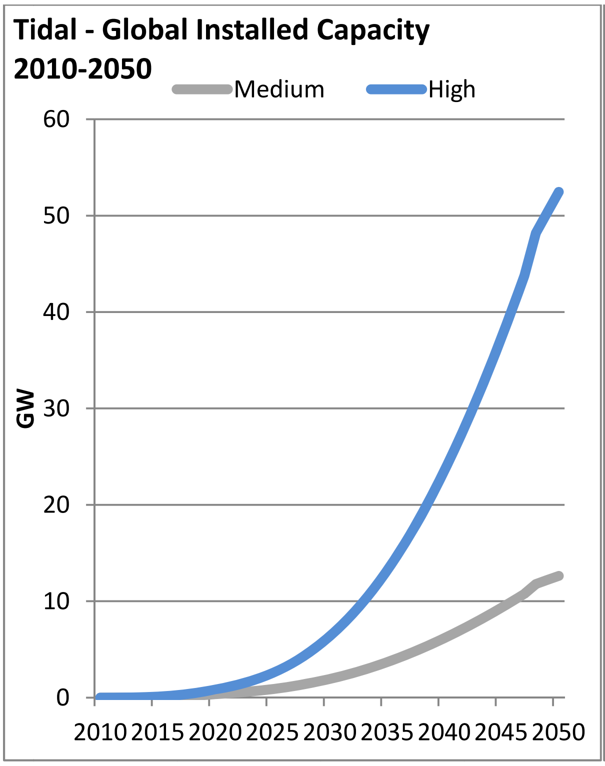
Tidal Stream Market Opportunity

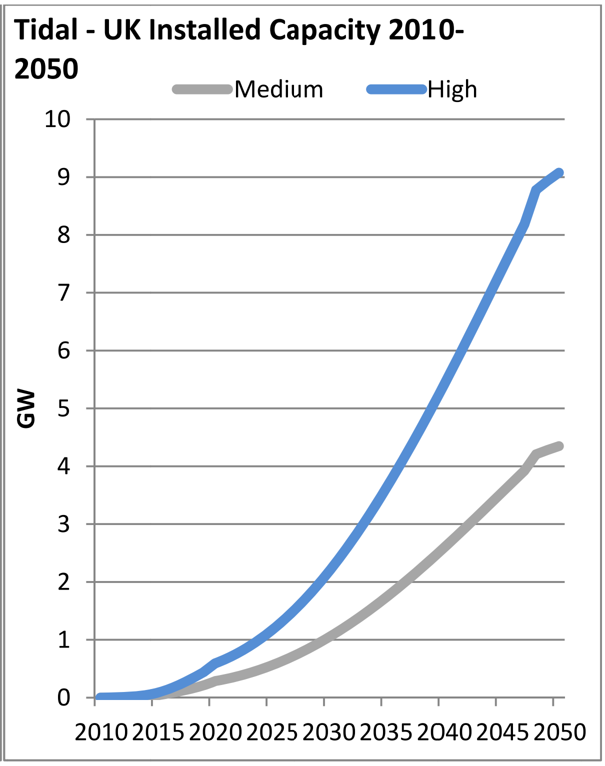
Scenarios suggest that the deployment of tidal energy worldwide could be substantial by 2050. Based on IEA scenarios we estimate global tidal deployment of up to 52GW by 2050[7].

Tidal stream technology could be argued to be slightly ahead of wave technology in terms of technology innovation, as suggested by the convergence in design of most of the technologies being tested. Nevertheless, considerable deployment risks remain in line with our assessment of wave above and the risk of much smaller or “zero” deployment remains high.

---

7 IEA Blue MAP scenario projects ocean energy generation. We have assumed that tidal energy is 20% of ocean energy generation (remainder is tidal range) with a capacity factor of 30%.



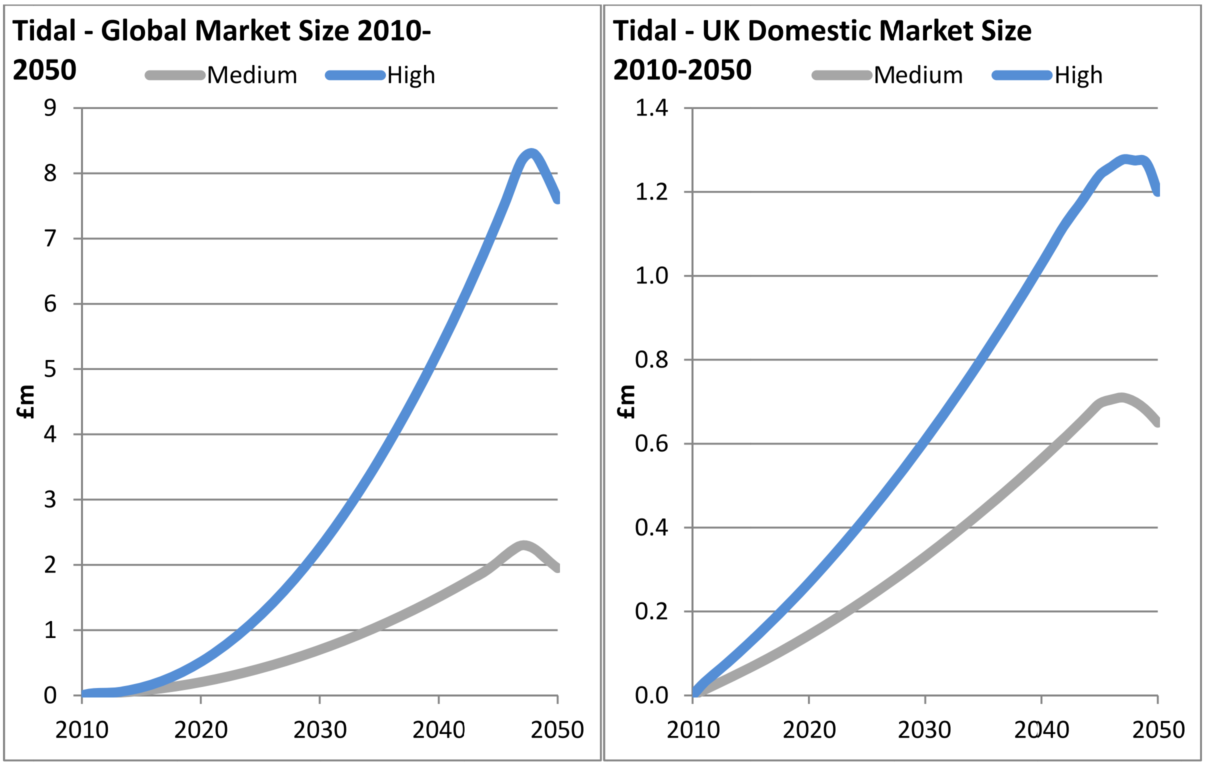


Source: Carbon Trust analysis

In the high scenario, the total global market for tidal stream energy technology could be worth nearly £8bn/year by 2050.

The cumulative global market size (turnover) from 2010-2050 could be c.£126bn (undiscounted). Again, we have estimated the UK's likely tradable market to be in the region of 70-75% of the global market, suggesting that the UK could access up to **£93bn** (cumulative, undiscounted), with a peak annual figure (in the 2040s) of c.£6bn.

In terms of a present value contribution to GDP, this accessible market translates into **c.£20bn** in value.



Note: The market value in any year includes the installed costs of tidal stream devices deployed in the year and the operating and maintenance costs of all tidal stream devices operating in the year
Source: Carbon Trust analysis

The peaking of market value in the 2040s is due to the saturation of tidal stream technology, with overall tidal stream capacity expected to level off, leading to lower sales of new and replacement capacity.

The deployment of tidal stream technology is assumed to be relatively low before 2020 (as the technology is being proved), with significant capacity coming on-stream after 2020. This leads to more growth in the market for tidal stream energy devices between 2020 and 2050 for the UK and worldwide of 5%/year and 9%/year, respectively.

Marine Renewables Market Landscape

The UK is currently the global leader in terms of the marine renewable development and its level of innovation activity and has significant capabilities compared to the rest of the world. Along with its significant natural resources, the UK could therefore become the “natural owner” of these technologies and lead the commercialisation process for the rest of the world, capturing significant economic value in the process. At the same time, given the relatively early stage of technology development, the multi-year demonstration required, and the perennial threat of “fast followers”, the UK’s world leading position is carries significant exposure.

Resources

The UK has a large wave and tidal resource, estimated at almost half of Europe’s wave and over 25% of tidal resources, representing c. 2-3% of global wave and around c.10% of global tidal resources. Other European countries with an Atlantic coastline also have large, albeit lower accessible resources (e.g. France, Ireland, Spain, Portugal, Norway). Outside Europe high levels of resource are also found in North America, South America (e.g. Chile), and parts of Asia (e.g. Korea).

Developers
Globally there are estimated to be c.70-80 device developers in **wave** energy technology. Around 80% of developers are at the early research stage. Leading developers, such as Pelamis (UK), Ocean Power Technology (US) and Aquamarine Power (UK), are currently in full scale sea testing. The UK is home to arguably the most advanced concepts. The US is probably second.

In **tidal stream** there are currently around 50 developers active globally. While around 8 leading companies have or are building devices at full scale, the majority of concepts being developed are at 1/3 scale or below. Nevertheless, these earlier stage devices can be deemed to be second generation designs, and look to build upon experience gained through the development of the later stage devices. This is not the case for wave devices where the lack of design convergence means that earlier stage devices varies more markedly. Leading concepts include Marine Current Turbines, Atlantis, Hammerfest Strom, Voith Hydro, Pulse Tidal, Tidal Generation, and Open Hydro who are developing significant projects in the UK. For tidal stream, the UK leads with around 15 devices. Canada has around 7 devices, and the US around five.

For both wave and tidal attritions rate at the early stage are high, and of the numerous concepts in the initial stages of R&D a proportion will be expected to fail.

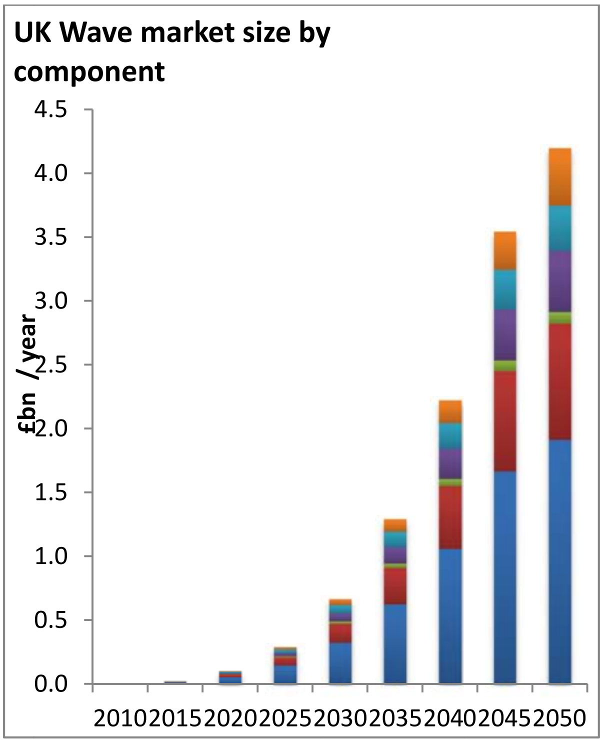
R&D
The UK has a strong university R&D base in marine technologies. Out of c.40 universities identified globally which are currently focused on research into marine renewable devices, c.13 are in the UK. Universities play a key role in both wave and tidal in helping to link theoretical modelling to concept development. The UK has good testing infrastructure (component, device and array) through NaREC, EMEC and WaveHub test facilities.

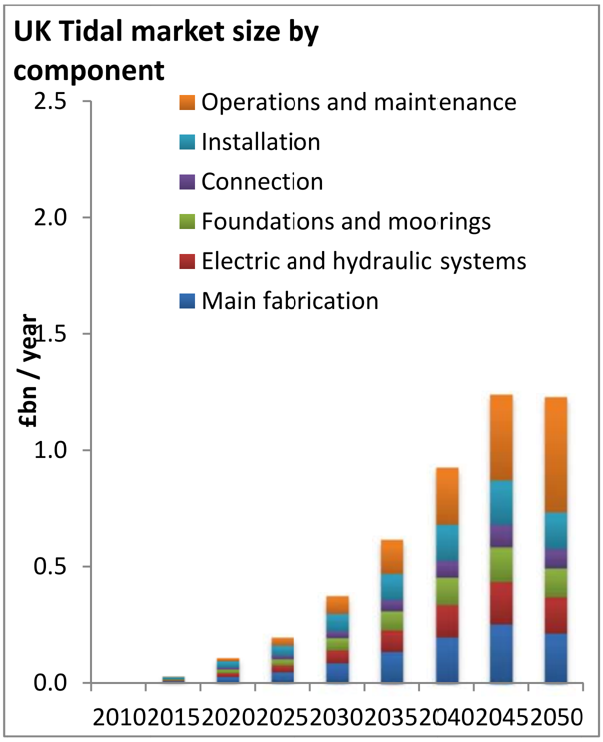
Supply chain capabilities
Marine energy systems can be split in 5 major components: the structure & prime mover, the power take-off, foundations & moorings, connection, installation process and O&M process. Overall UK competitive advantage is high or very high in nearly all areas thanks to a strong research and development base, a strong share of device developers, and the existence of the oil & gas and offshore wind industries. The main exception is probably in power take-off technologies. Whilst UK device developers will undoubtedly have a high share in the area of device control systems, areas dominated by technology hardware such as generators and transformers is more likely to be dominated by larger foreign electric engineering companies e.g. ABB and Siemens. In addition, the UK can draw strength from a number of related industry sectors including the UK's offshore experience from maintaining oil and gas facilities in the North Sea which is valuable for wave and tidal device operations and maintenance. The UK can also leverage offshore wind related technologies.

4. BENEFITS FOR THE UK

Based on the UK's strengths in marine renewables, we believe UK-based businesses could capture a substantial share of the tradable global market. We have estimated potential market shares ranging from c.40% market share for core device components such as the prime mover to 2% for components which have multi-industry use and the UK does not have unique capabilities such as elements of power take-off systems such as generators.

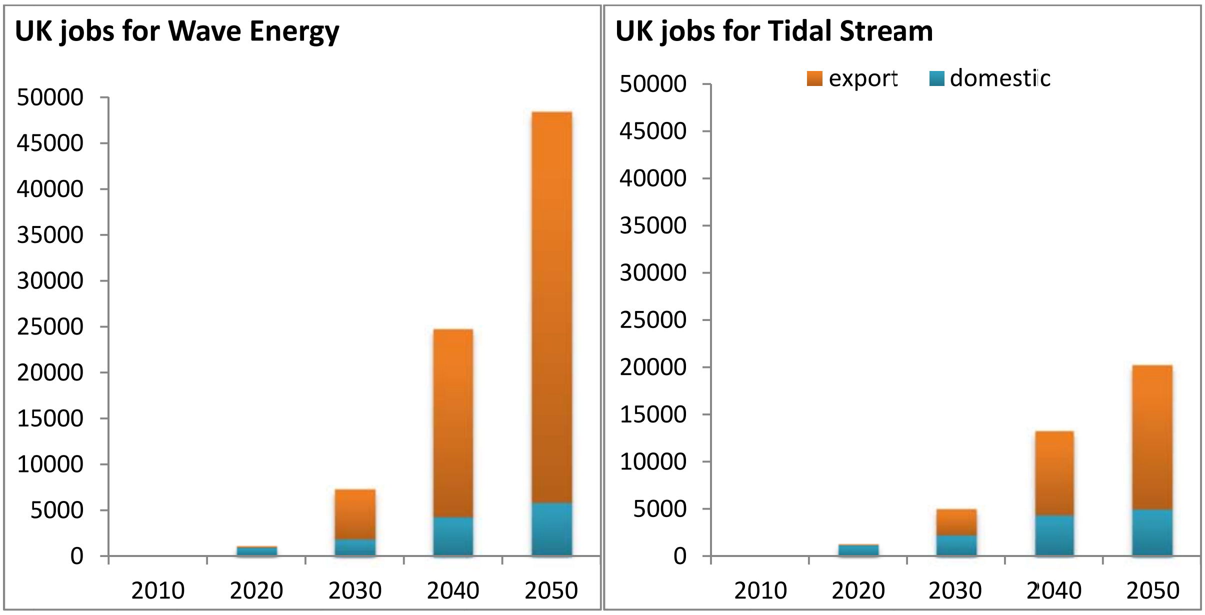
Based on these estimates, we consider that the UK could capture **c.£76bn** of the overall marine global tradable market (undiscounted) in the period 2010-2050, or c.22%. Converting this to gross contribution to GDP (i.e. GVA) suggests a present value contribution of **c.£15bn** over the forecasted period (c.£10bn for wave, and c.£5bn for tidal, and not accounting for any displacement effects), with a substantial portion of this generated by exports.





Source: Carbon Trust analysis

The single largest potential contributor to UK revenues and GVA comes from the manufacture of the main body component in wave energy. This is due to the fact that the manufacturing of these parts is likely to take place close to the deployment sites, with the UK having substantial resources. In tidal devices the greatest potential contributor to UK revenues and GVA is from the operation and maintenance of the energy conversion devices. Using estimates of jobs created per GDP generated implies there could be over 48,000 UK jobs from wave energy by 2050, and nearly 20,000 UK jobs from tidal stream energy that year[8]. About 70% of tidal and 85% of wave jobs will come from exports.



Source: Carbon Trust analysis

[8] Gross job creation, not accounting for displacement effects