The Economic Case for a Tidal Lagoon Industry in the UK

A scenario-based assessment of the macroeconomic impacts of tidal lagoons for power generation on the UK economy

Report for Tidal Lagoon Power Ltd.
July 2014

Cebr

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Disclaimer

Authorship and acknowledgements

This report has been produced by Cebr, an independent economics and business research consultancy established in 1992. The study team included Oliver Hogan (Director & Head of Microeconomics), Colm Sheehy (Senior Economist), Osman Ismail (Senior Economist) and Mohsin Raza (Analyst). A foreword is provided by Douglas McWilliams (Cebr founder and Executive Chairman). The views expressed herein are those of the authors only and are based upon independent research by them.

This study has been commissioned by Tidal Lagoon Power Ltd (TLP) and has utilised a combination of data provided or pointed out to us by TLP and those available in the public domain through DECC, ONS, National Grid, and a range of other sources.

The report does not necessarily reflect the views of Tidal Lagoon Power Ltd or Tidal Lagoon (Swansea Bay) plc.

London, July 2014

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Foreword

This report, prepared by my colleagues at Cebr, documents the first ever comprehensive study of the economic potential of tidal lagoons for power generation in the UK.

The UK has a distinct advantage in having some of the largest tidal range resources in the world. Tidal lagoon power stations can make a significant addition to the range of options for clean electricity generation, helping to achieve a decarbonised power sector and enabling the UK to capture significant additional value from the wider industrial benefits that the sector will deliver.

Our study considers the underlying economics of using tidal lagoons for power generation and demonstrates how a tidal lagoon industry can harness the UK's substantial tidal resources for electricity generation to create thousands of jobs, enhance economic growth and reduce our dependence on imported fossil fuels.

Despite the optimistic sentiment on North Sea oil and gas production, the UK is increasingly dependent on imported fuel. UK gas production has fallen 64% since its peak in 2000. Imports are projected to rise to 92% of the demands for gas by 2030. We faced the same problem in the 1970s when two oil supply crises forced action, and we responded by supporting the offshore oil & gas industry which has, in turn, delivered significant benefits to the UK economy. The current political crises in the Ukraine and the Middle East highlight the dangers of excessive reliance on imported energy from politically unstable parts of the world. Other countries are undertaking major investments to secure domestic sources of clean energy – for example, the United States and China have the largest installed wind capacity in the world amounting to 91 GW and 61 GW respectively. Tidal lagoons give the UK the ability to follow through on Government's ambitious low carbon targets and benefit from a potentially unique set of economic and energy advantages associated with this technology.

Tidal lagoons can be privately funded with relatively little subsidy or price support. And the 120-year project life of a tidal lagoon power plant means that, once such supports have expired, UK electricity consumers can enjoy the benefits of cheap clean power long into the future. What we show in this report is that a fully operational industry could contribute 0.24% of GDP per year and could create or sustain close to 40 thousand jobs, potentially throughout the country but with a definite concentration in Wales, where 4 lagoons are planned to be built. On top of this, up to 71 thousand jobs could be sustained for the projected 12-year construction period, many of which would be in relatively less well-off regions where the lagoons are to be located.

The tidal lagoon industry can play two further important roles. First, the building of the lagoons will boost UK manufacturing and construction if the extensive use is made of domestic supply chains for that purpose. Because many of the components can be sourced within the UK, it could also have one of the best returns in terms of GDP impact per pound invested compared to other energy investments.

Second, in developing and delivering the first tidal lagoon in the world, the UK supply chain would hold a distinct advantage in the global market. Our estimates suggest that there are potentially 80 GW of lagoon sites around the globe with good commercial potential for development, worth an estimated £383 billion in today's prices. In the same way that Denmark and Germany were the first to develop a commercial wind industry and are now global leaders in wind turbines, the UK tidal lagoon supply chain can be a dominant player in the global market for tidal lagoon components and services. This would boost exports and help to close the deficit in the balance of trade.

The report explains our finding that a tidal lagoon industry could provide for as much as 8% of UK electricity needs and reduce fossil fuel imports by as much as half a billion pounds per year by 2027. Further, new interconnector capacity will allow the UK to export more electricity at times of over-supply, and we estimate that the tidal lagoon industry could export as much as 4,300 GWh per year, thus further improving the balance of trade.

Tidal lagoon is not the only renewable technology being deployed in the UK but it could be the important missing piece in the energy generation mix. In contrast to wind and solar, it produces totally predictable power 14 hours a day, reducing the cost of stand-by generators. The electricity it produces is expected to be cheaper than offshore wind and similar in cost to new nuclear.

What this study demonstrates is that, not only does a tidal lagoon industry have the potential to make a significant contribution to the UK economy, but that it can also help secure our energy independence for many years to come. As such, the study is an important and timely contribution to the debate on this country's energy future.

Douglas McWilliams

Founder and Executive Chairman, Centre for Economics and Business Research

July 2014

Executive Summary

Being an island nation, the UK has an immense untapped energy resource. Harnessing the tidal range of the seas that surround us could help the UK in its objective of regaining energy independence following the demise of domestic coal and gas production. Tidal Lagoon Power Ltd. has plans to build six tidal lagoon power stations in the UK – the first of which, if granted the relevant permissions, will be located in Swansea Bay.

A fully operational tidal lagoon infrastructure industry (as represented by the six proposed lagoons) could produce as much as 8% of the UK's electricity needs – enough to power 7.9 million homes. The investment in and operation of these lagoons are expected to deliver a range of benefits to the UK economy, as well as to the environment. These include:

- **An investment programme with an accumulated contribution of £27 billion[1] to UK GDP over the period 2015-2027 sustaining an annual average 36,000 jobs throughout the UK. At its peak in 2021, the programme is expected to sustain up to 71,000 jobs.[2]**
- **The creation of an estimated 6,400 jobs across the UK in the operation and maintenance of the lagoons and throughout the supply chain that supports these activities. When the impact in terms of easing the UK balance of payments constraint are taken into account, up to 40,000 jobs could be created or sustained.[3]**
- **Generating 30 TWh of electricity per year - equivalent to 18 million barrels of oil – for 120 years.**
- **Enabling a cumulative annual reduction in fossil fuel imports of £0.5 billion by 2030.**
- **Reducing emissions by 5.3 million tonnes of CO_2 by 2030[4] – equivalent to 0.9% of the UK's annual emissions in 2013.**

This report by Centre for Economics and Business Research (Cebr) presents the findings of a scenario-based study that explores the impact and economic benefits that a tidal lagoon infrastructure industry could bring to the UK. The study concludes that such an industry, based on the plans of Tidal Lagoon Power Ltd., can be expected to have the following impacts[5]:

Contribution to UK GDP

- The £35.3 billion investment programme to build six lagoons can be expected to result in a cumulative contribution to UK GDP of £27 billion over the period 2015-2027, rising to £35.5 billion when the

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[1] All estimates within the report are presented in 2014 prices unless otherwise stated.

[2] The periods of construction of the six lagoons are expected to overlap.

[3] The balance of payments constraint, if the UK is subject to one as we suspect it is (at least to some extent), is eased by the reduction in the requirement to import fossil fuels and by the boost to exports through (i) tidal lagoon-generated electricity fed through international interconnectors during periods of excess tidal lagoon supply and (ii) the tidal lagoon infrastructure industry that will supply the components and expertise required to support the development of lagoons abroad. In these circumstances, the multiplier impacts produced by the economic modelling framework are more significant than when estimated in a domestic model that ignores the international trade impacts.

[4] Before construction carbon is discounted.

[5] These impacts relate to a scenario where all six lagoons are built and fully operational by 2027.

balance of payments impact is taken into account. During the busiest year of the investment programme, 2021, the annual percentage contribution to forecasted GDP in that year could be as much as 0.30%.

- The operation of the lagoons (which have a design life of 120 years) and the electricity they would generate could contribute £3.1 billion per year to the UK economy, rising to £5.8 billion per year if the balance of payments impact is considered, equating to an annual 0.24% contribution to GDP.[6]
- There is also a significant opportunity for UK industries involved in both delivering and operating the tidal lagoon power stations to serve international tidal lagoon projects. There is an estimated 80 GW of capacity at sites already identified as having commercial development potential, amounting to a potential combined investment of £383 billion. These are conservative estimates of the global tidal resource, but even these suggest that the tidal lagoon export market could be worth as much as £3.7 billion per year to UK GDP or an accumulated total of £70 billion between 2030 and 2050.

Employment creation

- Investment in the development of six tidal lagoon power stations is expected to contribute an average of 12,700 direct full time equivalent (FTE) jobs over the 12-year construction period. Once indirect and induced impacts are taken into account, there could be as many as 70,900 jobs sustained in the peak year of construction.[7] These projections do not take into account investments in fabrication and manufacturing capacity at sites in Wales in order to support the demands of the tidal lagoon investment programme. Such investment would provide for further contributions to employment.
- Operating the lagoons would create up to 240 direct FTE jobs in operations and maintenance roles per site as well as approximately 300 jobs in ancillary activities on the sites. However, the potential jobs supported through indirect and induced effects will be far more substantial. Our multiplier estimates suggest that as many as 6,400 FTE jobs in total could be supported, at least some of which should be newly created jobs.
- The location of tidal power stations in more disadvantaged regions will have a disproportionate impact on local economies. In particular, four of the six lagoons are planned to be located in Wales, representing about 40% of total installed capacity. And following a sustained period of employment supported by construction expenditure, 995 direct, indirect and induced jobs could be created from operational lagoon expenditure within the region.

Electricity exports and energy security

- It is expected that as much as 9% of tidal lagoon power output would be exported (through international interconnectors) by 2030, generating annual export revenues of £0.28 billion per year.
- The renewable electricity produced by tidal lagoon power stations could reduce fossil fuel imports by as much as £0.5 billion per year by 2030. This would contribute to the energy security of the UK by producing more of the energy we use at home and reducing our dependence on foreign suppliers and volatile energy markets.

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[6] Based on forecasted (real) GDP levels in 2027.

[7] For example, the development of the first tidal lagoon in Swansea Bay is expected to support a cumulative 5,000 FTE jobs over the period 2015-2018, where an FTE job in this case is full-time work for one year.

Reducing the trade deficit

- The export of tidal lagoon electricity and of the components and expertise to support the delivery of tidal lagoon projects abroad, combined with a reduction in fossil fuel imports, could increase net exports by as much as £3.7 billion per year by 2040, equivalent to 13% of the current trade deficit. Reducing the trade deficit is a key priority for government and would help to improve the long-term growth potential of the UK economy.

Further benefits

- **Flood defence** – several of the proposed locations for the tidal lagoons are those that have been worst hit by recent coastal flooding. Colwyn Bay, one of the proposed sites, suffers from frequent flooding which costs local residents, local authorities and businesses millions of pounds in flood damage. Flooding will reoccur unless a long term solution can be found. Tidal lagoons are designed to withstand storm surges and sea level rises. In areas subject to increasing occurrence of storm surges and coastal erosion, tidal lagoons could enhance defences, help protect coastal communities and provide flood defences which would otherwise require hundreds of millions of Government investment. A lagoon at sites such as Colwyn Bay could therefore provide a permanent solution to the flooding problems, generating long-term benefits and savings for the local economy.[8]
- **Electricity generation mix –** Due to the cyclical nature of tides, electricity output from tidal lagoons is predictable, in contrast to wind and solar power which are subject to forecast error and produce at different levels depending on the time of year. Lagoon deployment, with a balance between northern and southern locations, would allow balanced production throughout the day and would, therefore, require a far lower stand-by capacity to balance supply and demand at peak times. This makes tidal lagoons a beneficial addition to the UK electricity generation mix.
- **Electricity consumer benefits -** Developing a tidal power industry can benefit the consumer in the form of cheaper renewable electricity. A recent report by Poyry[9] has found that the levelised cost of tidal lagoon power could be cheaper than offshore wind and, in the case of larger lagoons, comparable with nuclear.

[8] The value of the flood defence benefits described here have not been calculated as part of this study. They would most likely be additional to the economic benefits presented in this report.

[9] Poyry Management Consulting, 2014, 'Levelised Costs of Power from Tidal Lagoons'.

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1 Introduction and background

This is a report by Centre for Economics and Business Research (Cebr) on the potential macroeconomic impacts of investment in a tidal lagoon industry. The assessment produces estimates of the impacts on the UK economy of various scenarios for the roll-out of up to six lagoons on the west coast of Great Britain. This report and the supporting analysis were commissioned by Tidal Lagoon Power Ltd.

Tidal lagoon power is a renewable electricity generation technology that uses the differential between water levels inside and outside the lagoon ('head'), created by the rise and fall of the tides, to generate electricity. This involves the construction of a bund wall connected to the shore that encloses an area of the sea. Lagoon sites require locations with shallow water and a high tidal range. Water levels are controlled within the lagoon to create the necessary head difference to the sea level, whereupon gates are opened and water is allowed to flow in and out of the lagoon via turbines installed in the bund wall. Power is generated from the incoming and outgoing tides for approximately 14 hours per day in accordance with the highly predictable tidal cycle.

The following sections present the energy policy context for the development of a tidal lagoon industry.

1.1 The tidal lagoon industry in context

Tidal lagoons differ from existing tidal range plants in that they involve the construction of a sea wall connected to the shore that encloses an area of the sea. Lagoon sites require locations with shallow water and a high tidal range. Lagoons are designed to have a 120 year infrastructure lifespan. A key advantage of a tidal lagoon compared to a tidal barrage is the lower environmental impact. A lagoon does not require the blocking of a river or bay which greatly reduces the impact on the estuary ecosystem.

Tidal Lagoon Power Ltd. (TLP) plans to develop six lagoon power stations in the UK - the first of which is a 320 MW power station in Swansea Bay where construction is due to commence during the first half of 2015. The entire lagoon construction programme will be spread over a 12-year period (from 2015 to 2027[10]). Once fully operational in 2027, the six lagoons would generate 30 TWh of electricity per annum, equivalent to 8%[11] of forecasted UK electricity production in 2027 and enough to power 7.9 million homes.

The location of the lagoons is spread between the Severn Estuary, North Wales and the North West coast of England. The pairing of northern and southern lagoons allows for a smoother power production profile throughout the day due to the difference in the timing of high and low tides at different locations.

Developing a full-scale tidal lagoon industry in this manner (as opposed to building a single power plant) can benefit from significant economies of scale in both construction and operation. Developing six lagoons with overlapping construction schedules allows for bulk orders of components, shared resources and operational efficiencies which can be applied across multiple lagoons.

A key advantage of lagoon construction is the domestic oriented nature of the supply chain. A majority of the value of components and construction contracts required to complete a tidal lagoon can be sourced

[10] The construction schedule covers a period from 2015 to the first half of 2027. For the purposes of the analysis, a more simplified schedule has been used which assumes a construction period spanning 2015 to 2026.

[11] Alternatively, power output equates to 9% of electricity production in 2013.

in the UK. This means that a higher share of the benefits associated with these large scale investments can be retained within the domestic economy.

Developing a tidal power industry can also benefit the consumer in the form of cheaper renewable electricity. A recent report by Poyry[12] states that the levelised cost[13] of tidal lagoon power could be cheaper than offshore wind and comparable with nuclear generation for larger lagoons (a comparison with other renewable technologies is presented in Figure 2 in the next section). The long lifespan of each lagoon (120 years) means that consumers will be able to benefit from low-cost electricity from a domestic renewable energy resource long after the initial capital investment has been paid for.

The combination of these benefits means that tidal lagoon power presents an excellent opportunity for the UK to strengthen the electricity generation portfolio, helping to guarantee security of supply, whilst also achieving long term climate change objectives at a lower cost to the consumer and providing a significant final demand stimulus to the economy through the investment programme.

1.2 Overview of Government policy towards tidal lagoon power

The UK Government has recently introduced a range of electricity market reforms aimed at securing the UK's electricity supply, meeting commitments to carbon targets and ultimately reducing the cost of electricity to the consumer over the longer term.

The UK is legally committed to reducing greenhouse gas emissions by 80% by 2050 and to meeting 15% of energy demands from renewable sources by 2020. To achieve these renewable energy and emissions goals, the UK must increase the amount of electricity generated from renewables almost 5-fold on 2009 levels by 2020. The Department for Energy and Climate Change (DECC) wants electricity from renewable sources to play a key role in helping to decarbonise our energy sectors.

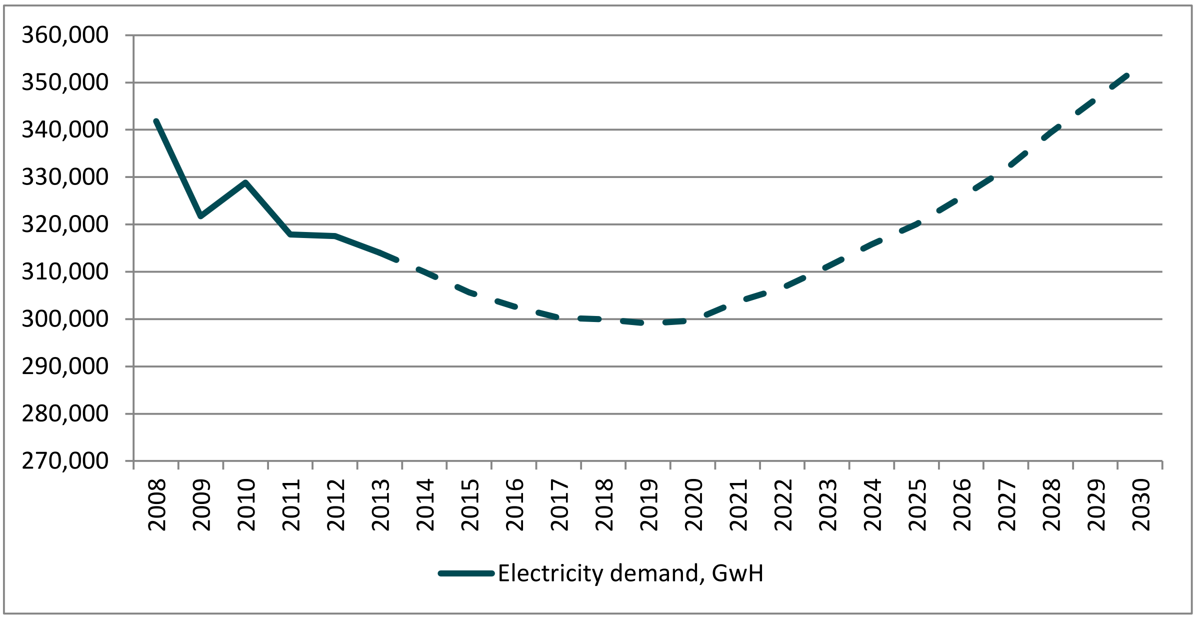
New capacity is needed over the next number of years due to the planned closure of fossil fuel plants. This presents an opportunity for the UK to reshape the electricity generation industry in a way that meets climate change targets and insures the country against exposure to price volatility in fossil fuels sourced from abroad.

The Government's view is that we cannot rely on any single form of generation and instead we should pursue a diverse mix. Renewables, new nuclear and carbon capture and storage, as well as demand-side measures to increase energy efficiency (like, for example, installing insulation in homes) are part of the Government's strategy to address these future energy requirements. In addition, a shift away from fossil fuels towards a more extensive role for electricity within the economy (such as the move towards electric vehicles) means that demand for electricity is projected to begin to increase by 2020 after a long period of decline (see Figure 1).

[12] Poyry, 2014, 'Levelised Costs of Power from Tidal Lagoons'.

[13] Levelised cost of electricity: the price at which electricity generated must be sold in order to break even over the lifetime of the project.

Figure 1: Electricity demand, GwH, Historic and projected



Source: DECC Energy & Emissions Projections, Reference scenario

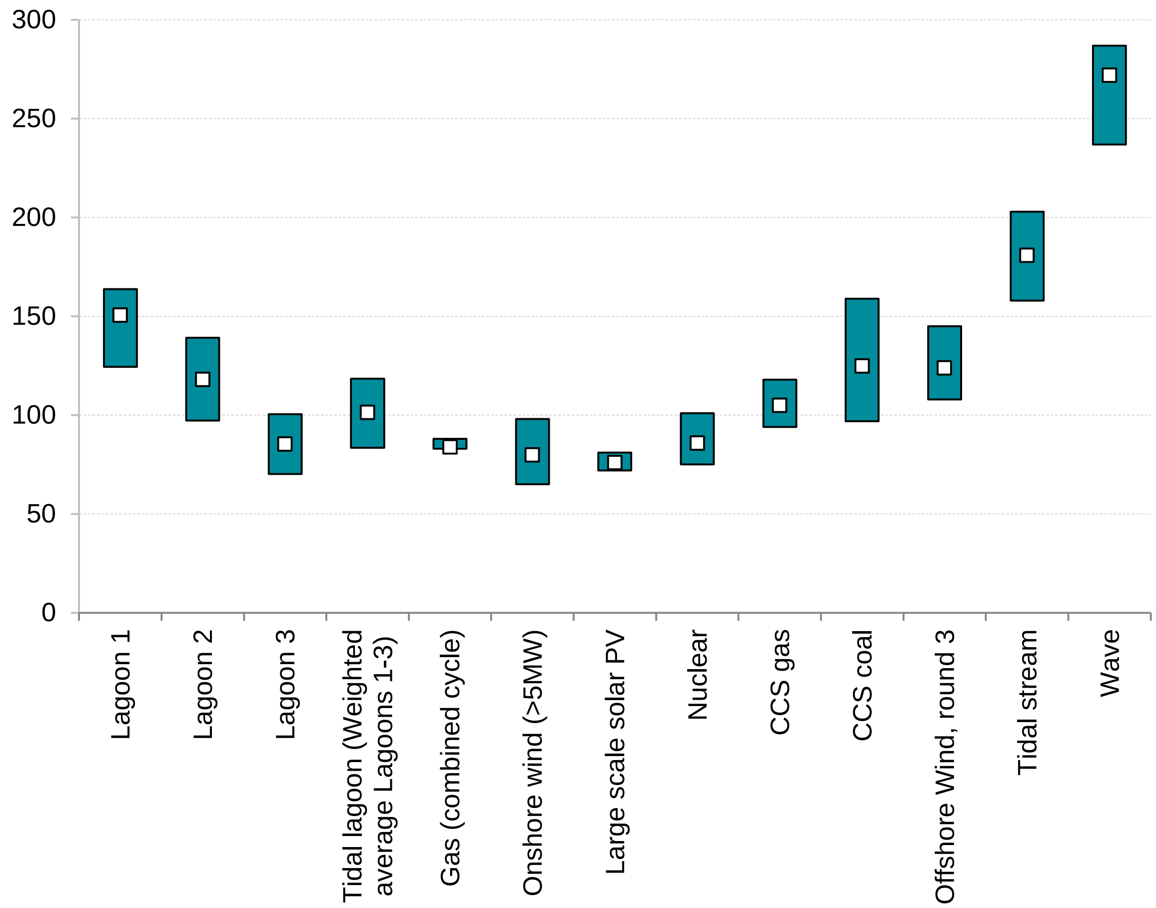
Wind power remains the dominant renewable energy technology in the UK with 8.9 GW of installed capacity in 2012 and its share of generating capacity is projected to continue to increase as new schemes are commissioned. However, wind power suffers from several significant downsides that limit its ability to fill the gap in UK electricity generating capacity left by the closure of fossil fuel plants. Wind power has a highly variable output which means that it cannot produce the predictable generation that is needed by the National Grid to meet base load electricity demand. In addition, wind turbines are generally assumed to have a short lifespan of between 20 and 25 years which adds to their long term investment cost relative to other technologies.

Power from tidal lagoons represents an important component of this future electricity generation portfolio. Due to the cyclical nature of tides, power generation from tidal lagoons can be predicted years in advance. This gives tidal lagoon power a distinct advantage over some other renewable technologies as it does not suffer from the same forecast error. Therefore it often requires a lower stand-by capacity (normally provided by a gas-fired plant which can be activated on demand) to balance supply and demand at peak times. At times when stand-by capacity is required, it can be provided by tidal lagoons operating to different tide timetables in other locations, or booked long in advance, thereby reducing unit cost.

To incentivise the development of new low carbon electricity generation capacity, the UK Government has introduced a contract for difference (CfD) mechanism designed to reduce exposure to volatile electricity prices. CfDs are an agreement between a Government-funded company[14] and the generator. At times where a pre-agreed 'strike price' is above the market reference price, the generator pays the difference back to the government. Where the market price falls under the strike price, the generator must be paid the difference by Government. This provides the necessary price support for different generating technologies to attract investment.

[14] The Low Carbon Contracts Company Ltd

Figure 2: Levelised cost estimates for projects being commissioned in 2025, £/MWh, 2012 prices



Source: Poyry

For most generating technologies, the Department for Energy and Climate Change has published set strike prices that would apply to eligible projects. The UK government has not published a set strike price for tidal lagoon power, acknowledging that the lack of cost data and the variable capital investment to power output ratio does not make it possible to consider an appropriate strike price at an industry level. The CfD for tidal lagoon projects will instead be determined on a case-by-case basis. This has also been the approach taken by DECC for large scale nuclear plants such as Hinkley Point C and for future large scale hydroelectric and carbon capture and storage plants.

1.3 Purpose and structure of the report

The purpose of this report is to present and define the benefits to the UK economy from the development and operation of a full-scale tidal lagoon industry. The study focuses not just on the benefits to the UK economy but also on regional economies, with specific attention paid to Wales (where the first lagoon at Swansea Bay is planned to be built). The report also provides historic lessons on how early government support of the UK oil & gas industry and the German and Danish wind industry was crucial in their success and their ability to produce long term economic benefits.

The report is structured as follows:

- Chapter 2 provides an outline of the methods and assumptions used in our assessment of the economic impacts of investment in a tidal lagoon industry in the UK.
- Chapter 3 presents the results of our analysis of the economic impact of a tidal lagoon industry at the UK level.
- Chapter 4 presents an analysis of the how employment generated by the tidal lagoon industry will disproportionately benefit disadvantaged areas in the UK.
- Chapter 5 presents case studies that demonstrate how early support for the UK oil and gas industry and the Danish and German wind industries.

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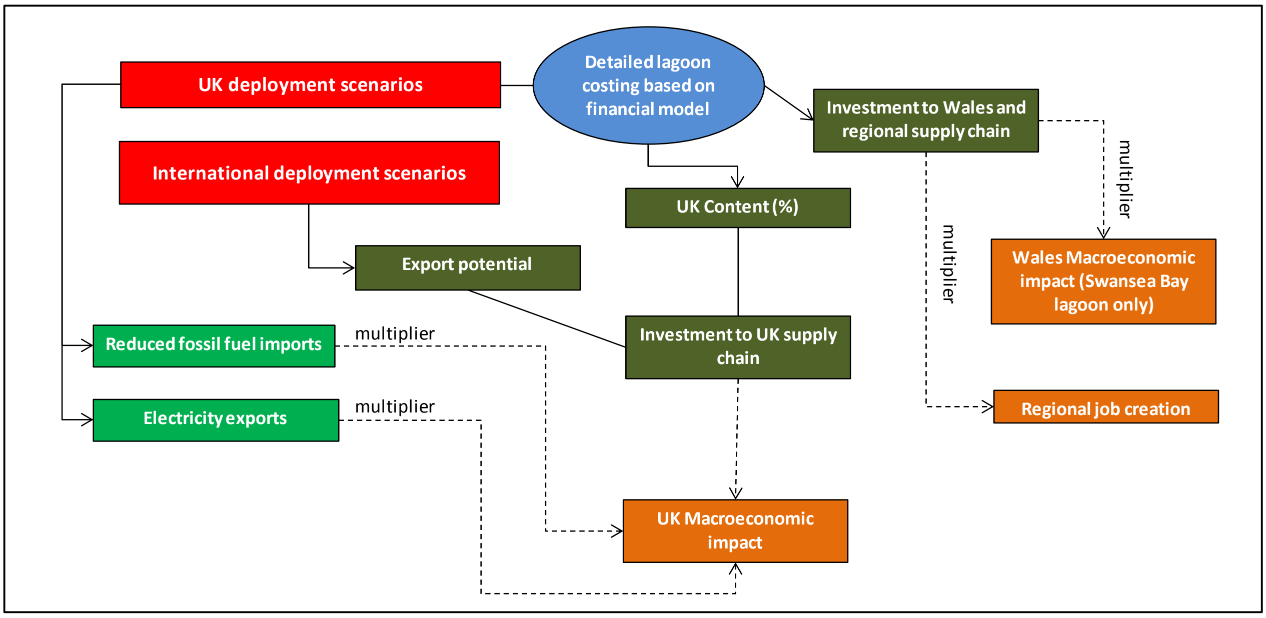
2 Methodology and assumptions

This chapter sets out the methods and assumptions used to determine an appropriate structure for a UK tidal lagoon industry. Section 2.1 presents the deployment scenarios for a series of planned UK lagoons located in the Severn Estuary, North Wales and the North West coast of England. Section 2.2 presents scenarios for international deployment of tidal lagoons. Section 2.3 describes the manner in which we embed the UK industry within the economic framework underlying Cebr's macroeconomic impact models. Section 2.4 outlines the methodologies on which these impact models are based.

2.1 Scenarios for development of a UK tidal lagoon industry

To model the overall macroeconomic impact of a tidal lagoon industry in the UK, Cebr constructed a bespoke tidal lagoon energy model with several parts. Detailed cost inputs on each lagoon along with estimates of energy generation and operational requirements were provided by TLP. These inputs were in turn fed into the tidal lagoon energy model constructed to produce annual data for each scenario and each stage of construction that could be analysed within Cebr's input-output models. A flow chart representing our broad modelling approach is provided in Figure 3.

Figure 3: Cebr tidal lagoon energy model



Source: Cebr

Domestic development scenarios

TLP is planning to construct six lagoons of varying size beginning in 2015, all of which are expected to be fully operational by 2027. For the purposes of providing a range of estimates dependent on the eventual size of the UK tidal lagoon industry, Cebr has developed a set of scenarios for domestic roll-out. Installed capacity and power output for each of these scenarios is summarised in Table 1.

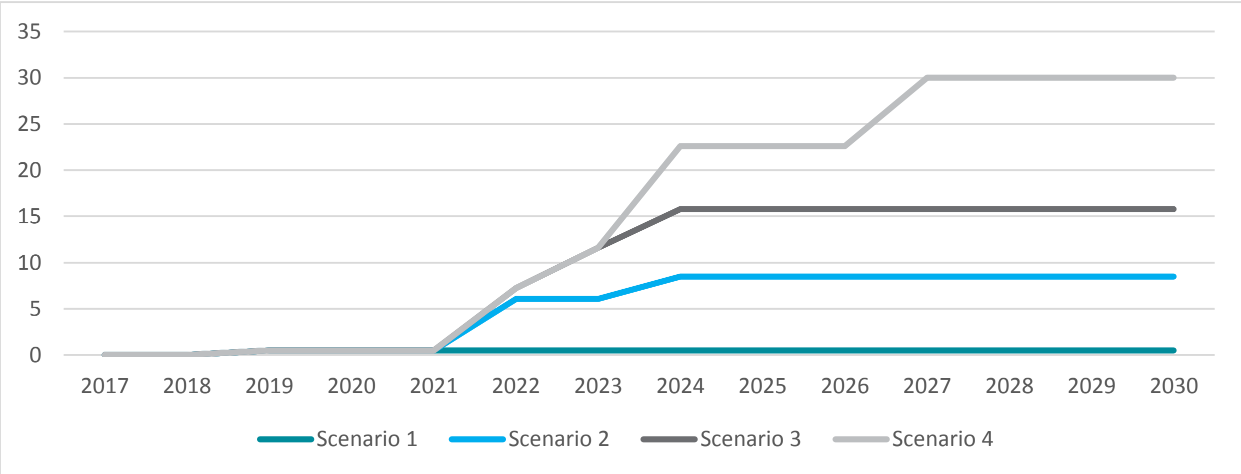
Table 1: Domestic development scenario summary

	Scenario name	Number of lagoons	Installed capacity (GW)	Power output (TwH)
Scenario 1	Swansea Bay only	1	0.3	0.5
Scenario 2	Low	3	5.1	8.5
Scenario 3	Mid	5	9.3	15.8
Scenario 4	Max	6	15.9	30.0

Source: Tidal Lagoon Power Ltd, Cebr analysis

Six fully operational lagoons will have a combined installed capacity of 15.9 GW. These lagoons would generate approximately 30 TWh of electricity per annum, equivalent to approximately 8% of UK electricity production when all lagoons are fully operational in 2027. The roll-out schedule, in terms of electricity output per deployment scenario, is presented in Figure 4.

Figure 4: Domestic lagoon roll-out scenarios, electricity output (TWh)



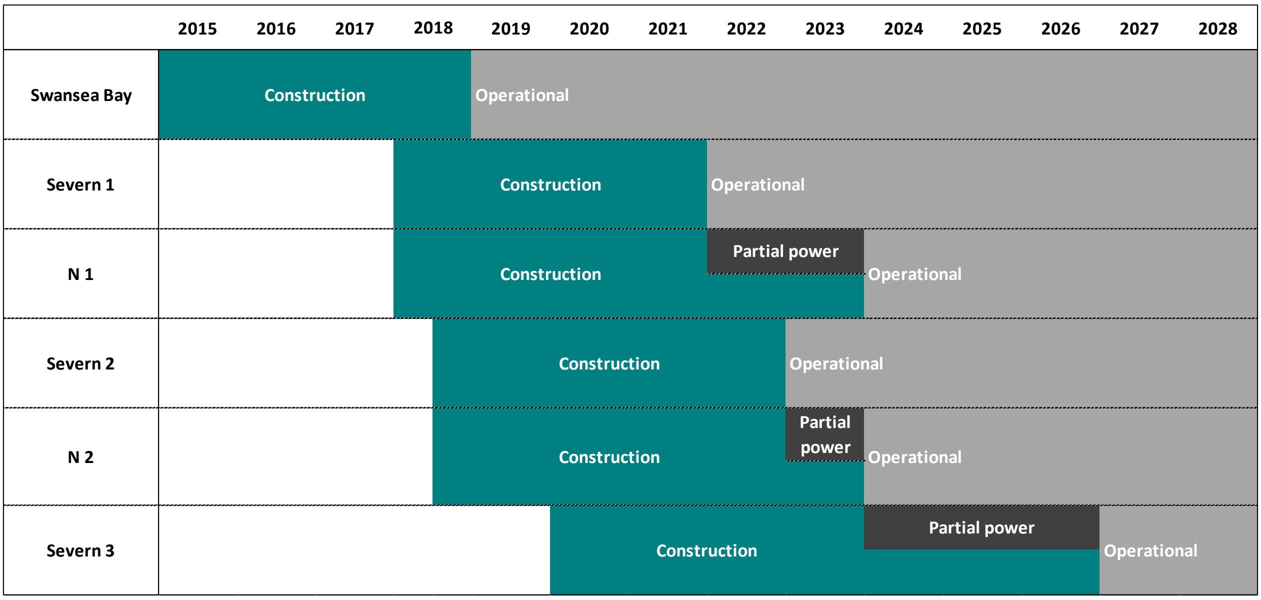
Source: TLP, Cebr analysis

Development timeframe

The development programme involves the construction of six lagoons – one lagoon at Swansea Bay, three further lagoons in the 'South' (Welsh and English waters in the Severn Estuary) and two further lagoons in the 'North' (North Wales and the North West of England). Each lagoon will involve a construction programme that lasts between 3 and 7 years depending on the scale of the lagoon. It is planned that the first lagoon in Swansea Bay would involve a construction period of approximately 3.5 years.

The optimal deployment pattern for lagoons involves developing a balance of geographically dispersed sites. Such a pattern takes advantage of the difference in timing of high and low tides along the west coast, allowing for more even power production from the six fully operational lagoons across a 24 hour period. The provisional development order of the specific 'North' and 'South' lagoon sites used in the energy model is subject to commercial sensitivity and therefore is not listed in this report. Figure 5 provides an indicative construction timetable for each proposed lagoon.

Figure 5: Indicative lagoon construction timetable



Source: Tidal Lagoon Power Ltd, Cebr analysis

UK and Wales content for tidal lagoon infrastructure investments

The extent to which the UK economy will benefit from the investment made in tidal lagoon power stations depends on the degree to which a supply chain of UK suppliers and contractors can be brought together to supply the industry. Tidal lagoon construction typically requires a high proportion of material that is locally sourced. This means that less of the investment required to build a tidal lagoon power station is spent on imported products – resulting in higher direct and multiplier effects for the UK compared to other renewable technologies. The aggregate UK content for the Swansea Bay lagoon is estimated at 71%. The development of further lagoons will coincide with an increase in the capacity of the tidal lagoon supply chain, which is expected to result in a further increase in UK content for later lagoons.

The Swansea Bay lagoon will be the first tidal lagoon developed in the UK and will involve a significant investment in the Wales economy. Efforts have been made by the developer to source local suppliers from within Wales – ensuring that the Welsh content of the project will be close to half of its total cost. A total of four lagoons will be built in Wales providing a significant contribution to the Welsh economy. The first lagoon at Swansea Bay is currently scheduled to source 48% of products and services for lagoon construction from within the Welsh economy.[15] Table 2 presents the proportion of expenditure at each development stage of the Swansea Bay lagoon that will go towards purchasing UK and Welsh products and services[16].

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[15] This is calculated based on information supplied by TLP on the identified preferred suppliers for Swansea Bay lagoon, the products and services they would supply, the location of suppliers and the value of these cost components.

[16] UK and Wales content estimates have been constructed from detailed information provided by preferred suppliers for the Swansea Bay lagoon.

Table 2: UK and Wales content by lagoon construction development stage, Swansea Bay lagoon

Development Stage	UK content	Wales content*
Preconstruction Costs	98%	54%
Bund	70%	49%
Turbine Area Mechanical & Engineering Works	59%	24%
Turbine Area Civil Engineering	93%	70%
Other Construction Costs	92%	77%
Public Realm	100%	100%
Other Costs	85%	34%
Total	**71%**	**48%**

Source: supplier estimates, Cebr analysis

** This is the percentage of total investment expenditure on products and services sourced in Wales*

Analysis of lagoon cost components

To determine the macroeconomic impact on the UK of tidal lagoon investment expenditure, it is necessary to determine the industry sectors to which this investment will flow. Cebr has utilised financial and cost data provided by TLP which contains detailed information on the cost of construction and operation of individual lagoons.

Each cost component of lagoon construction was mapped to the relevant production activities under the Standard Industrial Classification (SIC) system in the relevant year of construction for each lagoon. Annual production activities were in turn apportioned to their relevant development scenarios based on the construction schedules described in Figure 5 and the distribution of expenditure by cost component over each construction schedule. The major cost components for each development stage are listed in Table 3.

Table 3: Lagoon capex cost components by development stage and their related industry sectors

Development stage	Cost components	Related industry sectors
Pre-construction	Environmental Monitoring	Other Professional, Scientific and Technical services
	Detailed Design & Planning	Engineering Services for Design Testing
	Legal and Due Diligence	Real Estate services, Legal services, Accounting services
Bund	Public Realm & Surface Works	Construction
	Bund construction	Quarrying products, Textiles, Manufacture of cement, lime & plaster, Ships and boats
	Channel Realignment Works	Other mining and quarrying products, ships and boats
Turbine Area M&E Works	Start/stop gates	Fabricated Metal Products
	Sluice gates	Machinery and Equipment N.E.C.
	Gantry Crane	Machinery and Equipment N.E.C.
Turbine Area Civil Engineering	Cofferdam	Other Mining and Quarrying Products, Fabricated Metal Products, Construction

Development stage	Cost components	Related industry sectors
	Turbine Housing Construction	Manufacture of Cement, Construction, Fabricated Metal Products
	Wingwalls	Manufacture of Cement, Construction, Fabricated Metal Products
	Cofferdam Dredging	Ships and Boats
	Maintenance Island Construction	Manufacture of Cement, Lime and Plaster, Construction
Other Construction & Maintenance costs	Turbine Exclusion Zone Protection	Fabricated metal products, Rubber and plastic products, Construction
	Grid Connection	Electrical equipment, Electricity, Transmission and Distribution
	Storm water outfall mitigation	Sewerage Services
	Ground Preparation	Construction
Public Realm	O&M Critical Public Realm Works	Construction
	Visitor & other Amenity Buildings	Construction

Lagoons will incur annual maintenance and dredging costs as well as costs in the operation of the power station. This expenditure will stimulate productive activities that can also be mapped to their relevant production activities under the Standard Industrial Classification (SIC) system and apportioned to development scenarios. The cost components for annual operation and maintenance expenditure are listed in Table 4.

Table 4: Lagoon opex cost components and their relevant industry sectors

Development stage	Cost components	Related industry sectors
Operation & Maintenance	Turbine Maintenance	Machinery and Equipment, Electrical Equipment
	Sluice Gates Maintenance	Machinery and Equipment, Construction
	Bund Maintenance	Concrete, Quarrying Products, Construction
	Maintenance Dredging	Ships and Boats
	Insurance	Insurance Services
	Staffing Costs	Electricity, Transmission and Distribution
	Land Leasing	Financial Services
	Ongoing EIA Remedial Costs	Other professional, scientific and technical services
	Leisure/Community Facility Operational Costs	Sports and Recreation Services

Current estimates suggest that the Swansea Bay lagoon will require approximately 31 full time equivalent (FTE) staff. This will include roles in operations, security, maintenance and administration. These staff will be directly employed by the power station operator. Subsequent lagoons will be of larger size and will require between 5 and 10 additional staff, mainly in maintenance and engineering roles.

Approximately 50 staff (not employed by the operator) are expected be employed at each lagoon site in non-core activities. These activities include the operation of a visitor centre, mariculture activities (for example lobster hatcheries) and employment in public amenities specific to each site.

2.2 Electricity market scenarios

In this section, we present the assumptions used to develop scenarios for the future integration of tidal lagoon power into the GB electricity market.

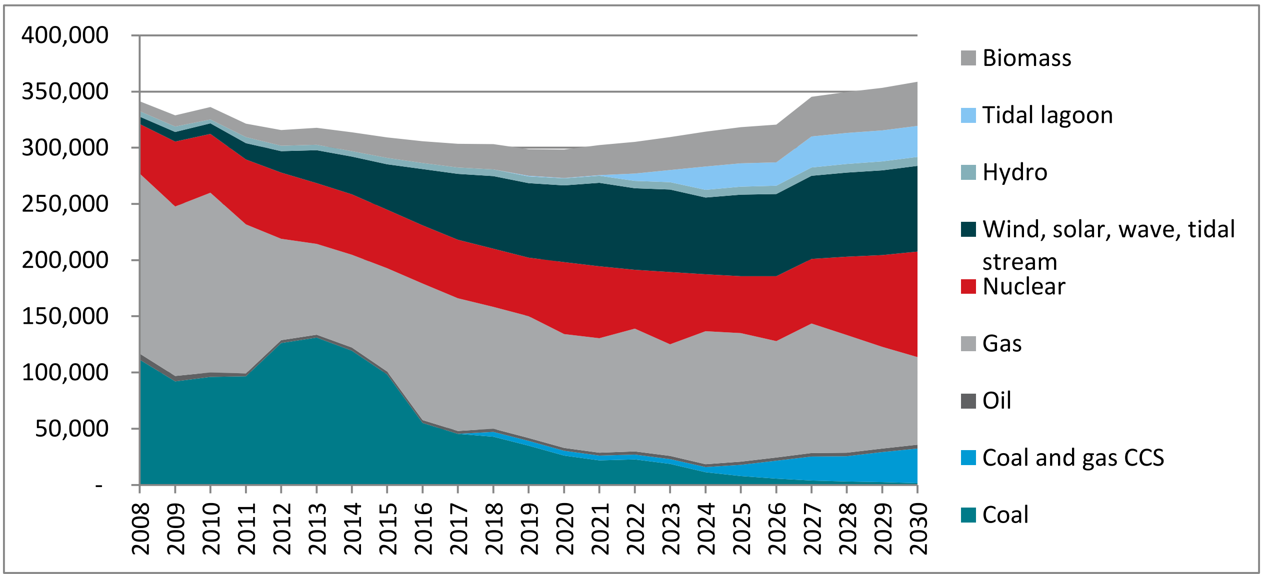
The future energy challenge

The UK faces a great deal of energy challenges over the medium term as existing fossil fuel and nuclear power plants close, North Sea gas and oil production dwindles and electricity demand grows after a long period of decline. The impending electricity supply shortage means that substantial new generating capacity will need to be built over the next 15 years.

The closure of all but one of the UK's 16 nuclear reactors by 2023 will leave an 8 GW shortfall that increases the urgency to develop replacement generating capacity. The nuclear industry plans to develop a new generation of reactors with approximately 16 GW of capacity. However, the first of these new plants is only expected to come on stream in 2023 at the earliest. This means that developing new renewable capacity along with new gas power stations has become a necessity given their relatively short development period. A projection of the future electricity generation mix including a full portfolio of six tidal lagoons is presented in Figure 6.

Our estimates suggest that as much as 14 GW of new generating capacity will be needed between 2015 and 2030 just to replace the overall reduction in fossil fuel power. A further 11GW of new capacity will be needed to meet rising demand. Tidal lagoon power can play an important role in meeting this impending need for new capacity and can also help to provide a more diversified low-carbon energy mix. Developing six lagoons would provide 15.9 GW of new installed capacity and 30 TWh of electricity per annum meeting circa 8% of the total electricity supplied in the UK in 2027.

Figure 6: Projected electricity generation mix, DECC reference scenario integrating tidal lagoon scenario 4, GWh



Source: DECC Updated Energy & Emissions Projections - September 2013, Cebr projections, TLP

Table 5 presents projections of the future generating mix embedding tidal lagoon within the most recent DECC projections.

Table 5: Projections of electricity generation mix (GWh), DECC reference scenario integrating tidal lagoon scenario 4

	2014	2020	2027
Coal	38.1%	8.7%	1.2%
Coal and gas CCS	0.0%	1.5%	6.2%
Oil	0.8%	0.9%	0.9%
Gas	26.3%	33.9%	33.5%
Nuclear	17.2%	21.5%	16.7%
Wind, solar, wave, tidal stream	10.7%	22.9%	21.5%
Hydro	1.6%	2.1%	2.2%
Tidal lagoon	0.0%	0.2%	8.0%
Biomass	5.3%	8.4%	10.2%

Source: DECC Updated Energy & Emissions Projections - September 2013, Cebr analysis, TLP

Electricity exports

Further integration of intermittent renewable technologies, such as wind and solar as well as less flexible nuclear and coal & gas CCS, may lead to a significant underutilisation of generation capacity at off-peak times and shortfalls at peak times. Without sufficient strategies to balance load and export surplus electricity at times of low domestic demand, these network inefficiencies could impose significant additional costs on electricity consumers. Further, the widespread deployment of renewable power will require the ability to export surplus electricity when supply exceeds domestic demand. This will necessitate the development of increased interconnector capacity to cope with these export and balancing requirements.

Great Britain already has electricity interconnections with France, The Netherlands, Northern Ireland[17] and the Republic of Ireland totalling 4,000 MW. These links have been important in recent years for balancing electricity supply and demand in the face of increasing supply constraints caused by the closure of ageing coal and oil power stations as well as a shift towards intermittent wind power.

In 2012, Great Britain imported 13,700 GWh of electricity representing 3.7% of energy supplied by the National Grid. Currently, imports far exceed exports of just 1,700 GWh in 2012. This balance is expected to change in the next decade as the share of renewable generation capacity continues to increase and the projected supply crunch begins to ease. This means that imports will continue to outweigh exports in the use of current interconnector capacity until at least 2023 when electricity exports are projected to occur in higher volumes.

In response to the projected increase in the need to import and export electricity, plans are in place to significantly expand Great Britain's interconnection capacity well beyond the current level. Planned new interconnectors could provide as much as 11.3 GW of additional interconnector capacity although not all the projects are expected to go ahead. The operational and planned interconnector projects are listed in Table 6 below.

[17] Although a part of the UK, the Northern Ireland power network is not integrated with the National Grid.

Table 6: Operational and planned electricity interconnectors, Great Britain

Country	Capacity (MW)	Commissioning date	Project name
France	2,000	operational	IFA
Netherlands	1,000	operational	BritNed
Ireland	500	operational	East West
Northern Ireland	500	operational	Moyle
France	500 - 1000	2016	ElecLink
France	2,000	2018	IFA 2
Belgium	1,000	2018	NEMO
Norway	1,400	2020	NSN
France	1,800	2020	FAB
Norway	1,400	2020	NorthConnect
Iceland	800 - 1200	After 2020	IceLink
Denmark	1,000	After 2020	-
Ireland	500	After 2020	East West Cable One

Source: National Grid, Cebr

Cebr has drawn its interconnector capacity projections from the National Grid 'UK Future Energy Scenarios' projections[18]. These are presented in Table 7.

Table 7: Projected GB interconnector capacity, UK National Grid 'Gone Green' scenario

	2014	2020	2030
Capacity (GW)	4,000	6,200	7,600

Source: National Grid

Utilising DECC's reference projections for future electricity demand and supply, National Grid Future Energy Scenario export forecasts as well as Cebr's analysis of how tidal lagoons would integrate into the future generating mix, Cebr has produced estimates of future electricity exports that could be achieved across each scenario.

Cebr projects a full portfolio of tidal lagoon power stations (6 lagoons, scenario 4) could export 14% annual electricity production or an estimated 4,300GWh per year by 2040, equivalent to 2.5 times the amount of total electricity exports in 2013. These projections are presented in Table 8.

[18] National Grid, 2013, 'UK Future Energy Scenarios 2013', National Grid. Available at: http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=10451

Table 8: Projected annual tidal lagoon electricity exports, by development scenario and year, GWh

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2020	5	5	5	5
2025	41	677	1,259	1,801
2030	65	1,073	1,995	3,787
2035	69	1,143	2,126	4,035
2040	74	1,224	2,277	4,322

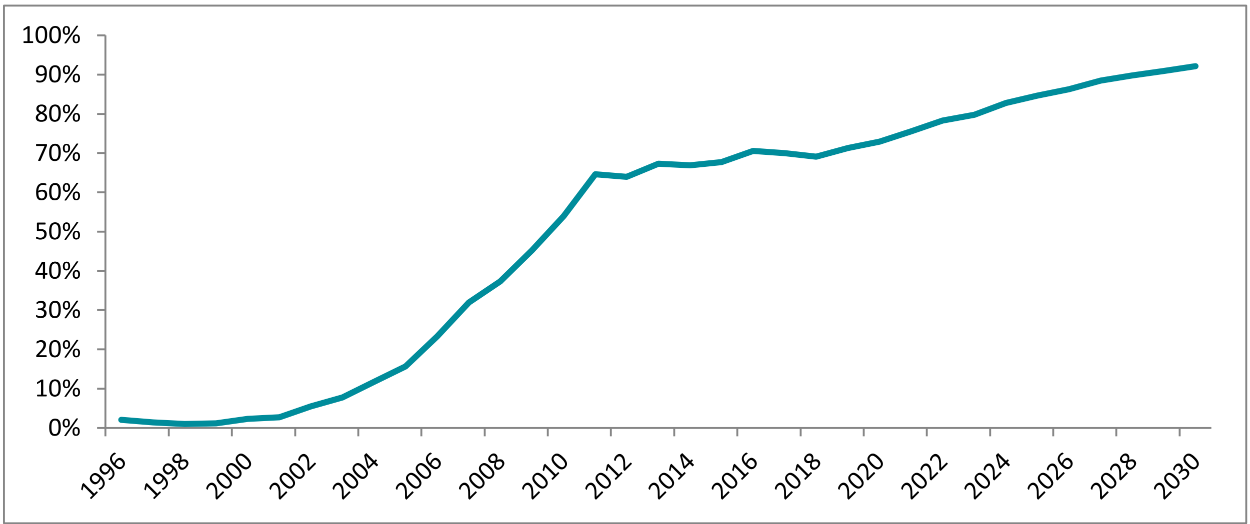
Source: TLP

Reduction in fossil fuel imports

Increasing the proportion of renewable electricity generation – which utilises domestically sourced energy – decreases the UK's dependence on fossil fuels such as coal, gas and oil. In 2013, 15% of domestic electricity production comes from renewable sources (tidal stream, wind, hydro, biomass and solar), with nuclear providing 17% of the total and the remainder (68%) being provided by fossil fuels (coal, gas and oil)[19].

Coal is the single largest generation source providing 41% of total electricity production. However, its contribution is expected to decline as some generating units at coal power stations such as Drax in Yorkshire are converted to biomass. Further, imports of coal have increased substantially in recent years – from 14% of total supply in 1990 to 70% in 2012 and this trend is expected to continue given the recent closure of a number of coal pits. This means that electricity generation from coal is heavily import dependent.

Figure 7: Historic and projected imports of natural gas, % of total supply



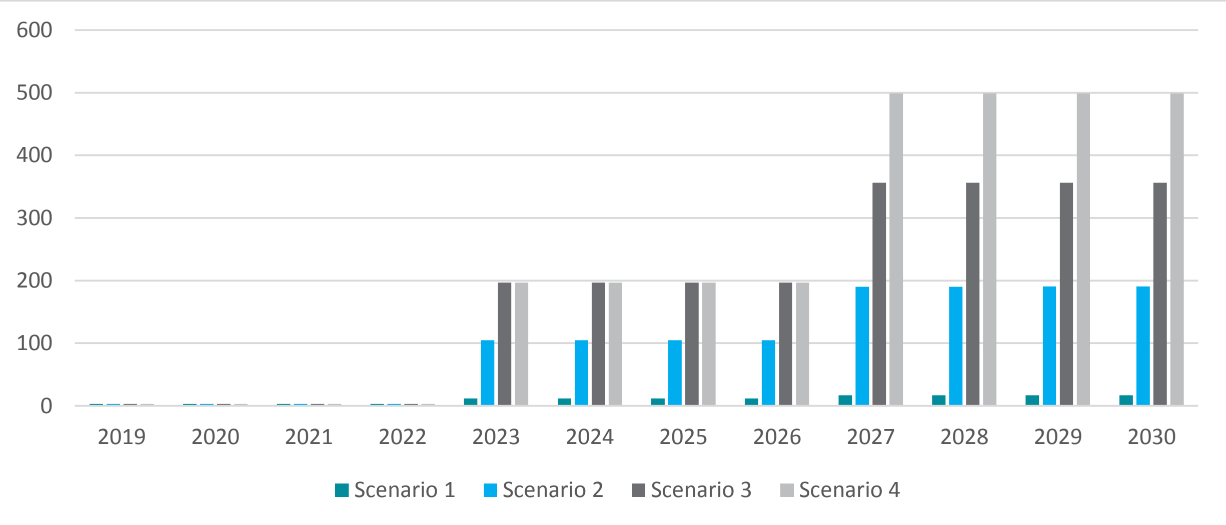
Source: DECC (historic), Cebr (forecasts)

[19] DECC, Digest of UK Energy Statistics (DUKES) 2013

In 2012 (the latest data available), the UK imported 64% of gas supplies from abroad. Without the development of alternative supplies (such as through shale gas), Cebr projects that the UK will be dependent on imports for 92% of gas supplies by 2030 (see Figure 7). A further issue is the lack of sufficient gas storage to fuel gas fired power stations during a long winter spell. Consequently, securing a domestic source of energy used for electricity production – such as tidal power – is vital for ensuring the UK's future energy security.

Based on projections of future coal and gas imports and tidal lagoons share of the displacement of fossil fuel power production, Cebr has developed projections of the cumulative reduction in fossil fuel requirements associated with tidal lagoon power generation. Projections in terms of the wholesale value of displaced coal and gas between 2020 and 2030, are presented in Figure 8.

Figure 8: Cumulative wholesale value of displaced coal & gas imports, £m, 2014 prices, 2019 – 2030



Source: DECC, Cebr analysis

2.3 International tidal lagoon industry scenarios

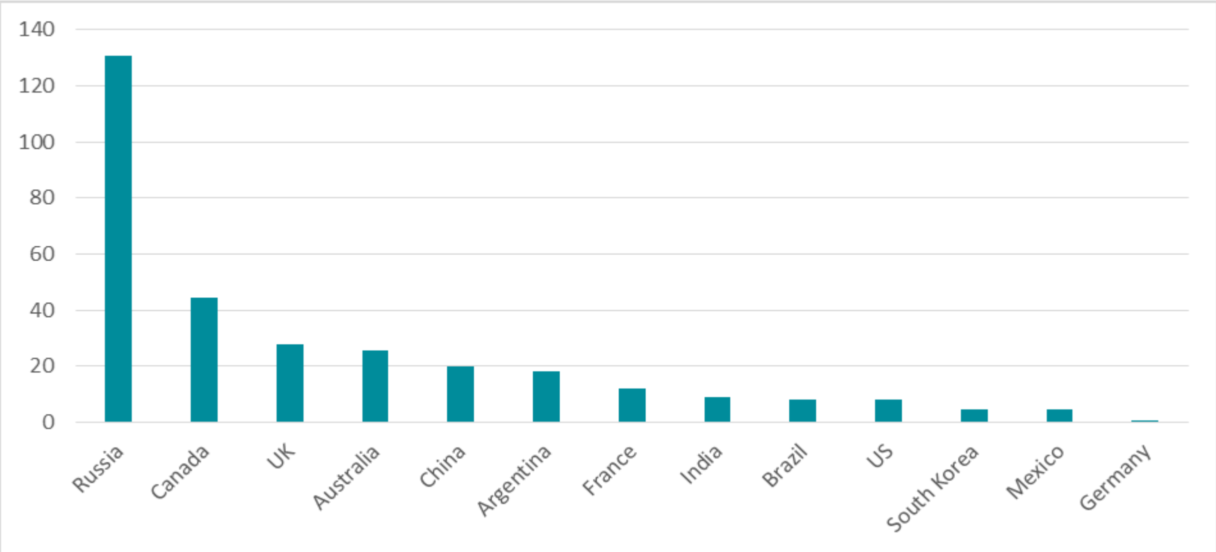
Export potential of tidal lagoon products and expertise

The UK tidal lagoon supply chain also has the potential to benefit from the development of tidal lagoons in other countries through export of products and services that have been developed for the UK tidal lagoon industry. A small number of tidal range projects are in operation around the world. Most notable examples include Sihwa Lake (254 MW) in South Korea and La Rance in France (240 MW). However, the tidal barrage designs used in these projects have disadvantages relative to tidal lagoon designs in terms of environmental impact and cost of deployment. Therefore, it is reasonable to assume that a large share of future tidal range deployment will use tidal lagoon designs. The UK tidal lagoon supply chain being the first to implement the technology on a large-scale basis will be well placed to benefit from international development of tidal lagoon power plants.

Academic studies have identified tidal range sites around the world that have a combined potential installed capacity of 313 GW[20]. This provides an indicative but incomplete assessment of global tidal range sites with development potential. It is unlikely that many of the identified sites would be developed. For example, although Russia has the largest potential resource at 131 GW, all of these sites are located within the Arctic Circle. Without proximity to large population centres or industrial customers that can use the electricity, the sites are feasible only in theory.

In contrast to Russia, most of Canada's proposed tidal range sites are located near large population centres and therefore have better potential for commercial development. In the UK, there have been numerous schemes proposed – many of which involve tidal barrage designs – amounting to 28 GW[21]. Details on proposed tidal range sites by country are presented in Figure 9.

Figure 9: Proposed tidal range sites by country, GW



Source: Bernshtein (1996), Baker (1991), Clark (2007), Cebr analysis

To date, no studies have been carried out to estimate the value of sites around the world with commercial development potential. For this reason, Cebr has carried out an analysis that attributes a development potential score to each of the identified tidal range sites with the goal of providing an estimate of the value of a potential pipeline of projects around the world. On this basis, we estimate that, at present, the capacity of the international tidal lagoon sites with the potential for commercial development amounts to 80 GW. Using the cost per GW of the planned UK lagoons, the global pipeline of tidal range projects is estimated to be worth as much as £383 billion.

Further to this analysis, the cost components of a typical lagoon have been considered in terms of their UK content and the exportability of that content. Based on information from the developers and preferred

[20] An analysis was carried out to compile the potential installed capacity at sites previously identified by these academic studies. These include Bernshtein (1996), Baker (1991), and Clark (2007). Information on further identified sites which have been proposed since these studies were published were incorporated within the analysis.

[21] This estimate does not represent an assessment of the total UK tidal range resource but simply refers to sites that have been previously identified.

suppliers for the UK lagoons, estimates have been made on the exportable content within each lagoon. Scenarios on UK exportable content ranges from 16% to 25%[22]. This is dependent on assumptions made about how the UK content share of international projects would grow up to 2050. This implies total potential UK exportable content ranging from £57.1 billion to £70 billion. Assuming international tidal lagoon development over a 20 year timeframe (2030 - 2050), this could amount to annual exports of between £2.8 billion and £3.7 billion by the end of the period. To put this in context, the UK construction industry exported just £1.5 bn in 2012. These scenarios are presented in Table 9.

Table 9: Exportable UK content, 2014 prices, 2050

	Low	Medium	High
UK content (%)	16%	20%	25%
UK exportable content 2030 to 2050 (£bn)	57.1	63.4	70.0

Source: Cebr analysis

2.4 Embedding tidal lagoon investments within an economic impacts framework

This section describes the manner in which we have embedded the tidal lagoon industry within the economic framework underlying Cebr's macroeconomic impact models.

To formulate a working definition of the tidal lagoon industry that was relevant for the study, we used as our guide the structure of the economy on which the UK Office for National Statistics (ONS) bases its system of national accounts. Products and services, as well as economic activities are broken down according to Standard Industrial Classifications (SIC), the most recent being SIC 2007. This approach facilitates the estimation of the size and economic impact of the UK tidal lagoon industry within the framework of the ONS' supply-and-use tables, the most detailed official record of how sectors of the economy interact with one another, consumers and international markets in producing the nation's GDP and national income.

We analysed tidal lagoons by adapting these tables to assign the industry a role within them. This involved the reassignment of elements of other industries to the newly created UK tidal lagoon industry, and re-mapping the relationships between the group of subsets of industries that constitute the whole with the industries and sectors that make up the rest of the economy.

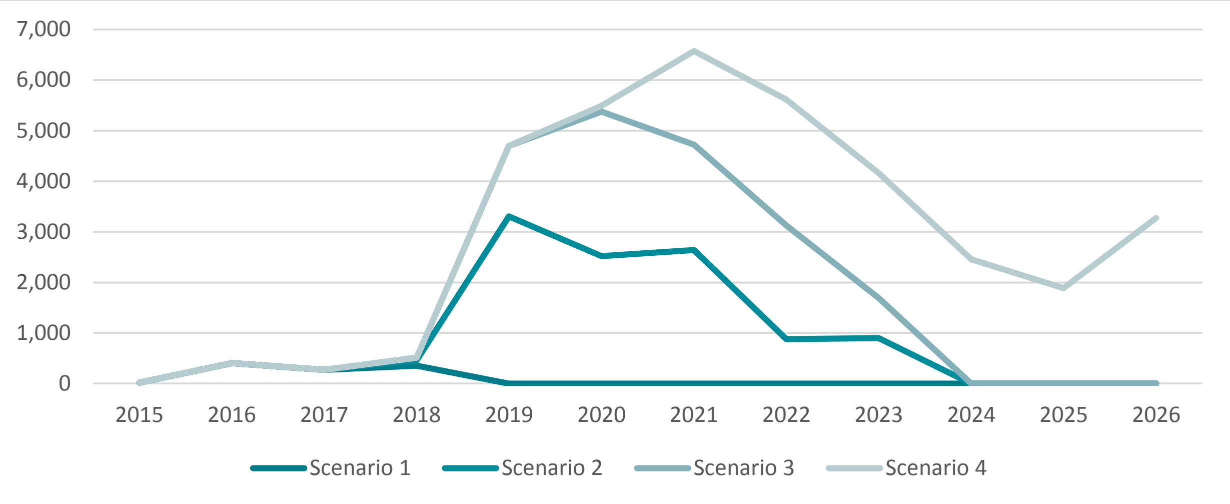
Baseline final demand stimuli – construction phase

The construction of six tidal lagoons over a 12 year timeframe will involve an overall investment of £35.3 billion (2014 prices)[23]. The expenditure profile over the construction programme for each of the four development scenarios are presented in Figure 10.

[22] Our UK supply chain export projections assume turbines are manufactured outside the UK. Given that turbines represent circa 25% of the cost of a tidal lagoon power plant, UK manufacturing of turbines would substantially increase the exportable content share of international lagoons well beyond what is presented here.

[23] Grant funding estimates for individual lagoons have been excluded from all calculations presented within this report.

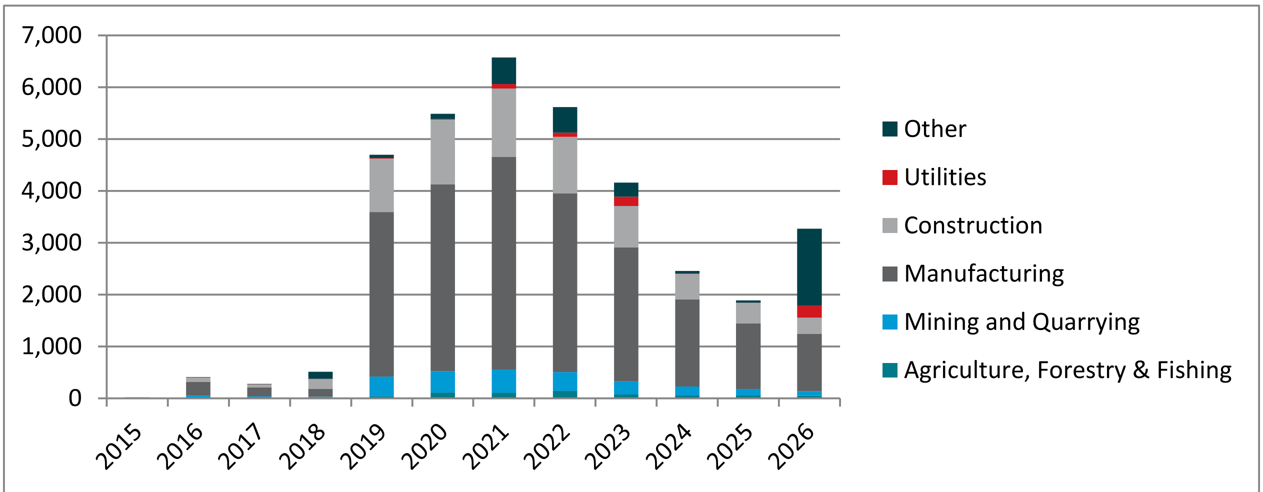
Figure 10: Tidal lagoon capital expenditure programme, £m, 2014 prices



Source: Cebr analysis

The investment in the construction of tidal lagoons creates a final demand stimulus for the products and services required to realise that investment. These products and services are purchased from both UK based and foreign suppliers. The expenditure profile for scenario 4 (6 lagoons) is shown below in Figure 11 where they are categorised by broad industry group and presented for each year of construction expenditure. Manufacturing represents the largest supplier industry with 62% of expenditure during the year of maximum output followed by the construction industry with 20% of the total. A significant share of this expenditure relates to the purchase of turbines.

Figure 11: Final demand stimuli from tidal lagoon construction, by broad product group, scenario 4, 2014 prices, £m



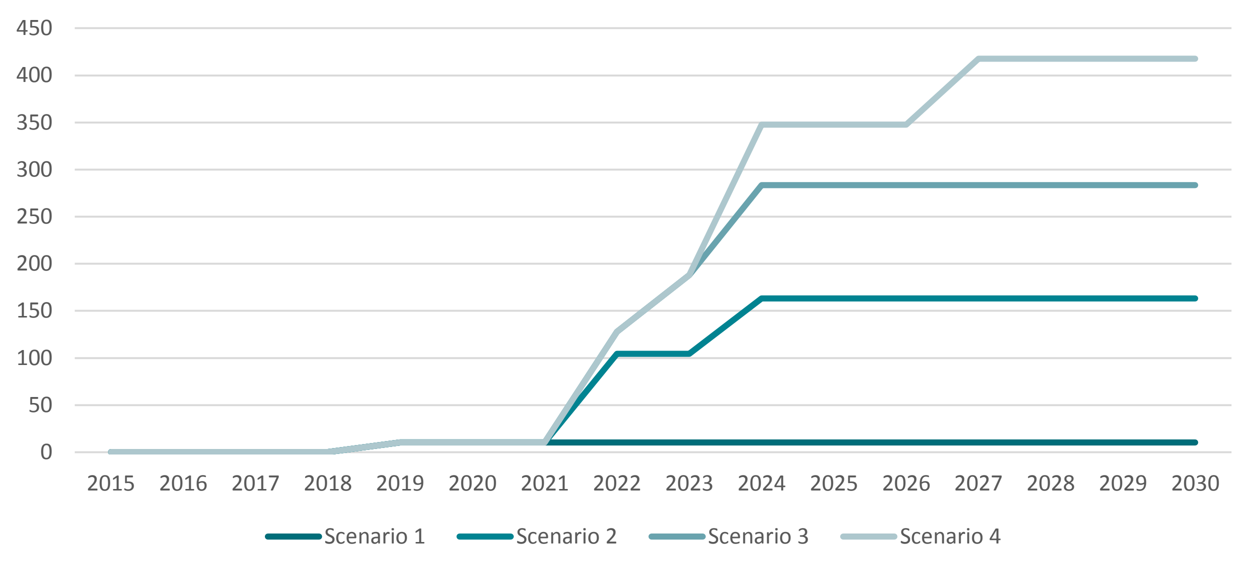
Source: Cebr analysis

Baseline final demand stimuli – operational phase

Once the tidal lagoon power plants are constructed, their operation creates a final demand stimulus for a different (more limited) set of products and services. Based on the methods outlined in sections 2.1 and

2.2 and detailed data on the operation cost profile of planned lagoons, we established the profiles of annual operating expenditures associated with an operational tidal lagoon industry. These are presented in Figure 12.

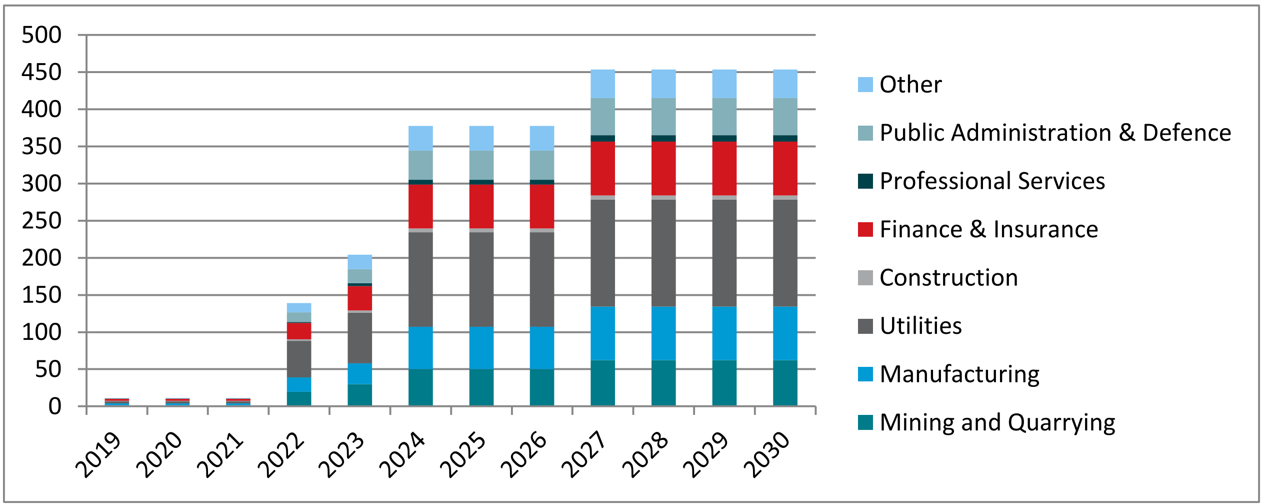
Figure 12: Tidal lagoon annual operational expenditure, 2015 – 2030, £m, 2014 prices



Source: Cebr analysis

Figure 13 presents the operational expenditure profile breakdown by broad product group when lagoons become fully operational. The largest share of expenditure will accrue to the utilities sector. This spending includes the cost of operating lagoons, staff costs as well as electricity network access charges.

Figure 13: Final demand stimuli from tidal lagoon operation, by broad product group, scenario 4, 2014 prices, £m



Source: Cebr analysis

Domestic production and intermediate demand responses and completion of the embedding process

Having established the share of UK tidal lagoon construction and operation that is met through domestic production – by subtracting imports from overall expenditure – we used the inter-industry relationships in the combined use matrix of the supply-and-use tables to map the intermediate demand responses of the industries that produce the products and services required to deliver, operate and maintain tidal lagoon power stations.[24]

Aggregating the tidal lagoon expenditure data across the specific product and service categories and the corresponding SIC-based industries provided what was required to **adapt the supply-and-use tables by assigning the newly created UK tidal lagoon 'industry' an explicit role within them**.

These adapted supply-use tables provided the basis for estimating the size of the direct economic contributions that this industry can be expected to make as tidal lagoons are constructed and commissioned. By linking our supply-and-use (and input-output) models to the scenario capability of our bespoke tidal lagoon energy model, we were able to assess how these economic contributions could be expected to change over time and under the four different development scenarios.

Embedding effects of the rollout of tidal lagoons on other industries

In section 2.2 above, we developed estimates of the reductions in fossil fuel imports and electricity exports that can be expected to result from the deployment of tidal lagoon power stations. The magnitudes involved, according to our estimates, are those shown in Table 10 below.

Table 10: Impact of tidal lagoon investment on fossil fuel imports and electricity exports, 2014 prices, £m

	Year	Cumulative Reduction in Fossil Fuel Imports, value of coal & gas displaced	Electricity Exports
Scenario 1	2020	3	0
	2025	12	3
	2030	17	5
	2040	17	5
Scenario 2	2020	3	0
	2025	105	49
	2030	190	80
	2040	190	79
Scenario 3	2020	3	0
	2025	197	92

[24] We made the simplifying assumption that all products and services required for tidal lagoon construction and operation are produced by the corresponding industry in the SIC classification system. The SIC system is used to classify product and service categories and producing industries using the same coding system. However, not all of a product or service category is necessarily produced by the corresponding industry and not necessarily all of an industry will be dedicated to the production of the corresponding product or service category. (Note we use 'product category' and 'product or service category' interchangeably throughout the report.)

	Year	Cumulative Reduction in Fossil Fuel Imports, value of coal & gas displaced	Electricity Exports
	2030	356	149
	2040	356	147
Scenario 4	2020	3	0
	2025	197	131
	2030	499	284
	2040	499	279

Source: Cebr analysis

2.5 Input-output modelling and alternative multiplier concepts

Having assigned a role for the industry that will grow to provide for tidal lagoon power plant construction and operation within the supply-use framework, we had the foundation for establishing the size of the economic contributions made by this industry under each of our scenarios and over time. We estimate these contributions using standard metrics relating to gross value added (GVA) and percentage contribution to UK GDP; absolute and percentage shares of UK employment.

To measure broader economic contributions that can be expected to occur through the multiplier process, we used the approaches of a number of well-known authorities in the area. The appropriateness of these alternatives depends on how the prevailing macroeconomic circumstances and policies are to be interpreted. The alternative approaches and the relevant economic circumstances are outlined as follows.

Leontief matrix multipliers for the domestic economy

Multipliers show the ratio of an induced change in national income to an initial change in the level of final demand spending, where the multiplier effect denotes the phenomenon whereby some initial increase (or decrease) in the rate of spending will bring about a more than proportionate increase (or decrease) in national income. The Keynesian approach barely requires a mention but is very much grounded in macroeconomic analysis, offering little capability to analyse impacts of entities that are smaller than the whole economy.

Input-output analysis, due largely to the work of Wassily Leontief, while macroeconomic in the sense that it involves analysing the economy as a whole, owes its foundations and techniques to the microeconomic analysis of production and consumption. According to ten Raa (2005), some people argue that input-output analysis is at the interface of both, defining it as the study of industries or sectors of the economy.

The well-known Leontief inverse matrix, which shows the inter-industry dependencies of an economy, is the basis for producing so-called 'ordinary' (or traditional) input-output multipliers. These are some of the most important tools for measuring the total impact on output, employment and income when there is a change in final demand.

The Leontief inverse matrix can also be described as the output requirements matrix for final demand, that is, it shows the input requirements from the other sectors of the economy per unit of output produced in the sector under examination in response to a final demand stimulus. The matrix can be used to produce two types of multiplier – the Type I multiplier incorporating direct and indirect (supply chain) impacts and the Type II multiplier incorporating induced (through higher incomes and resulting greater consumption) impacts as well.

Cebr's baseline multiplier model is based on this Leontief input-output modelling approach. The model is, however, based on a so-called 'domestic use' table, from which imports are extracted from intermediate demands in order to focus on the domestic economy impacts of final demand stimuli. However, in given sets of circumstances, this will not tell the full story. The current economic circumstances suggest that it is appropriate to explicitly incorporate international trade in our analysis, through the calculation of foreign trade multipliers. We explain why in the following paragraphs.

Foreign trade multipliers

A foreign trade multiplier (FTM) shows the ratio of an induced change in national income to an initial change in the amount of exports. The required models build on Cebr's existing 'domestic' input-output models. The relevant issues are briefly discussed later. First we explain why foreign trade multipliers – normally associated with fixed exchange rate regimes – to which the UK has not been officially subject since its exit from the ERM on "Black Wednesday" in 1992 – are a relevant consideration again, and particularly for this study.

Motivation for using FTMs

The UK – and much of the Western World - is going through a major competitive challenge as two-thirds of the world industrialises rapidly, while still working hours and paying themselves wages based on their history as poor countries. This implies very low unit labour costs, particularly in light of their productivity potential. Meanwhile, the growing demands from these newly industrialising economies are placing a strain on the balance between supply and demand for primary products, raising and sustaining higher commodity prices and, thus, raising the cost base – in production and consumption - of already struggling Western economies.

The newly industrialising nations have, therefore, turned the terms of trade dramatically against the UK and the other countries being challenged. While the evidence suggests that this is some sort of disequilibrium, it could easily persist for at least a generation (20-30 years) and possibly twice that. Singapore, for instance, has had a higher GDP per capita than the UK on and off since the late 1990s (pre-Asian crisis) yet the latest 2010 data from the U.S. Bureau of Labour Statistics still shows that hourly compensation in manufacturing in Singapore is still only 55% of the UK level and progress in narrowing the gap is surprisingly slow – the percentage was 52.7% in 1997.

Countries facing this competitive challenge could, in theory, devalue themselves into eventual prosperity (using their currencies) but there is an inflation constraint that means that this is not possible in practice. Any devaluation at sufficient speed to enable the declining economy to achieve what would previously have been thought of as a state of full employment (or a non-accelerating inflation rate of unemployment) would, particularly when the terms of trade are being turned against the declining economy, lead to excess inflation and a risk of inflation becoming embedded.

Therefore, for the UK, the Bank of England's inflation target effectively acts as a lower bound on the value of the Pound, limiting any scope for currency devaluation. The (previously successful) UK economy is forced to either cope with long term underutilisation of resources or adjust in a way that results in lower labour costs, whilst also improving the supply curve of labour. Without action of this kind, medium to long term underutilisation of resources is highly likely for an uncompetitive economy. The amount of capital stock in the system might decay to the point where it is no longer in surplus and human skills and abilities are bound to degenerate as a result of persistent long term unemployment.

The implication is that economic growth in Western economies is likely to be depressed as they adjust to the competitive challenge placed on them by newly emerging economies like China. The impact of this on growth is likely to be most keenly felt in countries, like many in Europe, with rigid labour markets and high labour costs, particularly where these are combined with high taxes.

The current economic circumstances and the challenges facing the UK and most of Europe highlight the importance of taking actions that will turn the terms of trade back in their favour in order to improve their trade balance (net exports). Such actions are acting directly on the factor that is constraining growth and consequently can be expected to have particularly important multiplier effects.

This provided the motivation for undertaking a foreign trade multiplier analysis of the impact of increasing levels of investment in the construction of tidal lagoons and export of expertise and components. It is Cebr's contention that, given the aforementioned positive impacts on the UK's balance of trade, these significant multiplier impacts can be expected to derive from investment in tidal lagoons.

Methods used to calculate FTMs

We noted above the limitations of the Keynesian approach in terms of the ability to work at the sector level, while Miazawa (1960) points to defects in the treatment of imported intermediate goods which casts doubt over the usefulness of the approach for FTM analysis.

The author also points to the limitations of the standard Leontief matrix multiplier approach relative to FTMs. The Leontief approach is devoted entirely to the analysis of intermediate products in the circular flow and, unlike the Keynesian model, lacks analysis of the multiplier process via the consumption function. Formally, he notes, the Leontief system can regard the household sector as an industry whose output is labour for which they receive compensation and whose inputs are consumption goods. But, according to Miazawa, the correct procedure for dealing with consumption is not to regard it as a fictional production activity, but to incorporate the Keynesian consumption function in its disaggregated form.

While the Keynesian approach to the foreign trade multiplier takes account of imports of intermediate goods required for the production of consumption goods, the entire propagation (multiplier) process is projected into the income-spending or expenditure aspect only, with no explicit distinction between leakage (through imports) in the expenditure process and in the production process. Meanwhile, the Leontief matrix approach, in regarding the household sector as an industry just like the other 'actual' industries, assumes that households' input-output ratios are constant. But, Miazawa notes, consumers are not a technologically determined production process, but choice-making organisms and the factors of choice-making (that is, the consumption coefficients) are not as stable as the input coefficients for the standard industries.

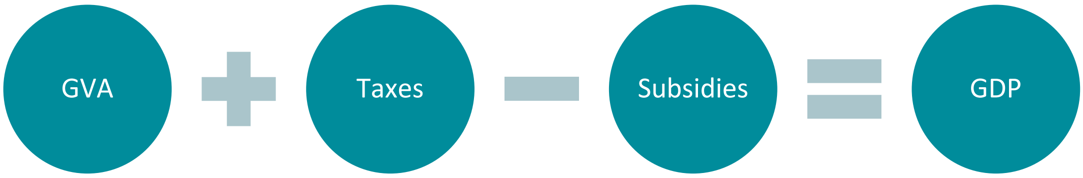
In Miazawa's foreign trade multiplier, the import of intermediate goods is taken into account at the proper place, namely, in the circular flow of intermediate products. His formula consists of the Leontief FTM inverse matrix and an inverse matrix showing the effects of endogenous changes in the consumption demand of the household sector. This can be interpreted as the multiplier combining Leontief's production-based propagation process and the Keynesian consumption-based propagation process. This, in turn, overcomes the difficulties with using either the Keynesian approach or the Leontief approach in isolation.

3 A UK tidal lagoon industry: size, economic contribution and impacts

This chapter presents the results of our analysis on the impact on the UK economy of a fully operational tidal lagoon industry.

Results are presented in terms of the gross value added (GVA) generated from the construction and operation of the lagoons. Gross value added[25] is calculated by subtracting intermediate consumption – the goods and services used in production – from the total output of an industry. This gives us a measure of the additional value that is created within the economy from the output of an industry that can be measured by Cebr's bespoke input-output models. A simplification of the relationship between GVA and GDP is presented in Figure 14.

Figure 14: Relationship between GVA and GDP



GVA generated from the construction and operational activities of the industry will also support employment throughout the UK and generate taxes on the purchase of products and services and on the output of the power stations, all of which can be measured by Cebr's bespoke input-output models.

A tidal lagoon industry will also be of sufficient scale to have balance of trade impacts. Exports of electricity, reduction in the need to import fossil fuels along with imports and exports of goods and services for the tidal lagoon industry will all have impacts on the balance of trade. Cebr's foreign trade (FT) input-output model was used to account for the contribution to UK GVA and employment arising from the easing of the balance of payments constraint to which we suspect the UK is subject (at least to some extent). These impacts are not captured in traditional domestic input-output models.

[25] GVA or gross value added is a measure of the value from production in the national accounts and can be thought of as the value of industrial output less intermediate consumption. That is, the value of what is produced *less* the value of the intermediate goods and services used as inputs to produce it. GVA is also commonly known as income from production and is distributed in three directions – to employees, to shareholders and to government. GVA is linked as a measurement to GDP – both being a measure of economic output. That relationship is (GVA + Taxes on products - Subsidies on products = GDP). Because taxes and subsidies on individual product categories are only available at the whole economy level (rather than at the sectoral or regional level), GVA tends to be used for measuring things like gross regional domestic product and other measures of economic output of entities that are smaller than the whole economy, such as either the wider or 'traditional' construction sector. GVA must be distinguished from turnover measures, which capture the entire value of sales. By contrast, GVA captures the value added to a set of inputs by a firm on their journey from raw materials to finished consumer products. Thus the value added of a firm that uses oil imports to make plastics is equal to the price that it sells the plastic for minus the cost of the oil it uses as inputs. Similarly the value added of a manufacturer that uses that plastic to make a bus shelter is equal to the price that it sells the bus shelter for minus the cost of the plastic it uses as an input. The concept of added value enables the avoidance of double counting when estimating the size of an economy.

This chapter is divided into a number of sections: section 3.1 considers the contribution of the Swansea Bay lagoon to the Welsh economy, sections 3.2 and 3.3 consider the impact of a tidal lagoon industry on UK GDP and employment respectively and section 3.4 presents the potential impact of a tidal lagoon industry on the UK balance of trade.

3.1 Contribution of the Swansea Bay Lagoon to the Wales economy

The first tidal lagoon to be built in the UK will be located at Swansea Bay and will involve an investment of £1,046 million (2014 prices). Close to half of this investment will be retained within the Welsh economy with Wales-based companies heavily involved in construction of the lagoon. This is expected to have a significant impact on the Wales economy – which can be measured using a regional input-output model. This section specifically focusses on the economic benefits of the construction and operation of the Swansea Bay lagoon on GVA and employment within the Welsh economy.

GVA and employment impacts during construction phase

It is estimated that the overall impact on annual Welsh GVA from construction of Swansea Bay tidal lagoon could amount to £316 million during the construction programme. This would result in an estimated boost to Welsh GVA ranging from 0.02% to 0.23% over the construction period.

The construction programme will also generate significant number of jobs in Wales, not just in employment on site but also from purchases of goods and services from Welsh based companies. This will amount to approximately 1,900 jobs at the height of the construction programme. A summary of construction GVA and employment impact from the Swansea Bay lagoon on the Welsh economy are presented in Table 11.

Table 11: Summary of GVA and employment impacts of construction of Swansea Bay tidal lagoon on the Welsh economy, 2014 prices

Metric	Unit	2015	2016	2017	2018	Total
GVA	£m	9	124	84	99	316
Employment	Jobs (FTE)	191	1,922	1,305	1,584	
% Contribution to Welsh GVA	£m	0.02%	0.21%	0.14%	0.17%	

Source: Cebr analysis

GVA and employment impacts during lagoon operation

It is estimated that the annual overall impact on Welsh GVA of the Swansea Bay tidal lagoon during operation could amount to approximately £76 million per year (2014 prices) over the 120 year design lifespan of the power station. This would result in an estimated annual boost to Welsh GVA of 0.14%.

Annual operation of the tidal lagoon will also generate direct, indirect and induced jobs for the Welsh economy. This would amount to approximately 181 full-time equivalent (FTE) jobs each year. A summary of construction GVA and employment impact from operation of the Swansea Bay lagoon on the Welsh economy are presented in Table 12.

Table 12: Summary of GVA and employment impacts from operation of the Swansea Bay tidal lagoon on the Welsh economy, 2014 prices

Metric		2020
Employment	Jobs (FTE)	181
GVA	£m	76
% Contribution to Welsh GVA	% of Welsh GVA	0.14%

Source: Cebr analysis

3.2 Contribution of a tidal lagoon industry to UK GDP

The operational and construction phases of the lagoons will generate direct economic impacts through an increase in demand for goods and services. Expenditure in these goods and services will also generate indirect economic impacts – the stimulus to demand through direct suppliers will increase demand throughout the supply chain. The direct and indirect multiplier effects on UK GDP are presented in this section. In addition, alternative foreign trade GVA and employment multipliers which incorporate multiplier effects in addition to balance of trade effects are presented for the construction and operational phases.

GDP impacts during construction phase

Under scenario 4, in which all six lagoons are built, it is estimated that the overall impact on annual GVA from construction of tidal lagoons could reach £4.3 billion by 2021 at the height of the construction programme. This would result in an estimated 0.25% boost to GDP during the most active year of the construction programme. Under scenario 4, it is estimated that the construction programme in total would contribute a total of £27.1 billion to UK GDP. These results are presented in Table 13.

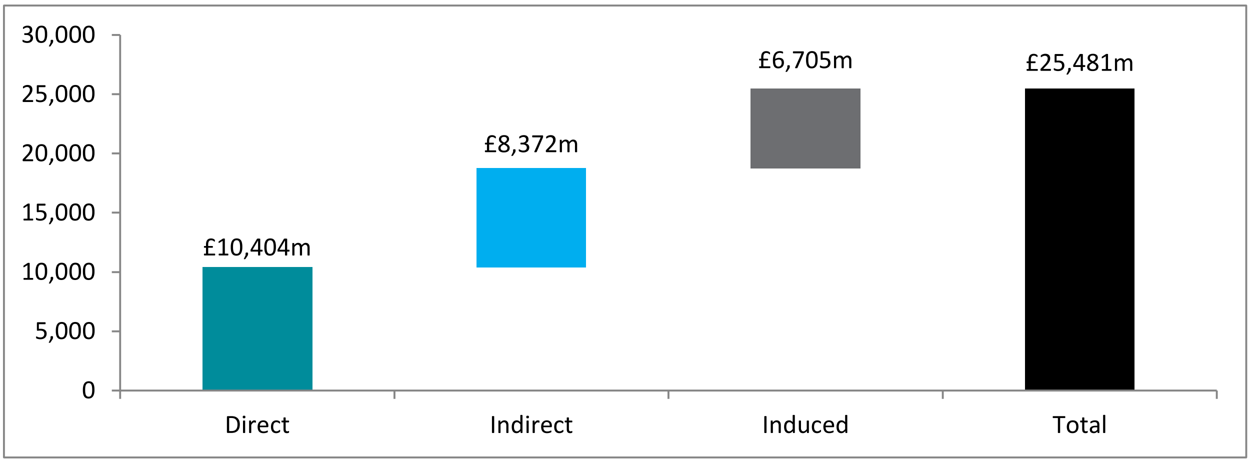
Depending on the year and scenario, the domestic GVA multiplier (Leontief matrix approach) during the construction phase ranges from 2.16 to 2.52. This multiplier can be interpreted as follows: for every £1 of GVA generated directly by producers of the products and services required for tidal lagoon construction, an additional £1.16 to £1.52 of GVA is generated in the wider economy through indirect and induced impacts. The direct, indirect and induced impacts on GVA are decomposed in Figure 15.

Table 13: Summary table of economic contributions and impacts of investment in tidal lagoon construction, 2014 prices

		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Direct impacts					
Direct GVA	£m	326	3,315	6,020	10,404
Taxes less subsidies (on products) - direct	£m	21	210	381	660
Direct contribution to GDP	**£m**	346	3,525	6,402	11,064
Direct + multiplier impacts					
Domestic GVA multiplier (max output year of construction)		2.51	2.54	2.53	2.53
Aggregate GVA impact (domestic multiplier)	£m	788	8,206	14,898	25,481
Taxes less subsidies (domestic multiplier)	£m	50	519	943	1,615
Aggregate contribution to GDP (domestic multiplier)	**£m**	**837**	**8,725**	**15,841**	**27,096**
Direct + multiplier impacts including balance of trade effects					
FT GVA multiplier (max output year of construction)		3.56	3.56	3.56	3.56
Aggregate GVA impact (FTM multiplier)	£m	1,115	11,211	19,636	33,339
Aggregate contribution to GDP (FTM multiplier)	**£m**	**1,185**	**11,920**	**20,880**	**35,453**

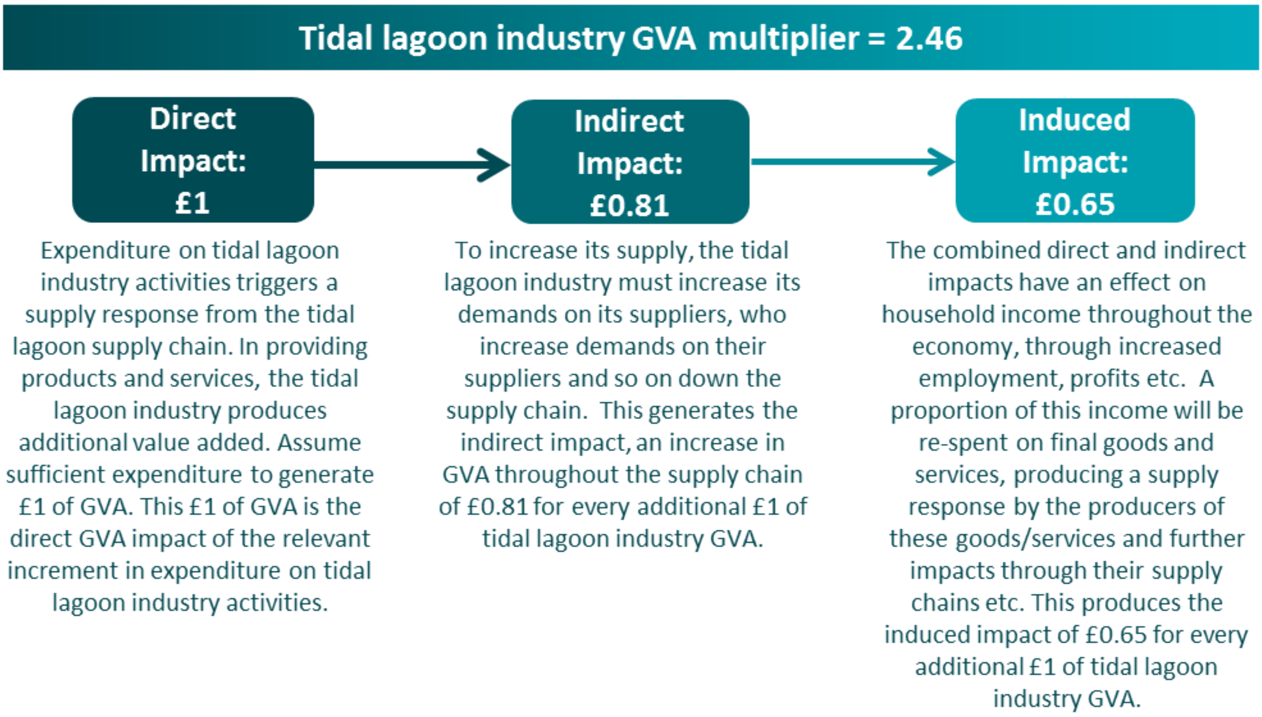
Source: Cebr analysis

Figure 15: Tidal lagoon contribution to UK GVA during construction period, scenario 4, 2014 prices, £m, 2015 to 2027



Source: Cebr analysis

Figure 16: Components of the estimated domestic GVA multipliers for the tidal lagoon construction programme, scenario 4, 2021 estimates (year of maximum construction output)



Source: Cebr analysis

When conditions are such that foreign trade multipliers (FTMs) are in play, investment in a tidal lagoon industry can be expected to produce consistently larger economic contributions.

The FTM multipliers presented in Table 14 are higher than domestic multipliers, indicating that the balance of trade effects of the construction of a tidal lagoon industry have an overall positive effect on UK GVA. For instance, under scenario 4, the FTM multiplier is 3.56 in the year of maximum construction output (2021), compared with a domestic multiplier estimate of 2.53. These multipliers indicate that the overall GDP impact from the construction of all six lagoons could be as much as £35.5 billion.

GDP impacts during operational phase

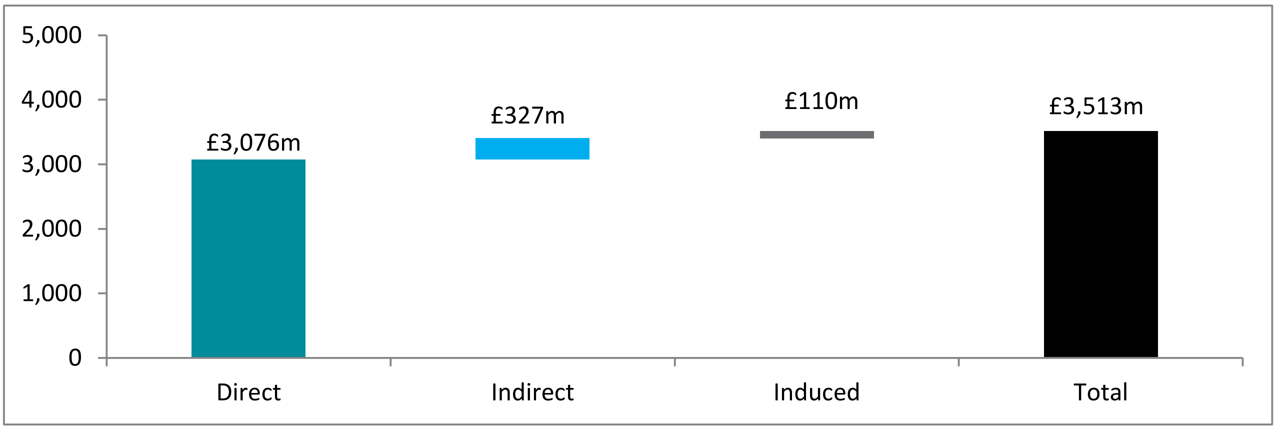
Once lagoons are fully operational and generating power, it is estimated that the six lagoons in scenario 4 would contribute an estimated £3.1 billion per year to UK GVA. This would correspond to a contribution to UK GDP of approximately 0.13% in 2027. Results are presented for 2027 when all lagoons are expected to be operational. These are summarised in Table 14.

Table 14: Summary table of economic contributions and impacts of annual tidal lagoon operation, 2014 prices, 2027

		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Direct GVA impacts					
Direct GVA	£m	69	794	1,449	2,564
Taxes less subsidies - direct	£m	1	15	27	45
Direct contribution to GDP	**£m**	**70**	**809**	**1,476**	**2,609**
Multiplier GVA impacts					
Domestic GVA multiplier		1.17	1.21	1.20	1.17
Aggregate GVA impact (domestic multiplier)	£m	80	961	1,743	3,000
Taxes less subsidies (domestic multiplier)	£m	1	18	33	53
Aggregate contribution to GDP (domestic multiplier)	**£m**	**82**	**980**	**1,776**	**3,053**
Aggregate contribution to GDP (domestic multiplier)	**%**	**0.00%**	**0.04%**	**0.08%**	**0.14%**
Multiplier GVA impacts including balance of trade effects					
FT GVA multiplier		1.97	2.05	2.04	1.99
Aggregate GVA impact (FT multiplier)	£m	136	1,625	2,949	5,102
Taxes less subsidies (FT multiplier)		2	31	55	90
Aggregate contribution to GDP (FT multiplier)	**£m**	**138**	**1,656**	**3,004**	**5,191**
Aggregate contribution to GDP	**%**	**0.01%**	**0.08%**	**0.14%**	**0.24%**

Source: Cebr analysis

Figure 17: Tidal lagoon annual contribution to UK GVA during operational phase, scenario 4, 2014 prices, £m, 2027



Source: Cebr analysis

During the operational phase, the domestic GVA multiplier is estimated to be 1.17 for scenario 4 when all six lagoons are operational in 2027. Again, this multiplier can be interpreted as follows: for every £1 of GVA generated directly by producers of the products and services required for tidal lagoon construction, an additional £0.17 of GVA is generated in the wider economy through indirect and induced impacts.

Foreign trade multipliers for the operational phase of the industry are higher than domestic multipliers, demonstrating a positive balance of trade effect. These multipliers indicate an overall GDP impact from the operation of all six lagoons could be as much as £5.2 billion.

3.3 Contribution of a tidal lagoon industry to UK employment

The tidal lagoon industry will generate jobs through the employment of staff during construction and through the operation and maintenance of lagoons. Employment will also be generated in other industries via the indirect impacts of expenditure and output generated by the tidal lagoon industry.

Employment impacts during construction phase

The employment contribution of the construction of six lagoons including indirect and induced employment is estimated to reach 70,900 full-time equivalent jobs (FTEs) at the peak of construction in 2021. This would amount to 0.22% of UK employment in that year. Over the whole construction period, it is estimated that an average of 34,700 jobs (FTEs) would be supported.

The domestic employment multiplier during the construction phase ranges between 2.64 and 3.26. This can interpreted in as follows: for every one FTE job generated directly by producers of the products and services required for construction of tidal lagoons, an additional 1.64 to 2.26 FTE jobs can be expected to be generated in the wider economy through indirect and induced impacts. A summary of the employment contribution of the construction phase are presented in Table 15.

Table 15: Summary table of contribution to employment from investment in tidal lagoon construction

Employment impacts		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Direct jobs	**average FTEs**	**1,082**	**5,721**	**10,353**	**12,668**
Aggregate jobs impact	**average FTEs**	**2,942**	**15,519**	**28,138**	**34,705**
Domestic employment multiplier (max output year of construction)		2.90	2.86	2.88	3.26
FTM employment multiplier (max output year of construction)		3.07	3.17	3.15	3.09
Aggregate employment impact (FTM multipliers)	**average FTEs**	**3,289**	**16,915**	**29,556**	**35,834**

Source: Cebr analysis

The difference between the estimated domestic and foreign trade multipliers during the construction phase is minimal, suggesting a limited foreign trade multiplier impact on UK employment.

Employment impacts during operational phase

Each lagoon is projected to employ between 31 and 41 staff directly with a further 50 staff employed in public amenity facilities at each site. However, the substantial output generated by 6 fully operational lagoons will stimulate substantial economic activity throughout the economy, creating indirect and induced GVA impacts which far exceed direct employment.

Table 16: Summary table of contribution to employment from an operational tidal lagoon industry, 2030

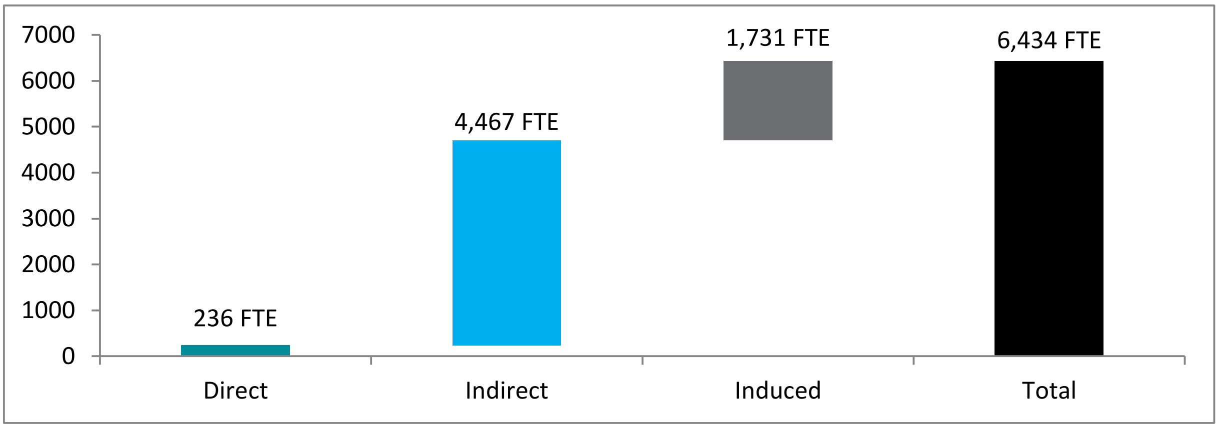
Employment impacts		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Direct jobs	**FTE**	**31**	**113**	**195**	**236**
Aggregate jobs impact	**FTE**	**181**	**2,405**	**4,348**	**6,434**
Contribution to UK employment	**%**	**0.00%**	**0.01%**	**0.01%**	**0.02%**
Domestic employment multiplier		5.84	21.28	22.30	27.26
FTM employment multiplier		34.07	114.41	120.28	168.11
Aggregate employment impact (FT multiplier)	**FTE**	**1,056**	**12,929**	**23,456**	**39,674**
Contribution to UK employment (FT multiplier)	**%**	**0.00%**	**0.04%**	**0.07%**	**0.12%**

Source: Cebr analysis

The domestic employment multiplier for the operational phase is estimated at 27.3 once all 6 lagoons are operational. This is an exceptionally high employment multiplier, which arises from the fact that tidal lagoons have a very high output-to-employment ratio. This means that lagoons directly-employ relatively few people, in order to produce substantial economic output. Therefore, there is a large degree of economic output associated with each 1 FTE directly-employed at a tidal lagoon site. This output draws upon inputs from much more labour-intensive activities, thereby supporting a large increment of additional employment elsewhere in the economy.

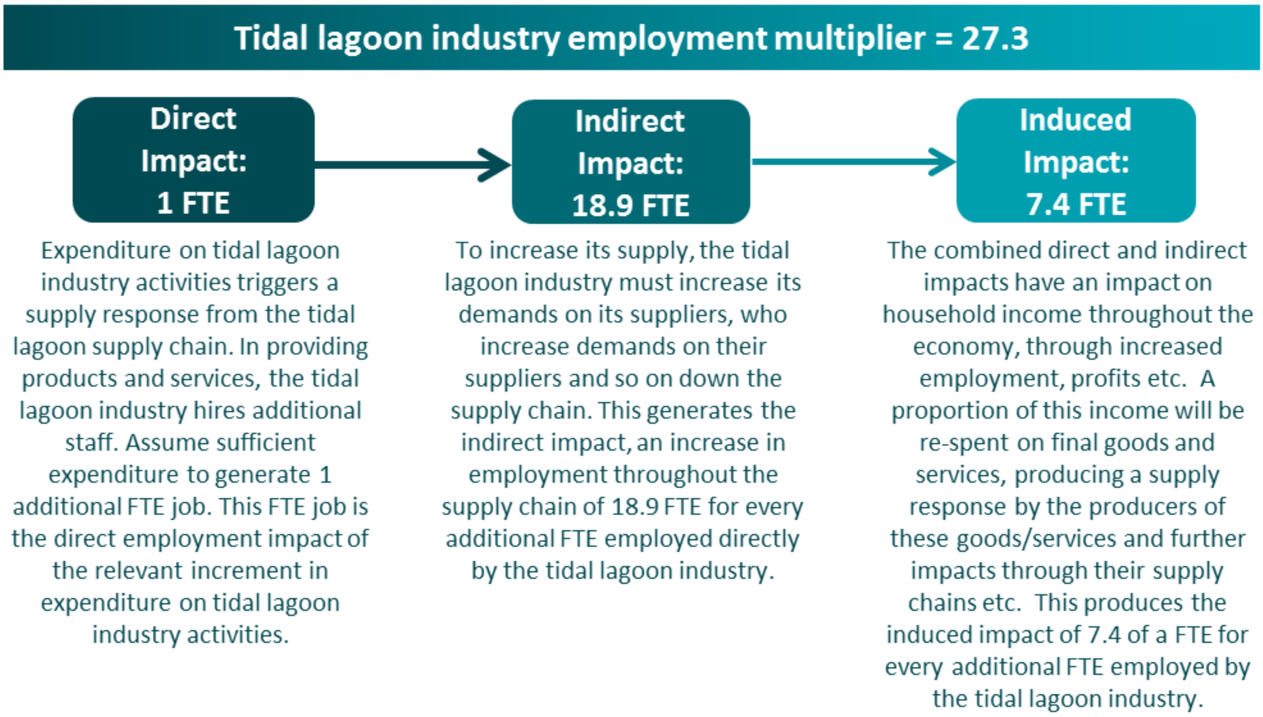
This multiplier effect can be interpreted as follows: for every one FTE job generated directly by producers of the products and services required for construction of tidal lagoons, an additional 26.3 additional FTE jobs can be expected to be generated in the wider economy through indirect and induced impacts (see Figure 19 for further explanation of the relationship between direct, indirect and induced employment). This multiplier estimate means that as many as 6,400 jobs would be supported across the UK once all six lagoons in scenario 4 are operational. This would equate to an estimated 0.02% of UK employment in 2030.

Figure 18: Estimated direct, indirect and indirect employment impact of operational tidal lagoon industry, scenario 4, 2030



Source: Cebr analysis

Figure 19: Components of the estimated domestic employment multipliers an operational tidal lagoon industry, scenario 4, 2030



Source: Cebr analysis

Given the high domestic employment multiplier for operational lagoons and the very large output-to-employment ratio, it follows that a positive balance of trade effect would magnify these benefits. The estimate for employment foreign trade multipliers indicates that the operation of the tidal lagoon industry could sustain as many as 40,000 jobs in the UK – either through direct employment, in the supply chain or from induced effects.

3.4 Contribution to UK balance of trade and impact on other industries

We used projections for fossil fuel displacement, energy exports, construction and operational imports, and supply chain exports to calculate the net balance of trade impacts of the tidal lagoon industry for selected years and for each scenario. These are presented in Table 17.

Table 17: Net UK balance of trade impacts, 2014 prices, £m

Scenario	Year	Reduction in Fossil Fuel Imports	Electricity Exports Increases	Tidal lagoon industry imports	Tidal lagoon industry exports	Net balance of trade impact
Scenario 1	2020	3	0	2	0	**1**
	2025	12	3	2	0	**12**
	2030	17	5	2	1,021	**1,041**
	2040	17	5	2	1,244	**1,263**
Scenario 2	2020	3	0	396	0	**-393**
	2025	105	49	16	0	**138**
	2030	190	80	36	1,532	**1,766**
	2040	190	79	36	1,866	**2,099**
Scenario 3	2020	3	0	836	0	**-833**
	2025	197	92	27	0	**262**
	2030	356	149	60	2,042	**2,487**
	2040	356	147	60	2,488	**2,930**
Scenario 4	2020	3	0	842	0	**-839**
	2025	197	131	291	0	**37**
	2030	499	284	97	2,553	**3,238**
	2040	499	279	97	3,110	**3,790**

Source: Cebr analysis

The expected net impact on the balance of trade is significant. By 2030, under scenario 4, the expected increase in net exports is estimated to be £3.79 billion, equivalent to 14.2% of the UK trade deficit (recorded at £26.7 billion in 2013).

4 Creating and supporting jobs and industry in disadvantaged areas

This chapter highlights the relative deprivation of the regions[26] in which the tidal lagoons are proposed to be built and outlines the economic benefits, in terms of GVA and employment, the operation and maintenance of each lagoon is expected to bring to the regions and countries where they will be built.

Under current HM Treasury Green Book guidelines, the generation of economic activity and employment in more disadvantaged regions is more valuable than the generation of similar employment and economic activity in less deprived regions. This is derived from the economic concept of diminishing marginal utility, which states that the utility (satisfaction) gained from each additional unit of income falls as total income rises. As the economic impacts of each tidal lagoon will be heavily concentrated in regions with relatively low income and employment levels, the total economic benefits of each project in utility terms would be even greater than those indicated by considering solely the projected employment and GVA contribution.

The purpose of the analysis presented in this chapter is to demonstrate the disproportionate beneficial effects the lagoons will have on each of the regions in which they will be located, relative to the rest of the United Kingdom, due to their relative economic disadvantage. The chapter continues as follows: section 4.1 outlines the relative deprivation of the three regions in which the lagoons will be located in terms of economic activity, employment and education. Section 4.2 presents the in-region/in-country economic impacts of the proposed tidal lagoons.

4.1 Relative economic disadvantage of regions where lagoons are planned

Regional GVA

GVA per capita in the three regions in which the lagoons are due to be built is below the England and Wales average, as shown in Figure 20. This difference is especially striking in Wales, where GVA per capita is half that of London, showing a lower level of economic activity per person. Regional GVA per capita in the North West and South West also falls below the average, highlighting the need for extra stimulus to these regional economies.

Figure 20: GVA per head; by region; 2012

Source: Regional Gross Value Added (Income Approach), December 2013

[26] For the purposes of this chapter, "regions" refers to Wales and the English regions.

Employment

The three regions, in which the tidal lagoons will be based, currently have lower employment levels as well as higher unemployment rates in comparison to other regions. As of February 2014, the employment rate in Wales was the second lowest amongst all the regions (56%). The North West had a similarly low level of employment (57%). Figure 21 shows the employment rates across the regions, along with the England & Wales average.

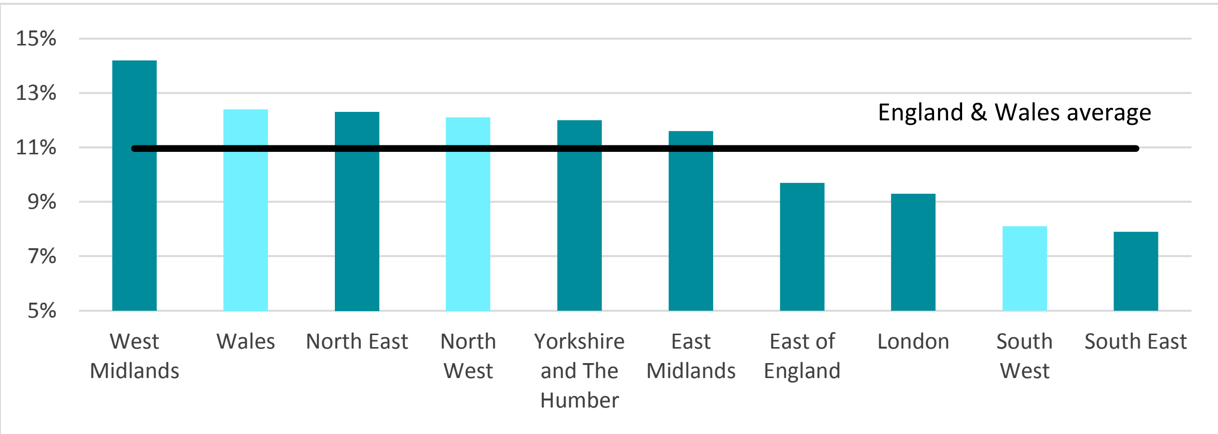
Figure 21: Employment rates; by region; February 2014

Source: ONS Regional Labour Market Statistics, April 2014

Education

In addition to the major economic indicators, Wales and the North West in particular have relatively low education levels, as shown in Figure 22.

Figure 22: Percentage of 16 to 64 year olds with no qualifications; by region; Jan 2011 - Dec 2011



Source: ONS regional economic indicators, 2013

4.2 Regional economic benefits

The building of the lagoons in more disadvantaged regions/ countries will have a substantial impact on their respective economies. The operation of these lagoons will create demand for products and services sourced in those regions. As part of the analysis of lagoon cost components, the regional shares of lagoon operational expenditures have been identified.

In-region expenditure results in a significant direct economic boost to each of the respective regional economies. In addition, the regionally-based businesses supplying these goods and services will in turn purchase from their own local suppliers to meet their higher demands, and so on. This will result in a further boost in GVA and employment within the regions in which the lagoons are to be located.

A combination of these direct and indirect effects will in turn raise incomes of households in Wales, the South West and North West of England through higher employment. A proportion of this additional income will then be re-spent within these regions – a process likely to continue iteratively until the final induced economic benefits are realised. The regional multipliers representing these direct, indirect and induced impacts are displayed in Table 18 and Table 19 below.

Contribution to GVA

The direct impact on the Welsh economy from the operation of the four planned lagoons would be approximately £1.04 billion, with the GVA multiplier calculated to be around 1.04. This means that for every £1 of GVA generated directly from tidal lagoon construction, 4 pence of additional GVA is generated in the Welsh economy through both indirect and induced impacts. This amounts to a total of approximately £1.08 billion in GVA being contributed each year once all the lagoons are operational.

This would be particularly beneficial for Wales, where GVA per head is currently the lowest amongst all regions in the United Kingdom. Rising GVA would therefore help the regional economy to converge towards that of other regions, resulting in more balanced economic success across the UK.

Table 18: Regional impact on GVA if all six tidal lagoons are operational; 2030

		Wales	South West	North West
Installed capacity	GW	6.3	6.6	3
Direct GVA	£m	1,040	1,070	455
Regional multiplier	Type II	1.04	1.03	1.02
Total GVA	£m	1,080	1,102	465
GVA per GW installed	£m	171	167	155

Source: Cebr analysis

Although the South West and the North West are slightly more prosperous than Wales, they still lag behind the other regions. They are expected to derive direct GVA impacts of £1.07 billion and £455 million with final multipliers of 1.03 and 1.02 respectively. This means that building tidal lagoons in these areas would add an extra 3 pence for every £1 of initial boost in GVA in the case of the South West, and an extra 2 pence for every £1 of initial GVA boost in the North West. In summary, the three regions identified would experience a boost in GVA amounting to £2.65 billion if all six lagoons are built.

Contribution to employment

The operation of the lagoons using local products and services will also stimulate employment within the regions. Firstly, there will be a requirement for workers to operate and maintain the sites – many of whom are likely to be based within the region. As this initial boost will translate to more activity further down the supply chain, local businesses will subsequently need to hire additional employees to meet the growing demand for their goods and services. As the induced effects set in, the rise in household spending throughout the regional economies will lead to further employment growth as the boost in overall demand is met by additional workers being hired.

Table 19: Regional impact on employment if all six tidal lagoons are operational; 2030

		Wales	South West	North West
Installed capacity	GW	6.3	6.6	3.0
Direct Employment	Jobs (FTE)	154	41	41
Regional multiplier	Type II	6.67	5.25	3.90
Total Employment	Jobs (FTE)	995	215	160

Source: Cebr analysis

Wales would experience the largest boost in employment as a direct result of the operation and maintenance of the lagoons, with 154 direct FTE jobs being created. It also has the highest expected regional employment multiplier; estimated at 6.67, which means that for every FTE job generated for the operation and maintenance of the tidal lagoons, an additional 5.67 FTE jobs will be created overall in Wales. This translates to a total of 995 FTE jobs being created in Wales once the proposed sites are operational. Presently, Wales has one of the lowest employment rates in the country, meaning the tidal lagoons will substantially benefit the country in this regard.

Both the North West and South West regions are expected to have a lower number of direct jobs than Wales, as well as lower employment multipliers. This is expected to result in a total of 160 and 215 new FTE jobs being created respectively as a result of in-region expenditure.

5 Industry case studies

The future of energy production in the UK is uncertain. Without intervention, the UK will increasingly rely on imported energy sources for its electricity generation needs. However, the UK has the potential to regain its energy independence through harnessing its vast renewable energy resources for the production of electricity. The UK can use this opportunity to develop these renewable resources to create an industry which substantially contributes to the economy (and to tax revenues) – similar to the UK oil and gas industry.

Successes have already been achieved in attempts to transfer British oil & gas expertise over to renewable technologies such as offshore wind farms. Britain may have the opportunity to capitalise on its position as a world leader in the nascent tidal lagoon industry.

This chapter brings together lessons, in the form of case studies, on how government actions have supported the growth of both the UK oil & gas industry and the Danish wind industry, helping these industries become world leaders in their fields.

5.1 Case study 1 – The UK Oil & Gas Industry

Introduction

For most of the 20th Century the UK could not keep up with its rapidly increasing energy consumption. Such consumption initially relied heavily upon coal, a resource richly abundant in the British Isles.

The increasing prevalence of motorised vehicles, advances in crude oil & gas extraction and a slow depletion of coal stocks forced a gradual rise in imports of oil and gas in order to satiate the increasing consumer demand for energy. By 1974 annual net imports of crude oil had risen to over 112 million tonnes – a rise of almost 7000% from 1920. This activity served to deteriorate the UK's balance of payments account and threatened to pose serious downward pressure on economic growth, as the century drew to a close.

However, this trend was abruptly reversed in the 1960s when British Petroleum – under the auspices of the Government – began to prospect and exploit crude oil and natural gas deposits. Early exploration was successful with oil and gas both found in abundance. As shown in Figure 23, for a short period between 1997 and 2003, the UK was self-reliant in its oil and gas needs whilst also being a world leader in fossil fuel extraction and production.

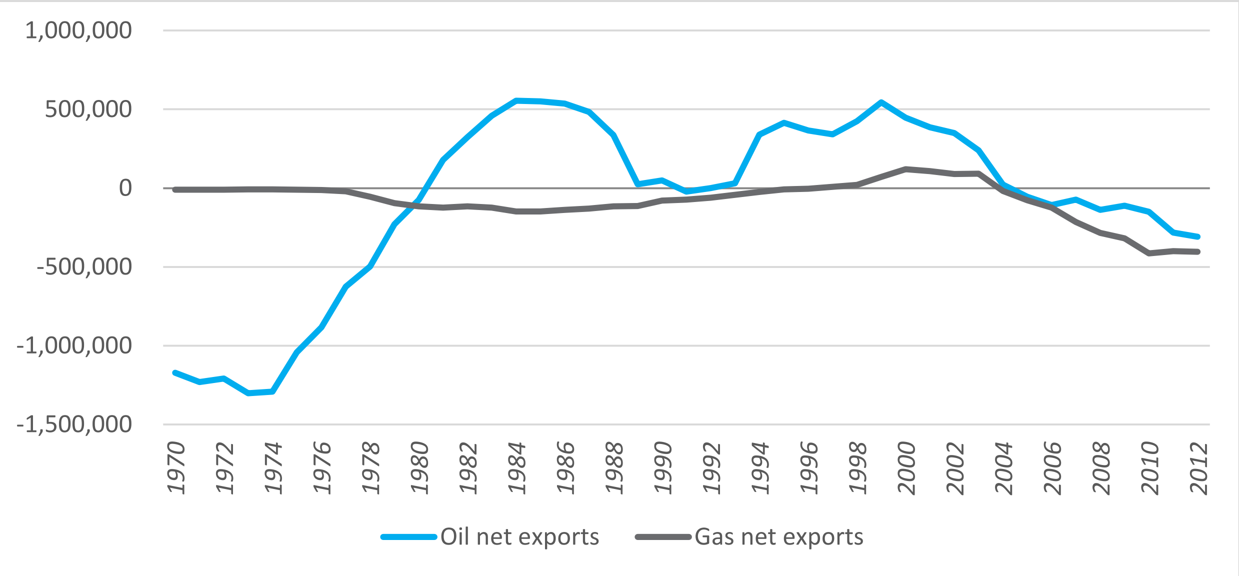
The heyday of British crude and methane extraction/production appears to have drawn to a close. Yields of both oil and gas have been declining for the past 10-15 years as the existing fields deplete and the resource that remains grows increasingly difficult to extract. Economically speaking, the pinnacle is most certainly behind us. For the UK to avoid a return to its dependence on fossil fuel imports, an effort needs to be made to develop domestic energy resources which minimise the requirement for fossil fuels.

While the oil and gas has begun to run out, the same cannot be said for British expertise. Today the industry generates a turnover of £27 billion per year and exports £7.5 billion worth of oil & gas related products and services[27]. In terms of employment, approximately 36,000 people work directly in oil & gas

[27] Oil & Gas UK, Economic Report 2013

extraction. The supply chain is estimated to consist of 1,100 companies, with a workforce of close to 236,000. Whilst in 2013, the oil & gas industry made investments in new and existing infrastructure amounting to £14.4 billion.

Figure 23: UK crude oil and natural gas net exports, GWh



Source: DECC digest of UK energy statistics

Government Support and Intervention

The government took various measures in the early days of North Sea exploration to protect British providers and to ensure the development of the then-nascent industry. Initially, the government gave preferential treatment to British firms and to foreign firms willing to share their expertise, with the intention of building all areas of the industry: exploration, production, transportation, refinement and distribution.

Successive governments showed foresight in focussing on the development of the entire industry, rather than concentrating on rapid extraction and revenue collection, and the technology and expertise of offshore exploration will be retained within British firms long after North Sea reserves are depleted.

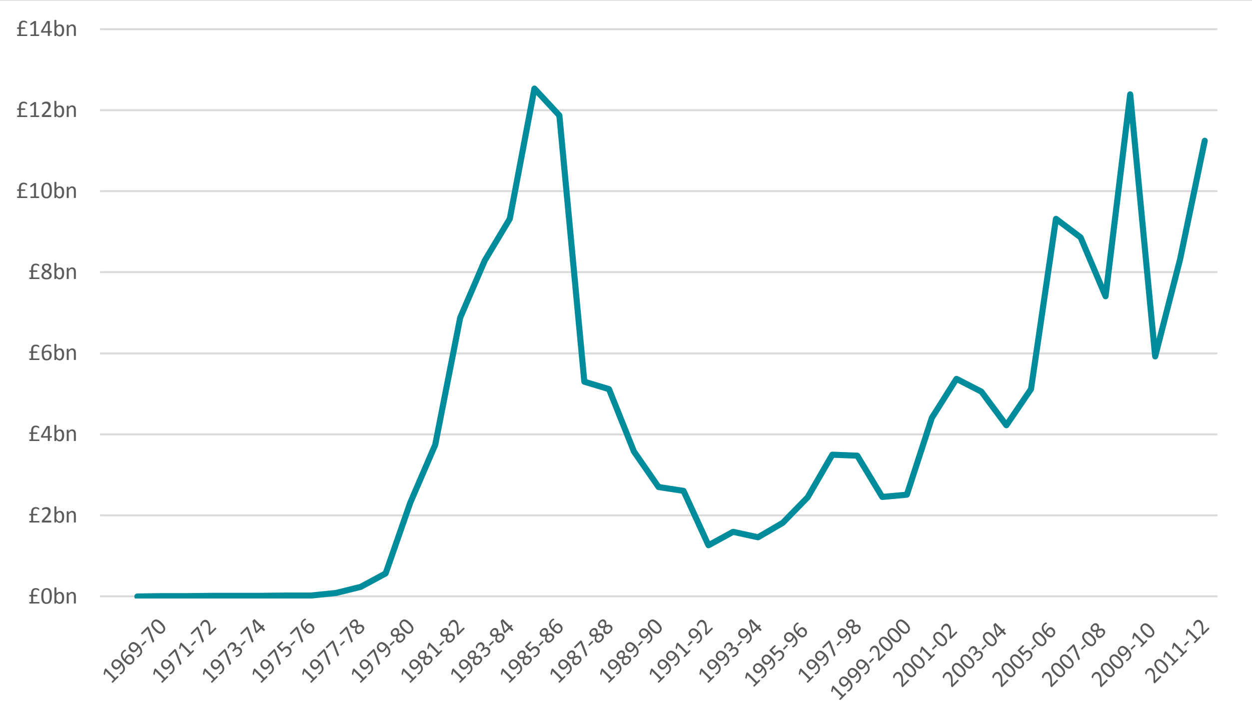
The British oil & gas industry lacked key competencies before the government intervened to support it and nevertheless now has some of the most sought-after technical expertise in the world. The same type of incentives and support for the tidal lagoon industry could lead to another world-beating specialist industry, especially since the nascent UK industry is currently in pole position globally.

Licensing and taxation

The North Sea oil & gas tax and licencing system was used by the government to determine the direction taken by the industry through encouraging exploration or extraction of resources at different times, in order to maximise revenues. The changing taxation system, while occasionally causing uncertainty, has been very powerful in directing resources towards different activities within the industry, illustrating the effectiveness of fiscal measures.

The oil & gas sector is now the UK's largest corporation tax payer, contributing 12.1% of total Government corporation tax receipts[28] in 2012/13.

Figure 24 - Government revenue from oil & gas production



Source: DECC, "Government revenues from oil and gas production"

Developing the UK Industry and Supply Chain

The government has initiated numerous policies to enhance UK involvement in the North Sea: directly favouring British firms in licensing, encouraging foreign firms to share expertise, and developing the supply chain, all with considerable spill-over effects for numerous industries. The supply chain now employs approximately ten times the number of people at work on the North Sea itself and includes almost every conceivable sphere of activity, from construction and steelmaking to consulting and legal services.

The expertise developed in the fifty-year history of North Sea exploration is now vital to UK exports. If the appropriate support is available, the potential exists for similar success in developing a supply chain for tidal power with considerable advantages in technology and human capital, positioned to become a leading UK export industry.

Conclusion

After considerable government assistance, in the form of preferential treatment for domestic firms and support building the UK presence in the supply chain, the future of the oil & gas industry is no longer solely

[28] HMRC Corporation Tax Statistics 2013

focussed on direct extraction of our own resources. Instead the UK oil & gas industry is now positioned as a global leader, exporting precision machinery and high-level expertise.

With the right support, Britain could reach the same position in the renewables industry and tidal lagoon power could play an important role in reaching that goal. The nation already has leading specialists in the technology along with some of the most favourable natural locations for its implementation, putting itself in a position to be first-to-market in this exciting industry and potentially assume a world-leading position, similar to that currently enjoyed by the British oil & gas industry, in the very near future.

Being a capital-intensive industry with a large potential for UK supplier involvement, there is also scope for supply-chain benefits to boost numerous other British industries including in the design, project management and civil engineering phase of lagoon construction. There is also potential for the UK to move into the turbine production process, with British engineering firms having the necessary expertise in the fields of casting, forging, machining, etc.

Timeline of UK Oil and Gas

1930 - 1964	Small quantities of commercially viable oil discovered on-shore in the 1930s. **Gas Act 1948:** Nationalised the gas industries and merged existing gas companies into 12 area gas boards. **UK Continental Shelf Act** came into force in 1964 and issued the first licenses for the extraction of oil and gas from the UKCS. These were given on a discretionary basis and heavily favoured British companies.
1965 – 1972	**North Sea exploration:** Exploration began in 1965. This resulted from geological data gathered by BP suggesting that the sedimentary basin in which oil was found extended eastwards into the North Sea. The West Sole gas field was discovered in 1965 followed by the giant Forties oil field five years later. **The Gas Act** (1972): Merged all area boards and created British Gas Corporation. 'Study of potential benefits to British industry from offshore oil and gas developments'[29] commissioned by the government made recommendations of providing financial support for R&D, infrastructure development, and encouragement of downstream activities in Scotland.
1973	**Offshore Supplies Office (OSO)** set up by the government ensured that UK industries were given 'Full and Fair Opportunity' to compete in the North Sea. **Oil supply crisis**: Crude oil prices increased significantly, making investment in North Sea exploration a potentially lucrative opportunity.
1975	**Royalty:** Set at 12.5% of gross revenue generated by oil companies.

[29] International Management and Engineering Group of Britain - Study of potential benefits to British industry from offshore oil and gas developments - Dept. of Trade and Industry, H.M. Stationery Office, 1972

Timeline of UK Oil and Gas	
	Petroleum Revenue Tax (PRT): 45% tax on the profits from oil and gas production. **Ring fence corporation tax**: Tax on companies' profits solely generated from oil related activity. This ensured expenses incurred from other activities didn't reduce the amount of taxable profit from oil activities.
1976 - 1981	**British National Oil Corporation (BNOC) formed in 1976**: The state oil company was given powers to acquire at least 50% of the British production of oil at market prices. **Supplementary Petroleum Duty (SPD) in 1981:** The tax imposed on oil producer was set at 20% of gross revenues less an allowance of 1 million tonnes of oil per year.
1983-1986	The 1983 budget removed royalties and doubled the PRT volume allowance to encourage further investment as new fields became smaller and oil prices began to cool. The Advanced Petroleum Revenue Tax briefly replaced the SPD in 1983. It was phased out on a sliding scale basis before being completely abolished in 1986.
1988-2003	Piper Alpha oil disaster occurred in 1988, as UK crude oil production fell sharply. **Finance Act (1993):** Abolished PRT for those fields granted Annex B approval after 15 March 1993. The rate of PRT on existing fields was also reduced to its lowest level since 1978. Production then began to rise significantly. Gas production peaks in 2000 as the UK returns to being a net importer of both oil and gas in 2004.

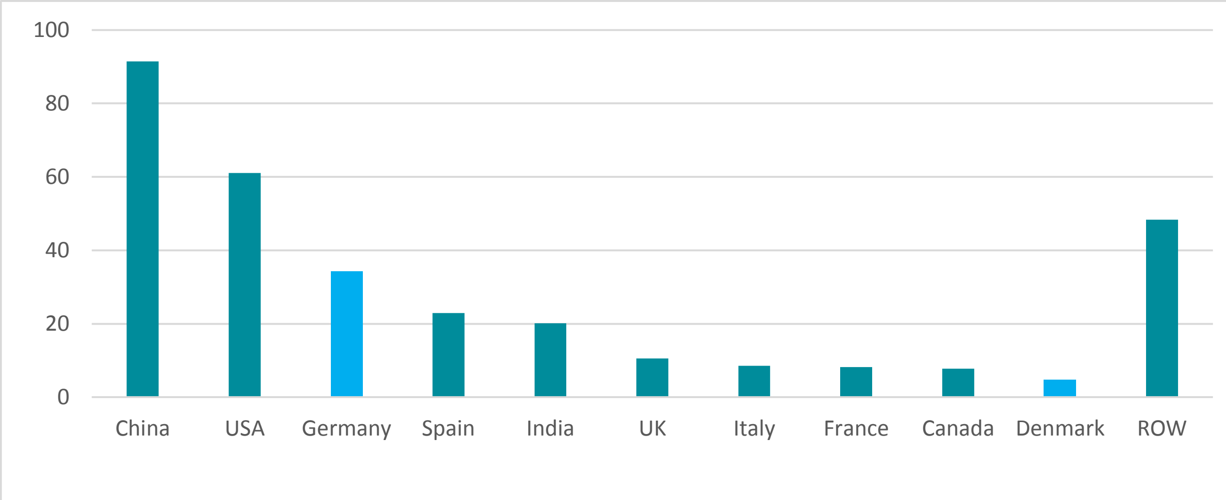
5.2 Case Study 2 - Wind energy in Denmark and Germany

Introduction

The Danish and German wind energy industries are largely seen as the pioneers of commercialised wind energy. This has been achieved through innovative and timely Government policies supporting the growth of these industries over the years, with Germany largely replicating Denmark's successful strategy.

As a result of this support, both countries now have amongst the highest levels of installed wind capacity in the world, as shown in Figure 25. The respective wind energy sectors also make substantial contributions through reduced carbon emissions, job creation and exports.

Figure 25: Installed wind capacity by country; GW; end of 2013



Source: Global Wind Energy Council, "Global wind statistics 2013"

Denmark was the first country to develop a wind energy sector. Danish manufacturers – who gained their expertise originally through meeting the domestic demand for wind turbine installations – have been able to export this knowledge to meet growing demand in foreign countries. As a result, wind industry exports reached €7 billion in 2012[30] - over 5% of the country's total exports – as compared to only €0.5 billion in 1997.

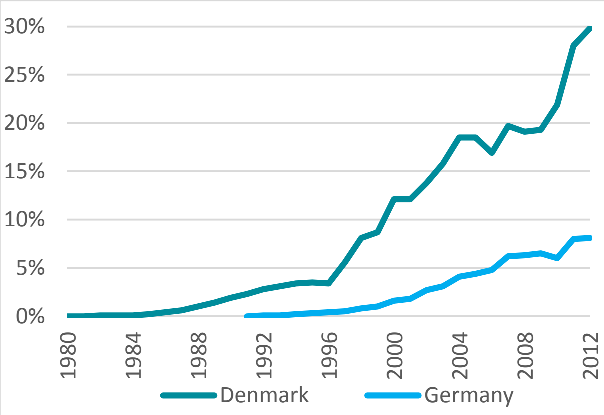
The wind energy industry has also advanced markedly in Germany. Following on from Denmark's lead, the country now boasts the third highest installed wind capacity in the world and is worth 17.5% of the global wind sector[31]. German wind-related exports are also extremely strong. Two of the four largest wind turbine manufacturers in the world are German and the export share of total sales in the wind industry of around 80% in 2011[32]. Figure 26 shows how wind energy grew in the country relative to the total energy market and highlights the subsequent environmental benefits.

[30] Source: Danish Wind Industry Association, annual statistics 2013.

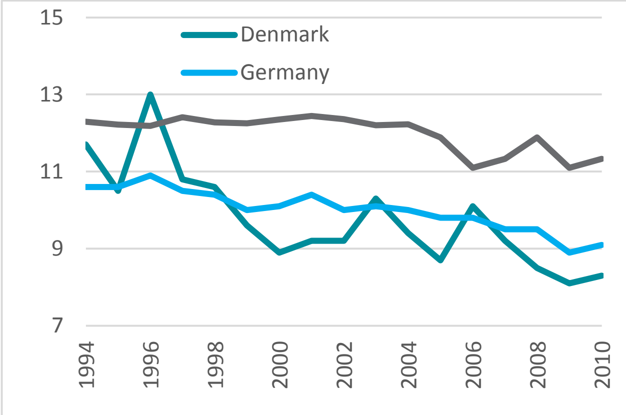
[31] Source: O'Sullivan, M. et al. (2012) "Gross employment from renewable energy in Germany in 2011", research project commissioned by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

[32] German Wind Energy Association (2011), "Wind Industry in Germany".

Figure 26: Wind power's share of domestic electricity supply; Denmark and Germany; 1980 – 2012



CO2 emissions (metric tons per capita); Germany, Denmark and high-income OECD, 1994 - 2010



Source: Danish Energy Agency, annual energy statistics, 2012; The World Bank

Some of the major policies that contributed to the growth of the wind sector included publicly funded research & development programmes, capital subsidies and feed-in tariffs. The design and timeliness of such policies played an important part in determining the trajectory of wind energy in both countries; policymakers in the UK can use similar mechanisms to help develop tidal lagoon power both at home and abroad.

The first multi-megawatt wind turbine was constructed in Denmark in 1978, following enhanced R&D on wind energy - funded by taxes imposed on electricity generated from non-renewable sources. After over 30 years of progress in the sector, electricity generated from wind now accounts for around 30 percent of total electricity supply. This has helped to reduce the country's CO_2 emissions at a faster rate than the average amongst OECD high income countries (see Figure 26). In addition, wind energy has also contributed to the domestic economy. The sector contributed €1.5 billion in gross value added in 2009[33] and employed 27,490 people at the end of 2013[34].

Government support and intervention

Both the Danish and German wind sectors have developed after receiving substantial support through a number of different policies, with Germany largely following the set of measures employed by the Danish government. These policies can be replicated in the UK to get a tidal lagoon industry thriving, which would result in multiple economic benefits in the future.

In 1981, the Danish government launched the Energiplan81, which provided capital subsidies initially covering 30% of installation costs of wind turbines. These were subsequently lowered to 20% and then 10% over the 1980s, before being completely removed in 1988 as installations gathered pace.

Meanwhile, oil and coal consumption was taxed further to make electricity generated from renewable energy more attractive. All these measures provided sufficient incentives and security to potential

[33] Source: Centre for Politiske Studier (2009), "Wind Energy: The Case of Denmark"

[34] Source: Danish Wind Industry Association, annual statistics 2013.

investors, enabling installed wind capacity to rise by an average of 65% each year in the 1980s. In 1989, Denmark had a total installed capacity of 247MW, compared with just 3MW at the start of the decade.

In Germany, the 250MW Wind programme - which was initially the 100MW programme - was extended in February 1991. It provided grants for the installing and operating of wind turbines with the aim of supporting new and innovative wind turbine technologies, as opposed to simply helping technologies that were already fully commercial. The programme provided grants covering up to 60% of initial investment, as well as operation-based premiums for every kWh entering into the public grid. In total, 1,467 wind turbines with a combined capacity of 354MW were promoted using these measures, kick-starting the German wind sector[35]. The majority of this support was given to domestic manufacturers, resulting in 67% of all wind plants in the country being built and operated by native companies. This allowed them build expertise of their own, helping Germany reach a wind export share of around 80% in 2012[36].

Price support

Feed-in tariffs (FITs) have also played a major role in the development of both countries' wind energy sectors. In the case of Denmark, an FIT was introduced in 1993 as producers were offered guaranteed grid connection at a price equalling 85% of utility production and distribution costs[37]. As the purchase of all electricity produced from wind was guaranteed and the price wasn't controlled by the suppliers, producers of wind energy were simply looking to maximise the amount of energy they can generate – either through new installations or expanding existing ones. These tariffs also gave investors some guarantees about the potential returns from wind energy, helping to finance new installations. As a result, installed wind capacity rose by an average of 21 percent each year over the next ten years.

Germany also employed a similar version of this policy following its success in the Danish wind market. The Renewable Energy Sources Act (EEG) came into force in 2000, introducing a system which had fixed, regressive, and temporarily limited feed-in tariffs. Under the EEG, remuneration rates for wind energy were raised from the level introduced in the Act on Supplying Electricity from Renewables (StrEG), with the feed-in tariffs fixed for 20 years. These tariffs were also lowered for new installations over time, as electricity from renewable sources was also given priority access into the grid. This again provided long-term guarantees of sufficient returns, incentivising further investment in the installation of new wind turbines. Regressive tariffs also promoted innovation as new entrants were only guaranteed lower prices, causing them to look for new ways to maximise their profits. This contributed greatly to the German wind sector as installed wind capacity grew exponentially from 2000 onwards, as shown in Figure 27.

The FITs are somewhat comparable to the contract for difference mechanism (CfD) introduced by the UK Government. Both measures seek to reduce price volatility faced by the producers of wind or tidal power in order to guarantee returns and attract investment. The CfD however puts the risk of market prices changing on the UK Government, whereas the FITs put this burden on the utilities. The CfD might therefore

[35] Source: Dr. Langniss, O. (2006), "The German 250-MW-Wind-Program", Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW).

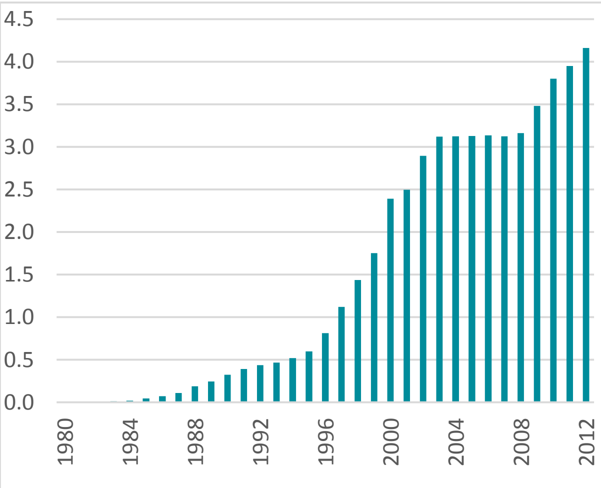
[36] Source: German Energy Agency. Weblink: http://www.renewables-made-in-germany.com/en/start/windenergie.html, retrieved 26/06/2014.

[37] .Source: International Renewable Energy Agency (2012), "30 Years of Policies for Wind Energy: Lessons from 12 Wind Energy Markets". Global Wind Energy Council.

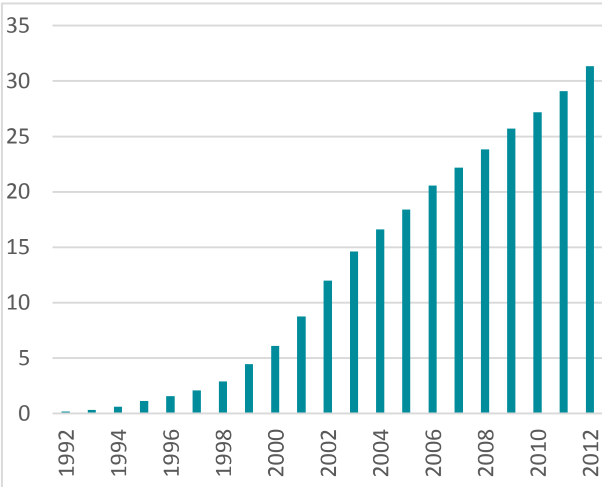
ensure both distributors and generators of tidal power are benefitting from tidal lagoon power, possibly resulting in a more stable market where all agents can focus on fully utilising the energy source.

Denmark began to remove feed-in tariffs in 1999 as a renewable portfolio standard (RPS) mechanism was phased in alongside an emissions trading system. Remuneration was now made up of the market price plus a capped premium, with guarantees of interconnection removed. This occurred when the government believed the wind industry in the country had matured, resulting in the introduction of more measures to enhance competition. However, once the feed-in tariffs were completely removed in 2004, the wind industry stagnated and installed capacity grew by an average of just 0.3% each year until 2008. This highlights the importance of ensuring support mechanisms are carefully managed by the UK government when trying to develop the tidal lagoon industry.

Figure 27: Installed wind capacity in Denmark; GW



Installed wind capacity in Germany; GW



Source: Danish Energy Agency, annual energy statistics, 2012; Ministry for Environmental Protection and safety of nuclear plants, "Time series of the development of renewable energy in Germany", July 2012

Conclusion

Effective support measures have proved vital in the development of the Danish and German wind industries. Policies designed in the early stages provided backing to wind energy through capital subsidies and soft loans, whilst also imposing heavier taxes on the consumption of non-renewable energy sources. Once the sector started to grow, guaranteed connection to the grid and fixed prices helped create a more secure investment environment. This proved to be vital as installed wind capacity grew exponentially in both countries, firmly establishing both wind sectors as significant sources of electricity generation. The UK can support the tidal lagoon industry to develop in the same way, provided the right level of support is given.

Due to their focus on wind and other renewable energy sources, Denmark and Germany have both been able to reduce their carbon emissions significantly more than the high income OECD average in recent years. They have also enjoyed economic benefits through raised output, job creation, and rising exports – which accounted for around 60% of total wind industry revenues in Denmark in 2012 and 80% in Germany in 2011.

A lot of this success can be attributed to both countries enjoying early mover advantages. The expertise gained from installing wind turbines at home became desirable to foreign countries looking to turn towards wind energy themselves. This resulted in sustained demand for wind turbine manufacturers, even after the domestic market had started to slow. If similar policies are employed by the UK government to promote a tidal lagoon industry, it can deliver similar economic benefits to the country as it exploits its own first-mover advantages.

Danish wind industry timeline	
1973	Supply shocks from the oil crisis raised desire to be more self-sufficient
1976	**Dansk Energipolitik:** Energy taxes on electricity prices were imposed and used to support R&D for renewable energy.
1981	**Energiplan81:** Introduced capital subsidies of 30 percent of total project costs.
1988	Capital subsidies removed completely after being progressively reduced to 20% and then 10% of total project cost.
1993	**Feed-in tariff:** Producers of electricity from wind sources were guaranteed access to the grid at a price which was eventually set at 85% of utility production and distribution costs.
1999	**Feed-in tariff phase out:** A renewable portfolio standard (RPS) with tradable credits was phased in an attempt to encourage greater competitiveness of the renewable energy plants.
2004	**Feed-in tariff completely removed:** Power supply sector was restructured as power companies were privatised, and power distribution, transmission and production became independent sectors.
2009	Environmental premium of USD 0.05/kWh for 22 000 full load hours (equivalent to around 10 years of operation) was added to the market price along with an additional compensation for balancing costs.

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