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Economic Impact Study into the Development of the UK Offshore Renewable Energy Industry to 2020

on behalf of the Offshore Renewable Energy Catapult

CATAPULT Offshore Renewable Energy

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1 Introduction

We analyse the economic impacts resulting from the development of the offshore renewable energy industry for the UK economy in the period up to 2020. Given this time frame only Offshore Wind and Tidal technologies are the focus of this report.

The economic impact on the UK is estimated using Input-Output (IO) models. The IO approach is a commonly used multi-sectoral, general equilibrium modelling approach to assessing economic impact. Input–output (IO) analysis (Leontief, 1941; Miller and Blair, 2009) continues to be the most widely employed method of assessing the impact of major new expenditures on regional and national economies in general, and the impacts of expenditures in establishing renewable energy capacity in particular (Arthur D. Little Ltd, 2005; O'Herlihy and Co. Ltd, 2006; Flynn and Carey, 2007; Lehr et al., 2008; Cebr, 2012).

The results shown in this report are based on expenditures estimated by *BVG associates* that reflect the best current assessment of the likely development of the UK offshore wind and tidal industries.

The report is organised as follows. In Section 2 we outline the IO methodology that we use to assess the economic and environmental benefits of developing an offshore renewable energy sector in UK. In Section 3 we describe our simulation strategy, the type of scenarios analysed in the report and the assumptions that underly our modelling approach. In Sections 4 and 5 we discuss the results for the offshore wind energy and tidal developments, respectively. Section 6 is a brief conclusion.

2 Methodology

The analysis is performed using the UK IO table for the year 2004. This is the most up-to-date symmetric IO table that exists for the UK economy. However, in this study we analyse the impact of development of the offshore renewable energy for the UK for the period 2014-2020. We assume that the economic structure of the UK economy has remained relatively stable over the relevant period.

An Input-Output table is a collection of economic accounts for a specific country[1] and for a given time period (generally one year). The IO system of accounts is based on the concept of double-entry book-keeping; each sale has a buyer and vice-versa, and can be viewed as a snapshot of an economy which reconciles the income, output and expenditure measurements of Gross Domestic Product (GDP).

[1] There also exist multi-regional Input-Output models (e.g. Oosterhaven, and Hewings 2014).

All of the economic transactions in the IO table are disaggregated into economic sectors or industries. The IO table itself details all of the inter-industry transactions within an economy and reflects the fact that all output of a sector requires inputs, in the form of materials, other goods, labour and capital. Each row of the matrix shows the sales and each column gives the purchases of the corresponding sector/ industry. In a standard IO format figures are usually measured in monetary values.

The UK model used in this report has 25 economic sectors, 10 of which are energy sectors. Among the energy sectors we identify 9 electricity generation sectors and one transmission electricity sector. The electricity generation sectors are those for Coal generation, Gas + Oil, Nuclear, Hydro, Biomass, Wind (Onshore), Wind Offshore, Other, Marine/solar generation. The full sectoral disaggrgation can be found in Table A.1 in the Appendix.

The IO model is a demand-driven general equilibrium framework that allows us to determine the macroeconomic impact of a change in final demand on the rest of the economy. The total impact can be decomposed into three elements: direct, indirect and induced effects. The analysis reported in this report is conducted under the general IO assumption of passive supply. Under this assumption, supply is able fully to satisfy changes in final demand, i.e., there are no supply-side constraints on factors of production. Furthermore, The IO model assumes no substitution between inputs. The price of commodities is fixed and technical coefficients do not change over time.

The model is technically constituted by a set of linear simultaneous equations representing how each sector's output is used by other sectors or agents in an economy. The matrix form of the IO tables enables a clear representation of the complex interdependencies between industry and final demand, as well as the inter- and intra-sectoral linkages. The advantage of the IO analysis is the possibility relatively simply to transform this system of equations to determine the "knock-on" impacts of a change in final demand for one sector on all other sectors, and thus on the economy as a whole.

The conventional model can be reformulated in order to express the output as a function of the exogenous final demand:

$$X = (I - A)^{-1}Y \qquad (1)$$

Where X, I, A and Y are respectively, the vector of output, the identity matrix, the matrix of input coefficients and final demand. $(I - A)^{-1}$ is the Leontief inverse matrix that summarises the economic structure of a country. The sum of the columns of this matrix identifies the backward linkage. In the framework of an IO model, production by a particular sector has economic effects on other sectors in the economy. If sector j increases its output, this means there will be increased demands from sector j (as a purchaser) for the outputs of the sectors whose goods are used as inputs to production in j. This is the direction of causation in the usual demand-side model, and the term backward linkage is used to indicate the interconnection of a particular sector with those sectors from which it purchases inputs.

Eq. (1) illustrates the dependence of sectoral output on final demand components (Miller and Blair, 2009). This relationship is used to determine the Type I (direct and indirect) and Type II (direct, indirect and induced) impact of a change in final demand on sectoral output. The Type I multiplier is derived from a model that is termed the *closed Leontief model*, while the Type II multiplier is derived from the *open Leontief model*. Multipliers are defined as the sum of elements in each column of the relevant Leontief inverse.

The direct effect is the initial effect that occurs after the change in final demand. This is a change in the supply of a given product by the same amount. Thus the demand for inputs required to produce the additional output will in turn result in additional demands for products. This is the indirect effect. While the direct impact only represents the change in output in the sector which is subject to the change in final demand, the indirect impact reflects the backward linkages of the directly impacted sector. For example, if final demand for the electricity sector increases, the direct impact is the increase in electricity output to adjust to meet the change in final demand. However, other sectors in the supply-chain of the electricity sector will be positively impacted by the increase in electricity output. These sectors' outputs will increase as an indirect impact, thus the total positive impact on the economy will be larger than the initial direct impact.

The induced effects are obtained by incorporating the household income-consumption relationship into the calculation of the Leontief inverse. This Type II multiplier where induced effects are obtained from changes in households' income, as a result of the change in final demand. As sectoral outputs adjust to the new vector of final demands, households' income (payment for labour inputs into production) adjusts as well. This change in income results in a change in household final consumption, a component of final demand.

Using equation (1) the impact of an exogenous increase in final demand, Y, on total output, X, it can be measured as follows:

$$\Delta X = (I - A)^{-1} \Delta Y \tag{2}$$

The impact on GDP is given by:

$$\Delta V = Z(I - A)^{-1} \Delta Y \tag{3}$$

where ΔV is the change in gross value added and Z is the value added ratio in a diagonal matrix. Similarly the impact on employment, given a diagonal matrix of employment coefficients L, is given by:

$$\Delta E = L(I - A)^{-1} \Delta Y \tag{4}$$

This model is based on a number of assumptions. The supply side is passive, so that the final demands drive economic activity. Prices are assumed to be fixed, and therefore no crowding out effects occurs. This approach assumes excess capacity (and thus also involuntary unemployment) or very elastic factor supplies, so that the economy can expand without putting any upward pressure on wages and prices. This implies that the supply side of the economy reacts passively to changes in demand.

In the simulation performed in this report we are assuming that technology (the Leontief coefficients), and thus the cost structure of each economic activity, is constant over time. Therefore, the results described in this report provide estimates for the economic impact in the absence of structural change in the economy over the period under consideration.

3 Simulation strategy

As already noted, we examine the economic impacts of the development of the offshore renewable energy industry for the UK economy. Offshore wind and tidal technologies are the key developments that are expected to exert economic impact in the period to 2020.

For offshore wind energy development we explore two alternative projections. The *Gradual growth* and the *Accelerated growth* scenarios[2]. Under the *Gradual growth* scenario, confidence in the long term remains as it is in 2014 and there is a gradual increase in the UK content of development expenditures. Under the *Accelerated growth* scenario, there is greater investment in the UK supply chain as well as greater UK content. This reflects confidence in UK-based companies that they can lead the market in cost and quality.

Both scenarios are related to both UK and non UK projects. UK projects represent expenditures within the UK from projects that are developed within UK territorial waters, while the non-UK projects reflect expenditures on the UK supply chain from all offshore wind projects elsewhere in the EU.

For each of the two growth scenarios we analyse two possible development states for both "Low" and "High" Offshore wind deployment. Under the Low Offshore wind deployment perspective the UK achieves 8GW of installed capacity by the end of 2020, while under the High deployment option we expect 15GW of installed capacity by 2020[3].

In our analysis of Tidal development we explore a single scenario in which we assume that about 100MW of capacity is installed by the end of 2020.
Expenditures on offshore wind devices fall within a number of different categories:

[2] Expenditures related to the development of the UK supply chain from 2014 to 2020 are obtained from BVG, 2014.

[3] The installed capacity to 2020 refers to the offshore wind scenario reported in DECC, 2013.

Development and project management; Nacelle and hub; Blades; Cables; Onshore cables; Foundation and substructure; Substation; Foundation installation and commissioning; Cable installation and commissioning; Turbine installation and commissioning; Onshore cable installation and commissioning; Substation installation and commissioning and operational expenditures. In each year, roughly between 25% and 33% of the total expenditures are costs related to the nacelle and hub. The other important component is the Foundation and substructure.

Table 1 Bridge Matrix

	Glass and Ceramics	Clay, cement, lime and plaster	Iron and Steel; non-ferrous metals	Generation -Gas + Oil	Electricity distributio n and supply	Generatio n - Wind Offshore	Constructi on	Other Manufactur ing and wholesale retail trade	Air Transport	Other Transport	Services
Development and project management	0%	0%	0%	2%	5%	0%	0%	0%	0%	10%	83%
Nacelle and hub	0%	0%	73%	2%	10%	0%	0%	5%	0%	5%	5%
Blades	73%	0%	0%	2%	10%	0%	0%	5%	0%	5%	5%
Tower	0%	0%	78%	2%	10%	0%	0%	5%	0%	5%	0%
Export cables	2%	0%	40%	2%	10%	0%	0%	38%	0%	5%	3%
Array cables	2%	0%	35%	2%	10%	0%	0%	41%	2%	5%	3%
Onshore cables	2%	0%	25%	2%	10%	0%	0%	53%	0%	5%	3%
Foundation	0%	20%	58%	2%	10%	0%	0%	0%	0%	5%	5%
Electrical infrastructure - offshore	0%	0%	80%	2%	10%	0%	0%	3%	0%	0%	5%
Electrical infrastructure - onshore	0%	10%	70%	2%	10%	0%	0%	3%	0%	0%	5%
Foundation installation and commissioning	0%	0%	20%	20%	0%	0%	0%	5%	0%	50%	5%
Export cable installation and commissioning	0%	0%	20%	20%	0%	0%	0%	5%	0%	50%	5%
Array cable installation and commissioning	0%	0%	20%	20%	0%	0%	0%	5%	0%	50%	5%
Turbine installation and commissioning	0%	0%	20%	20%	0%	0%	0%	5%	0%	50%	5%
Onshore cable installation and commissioning	0%	0%	15%	5%	0%	0%	25%	0%	0%	50%	5%
Offshore substation installation and commission	0%	0%	20%	20%	0%	0%	0%	5%	0%	50%	5%
Onshore substation installation and commissioni	0%	0%	20%	5%	0%	0%	30%	0%	0%	40%	5%
Operational cost	0%	0%	0%	0%	10%	60%	0%	0%	4%	0%	26%

Each of these categories of expenditure is then allocated to an appropriate Standard Industrial Classification (SIC) using a bridge matrix[4] reported in Table 1. This is necessary because the Input Output table and model employ this official UK classification of sectors. Thus Table 1 shows a matrix of coefficients that allow us to convert category of expenditures into economic sectors. For instance, 73% of expenditures associated to Blades are allocated to the Glass and Ceramic sector. Operational cost are allocated primarily to the Offshore wind Generation sector (60%) and the remaining costs are attribute to the Services sector (26%), the Electricity transmission sector (10%) and Other Transport (4%).Note that the direct impact of installation is heavily concentrated in two sectors, *Iron and steel* and *Transport*.

The aggregate level of expenditures for the UK (for total UK and non-UK projects) associated with offshore wind energy scenarios are reported in Figure 1. These are presented for the High and Low Offshore wind options (15GW and 8GW of capacity by 2020 respectively) for both the *Gradual* and *Accelerated Growth* scenarios.

[4] The bridge matrix has been constructed by BVG associates.

Figure 1. Expenditures on Offshore Wind Development: Gradual and Accelerated growth for the 8GW and 15GW scenarios

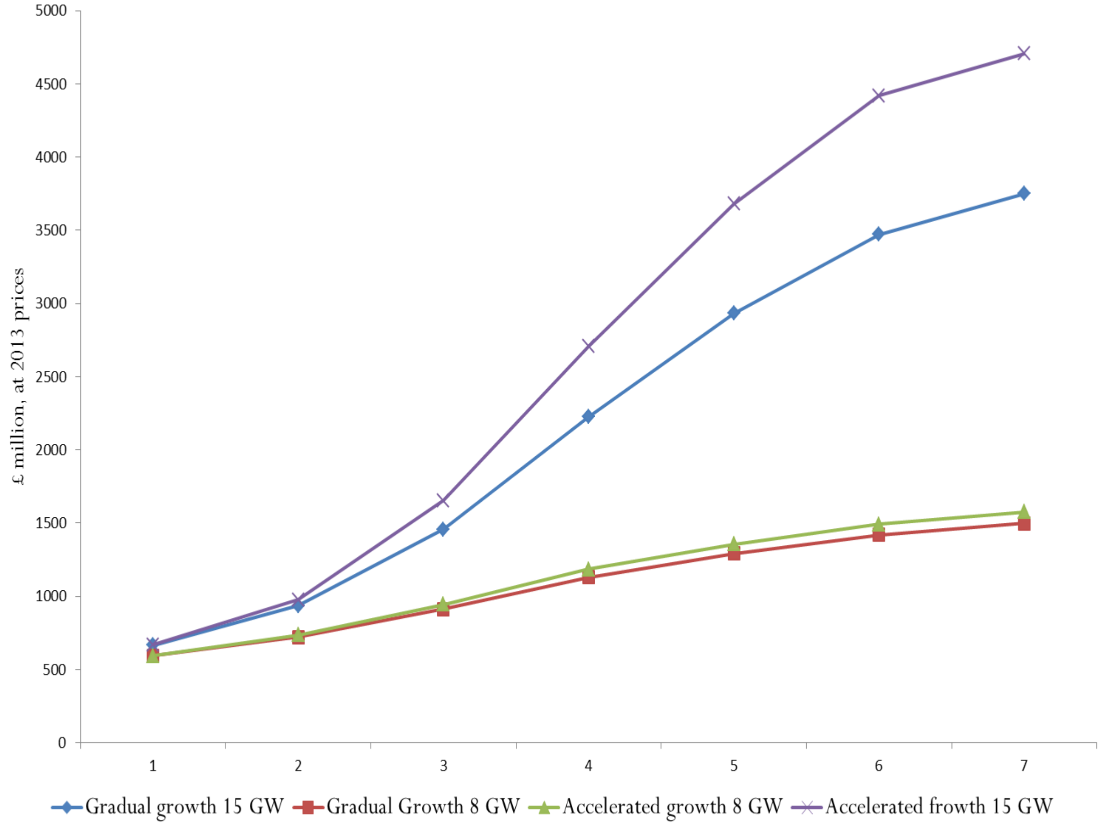
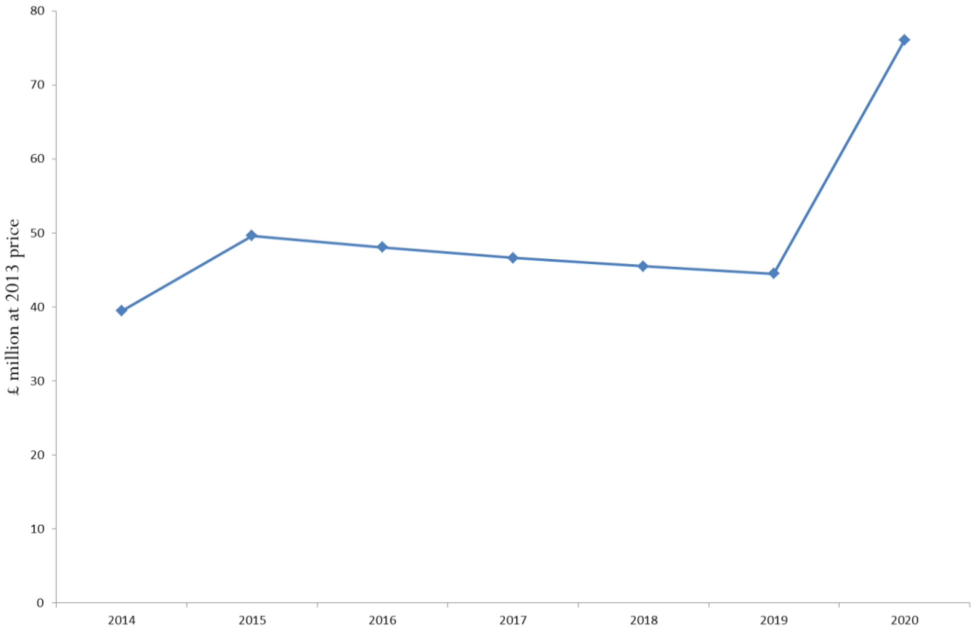


Figure 2. Expenditures on Tidal develoment



Expenditures incurred by the development of the offshore wind energy industy increase in each year. Under the accelerated growth scenario the expenditures are higher than in the gradual growth scenario, reflecting the more optimistic perspective on the development of the UK supply chain. Naturally, the total level of expenditures for the High Offshore wind energy scenario is greater than for the Low Offshore wind energy case (since capacity by 2020 in the former is nearly double that of the latter). The gap between the two scenarios increases in each year. This will, of course, be reflected in the simulation results as well.

In Figure 2 we show the aggregate value of expenditures on the development and deployment of Tidal devices. Total expenditures in the Tidal development scenario fall slightly after the first two periods, but then increase rapidly in the last two periods of the analysis.

In each of the 7 years from 2014 to 2020 the appropriate sectorally disaggregated installation and operation expenditures are entered as a stimulus to the demand side of the model. The model is run forward for 7 periods so that the sole ''disturbance'' to the UK economy is the set of expenditures required to establish the 3GW capacity for marine energy and 8 GW or 15 GW capacity for offshore wind energy. It is important to note that we are not using the IO analysis as a forecasting model in this process. The economy is assumed to be initially in equilibrium (steady state equilibrium) so that if the model is run forward with no expenditure injections it would simply replicate the base year values. The simulation results reported here are all measured relative to constant base values. Accordingly, all of the changes are directly attributable to the impact of the positive demand disturbance associated with the creation of additional capacity in the offshore wind or marine energy sectors.

In the next two sections we separately analyse the likely economic impacts of the offshore wind scenarios and the tidal scenario. In each case, we discuss results by reporting changes in key economic variables such as, output, GDP and employment. In general, unless otherwise specified, we report figures of output and gross value added (GVA) in millions of pounds at constant 2013 prices.

The GVA figures reported in the charts and tables refer to the sum of capital and labour income. (In the computation of the GVA we are therefore not accounting for net indirect taxes.) The employment impact is reported in terms of full-time-equivalent (FTE) jobs. Total production (output) is given by the sum of intermediate sales and final demand. The latter includes the exports of goods and services to both the Rest of Europe and Rest of the World.

All of our reported results relate to Type II multipliers, and so include induces, as well as direct and indirect effects. The model determines the value of a number of multipliers, for: total output, GVA and employment. In each case these are determined by the ratio of the total to the direct impact. For example, the GVA multiplier figures are determined as the total GVA effects (direct plus indirect plus induced effects) divided by the direct GVA impacts. The direct GVA impact is given by the total demand disturbance multiplied by the GVA-output coefficients in each sector. Similarly, the employment multiplier figures are determined as the total employment effects divided by the direct jobs. The direct jobs are obtained by multiplying the employment-output coefficient by the total demand disturbance.

In our discussion of the sectoral results, we distinguish between two types of sectors: those where demand for output has increased directly, which we term the "directly stimulated" sectors; those whose output has not been increased directly by the demand disturbance, the "non-stimulated" sectors[5]. The "non-stimulated" sectors may be affected by the demand disturbance through the indirect effect of providing inputs to the sectors that experience a direct stimulus to demand (Miller and Blair, 2009). Therefore a single directly simulated sector not only benefits from its own direct monetary injection, but also enjoys the indirect effects coming from the other stimulated sectors and the induced effects from the stimulus to employment, income and consumption.

We begin by analysing the impact of the development of offshore wind and then consider the impact of marine development.

For both technologies, we focus initially on the economic impact of the *Gradual growth* scenario, and within Offshore wind we consider both the Low and High offshore wind energy capacities. (Recall that the former assumes an installed capacity of 8 GW by 2020, and the latter assumes 15 GW.) Differences in capacity are, of course, reflected in the size of the demand disturbance. However, there are also some differences in the sectoral allocation of the expenditure changes among economic sectors. For example in 2020, under the High Offshore wind scenario the total level of expenditure is £2253 million higher than the Low Offshore wind Scenario. As for the sectoral distribution of the shock, for instance under the High offshore wind energy scenario we observe an increase in the share of expenditures allocated to the *Iron and Steel; non-ferrous metals* sectors. The15 GW target need to be achieved with more expenditures on nacelle and blade. However, the supply chain for nacelle components remains the same as the low scenario although a higher volume is now required.

We then discuss and compare the results obtained for the *Accelerated growth* scenario. Again both High and Low Offshore Wind cases are considered. However, we again explore only one scenario for Tidal.

4 The macroeconomic impacts of offshore wind development in UK

Given the size and the distribution of the expenditures across economic sectors, we would expect increasingly positive changes in key economic variables and a significant impact on the offshore wind and other renewable energy sectors.

[5] These can also be termed: perturbed and non-perturbed sectors or directly and non-directly shocked sectors.

Macroeconomic impacts under Gradual Growth

Results for the Gradual growth scenario are reported in Table 2. In the Gradual growth scenario for the 8 GW installed capacity, output, GDP and employment increase in each year as a consequence of a continuous and increasing expenditure shock. For instance, in 2014 total output rises by 0.12% and by 0.30% at the end of the period in 2020. The percentage changes in GVA and total employment are slightly lower.

Table 2 The macroeconomic impact of the Gradual growth scenario

	8 GW - Gradual Growth							15 GW - Gradual Growth						
	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
Demand disturbance (£ million)	593	722	914	1129	1293	1419	1498	666	935	1457	2225	2933	3472	3751
Direct FTE Jobs	4695	5653	7008	8584	9822	10791	11383	5436	7529	11311	16942	22187	26240	28326
Direct GVA impact (£ million)	237	282	345	416	475	522	555	272	368	539	789	1026	1215	1332
Impact on total production														
£ milion	2550	3099	3911	4828	5527	6074	6418	2857	3995	6194	9439	12443	14745	15966
% change from base year value	0.12%	0.14%	0.18%	0.22%	0.26%	0.28%	0.30%	0.13%	0.19%	0.29%	0.44%	0.58%	0.69%	0.74%
Output Multiplier - Type II	4.30	4.29	4.28	4.27	4.28	4.28	4.28	4.29	4.27	4.25	4.24	4.24	4.25	4.26
Impact on GVA														
£ milion	894	1081	1353	1661	1900	2088	2210	1008	1398	2137	3225	4240	5024	5456
% change from base year value	0.09%	0.10%	0.13%	0.16%	0.18%	0.20%	0.21%	0.10%	0.13%	0.21%	0.31%	0.41%	0.48%	0.53%
GVA Multiplier - Type II	3.77	3.83	3.93	3.99	4.00	4.00	3.98	3.71	3.79	3.96	4.09	4.13	4.13	4.10
Impact on employment														
FTE Jobs	19400	23539	29621	36518	41802	45924	48487	21923	30620	47190	71651	94279	111622	120686
% change from base year value	0.08%	0.10%	0.12%	0.15%	0.18%	0.19%	0.20%	0.09%	0.13%	0.20%	0.30%	0.40%	0.47%	0.51%
Employment Multiplier - Type II	4.13	4.16	4.23	4.25	4.26	4.26	4.26	4.03	4.07	4.17	4.23	4.25	4.25	4.26

In each year the total output multiplier generated by the model is around 4.3. This means that given a direct injection of £593 million in 2014 the resulting increase in output amounts to £2550 million, while in 2020 a direct injection of £1498 generates an increase in total output of £6418 million. The stimulus to expenditures clearly generates significant indirect and induced effects.

Indirect effects are obtained as the difference between the total and the direct injections and are the results of the linkages existing between a sector subject to the shock and the other sector in the economy. For instance, in 2014 the direct injection allocated to the *Generation-offshore wind* sector equates to £157 million. Given a multiplier of 4.66 (identified as the sum in column of the Leontief Matrix) the total increase in output generated by this sector in the whole economy amounts to £731 million. So some 10% of the total output effects are the results of increasing capacity only in the offshore wind industry. This can be seen in Table 3 where backward linkages are reported for the 2014 and 2020.

Under this (Low Offshore Wind) scenario, the effect on the UK economy in 2014 is an increase in GVA of £894 million, with an additional 19400 FTE jobs. At the end of the period GVA and employment increase significantly. By 2020 GVA increases by £2210 million and in the same year the aggregate level of additional jobs increases by 48487 FTEs.

Table 3 Backward linkages under the Gradual growth scenario

	Type II multiplier	Low Offshore wind: Demand disturbance £ million		Low Offshore wind: Backward linkages £million		High Offshore wind: Demand disturbance £ million		High Offshore wind: Backward linkages £million	
Low offshore wind		**2014**	**2020**	**2014**	**2020**	**2014**	**2020**	**2014**	**2020**
Glass and Ceramics	4.45	14.67	60.48	65.32	269.24	16.24	185.80	72.30	827.09
Clay, cement, lime and plaster	4.12	4.63	20.28	19.07	83.50	5.49	112.67	22.61	463.92
Iron and Steel; non-ferrous metals	4.24	119.92	453.55	508.35	1922.67	131.02	1330.36	555.40	5639.66
Generation -Gas + Oil	3.43	25.36	54.25	87.03	186.21	26.87	169.86	92.24	583.00
Electricity distribution and supply	3.62	43.98	123.84	159.14	448.11	48.43	290.52	175.25	1051.25
Generation - Wind Offshore	4.66	157.04	335.27	731.48	1561.70	157.04	513.07	731.48	2389.86
Construction	4.38	8.23	13.38	36.04	58.59	8.76	51.13	38.37	223.82
Other Manufacturing and wholesale retail trade	4.43	13.30	42.45	58.88	187.97	14.41	115.97	63.79	513.46
Air Transport	3.61	10.52	22.62	38.02	81.77	10.54	34.87	38.09	126.04
Other Transport	4.54	72.14	144.69	327.24	656.34	78.92	466.73	358.00	2117.25
Services	4.23	122.91	227.47	519.53	961.49	167.91	480.39	709.76	2030.59
Total		592.69	1498.29	2550.11	6417.60	665.63	3751.36	2857.28	15965.94

Under the High offshore wind energy scenario (15GW installed capacity by 2020), over the period from 2014 to 2020 the GVA multiplier varies between 3.71 and 4.13. By 2014 the absolute increase in GVA is £1008million while the contributions of the offshore wind developments to the UK GDP in 2020 increases to £5456 million. In terms of percentage changes from base year values, GVA increases by 0.10% in 2014 and by 0.53% in 20120.

The results of the model simulations suggest that under the High offshore wind energy scenario, the absolute level of employment reaches 21923 additional FTE jobs by 2014 and 120658 by 2020. This represents an increase of 0.09% and 0.51% relative to base year values of total employment in in 2014 and 2020 respectively. The employment multiplier lies within the range 4.03 to 4.26 over the period.

Naturally, given the differences in capacities by 2020, offshore wind investments are expected to produce significantly larger economic impacts under the High offshore wind energy scenario than under the Low counterpart. In each period the percentage change from base year values in output, GVA and employment are larger than those observed under the Low offshore wind energy scenario.

However, the Type II output multipliers generated by the model are slightly lower in the High than in the Low Offshore wind energy scenario. For example, in 2020 the output multiplier generated under the Low offshore wind energy scenario is 4.28 compared to 4.26 under the High offshore wind energy case. This difference is mainly due to the different sectoral allocation of the expenditures in each case. As noted above, under the High offshore wind energy scenario, the share of expenditures allocated to the Iron and Steel; non-ferrous metals sector is now slightly lower and this sector has very high backward linkages. This is the reason why the size of the multiplier generated by the model is slightly lower under the High Offshore Wind energy scenario.

Macroeconomic impacts under Accelerated Growth

In Figures 3 and 4 we plot the absolute value of GVA and additional FTE jobs for the *Accelerated* and *Gradual Growth* scenarios, respectively. Of course, under the *Accelerated Growth* scenarios we generally observe a larger effect in GVA and employment compared to the *Gradual* scenario. For example, as we show in Table 4, by 2020 the expected increase in GVA and employment is £6765 million and 150642 FTE jobs under the High Offshore Wind development case. In contrast, under the Low Offshore Wind energy scenario, by 2020 the GVA change is £2317 million and the number of additional FTE jobs is 50917.

Table 4 The macroeconomic impact of the Accelerated growth scenario

	8 GW - Accelerated Growth							**15 GW - Accelerated Growth**						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Demand disturbance (£ million)	593	736	946	1183	1357	1492	1576	669	976	1654	2706	3681	4420	4707
Direct FTE Jobs	4696	5742	7214	8937	10249	11278	11905	5458	7793	12659	20229	27340	32731	34870
Direct GVA impact (£ million)	237	286	353	431	492	543	578	272.86	379.95	595.40	924.50	1238.25	1484.10	1604.80
Impact on total production														
£ milion	2550	3157	4045	5054	5797	6381	6745	2871	4166	7020	11452	15577	18719	19972
% change from base year value	0.12%	0.15%	0.19%	0.24%	0.27%	0.30%	0.31%	0.13%	0.19%	0.33%	0.53%	0.72%	0.87%	0.93%
Output Multiplier - Type II	4.30	4.29	4.28	4.27	4.27	4.28	4.28	4.29	4.27	4.24	4.23	4.23	4.24	4.24
Impact on GVA														
£ milion	894	1100	1396	1735	1988	2189	2317	1013	1454	2407	3881	5263	6321	6765
% change from base year value	0.09%	0.11%	0.13%	0.17%	0.19%	0.21%	0.22%	0.10%	0.14%	0.23%	0.37%	0.51%	0.61%	0.65%
GVA Multiplier - Type II	3.77	3.85	3.95	4.03	4.04	4.03	4.01	3.71	3.83	4.04	4.20	4.25	4.26	4.22
Impact on Employment														
FTE Jobs	19402	23974	30613	38193	43804	48202	50917	22027	31884	53358	86701	117748	141343	150642
% change from base year value	0.08%	0.10%	0.13%	0.16%	0.18%	0.20%	0.21%	0.09%	0.13%	0.22%	0.36%	0.49%	0.59%	0.63%
Employment Multiplier - Type II	4.13	4.17	4.24	4.27	4.27	4.27	4.28	3.71	3.83	4.04	4.20	4.25	4.26	4.22

Under the Low Offshore Wind development scenario the absolute level of GVA is very similar under both the *Gradual* and the *Accelerated growth* scenarios, while under the 15 GW installed capacity the differences of the GVA simulation results between the *Gradual* and the *Accelerated* scenarios become larger over time.

Until now we have only considered the impact derived from a demand disturbance that includes both installation and operational expenditures. In Figures 5a and 5b we show the evolution of GVA changes obtained when we separately simulate the impacts of capital and operational expenditures. Operating expenditures are small relative to the capital costs in the period under consideration. Naturally the impact obtained when we only consider the capital expenditure is greater than the impact of operational expenditures alone. This reflects the lower share of operational expenditures of total expenditures over the simulation period. The GVA impact of operational expenditures increases faster after 2017 for the case of high offshore wind energy development (Fig. 5b). However, from the same year the output change increases at a lower rate for the case of capital expenditures (Fig. 5a). We observe a reduction in the share of capital expenditures in favour of more operational expenditures as a consequence.

In Figure 6 we report the GVA evolution over time for each of the category of expenditures. To simplify the analysis we only report the impact obtained under the *Accelerated Growth* for the two alternative installed capacities[6]. We observe that under the Low Offshore Wind scenario *Nacelle and hub,* and *OPEX* are the expenditures that make the greatest contribution to the overall GVA impact. However, under the High Offshore Wind scenario the contribution of *OPEX* expenses is now reduced while the GVA impact resulting from *Foundation* has now increased. *Nacelle and hub* expenditures continue to generate a greater share of the total impact.

Figure 3 GVA impact (£ million, at 2013 prices) under the Gradual and Accelerated growth cases for the 8GW and 15GW scenarios

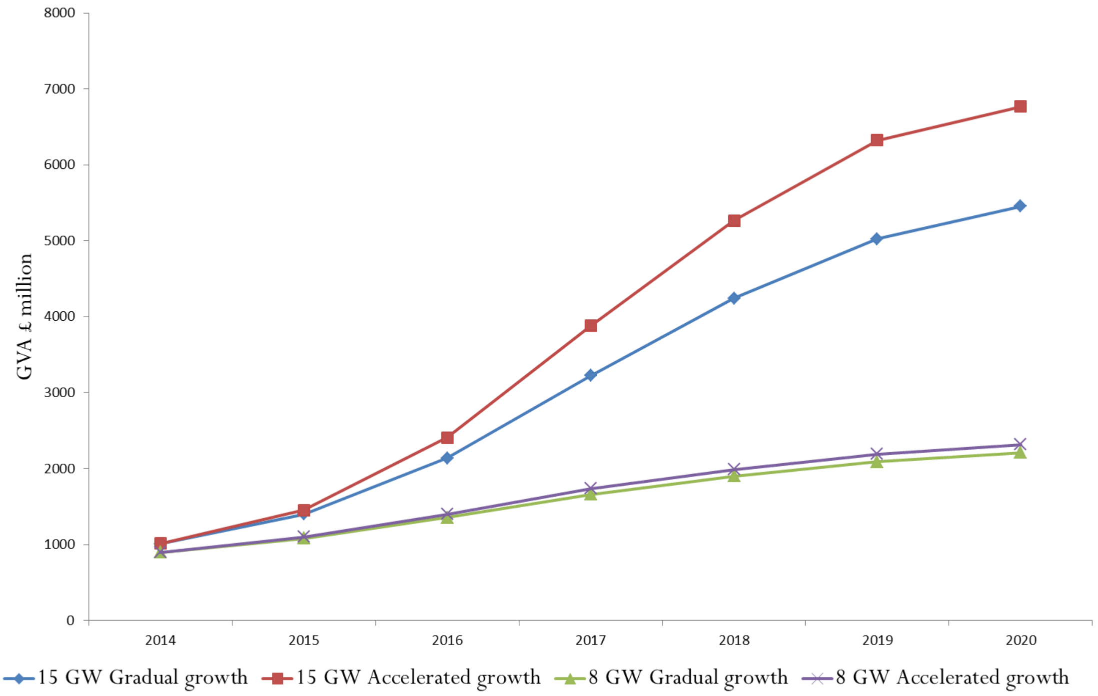
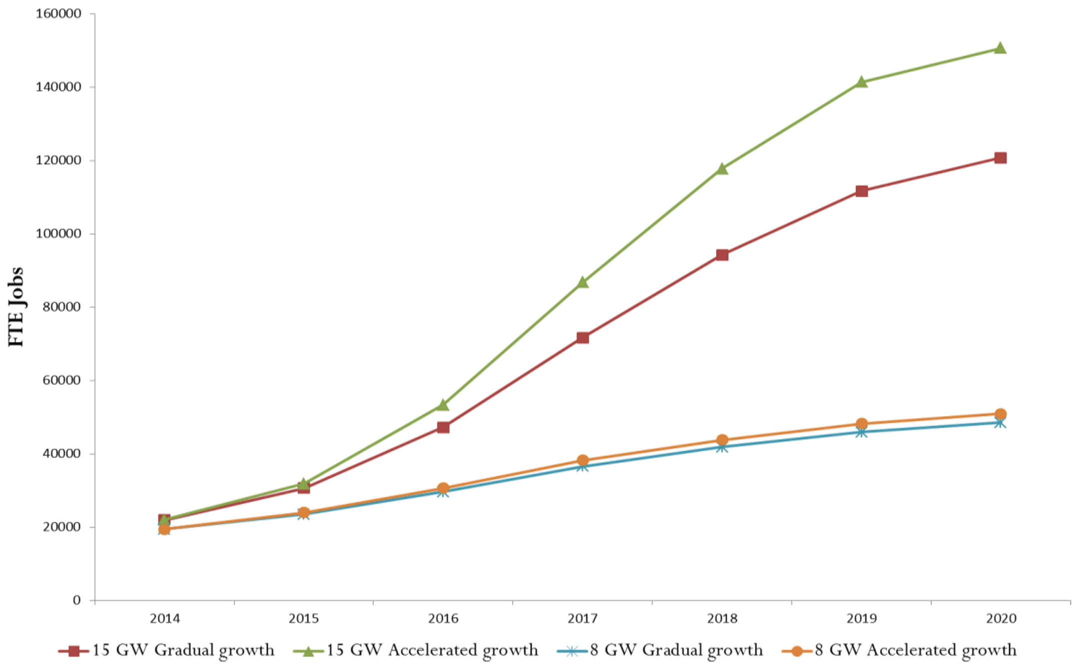


Figure 4 Employment impact (FTE jobs) under Gradual and Accelerated scenario for the 8GW and 15GW scenarios

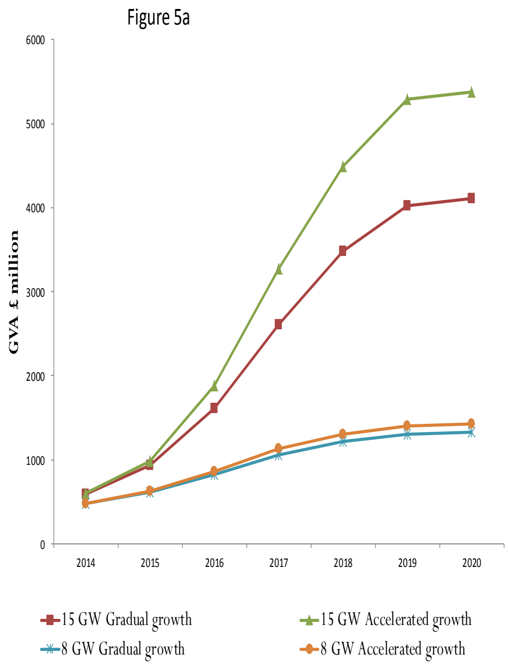
[6] The impact related to the Gradual growth scenario is reported in Appendix



The sectors that benefit most from the development of the offshore wind energy in UK are the *Service* sector and the *Other Manufacturing* sector. This can be seen in Figure 7 where the sectoral GVA impact obtained under the *accelerated growth*-15 GW scenario is plotted. The *Service* and the *Other Manufacturing* sectors only benefit from a direct demand disturbance but also enjoy very high linkages with the other sectors directly stimulated. They enjoy strong linkages especially with another sector directly shocked that is, the *Iron and Steel; non-ferrous metals* sector which receives a huge direct impact in all of the 4 cases analysed here. For instance, a direct injection of £133 million (which corresponds to the demand disturbance we have under the *Accelerated growth*-15 GW development) in the *Iron and Steel sector* is able to generate an increase in output of £94.90 million and £110.69 million in the *Other-manufacturing* sector and in the *Service* sector respectively. These are the resulting indirect plus induced effects.

Among the non-stimulated sectors the *Gas Mining and quarrying*, and *Other traded e.g. Food and drink* are those sectors that more than others enjoy links with the sectors directly perturbed.

Figure 5 CAPEX and OPEX GVA impact under the Gradual and Accelerated growth scenario for the 8GW and 15GW cases.



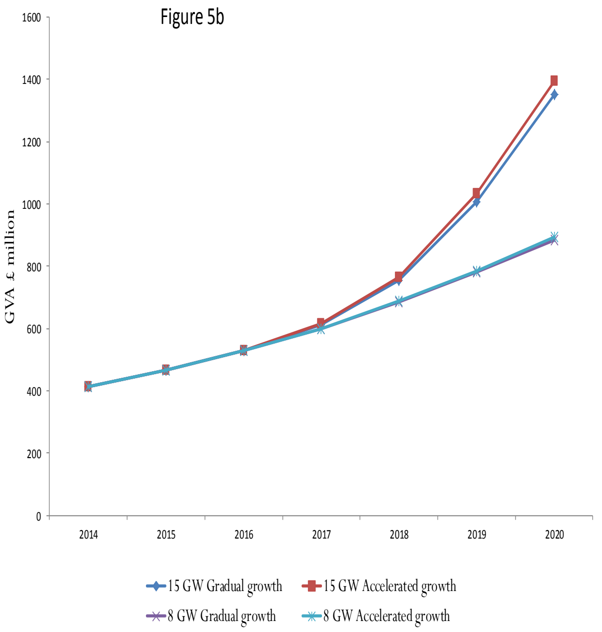
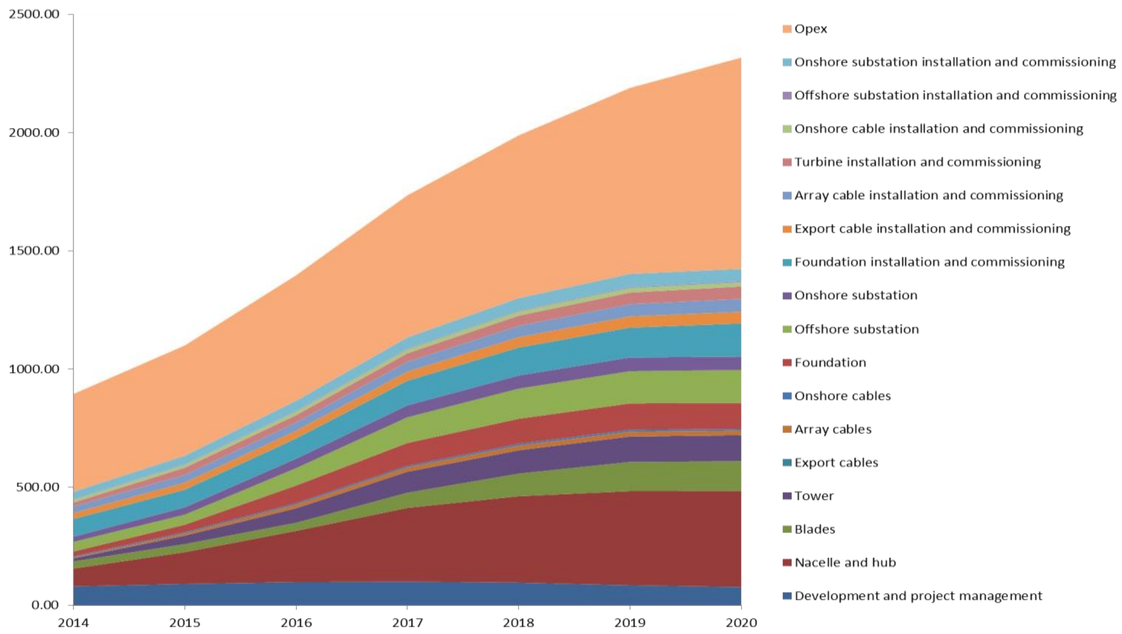


Figure 6. The GVA impact of each category of expenditures under the accelerated growth scenario

6a) 8GW



6b) 15GW

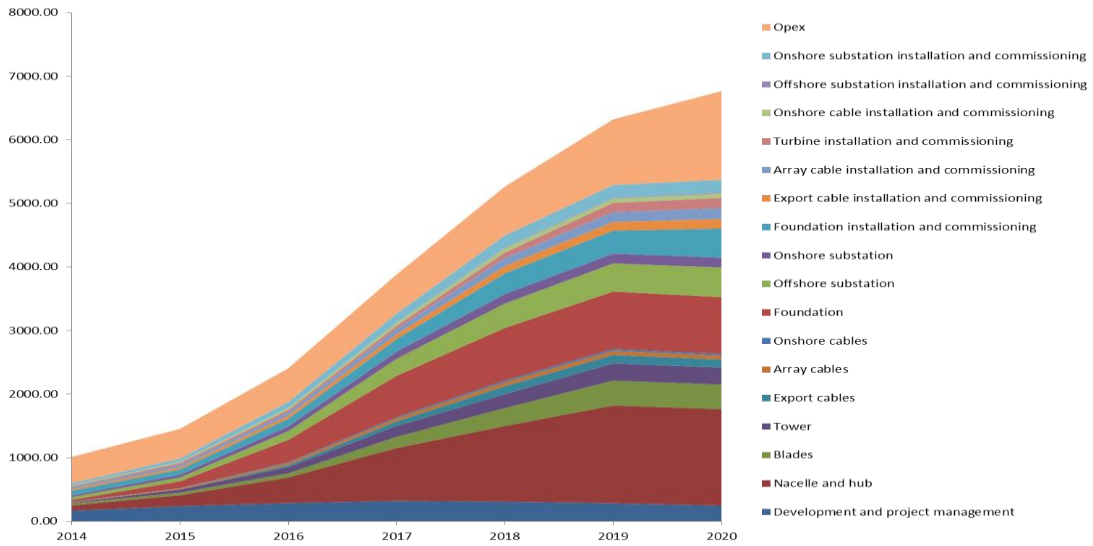
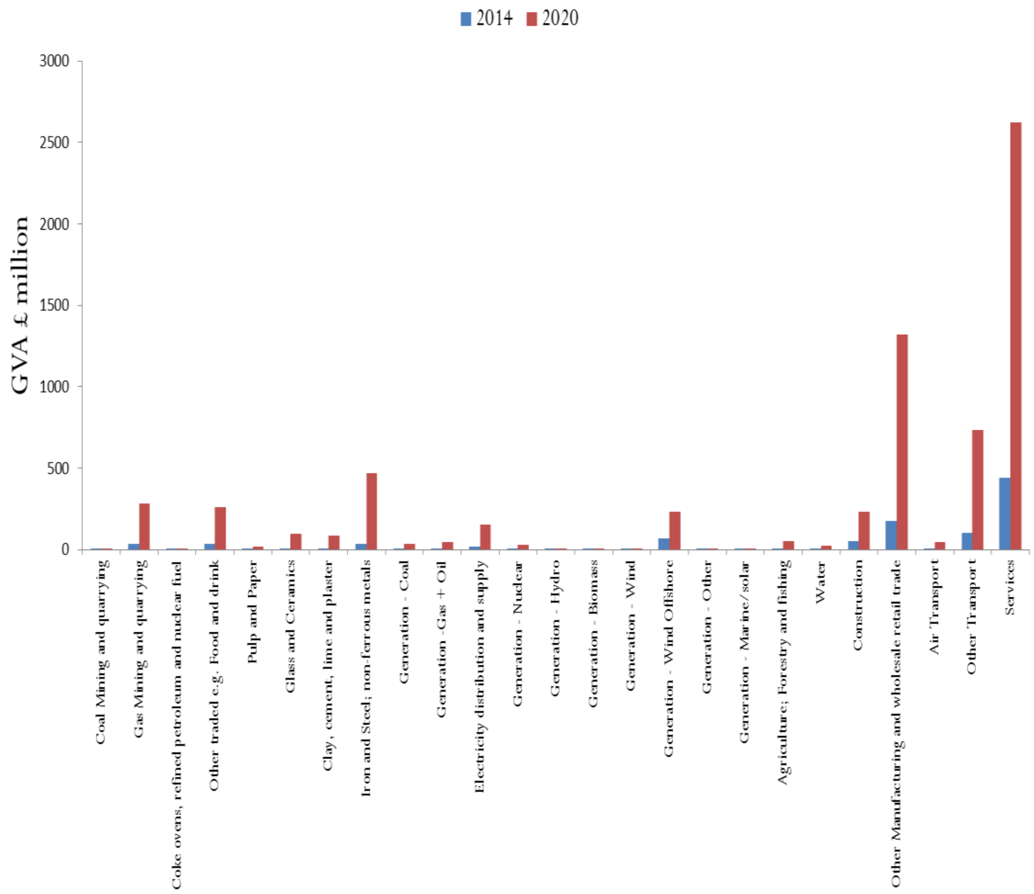


Figure 7. The sectoral GVA impact under the *Accelerated growth* 15 GW scenario



5 The macroeconomic impact of marine energy development in the UK

In the period 2014-2019, the monetary injection is less than £50 million in each year, however in the last period the direct impact is about £76 million. The total impact on output, GDP and employment are reported in Table 5. In the first year of the shock a direct injection of £39 million is able to generate a total increase in output of £167 million that equates to a multiplier effect of 4.22. Therefore, the indirect plus induced effects, that is to say, the total effect minus the direct injection is £127 million. The change in GDP associated with this simulation is £56 million and 1259 additional FTE jobs.

The greater impact is recorded in the year 2020 where a direct injection of £76 million generates an increase in total output of £323 million. The multiplier produced by the model is 4.24. This is slightly less than the one obtained in the first and in the second years of the shock as reported in Table 5. However, the indirect effects are still significant and equal to £ 247 million.

Table 5 The macroeconomic impact of marine energy development

	2014	2015	2016	2017	2018	2019	2020
Demand disturbance £million	39	50	48	47	45	44	76
Direct FTE Jobs	296	376	367	357	355	346	588
Impact on total production							
£ milion	167	210	203	198	193	189	323
% change from base year value	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Output Multiplier - Type II	4.22	4.23	4.24	4.24	4.25	4.26	4.24
Impact on GVA							
£ milion	56	71	69	67	66	65	109
% change from base year value	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
GVA Multiplier - Type II	4.32	4.30	4.24	4.20	4.10	4.03	4.18
Impact on employment							
FTE Jobs	1259	1588	1542	1499	1470	1439	2459
% change from base year value	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Employment Multiplier - Type II	4.26	4.22	4.20	4.20	4.15	4.16	4.18

There are sectors that contribute more than others to the total impact in the economy. In Table 6 we consider the capacity of the directly impacted sector to generate an increase in output for the total economy. Given that the distributional allocation of the monetary injection is similar in each year, in Table 6 we only report results related to the last period of the shock.

The shock is concentrated in 11 sectors only. In the first column we show the multiplier impact of the simulated sectors (the sum in column of the Leontief matrix) while in the second we report the total effect associated to each of these sectors. We can see that *Construction* and the *Offshore wind* sectors have the highest backward linkage type II multiplier. However, the monetary injection to these sectors is small and so, does not generate a significant output effect. Iron and Steel; non-ferrous metals exhibits the largest direct effect (£128.9 million) and consequently generates a larger impact in the whole economy. This sector is able to produce more than the 40% of the total impact in the whole economy.

In Table 6 we have seen the capacity of the directly impacted sector to generate an increase in output for the total economy. In the following analysis we focus on the specific increase in output generated by the shock in each sector of the economy. In Figure 8, we report the direct and indirect plus induced impact of the directly and non-directly shocked sectors for the year 2020. We again start by analysing the sector directly shocked.

Table 6 Backward linkages for Tidal development

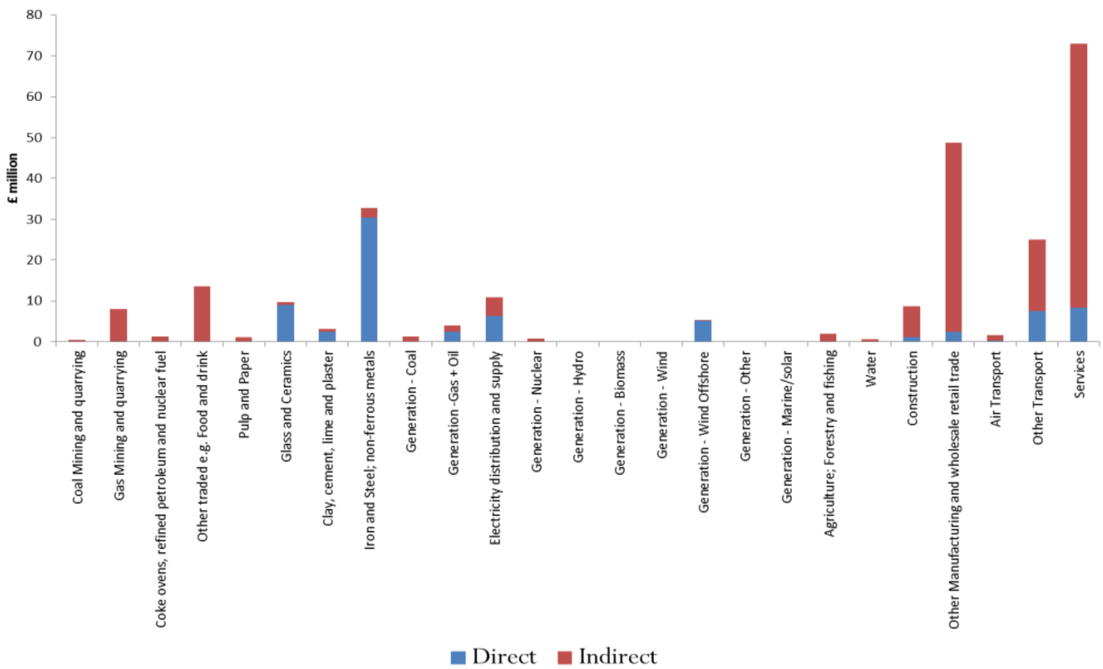
	Type II multiplier	Backward linkage £ million
Glass and Ceramics	4.45	39.93
Clay, cement, lime and plaster	4.12	10.51
Iron and Steel; non-ferrous metals	4.24	128.90
Generation -Gas + Oil	3.43	8.65
Electricity distribution and supply	3.62	23.26
Generation - Wind Offshore	4.66	24.04
Construction	4.38	5.21
Other Manufacturing and wholesale retail trade	4.43	10.85
Air Transport	3.61	1.24
Other Transport	4.54	34.45
Services	4.23	35.66
Total		322.69

Within the sector directly shocked, as we have seen in Table 6, the *Iron and Steel; non-ferrous metals* is the sector that benefits more than others from marine energy development. In this sector, total output increases by £32.71 million. The contribution of the indirect component is small and equal to 2.31 million. The indirect component reflects the linkage of this sector with the other sectors directly shocked and not the capacity of the sector to generate benefits for the whole economy (this has been seen in Table 5).

The sector directly shocked that records the largest indirect plus induced effects is the *Other Manufacturing and wholesale retail trade*. The effect observed amounts to £46.30 million and the total effect is about £48.75million. This means that roughly 95% of the total increase in output in this sector is determined by the linkages existing between this sector and the other sectors subjected to the stimulus. In particular, *Other Manufacturing* and *Wholesale retail trade* is highly linked with the *Iron and Steel; non-ferrous metals*.

Among the non-stimulated sectors, the *Gas Mining and quarrying* and the *Other traded e.g. Food and drink* sectors report the greater increases in output. The output in the *Gas Mining and quarrying* increases by £8.06 million while the change in output in the *Other traded sectors* is about £13.5 million. The rise in outputs in these sectors is only generated by the linkages with the sectors directly shocked. Specifically, the *Gas Mining and quarrying* sector has high linkage with the *Generation -Gas + Oil* while for the *Other traded sectors* are observed important linkage with the *Iron and Steel; non-ferrous* metals and the *Other Manufacturing and wholesale retail trade*.

Figure 8. The direct, indirect and induced effects of marine energy



6 Conclusions

The use of renewable technology to generate electricity has grown rapidly across the UK in the last decade. However, the development of an offshore renewable energy industry in the UK requires further substantial investment expenditures. In this report we explore the potential economic and environmental benefits that these expenditures could have on the UK economy.

We assess the macroeconomic, or system-wide, impacts using an input-output modelling approach. The results that we report are entirely attributable to the additional investment and operating expenditures required for the development of the offshore renewable energy sector. The results show that that the development of an offshore renewable energy sector can have substantial and beneficial impacts on output, GDP and employment over the period up to 2020. For example, by 2020 we estimate that the number of FTE jobs created is likely to lie in the range of 120,686 to 150,642 full-time equivalent jobs for the installation of 15 GW of offshore wind capacity and around 2,460 FTE jobs for the installation of 0.1 GW of marine capacity.

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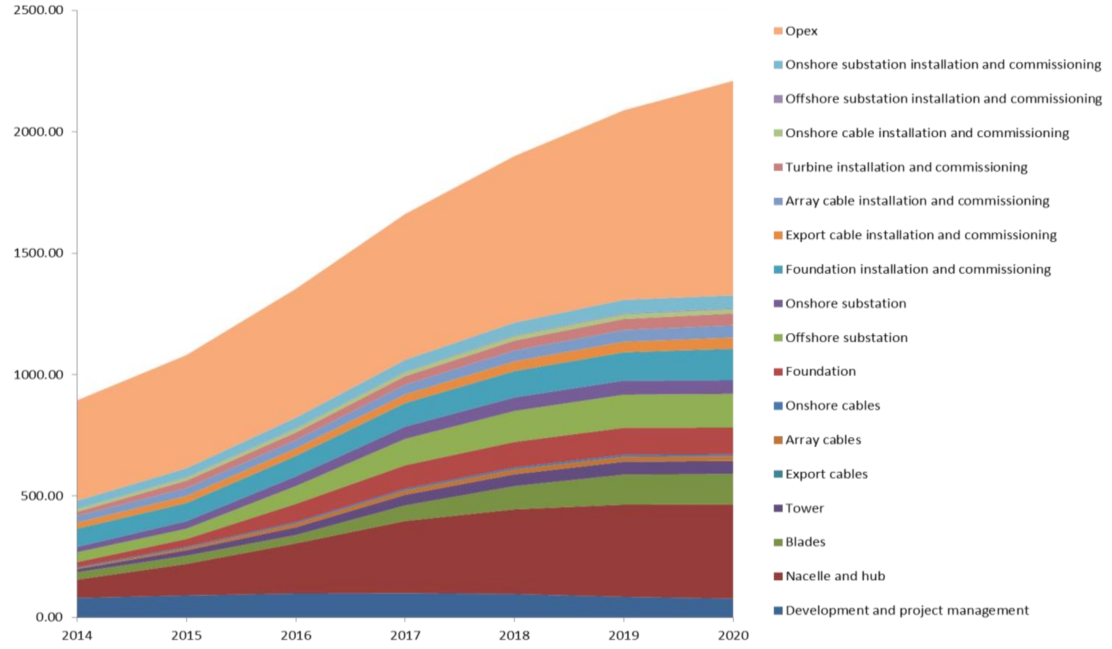
Appendix

Table A.1. Sectoral disaggregation of the UK model

	Sector Title	123 sectors
1	Coal Mining and quarrying	4
2	Gas Mining and quarrying	5, 86
3	Coke ovens, refined petroleum and nuclear fuel	35
4	Other traded e.g. Food and drink	6-19, 21-31, 34, 36-38, 77-80
5	Pulp and Paper	32-33
6	Glass and Ceramics	49-50
7	Clay, cement, lime and plaster	51-52
8	Iron and Steel; non-ferrous metals	53-56
9	Generation - Coal	85
10	Generation -Gas + Oil	85
11	Electricity distribution and supply	85
12	Generation - Nuclear	85
13	Generation - Hydro	85
14	Generation - Biomass	85
15	Generation - Wind	85
16	Generation - Wind Offshore	85
17	Generation - Other	85
18	Generation - Marine/solar	85
19	Agriculture; Forestry and fishing	1-3
20	Water	87
21	Construction	88
22	Other Manufacturing and wholesale retail trade	20, 39-48, 57-76, 81-84, 89-92
23	Air Transport	96
24	Other Transport	93-95, 97-99
25	Services	100-123

Figure A1. The GVA impact of each category of expenditures under the gradual growth scenario

6a) 8GW



6b) 15GW