Appendix 5.1

Sustainability: Carbon Balance

Appendix: Sustainability: Carbon Balance

Contents

1.0 Introduction

1.0.0.1 Tidal Lagoon Swansea Bay Plc. (TLSB) is proposing the development of a Tidal Lagoon at Swansea Bay (the Project) for the purpose of generating electricity. The development is proposed for Land at Queens Dock, land at Crymlyn Burrows and Land at Baglan Bay, Swansea and a marine area within Swansea Bay. The Project is a hydroelectric scheme. Hydroelectric power is the energy derived from flowing water. This can be from rivers or man-made installations. Turbines placed within the flow of water extract its kinetic energy and convert it to mechanical energy. This causes the turbines to rotate at high speed, driving a generator that converts the mechanical energy into electrical energy. The amount of hydroelectric power generated depends on the water flow and the vertical distance (known as 'head') the water falls through.

1.0.0.2 This Appendix focuses on an overall carbon balance for Tidal Lagoon Swansea Bay, known as the Project. In this context, 'carbon' is used as shorthand for greenhouse gases. The greenhouse gas emissions that will arise during the Project's life-cycle can be estimated. These include direct emissions occuring during Project construction, operation and decommissioning; and indirect emissions occuring in the manufacture and transport of Project components such as turbines, sluice gates, cables, etc. These emissions are normalised to the electricity produced over the Project's life to estimate a 'carbon footprint' for the Project. This footprint is then compared to the latest equivalent data for the UK grid average generation footprint. Estimates of the greenhouse gas emissions savings associated with the Project can then be assessed.

1.0.0.3 The Project is not yet at a stage where indirect emissions, for example from the manufacture of marine turbines, can be specifically quantified (because of the early stage of design). However, the direct emissions – those over which the Project has a greater degree of control – are estimated. It is important to note that this is an 'inventorisation exercise' and no impact assessment is carried out.

2.0 Legislation, Planning Policy and Guidance

2.0.0.1 The overarching policy context is described in Chapter 5 Planning and Policy Context and the need for the Project is discussed in detail in Chapter 1 Introduction and Chapter 5. In summary, the UK must contribute to efforts to reduce greenhouse gas emissions in order to avoid the adverse consequences of global warming. The United Nations Joint Declaration "The Way Forward on Renewable Energy" was signed by the European Union in 2002. As part of the First declaration, member states are committed to "the increase of the share of renewable energy sources in the global total primary energy supply". According to the UK Marine Policy Statement (March 2011), tidal power has the potential to provide a significant contribution to the share of energy supply from renewable resources in Wales and the UK.

2.0.0.2 Greenhouse gas emissions have a global, rather than local, effect so it is important to consider the life-cycle of a project such as Tidal Lagoon Swansea Bay. Also, because an overall increase in power demand may act as a confounding factor, it is important to account for the extent to which greenhouse gas emissions are actually saved (offset) by replacing fossil-fuelled generation, and the amount of the offset claimed (since building the tidal lagoon will itself result in greenhouse gas emissions). That is the aim of the carbon balance assessment in this section, which has used accepted standard approaches for the calculation of the carbon balance.

2.0.0.3 The Project's direct onshore greenhouse gas emissions are essentially limited to emissions from the exhausts of construction plant, road vehicles and non-road construction equipment. The policy and legislation is wide-ranging on such matters. Policies act to reduce carbon emissions from this sector by encouraging better fuel efficiency, substitution with lower carbon fuel alternatives, and lower emissions for example. Examples of measures used include: CO_2 emissions being a mandatory element of vehicle specification and vehicle excise duty being set on the basis of those emissions; measures to promote use of sustainable biofuels; and rebates on the purchase of electric vehicles.

2.0.0.4 This section also considers impacts that occur in the Project's supply chain. The legislative and policy context that relates to such impacts is impossible to detail here, as range of processes and products involved is so wide, might occur anywhere in the world, and may be outside the direct control of the Project. However, assumptions for upstream carbon emissions have been included in the carbon balance assessment based on the current supply chain.

3.0 Assessment Methodology

3.0.0.1 At this stage of Project development, many of the specific elements that will generate emissions are not yet defined. For example:

i. The marine turbine type and number (which, in turn, affects the location of the supplier amongst many other aspects);

ii. The fabrication of large items such as the sluice gates and turbine elements in the locale of the Project;

iii. The finalised detailed design of the Lagoon seawalls and the coffer dam and the materials to be used in their construction;

iv. The complete breakdown of materials to be used and their supply route;

v. The complete breakdown of emissions resulting from electrical equipment maintenance and replacement (such as generators, batteries, transformers etc.) during the operational phase;

vi. The vessels to be used to construct and decommission the facilities; and

vii. The transport arrangements for the workforce to site – use of buses etc.

3.0.0.2 It is therefore not possible to carry out a full, Project-specific life-cycle inventory complying with relevant standards such as ISO 14044, the Greenhouse Gas Protocol Product Standard or the Environmental Product Declaration programme rules. TLSB cannot presently meet the relevant data quality requirements due to the uncertainties in the Project, as detailed designs are still in progress. Therefore, this carbon balance assessment relies on published literature, while also examining Project-specific factors that may influence the literature values.

3.0.0.3 There is no establishment of baseline environmental parameters in this Appendix. The baseline relevant to the emission of greenhouse gases is the concentration of these gases in the atmosphere and the global climate. It is therefore beyond the scope of this carbon balance assessment.

3.0.0.4 For the same reasons, there is no quantitative impact assessment in this Appendix, which comprises an 'inventorisation' of the life-cycle greenhouse gas emissions.

4.0 Carbon Footprint of Hydro Power projects

4.0.0.1 Below are provided excerpts from papers and publications that TLSB has examined in order to estimate the carbon footprint of large scale hydro power projects.

Parliamentary Office of Science and Technology, Postnote October 2006 No 268.

4.0.0.2 Hydropower converts the energy from flowing water, via turbines and generators, into electricity. There are two main types of hydroelectric schemes: storage and run-of-river. Storage schemes require dams. In run-of-river schemes, turbines are placed in the natural flow of a river. Once in operation, hydro schemes emit very little CO_2, although some methane emissions do arise due to decomposition of flooded vegetation. Storage schemes have a higher footprint (~10-30gCO_2eq/kWh) than run-of-river schemes as they require large amounts of raw materials (steel and concrete) to construct the dam. Run-of-river schemes have very small reservoirs (those with weirs), or none at all, so do not give rise to significant emissions during their operation. Carbon footprints for this type of hydro scheme are some of the lowest of all electricity generation technologies (<5gCO_2eq/kWh).

Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia – Lenzen, M. (2008) Life cycle energy and greenhouse gas emissions of nuclear energy: A review. *Energy Conversion and Management* 49, 2178-2199.

4.0.0.3 There are two main types of hydroelectric conversion technology: reservoir hydropower plants and run-of-river plants. The first type can be quite large in size, up to around 1000 MW for single facilities is common, the limit being mainly imposed by the local topography and the water resource. Run-of-river hydroelectricity in contrast is usually at a smaller scale (approximately 200 MWe maximum) and its application under different conditions is more flexible.

4.0.0.4 There are two main energy-related issues and sources of emissions for the establishment of hydro power. One is due to the materials embodied in the construction (substantially concrete), with lifetimes often of up to 100 years, which is usually the time used in many analyses. The second concerns the release of greenhouse gases due to changes in the use of land, primarily relating to the rotting of vegetation and subsequent release of greenhouse gases. One example of this is the flooding of valleys to create large reservoirs which could lead to biomass decay and emissions of upto 400 gCO_2-e/kWh. These second types of emissions can largely be ignored for the run-of-river systems considered here.

4.0.0.5 A selection of literature values for the greenhouse intensity of hydro electricity is shown in Table 1. It can be seen that although there is quite a range, hydro power is still a relatively low emissions form of electricity.

Table 1: Energy and greenhouse intensity summary for hydroelectricity.

Reference	Type of Reservoir	gCO_2e/kWh
Gagnon et al 2002	Reservoir	15
Gagnon et al 2002	Run-of-river	2
EcoInvent report	Reservoir	5 – 34
EcoInvent report	Run-of-river	3
Dones and Gantner	Swiss run-of-river	3.7
Dones and Gantner	Swiss reservoir	4.5
Van de Vate	Small run-of-river	1 – 3
Van de Vate	Small reservoir with concrete	10 – 40
Van de Vate	Large concrete reservoirs	1 – 5
Vattenfall hydro	Large concrete reservoirs	~4.5
Chamberland et al	Quebec Hydro	57

Source EDF Energy web site http://www.edfenergy.com/energyfuture/energy-gap-climate-change/hydro-marine-and-the-energy-gap-climate-change accessed 13/10/13.

4.0.0.6 In generating electricity, hydroelectric power plants do not release carbon dioxide (CO_2). The carbon footprint associated with hydropower comes mostly from the construction and decommissioning processes. Government research has found that a large hydroelectric power station emits the equivalent of between 10 and 30 grams of CO_2 for each kilowatt-hour (kWh) of electricity it generates.

4.0.0.7 This figure takes into account the CO_2 released during construction and decommissioning of the power station, and methane emissions from decomposing vegetation in the area flooded to make the reservoir. Building a dam may require the removal of trees that help absorb carbon from the atmosphere. When land is cleared for construction, greenhouse gases also escape from the soil and future capacity to absorb carbon is lost too.

4.0.0.8 The carbon footprint involved in making and transporting the concrete used to construct a large-scale hydroelectric power station is significant. Making cement, an ingredient of concrete, releases large quantities of CO_2 into the atmosphere. But the working life of a large-scale hydroelectric power station can exceed 100 years, so when the average lifetime emissions of a hydroelectric power station are calculated, these initial CO_2 emissions are offset by the subsequent decades of zero-carbon electricity generation.

A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies – Daniel Weisser, PESS / IAEA

4.0.0.9 In the majority of the analysed cases, most of the GHG emissions typically arise during the production and construction of the hydroelectric power plant (especially for reservoir dams). In the illustrated cases, emissions for construction and production roughly lie between 2-9 $gCO_2eq/kWhe$. However, in some cases hydro power plants that use reservoirs can emit significant quantities of GHGs that easily surpass all other GHG emissions in the energy chain, due to land-clearance prior to construction but especially due to flooding of biomass and soil. For example, flooded biomass decays aerobically – producing carbon dioxide – and anaerobically – producing both carbon dioxide and methane. The amount of GHG released depends on reservoir size, type and amount of flooded vegetation cover, soil type, water depth, and climate. As reported by Bauer for European examples, these releases can vary considerably depending on the specific GHG releasing characteristics – as discussed above – and lie between 0.35 $gCO_2eq/kWhe$ for reservoirs in the alpine region and on average 30 $gCO_2eq/kWhe$ for reservoirs in Finland, although peat soils have reportedly higher GHG releases.

4.0.0.10 Overall, the life-cycle GHG emissions for the assessed cases range between approximately 1-34 $gCO_2eq/kWhe$, depending on the type of plant (run-off or reservoir), its size and usage (e.g. pumped hydro), as well as the electricity mix (and hence emissions) used for its operation. However, it is important to emphasise that the emission results from pumped storage, run-of-river and reservoir do vary significantly. In fact, the life-cycle GHG emissions from pumped hydro can be significantly larger than the values quoted here when the electricity used to pump/store water is generated from fossil fuel-based technologies.

5.0 Carbon Footprint of Tidal Lagoon Hydro Power projects

5.0.0.1 There is much less evidence of carbon footprint calculation for tidal lagoon hydro power projects and much of the work has focused on prospective wave energy projects rather than tidal lagoons or tidal barrages. The Parliamentary Postnote on the Carbon Footprint of Electricity Generation referred to above also deals with tidal energy, both wave energy converters and tidal stream (lagoons) and tidal barrages.

Parliamentary Office of Science and Technology, Postnote October 2006 No 268.

5.0.0.2 There are two types of marine energy devices: wave energy converters and tidal (stream and barrage) devices. Marine-based electricity generation is still an emerging technology and is not yet operating on a commercial scale in the UK. Some prototypes are being tested at the European Marine Energy Centre (EMEC), in Orkney. Because these technologies are still at this early stage, no formal life-cycle analyses have been carried out. However, the Carbon Trust's 2006 report on *Future Marine Energy* gives an example of life-cycle analysis for a wave energy converter. Most CO_2 is emitted during manufacture of the structural materials, and a wave converter device presently requires 665 tonnes of steel. Life-cycle emissions for this type of marine technology are estimated between 25-50gCO_2eq/kWh, roughly equivalent to life-cycle CO_2 emissions from current PV technologies.

5.0.0.3 Tidal Lagoon Hydro Power projects are very similar in design and context to the run-of-river projects referred to in Section 4. Unlike reservoir hydro power projects there is no rotting vegetation contributing to greenhouse gases as the Lagoon impounds sea water up to the existing foreshore. The Project will generate power on a regular basis matching the tide cycles, unlike run-of-river projects which may be dependent on seasonal water levels.

5.0.0.4 While there is a wide range of input parameters, methods and study boundaries that can affect such studies, it is considered that there is a reasonably high degree of agreement among the studies for both conventional hydro power and tidal lagoon energy.

6.0 Carbon footprint of UK grid electricity

6.0.0.1 The latest available carbon footprint of UK electricity generated (supplied to the grid, plus imports), as published in DEFRA's 2013 GHG Conversion Factors for Company Reporting: reporting guidelines is 445.48gCO_2e/kWh. This electricity conversion factor represents the average CO_2 emission from the UK national grid per kWh of electricity generated. This figure:

i. Factors in net imports of electricity via the interconnectors with Ireland and France.

ii. Includes only direct CO_2, CH_4 and N_2O emissions at UK power stations and from autogenerators, plus those from the proportion of imported electricity.

iii. Does not include emissions resulting from production and delivery of fuel to power stations (i.e. from gas rigs, refineries and collieries, etc.).

iv. Is the actual in-year (i.e. non-rolling average) emission factor. This is due to changes from year to year as the fuel mix consumed in UK power stations (and autogenerators) changes, and as the proportion of net imported electricity also changes.

7.0 Project Specific Life-cycle Elements

7.0.0.1 As discussed earlier in this section, the Project is not yet at a stage where a robust, Project-specific life-cycle can be defined and analysed, as many different elements are still to be finalised. For that reason, no attempt has been made to specifically quantify the emissions from the raw material acquisition and pre-processing and the manufacturing and assembly stages.

7.0.0.2 However, the design work on the Project completed to date does enable a calculation for the quantities of materials to be used and for the method of construction using the Environment Agency's carbon calculator (https://publications.environment-agency.gov.uk/skeleton/publications/ViewPublication.aspx?id=b426d324-8ad1-4980-9c2d-e1528c61af70). The use of Geotubes enables the Project to use silt dredged from the seabed in the vicinity of the Project location with a much lower carbon impact than the use of aggregates sourced either from land-based quarries or permitted seabed marine aggregate sites. The number of turbines and sluice gates has also been largely fixed allowing for an estimate of the volumes of concrete to be assessed for the construction of the turbine housing and the sluice gates.

7.0.0.3 The estimated CO_2 emissions during the manufacturing, transport and construction phase for the various elements of the Project have been calculated using the Environment Agency's carbon calculators as follows:

7.1 Turbines

7.1.0.1 The weight per unit of turbine is approximately 500 tonnes. Of this a certain amount will be stainless steel or similar alloys, which generate more CO_2 emissions in manufacture. On the suppliers' advice this has been estimated as 30 per cent of the turbine by weight. The total weight for 16 turbines with transport from place of manufacture to site has been inputted into the carbon calculator. The result is given below.

Title of project: Tidal Lagoon Swansea Bay
Construction cost: 650 000

Total Carbon Footprint: 23,643.9 tonnes fossil CO_2e

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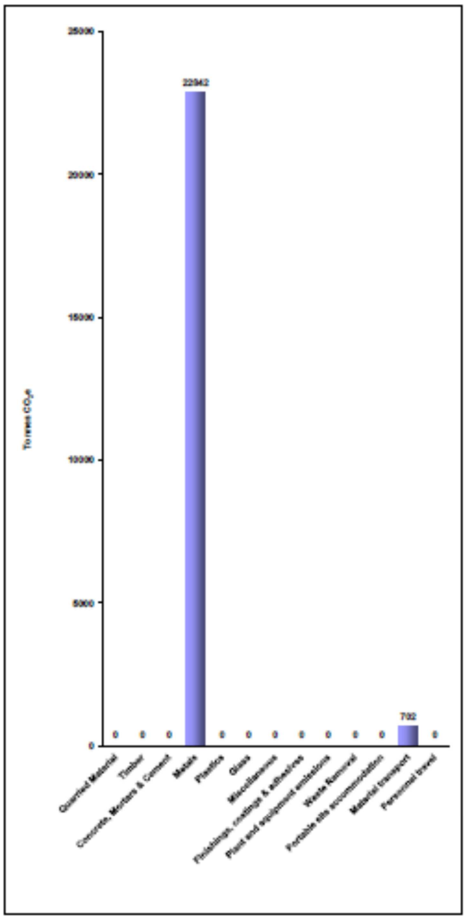
Please send your completed examples to ccc@environment-agency.gov.uk. Do not forget to include a short description of the actions / measures you have identified for the reduction of the total carbon footprint in the Project Information page.



Environment Agency

Sub-totals	tonnes CO_2e	%
Quarried Material	0.0	0%
Timber	0.0	0%
Concrete, Mortars & Cement	0.0	0%
Metals	22942.4	97%
Plastics	0.0	0%
Glass	0.0	0%
Miscellaneous	0.0	0%
Finishings, coatings & adhesives	0.0	0%
Plant and equipment emissions	0.0	0%
Waste Removal	0.0	0%
Portable site accommodation	0.0	0%
Material transport	701.5	3%
Personnel travel	0.0	0%

Significant materials (figures include transport to site)		
Steel: Stainless	14908.935	tonnes CO2e
Steel: General - UK (EU) Average Recycled Content	8034.969	tonnes CO2e

The accuracy of individual values is unlikely to be better than +/ -5%. As a consequence of using default factors and estimated tonnages, carbon footprints obtained from this calculator might be expected to be within +/ -25% of the true value. Given the range of values associated with certain materials (cements for example), default values may give results that are out by 100% or more. Local data should be used where available.

7.2 Permanent seawalls and temporary bund around turbine and sluice gate housing

7.2.0.1 The Project's supplier of the Geotube system used the carbon calculator to make an assessment of the carbon emissions per 100m length of seawall construction. This has been multiplied by the length of the seawall to obtain the total carbon emissions for this element of the Project. In addition, a comparison was made between the construction methodology being used for the Project and conventional breakwater construction to demonstrate the low carbon advantages of this construction methodology. The same calculations were used for the estimation of the temporary bund construction. The results are given below:

7.2.1 Input calculation

Breakwater Carbon Calculator

0. Fill In Key

Cell Colour	Key
(blue)	**Fill in or select details**
(green)	Calculated from blue cells

SELECT metric or imperial units of operation	**Metric**	**NOTE:** This is used for the input parameters. If you fill in the sheet and then change this box the numbers entered in the blue cells won't change, but only the units of operation, e.g. from 10 "meters" to 10 "yards".

1. Filter Layer (same for both systems)

Description	Value	Units	Guide
Filter layer area	6.500	m2	Polypropylene liner
Filter layer weight	500,0	grams / m2	Weight based on proposal of design officer
Filter Layer Transport			
Road	250	km	Assumes average of all truck capacities
Rail	0	km	
Sea	1.000	km	Assumes cargo ship

2. TenCate Geotube® Breakwater System Requirements

2.1 Quantity of TenCate Geotube® containers

Description	Value	Units	Guide
TenCate Geotube® container layer 1 diameter	5	m	
TenCate Geotube® container length	1800	m	
TenCate Geotube® container layer 2 diameter	0	m	
TenCate Geotube® container length	0	m	
Quality	GT1000	-	Select GT 1000 or GT 500 Geotube® containers
TenCate Geotube® Container Transport			
Road	250	km	Assumes average of all truck capacities
Rail	0	km	
Sea	1.000	km	Assumes cargo ship

2.2 Rocks

Description	Value	Units	Guide
Type of rock	Granite, boulders	-	
Weight of rock	12.000	tonnes	
Rock Transport			
Road vehicle type	> 33 tonne truck	-	Pick truck type
Road	400	km	
Rail	0	km	
Sea	0	km	Assumes cargo ship

2.3 Dredging & Pumping of Sand (TenCate Geotube® Container Filling)

Description	Value	Units	Guide
Where has the sand come from?	On-site	-	If purchased sand was used please fill in delivery distance further below. For on-site sand fill in energy consumption of dredging below.
Weight of sand	54000	tonnes	
Energy consumption of dredging & pumping	2,30	Ltrs diesel / tonne landed	**Suggested values: Metric:** Shallow dredging = 1.50 (1,50) litres diesel / tonne Deep dredging = 2.30 (2,30) litres diesel / tonne **Imperial:** Shallow = 0.36 US gallon / short tonne Deep = 0.55 US gallon / short tonne ***Note:*** *In English numbers are decimalised* 1,000,000.00 *In many other languages numbers are* 1.000.000,00
Purchased Sand Transport			
Road vehicle type	> 17 tonne rigid truck	-	Pick truck type
Road	0	km	

2.4 Cover Layer

Description	Value	Units	Guide
Area of cover layer	7.500	m2	Polypropylene liner. Weight based on proposal of design officer assumed that coverlayer weight is equal to filterlayer weight.
Cover Layer Transport			
Road	200	km	Assumes average of all truck capacities
Rail	0	km	
Sea	1.000	km	Assumes cargo ship

3. Rock Breakwater System Requirements

3.1 Rocks

Description	Value	Units	Guide
Type of rock	Granite, boulders	-	Select type of rock
Weight of rock	90.000	tonnes	
Rock Transport			
Road vehicle type	> 33 tonne truck	-	Pick truck type
Road	400	km	
Rail	0	km	
Sea	0	km	Assumes cargo ship

3.2 Purchased Sand

Description	Value	Units	Guide
Amount of purchased Sand		tonnes	
Purchased Sand Transport			
Road vehicle type	> 17 tonne rigid truck	-	Pick truck type
Road	0	km	
Rail	0	km	
Sea	0	km	Assumes cargo ship

3.3 Concrete

Description	Value	Units	Guide
Type of concrete	In-situ concrete	-	Select if precast concrete or in-situ concrete
Amount of concrete	0	tonnes	
Concrete Transport			
Road vehicle type	> 17 tonne rigid truck	-	Pick truck type
Road	0	km	
Rail	0	km	
Sea	0	km	Assumes cargo ship

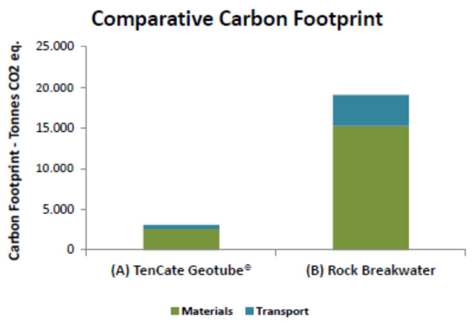
7.2.2 Results

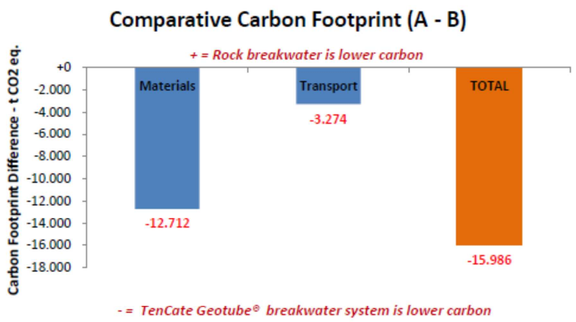
Breakwater Carbon Calculator Results

TENCATE materials that make a difference — sustain

1. Summary Results - TenCate Geotube® System V Rock Breakwater

HEADLINE RESULTS	TenCate Geotube® is lower carbon by	15.986 tonnes CO2e
	(A) TenCate Geotube® Results	3.105 tonnes CO2e
	(B) Alternative Breakwater Results	19.091 tonnes CO2e

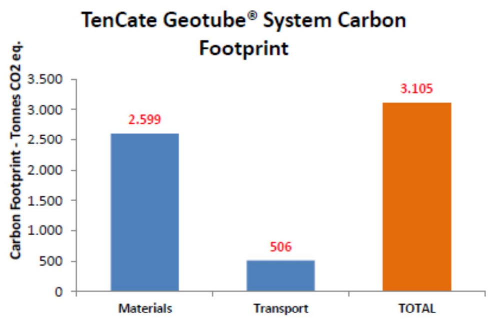


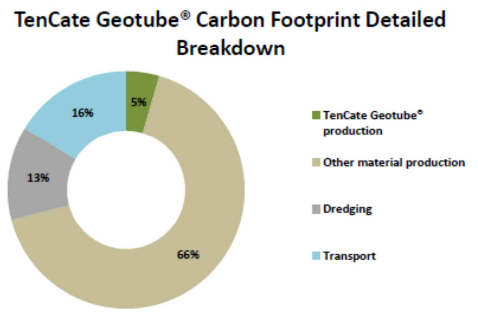


GO BACK TO CALCULATOR

2. TenCate Geotube® System Results Breakdown

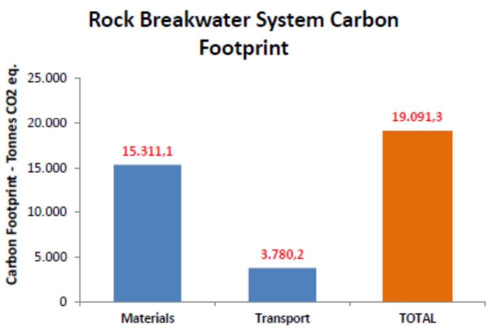
HEADLINE RESULTS	3.105 tonnes CO2e

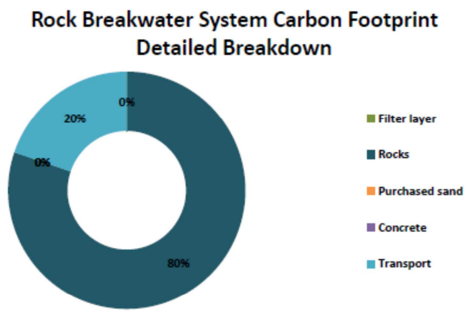




3. Rock Breakwater System Results Breakdown

HEADLINE RESULTS	19.091 tonnes CO2e





7.3 Concrete works, sluices, roadways, personnel

7.3.0.1 The quantities of materials for the concrete works associated with the turbine and sluice gate housing, the roadways and pathways on top of the seawalls and the impact of materials and personnel travel has been inputted into the Environment Agency carbon calculator (see below).

7.3.0.2 This calculation is based on the following assumptions:

i. Lagoon design with 16 turbines and 10 sluices;

ii. Concrete quantities based on this casement design;

iii. Turbine steel tonnage of 500 t per unit with an assumption of 30 per cent stainless steel or similar alloys;

iv. Temporary bund wall / coffer dam with a length of 1600m

v. Re-use of rock and materials from the temporary bund to the permanent seawalls;

vi. Sluice gates are stainless steel; and

vii. Method of transport for each element as calculated by the Environment Agency Carbon calculator, assuming a worst case where this is not yet finalised.

7.3.0.3 The calculations above include transport of materials, including local assembly of elements of the turbine units. It does not fully reflect the local supply chain initiatives that the Project is undertaking to maximise manufacture and fabrication of the mechanical and electrical elements of the Project in South Wales and the UK.

7.3.0.4 A contingency of 30 per cent has been added to the overall figures to allow for the elements of the Project that will form part of the final scheme, but for which there are not sufficient details of materials used to input into the carbon calculator. These include the onshore and offshore buildings, which will employ low carbon footprint design and build criteria, the power export connection, works to the long sea outfall for DCWW and other onshore facilities such as roadways etc. Table 2 below gives the outputs from the calculations.

Table 2: Summary of calculation outputs

Element	Tonnes CO_2e
Turbines	23,550
Permanent Seawall	339,220
Temporary Bund	26,830
Concrete works, sluices, roadways, personnel	104,620
Contingency, including onshore and offshore visitor centres, grid connection, long sea outfall works etc. (30%)	148,270
Total	**642,490**

7.3.0.5 The result is given below.

Title of project:	Tidal Lagoon Swansea Bay	
Construction cost:	650 000	
Total Carbon Footprint:	104,616.8	tonnes fossil CO_2e

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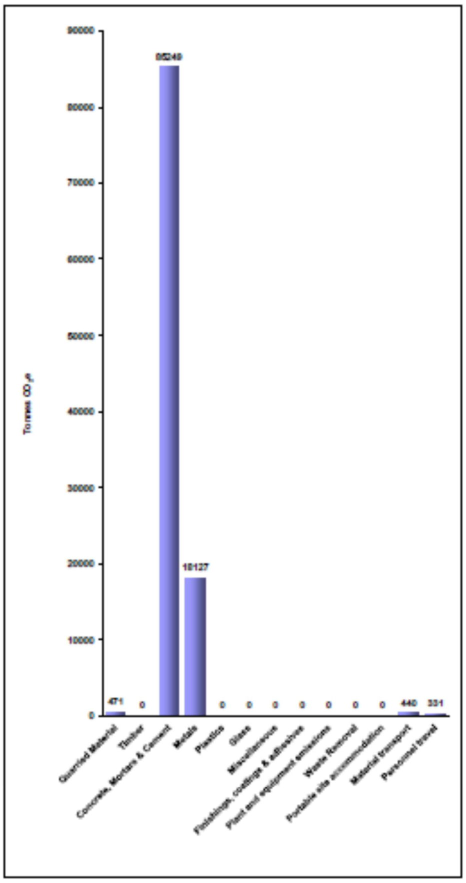

The accuracy of individual values is unlikely to be better than +/-5%. As a consequence of using default factors and estimated tonnages, carbon footprints obtained from this calculator might be expected to be within +/-25% of the true value. Given the range of values associated with certain materials (cements for example), default values may give results that are out by 100% or more. Local data should be used where available.

Environment Agency

Sub-totals	tonnes CO_2e	%
Quarried Material	470.5	0%
Timber	0.0	0%
Concrete, Mortars & Cement	85248.6	81%
Metals	18127.3	17%
Plastics	0.0	0%
Glass	0.0	0%
Miscellaneous	0.0	0%
Finishings, coatings & adhesives	0.0	0%
Plant and equipment emissions	0.0	0%
Waste Removal	0.0	0%
Portable site accommodation	0.0	0%
Material transport	438.7	0%
Personnel travel	330.7	0%

Significant materials (figures include transport to site)		
Concrete: XS3	**54478.454**	**tonnes CO2e**
Concrete: XS2	**31172.100**	**tonnes CO2e**
Steel: Stainless	**17912.028**	**tonnes CO2e**
Asphalt, 5% (bitumen) binder content	444.317	tonnes CO2e
Personnel travel (estimated)	330.653	tonnes CO2e
Steel: Sections - UK (EU) Average Recycled Content	230.300	tonnes CO2e
Quarried aggregate	47.526	tonnes CO2e
Handrail: stainless steel welded	1.438	tonnes CO2e

7.3.0.6 The operational impact of the Lagoon is netted out using the net electrical output of the plant rather than the gross output. There will be an element of periodic maintenance to the seawalls using specialist boats. However, over the 120 year life of the Project the carbon footprint of these works will be negligible and can be assumed to be covered by the operational losses netted out with the electrical output.

7.3.0.7 Due to the long expected life of the Lagoon, the method of decommissioning (and hence the associated environmental impacts) is impossible to predict with any certainty. Therefore, the decommissioning stage is excluded from the assessment results, which is in-line with all other previous studies reviewed. In all probability, if it is decided not to extend the life of the Project through refurbishment and upgrade of the turbines, they will be removed together with the sluices and the Lagoon left open to the sea to serve as a marina or tidal defence. The turbine and sluice materials will be sent for recycling, thus balancing any carbon footprint involved in the removal.

8.0 Carbon balance and hydroelectric schemes

8.0.0.1 If the estimated equivalent tonnage of carbon emitted during the construction of the Project is divided by the annual output (400GWh) and the operational life of the plant (120years), then the gross normalised footprint (excluding credits for recycled material at the end of life) of the Project's generated electricity will be 14gCO_2e/kWh. This accords with the range given in the sources described above for run-of-river facilities. The fact that it is slightly higher than the run-of-river figures is due to the larger volume of civil works required for the seawall, but unlike reservoir hydro projects with large impoundments there will not be any CO_2 emissions from vegetation for a tidal lagoon plant.

8.0.0.2 Using the most comparable grid footprint factor of 445.48gCO_2e/kWh (see paragraph 6.0.0.1), the Project saves 431gCO_2e per kWh generated. This means that, after 1487 GWh is generated, the Project will have saved the carbon that was emitted during, and as a result of, its own manufacture and construction and will be emitted throughout its life-cycle, i.e. after adding operation. This generation will be achieved after approximately 3.1 per cent of its operational lifetime, or around 4 years.

8.0.0.3 After approximately 4 years therefore, the facility is likely to be 'carbon neutral', in that it will have saved the emissions that were created in its inception. The Project is a hydroelectric scheme generating energy derived from flowing water. The total hydroelectric installed capacity in the UK at the end of 2011 was approximately 1676 megawatts, which is around 1.9% of the current total UK generating capacity and 14% of renewable electricity generation capacity. The UK currently (2011) generates about 1.5% (5,700 GWh) of its electricity from hydroelectric schemes. Hydroelectric energy uses proven and efficient technology; the most modern plants have energy conversion efficiencies of 90% and above. Hydro has a typical load factor of 35 to 40% (Department of Energy and Climate Change website: https://www.gov.uk/harnessing-hydroelectric-power, accessed 14 January 2014: Harnessing Hydroelectric Power). In the remainder of its life, it will therefore be an efficient form of energy generation continuing to save emissions relative to the UK grid mix.

9.0 Conclusions

9.0.0.1 At this stage of the Project's design, it is not possible to carry out a project-specific life-cycle greenhouse gas inventory analysis, as detailed specifications of the Project elements would be required to complete such an exercise.

9.0.0.2 The most representative studies find that electricity from hydro power has a life-cycle carbon footprint of between 2 and 50gCO_2e/kWh with run-of-river schemes which are most similar to the technology employed on the Project tending towards the lower end of this scale. This is heavily weighted to the seawall construction and the materials manufacture stage and particularly the extraction and processing of iron ore into steel for the turbines, foundations and cabling. Other life-cycle stages such as installation, operation and transport were found to be much less significant contributors to the life-cycle footprint. At the end of the marine turbines' life, they can be recycled or reused, making a beneficial contribution to the carbon footprint, as it avoids the need for the extraction and processing of virgin materials for the application they are put to.

9.0.0.3 This life-cycle electricity footprint can be compared with the current UK grid electricity mix (based substantially on fossil-fuelled generation), which has a footprint of 445.48gCO_2e/kWh. This is clearly many times higher than the Project's predicted carbon footprint and illustrates the greenhouse gas savings that result from tidal lagoon power generation. Even with conservative assumptions around the Project's footprint and its lifetime, it is concluded that the Project will 'pay back' the carbon emitted own manufacture and construction and will be emitted throughout its life-cycle, i.e. after adding operation in around four years. Thereafter, it will of course continue to save emissions throughout its lifetime.

10.0 References

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