DECC

SEVERN TIDAL POWER - SEA TOPIC PAPER

Air and Climatic Factors

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Prepared by
Parsons Brinckerhoff Ltd
Queen Victoria House
Redland Hill
Bristol
BS6 6US

In association with
Black and Veatch Limited

Prepared for
DECC
3 Whitehall Place
London
SW1A 2HD

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Date	**:**	**April 2010**
Prepared by	**:**	**Peter Walsh, Sian Wilson, Laura Martinez**
Checked by	**:**	**Bethan Tuckett-Jones, Roger Middleton, Ben Sang.**
Approved by	**:**	**Bethan Tuckett-Jones, Roger Middleton, Ben Sang.**

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NON TECHNICAL SUMMARY

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Introduction

A strategic environmental assessment (SEA) is being conducted as part of the Severn Tidal Power (STP) feasibility study, in accordance with the requirements of the EU SEA Directive and UK Regulations. The SEA comprises two phases: Phase 1, the scoping stage, has already been undertaken. This Air and Climatic Factors topic paper forms part of the reporting arising from Phase 2, the main assessment of short-listed options.

The Air and Climatic Factors topic paper reports the assessment of the effects of the STP alternative options on Air Quality and Carbon Footprint. Although intrinsically linked and therefore presented here together, the two areas have been studied by specialists in the individual fields. Where necessary the specialists have shared data and importantly, assumptions. The report is structured as follows:

Non Technical Summary	A summary of the scope of work undertaken and key findings in non-technical language.
Section 1 - Introduction	Presents the context of the Air & Climatic Factors Topic Paper, Summarises the SEA Objectives agreed in Phase 1 and the consultation undertaken to date. Explains the structure and of the Air & Climatic Factors Topic Paper
Section 2 - Baseline - Air Quality	Sets out the Air Quality receptors, environmental baseline and future environmental baseline taking into account current understanding of existing trends.
Section 3 - Evaluation of Plan Alternatives - Air Quality	Reports on the assessment of likely significant Air Quality effects associated with the alternative options.
Section 4 - Assessment against SEA Objectives Air Quality	Presents the assessment of the alternative options against the Air Quality SEA Objectives
Section 5 - Baseline - Carbon Footprinting	Sets out the Carbon Footprinting receptors, environmental baseline and future environmental baseline taking into account current understanding of existing trends.
Section 6 - Evaluation of Plan Alternatives - Carbon Footprinting	Reports on the assessment of likely significant Carbon Footprinting effects associated with the alternative options.
Section 7 - Assessment against SEA Objectives - Carbon Footprinting	Presents the assessment of the alternative options against the Carbon Footprinting SEA Objectives
Section 8 - Plan Implementation.	Summarises potential legislative and policy compliance of each alternative option with regard to Air Quality and Carbon Footprinting. Provides suggestions for monitoring and further research should Government choose to support the development of Severn Tidal Power.

Consultation

The following consultation activities have been undertaken for the Air and Climatic Factors topic:

- Scoping consultation in January 2009
- Technical Workshops held in June 2009 and December 2009

SEA Objectives
SEA Objectives have been developed to enable alternative options to be compared. Objectives may not necessarily be met in full by a given alternative option, but the degree to which they do will provide a way of identifying preferences when comparing effects of alternative options. The SEA Objectives for Air Quality and Carbon Footprinting are listed below:

SEA Objective	Assessment Criteria	Indicators
Air Quality		
SE.4 To avoid adverse effects on physical and mental health	Will the option result in deterioration in the quality of life (health and well-being) as measured by increase in air emissions?	Relative increases in air emissions anticipated from traffic, construction equipment, etc
CF.1 To maximise the opportunities for use of sustainable sources of energy for the UK.	What is the pollutant footprint of each option (life cycle emissions in relation to other options)?	The pollutant (equivalent) emissions payback period will indicate which option is most emissions efficient.
TFE.1 To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.	Will the option result in the loss of terrestrial and freshwater habitats of international or national importance?	Changes in quality/extent of internationally important site features, e.g. within SPAs, SACs Ramsar Sites.
TFE.2 To avoid adverse effects on valuable terrestrial and freshwater ecological networks.	Will the option adversely affect ecological networks for terrestrial and freshwater habitats and species?	Changes in quality/extent of nationally important site features, e.g. within SSSIs.
Carbon Footprinting		
CF.1 To maximise the opportunities for use of sustainable sources of energy for the UK	The level of renewable energy production from the alternative option, the unit $kgCO_2$/kWh emission from that option and the payback period.	The renewable annual energy production from each option, the resulting unit $kgCO_2$/kWh of the energy and the payback period.
CF.2 To avoid adverse effects from GHG emissions over the lifecycle of the project	The total CO_2 emissions released as a result of each phase of the option, and the net CO_2 emissions.	The construction, operation and decommissioning phase emissions. The net CO_2 emissions ($kgCO_2$).

Baseline Environment

Baseline information provides the basis for predicting and monitoring environmental effects, by describing the area that may be affected. Due to the long timescales associated with the construction and operation of alternative options, baseline information is considered over three time periods, to reflect the predicted changes in the area when considered without the development of a Severn Tidal Power project. The baseline therefore also describes the estuary in a ‘do-nothing’ scenario. The baseline environment for Air Quality and Carbon Footprint are both linked to Greenhouse Gas (GHG) emissions as described below.

Air Quality Baseline Environment

Baseline environment from 2009 through to 2140

Air quality baseline environment was determined using current UK and projected air pollutant concentrations and emissions as published by DEFRA, assuming that a tidal power option is not installed.

Baseline human and habitat receptors were described as estimated human population percentages and area of habitat which experience an exceedance of either air quality objective and critical loads respectively (Table 1 and 2). At the national level, insufficient data exists to robustly estimate future air quality between 2020 and 2140. However, overall decreases in emissions to air and ambient pollutant concentrations, due to improvements in technology and a move to low carbon economy, are anticipated to result in gradual decreases in the level of pollutant deposition over time.

Table 1 Percentages total population within area of the UK where air quality objectives exceeded

Pollutant	**Threshold**	**2005**	**2015**	**2020**
SO_2	Hour and 24 hr mean	0.01	0.01	0.01
NO_2	Annual Mean > 40μg/m^3	2.3	0.3	0.3
PM_{10}	Annual mean > 31.5μg/m^3	0.1	0	0

Table 2 Estimated Area of Exceedance of Critical Loads for all UK SACs and SPAs (Ha)

	Estimated UK Habitat Total Area exceedance Statistics for 1999-2001 and			
Broad Habitats	**SAC Area Acidity exceedance/Ha**	**SAC Nutrient Nitrogen exceedance/Ha**	**SPA Area Acidity exceedance/Ha**	**SPA Area Nutrient Nitrogen exceedance/Ha**
All habitats 1999 – 2001	101353	88783	814147	982419
All habitats 2020	79261	82355	636686	911287

Key Environmental Issues and Problems with Air Quality Baseline Environment

Nationally and locally, air quality effects upon human health and ecosystems are of sufficient concern to require legislative action. Currently the majority of air quality problems, within the STP SEA study area and nationally, are largely related to emissions from road transport, on major highways and within conurbations generally.

However, with predicted improvements in vehicle technology, emissions from road vehicles have been estimated to decrease and, therefore, significant improvements in air quality have been predicted to occur over time. Furthermore, enforcement of the PPC regulations and the use of ‘best available technology’ will ensure a continued reduction in emissions from industry throughout the UK.

Consequently, ambient pollution levels and, in particular, exceedences of air quality objectives for the protection of human health and objectives for the protection of ecosystems are predicted to reduce over time.

Furthermore, the introduction of renewable, and low carbon technologies are predicted to have additional effects of reducing pollutants emissions. As a consequence of carbon reductions measures and the UK Government's target of an 80% reduction in carbon emissions by 2050, air quality throughout the UK is predicted to improve (DECC, 2009).

Carbon Footprint Baseline Environment

It should be noted that the predicted baseline for both Global and UK GHG emissions are based on the assumption that International and National targets set today, to reduce emissions, are successfully achieved. It is recognised in this report that the impact of emissions is a Global and therefore the Global emissions are considered as a baseline receptor. Nevertheless, the UK GHG emissions, are primary focus in this report for impacts to UK emissions levels.

Global GHG emissions - Baseline environment (2009 until 2140)

Baseline environment of GHG emissions up to 2009 and through to 2140 is taken from ENSEMBLES data Scenario E1 (see Figure 1 below). The ENSEMBLES data used in this assessment was funded by the EU FP6 integrated project ENSEMBLES (Contract Number 505539), whose support is gratefully acknowledged.

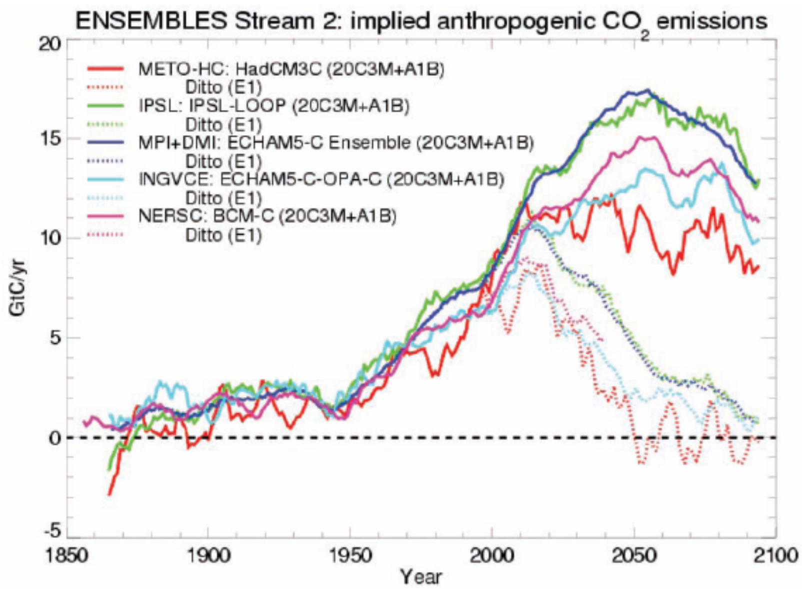

Figure 1 ENSEMBLES Global mitigated anthropogenic GHG emissions

UK GHG emissions - Baseline environment (2009 until 2140)

The UK predicted baseline GHG emissions are shown in Figure 2. UK baseline data has been taken from DECC Low Carbon Transition Plan, 2009, which provides a baseline up to 2022. The baseline takes into account all the current policies for carbon reduction in the UK.

The emissions post 2022 have also been taken from the Low Carbon Transition Plan which assumes a decrease in emissions towards the 2050 target of 80% reduction. Error bands are incorporated at the 2050 point in the Plan and these are utilised in this report.

Beyond 2050 the emissions projections are most uncertain as they rely upon the successful implementation of all current UK Policy in addition to future policy post 2050 which, at the time of writing, are not published. The predictions are based on continuations of the curve however it is possible that the economy could be decarbonised at some point prior to 2140 which is not currently shown on these projections.

The UK Renewable Energy Strategy, HM Government, July 2009, Page 201 states that no decision on the Severn Tidal Power options has yet been made in relation to policy and emission reduction targets. Therefore, at this time, there is no emissions reductions as a result of Severn Tidal Power included in the emissions reductions assumed for the UK baseline.

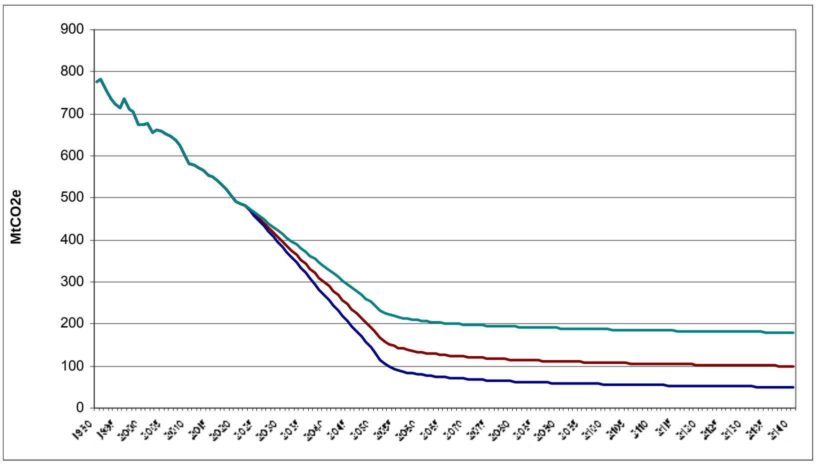

Figure 2 Annual UK GHG emissions; observed and predicted

Key Environmental Issues and Problems with Carbon Footprint Baseline Environment
In summary there are two main issues with the Baseline environment. The first is that the baselines both rely upon the implementation of policy to achieve the emission reductions. This subsequently has a significant impact on the displaced emissions achieved by each option. The second that is in relation to the UK baseline, is that there is no published policies available at this time on which to base assumptions about the likely scenario of emissions reduction going forwards from 2050 to 2140. The emissions may continue to decrease further; however, there are many possibilities for the rate and distribution at which the last 20% of emissions are reduced from 2050 through to 2140. For this reason the distribution is, as provided, with a continuation of the curve.

Evaluation of Plan Alternatives

Assessment Methodology
The SEA Directive specifies the criteria that should be taken into account when determining the likely significant effects of the plan and thus these criteria have been adopted throughout the assessment process of this SEA. This topic paper therefore considers the characteristics of the effects and of the area likely to be affected.

In the Air and Climatic Factors paper, both the air quality and the carbon footprint parts of the study have been completed from desk based assessments only. The carbon footprint analysis is a life cycle assessment of each of the plan alternatives. Where information is available this is based on data however, many of the effects are unquantifiable and have therefore been based on qualitative descriptions.

Alternative Options
There are five short listed alternative options that are being assessed within Phase 2 of the SEA for their likely significant effects. These alternative options and key parameters associated with the alternative options are:

Alternative	Location	Length (approx)	Operating mode	Turbine type	No. turbines	Annual energy output	Caissons	Locks
B3: Brean Down to Lavernock Point Barrage (also known as Cardiff to Weston)	Lavernock Point to Brean Down	16km	Ebb only	Bulb-Kapeller	216 (40MW)	15.1 to 17.0 TWh/year	129	2
B4: Shoots Barrage	West Pill to Severn Beach	7km	Ebb only	Bulb-Kapeller	30 (35MW)	2.7 to 2.9 TWh/year	46	1
B5: Beachley Barrage	Beachley to land directly to the east on the English side	2km	Ebb only	Straflo	50 (12.5MW)	1.4 to 1.6 TWh/year	31	1
L2: Welsh Grounds Lagoon	River Usk to Second Severn Crossing	28km	Ebb only	Bulb	40 (25MW)	2.6 to 2.8 TWh/year	32	1
L3d: Bridgwater Bay Lagoon	Brean Down to Hinckley Point	16km	Ebb & Flood	Bulb-Kaplan	144 (25MW)	5.6 to 6.6 TWh/year	42	1

Assessment of Likely Significant Effects on the Environment

The environment in the case of Air Quality is both human population and habitat but for Carbon Footprint it is GHG emission levels.

Air quality issues and problems are principally associated with the emissions of air pollutants during the period of construction of the tidal power scheme, in particular emissions from both shipping and construction vehicles could produce short-term, localised degradation to air quality.

Construction emissions have been generated from information provided by the engineering team at PB combined with assumptions used by the Air and Climatic Factors and the Resources and Waste Topic papers. The construction emissions relate directly to the physical size of the scheme and thus the resources, transportation and overall, embodied energy associated with each option. B3 is the physically largest scheme, followed by the two lagoon options with the smallest being B4 and B5. The emissions released during construction may be a key criteria because they would be released at a time when the UK requires considerable emission reduction.

The operational emissions released for maintenance are proportional to the number and size of turbines. Operational emissions from estuarine changes are still very uncertain therefore these are incorporated into the range of results, which represents the low and high case. It should be noted that the potential variation is subject to the uncertainty in the quantities and effects, and the uncertainty in the carbon data.

It is recognised that the operation of the lagoons and barrages may have an impact on the operation of vessels in the area and this has been researched in a report called Phase 2 REIS, completed by STP Regional Workstream. No specific data has been produced to date on the actual tonnage which may be diverted during operation of any of the STP options. It is recognised that the impacts on Bristol Port may be most sensitive to the B3 option. We have therefore completed an estimate of the impacts as a result of the B3 option. Bristol Ports saw a total of 11.53mTonnes of cargo during 2008, the majority as import. The assumption has been made that there could be 40% of the cargo rerouted to other ports and therefore a rail transfer back to Bristol. The average distance between Bristol to Southampton and Bristol to Liverpool has been used as the additional on land distance.

Cumulative and consequential effects have been considered qualitatively only. The cumulative effects are considered at a high descriptive level. The major difference which could be considered when planning the timescales of projects which will emit carbon are built or decommissioned, particularly during the construction phase of the Severn Tidal Power project, is that in the future more advanced technologies and energy efficient means of construction or demolition may be available. Therefore, it could be prudent, if it was economically and environmentally viable, to delay appropriate projects. For example decommissioning projects could be delayed.

The consequential developments described below have been identified by the SEA team for consideration of potential impact on UK GHG emissions during operation of the option:

- Energy intensive industry drawn to the area: Initially if the industry is drawn in from outside the UK where processes are still more energy intensive then if the industry moves into the UK there will be an overall Global emissions savings. The UK emissions savings in this scenario could be cancelled out by the new industry. The second is that an existing industry in the UK moves to site near the Severn Tidal Power Option. The renewable energy would therefore be offsetting an existing source of power and therefore contribute to UK reduction targets. Lastly, it is possible that a new industry would set up in the UK. This would therefore counteract any emissions savings with new UK emissions and potentially increase emissions. This would clearly be a consideration outside the scope of this project.

- Recreational usage of water bodies altered: It is considered that with an increasing size of Severn Tidal Power option there would be increasing recreational activity associated with it. It is likely nevertheless that the activities would mainly involve non-motorised sports and therefore that increase in emissions would be proportional to increase in the number of visitors. This will however decrease per vehicle over the life of the project, as Government policies on transport are brought to fruition.

Assumptions, Limitations and Uncertainty

A complete list of the assumptions made during the construction, operation and decommissioning of the schemes is given within the Air Quality and the Carbon Footprinting reports. The result for both the assessments has a very high level of uncertainty. Uncertainty is carried through the assessment from initial conversion factor data through to the assumptions made and therefore, although the results obtained are as realistic as possible, they have a substantial error band on them.
These assumptions which impact both Air Quality and Carbon Footprinting include, among others:

- Source of construction materials;
- Transport means and distances;
- Workers accommodation;
- Dredging material re-use;

- Maintenance requirements;
- Pumping requirements during construction and operation;
- Dredging requirements during operation;
- Estuarine changes (sequestration, methanogenesis, siltation and changes to the nitrogen cycle);
- Emissions factors.

Both assessments use the displaced emissions associated with using renewable electricity instead of general grid mix electricity. The values used in the report assume that the UK successfully implements all policies to decarbonise our power supply but this should be noted as a source of uncertainty because it has a significant impact on net emission savings from each option. A sensitivity of this is completed in the report.

The principal area of uncertainty in the case of the air quality assessment are the estimated emissions of air pollutants during construction due to both shipping and dredging activities, where the greater use of small vessels increases the emissions of all pollutants. One of the major areas of uncertainty for Carbon Footprinting is establishing the impacts on GHG emissions from estuarine changes, including, sequestration, methanogenesis, impacts on the nitrogen cycle and most importantly siltation. Results from Water Quality and Marine Ecology have been used where available however the potential changes in the processes, due to the nature of the environment, are still uncertain. The impact of estuarine process on the baseline carbon footprint is therefore highly uncertain.

Measures to prevent, reduce and as fully as possible offset any significant adverse effects

Offsetting measures within this SEA are measures to as fully as possible offset any significant adverse effects on the environment. These measures therefore make good for loss or damage to an environmental receptor, without directly reducing that loss/damage.

Potentially pollutant emissions to atmosphere from shipping activities during the construction phase may have some effect upon the local human and habitat receptors. Use of larger vessels rather than smaller vessels would optimise the emissions to atmosphere per payload. Additionally pollution emissions to the atmosphere from shipping may be minimised where vessels switch from fossil fuel to electrical power when in port. The longer term emissions from disruption to shipping during the operation of the project are currently being considered in the Phase 2 REIS paper which is being completed by the STP Regional Workstream. Once this is completed the information will be incorporated into the carbon footprint.

In this SEA 'compensation', a subset of offsetting, is only used in relation to those measures needed under the Habitats Directive. Should further habitat be created where, for example, inter-tidal areas are lost this could potentially have a significant impact on the operational carbon footprint. The process changes in the estuary are unclear, however, the production of new habitat is, dependent on the location and type of habitat, likely to sequester.

Assessment against SEA Objectives

This topic paper includes a full assessment of how each alternative option performs against each SEA Objective over the course of its entire life-cycle.

Air Quality Objectives

SEA Objective CF1 - To maximise the opportunities for use of sustainable sources of energy for the UK

This objective seeks to maximise the availability of renewable energy sources with the greatest magnitude of air pollutant off setting. Option B3 provides the largest offsetting of air pollutants and so therefore appears the option that fulfils this objective to the greatest degree.

SEA Objective SE1- To avoid adverse effects on physical and mental health

This objective relates to the avoidance or minimising significant detrimental air quality impacts upon the local and UK population. The option with the lowest short-term detrimental air quality impact to the local population is option B5.

SEA Objective TFE1 - To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.

SEA Objective TFE2 - To avoid adverse effects on valuable terrestrial and freshwater ecological networks.

The above two objectives relate to the long term detrimental impacts upon both local and national habitats from air pollutants, this relates to the option with the greatest magnitude of off-setting of air pollutants. Option B3 provides the largest offsetting of air pollutants and so therefore appears the option that fulfils this objective reduction to the greatest degree.

Carbon Footprinting Objectives

SEA Objective CF1 - To maximise the opportunities for use of sustainable sources of energy for the UK

This objective relates to the level of renewable energy produced and thus the annual energy output of each of the options. The unit CO2 emissions per kWh produced are also used as an indicator for this objective. The most effective way of comparing the options' overall impact on GHG emission levels over the lifecycle of the project is by looking at the CO2 per unit of energy produced which has been estimated throughout this project and which could be readily compared to other forms of energy generation. The range (due to uncertainty) of unit emissions and the carbon payback period are summarised in Table 4 below for comparison. It is noted that the carbon payback period is different to the time required for the scheme to become carbon neutral.

Table 4: CO_2 per unit of energy produced

Alternative	Unit CO_2 emissions (kg CO_2/kWh)	Carbon Payback (years)
B3 - Brean Down to Lavernock Point Barrage	0 to 0.023	-0.8 to 7
B4 – Shoots Barrage	-0.02 - 0.026	-6.3 to 7.8
B5 – Beachley Barrage	-0.02 - 0.023	-5.7 to 7.7
L2 – Welsh Grounds Lagoon	-0.02 - 0.05	-4.2 to 15
L3d – Bridgwater Bay Lagoon	0.01 - 0.027	2.6 to 8.5

SEA Objective CF2 - To avoid adverse effects from GHG emissions over the lifecycle of the project

This Objective refers to the avoidance of GHG emissions into the atmosphere and thus the total CO_2 emissions released as a result of each phase of the option, and the net emissions over the life of the project. Section 6.5 describes all the likely environmental effects (changes to GHG emission levels) and importantly, includes the assumptions and uncertainty associated with the impact on carbon emissions of a Severn Tidal Power alternative option.

Table 5: Net CO_2 emissions and total CO_2 emissions per phase

Alternative	Net emissions displaced (Mt CO_2)			Construction (Mt CO_2)	Operation emissions (Mt CO_2)	Decommissioning (Mt CO_2)
	Low	Base	High			
B3 - Brean Down to Lavernock Point Barrage	-147	-114	-78	14 to 28	-20 to 13.5	0.7 to 3
B4 – Shoots Barrage	-34	-22	-16	2.3 to 4.5	-10 to 3.8	0.1 to 0.4
B5 – Beachley Barrage	-20	-13	-9	0.8 to 1.6	-5 to 2.6	0.03 to 0.07
L2 - Welsh Grounds Lagoon	-30	-17	-6.5	7 to 14	-12 to 2.6	0.4 to 0.75
L3d – Bridgwater Bay Lagoon	-54	-47	-29	8 to 15	-1.5 to 4.8	0.3 to 0.7

Plan Implementation

Legislation and policy compliance

This paper contains a review of legislation and policy that is specifically relevant to this topic. An assessment has been made as to whether each alternative option would be compliant with existing relevant legislation and policy.

The Air Quality Strategy for England, Scotland, Wales and Northern Ireland sets out air quality standards which apply to all areas where potential human and habitat exposure could occur. This strategy employs an exposure reduction approach which generally supports the pursuit of renewable energy where emissions reductions can be achieved.

There are legally binding targets in place to reduce UK GHG emissions therefore the plans are part of ongoing consideration by DECC to consider Severn Tidal Power.

Monitoring of significant environmental effects

The SEA Directive requires that monitoring measures are described within the environmental reporting. The monitoring proposals contained within this paper are applicable to all of the alternative options under consideration.

In order to assess the potential contribution to local air quality within the SEA study area it is recommended that air quality monitoring of NO_2, PM_{10} and SO_2 is undertaken at the landfall areas for a minimum period of 6 months prior to the barrage construction being undertaken and throughout the period of its construction. In addition survey and analysis of existing air quality monitoring stations is recommended to be undertaken throughout the construction period of the barrage.

Carbon footprint – UK and Global emissions will continue to be monitored for policy requirements. In terms of the project the following should be monitored:

- Design review changes should be assessed in relation to the carbon footprint effect on construction , operation and decommissioning;
- Construction site (e.g. site gate inventory and fuel use on site);
- Construction emissions (pumping and dredging requirements);
- Operational emissions related to ecosystem changes (would link with water quality and marine ecology monitoring);
- Decommissioning (same inventory as construction).

CONTENTS

Page

NON TECHNICAL SUMMARY **V**

ABBREVIATIONS **XXI**

SECTION 1 **1**

INTRODUCTION **1**
1.1 Introduction 3
1.2 Report Structure 3
1.3 Scope of the Topic Paper 5
1.4 Interfaces between topics and other work conducted within Feasibility Study 6
1.5 Consultation 6
1.6 SEA Objectives 8

SECTION 2 **11**

BASELINE ENVIRONMENT – AIR QUALITY **11**
2.1 Introduction 13
2.2 Methodologies used to develop the baseline 16
2.3 Links to existing legislation and policy 19
2.4 Baseline Environment 20
2.5 Key Environmental Issues and Problems 26
2.6 Value and Vulnerability of Receptors 27

SECTION 3 **29**

EVALUATION OF PLAN ALTERNATIVES – AIR QUALITY **29**
3.1 Introduction 31
3.2 Assessment Methodology 31
3.3 Alternative Options 33
3.4 Summary of Potentially Significant Issues 34
3.5 Assessment of Likely Significant Effects on the Environment 35
3.6 Measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment 44

SECTION 4 **53**

ASSESSMENT AGAINST SEA OBJECTIVES – AIR QUALITY **53**
4.1 Introduction 55
4.2 Assessment Methodology 55
4.3 Objectives-led Assessment Summary 55
4.4 Assumptions, Limitations and Uncertainty 56

SECTION 5 **59**

BASELINE ENVIRONMENT – CARBON FOOTPRINTING **59**
5.1 Introduction 61
5.2 Methodologies used to develop the baseline 62
5.3 Links to existing legislation and policy 63
5.4 Baseline Environment 64
5.5 Key Environmental Issues and Problems 66
5.6 Value and Vulnerability of Receptors 66

SECTION 6 **69**

EVALUATION OF PLAN ALTERNATIVES – CARBON FOOTPRINTING **69**
6.1 Introduction 71
6.2 Assessment Methodology 71
6.3 Alternative Options 73
6.4 Summary of Potentially Significant Issues 74
6.5 Assessment of Likely Significant Effects on the Environment 76
6.6 Likely effects of estuarine changes 91
6.7 Measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment 111

SECTION 7 **115**

ASSESSMENT AGAINST SEA OBJECTIVES – CARBON FOOTPRINTING **115**
7.1 Introduction 117
7.2 Assessment Methodology 117
7.3 Objectives-led Assessment Summary 117

SECTION 8 **121**

PLAN IMPLEMENTATION **121**
8.1 Introduction 123
8.2 Legislation and policy compliance 123
8.3 Monitoring of significant environmental effects 124

SECTION 9 **125**

GLOSSARY **125**

SECTION 10 **133**

REFERENCES **133**

SECTION 11 **139**

APPENDICES **139**

APPENDIX A **141**

AIR QUALITY BASELINE RECEPTOR: VALUE, VULNERABILITY AND THRESHOLDS FOR MAGNITUDE OF EFFECT **141**

1.1	Introduction	144
1.2	Requirements of the Strategic Environmental Assessment Directive	144
1.3	Definitions of Value and Vulnerability	145
1.4	Summary of Value and Vulnerability for Air Quality	145
1.5	Definitions of Thresholds for Magnitude of Effect	146
2.1	Receptor Scale	148
2.2	Human Health Receptor	148
2.3	Habitat Receptor	148
3.1	Human Health Receptor Value	148
3.2	Habitats and Species	149
4.1	Vulnerability of Human Health	151
4.2	Vulnerability of Habitat Receptors	152
4.3	Vulnerability Assessment	153

APPENDIX B **159**

VALUE VULNERABILITY AND MAGNITUDE OF EFFECTS – CARBON FOOTPRINTING **159**

1.1	Introduction	162
1.2	Requirements of the Strategic Environmental Assessment Directive	162
1.3	Definitions of Value and Vulnerability	163
1.4	Definitions of Thresholds for Magnitude of Effect	163

APPENDIX C **167**

AIR QUALITY LOCAL HABITAT IDENTIFICATION & CALCULATIONS **167**

APPENDIX D **179**

AIR QUALITY EMISSIONS ASSUMPTIONS **179**

APPENDIX E **185**

RAIL AND SHIPPING CAPACITY ASSUMPTIONS **185**

APPENDIX F **189**

AIR QUALITY OFF-SETTING **189**

APPENDIX G **195**

AIR QUALITY TRANSORT EMISSIONS **195**

APPENDIX H **201**

AIR QUALITY TOTAL DREDGING EMISSIONS **201**

ABBREVIATIONS

ABBREVIATIONS

The following abbreviations are used in this Topic Report:

BAP	Biodiversity Action Plan
BERR	Department for Business, Enterprise and Regulatory Reform
CCGT	Combined Cycle Gas Turbine
CCW	Countryside Council for Wales
CHP	Combined Heat and Power
CO_2	Carbon dioxide equivalent
cSAC	Candidate Special Area of Conservation
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DWT	Dead weight tonnes
EIA	Environmental Impact Assessment
EC	European Commission
EU	European Union
FCCC	Framework Convention on Climate Change
GIS	Geographical Information System
GHG	Greenhouse Gas
GW	Gigawatts
GWP	Global Warming Potential
G8	Group of 8 Nations
HRA	Habitats Regulations Assessment
LNR	Local Nature Reserve
MW	Megawatts
NERC	Natural Environment and Rural Communities Act
NNR	National Nature Reserve
N_2	Nitrogen
NH_3	Ammonia
NH_4^+	Ammonium Salts
NO_2	Nitrogen Dioxide
NO_X	Oxides of Nitrogen
NP	National Park
NAQIA	National Air Quality Information Archive
NPS	National Policy Statement
ODPM	Office of the Deputy Prime Minister
PM10	Fine Particulate Matter with Diameter less than 10µm
PPG	Planning Policy Guidance
PPS	Planning Policy Statements
SAC	Special Area of Conservation
SDC	Sustainable Development Assessment
SEA	Strategic Environmental Assessment
SLR	Sea Level Rise
SNCI	Sites of Nature Conservation Importance
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
STP	Severn Tidal Power
SWRDA	South West Regional Development Agency
TWh	Terrawatt hours
UKCIP	United Kingdom Climate Impacts Programme
UN	United Nations
WAG	Welsh Assembly Government

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 Introduction

1.1.1 The Government announced a two-year feasibility study on harnessing the renewable energy from the tidal range in the Severn Estuary in January 2008. This work is being carried out by a cross-Government team led from the Department for Energy and Climate Change (DECC), including representatives of the Welsh Assembly Government (WAG) and the South West Regional Development Agency (SWRDA), taking external advice as necessary and engaging stakeholders and the wider public. The aim of the Severn Tidal Power (STP) Feasibility Study is to investigate whether Government could support a tidal power scheme in the Severn and, if so, on what terms.

1.1.2 The Feasibility Study is split into two phases:

- Phase One: Examining the scope of work and analysis required to make an evidence-based decision on whether to support a tidal power project in the Severn and what potentially feasible schemes exist for converting this energy. Phase one ended with the publication of the consultation document in January 2009.

- Phase Two: Work on environmental, regional, economic, commercial, technical and regulatory issues to inform the study conclusions including whether any of the potential schemes are feasible.

1.1.3 A Strategic Environmental Assessment (SEA) is being carried out in support of the Feasibility Study, in accordance with EU Directive 2001/42/EC (the SEA Directive), implemented in England and Wales through the Environmental Assessment of Plans and Programmes Regulations (SI 2004/1633 and Welsh SI 2004/1656), to predict and analyse the environmental effects of alternative short-listed Severn tidal power options over their entire lifetime, in order to inform decision making at the end of the Feasibility Study.

1.1.4 In parallel to the Feasibility Study, the Severn Embryonic Technologies Scheme is helping developers of emerging technologies map their development path. They are not being assessed as part of this SEA currently, as they are not at the stage whereby they can be considered reasonable alternatives.

1.1.5 The scope of the SEA, published by the Government in January 2009 (DECC, 2009a) is based on the assessment of a defined set of issues within 'topic papers'. These papers will be aggregated into 'theme' papers to ensure that the interrelationships between effects are considered and understood – see Section 1.4. The topic and theme papers will provide supporting information to the Environmental Report that is needed to fulfil the requirements of the SEA Directive.

1.2 Report Structure

1.2.1 This is the Air & Climatic factors Topic Paper, within the Air & Climatic Factors, Resources and Waste Theme paper. This document reports on both the Air Quality and Carbon Footprint topic assessments.

1.2.2 The structure of the paper is summarised in Table 1.1 below.

Table 1.1: Structure of the Air & Climatic Factors Topic Paper

Report Section	Summary Content
Non Technical Summary	A summary of the scope of work undertaken, and key findings in non-technical language.
Section 1 - Introduction	Presents the context of the Air & Climatic Factors Topic Paper, Summarises the SEA Objectives agreed in Phase 1 and the consultation undertaken to date. Explains the structure and of the Air & Climatic Factors Topic Paper
Section 2 - Baseline - Air Quality	Sets out the Air Quality receptors, environmental baseline and future environmental baseline taking into account current understanding of existing trends.
Section 3 - Evaluation of Plan Alternatives - Air Quality	Reports on the assessment of likely significant Air Quality effects associated with the alternative options.
Section 4 - Assessment against SEA Objectives Air Quality	Presents the assessment of the alternative options against the Air Quality SEA Objectives
Section 5 - Baseline - Carbon Footprinting	Sets out the Carbon Footprinting receptors, environmental baseline and future environmental baseline taking into account current understanding of existing trends.
Section 6 - Evaluation of Plan Alternatives - Carbon Footprinting	Reports on the assessment of likely significant Carbon Footprinting effects associated with the alternative options.
Section 7 - Assessment against SEA Objectives - Carbon Footprinting	Presents the assessment of the alternative options against the Carbon Footprinting SEA Objectives
Section 8 - Plan Implementation.	Summarises potential legislative and policy compliance of each alternative option with regard to Air Quality and Carbon Footprinting. Provides suggestions for monitoring and further research should Government choose to support the development of Severn Tidal Power.

1.3 Scope of the Topic Paper

1.3.1 **The scope of the air quality assessment** includes the potential impacts of the construction, operation and decommissioning of the Options on:

- Local air quality and human health;
- The regional contribution to trans-boundary pollutants (excluding Carbon).

1.3.2 The scope also includes an assessment of potential opportunities and methods for maximising benefits and minimising adverse impacts.

1.3.3 The receptors considered in the assessment include both humans and habitats. For human health impacts, the receptors are consistent with those considered in the Society and Economy Phase 1 Scoping Topic Paper and comprise:

- Welsh urban population;
- South-west England urban population;
- Welsh rural population;
- South-west England rural population.

1.3.4 For the assessment of habitats impacts, the receptors comprise:

- Designated sites in the vicinity of the short-listed options and potentially susceptible to changes in local air quality;
- Designated sites at the National (UK) level, potentially affect by changes in air quality resulting from the off-setting of pollutant emissions from fossil power generation.

1.3.5 For the phase 2 assessment, these receptors were refined into two geographic groupings: local and national. Therefore the receptors considered in the Air Quality topic paper for phase 2 are as follows:

- Local population;
- UK population
- Local habitats
- UK habitats

1.3.6 **The Carbon Footprint scope** has considered potential changes in the UK & Global GHG emissions as a result of a Severn Tidal Power option being installed.

1.3.7 The carbon footprint study area is Global as emissions could be released globally (from for example, transportation and component fabrication) as a result of a Severn Tidal Power option. Nevertheless this would be a UK based project and therefore the emissions would be accounted for within the UK and against UK targets for reduction. For this reason the study area is also considered to be UK based.

1.3.8 The carbon footprint receptors have been selected as Global GHG emissions and UK GHG emissions.

1.4 Interfaces between topics and other work conducted within Feasibility Study

1.4.1 Each SEA topic paper sits within a theme of related topics – see Table 1.2 below. The theme papers reflect the many inter-relationships associated with the Severn estuarine system, and provide an additional tier of technical reporting to ensure that the many complex issues that are not self-contained within a given topic are recognised and their implications understood.

Table 1.2: SEA themes and topics

SEA Theme	SEA Topics
Physicochemical	Hydraulics & Geomorphology; Marine Water Quality; Freshwater Environment & Associated Interfaces; Flood Risk & Land Drainage
Biodiversity	Waterbirds; Terrestrial & Freshwater Ecology; Marine Ecology; Migratory & Estuarine Fish
Landscape & Historic Environment	Landscape & Seascape; Historic Environment
Society & Economy	Communities; Navigation; Other Sea Uses; Noise & Vibration
Air, & Climatic factors, Resources & waste	Air & Climatic factors (including Carbon Footprint); Resources & Waste

1.4.2 The SEA, and its supporting studies captured within each topic paper, comprise part of the Feasibility Study. Other relevant studies within the Feasibility Study but not contained within the SEA include supply chain, electricity grid connection, and ecosystem goods and services valuation studies.

1.5 Consultation

1.5.1 Both the Feasibility Study and the SEA within it have included a programme of formal and informal consultation activities. These include the public consultation exercise in early 2009, technical workshops during both Phase 1 and 2, and informal meetings and other communications. These are summarised for this topic below.

<u>Scoping Consultation</u>

1.5.2 In January 2009, Government launched a consultation on the conclusions of the first phase of the Feasibility Study (DECC, 2009a). The consultation included a recommended short-list of schemes for more detailed analysis, and provided the scope of the SEA. The Government's consultation response published in July 2009 confirmed the shortlist of alternative options, and the scope of the SEA (DECC, 2009b).

1.5.3 As a consequence of both the consultation process and internal review by the SEA team the scope of the Air Quality assessment was broadened to include regional contribution to the trans-boundary pollutants as well as an assessment of the impacts upon habitats emissions. This was as a direct outcome of the extending the assessment to take account of the potential opportunities for maximising benefits/minimising adverse impacts and measures to prevent or reduce adverse effects. This revision broadened the original scope of the SEA Air Quality study, extending the workplan as well as the operation required to complete the assessment.

1.5.4 The initial consultation phase in January 2009 allowed valuable feedback to be provided on the scoping of the carbon footprint work, highlighting some key areas for consideration to ensure adequate coverage in the phase 2 carbon footprint assessment. However, these did no alter the Carbon Footprinting scoping topic paper.

Technical Workshops

1.5.5 A series of 'Technical Workshops' was convened during phase 1 and 2 of the Feasibility Study, principally to provide the opportunity for technical specialists across many organisations to input to the developing SEA. Table 1.3 below summarises the workshops held in support of this topic.

Table 1.3: SEA technical workshops for the Air & Climatic Factors SEA topic

Phase, date	Workshop purpose
Phase 1, January 2009	To undertake a preliminary scoping of issues and the assessment approach needed within phase 1 of the SEA (Carbon Footprinting only)
Phase 2, 16th June 2009]	To confirm scope of SEA work planned in phase 2 and review key aspects of assessment methodology.
Phase 2, 8th December 2009]	To review preliminary findings and approaches to identifying measures to prevent, reduce and as fully as possible offset significant environmental effects.

1.5.6 The first technical workshop in June 2009 provided the opportunity for confirmation of the scope of the SEA topic paper scope of work, including receptors, spatial extent and definition of key terms for use in the phase 2 assessment. Following the technical workshop these definitions were circulated to attendees in the Value, Vulnerability and Magnitude of Effect papers for both the air quality and carbon footprint studies. (Appendices A and B to this report).

1.5.7 The second technical workshop in December 2009 was used as an opportunity to review the work completed to date, specifically the applied methodology and associated assumptions. Some early stage results were presented to enable discussions around assumptions and, importantly, uncertainty and results presentation. No amendments to the scope of the work undertaken were required for either the Air Quality and Carbon Footprinting studies.

Other Consultation

1.5.8 Throughout all the consultation processes there were three issues that became clear areas of concern for the stakeholders and, therefore, we believe, the public. These are summarised here but are considered in more detail throughout the report:

- Consideration of the scope of works for Severn Tidal Power SEA carbon footprinting against the scope of works used for the Sustainable Development Commission Severn Tidal Power carbon footprint. The variation in scope and thus results are taken into consideration in the error bands of the results.
- The impact of ecological changes in the estuary on carbon emissions are described in more detail in Section 6.5.48..
- Any construction and ongoing operational delays to shipping (see Section 6.5.40).

1.6 SEA Objectives

1.6.1 SEA Objectives are a recognised tool for comparing alternative options. This technique is proposed in the SEA Practical Guide (ODPM et al., 2005). SEA Objectives usually reflect the desired direction of change. It therefore follows that these objectives may not necessarily be met in full by a given option, but the degree to which they do will provide a way of identifying preferences when comparing options.

1.6.2 This approach requires judgments to be made on the performance of alternative options against each SEA Objective. 'Assessment criteria' and 'indicators' have also been developed to aid these judgements. The assessment criteria are a series of questions developed to guide the judgement of objective compliance. An indicator is measure of a variable over time, often used to measure achievement of objectives.

1.6.3 The SEA Objectives, assessment criteria and indicators were drafted and consulted upon as part of the Phase 1 SEA scoping stage. The Government response to the consultation for the most part confirmed the SEA Objectives and in some cases made some minor modifications (DECC, 2009b).

1.6.4 As a result of the extension of the scope of the air quality assessment and the inter-relationship between air quality and the other Themes, a number of existing SEA Objectives, relevant to air quality, have been adopted and incorporated into this topic paper. The SEA objectives for air quality and carbon footprinting are provided in Table 1.4. They have been derived from the Communities Topic paper, the Carbon Footprinting element of the Air and Climatic Factors Topic paper and the Terrestrial and Freshwater Ecology Topic papers.

1.6.5 The Objectives in Table 1.4 allow consideration of impacts upon human health, opportunities for pollution emissions reduction through maximising sustainable sources of energy, attempts to protect both international and national wildlife sites and ecological networks.

1.6.6 Assessment criteria and indicators for the four objectives were adopted at the scoping stage for the Communities (then Society & Economy), Carbon Footprinting and the Terrestrial & Freshwater Ecology Topic papers. These were limited to a single outcome/output in order to reduce the assessment parameters and ensure an easily interpretable but consistent assessment output across SEA Topics and Themes.

Table 1.4: SEA Objectives, Assessment Criteria and Indicators

SEA Objective	Assessment Criteria	Indicators
Air Quality		
SE.4 To avoid adverse effects on physical and mental health	Will the option result in deterioration in the quality of life (health and well-being) as measured by increase in air emissions?	Relative increases in air emissions anticipated from traffic, construction equipment, etc
CF.1 To maximise the opportunities for use of sustainable sources of energy for the UK.	What is the pollutant footprint of each option (life cycle emissions in relation to other options)?	The pollutant (equivalent) emissions payback period will indicate which option is most emissions efficient.
TFE.1 To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.	Will the option result in the loss of terrestrial and freshwater habitats of international or national importance?	Changes in quality/extent of internationally important site features, e.g. within SPAs, SACs Ramsar Sites.
TFE.2 To avoid adverse effects on valuable terrestrial and freshwater ecological networks.	Will the option adversely affect ecological networks for terrestrial and freshwater habitats and species?	Changes in quality/extent of nationally important site features, e.g. within SSSIs.
Carbon Footprinting		
CF.1 To maximise the opportunities for use of sustainable sources of energy for the UK	The level of renewable energy production from the alternative option, the unit $kgCO_2/kWh$ emission from that option and the payback period.	The renewable annual energy production from each option, the resulting unit $kgCO_2/kWh$ of the energy and the payback period.
CF.2 To avoid adverse effects from GHG emissions over the lifecycle of the project	The total CO_2 emissions released as a result of each phase of the option, and the net CO_2 emissions.	The construction, operation and decommissioning phase emissions. The net CO_2 emissions ($kgCO_2$).

SECTION 2

BASELINE ENVIRONMENT – AIR QUALITY

2 BASELINE ENVIRONMENT AIR QUALITY

2.1 Introduction

2.1.1 Baseline information provides the basis for predicting and monitoring environmental effects. Both qualitative and quantitative information can be used for this purpose.

2.1.2 The baseline information is described for the area that may be affected in terms of a range of 'receptors'. A receptor is an entity that may be affected by direct or indirect changes to an environmental variable. Relevant receptors were identified and consulted upon during the SEA scoping stage.

2.1.3 Alternative options considered within this Feasibility Study would only be developed several years into the future and would have a long life. It is therefore necessary to project a 'future baseline' against which to compare effects, rather than using the present day baseline. This is an especially important concept when considering dynamic systems such as estuaries that are subject to climate change effects such as sea level rise.

2.1.4 The approach taken is therefore to describe baseline information in the following stages:

- Baseline environment and receptors up to 2009, including environmental problems and opportunities;
- Future baseline during construction: 2014-2020, including anticipated problems and opportunities;
- Future baseline during operation 2020-2140, decommissioning and longer term trends, including anticipated problems and opportunities.

2.1.5 This paper describes the baseline for the relevant receptors with this topic. It will thereby inform the description of the baseline environment for the affected area as a whole, contained within the SEA Environmental Report.

<u>Study area</u>

2.1.6 Air Quality impacts can occur at a number of spatial levels. For the purposes of the Severn Tidal Power SEA it is appropriate to consider receptors at a local level, i.e. those receptors in the vicinity of the short-listed options and susceptible to any localised impacts, and at a national level where any changes in air quality as a result of off-setting pollutant emissions from fossil power generation can be assessed. For the purposes of the Air Quality study, the UK is considered to constitute the national study area.

2.1.7 Both the local area immediately surrounding the Severn Estuary (see Figure 2.1) and the UK at the national level were established as the two study areas required for the air quality assessment of the alternative options.

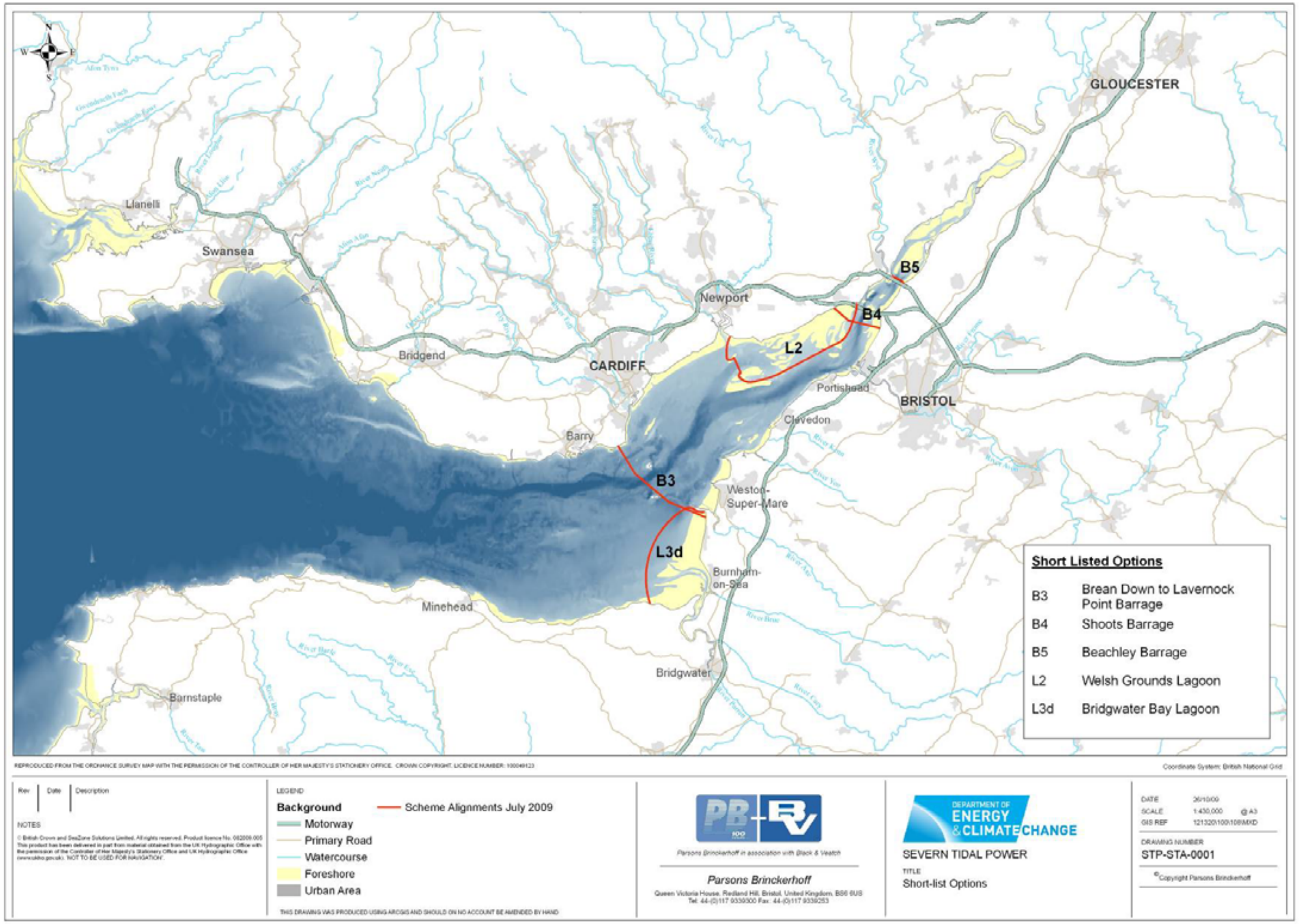

Figure 2.1: Short Listed Options Study Area

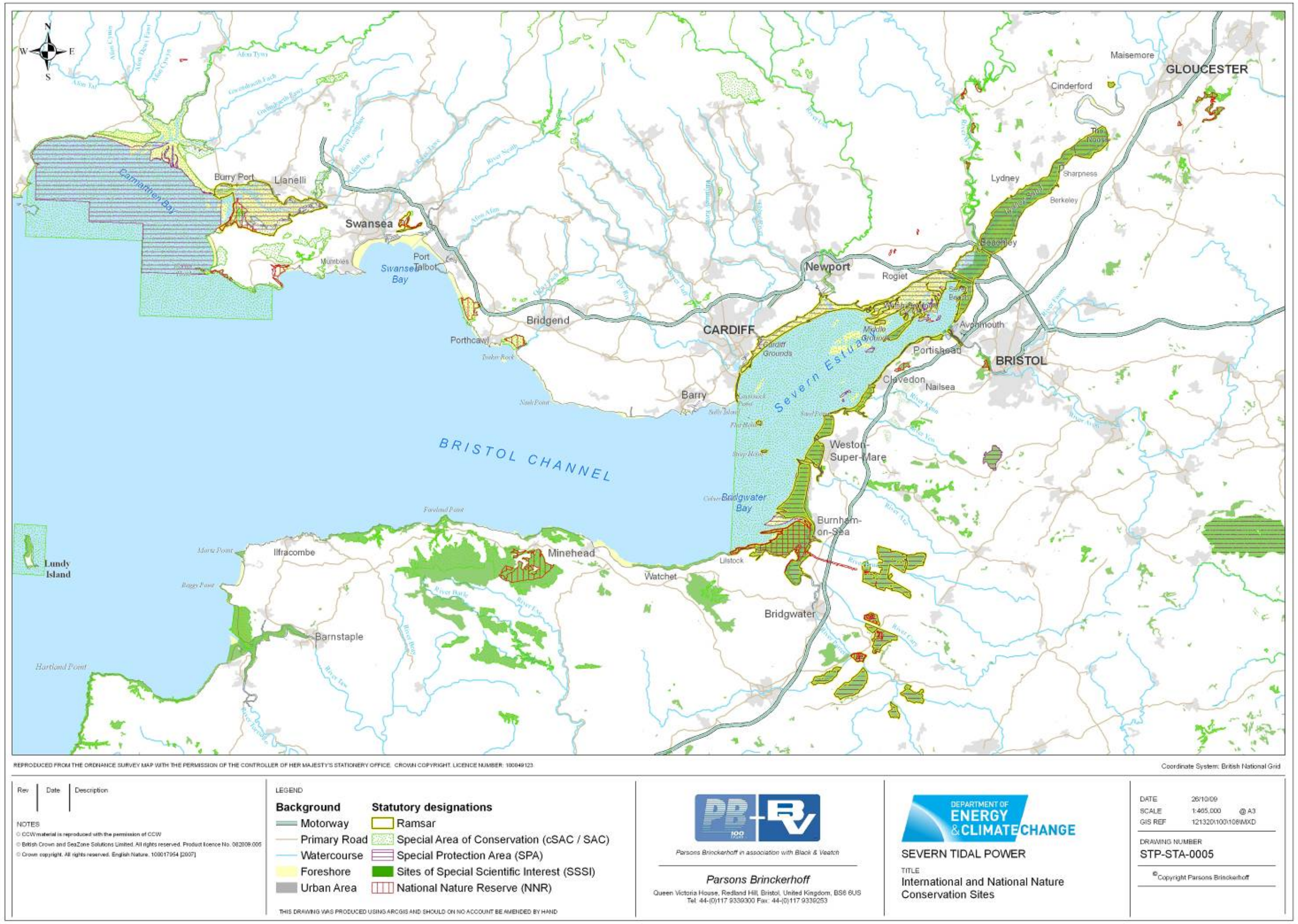

Figure 2.2: International and National Nature Conservation Sites

Receptors

2.1.8 Receptors identified within the phase 1 scoping study, South West and Welsh urban population; South West and Welsh rural population; local designated habitat sites; national designated habitat sites, (1.3.3 and 1.3.4) were refined into two geographic groupings : Local and National population and habitat receptors.

2.1.9 Local receptors for air quality comprise of both human populations and natural ecosystems, which are sensitive to the concentration of air pollutants. High concentrations of air pollution can have a direct impact on human health as well as vegetation growth and biodiversity.

2.1.10 In 2008, the total local study area population was estimated to be 2.02 million, with Bristol, Cardiff, South Gloucestershire and North Somerset being the largest local populations. Figure 2.2 shows the identified international and national nature conservation designations within the study area.

2.1.11 National receptors for air quality are comprised of both human populations and natural habitats, where changes in national air pollutant emissions can lead to either a degradation or improvement in both human and habitat health. Both humans and habitats were recognised as the two receptors essential for the air quality assessment of the alternative options.

2.1.12 Habitat receptors are identified by reference to their statutory designations and component broad habitat types. It is assumed that there are also non-designated habitats within both geographic scales that would potentially be affected in a similar way; however, given the scale of this study it is impractical to seek to identify all such sites.

2.2 Methodologies used to develop the baseline

Sources of Data

2.2.2 The air quality baseline assessment was derived using a series of published sources including but not limited to:

- Local Authorities;
- National Air Quality Information Archive (NAQIA);
- Air Pollution Information System;
- Centre for Hydrology and Ecology (CEH);
- National Atmospheric Emissions Inventory (NAEI).

2.2.3 Established sources of air pollutant emissions and air quality information, such as the National Air Quality Information Archive and the National Atmospheric Emissions Inventory allow direct derivation of both current and near future air quality information. In addition both the National Air Quality Strategy 2007 and the UK Low Carbon Transition Plan allow for future emissions of air pollutants to be derived as a product of both the estimated future energy mix and the predicted future energy requirement.

2.2.4 The list of sites within the local Study Area was developed in consultation with the Terrestrial & Freshwater Ecology and Marine Ecology topic papers. The broad habitat types identified within these designations were then identified (see Appendix

C). Habitat baseline information was obtained from the Centre for Hydrology and Ecology, the Joint National Countryside Committee (JNCC) and the Air Pollution Information System. In addition Appraisal of Sustainability reports by the Department for Energy and Climate Change and Ministry of Defence (for Oldbury and Hinkley Point) contained relevant local baseline habitat information.

2.2.5 Habitats critical loads baseline information was derived from the National Critical Loads Mapping Programme undertaken by the Centre for Ecology and Hydrology in 2007 in association with mapped areas of protected Habitat supplied by the Joint Nature Conservation Committee (JNCC). For the purpose of clarity and consistency assessed habitats were restricted to those which fall within the Biodiversity Action Plan (BAP) Broad habitats (Heywood, 2007).

Assumptions, limitations and uncertainty

2.2.6 It is important to acknowledge the assumptions, limitations and uncertainties inherent in predicting changes to complex systems at a strategic level. Where possible, generalised assumptions and approaches for dealing with uncertainty have been developed to be applied consistently across the topics, as is the case with Climate Change and Policy. Where this is not possible and topic-specific consideration is required, the assumptions, limitations and uncertainty are clearly identified. Further detail is given below.

General Climate Change Assumptions

2.2.7 In developing the future baseline projections, assumptions are made about environmental trends, and policy responses to these trends. It has been assumed that UK Climate Projections (UKCP09) central estimate projections for the medium emissions scenario apply for most topics (UKCP09, 2009).

General Assumptions Concerning Application of Government Policy

2.2.8 It also has been assumed that, in general, existing Government policies relating, for example, to climate change response and biodiversity, will continue to apply into the future. .

Topic Specific Assumptions, Limitations and Uncertainty

2.2.9 The baseline for the air quality paper was limited to the key pollutants associated with activities typical of a large scale construction project as well as those associated with power production. Baseline pollutants were therefore limited to emissions and ambient air concentrations of NO_X and NO_2[1], SO_2 and PM_{10}.. Baseline reporting of the above pollutants was limited to parameters which were readily available, could be reliably reported for the baseline years and could be reasonably estimated or modelled for the assessment years.

2.2.10 Estimations for the future year baseline of NO_2 were made through the incorporation of predicted decreases in both background concentrations of NO_X and estimated improvements in road vehicle technology leading to a reduction in the emission of NO_X from road vehicles. However emissions reductions in NO_X from the UK road fleet as a whole have to date not been validated and it is widely accepted that these estimated improvements in road vehicle technology have been over optimistic.

[1] It should be noted that emissions of nitrogen oxides from combustion sources occur primarily as nitrogen oxide, NO, with a smaller proportion of nitrogen dioxide, NO_2. NO may subsequently be converted to NO_2 in the atmosphere via a series of complex reactions involving ozone. In relation to human health, NO_2 is the most significant. For habitats, both total levels of nitrogen oxides and the deposition of nitrogen to the surface are insignificant.

2.2.11 Emissions for air pollutants were derived from the National Atmospheric Emissions Inventory and estimates were restricted to either the emissions available within the inventory or available emissions factors. Data within the National Emissions inventory, previously derived for national annual emissions reporting, indicated that the uncertainties in the emissions of both SO_2 and NO_x were generally low (i.e. less than 10%) and the level of uncertainty for PM_{10} is acceptable but somewhat higher at between – 20 to + 50% (**Table 2.1**).

2.2.12 **Table 2.1: Uncertainty in the national emission total as a percentage relative to the mean or best estimate (DEFRA, 2003)**

Pollutant	Uncertainty
SO_2	+/- 3%
NO_x	+/- 7%
PM_{10}	-20% to +50%

2.2.13 Atmospheric emissions during the construction phase were modelled using a broad low resolution approach, appropriate to the detail of construction materials, construction traffic and level of activity on site. All construction phase data were taken directly from the feasibility study and option definition report. Detailed assumptions are set out in Appendix D.

2.2.14 A number of major new developments are planned which may have some impact upon the air quality within the STP SEA study area. These include;

- Severn Power 800MW Combined Cycle Gas Turbine (CCGT) due 2010;
- Prenergy Woodchip Plant Biomass power station fuelled by wood chips (350MW), due 2011;
- Helius Energy Biomass Power Station Biomass fired power station to generate 100 MW, 2009;
- E.ON Energy Biomass Power Station Biomass fired renewable energy power station to generate 150 MW, due 2013.

2.2.15 Future baseline estimations calculations have included emissions from the above developments.

2.2.16 Habitats baseline information was derived from the National Critical Loads Mapping Programme undertaken by the Centre for Ecology and Hydrology in 2007 in association with mapped areas of protected Habitat supplied by the Joint Nature Conservation Committee. For the purpose of clarity and consistency assessed habitats were restricted to those which fall within the Biodiversity Action Plan (BAP) Broad habitats (Heywood, 2007). Habitats receptor effects within this SEA were mapped as critical loads and not critical levels. This was due to the extensive and consistent information upon critical loads, unlike critical levels, including predictions of future baselines of critical loads upon broad habitats within the UK.

2.2.17 The estimated long-term critical load exceedences for habitat systems contained large uncertainties. For this reason, areas of critical load exceedences were incorporated in the assessment in an indicative exercise only, designed to illustrate the potential area of exceedance, rather than as an estimation of the absolute area of exceedance

2.2.18 Baseline critical load exceedences were not directly available for all selected habitats. Therefore an assumption was made that the proportion of critical load exceeded for non-protected UK habitat would be the same proportion as critical load exceeded for protected UK habitats. Exceedance proportions between protected and non-protected habitats were matched between BAP broad habitats of protected and non-protected habitats.

2.2.19 Baseline air quality information for the decommissioning year 2140 was unavailable, as no available air quality baseline data currently exists for the year 2140 and credible predictions of an air quality baseline were limited. Current air pollutants emissions are largely associated with fuel use, its type, intensity and spatial and temporal distribution. Energy use and fuel types are largely unknown for the year 2140 as is the distribution of the population within the UK.

2.3 Links to existing legislation and policy

2.3.1 A review has been conducted of relevant national, regional and local policies, plans and programmes, to assist with the identification of synergies and potential inconsistencies with the Feasibility Study, and thus contributing to the development of SEA Objectives (STP, 2009a). Existing legislation and policy of particular relevance to this topic are summarised below.

- The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007).
- EU Directives on Ambient Air Quality (2008/50/EC) and (2004/107/EC)
- The Air Quality Standards Regulations, Statutory Instrument 2007 No 64
- Clean Air for Europe (CAFE) (2001)
- The Environmental Permitting Regulations
- Habitats Directive Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora
- the Conservation (Natural Habitats, & c.) Regulations 1994
- UN-ECE Convention on Long-Range Transboundary Air Pollution.1979.
- National Emission Ceilings Directive 2000/81/EC
- The Control of Dust and Emissions from Construction and Demolition, Best Practice Guidance, November 2006, London Councils and the Greater London Authority

2.3.2 European Directive limits and target values exist for the protection of human health and ecosystems. These have been either incorporated directly or improved as National Air Quality Objectives within the Air Quality Strategy for England, Scotland, Wales and Northern Ireland.

2.3.3 In addition, for particulate matter (as PM2.5), EC Directives and the Air Quality Strategy set out an exposure reduction approach. This new approach to regulating ambient air quality resulted from growing evidence that it was the finer fraction of PM10 which was most closely linked with health effects and that no safe exposure level for particulate matter could be defined. As a result, it was acknowledged that a reduction in the overall emissions of particulates would have an impact of greater magnitude than the limited emissions reductions measures aimed at areas where concentrations of particulates are considered very high.

2.3.4 Pollution Prevention and Control Regulations follow the philosophy of 'Best Available Technology', where installations are expected to reduce emission to air through technological improvements. Application of the PPC regulatory regime that industrial processes continually improve on both their abatement measures and process efficiency thereby reducing their emission to air.

2.4 Baseline Environment

2.4.1 This SEA baseline environment describes the area that may be affected in terms of 'receptors', and has examined the potential for significant effects in relation to these. The receptors were developed during Phase 1 SEA scoping. The list of receptors was subsequently consulted upon as part of the Phase 1 consultation.

2.4.2 A review has been conducted of other projects in and around the Severn Estuary that may have an influence on the future baseline (STP, 2009b). Those projects that are considered to be reasonably foreseeable as implemented by 2014, have been considered part of the future baseline environment.

National (UK) Population Receptor

Baseline environment (up to 2009)

2.4.3 In the UK as a whole, and away from major sources of pollution such as main roads or large industrial processes, air quality within the UK is generally good, where the National Air Quality Information Archive mapped concentrations indicate large areas of the UK where air pollution levels are well below the national air quality objectives, and only large conurbations and major roads appear to have poor air quality. However, pockets of poor air quality exist, both in the major urban centres and in rural areas. Of the 423 Local Authorities within the UK, 229 have declared an Air Quality Management Area due to poor air quality. The percentage of the total population within an area of the UK where air quality objectives were exceeded, were modelled on a pollutant specific basis for 2005 (Table 2.2). As the modelled year was 2005 it has been assumed that to represent the up to 2009 baseline environment (DEFRA, 2007).Generally air quality in the UK has been slowly improving for the previous 10 years, the trend has been a decrease in the population within an area where air quality objectives were exceeded.

Table 2.2: Percentages of total population within in an area where air quality objectives were exceeded (total population modelled 58,160,071) DEFRA, 2007

Pollutant	Threshold	2005
SO_2	Hour and 24 hr mean	0.01
NO_2	Annual Mean > 40μg/m^3	2.3
PM_{10}	Annual mean > 31.5μg/m^3	0.1

2.4.4 It can be seen that the occurrence of NO_2 exceedences are significantly higher than either SO_2 or PM_{10}. , This is due to the ubiquitous emission of oxides of nitrogen from any high temperature combustion process, in particular road vehicles. That said, it is not possible at present to discern a threshold below which health effects from particulate matter do not occur. Therefore, the fact that a relatively small proportion of the UK population is exposed to particulate matter concentrations above the air quality objectives should not be used to infer that health effects are not occurring. In fact, it was estimated that in 2005, exposure to man-made particulate air pollution in the UK would be expected to reduce life expectancy by up to about 7-8 months, when averaged over the UK population.

Baseline during construction (2014 – 2020)

2.4.5 There are significant improvements in air quality predicted between current levels and 2020, and this is expressed as a decrease in both the background pollution levels and the areas of exceedences of air quality objectives. Percentages of the total population within an area of the UK where air quality objectives are predicted to be exceeded have been modelled for 2010 and 2020 (Table 2.3). The modelled year 2010 was assumed to represent the baseline environment up to 2014. (DEFRA, 2007). The effects of the predicted decrease in NO_2 concentrations within the UK between 2010 and 2020 are apparent. However these predictions rely heavily upon estimated improvements in road vehicle technology and reductions in emissions of NOX from the UK road fleet as a whole which, to date, have not been validated. Furthermore, it is widely accepted that these estimated improvements have been over optimistic and may not be attained.

2.4.6 Reductions in exposure to particulate matter pollution are expected to result in a reduction in health impacts from current levels, such that, by 2020, reduced life expectancy due to exposure to man-made particulate pollution, averaged over the whole population of the UK, would be around 5.5 months.

Table 2.3: Percentages of total population within an area of the UK where air quality objectives were exceeded (total population modelled 58,160,071) DEFRA, 2007

Pollutant	Threshold	2015	2020
SO_2	Hour and 24 hr mean	0.01	0.01
NO_2	Annual Mean > 40μg/m^3	0.3	0.3
PM_{10}	Annual mean > 31.5μg/m^3 (indicative of the daily mean standard)	0	0

Baseline during operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.7 Insufficient data exist to robustly estimate future air quality between 2020 and 2140. However, air quality across the UK has been predicted to improve with the continued introduction of improved road vehicle technology, introduction of best available technology throughout industry and the emergence of renewable technologies as part of the low carbon transition plan for the UK (DECC, 2009). It has been predicted that approximately 25% of all cars on the road will be either a hybrid or electrically powered by 2025 (Idtechex, 2009). The gradual introduction of low carbon technologies through industry and domestic use are likely to reduce emissions of air pollutants. However, at this stage, reliable methods of predicting the extent of these improvements do not exist.

Local Population Receptor

Baseline environment (up to 2009)

2.4.8 Generally air quality within the local study area, up until 2009, is very good with isolated areas of poor air quality in urban areas and residential areas which are very close to emissions from road transport. Of the 12 local authorities which operate within the defined STP SEA study area, 5 local authorities have declared one or more air quality management areas due to poor air quality. The majority of the air quality management areas were declared for the exceedance of NO_2 objectives due primary to emissions from road transport, with a small number declaring AQMAs due to high PM_{10} concentrations. No AQMAs were declared within the study area due to SO_2.

2.4.9 On a broad scale, the NAQIA provides mapped annual mean concentrations of pollutants over the UK at 1km resolution. The most recent predictions were made for a 2006 baseline year, with projections to 2020. Within the study area, mapped concentrations of nitrogen dioxide range from 10 to 30 µg/m^3, which are well within the air quality objective of 40 µg/m^3. The higher concentrations are found in the urban areas and alongside major roads. PM_{10} concentrations range from 15 to 25µg/m^3, which should be compared to the air quality objective of 40 µg/m^3. Background SO_2 concentrations are very low everywhere.

Baseline during construction (2014 – 2020)

2.4.10 Air quality within the study area cannot be reliably estimated without detailed emissions data for the whole study area. However it has been predicted that air quality across the UK (Table 2.3) will improve between 2014 and 2020, particularly with respect to NO_2 emissions. By inference it can assumed that these national improvements in air quality will extend to the study area. Therefore, it is expected that some reduction in the number of AQMA's within the study area will occur, with potentially all of the AQMA's declared for NO_2 being revoked by 2020.

2.4.11 The NAQIA predicted concentrations for the study area show that background levels of NO_2 and PM_{10} are predicted to decrease from current levels to 8 to 20µg/m^3 and 12.5 to 20µg/m^3 respectively by 2020. Background SO_2 concentrations are predicted to remain very low everywhere.

Baseline during operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.12 Insufficient data exists to robustly estimate future local air quality between 2020 and 2140. However, as at the regional level, air quality has been predicted to improve with the continued introduction of improved road vehicle technology, introduction of best available technology throughout industry and the emergence of renewable technologies as part of the low carbon transition plan for the UK (DECC, 2009). The gradual introduction of low carbon technologies through industry and domestic use will reduce emissions of air pollutants.

Internationally Protected Habitats Receptor – National Scale

Baseline environment (up to 2009)

2.4.13 The air quality impact on habitats is through direct exposure to air pollution, and in particular NO_X and SO_2, but also through acidification and eutrophication by the deposition of pollutants onto the plant surfaces and onto soils. The threshold pollutant concentration is termed a critical level. Deposition is assessed against a critical load, which is defined as a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. The baseline status of a habitat for the purpose of this assessment will be the status of the BAP habitats with respect to their critical load and potential exposure to pollution above the critical level. The latter are incorporated into the UK's air quality regulations and EU air quality directives for NO_X and SO_2, with applicability limited to areas distant from major pollution sources.

2.4.14 Mapping of exceedences of critical loads of habitats (CEH, 2004) across the UK has indicated that between 23 to 86% of ecosystems within the broad BAP category of habitats experienced an exceedance of critical load. Data was unavailable on the extent of critical load exceedences for internationally designated habitats. Therefore, the proportions of exceedences among non-protected habitats (all BAP habitats) were assumed applicable to SACs and SPAs (Table 2.4) Battarbee R.W. (1994)

2.4.15 The mapped pollutant concentration data of the NAQIA show that, in 2006, across the UK as a whole, background NO_X and SO_2 concentrations were well within their respective critical levels, except within the major conurbations and in the vicinity of major roads where the air quality objectives for the protection of vegetation do not apply. The key parameters for the assessment of impacts of habitats are, therefore, the exceedences statistics for acidification and eutrophication.

Table 2.4: Estimated area of exceedance of critical loads for UK SACs and SPAs

	Estimated UK Total Area Exceedance Statistics for 1999-2001			
Broad Habitat	**SAC Area Acidity exceedance (Ha)**	**SAC Nutrient Nitrogen exceedance (Ha)**	**SPA Area Acidity exceedance (Ha)**	**SPA Area Nutrient Nitrogen exceedance (Ha)**
Unmanaged woods	35368	22954	13615	20978
Other habitats	7422	4083	183358	333338
Coniferous Woodland	6923	9798	19350	13672
Broadleaved Woodland	939	1237	59180	44959
Acid Grassland	3971	2541	97813	152874
Dwarf Shrub Heath	1360	3441	52739	20844
Bogs	745	1217	5449	3333
All habitats	101353	88783	814147	982419

Baseline during construction (2014 – 2020)

2.4.16 As was the case for air pollutant concentrations in ambient air, pollutant deposition levels are predicted to decrease over time. In a recent deposition modelling exercise (CEH, 2007), in which generic exceedance percentages were derived from deposition modelling of acidification from sulphur and nitrogen as well as deposition from nutrient nitrogen, the area of exceedences of critical loads was predicted to decrease from current levels by around 20% for acidity and 7% for eutrophication. Using these reductions, the areas of exceedences of acidity and nutrient nitrogen critical loads were calculated for the UK's internationally designated sites (Table 2.5). It was assumed that for 2014- 2020 the area of SAC and SPA habitats for the UK would remain the same area as in 2009.

Table 2.5: Estimated area of exceedance of critical loads for UK SACs and SPAs for 2020

	Estimated UK Total Area exceedance Statistics for 2020			
Broad Habitat	**SAC Area Acidity exceedance (Ha)**	**SAC Nutrient Nitrogen exceedance (Ha)**	**SPA Area Acidity exceedance (Ha)**	**SPA Area Nutrient Nitrogen exceedance (Ha)**
Unmanaged woods	27659	21292	10647	19459
Other habitats	5804	3787	143391	309203
Coniferous Woodland	5414	9089	15132	12682
Broadleaved Woodland	734	1147	46280	41704
Acid Grassland	3105	2357	76493	141805
Dwarf Shrub Heath	1064	3192	41243	19335
Bogs	583	1129	4261	3092
All habitats	79261	82355	636686	911287

Baseline during operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.17 Insufficient data exists to robustly estimate future air quality between 2020 and 2140. Nevertheless, air quality has been predicted to improve with the continued introduction of improved road vehicle technology, introduction of best available technology throughout industry and the emergence of renewable technologies as part of the low carbon transition plan for the UK (DECC, 2009). The gradual introduction of low carbon technologies through industry and domestic use will reduce emissions of air pollutants. Furthermore, these anticipated continued improvements in ambient pollutant concentrations will also lead to reductions in the levels of pollutant deposition over time.

Habitat Receptors – Local Scale

Baseline environment (up to 2009)

2.4.18 As at the national level, the baseline status of local habitats for the purpose of this assessment is taken to be the status of the BAP habitats within the study area with respect to their critical loads (Table 2.6) and potential exposure to pollution levels above the critical levels. Significant areas of exceedences of critical loads are predicted, over 47,000 ha of habitats in the case of SACs, which represents 60% of the total area. Appendix C lists the SAC sites within the study area, together with their constituent SSSI and habitats.

2.4.19 Within the study area the predicted concentrations of sulphur dioxide are very low and well within their critical level at all locations. Background concentrations of NOX are generally less than 20µg/m^3, well within the air quality objective of 30µg/m^3. Near the major conurbations e.g. Cardiff/Newport and Bristol, concentrations increase to above 40µg/m^3, but the air quality objectives do not apply in these areas and the majority of the habitats sites are in rural areas.

Table 2.6: Estimated area of exceedance of critical loads for SEA Study Area SACs and SPAs

	Estimated Study Area Total Area exceedance Statistics for 1999-2001			
Broad Habitat	**SAC Area Acidity exceedance (Ha)**	**SAC Nutrient Nitrogen exceedance (Ha)**	**SPA Area Acidity exceedance (Ha)**	**SPA Area Nutrient Nitrogen exceedance (Ha)**
Unmanaged woods	77	107		
Coniferous Woodland	1,392	1,637		
Broadleaved Woodland	395	547	177	250
Acid Grassland	37	26		
Dwarf Shrub Heath	1,068	750		
Bogs	323	176	246	135
Other habitats	44,378	43,609	17694	17331
All habitats	47,668	46,851	18116	17716

Baseline during construction (2014 – 2020)

2.4.20 By 2020, the area of exceedences of critical loads is predicted to decrease (CEH, 2007) in line with national trends (Table 2.7). For example, the area of exceedences of acidity in SACs is predicted to reduce from some 60% of all habitats at present to 39% during the construction period.

2.4.21 In the NAQIA mapped data, background concentrations of SO_2 remain very low, and background concentrations of NO_X decrease to within the objective at nearly all locations, including the conurbations and near major roads, by 2020.

Table 2.7: Estimated area of exceedance of critical loads for SEA study area SACs and SPAs

	Estimated Study Area Total Area exceedance Statistics for 2020			
Broad Habitat	**SAC Area Acidity exceedance (Ha)**	**SAC Nutrient Nitrogen exceedance (Ha)**	**SPA Area Acidity exceedance (Ha)**	**SPA Area Nutrient Nitrogen exceedance (Ha)**
Unmanaged woods	46	54		
Coniferous Woodland	948	1110		
Broadleaved Woodland	225	274	105	123
Acid Grassland	272	332		
Dwarf Shrub Heath	727	851		
Bogs	172	201	131	153
Other habitats	29921	35108	12517	14654
All habitats	32273	37930	12753	14930

Baseline during operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.22 As outlined at the national level, insufficient data exists to robustly estimate future air quality between 2020 and 2140. However, overall decreases in emissions to air and ambient pollutant concentrations, due to improvements in technology and a move to low carbon economy, are anticipated to result in gradual decreases in the level of pollutant deposition over time.

2.5 Key Environmental Issues and Problems

2.5.1 Nationally and locally, air quality effects upon human health and ecosystems are of sufficient concern to require legislative action. However, air quality and its impacts within both the SEA STP study area and the UK as a whole are predicted to improve between 2009 to 2020.

2.5.2 Currently the majority of air quality problems, within the STP SEA study area and nationally, are largely related to emissions from road transport, on major highways and within conurbations generally.

2.5.3 With predicted improvements in vehicle technology, emissions from road vehicles have been estimated to decrease and, therefore, significant improvements in air quality have been predicted to occur over time. Furthermore, enforcement of the PPC regulations and the use of 'best available technology' will ensure a continued reduction in emissions from industry throughout the UK.

2.5.4 As a result, ambient pollution levels and, in particular, exceedences of air quality objectives for the protection of human health and objectives for the protection of ecosystems are predicted to reduce over time. Furthermore, the reduction in pollution levels will also lead to a reduction in pollution deposition leading to a decrease in the area of exceedences of critical loads within designated habitats sites.

2.5.5 Furthermore, the introduction of renewable and low carbon technologies are predicted to have additional effects of reducing pollutants emissions. As a consequence of carbon reductions measures and the UK Government's target of an 80% reduction in carbon emissions by 2050, air quality throughout the UK is predicted to improve (DECC, 2009).

2.5.6 Three new biomass plants and a new combined cycle gas turbine power station within the STP SEA study area equate to four new significant point sources of both NO_2 and PM_{10}. However new sources of power often replace other older less efficient and clean technology. Therefore these new sources may in the longer term provide an opportunity for the reduction in emissions within the STP SEA study area.

2.6 Value and Vulnerability of Receptors

2.6.1 The SEA seeks to identify those environmental effects which are likely to be significant. In forming a judgement on effect significance, in line with the SEA Directive, it is necessary to take into account the attributes of the affected area. In this SEA, the area likely to be affected is described in terms of receptors; and the most relevant receptor attributes are their value and vulnerability. These are defined as:

- **Value**: based on the scale of the geographic reference, rarity, importance for biodiversity, social or economic reasons, and level of legal protection;
- **Vulnerability**: the potential for a pathway for exposure of a receptor to a given environmental effect, brought about by a Severn Tidal Power option, together with the sensitivity of the receptor to that effect.

2.6.2 A standardised approach has been adopted across all topics of this SEA to the assignment of receptor attributes. Nonetheless this approach did allow for some flexibility to reflect the needs of each topic area. This is discussed further below for this topic.

2.6.3 In order to assess impacts of pollutants emissions from both power generation and material manufacture the UK population has been assigned a HIGH value. In addition in order to assess the effect of emissions from both transport and construction activities on the Local Population to the scheme, which includes the population of South Wales and the South West of England, has also been considered a receptor and has also been assigned a HIGH value. High values were assigned to both human health receptors as the improvement of air quality and the protection of human health are both requirements under the Air Quality Framework Directives, regardless of spatial extent and the size of population affected. Further details are contained in Appendix A.

2.6.4 Criteria applied to assign the habitat receptor value of the Air Quality study within the scope of this SEA, are established along a sliding scale which reflects the level of the protection status assigned to a particular habitat (Table 2.8). As both international (e.g. RAMSAR, SAC, SPA) and national features are legally protected they have been assigned a HIGH value. (e.g. SSSI or ASSI). Locally protected habitats (e.g. environmentally sensitive areas) were assigned a low value. Further details are contained in Appendix A.

Table 2.8: Value of receptors

Receptor	Assigned Value
UK Population	High
Local Population	High
International feature, e.g. SPA, SAC, Ramsar Site	High
National feature, e.g. SSSI	High
Local feature, e.g. Environmentally Sensitive Area	Low

2.6.5 For the purposes of assessing the vulnerability of human receptors, where a population is currently exposed to air pollution levels at or above the UK Air Quality Objective and Limit Values, then this population has been assigned a HIGH vulnerability due to their current heath risks. Conversely a population currently exposed to air pollutants below the UK Air Quality Objectives and Limit Values was assigned a LOW vulnerability (Table 2.9).

2.6.6 A habitat vulnerability status of HIGH was assigned to areas where a critical load was exceeded for at least one species and some minority of the ecosystem was known to be sensitive to both acidification and eutrophication (Table 2.9).

Table 2.9: Vulnerability of receptors

Receptor	Assigned Vulnerability
UK Population	High/Low
Local Population	High/Low
International Habitat feature, e.g. SPA, SAC, Ramsar Site	High
National Habitat feature, e.g. SSSI	High
Local Habitat feature e.g. Environmentally Sensitive Area	High

SECTION 3

EVALUATION OF PLAN ALTERNATIVES – AIR QUALITY

3 EVALUATION OF PLAN ALTERNATIVES – AIR QUALITY

3.1 Introduction

3.1.1 The SEA Directive requires the preparation of an Environmental Report on the 'likely significant effects' of implementing the plan, and reasonable alternatives. The main purpose of this topic paper is to inform the SEA Environmental Report and its assessment of likely significant environmental effects. This is by providing an assessment of effects in relation to the topic paper's relevant receptors. The Environmental Report will then consolidate the individual topic assessments to provide a description of all likely significant effects across the affected area.

3.1.2 The SEA Directive instructs that SEA is to be based on information that can reasonably be required, taking into account *inter alia* current knowledge and methods of assessment.

3.1.3 For the purposes of this SEA, the plan alternatives are the shortlisted options currently under consideration following the phase 1 consultation (DECC, 2009a). These are described as the alternative options in this document.

3.2 Assessment Methodology

3.2.1 The SEA Directive specifies in Annex II the criteria that should be taken into account when determining the likely significant effects of the plan. The criteria for identifying these significant effects are defined in the Directive in relation to determining whether an SEA is needed. These criteria will also be adopted for this assessment. In line with the SEA Regulations, the Practical Guide advises the use of these criteria for assessing significant environmental effects.

3.2.2 This topic paper therefore considers, the characteristics of the effects and of the area (i.e. relevant receptors) likely to be affected, having regard, in particular, to:

- the probability, duration, frequency and reversibility of the effects;
- the cumulative nature of the effects;
- the transboundary nature of the effects;
- the risks to human health or the environment (for example, due to accidents);
- the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected);
- the value and vulnerability of the area likely to be affected due to:
    - special natural characteristics or cultural heritage;
    - exceeded environmental quality standards or limit values; or
    - intensive land-use; and
- the effects on areas or landscapes which have a recognised national, Community or international protection status.

3.2.3 The SEA Directive (Annex I) also states that these effects should include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects. The Practical Guide recognises that some of these terms are not always mutually exclusive and for the avoidance of doubt, within this SEA the following approaches are adopted.

3.2.4 Indirect effects are those which are not a direct result of a Severn Tidal Power alternative option, but occur away from the original effect or as a result of a complex pathway. There are many such interactions within estuarine systems that need to be taken into account in this assessment. The SEA does not use the term 'secondary effects' as this is covered by indirect effects.

3.2.5 There is the potential for effects to extend large distances from the Severn estuary. The assessments of these 'far field' effects will have greater uncertainty attached and are described separately.

3.2.6 Cumulative effects arise, for instance, where several developments each have insignificant effects but together have a significant effect. The plans and projects taken into account in the cumulative effects assessment have been identified and agreed (STP, 2009b). These are discrete projects or programmes which are expected to be implemented during the planned Severn Tidal Power project construction period (2014-2020) or during the operation period (2020-2140).

3.2.7 For simplicity, this SEA does not use the term 'combined' effects, as these are considered to be included within cumulative effects, nor does it use the term 'synergistic' effects, as these are considered within direct, indirect and cumulative effects.

3.2.8 A major tidal power scheme may facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as 'consequential developments'. The types of consequential development considered throughout the assessment have also been identified (STP, 2009b). These consequential developments are not well-defined and only a concise high level qualitative assessment of the likely effects is possible.

3.2.9 For the purposes of the air quality assessment for this SEA, estimations of emissions to atmosphere of pollutants from the construction, operation and decommissioning phases of the STP project were undertaken through emissions modelling for each of the options. Information taken from the Materials Summary Report derived from the STP options definition report (DECC, 2009) was applied in conjunction with air pollutants emissions factors available from the National Atmospheric Emissions Inventory (NAEI). Where emissions factors were inappropriate or unavailable emissions factors were applied from verified industrial and published sources.

3.2.10 Several broad assumptions, appropriate to the level of detail required in an SEA, were made regarding transportation, construction traffic, on-site traffic, construction activities and materials manufacturing and supply in order to maintain a robust approach to modelling the emissions across options. Emissions from road construction and on-site road transport were modelled using the NAEI emissions factors and fleet technology mix projections through the use of the Regional application of the Highways Agency's Design Manual for Roads and Bridges (DMRB) screening methodology spreadsheet. These factors take into account anticipated improvements in vehicle emissions over time. Modelling of other transportation methods (e.g. shipping, rail) was undertaken using assumed journey lengths and relevant NAEI emissions factors (Appendix D Emissions Assumptions).

3.2.11 In addition to the primary air quality impacts assessed within this SEA, it is known that there are far-reaching non-linear processes which are likely to occur as a result of emissions to air from each of the tidal power options. Typical of such non-linear impacts is the equilibrium balance between nitrogen dioxide and ozone, where changes in one affect the concentration of the other; another is the health effects resulting from changes in local air quality. This assessment does not address such secondary or tertiary impacts or effects due to the changes in pollutant concentrations or overall air quality.

3.3 Alternative Options

3.3.1 Five options for the development of tidal power using the tidal range of the Severn Estuary have been identified as the preferred candidates for more detailed study. The five options comprise three tidal barrages and two tidal lagoons. The details of these options are described below.

Alternative Option B3: Brean Down to Lavernock Point Barrage

3.3.2 B3 'Brean Down to Lavernock Point' barrage is the largest of the barrage short-listed options being an approximately 16km long structure impounding the Bristol Channel between Lavernock Point near Cardiff and Brean Down, adjacent to Weston-Super-Mare. The deepest point of this barrage location is at its centre, reaching between 30 to 40m deep. The chosen variant (original) functions in ebb only mode. In total there are 216 Bulb-Kapeller type turbines with a rated output of 40MW. The estimated annual energy output for the variant (including 5% outages) is 15.1 to 17.0 TWh/year.

3.3.3 Key features include a total of 129 caissons of which 29 are plain caissons, 46 are sluice caissons and 54 are turbine caissons, spread across the length of the barrage. The central point includes a 778m long embankment flanked by two sets of the turbine caissons. The barrage also includes two locks, one main shipping lock towards Lavernock Point side and a small ship lock towards Brean Down.

Alternative Option B4: Shoots Barrage

3.3.4 The B4 Shoots Barrage is an approximately 7km long structure impounding the Inner Bristol Channel between land adjacent to West Pill on the Welsh side and Severn Beach on the English side. The proposed structure comprises a combination of embankments within the shallow water and caissons within the deeper channel. Variant 3 was chosen as the short-listed option. It operates in ebb only mode with 30 Bulb-Kaplan type turbines, with a rated output of 35MW. The estimated annual energy output for the variant (including 5% outages) is 2.7 to 2.9 TWh/year.

3.3.5 The barrage consists of a total of 46 caissons (6 plain, 25 sluice and 15 turbine/sluice caissons), enclosed on both sides by 2 embankments totalling approximately 5km (3km approximate length of embankment to the Welsh Side and 2.2km approximate length to the English side). A 40m wide shipping lock has been placed at the deepest section of the channel.

Alternative Option B5: Beachley Barrage

3.3.6 The B5 Beachley Barrage is the smallest of the short-listed barrage schemes. It is a 2km long structure running from Beachley on the Welsh side of the River Severn to land directly to the east on the English side. The original variant was chosen as the short-listed option, operating in ebb only mode with 50 Straflo type turbines with a rated output of 12.5 MW. The estimated annual energy output for the variant (including 5% outages) is 1.4 to 1.6 TWh/year.

3.3.7 Its key features include a total of 31 caissons (9 plain, 9 sluice and 13 turbine/sluice) spread across approximately 1.5km of the length of the barrage and flanked by two embankments. A 40m wide shipping lock is located on the English side of the barrage.

Alternative Option L2: Welsh Grounds Lagoon

3.3.8 L2 Welsh Grounds Lagoon is the largest of the lagoon short-listed options with an approximate length of 28km starting from land adjacent to the mouth of the River Usk, running in a general easterly direction across an area referred to as Welsh Grounds, continuing to the south of Denny Island and reaching land fall adjacent to the Second Severn Crossing. L2 variant 8 was based on a turbine selection proposed by the Fleming group. It was unique in this respect compared to other variants whose turbine selections have all been made by PB. Variant 8 operates in ebb only mode with 40 Bulb Turbines with a rated output of 25MW. The estimated annual energy output for the variant (including 5% outages) is 2.6 to 2.8 TWh/year.

3.3.9 Key features include a total of 32 caissons (8 plain, 14 sluice & 10 turbine caissons), and one shipping lock.

Alternative Option L3d: Bridgwater Bay Lagoon

3.3.10 L3D Bridgwater Bay Lagoon is a land connected tidal lagoon comprising approximately 16km long embankment, proposed to run from land falls at Brean Down in the north to just east of Hinckley Point in the south. The short-listed Variant 9 option is the only scheme to operate in ebb & flood mode, with a total of 144 Bulb-Kaplan turbines with a rated output of 25MW. The estimated annual energy output for this variant (including 5% outages) is 5.6 to 6.6 TWh/year.

3.3.11 Key features include a total of 42 caissons (6 plain and 36 turbine caissons), a 40m wide shipping lock and approximately 12km of embankment.

3.4 Summary of Potentially Significant Issues

3.4.1 During Phase 1 SEA Scoping, a review was conducted of the environmental issues that should be considered within the scope of the SEA (DECC, 2009a). The scope of issues was for the most part confirmed through the Government response to the consultation (DECC, 2009b). These issues formed the starting point for the assessment of likely significant environmental effects, and are discussed further for this topic below.

3.4.2 An update of the scoping for the Air Quality effects of the alternative options occurred as a consequence of the consultation and during the first technical workshop. The potentially significant issues identified were associated with the effects that any changes in emissions and air quality may have upon both human and habitat upon both the national and local scale, namely:

- Impact upon the local population from emissions of air pollutants from construction traffic;
- Impact upon the local population from emissions of dust and air pollutants due to construction activities;
- Impact upon the national population from emissions of air pollutants during materials manufacture;

- Impact upon local habitats from emissions of air pollutants from construction activities;
- Impact upon national habitats from emissions of air pollutants during materials manufacture;
- Impact upon national population from reduction in emissions of air pollutants from fossil fuel power stations;
- Impact upon national habitats from reduction in emissions of air pollutants from fossil fuel power stations.

3.5 Assessment of Likely Significant Effects on the Environment

3.5.1 This section considers, within Air Quality, the likely significant effects on the environment for each alternative option. These may arise from direct, indirect, far-field, cumulative and consequential development effects during construction, operation and decommissioning phases.

3.5.2 The following section is an aggregated summary of the direct, indirect, far field, accumulative and consequential effects for the alternatives which highlights the scale of the effects for each alternative. Appendices F, G and H present the graphical output of the calculated effects.

Direct Effects

Construction Phase

3.5.3 Emissions from construction traffic movements to and from the buffer zones may have a detrimental impact upon local air quality along the road transport routes.

3.5.4 Additional emissions of nitrogen dioxide, particulates and dust from construction activities within the buffer zones may also have a detrimental effect upon air quality in the immediate area affecting both the local population and SSSI's.

3.5.5 Emissions resulting from shipping movements and dredging activities, where close to areas of landfall, are likely to result in an additional contribution to background pollutant concentrations. Should these occur close to areas of residential population then they could have a detrimental effect on human exposure to degraded air quality.

3.5.6 The estimated emissions from the shipping of construction materials constitute the largest contribution to all air pollutants emissions. Due to the uncertainties associated with the specification of vessel type and capacity to be utilised, estimations were made for two emissions scenarios, with the first scenario assuming only small vessels are used and the second scenario assuming only large vessels are used. As expected the emissions efficiency of using large vessel for the shipping of construction materials is apparent. However, it is unrealistic to assume that only one vessel size will be utilised and the actual air pollutant emissions profile are expected to be a compromise between the small and large vessel values.

Table 3.1: Estimated direct air pollutant emissions between 2016 and 2024 from option construction

Emissions Source	Air Pollutant Emissions during Construction Phase		
	NO_x/ Tonnes	PM_{10}/ Tonnes	SO_2/ Tonnes
B3 - Brean Down to Lavernock Point Barrage	39800	760	7030
B4 – Shoots Barrage	8500	167	1500
B5 – Beachley Barrage	2250	44.8	394
L2 - Welsh Grounds Lagoon	30000	584	5280
L3d – Bridgwater Bay Lagoon	30200	584	5280

3.5.7 Extended fuel use within the buffer zone will result in the emissions of air pollutants and could result in an additional contribution to the local background air pollutant concentrations. Subsequently this could result in a detrimental impact upon air quality in the area immediately surrounding the buffer zone.

3.5.8 The effects of each of the options during the construction phase on local air quality would result in a short – term negative, reversible impact on human receptors. An air pollutant emissions inventory was compiled from the National Air Emissions Inventory (NAEI) for the STP SEA study area for the entire construction period, 2016 to 2024 (Table 3.1).

3.5.9 For all options, emissions to atmosphere during construction (Table 3.1) forms a large proportion of the estimated current study area annual emissions (Table 3.2). Emissions to atmosphere are slightly elevated where it has been assumed that small vessels are utilised in the shipping of construction materials. Should the estimated emissions to atmosphere as a direct result of construction occur uniformly across the entire construction phase, emissions as a result of construction would still represent a significant proportion of the study area's emissions.

Table 3.2: STP SEA study area estimated annual emissions (Defra, 2007)

Study Area Estimated Annual Emissions (2007)		
NO_x/ Tonnes	PM_{10}/ Tonnes	SO_2/ Tonnes
52500	4190	27400

3.5.10 It is probable that detectable changes in air pollutant concentrations, as a result of the emissions to atmosphere from construction, within the SEA STP study area would be highly localised and limited to areas of elevated construction traffic movements as well as the perimeter of the construction buffer zone.

Construction Traffic

3.5.11 Construction traffic estimates for each of the options for each of the land fall areas were provided within the Onshore Infrastructure Paper (21 October 2009). Details of daily movements, their routes, the population potentially affected, road carriageway type and potential constraints were supplied.

Construction Traffic Option B3

3.5.12 The construction traffic movements required for option B3 are estimated to be a maximum of 760 additional road vehicle movements per day. It has been assumed that these are all HGVs and that traffic movements have a split of 280 vehicle movements being required on the English side with 480 vehicle movements being required on the Welsh side of the B3 barrage.

3.5.13 The potential traffic routes run through market towns where poor air quality is an existing problem due to road traffic emissions. Such markets towns may be characterised by narrow carriageways with residential properties bordering the roads, a large number of HGVs passing through the town centre and some level of congestion. The combination of the above effects has often resulted in vehicle emissions presenting a problem to the extent that areas of towns have been declared air quality management areas.

Construction Traffic Option B4

3.5.14 Construction traffic route for option B4 passes through two villages of total population 3900. Elements of the construction traffic route to the Fleming Lagoon landfall site involve a standard single carriageway, where residential properties are in close proximity to the road. The suggested traffic routes to the western landfall of the B4 landfall site involve a potentially sub-standard single carriage way through a village centre. The movement of construction vehicles through village centres using sub-standard roads could potentially have a detrimental air quality impact upon the local community.

Construction Traffic Option B5

3.5.15 Construction traffic route for option B5 does not pass through a residential area. Therefore there is no known direct air quality impact upon the local community as a result from emissions from construction traffic for the B5 barrage option.

Construction Traffic Option L2

3.5.16 The specified construction traffic route for option L2 passes through two villages of total population 3900. Elements of the construction traffic route to the Fleming Lagoon landfall site involve a standard single carriageway, where residential properties are at close proximity to the road centre. The suggested traffic routes to the western landfall of the L2 landfall site involve a potentially sub-standard single carriage way through a village centre. The movement of construction vehicles through village's centres using sub-standard roads could potentially have a detrimental air quality impact upon the local community.

Construction Traffic Option L3d

3.5.17 Estimations of construction traffic movements for option L3d are that a maximum of 578 additional road vehicles movements are required per day. It has been assumed that these are all HGVs and traffic movement's estimations have assumed a split of 289 vehicle movements being required on the eastern side with 289 vehicle movements being required on the western side of the L3d barrage.

3.5.18 Though nearly all construction traffic movements would access each site from a motorway, local routes roads and minor roads would be required for the final section of the route to the barrage construction site.

3.5.19 Construction traffic route for option L3d passes through two villages of total population 2900 and Bridgwater Town centre of total population 36600. Elements of the construction traffic route to the Brean Down landfall site involve a standard single carriageway, where residential properties are at close proximity to the road centre, in addition there are four 90^{o} bends along the route, two of which occur in close proximity to residential properties.

3.5.20 Such a route is typically characteristic of a market town where air quality is a problem due to road traffic emissions. Such markets towns have narrow carriageways, a large number of HGVs passing through the town centre and involve a bottle neck creating congestion. A combination of the above has often resulted in vehicle emissions presenting a problem to the extent that the town has been declared an air quality management area.

3.5.21 The suggested traffic routes to the western landfall of the southern L3d landfall site involve a potentially sub-standard single carriage way through a village centre. The movement of construction vehicles through villages centres using sub-standard roads could potentially have a detrimental air quality impact upon the local community as could the movement of construction vehicle traffic through the town centre of Bridgwater.

3.5.22 Elements of the construction traffic route to the Fleming Lagoon landfall site involve a standard single carriageway, where residential properties are at close proximity to the road centre. The suggested traffic routes to the western landfall of the L2 landfall site involve a potentially sub-standard single carriage way through a village centre. The movement of construction vehicles through village's centres using sub-standard roads could potentially have a detrimental air quality impact upon the local community.

Effect of Construction Phase upon Human Receptors

3.5.23 The effect of the construction phase upon the local human population receptor over the 2016 baseline is expected to be a potentially small increase in the total population within an area of air quality objective exceedance. This impact would be reversible and of small magnitude and not significant.

Effect of Construction Phase upon Habitat Receptors

3.5.24 The effect of the construction phase on the local habitat receptors over the 2016 baseline is expected to be a potentially small increase in the total area experiencing pollutant deposition above the critical load for either acidity or nutrient nitrogen.

Operational Phase

3.5.25 Localised operational road traffic is likely to represent the largest direct operational effect of the option. However this is unlikely to represent any detectable impact upon the local populations and habitat receptors due to the low number of vehicles movements.

3.5.26 Maintenance dredging is expected to take place during the lifetime of the barrage. Estimated emissions from maintenance dredging are summarised in Table 3.3 below. Any effects upon the local populations receptor and habitat receptors are likely to be short-lived due to the brief periods (weeks) that maintenance dredging has been predicted to occur.

Table 3.3: Estimated annual direct air pollutant emissions between 2020 and 2140 from maintenance dredging for all alternative options

Emissions Source	Barrage Option		
	NO_x/ Tonnes	PM_{10}/ Tonnes	SO_2/ Tonnes
B3 - Brean Down to Lavernock Point Barrage	4720	234	1320
B4 – Shoots Barrage	4130	205	1155
B5 – Beachley Barrage	2360	117	660
L2 - Welsh Grounds Lagoon	0	0	0
L3d – Bridgwater Bay Lagoon	142	7	40

Decommissioning Phase

3.5.27 Decommissioning of the options has been assumed to be represented by a reversal of the construction process. In addition it has been assumed that UK government targets of an 80% reduction in carbon emissions by 2050 will be in place by 2140, the assumed year of decommissioning. For the purpose of this SEA the 80% reduction in carbon emissions has been extended to an 80% reduction in air pollutants. Therefore bulk air pollution emissions from the decommissioning process of each option were estimated using 20% of the construction air pollution emissions (Table 3.4). As a result, Table 3.4 shows that local shipping is considered to be the most significant activity in relation to emissions to air, and in particular emissions from smaller vessels.

3.5.28 Traffic movements to and from the buffer zones may also have an impact upon local air quality along the road transport routes, although are unlikely in 2140 to represent any impact upon the local population or local habitat receptors.

Table 3.4: Estimated direct air pollutant emissions from decommissioning between 2140 and 2148

Emissions Source	Option		
	NO_x/ Tonnes	PM_{10}/ Tonnes	SO_2/ Tonnes
B3 - Brean Down to Lavernock Point Barrage	7970	152	1410
B4 – Shoots Barrage	1700	33.5	300
B5 – Beachley Barrage	450	8.96	78.8
L2 - Welsh Grounds Lagoon	6010	117	1060
L3d – Bridgwater Bay Lagoon	6030	117	1060

3.5.29 Emissions from additional shipping movements and dredging activities, where close to areas of landfall, are again likely to result in an additional contribution to background pollutant concentrations. Should emissions to atmosphere occur close to areas of residential population then it could result in a detrimental effect upon human exposure to degraded air quality.

Indirect Effects

Construction Phase

3.5.30 All option's construction material manufacture are likely to take place off-site and their consequential atmospheric emissions have been considered to represent an indirect effect. At this stage it is uncertain where the production and fabrication of all materials will take place and it has been assumed for the purposes of this SEA that the majority of construction materials are manufactured within the UK.

3.5.31 Emissions of air pollutants have been estimated using construction materials data generated during the options feasibility study (DECC, 2009).

3.5.32 Primary emissions of air pollutants were calculated for the bulk materials i.e. cement and steel, using UK NAEI emission factors. Rail and shipping emissions were estimated using the quantity of bulk material as well as both rail and shipping emissions factors. (SRA, 2001; Shipping emissions). Emissions from the manufacturing of steel for construction purposes and emissions from the use of small vessel shipping are the two largest contributors to emissions of air pollutants which result in an indirect air quality impact for all of the options.

Table 3.5: Estimated indirect air pollutant emissions from construction between 2016 and 2024

Emissions Source	Option		
	NOx/ Tonnes	PM_{10}/ Tonnes	SO_2/ Tonnes
B3 - Brean Down to Lavernock Point Barrage	70600	1600	20600
B4 – Shoots Barrage	16700	347	4090
B5 – Beachley Barrage	4998	107	1555
L2 - Welsh Grounds Lagoon	54500	1090	11400
L3d – Bridgwater Bay Lagoon	54500	1090	11400

3.5.33 The indirect effect of the construction phase on the local human population receptor over the 2016 baseline is expected to be a potentially small increase in the total population within an area of air quality objective exceedance.

3.5.34 The indirect effect of the construction phase upon the local habitat receptors over the 2016 baseline is expected to be a potentially small increase in the total area of experiencing pollutant deposition levels above their critical load for acidity and/or nutrient nitrogen.

Operational Phase

3.5.35 Current generation of electrical power within the UK relies to a large extent on the burning of fossil fuels and therefore is responsible for the emissions of air pollutants including NO_2, PM_{10} and SO_2 (AEAT, 2007).

3.5.36 Emissions of air pollutants from the centralised generation of electrical power in the UK (Table 3.6) vary significantly with fuel type.

Table 3.6: Air pollutant emissions from fuels used in the generation of electrical power (NAEI, 2007)

Air Pollutant	UK Power Production Annual Fuel Emissions kT/MToe		
	Coal	Gas	Oil
NO_2	4.13	10	14
CO_2	430.5	3750	870
PM_{10}	0.093	0.23	0.382
SO_2	3.78	0.08	8

3.5.37 Current UK fuel use for the generation of centralised generation of electrical power in the UK relies largely upon the use of coal (Table 3.7). The future energy mix for UK electrical power generation has been predicted to reduce its dependency upon fossils fuels and increase the use of both nuclear power and renewable energy sources (DECC, 2009).

Table 3.7: UK electrical power generation by fuel type (BERR, 2006)

	Fuel Type		
	Coal	Gas	Oil
% Power generation	89.0%	8.60%	2.30%

3.5.38 As a consequence of the operation of any of the options it is envisaged that reductions in the emissions of air pollutants from the generation of electrical power from fossil fuel sources will occur across the UK.

3.5.39 An estimation of the ‘off-setting’ of potential air pollutants released from fossil fuel power generation by the utilisation of each of the options has been undertaken within this SEA, taking into account the gradual phasing out of large fossil fuel power generating capacity over time (Table 3.8). The power capacity of each option was obtained from the feasibility study option appraisal paper (DECC, 2009) and initial emissions factors for fossil fuel derived electrical power were used from the NAEI database. The gradual reduction of the fossil fuel mix of electrical power generation was accounted for by ensuring that fossil fuel air pollution emissions remained proportionate to the CO_2 emissions from overall power generation (DECC, 2009b).

3.5.40 Annual electricity generating outputs were estimated for each of the options (Table 3.7) for their operational periods.

Table 3.8: Total UK air pollutant off-setting for entire life span of options

	Pollutant / kT			Max Off-setting (NO_2) per annum
	NO_2	PM_{10}	SO_2	
B3 - Brean Down to Lavernock Point Barrage	791	18.1	579	0.4%
B4 – Shoots Barrage	80.1	1.8	58.6	0.04%
B5 – Beachley Barrage	152	3.5	111	0.07%
L2 - Welsh Grounds Lagoon	346	7.9	252	0.17%
L3d – Bridgwater Bay Lagoon	226	5.2	166	0.11%

3.5.41 The total estimated off-set of air pollution emissions for the entire estimated operational life of barrage B3 was seen to be the most significant of the options (Table 3.8), with NO_2 emissions off-set by an estimated 791kT over the 120 years operational period of option B3.

3.5.42 When set against the predicted UK air pollution emissions from power generation it can be seen that option B3 has an estimated maximum off-setting of up to 0.4% of the UK annual air pollutions emissions from electrical power generation.

3.5.43 Therefore, the indirect effects of the operational phase of all options on the national human population receptors against the 2016 baseline would be expected to be a very small decrease in the number of people within a population experiencing an air quality objective exceedance. It is expected that this decrease would be undetectable and not significant.

3.5.44 The indirect effects of the operational phase of all options upon the national habitat receptor against the 2016 baseline are expected to be a very small decrease in the total area experiencing pollutant deposition above the critical load for acidity and nutrient nitrogen. This decrease would be expected to be undetectable and not significant.

Decommissioning Phase

3.5.45 No indirect air quality effects are envisaged as a result of the decommissioning of option

Far-field Effects

Construction Phase

3.5.46 No far-field air quality effects are envisaged as a result of either the construction, operation or decommissioning phase of any of alternative options.

Cumulative Effects

Construction Phase

3.5.47 The development of four major power stations (section 2.5.6) are currently planned to take place between 2009 and 2013 within the study area.

3.5.48 Each of the power stations will add to the air pollution emissions of the study area, though it is expected that their development may be as a direct consequence of the removal of an existing power generating source. Therefore it is unlikely that the annual air pollutant emissions of the study area will be increased.

3.5.49 Estimated annual air pollution emissions from the two gas fired power stations represent an estimated 13% of the total study area 2007 atmospheric emissions, using the NAEI 2007 emissions factors. Together with the estimated increase in emissions resulting from the construction activities of any of alternative options, this represents an approximate annual increase of around 14% in the air pollution emissions within the study area during the construction period of any of alternative options. However as the power stations sources are point sources, these emissions to air would be dispersed across the study area and would only represent an increase in background pollution concentrations.

3.5.50 Cumulative effects during the construction phase of any of alternative options upon the national human population receptor against the 2016 baseline are expected to be a very small increase in the total population within an area of air quality objective exceedance. This decrease would be expected to be undetectable, reversible and not significant.

3.5.51 Cumulative effects during the construction phase of any of alternative options upon the national habitat receptor against the 2016 baseline are expected to be a potentially small increase in the total area experiencing deposition in excess of the critical load for both acidity and nutrient nitrogen. This decrease would be expected to be undetectable, reversible and not significant.

Consequential Development Effects

Construction, Operational Phase and Decommissioning Phase

3.5.52 No significant air quality effects are envisaged as a result of consequential development during either the construction, operation or decommissioning phase of any of alternative options.

Summary of Likely Significant Effects on the Environment

3.5.53 None of the alternative options present any likely significant effects (direct, indirect, far-field, cumulative and consequential development effects) on the receptors during construction, operation and decommissioning phases.

Assumptions, Limitations and Uncertainties

3.5.54 Emissions of air pollutants to atmosphere from shipping activities associated with the construction of all options are highly dependant upon the size of vessel and number of vessels used. Though emissions of air pollutants as a result of the use of only a small vessel fleet has been estimated within this topic paper, the assessment has been conducted on the assumption that a mixed vessel fleet will be used and that the air pollution emissions as a result of a small vessel fleet are largely improbable, but that those from the use of large vessels alone are overly optimistic

3.6 Measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment

3.6.1 The SEA Directive requires that information is provided on the measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme (Annex I). These measures are considered within this topic, and will thereby inform an overall assessment of such measures within the SEA Environmental Report.

3.6.2 In this SEA, and in line with UK practice, these measures are split into those measures to prevent or reduce effects, and measures to as fully as possible offset any significant adverse effects on the environment.

Measures to prevent or reduce effects

3.6.3 The measures identified to prevent or reduce likely significant adverse environmental effects within this topic are described below.

3.6.4 Assumed transport plans for the options have included non road vehicle methods for the transport of construction materials during the barrage construction phase. In addition a sustainable transport plan could be introduced which would include for example: the use of non-road transport where possible; the phasing of development; and robust monitoring by operators at sites to track changes throughout the lifecycle of proposed options.

3.6.5 On-site measures would require the implementation of an environmental management action plan which included the use of Euro IV or V HGVs onsite fleet, the reduction of dust generating activities towards the perimeter of the buffer area and the avoidance of unnecessary running of idling on-site vehicles, where not in use.

3.6.6 Off-site measures to reduce the air quality effects to the local community would involve the use of Euro IV or V engine within the construction traffic fleet, the distribution of construction vehicle movements throughout the day to avoid congestion within air quality sensitive areas and the maximum movement of construction materials by rail to limit the use of minor road routes by large numbers of HGVs.

3.6.7 The promotion of the use of some carbon efficient forms of transport and construction, those which exclude forms of combustion, during the option lifecycle are likely to assist in minimising air pollutant emissions to atmosphere from construction activities.

3.6.8 Potentially pollutant emissions to atmosphere from shipping activities during the construction phase may have some effect upon the local human and habitat receptors.

3.6.9 Use of larger vessels rather than smaller vessels would optimise the emissions to atmosphere per payload. Additionally pollution emissions to the atmosphere from shipping may be minimised where vessels switch from fossil fuel to electrical power when in port.

3.6.10 Monitoring should be undertaken in order to account for the potential consequential effects of pollution releases. This should include consideration of locations and periods where the barrage construction period overlaps with the four new power stations planned within the SEA study area come on line.

Measures needed to offset effects

3.6.11 The identification of offsetting measures is a requirement of the SEA Directive. For the purposes of this SEA, these are measures to as fully as possible offset any significant adverse environmental effects. Such measures make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. In this SEA, 'compensation', a subset of offsetting, is only used in relation to those measures needed under Directive 92/43/EEC (the Habitats Directive).

3.6.12 No offsetting measures for any of the alternative options have been identified as necessary as a result this air quality assessment.

Table 3.9: Assessment summary for B3 - Brean Down to Lavernock Point Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Local Population (High)/ (Low)	*Change in number of population within AQMA's as a result of emissions releases from construction site.*	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Local Population (High)/ (Low)	*Change in number of population within AQMA's as a result of emissions from construction traffic.*	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
UK Population (High)/ (High)	*Change in number of population within AQMA's as a result of emissions releases from manufacture of construction materials.*	*Indirect*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
UK Population (High)/ (High)	*Change in number of population within AQMA's as a result of barrage energy production off-setting emissions from other energy sources.*	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM_{10} & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load *as a result of emissions releases from construction site.*	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load *as a result of emissions releases from construction site.*	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load *as a result of emissions from construction traffic.*	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load *as a result of emissions from construction traffic.*	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
International/ national protected	Change in Area of Exceedance of Critical Load *as a result of*	*Direct*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in*	*N*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
habitats (High)/ (High)	*emissions releases from construction materials.*								*England & Wales.*	
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load *as a result of emissions releases from construction materials.*	*Direct*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load *as a result of barrage energy production off-setting emissions from other energy sources.*	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM_{10} & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load *as a result of barrage energy production off-setting emissions from other energy sources.*	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM_{10} & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*

Table 3.10: Assessment summary for option B4 - Shoots Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	*Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development*	*Probability (H/M/L/VL)*	*Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency*	**Irreversible/ reversible; temporary/ permanent**	*Magnitude (H/M/L/VL)*	*Spatial extent & trans-boundary*	*Positive/ Negative*	*Assumptions, Limitations, Uncertainties*	*Significant (Y/N)*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of emissions releases from manufacture of construction materials.	*Indirect*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for $_{NOx}$, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction materials.	*Direct*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*

Table 3.11: Assessment summary for B5 - Beachley Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	*Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development*	*Probability (H/M/L/VL)*	*Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency*	**Irreversible/ reversible; temporary/ permanent**	*Magnitude (H/M/L/VL)*	*Spatial extent & trans-boundary*	*Positive/ Negative*	*Assumptions, Limitations, Uncertainties*	*Significant (Y/N)*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of emissions releases from manufacture of construction materials.	*Indirect*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NOx, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction materials.	*Direct*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*

Table 3.12: Assessment summary for L2 - Welsh Grounds Lagoon

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	*Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development*	*Probability (H/M/L/VL)*	*Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency*	**Irreversible/ reversible; temporary/ permanent**	*Magnitude (H/M/L/VL)*	*Spatial extent & trans-boundary*	*Positive/ Negative*	*Assumptions, Limitations, Uncertainties*	*Significant (Y/N)*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of emissions releases from manufacture of construction materials.	*Indirect*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction materials.	*Direct*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*

Table 3.12: Assessment summary for L3d - Bridgwater Bay Lagoon

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	*Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development*	*Probability (H/M/L/VL)*	*Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency*	**Irreversible/ reversible; temporary/ permanent**	*Magnitude (H/M/L/VL)*	*Spatial extent & trans-boundary*	*Positive/ Negative*	*Assumptions, Limitations, Uncertainties*	*Significant (Y/N)*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Local Population (High)/ (Low)	Change in number of population within AQMA's as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of emissions releases from manufacture of construction materials.	*Indirect*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
UK Population (High)/ (High)	Change in number of population within AQMA's as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction site.	*Direct*	*L*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed all construction activity occurs uniformly across barrage buffer zone.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions from construction traffic.	*Indirect*	*H*	*Construction*	**Temporary, Reversible**	*VL*	*Local*	*Negative*	*Assumed construction traffic routes as per on-shore infrastructural paper.*	*N*
International/ national protected habitats (High)/ (High)	Change in Area of Exceedance of Critical Load as a result of emissions releases from construction materials.	*Direct*	*VL*	*Construction*	**Temporary, Reversible**	*VL*	*National*	*Negative*	*Assumed 100% steel & cement manufactured in England & Wales.*	*N*
Locally protected habitats (Low)/ (High)	Change in Area of Exceedance of Critical Load as a result of barrage energy production off-setting emissions from other energy sources.	*Indirect*	*H*	*Operation*	**Reversible**	*VL*	*National*	*Positive*	*Estimates for NO_x, PM10 & SO_2 off-setting based upon DECC emissions estimates for CO_2 until 2140.*	*N*

SECTION 4

ASSESSMENT AGAINST SEA OBJECTIVES – AIR QUALITY

4 ASSESSMENT AGAINST SEA OBJECTIVES – AIR QUALITY

4.1 Introduction

4.1.1 While not specifically required by the SEA Directive, the Practical Guide (ODPM et al., 2005) recommends that SEA Objectives are used to compare the effects of alternative options. The SEA Objectives, assessment criteria and indicators were drafted and consulted upon as part of the Phase 1 SEA scoping stage.

4.1.2 SEA Objectives reflect a desired direction of change. It therefore follows that these objectives may not necessarily be met in full by a given alternative option, but the degree to which they do will provide a way of identifying preferences when comparing alternative options.

4.1.3 This topic paper informs the Environmental Report and its assessment of alternative options against SEA Objectives. This is by providing an assessment specifically in relation to the topic's SEA Objectives. The Environmental Report will then consolidate each topic assessment to provide a description of the assessment in relation to all SEA Objectives.

4.2 Assessment Methodology

4.2.1 An SEA Objective compliance methodology requires judgements to be made on the performance of alternative options against each SEA Objective. The 'assessment criteria' and 'indicators' which accompany the SEA Objectives aid these judgements. The effects on receptors presented in section 3 are aggregated and related back to the SEA Objectives so that the environmental performance of each alternative option can be compared.

4.2.2 The SEA Objectives assessment summary table (Table 4.1) shows how each alternative option performs over its entire life-cycle against each SEA Objective, and whether this is major or minor, positive or negative or a combination of the two. For instance, some receptors covered by an SEA Objective may benefit from an alternative option, whereas others would be adversely affected. Furthermore, the judgement of whether the alternative option performance is minor or major depends on the number or proportion of receptors for each objective that are significantly affected, and their value. In addition to the SEA Objectives assessment summary table, the SEA Objectives are also discussed in relation to assessment criteria and indicators.

4.2.3 It recognised that there is a degree of judgement related to alternative option performance, and the assessment criteria are intended as an aid to these judgements. This activity has also been informed by inputs from the Technical Workshops and the Environment and Regional Workstreams.

4.3 Objectives-led Assessment Summary

4.3.1 Table 4.1 sets out the summary of the SEA Objectives assessment which is described in detail below.

SEA Objective CF1 - To maximise the opportunities for use of sustainable sources of energy for the UK

4.3.2 This objective seeks to maximise the availability of renewable energy sources with the greatest magnitude of air pollutant off setting. All options contribute to offsetting of air pollutants and so therefore fulfil this objective (see Table 3.).

SEA Objective SE1: To avoid adverse effects on physical and mental health.

4.3.3 According to this air quality assessment none of the options present significant effects in relation to quality of life as measured by a significant increase in air emissions and pollutant concentrations. This objective relates to the avoidance or minimising significant detrimental air quality impacts upon the local and UK population. The option with the lowest short-term detrimental air quality impact to the local population is option B5.

SEA Objective TFE1 - To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.

SEA Objective TFE2 - To avoid adverse effects on valuable terrestrial and freshwater ecological networks.

4.3.4 According to this air quality assessment none of the options present significant effects in relation to the deterioration of designated terrestrial and freshwater wildlife sites of international and national importance as measured by the increase in air emissions, pollutant concentrations and pollutant deposition.

4.3.5 The above two objectives relates to the long term detrimental impacts upon both local and national habitats from air pollutants, this relates to the option with the greatest magnitude of off-setting of air pollutants. Option B3 provides the largest offsetting of air pollutants and so therefore appears the option that fulfil this objective reduction

4.4 Assumptions, Limitations and Uncertainty

4.4.1 In undertaking the assessment of the alternative options against the SEA objectives, there are assumptions, limitations and uncertainties, particularly as there is a degree of judgement related to option performance. These issues are discussed for this topic below.

4.4.2 Assumptions within the assessment of the SEA objectives are largely upon the avoidance of adverse effects upon physical and mental health. It has been assumed that this would be derived solely from the effects of air quality impacts due to road transportation during the construction period. The air quality impacts during operation were considered too dispersed to be applied to this objective.

Table 4.1 SEA Objective Assessment Summary Table

Key

Performance is based on number or proportion of receptors linked to each SEA Objective for which significant effects have been predicted, and informed by consideration of SEA Assessment Criteria.			
Major negative performance against SEA Objective	--	Major positive performance against SEA Objective	++
Minor negative performance against SEA Objective	-	Minor positive performance against SEA Objective	+
No Effects	0	Uncertain	?

SEA Objective	**Relevant Receptors**	**Alternatives Performance against SEA Objectives over entire life-cycle**				
		Alternative Option B3: Brean Down to Lavernock Point Barrage	**Alternative Option B4: Shoots Barrage**	**Alternative Option B5: Beachley Barrage**	**Alternative Option L2: Welsh Grounds Lagoon**	**Alternative Option L3d: Bridgwater Bay Lagoon**
To maximise the opportunities for use of sustainable sources of energy for the UK	UK GHG emissions over lifetime of the project	++	+	+	+	+
		Total UK air pollutant offsetting: NO_2 791 kT (0.4%); PM_{10} 18kT SO_2 579kT	Total UK air pollutant offsetting: NO_2 80 kT (0.04%); PM_{10} 1.8kT SO_2 58.6kT	Total UK air pollutant offsetting: NO_2 152 kT (0.07%); PM_{10} 3.5kT SO_2 111kT	Total UK air pollutant offsetting: NO_2 346 kT (0.17%); PM_{10} 7.9kT SO_2 252kT	Total UK air pollutant offsetting: NO_2 226 kT (0.11%); PM_{10} 5.2kT SO_2 166kT
SE1 To avoid adverse effects on physical and mental health.	Local Population	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -
		39,836T NOx (Direct emissions only) 8% of Study area annual emissions	8,498T NOx (Direct emissions only) 4% of Study area annual emissions	2,249T NOx (Direct emissions only) 1% of Study area annual emissions	30,040T NOx (Direct emissions only) 11% of Study area annual emissions	30,169T NOx (Direct emissions only) 10% of Study area annual emissions
		Operational Phase 0	Operational Phase 0	Operational Phase 0	Operational Phase 0	Operational Phase 0
SE1 To avoid adverse effects on physical and mental health.	UK Population	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -
		110,443 NOx (direct & indirect emissions)	25,172 NOx (direct & indirect emissions)	7,247 NOx (direct & indirect emissions)	84,523 NOx (direct & indirect emissions)	84,651 NOx (direct & indirect emissions)
		Operational Phase +	Operational Phase +	Operational Phase +	Operational Phase +	Operational Phase +
		310 kT NOx for whole life of barrage	28.2kT NOx for whole life of barrage	55.2kT NOx for whole life of barrage	124kT NOx for whole life of barrage	81.3kT NOx for whole life of barrage
TFE1 To avoid adverse effects on designated terrestrial and freshwater wildlife	International/ national protected habitats - local	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -
		39,836T NOx (Direct	8,498T NOx (Direct	2,249T NOx (Direct	30,040T NOx (Direct	30,169T NOx (Direct

SEA Objective	Relevant Receptors	Alternatives Performance against SEA Objectives over entire life-cycle				
		Alternative Option B3: Brean Down to Lavernock Point Barrage	**Alternative Option B4: Shoots Barrage**	**Alternative Option B5: Beachley Barrage**	**Alternative Option L2: Welsh Grounds Lagoon**	**Alternative Option L3d: Bridgwater Bay Lagoon**
sites of international and national importance		emissions only) 8% of Study area annual emissions	emissions only) 4% of Study area annual emissions	emissions only) 1% of Study area annual emissions	emissions only) 11% of Study area annual emissions	emissions only) 10% of Study area annual emissions
		Operational Phase 0	Operational Phase 0	Operational Phase 0	Operational Phase 0	Operational Phase 0
		Offsetting 0.4% of national NOx emissions derived from power generation for whole life of barrage.	Offsetting 0.04% of national NOx emissions derived from power generation for whole life of barrage.	Offsetting 0.07% of national NOx emissions derived from power generation for whole life of barrage.	Offsetting 0.17% of national NOx emissions derived from power generation for whole life of barrage.	Offsetting 0.11% of national NOx emissions derived from power generation for whole life of barrage.
TFE1 To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance	International/ national protected habitats – local and national	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -	Construction Phase -
		110,443 NOx (direct & indirect emissions)	25,172 NOx (direct & indirect emissions)	7,247 NOx (direct & indirect emissions)	84,523 NOx (direct & indirect emissions)	84,651 NOx (direct & indirect emissions)
		Operational Phase +	Operational Phase +	Operational Phase +	Operational Phase +	Operational Phase +
		310 kT NOx for whole life of barrage	28.2kT NOx for whole life of barrage	55.2kT NOx for whole life of barrage	124kT NOx for whole life of barrage	81.3kT NOx for whole life of barrage

SECTION 5

BASELINE ENVIRONMENT – CARBON FOOTPRINTING

5 BASELINE ENVIRONMENT – CARBON FOOTPRINTING

5.1 Introduction

5.1.1 Baseline information provides the basis for predicting and monitoring environmental effects. Both qualitative and quantitative information can be used for this purpose.

5.1.2 The baseline information is described for the area that may be affected in terms of a range of 'receptors' (defined in Section 5.1.7). A receptor is an entity that may be affected by direct or indirect changes to an environmental variable. Relevant receptors were identified and consulted upon during the SEA scoping stage.

5.1.3 Alternative options considered within this Feasibility Study would only be developed several years into the future and would have a long life. It is therefore necessary to project a 'future baseline' against which to compare effects, rather than using the present day baseline. This is an especially important concept when considering air quality and GHG emissions.

5.1.4 The approach taken is therefore to describe baseline information in the following stages:

- Baseline environment and receptors up to 2009, including environmental problems and opportunities;
- Future baseline during construction: 2014-2020, including anticipated problems and opportunities;
- Future baseline during operation 2020-2140, decommissioning and longer term trends, including anticipated problems and opportunities.

For the Carbon Footprinting paper, the baseline has been established for each receptor as an ongoing emissions trajectory over the life of the project.

5.1.5 This paper describes the baseline for the relevant receptors within this topic. It will thereby inform the description of the baseline environment for the affected area as a whole, contained within the SEA Environmental Report.

<u>Study area</u>

5.1.6 The carbon footprint study area is global as emissions could be released globally as a result of a Severn Tidal Power option. Nevertheless this would be a UK based project and therefore the emissions would be accounted for within the UK and against UK targets for reduction. For this reason the study area is also considered to be UK based.

<u>Receptors</u>

5.1.7 The carbon footprint receptors have been selected as Global GHG emissions and UK GHG emissions.

5.2 Methodologies used to develop the baseline

Sources of Data

Global baseline environment from 1990 through to 2140

5.2.2 The ENSEMBLES data used in this assessment was funded by the EU FP6 integrated project ENSEMBLES (Contract Number 505539), whose support is gratefully acknowledged.

5.2.3 The data, which was produced as part of the 5 year program to assess “Climate change and its impacts at seasonal, decadal and centennial timescales”, was produced with the aim of providing researchers, decision makers, businesses and the public with results generated from range of scenarios using different global climate models with a probabilistic outcome.

5.2.4 A new E1 scenario has been generated which accounts for policy implementation and therefore emission measures to prevent or reduce adverse effects resulting in a stabilisation of emissions at a concentration of 450ppm. The emissions scenario was generated by assuming a maximum emissions concentration in 2140 to ensure stabilisation at 450ppm. This was then reversed to generate a scenario of required emissions reductions from present day out to 2140. Ten Global Climate Model’s were then run to generate possible measures to prevent or reduce adverse effects scenarios and the results are presented in Figure 5.1 below.

UK baseline environment from 2009 through to 2140

5.2.5 The UK baseline environment for the carbon footprint has been established using the current level of GHG emissions as published by DECC in the UK Low Carbon Transition Plan up until 2050. Post 2050 there are no published policies in place to continue further emission reductions at this time. This means that there is no information on which to base assumptions for continuing reduction.

5.2.6 The baseline receptors; UK and Global level of GHG emissions, are considered as ongoing curves over the lifetime of the project.

Key Environmental Issues and Problems

5.2.7 The Global baseline assumes successful implementation of International emission reduction targets

5.2.8 The UK baseline includes the outcomes of the Government’s Low Carbon Transition Plan, 2009 and associated policies, and therefore shows a decrease in emissions in line with Government estimates to reduce emissions by 80% by 2050.

5.2.9 These emission reductions have a significant impact on the complete emissions displaced by renewable energy and is therefore noted for discussion during the results section (Section 6.5.25).

Assumptions, limitations and uncertainty

5.2.10 It is important to acknowledge the assumptions, limitations and uncertainties inherent in predicting changes to complex systems at a strategic level. Where possible, generalised assumptions and approaches for dealing with uncertainty have been developed to be applied consistently across the topics, as is the case with Climate

Change and Policy. Where this is not possible and topic-specific consideration is required, the assumptions, limitations and uncertainty are clearly identified. Further detail is given below.

5.2.11 The nearer term predictions are more accurate than estimations into the future which rely upon implementation of future policy. Therefore, the baseline during the construction phase has more certainty than that during the operational life of the project. This is reflected by increasing uncertainty.

5.2.12 Uncertainty in our GHG baseline makes completing a comparison against the baseline complex. It is important to recognise this GHG baseline uncertainty and that any change in carbon emissions as a result of Severn Tidal Power is taken comparatively against a variety of possible future baselines.

5.2.13 From 2050 onwards through the operational life, there is greatest uncertainty in the baseline GHG emissions.

General Climate Change Assumptions

5.2.14 In developing the future baseline projections, assumptions are made about environmental trends, and policy responses to these trends. It has been assumed that UK Climate Projections (UKCP09) central estimate projections for the medium emissions scenario apply for most topics (UKCP09, 2009), however these do not supply UK GHG emission predictions.

General Assumptions Concerning Application of Government Policy

5.2.15 It also has been assumed that, in general, existing Government policies relating, for example, to climate change response and biodiversity, will continue to apply into the future.

Topic Specific Assumptions, Limitations and Uncertainty

5.2.16 Government's Low Carbon Transition Plan[2], 2009 sets out the plan to achieve the UK emission targets. It includes policies on the power sector, i.e. energy supply and transport policy. The UK specific baseline therefore includes the policies set out in up until 2022. This baseline does exclude Severn Tidal Power, shipping and aviation emissions. Beyond 2022 there is less confidence in policies and emissions reduction through to 2050. Post 2050 there is no policy information published.

5.3 Links to existing legislation and policy

5.3.1 A review has been conducted of relevant national, regional and local policies, plans and programmes, to assist with the identification of synergies and potential inconsistencies with the Feasibility Study, and thus contributing to the development of SEA Objectives (STP, 2009a). Existing legislation and policy of particular relevance to this topic are summarised below.

5.3.2 Under the Kyoto Protocol, which is legally binding, the UK has committed to reduce its GHG emissions to 12.5% below 1990 baseline for CO_2, methane and nitrous oxide, and below 1995 baseline for fluorinated compounds over the period 2008-2012. The UK has currently committed to a national goal of reducing CO_2 emissions by 20% by 2010, however this is not legally binding.

[2] Low Carbon Transition Plan, DECC, 2009, http://decc.gov.uk/en/content/cms/statistics/projections/projections.aspxvreduction

5.3.3 The Climate Change Act 2008 legally binds the UK into a long term framework to tackle the dangers of climate change including emissions reduction. The Act includes a target for the UK to reduce CO_2 emissions by at least 60% below the 1990 levels by 2050, with an interim target of 26% to 32% reduction in CO_2 emissions against 1990 levels by 2020. DECC has now increased the target to reduce the UK CO_2 emissions by 80% by 2050

5.3.4 In order to ensure contribution of the renewable energy sector to meeting these emissions reductions targets, the UK has committed to supplying 15% of the electricity from renewable energy by 2010. This is described in detail in the UK's Renewable Energy Strategy. The EU has committed to an intermediate target of providing 20% of energy from renewable sources by 2020.

5.3.5 It is possible, that any of the options described could be operational by 2020, specifically that B4 and B5 are operational in 2017, L2 and L3 are operational by 2018, and B3 is operational by 2019. It should be noted nevertheless that there would be an increase in emissions due to the construction phase. All options however could contribute to 2050 targets.

5.3.6 In addition to the current legislation and policy there may be further outputs of the Copenhagen Climate Change Summit which would feed down into UK policy.

5.4 Baseline Environment

5.4.1 This SEA baseline environment describes the area that may be affected in terms of 'receptors', and has examined the potential for significant effects in relation to these. The receptors were developed during Phase 1 SEA scoping. The list of receptors was subsequently consulted upon as part of the Phase 1 consultation.

5.4.2 A review has been conducted of other projects in and around the Severn Estuary that may have an influence on the future baseline (STP, 2009b). Those projects that are considered to be reasonably foreseeable as implemented by 2014, have been considered part of the future baseline environment.

5.4.3 One of the receptors for the carbon footprinting scoping topic paper is considered to be the global impacts of increasing greenhouse gas (GHG) emissions. It is not practical to measure the impact of a Severn Tidal Power option against this. Therefore, the UK GHG emissions are considered as the most sensitive receptor.

5.4.4 The level of GHG emissions in the UK will be used as the baseline for this assessment, and the changes in relation to the "do nothing" option will be included in the comparative assessment as net emissions.

Receptor A Global GHG emissions

Baseline environment (up to 2009 until 2140)

5.4.5 Baseline environment of GHG emissions up to 2009 and through to 2140 is taken from ENSEMBLES data Scenario E1. The ENSEMBLES data used in this assessment was funded by the EU FP6 integrated project ENSEMBLES (Contract Number 505539), whose support is gratefully acknowledged.

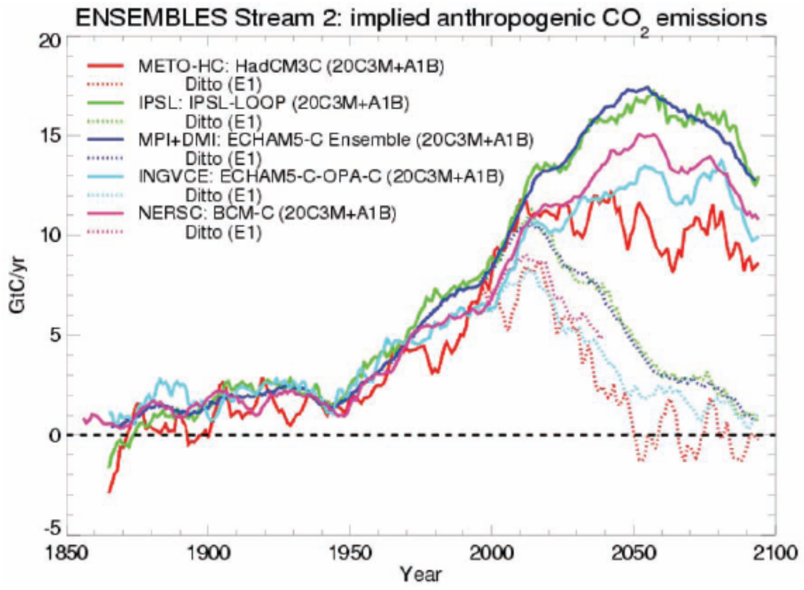

Figure 5.1 ENSEMBLES Global mitigated anthropogenic GHG emissions

Receptor B UK GHG emissions

5.4.6 The UK GHG emissions are shown in Figure 5.2.

5.4.7 It is noted that the UK Renewable Energy Strategy, HM Government, July 2009, (Page 201) states that no decision on the Severn Tidal Power options has yet been made in relation to policy and emission reduction targets. Therefore, at this time, there is no emissions reductions as a result of Severn Tidal Power included in the emissions reductions assumed for the UK baseline.

Baseline environment (up to 2009 until 2020)

5.4.8 UK predicted baseline data has been taken from DECC Low Carbon Transition Plan, 2009 which provides a baseline up to 2022. The baseline takes into account all the current policies for carbon reduction in the UK.

Baseline during operation (2020 – 2140), Decommissioning and Longer Term Trends

5.4.9 The emissions, post 2022 have also been taken from the Low Carbon Transition Plan which assumes a decrease in emissions towards the 2050 target of 80% reduction. Error bands are incorporated at the 2050 point in the Plan and these are utilised in this report.

Beyond 2050 the emissions projections are most uncertain as they rely upon the successful implementation of all current UK Policy in addition to future policy post 2050 which, at the time of writing, are not published. The predictions are based on continuations of the curve however it is possible that the economy could be decarbonised at some point prior to 2140 which is not currently shown on these projections.

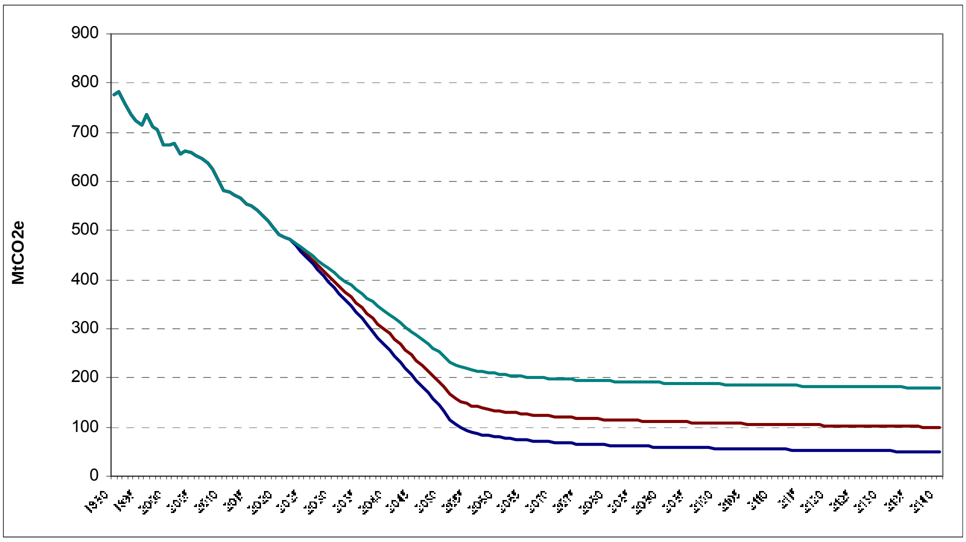

Figure 5.2 Annual UK GHG emissions; observed and predicted

5.5 Key Environmental Issues and Problems

5.5.1 In summary there are two main issues with the Baseline environment. The first is that the baselines both rely upon the implementation of future policy to achieve the emission reductions. The second that is in relation to the UK baseline, is that there is no published policies available at this time on which to base assumptions about the likely scenario of emissions reduction going forwards from 2050. The emissions may continue to decrease further however there are many possibilities for the rate and distribution at which the last 20% of emissions are reduced from 2050 through to 2140. For this reason the distribution is as provided with a continuation of the curve.

5.6 Value and Vulnerability of Receptors

5.6.1 The SEA seeks to identify those environmental effects which are likely to be significant. In forming a judgement on effect significance, in line with the SEA Directive, it is necessary to take into account the attributes of the affected area. In this SEA, the area likely to be affected is described in terms of receptors; and the most relevant receptor attributes are their value and vulnerability. These are defined as:

- **Value**: based on the scale of the geographic reference, rarity, importance for biodiversity, social or economic reasons, and level of legal protection;
- **Vulnerability**: the potential for a pathway for exposure of a receptor to a given environmental effect, brought about by a Severn Tidal Power option, together with the sensitivity of the receptor to that effect.

5.6.2 A standardised approach has been adopted across all topics of this SEA to the assignment of receptor attributes. Nonetheless this approach did allow for some flexibility to reflect the needs of each topic area. The receptor definitions for value and vulnerability are provided in Table.5.1 below; however, the full value and vulnerability report is in Appendix B.

Table.5.1 Definitions of value and vulnerability for carbon footprinting

	Sample receptor definitions	
	Value	**Vulnerability**
High	There is a recognised requirement for limiting and reducing emissions	The receptor is at a critical level
Low	There is no recognised requirement for limiting and reducing emissions.	The receptor is not at a critical level
None	N/A	N/A

5.6.3 Table.5.2and Table 5.3 below provide the assigned value and vulnerability to each receptor.

Table.5.2 Value of Receptors

Receptor	Assigned Value
UK level of GHG emissions	High
Global level of GHG emissions	High

Table 5.3 Vulnerability of Receptors

Receptor	Assigned Vulnerability
UK level of GHG emissions	High
Global level of GHG emissions	High

SECTION 6

EVALUATION OF PLAN ALTERNATIVES – CARBON FOOTPRINTING

6 EVALUATION OF PLAN ALTERNATIVES

6.1 Introduction

6.1.1 The SEA Directive requires the preparation of an Environmental Report on the 'likely significant effects' of implementing the plan, and reasonable alternatives. The main purpose of this topic paper is to inform the SEA Environmental Report and its assessment of likely significant environmental effects. This is by providing an assessment of effects in relation to the topic paper's relevant receptors. The Environmental Report will then consolidate the individual topic assessments to provide a description of all likely significant effects across the affected area.

6.1.2 The SEA Directive instructs that SEA is to be based on information that can reasonably be required, taking into account *inter alia* current knowledge and methods of assessment.

6.1.3 For the purposes of this SEA, the plan alternatives are the shortlisted options currently under consideration following the phase 1 consultation (DECC, 2009a). These are described as the alternative options in this document.

6.2 Assessment Methodology

6.2.1 The SEA Directive specifies in Annex II the criteria that should be taken into account when determining the likely significant effects of the plan. The criteria for identifying these significant effects are defined in the Directive in relation to determining whether an SEA is needed. These criteria will also be adopted for this assessment. In line with the SEA Regulations, the Practical Guide advises the use of these criteria for assessing significant environmental effects.

6.2.2 This topic paper therefore considers, the characteristics of the effects and of the area (i.e. relevant receptors) likely to be affected, having regard, in particular, to:

- the probability, duration, frequency and reversibility of the effects;
- the cumulative nature of the effects;
- the transboundary nature of the effects;
- the risks to human health or the environment (for example, due to accidents);
- the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected);
- the value and vulnerability of the area likely to be affected due to:
  - special natural characteristics or cultural heritage;
  - exceeded environmental quality standards or limit values; or
  - intensive land-use; and
- the effects on areas or landscapes which have a recognised national, Community or international protection status.

6.2.3 The SEA Directive (Annex I) also states that these effects should include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects. The Practical Guide recognises that some of these terms are not always mutually exclusive and for the avoidance of doubt, within this SEA the following approaches are adopted.

6.2.4 Indirect effects are those which are not a direct result of a Severn Tidal Power alternative option, but occur away from the original effect or as a result of a complex pathway. There are many such interactions within estuarine systems that need to be taken into account in this assessment. The SEA does not use the term 'secondary effects' as this is covered by indirect effects.

6.2.5 There is the potential for effects to extend large distances from the Severn estuary. The assessments of these 'far field' effects will have greater uncertainty attached and are described separately.

6.2.6 Cumulative effects arise, for instance, where several developments each have insignificant effects but together have a significant effect. The plans and projects taken into account in the cumulative effects assessment have been identified and agreed (STP, 2009b). These are discrete projects or programmes which are expected to be implemented during the planned Severn Tidal Power project construction period (2014-2020) or during the operation period (2020-2140).

6.2.7 For simplicity, this SEA does not use the term 'combined' effects, as these are considered to be included within cumulative effects, nor does it use the term 'synergistic' effects, as these are considered within direct, indirect and cumulative effects.

6.2.8 A major tidal power scheme may facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as 'consequential developments'. The types of consequential development considered throughout the assessment have also been identified (STP, 2009b). These consequential developments are not well-defined and only a concise high level qualitative assessment of the likely effects is possible.

6.2.9 The construction and operation of any of the alternative options for Tidal Power in the Severn Estuary will change the balance of GHG emission sinks and sources that currently take place in the estuary. The carbon footprint analysis has therefore included a lifecycle analysis of each option. The life cycle assessment includes a "cradle to grave" assessment of the emissions associated with constructing a tidal power option, operating it through the lifetime of the project, and finally decommissioning the scheme. The study therefore includes all the currently quantifiable changes to level of emissions as a result of the tidal power option being in place. Outputs from other topic areas, including but not limited to Water Quality, Marine Ecology, Navigation and Communities have been utilised to carry out a desk study on the likely effects on GHG levels for each option. Where specific data has not been available, assumptions have been generated and these are included in the review of alternative options below. Where there is no information available qualitative assessments have been included or the exclusion stated.

The lifecycle assessment provides three main outputs: Unit CO_2e emissions ($kgCO_2/kWh$); payback period (time after which the total emissions released due to the project are paid back from the production of renewable electricity), Net CO_2e emissions (emissions savings over the lifetime of the project).

6.2.10 The carbon payback is calculated based on the following equation:

$$Carbon\ Payback\ (years) = \frac{Total\ emissions\ (construction,\ operation\ \&\ decommisioning)}{Annual\ avoided\ emissions}$$

Comparison to Sustainable Development Commission

A carbon footprint assessment was completed as part of the Sustainable Development Commission (SDC) report “Turning the Tide”. The SDC report only had sufficient information to include an assessment of the embodied emissions of the raw material. This therefore excluded all other emissions that would be impacted and which are included within this lifecycle assessment, for example transportation to site, plant use on site during construction, dredging and pumping emissions, operational emissions and decommissioning. Although it is rightly flagged that that ongoing maintenance and decommissioning emissions would significantly decrease as a result of a decarbonising economy.

This difference in the methodologies results in a considerably lower payback period in the SDC report than the range of results produced in this report, which by its’ nature is a more detailed assessment.

6.3 Alternative Options

6.3.1 Five options for the development of tidal power using the tidal range of the Severn Estuary have been identified as the preferred candidates for more detailed study. The five options comprise three tidal barrages and two tidal lagoons. The details of these options are described below.

Alternative Option B3: Brean Down to Lavernock Point Barrage

6.3.2 B3 ‘Brean Down to Lavernock Point’ barrage is the largest of the barrage short-listed options being an approximately 16km long structure impounding the Bristol Channel between Lavernock Point near Cardiff and Brean Down, adjacent to Weston-Super-Mare. The deepest point of this barrage location is at its centre, reaching between 30 to 40m deep. The chosen variant (original) functions in ebb only mode. In total there are 216 Bulb-Kapeller type turbines with a rated output of 40MW. The estimated annual energy output for the variant (including 5% outages) is 17.0 TWh/year.

6.3.3 Key features include a total of 129 caissons of which 29 are plain caissons, 46 are sluice caissons and 54 are turbine caissons, spread across the length of the barrage. The central point includes a 778m long embankment flanked by two sets of the turbine caissons. The barrage also includes two locks, one main shipping lock towards Lavernock Point side and a small ship lock towards Brean Down.

Alternative Option B4: Shoots Barrage

6.3.4 The B4 Shoots Barrage is an approximately 7km long structure impounding the Inner Bristol Channel between land adjacent to West Pill on the Welsh side and Severn Beach on the English side. The proposed structure comprises a combination of embankments within the shallow water and caissons within the deeper channel. Variant 3 was chosen as the short-listed option. It operates in ebb only mode with 30 Bulb-Kaplan type turbines, with a rated output of 35MW. The estimated annual energy output for the variant (including 5% outages) is 2.9 TWh/year.

6.3.5 The barrage consists of a total of 46 caissons (6 plain, 25 sluice and 15 turbine/sluice caissons), enclosed on both sides by 2 embankments totalling approximately 5km

(3km approximate length of embankment to the Welsh Side and 2.2km approximate length to the English side). A 40m wide shipping lock has been placed at the deepest section of the channel.

Alternative Option B5: Beachley Barrage

6.3.6 The B5 Beachley Barrage is the smallest of the short-listed barrage schemes. It is a 2km long structure running from Beachley on the Welsh side of the River Severn to land directly to the east on the English side. The original variant was chosen as the short-listed option, operating in ebb only mode with 50 Straflo type turbines with a rated output of 12.5 MW. The estimated annual energy output for the variant (including 5% outages) is 1.4 TWh/year.

6.3.7 Its key features include a total of 31 caissons (9 plain, 9 sluice and 13 turbine/sluice) spread across approximately 1.5km of the length of the barrage and flanked by two embankments. A 40m wide shipping lock is located on the English side of the barrage.

Alternative Option L2: Welsh Grounds Lagoon

6.3.8 L2 Welsh Grounds Lagoon is the largest of the lagoon short-listed options with an approximate length of 28km starting from land adjacent to the mouth of the River Usk, running in a general easterly direction across an area referred to as Welsh Grounds, continuing to the south of Denny Island and reaching land fall adjacent to the Second Severn Crossing. L2 variant 8 was based on a turbine selection proposed by the Fleming group. It was unique in this respect compared to other variants whose turbine selections have all been made by PB. Variant 8 operates in ebb only mode with 40 Bulb Turbines with a rated output of 25MW. The estimated annual energy output for the variant (including 5% outages) is 2.8 TWh/year.

6.3.9 Key features include a total of 32 caissons (8 plain, 14 sluice & 10 turbine caissons), and one shipping lock.

Alternative Option L3d: Bridgwater Bay Lagoon

6.3.10 L3D Bridgwater Bay Lagoon is a land connected tidal lagoon comprising approximately 16km long embankment, proposed to run from land falls at Brean Down in the north to just east of Hinckley Point in the south. The short-listed Variant 9 option is the only scheme to operate in ebb & flood mode, with a total of 144 Bulb-Kaplan turbines with a rated output of 25MW. The estimated annual energy output for this variant (including 5% outages) is 6.3 TWh/year.

6.3.11 Key features include a total of 42 caissons (6 plain and 36 turbine caissons), a 40m wide shipping lock and approximately 12km of embankment.

6.4 Summary of Potentially Significant Issues

6.4.1 During Phase 1 SEA Scoping, a review was conducted of the environmental issues that should be considered within the scope of the SEA (DECC, 2009a). The scope of issues was for the most part confirmed through the Government response to the consultation (DECC, 2009b). These issues formed the starting point for the assessment of likely significant environmental effects, and are summarised for this topic in Table 6.1. Although the issues are assigned a significance level here they are all considered as part of the lifecycle assessment.

Table 6.1: Assessment of likely significant environmental issues (Phase 1)

Receptor & Sensitivity	Carbon footprint consideration of generic option	
	Description of Change & Magnitude	Significance
UK and therefore Global level of GHG emissions – High	Increase of emissions from raw material supply – Medium	Potentially significant
	Increase of emissions from manufacturing – Medium	Potentially significant
	Increase of emissions from transportation/plant equipment during construction and installation – Medium	Potentially significant
	Increase in emissions during construction from dredging – Low	Not significant
	Increase in emissions during construction from pumping – Low	Not significant
	Increase in emissions during construction from waste disposal – Low	Not significant
	Increase in emissions during construction due to disruption in traffic and vessels – Low	Not significant
	Increase in emissions during construction due to workers travelling to site – Low	Not significant
	Decrease in emissions released due to renewable electricity generation – High	Potentially significant
	Increase in emissions released due to maintenance – Low	Not significant
	Increase during operation due to continual dredging – Medium	Potentially significant
	Increase in emissions from operational (measures to prevent or reduce adverse effects) pumping – High	Potentially significant
	Increase in emissions due to loss of inter-tidal habitat for carbon sequestration – Medium	Potentially significant
	Change in emissions due to methanogenesis/CO_2 direct	Potentially significant

Receptor & Sensitivity	Carbon footprint consideration of generic option	
	Description of Change & Magnitude	Significance
	release/changes in estuarine conditions – Medium	
	Decrease in emissions due to new habitat creation under Habitats Directive	Potentially significant
	Change in emissions due to decommissioning of option – Medium	Not significant

6.5 Assessment of Likely Significant Effects on the Environment

This section considers, within this topic, the likely significant effects on the environment for each alternative option. These may arise from direct, indirect, far-field, cumulative and consequential development effects during construction, operation and decommissioning phases. It is important that all results within this report are taken in the context of the assumptions which were used to build up the results because they contribute, layer upon layer to the uncertainty in the range of results. Where available the information for assumptions has been taken from the Supply Chain Survey Report (DECC, 2010), DECC, or the Engineering Team. All the assumptions are therefore included within this section.

6.5.1 The following section is a summary of the direct, indirect, far field, cumulative and consequential effects for the alternatives as defined by the SEA Directive. Direct and Indirect effects relate to the effect on the environment and not the source of GHG emission which can and are described as direct or indirect sources in other carbon footprinting assessments.

Direct Effects

Direct Effects Construction Phase

6.5.2 Direct carbon dioxide emissions are generated as a result of the construction activities which are described below. For each construction item assumptions have been made, where required, and it is important that these assumptions are appreciated when considering the result scenarios. The uncertainty in the assumptions and the results are discussed further below.

6.5.3 Construction emissions are calculated over the construction period for the different options as per Table 6.2 . This information was provided from the Engineering Team.

Table 6.2 Construction Period for the Different Schemes

Scheme	Construction Period (years)
Brean Down to Lavernock Point Barrage (B3)	6
Shoots Barrage (B4)	4
Beachley Barrage (B5)	4
Welsh Grounds Lagoon (L2)	5
Bridgwater Bay Lagoon (L3d)	5

6.5.4 The direct construction effects include the following emission contributors:

- Embodied carbon emissions;
  - o Raw materials,
  - o Fabrication/Manufacture of components,
- Transportation and plant operation on site;
- Transportation to/from site including road, rail and shipping; and
- Dredging and pumping requirements during construction.

The assumptions for these are described below.

Embodied carbon emission assumptions

6.5.5 The embodied emissions factors used in the calculation of the carbon footprint for the different schemes are listed in Table 6.3. These have been taken from the University of Bath, Inventory of Carbon and Energy (University of Bath, 2008).

Table 6.3: Embodied emissions factors

Material	Kg CO_2/kg
Concrete (high strength)	0.211
Concrete reinforce (3% steel reinforce)	0.306
Aggregates for concrete	0.008
Sand & Gravel (stone/gravel/chippings)	0.017
Filling materials (as per sand & gravel)	0.017
Crushed rock (general)	0.056
Armour stone (imported)	0.747
Cement	0.82
Rebar	1.71
Steel	1.77
Fabricated steel/formwork steel (general)	1.78
Timber (plywood)	0.81
Asphalt (general)	0.045

Concrete

6.5.6 All concrete production will take place onsite using purpose built concrete batching plants. Therefore, emissions from transport are assumed to be negligible.

Aggregates for concrete

6.5.7 Aggregates for concrete include sand ballast and concrete ballast. In agreement with the Supply Chain Survey Report (DECC,2010), it has been assumed that aggregates for Beachley and Shoots barrage will be sourced from Wales and the South West, respectively. For B3 and lagoons, materials will be sourced from all over the UK.

Table 6.4 summarises the sources of aggregates for the different schemes.

Table 6.4: Sources of aggregates for concrete

Aggregates for Concrete	Source
Brean Down to Lavernock Point Barrage (B3)	UK
Shoots Barrage (B4)	Wales
Beachley Barrage (B5)	South West
Welsh Grounds Lagoon (L2)	UK
Bridgwater Bay Lagoon (L3d)	UK

Embankment Materials

6.5.8 Embankment materials include sand bed and sand core, gravel, crushed rock and armour rock, which are used for control structure and containment mounds, plus filter materials, wick drains, and filling materials for landing areas and locks.

The aforementioned materials have been grouped together as follows:

Sand & Gravel: Sand bed and core, and filter material Types 1 and 2. It has been assumed that wick drains will mainly be made of gravel.

Crushed rock: 70% of control structure rock fill and rock for containment mounds will be made of crushed rock.

Armour stone: 30% of control structure rock fill, and other fill and armour rock will be made of armour stone.

Having established the classification of embankment materials, the following paragraphs detail their respective sources.

Sand & Gravel: According to the Supply Chain Survey Report (DECC, 2010), the UK market could provide enough materials for the Beachley barrage only. As for the lagoons, additional resources would be required and these could include, overseas imports, increase in the output capacity of existing sources, or additional dredging licenses. The last two options have been assumed in order to provide sand and gravel for the lagoon schemes and B3 and B4.

Crushed rock: It has been estimated by the Supply Chain Survey Report (DECC, 2010) that the demand of crushed rock for Beachley barrage could be met by regional market. On the other hand, the national market could provide enough materials for the B3 and B4. For the lagoons, it is envisaged that imports of materials or an increase in the output capacity of existing UK quarries will be required. The latter has been assumed in order to source crushed rock for the lagoons schemes.

Armour stone: It is unlikely that the demand for armour stone for the different schemes could be met by the UK market. Therefore, it has been assumed that this resource will be sourced from Scandinavia (c. 1,250 miles).

Table 6.5 shows the source of embankment materials for the different options.

Table 6.5: Source of embankment materials

Scheme	Sand & Gravel	Crushed Rock	Armour Stone
Brean Down to Lavernock Point Barrage (B3)	UK	UK	Scandinavia
Shoots Barrage (B4)	UK	UK	Scandinavia
Beachley Barrage (B5)	UK	Wales	Scotland
Welsh Grounds Lagoon (L2)	UK	UK	Scandinavia
Bridgwater Bay Lagoon (L3d)	UK	UK	Scandinavia

Cement

6.5.9 All cement demand for the different schemes will be sourced from the Midlands (average distance 100 miles), and transported to site by rail.

Asphalt - Road Construction Onsite

6.5.10 It has been assumed that asphalt is sourced locally (average distance of 50 miles). It has been assumed that additional road access requirements highlighted in the Onshore Infrastructure paper (PB/BV Consortium, 2009) are minor, and are excluded.

Steel

6.5.11 Steel is used in different forms; as a rebar, in fabricated steelwork, in formworks, and in steel works for sluices gates, lock gates, cranes, etc. Steel is also used in the fabrication of turbines.

Rebar: It has been assumed that the UK market could meet the demand for rebar for Shoots and Beachley barrage and Welsh Grounds Lagoon. For B3 and B5 rebar overseas imports could be required. For overseas import, an average distance of 7,500 miles (steel sourced from Europe, Far East and the US) has been assumed.

Steel in formworks and steel works: It has been assumed by the Engineering Team that 75% of formworks is steel. The steel requirements for formworks and all steelworks will come from overseas. An average distance of 12,000 miles has been assumed.

It has been assumed that the steel in formwork can be reused a minimum of 30 times, reducing the need to import steel

Timber

6.5.12 Timber is required for the fabrication of formwork. It has been assumed that 25% of the formwork is timber, which will come from Scandinavia (average distance of 1,250 miles).

It has been assumed that timber need in formwork can be reused a minimum of 8 times, reducing the need to import timber.

Water

6.5.13 Water is required for the preparation of the cement and concrete. Although, it is not required to use drinking quality water, the production of cement and concrete requires water free of sulphites to avoid concrete decay. It is expected that water will be sourced close to the caissons yards. It has been assumed that the water will come from the mains, which is the worst case scenario regarding the carbon footprint estimates. This assumption is in line with the Resources and Waste Topic paper. The carbon emissions for water have been taken from Water UK (Water UK, 2007).

Turbines

6.5.14 It has been assumed that turbines will be manufactured in the Far East and either components or the manufactured turbines will be transported to the UK. Table 6.6 shows the breakdown of turbine components used.

Table 6.6: Break down of turbine materials (Alstom)

Component	40MW	12.5MW
Carbon Steel	76%	79%
Stainless Steel	4%	4%
Special Alloys	4%	4%
Silicon Steel	11%	8%
Cooper	5%	4%
Insulation	0%	1%
Other	<1%	<1%

<u>Onsite plant and transportation</u>

6.5.15 Onsite traffic has been estimated based on a nominal allowance of 1 vehicle per 4 of the number of vehicles required during construction. The estimated daily figures are presented below:

Brean Down to Lavernock Point Barrage (B3)	350 vehicles
Shoots Barrage (B4)	60 vehicle
Beachley Barrage (B5)	40 vehicles
Welsh Grounds Lagoon (L2)	90 vehicles
Bridgwater Bay Lagoon (L3d)	155 vehicles

It is expected that vehicles on site will include a mix of light and medium vans, JCBs, forklifts, small cranes, pickup trucks, flat bed vans, cherry pickers, vibrating rollers and the like. For the carbon footprint calculation the following has been assumed:

Speed on site:	Vehicles will have no idling and operate at 15 miles/hour
Operation:	24 hour day, 7 day a week
Type of vehicle	HGV
Fuel used:	Diesel

<u>Transport of Construction Materials</u>

<u>Transport Emissions Factors</u>

6.5.16 Transport emissions factors have been taken from the Defra GHG emissions factors (Defra, 2009). The main factors used are listed below:

Table 6.7: Transport conversion factors

Transport	Emission Factors
Diesel HGV	
Onsite: Rigid <3.5-7.5 tm100%	0.60346 Kg $CO_{2\ eq}$/per vehicle km
Offsite: Articulated >33 t 100%	1.13521 Kg $CO_{2\ eq}$/per vehicle km
Shipping	
Small Bulk Carrier	0.01109 Kg $CO_{2\ eq}$/tonne.km
Large Bulk Carrier	0.00706 Kg $CO_{2\ eq}$/tonne.km
Very large Bulk Carrier	0.00605 Kg $CO_{2\ eq}$/tonne.km
Rail	
Diesel	0.03190 Kg $CO_{2\ eq}$/tonne.km

Going forwards the transportation emissions have been reduced to take account of the Transport Policy in place in the UK.

<u>UK Resources</u>

6.5.17 It has been assumed that materials sourced from the UK are split as follows:

North 50% from Scotland and transported by sea, c.850 miles, using small bulk carriers;

East 30% and transported to the site by rail, c.150 miles;

South	10% and transported by rail, c.150 miles;
West	10% and transported by rail, c.75 miles.

Shipping

6.5.18 It has been assumed that UK sourced material will be transported in small bulk carriers (capacity 1,720 deadweight (DWT) tonnes). Large bulk carriers (capacity 14,201 DWT) and very large bulk carriers (capacity 70,000 DWT) will be used for the transport of imported materials, especially for steel shipments.

6.5.19 The major constraint on overseas sourced materials is the capacity of the receiving wharves to unload and distribute the materials. There is a potential need for increasing the wharf capacity. This has not been taken into consideration when estimating the carbon footprint for the different schemes.

Rail

6.5.20 Diesel freight trains would be used to transport materials.

Construction Vehicles - Road Transport

6.5.21 The figures provided by the Onshore Infrastructure Paper (PB/BV Consortium, 2009) represent the daily average number of vehicles required during construction. It has been assumed that these figures include park and ride transport for construction workers, waste carter offsite, transport of machinery to or from the site, etc. The construction traffic required during construction is given in Table 6.8.

Table 6.8 Construction traffic required during the construction period either to or from the site

Scheme	England (daily average vehicles movements)	Wales(daily average vehicle movements	Total (daily average vehicle movements
Brean Down to Lavernock Point Barrage (B3)	280	480	760
Shoots Barrage (B4)	234	126	360
Beachley Barrage (B5)	159	158	317
Welsh Grounds Lagoon (L2)	361	120	481
Bridgwater Bay Lagoon (L3d)	289	289	578

For the carbon footprint calculation the following has been assumed:

Type of vehicle	HGV
Distance travel - England	150 miles
Distance travel - Wales	50 miles

Dredging

6.5.22 Dredging material for construction will include mud and soft clay, sand and gravel, soft rock (mudstone), and hard rock (limestone). This is a valuable resource and it has been assumed that it will be reused as follows:

Mud and soft clay:	Not suitable for construction work, and therefore, will be used in the creation of compensatory habitat;
Sand & gravel:	Suitable for reuse as sand & gravel for embankment materials;
Soft & hard rock:	These are weak materials and could be used for land fill and in the creation of compensatory habitat.

Emissions from dredging are dependent on the type of material being dredged, as rock cutting is slower than suction of dredging sediment. The fuel oil use has been estimated based on the assumptions below which we recognise could vary significantly with dredger type:

Capacity Trailing suction hopper dredger	5,300 m^3
Total Power	0.2 litres/kWh
Fuel use	474 litres/hr
Rate dredging full load mud	3hr
Rate dredging full load sand	5hrs
Rate dredging full load rock/gravel	8hrs

To calculate the carbon emissions, fuel oil has been assumed as fuel type used by dredgers.

Pumping Requirements

6.5.23 At the time of writing this document, the pumping requirements during construction were not available however, these are considered to be a negligible constituent of the construction phase carbon footprint.

Direct Effects Operational Phase

6.5.24 The direct operational effects include the following emission contributors:

- Source of renewable energy and displaced emissions;
- Maintenance;
- Dredging and pumping requirements during operation;

Source of renewable electricity

6.5.25 It is considered that by producing renewable energy there is a saving in emissions that would otherwise have been released from generating combined cycle gas turbines (CCGT) (assumed to be grid mix) electricity. This reflects the level of generated renewable energy or displaced emissions and has been established by considering the annual energy output.

6.5.26 As Government policies are put in place the emissions associated with grid mix electricity will decrease as our National energy supply is decarbonised. The UK Low Carbon Transition Plan describes how the UK plans to meet the national targets for emission reduction. It will involve decarbonising our energy supply through encouraging energy efficiency, renewables, nuclear, and carbon capture and storage. The energy conversion factors in Table 6.9 have been defined by DECC and are therefore consistent with successful policy implementation..

Table 6.9 DECC energy conversion factors

Year	Energy Conversion Factor($kgCO_2/kWh$)
2008 - 2030	0.43
2031	0.39
2032	0.35
2033	0.31
2034	0.27
2035	0.23
2036	0.19
2037	0.15
2038	0.12
2039	0.08
2040 -2041	0.04
2042 - 2048	0.03
2049 – 2140	0.02

6.5.27 The net emissions i.e. the emissions saved over the lifetime of the project as a result of using tidal power are extremely sensitive to the numbers tabulated in Table 6.9 and this is demonstrated by looking at the difference in annual displaced emissions from 2030 when the grid mix is estimated to be $0.43kgCO_2/kWh$ to 2040 when emissions are $0.04kgCO_2/kWh$ (see Table 6.10). The period up until 2050 will clearly be critical for the UK in terms of achieving emissions reductions to meet policy targets However the longer term emissions saved from Severn tidal power is however most sensitive to the displaced emissions, see results in Table 6.10, and the rate at which reduction is achieved. If the policies are implemented faster there will be further reduced emissions savings from renewable energy sources. Similarly, if the policies do not achieve the reduction in the timescales provided the emissions displaced for this project will increase.

Table 6.10: Effects of displaced electricity on annual emissions

Annual displaced emissions ($ktCO_2e$)	2030	2040
Brean Down to Lavernock Point Barrage (B3)	-6,700	-630
Shoots Barrage (B4)	-1,160	-110
Beachley Barrage (B5)	-645	-60
Welsh Grounds Lagoon (L2)	-1,120	-104
Bridgwater Bay Lagoon (L3)	-2,700	-250

Maintenance

6.5.28 The operation of the different schemes will require a series of maintenance that will generate emissions and although they have an insignificant impact on emissions these activities include:

- The embodied emissions for the turbines as per direct construction effects.
- The replacement of all the turbines will have the impact of reducing power generation as per Table 6.11 for each of the given options, during the time period for turbine replacement.

- Maintenance requirements throughout the life time. It has been assumed by the engineering team that turbines will be replaced twice during lifetime of the project. This will take place over 2-6 years depending on the option, to reduce demand peaks and can be seen as a step on the carbon profile.

Table 6.11: Level of operation during turbine replacement

Scheme	%age operation
Brean Down to Lavernock Point Barrage (B3)	80%
Shoots Barrage (B4)	50%
Beachley Barrage (B5)	50%
Welsh Grounds Lagoon (L2)	50%
Bridgwater Bay Lagoon (L3d)	75%

<u>Dredging and Pumping during operation</u>

6.5.29 Dredging is likely to be required a measure to prevent or reduce adverse effects during the operational phase. The estimated quantities of dredging needed for the operational phase for each option are listed in Table 6.12.

Table 6.12: Operational dredging requirements

Scheme	Dredging requirements (Mm^3/year)
Brean Down to Lavernock Point Barrage (B3)	2
Shoots Barrage (B4)	1.75
Beachley Barrage (B5)	1
Welsh Grounds Lagoon (L2)	0
Bridgwater Bay Lagoon (L3d)	0.06

6.5.30 The estimated annual pumping requirements for each option has been provided by the engineering team and included in the model. It assumes the use of grid mix electricity with the same emission factors as presented in Section 6.5.25.

<u>Direct Effects Decommissioning Phase</u>

6.5.31 The decommissioning of the different schemes will have similar impact to the construction phase on the UK and Global GHG emissions. It has been assumed that the emissions during the decommissioning of the different schemes will be equal to the construction emissions minus the cement and dredging emissions, as these activities will not form part of decommissioning activities. Decommissioning has been assumed to take place over half of the construction period.

6.5.32 At this time the project assumes that the Tidal Power Option would be fully decommissioned at the end of the operational life. However, in practice it is not correct to assume this for the carbon footprint as this would unfairly skew the results. In practice it is likely that the electrical and mechanical components would be decommissioned and the main structure would remain in place. This would therefore have minimum impact on the carbon footprint. Alternatively, if the option was fully decommissioned, due to UK Government Transportation Policy and the drive for decarbonisation, it is likely that the plant equipment used for decommissioning would be powered by a low carbon means. For this reason the assumption is that the carbon footprint for decommissioning would be insignificant and is therefore included as 5% of the construction emissions.

Indirect Effects

Indirect Effects Construction Phase

6.5.33 The emissions associated with indirect effects during the construction phase include:

- Employment – transportation and accommodation;
- Navigational impacts.

6.5.34 The construction of the any of the schemes will generate employment for the area. During construction, it has been assumed that 20% of the work force will be covered by workers in the area, generating positive economic impacts locally. The transportation etc of the workforce and the living accommodation (local accommodation) will be included but are not a significant impact on the overall carbon footprint.

Accommodation for Construction Workers

6.5.35 The STP Options Definitions Topic Report (October 2009) and REIS Phase 1 Re-working and Updated Assessment have provided information below on the number of workers.

Table 6.13 Construction Workers

Scheme	Total Construction Workers
Brean Down to Lavernock Point Barrage (B3)	**43,500**
Shoots Barrage (B4)	**11,000**
Beachley Barrage (B5)	**8,000**
Welsh Grounds Lagoon (L2)	**18,000**
Bridgwater Bay Lagoon (L3d)	**29,500**

Workers Accommodation

6.5.36 Assumptions regarding the accommodation required for workers have been taken from the Communities Topic paper which used the experience of the London 2012 Olympic Park (21%), London Heathrow Terminal 5 (15%) and the Channel Tunnel (24%) to generate the assumptions.

6.5.37 The assumption adopted is that up to 20% of construction labour will be recruited locally provided this does not exceed 10% of the local area's supplier of construction sector employment.

6.5.38 For STP construction we have assumed 45% daily commuting given the size and geography of the wider sub-regional catchment (smaller than London but larger than Kent, and STP schemes are more centrally located in labour catchments than the Channel Tunnel in east Kent).

6.5.39 The experience of all three of the reference major projects is that the majority of construction workers requiring accommodation find it in local bed and breakfast accommodation, commercial and budget hotels and other short term lettings. In all cases the project promoters operated accommodation information/brokerage services to connect accommodation providers with customers. For T5 and the Channel Tunnel the contractors provided serviced caravan spaces for those workers with their own caravans (300 and 100 spaces respectively). As an indicator of absorptive capacity, the overwhelming majority of the Channel Tunnel's 5,000 construction workers were accommodated in local B&B and similar accommodation in East Kent (population 545,000 in 1989).

- **Heating**

The electricity consumption to supply heat is assumed to be 1,440kWh per year per person and this has been estimated from first principles

- **Hot water**

The electricity consumption to supply hot water has been estimated from base assumptions and is 742kWh per year per person.

The total energy demand has therefore been estimated to be 2,182 kWh per year per person. This has a high level of uncertainty as a result of all the assumptions which have been utilised to generate this number.

Shipping (Construction and Operational phases)

6.5.40 The effects of shipping on the GHG emissions during the construction and operational phases are discussed here.

6.5.41 The Navigation paper has estimated that the construction of barrages or lagoons schemes will not have a significant adverse effect on navigation once measures to prevent or reduce adverse effects are in place. These measures include:

Scheduling of transit times through locks to avoid congestion;

Sill-lowering at ports to avoid reduced access windows;

Dredging locally to avoid loss of depth owing to sedimentation;

For Beachley barrage, it has been recommended that the lock structure is relocated to the west of the barrage to prevent vessels transiting in front of the turbine locks.

6.5.42 The Navigation Paper has highlighted that further detailed analysis will be required to better understand risks to navigation from increased water velocity (particularly in close proximity to the barrage/lagoon structures) and sediment deposition in high risk areas.

6.5.43 The size of the lock structures has been adjusted in order to accommodate the larger vessels especially post-Panama. Therefore, there will be only delays to transit time and no re-routing of vessels has been taken into account for the estimation of the carbon footprint.

6.5.44 It is recognised that the operation of the lagoons and barrages may have an impact on the operation of vessels in the area and this has been researched in a report called Phase 2 REIS, STP Regional Workstream. No specific data has been produced to date on the actual tonnage which may be diverted during operation of any of the STP options. It is recognised that the impacts on Bristol Port may be most sensitive to the B3 option. We have therefore completed an estimate of the impacts as a result of the B3 option and these results are shown in Section 6.6.26 which summarises the likely effects. Bristol Ports saw a total of 11.53mTonnes of cargo during 2008, the majority as import. The assumption has been made that there could be 40% of the cargo rerouted to other ports and therefore a rail transfer back to Bristol. The average distance between Bristol to Southampton and Bristol to Liverpool has been used as the additional on land distance.

Indirect Effect Operational Phase

6.5.45 The operational phase indirect effects would be a result of the following changes to emission levels:

- Worker transportation to site;
- Estuarine changes.

Workers transportation to site

6.5.46 The figures of direct employment generated during operation are smaller in comparison with the employment generated during construction. As in construction, it is expected that these positions will be covered locally. These emissions are very low and therefore insignificant based on the following assumptions for workers transportation to site.

6.5.47 The number of workers required during operation will not be significant when compared to the number of workers during construction. It is expected that the majority of the work force will be hired locally, and therefore, this will not have a significant impact on the carbon footprint for the different schemes. An average commuting distance of 50 mile round trip has been assumed in order to estimate the carbon footprint due to transportation and 2 people per vehicle.

Table 6.14 Operation Workers

Scheme	Workers During Operation
Brean Down to Lavernock Point Barrage (B3)	850
Shoots Barrage (B4)	150
Beachley Barrage (B5)	90
Welsh Grounds Lagoon (L2)	150
Bridgwater Bay Lagoon (L3d)	250

Estuarine changes

6.5.48 Estuarine changes may have a significant effect on the GHG balance but there is great uncertainty on the actual changes that would occur and therefore it is very difficult to assess the impact on the level of GHG emissions.

6.5.49 Change in the area of intertidal mudflats and saltmarsh habitats provided by the Marine Ecology paper have been used here to estimate CO_2 equivalent flux for the following parameters:

• The impact of loss or gain of saltmarsh habitat and the impact that it has on sequestration;

• The impact on methanogenesis from change in mudflat habitat area; and

• Siltation, which is estimated as a total sequestration value over the life of the project.

6.5.50 It is recognised that there are estuarine changes which have not been quantified for this assessment. The areas which have been excluded are:

• Change in subtidal areas likely to be affected by the implementation of any option. Any change in habitat is likely to further impact levels of methanogenesis and sequestration.

- The changes related to NOx,
- The emissions released from storage as a result of change in habitat.
- Further ecological changes for example, increased algal growth.

These changes are described further in the Sections below.

Description of baseline for estuarine changes

Sequestration

6.5.51 Carbon sequestration occurs when a reservoir of stored CO_2 is increasing in size. As trees and plants grow they store increasing levels of CO_2 and it is at this stage in their lives they are sequestering carbon i.e. they are a carbon sink. When a tree or plant reaches maturity it is said that it maintains a state of equilibrium, absorbing and releasing the same amounts of CO_2 whilst holding a constant store within its organic matter. When this plant material dies the carbon dioxide within its store is released during the decomposition period. However, in some cases this decomposition can be delayed because the dead organic materials are stored in reservoirs – for example soils and peat bogs. In a similar fashion as plants store an increasing level of CO_2 until they reach maturity, a peat bog will behave in the same way. At this stage it too is a carbon sink because the reservoir is increasing.

6.5.52 In the case of peat bogs or soils, the carbon reservoir is maintained in equilibrium unless there is an environmental change, some examples of which are climate warming, forest fire and the destruction of forest, cultivation of natural land, land drainage or extraction/disturbance of peat bogs. A large volume of research and analysis has been carried out on forests and their absorption capacity, however little information is available on inter-tidal soils which can be very unstable.

6.5.53 Parties to the Framework Convention on Climate Change (FCCC) have to report CO_2e sinks and sources which result from land use change (under IPCC guidelines). The UK's submission is detailed in comparison to the basic submission requirements. Although not required under the IPCC guidelines, the UK estimated that all its saltmarshes sequester 0.367MtCO_2/Year ±20%. The area of saltmarsh in the UK is 45,500ha (England 32,500 ha, Scotland 6747 ha, Wales 6089 ha, and Northern Ireland 215 ha)[3]. We can therefore approximate that 45,500ha sequesters 0.367MtCO_2/year and therefore each ha sequesters on average 8tCO_2/year ±20%. Shepherd et al also report an approximate value of 1.61-6.5tCO_2/year/ha[4] and Trulio. L et al report a figure of c.9tCO_2/year/ha[5].

6.5.54 Estuaries have the highest primary productivity of all ecosystems (Odum, 1959). The autochothonous (photosynthesized in the estuary) and allochthonous (from outside the estuary) organic matter is processed within the estuary by filter feeders, decomposed and remineralized by benthic organisms, and moved through the system by tidal fluctuations (Potsma, 1967). Seagrasses, the rooted plants in non-marsh subtidal estuaries, stabilize sediments, dampen wave action, and collect particulates, including organic matter, from the water column (Gacia and Duarte, 2001; Gacia et al., 1999), (cited in Jesperson et al, 2007).

[3] UK Biodiversity action plan, Habitats action plan – coastal saltmarshes, http://www.ukbap.org.uk/UKPlans.aspx?ID=33#1 accessed 25th July 2008

[4] Shepherd et al, Integrated modelling of an estuarine environment: an assessment of managed realignment options. Tyndall Centre for Climatic Research. 2005

[5] Trulio et al, White Paper on Carbon Sequestration and Tidal Salt Marsh Restoration, 2007

6.5.55 The construction of a tidal power option would in certain cases create a large reservoir of water at the upstream of the barrage. The biological composition of the standing water body could potentially affect the sequestration rate of the estuary. Aquatic fauna will sequester carbon from the atmosphere through the process of photosynthesis, the creation of larger stores of water (and biological fauna by inference) or the starving of certain downstream areas of sediment will affect the level of carbon sequestration. The Marine Ecology paper has found that it is still unclear as to the level of photosynthesis that will occur with each option; however, the B3 scheme shows some potential but the estimates vary widely.

Sequestration – Siltation

6.5.56 The carbon sequestration rate of the sediment deposited within the Severn Estuary will depend upon the source and properties of the sediment, including the volume and concentration of organic matter. The Severn in particular is however known to have low primary productivity because of suspended sediment concentration. Most carbon comes from rivers and carbon cycling is mostly through a detrital pathway. Several studies are ongoing globally to research the sequestration properties of non-marsh or mangrove estuaries however there is very little information available on the Severn Estuary specifically.

6.5.57 Sediment is transported through the fluvial and marine system and deposited along the length, but also at the estuary. The sediment follows a natural pathway and the final destination is not easy to predict. The construction of a tidal power option across the sediment transfer path would inevitably lead to the build up of material behind the barrage or lagoon. Measures to prevent or reduce adverse effects can be put into place to alleviate the effects, but there will still be a disturbance to the natural flow of the sediments.

6.5.58 The fluvial siltation has been assessed by the modelling team but it is also believed that there would be marine siltation. It is likely that the increase in volume of siltation will result in a store of carbon which for some of the options may be significant. This has been estimated as a single number over the initial 5 years of operation however the rate of siltation adds additional uncertainty. Table 6.15 below provides the current baseline level of siltation in the estuary and the siltation volumes as modelled for the SEA given the installation of each option.

Table 6.15 Range of effects of the changes to saltmarsh and mudflats

6.5.59

Scheme	Import Siltation Mm^3
Baseline	55
Brean Down to Lavernock Point Barrage (B3)	500
Shoots Barrage (B4)	300
Beachley Barrage (B5)	150
Welsh Grounds Lagoon (L2)	300
Bridgwater Bay Lagoon (L3)	45

6.5.60 The most substantial long-term changes are the sediment deposition upstream of each tidal power option and increased low water levels reducing the inter-tidal area. The increase in siltation processes behind the barrage could lead to an increase in the build up of organic matter, pollutants and the creation of environmental conditions that were not previously retained within the Severn Estuary. This would be considered sequestration of carbon. Previous studies have been completed to quantify the level of carbon storage in soils. It is widely accepted that soils sequester approximately 3 times that of the vegetation above it. Each individual environment is however different and the concentration of carbon in an area depends on temperature, salinity, the density of the silt and the percentage of organic carbon. Jepersen and Osher[6] studied Taunton Bay Estuary, Maine. The paper indicates that there is between 400-750TCO_2/ha stored in the top 1m of silt in the Taunton Bay Estuary. The concentration of Carbon is similar to that of estuarine sediments in Massachusetts and coastal sediments in Maryland and Rhode Island.

6.5.61 In order to give a range of potential impacts on the carbon footprint of siltation a conservative range has been applied. These studies relate to existing environments whereas the siltation in the Severn would result continually if an option was installed. It is assumed that with every 1m depth per hectare, i.e. every 10,000m^3 that the carbon store increases. The highest band is based on 3 times the sequestration capabilities and the lowest error band is based on the lowest estimate from Jeperson and Osher of 400TCO_2/ha.

Methanogenesis

6.5.62 Methane has a global warming potential 25 times greater than that of carbon dioxide (based on an average over 100years); this increases to a global warming potential (GWP) of 72 if based over 20 years. This scoping assessment looks at the comparable impact of each of the options for Severn tidal power generation. This is therefore more important for consistency across all options being considered for future energy supply by DECC. Methanogenesis is the formation of methane in the final stage of decomposition of organic matter from the anaerobic respiration of microbes.

6.5.63 In addition to the loss of saltmarshes and mudflats potentially impacting the sequestering of CO_2 that occurs in the Severn Estuary, methanogenesis may be augmented due to the increased level of flooding however, this is highly dependent on environmental and biotic factors for different areas.

6.5.64 The construction of a lagoon or barrage, leading to an area of flooding could lead to an increase in the deposited organic material and a consequent increase in the level of methanogenesis. However, this is highly dependent on the amount and rate of deposition and the level of the biological activity in the utilising resource. Several studies into naturally occurring methanogenesis study the conditions to a depth of 1m below the surface. It has been shown in artificial conditions up to 6m however this is highly dependent on temperature. For the purposes of this assessment a study completed by Saarnio, 2007 determined that methanogenesis levels for saltmarshes were 0.84tCO_2/year/ha[7] with a range of 0 – 15tCO_2/year/ha and a 100-300% uncertainty based on 5 locations sampled. This has been used to provide an indication of the potential impacts however the high level of uncertainty is noted due to the individual nature of each individual location.

6.5.65 The micro-organisms involved in the process can be sensitive to local climate, and areas with extremes of cold will not produce the anaerobic conditions necessary for methanogenesis. Therefore, the climatic conditions at depths below a certain value may not be suitable for anaerobic processes to occur, and local ground conditions within the Severn Estuary will need to be taken into account.

[6] Jepersen and Osher, Carbon storage in the soils of a MesoTidal Gulf of Maine Estuary, Soil Science Society AM J72:372-379, 2007

[7] Saarnio et al, Methane release from wetlands and watercourses in Europe, Atmospheric Environment, Vol 43, 1421 – 1429, 2009.

Nitrogen flux

6.5.66 Estuaries are considered a major source of methane and nitrogen, primarily due to their supply of fresh water[8].

6.5.67 The uptake of nitrogen by natural flora is restricted to ammonia or nitrates. The most common form of nitrogen fixed by plant-life is through nitrates, as ammonia can be toxic in certain concentrations. In most ecosystems and environments, nitrogen is primarily stored in living and dead organic matter. During decomposition the organic nitrogen is converted into inorganic forms by bacteria, actinomycetes and fungi. These organisms modify the nitrogen during the mineralization process, converting ammonia (NH_3) to ammonium salts (NH_4^+). The nitrogen compounds are then chemically converted into nitrites by a bacterium belonging to the genus nitrosomonas, further nitrobacteria organisms then convert the nitrites into nitrates, for facile absorption by the roots of plants.

6.5.68 Denitrification can occur in anaerobic conditions and is the reduction of nitrate into nitrogen (N_2) and nitrous oxide (NOx), these gases then diffuse through the soil into the atmosphere. It is recognised that N_2O has 310 times more impact per unit weight than CO_2 (based on an average over 100 years), and therefore is an important GHG and contributor to the carbon footprint.

6.5.69 A high concentration of nitrates and suitable light conditions present within an area has been known to lead to the process known as eutrophication. Whereby, the increased levels of nitrates can lead to an acceleration of plant growth and decay, causing a starvation of oxygen and potential impacts upon other aquatic organisms.

6.5.70 Agricultural run off along the length of the River Severn and its tributaries could potentially be stored behind the barrage, whereas it previously would have been diluted by the natural processes of the tidal estuary. However, the barrage may trap saltwater, therefore potentially diluting the nutrient load more than at present. The sediment build-up could consequently increase the anaerobic condition if the deposition of organic carbon exceeds the consumption. Denitrification can occur in such conditions and result in the emission of nitrogen and nitrous oxide to the atmosphere. Studies completed on tidal saline wetlands indicate that the flux of Nitrogen Oxide, although it is sensitive to the processes described above, is negligible[9].

6.5.71 Summary of sequestration, methanogenesis and nitrogen flux

6.5.72 <u>The information provided above has been gathered to provide an indication as to the likely impact that a change in the estuary will have on the flux of GHG emissions and therefore the carbon footprint of each option. It has been highlighted in this research that there are a wide number of factors which impact the fluctuation in emissions levels. The pH, temperature, and redox potential are all factors which have been shown to have an impact on the levels of emissions.</u>

6.6 Likely effects of estuarine changes

6.6.1 The changes relative to current conditions (GHG emission release) are discussed however it is recognised that the future baseline for these issues is unknown. It is

[8] Bange,H, Nitrous oxide and methane in European coastal waters, Forschungsbereich Marine Biogeochemie, IFM-GEOMAR, Leibniz-Institut für Meereswissenschaften, Düsternbrooker Weg 20, 24105 Kiel, Germany,2006.

[9] Chmura et al, Global Carbon sequestration in tidal, saline wetland soils, Global Biogeochemical Cycles, Vol 17, No 4, 1111, 2003.

likely that there would be water quality and marine ecology changes in the future (see Water Quality and Marine Ecology Topic Papers):

6.6.2 Saltmarsh area; It is possible that new saltmarsh area may provide increased sequestration. The table below indicates the change in area relative to the baseline for each option. Option B4 is likely to experience a decrease in saltmarsh area, however all other options would see an increase. In particular L3 would see a considerable increase of c.1000ha. The level of sequestration is extremely site specific within a particular estuary as it relates to the factors described in the Sequestration section above. As specific assessments on the Severn have not been completed we have provided results based on the range described above (1.6 to 9tCO_2/ha/year) to provide an indication as to the potential impact that loosing or gaining saltmarsh could have. There would be a shift in the baseline of saltmarsh over the lifetime of the scheme and this may mean therefore that this impact would not be year on year until 2140. We have assumed that it is year on year for 25 years.

6.6.3 Mudflat area; mudflat areas are believed to store carbon and it is believed that this would not change should the mudflat be lost to flooding (see siltation). There is a possibility however that there would be an increase in methanogenesis due to the anaerobic conditions generated by flooding. It is believed that methanogenesis primarily occurs in the top 1m of sediment which would therefore relate the release of methane to area as described above this has been based on 0.84tCO_2/ha/year with an 80% error band.

6.6.4 Table 6.16 below provides a summary of the likely impacts of changes to the areas of saltmarsh and mudflat. This is the effect on an annual basis. The high estimate is shown as a percentage of displaced emissions at 2040 (which takes the decarbonised economy into account – see Section 6.5). Table 6.16 summarise the results which show that highest estimate for release of emissions results in a c.1% change on the level of emissions displaced.

Table 6.16 Range of effects of the changes to saltmarsh and mudflats

Scheme	Saltmarsh (ha)	Mudflat (ha)	Low tCO_2e/yr	High tCO_2e/yr	High as %age of Annual displaced emissions at 2040
Brean Down to Lavernock Point Barrage (B3)	-210	-4160	2500	6500	1
Shoots Barrage (B4)	140	-370	-1200	420	0.5
Beachley Barrage (B5)	80	-350	-600	450	1
Welsh Grounds Lagoon (L2)	80	-940	-550	1300	1.25
Bridgwater Bay Lagoon (L3)	250	-1710	-2000	2300	1

Siltation:

6.6.5 The potential for siltation to sequester over the life of the project varies considerably as per the results in Table 6.17 from the highest to the lowest estimates. The low case considers the highest potential for sequestration. When incorporated into the estimations for payback period, this has the potential to make a number of the schemes sequestration schemes although it is highlighted that further site assessment with regards to the specific silt in the estuary should be carried out to confirm this potential.

Table 6.17 Lifetime sequestration as a result of siltation

STP alternative option ($kTCO_2$)	Low estimate (highest level of sequestration)	High estimate (lowest level of sequestration)
B3	20,000	750
B4	12,000	450
B5	6,000	225
L2	12,000	450
L3	1,800	67

6.6.6 Nitrogen cycle: The potential changes to the Nitrogen cycle depend on the nutrients available in the estuary and could result in denitrification, eutrophication and dilution of agricultural run-off. All these areas are highly uncertain from water quality modelling carried out for the SEA. With the increase in sedimentation and therefore anaerobic conditions there is the possibility for increased denitrification. This is more likely for the options which have increased siltation.

6.6.7 Grassland has been considered but the loss of grassland in terms of emissions sequestration is considered insignificant.

6.6.8 These final effects are likely to have a positive impact on the carbon footprint and therefore increase the net emissions displaced.

Indirect Effects Decommissioning Phase

. No indirect effects of decommissioning are considered to impact the carbon footprint as new equilibriums would have been established in the estuarine effects.

Far-field Effects

Far-field Effects Construction Phase

6.6.9 The procurement of certain raw materials during the construction phase of the different schemes will have an impact on the GHG emissions of the country of origin and therefore in the global GHG emissions. This is the case for steel, armour stone, turbines, and timber and these could potentially be manufactured/extracted in the Far East and Scandinavia.

Far-field Effects Operational Phase

6.6.10 During operation, turbines will require replacement twice during the life time of the project. The Supply Chain Survey Report (DECC, 2009) concluded that it is likely that a consortium will formed between manufacturers, and these might invest on a new plant for the manufacturing of the turbines. However, at this stage it has been assumed that turbines will be manufactured overseas, and therefore the emissions generated due to the production and transport to the UK will have an impact in the country of origin and in the Global GHG emissions. The most impact on emissions is associated with the schemes which have the highest number of turbines requiring replacement.

Far-field Effects Decommissioning Phase

6.6.11 No far field effects are envisage during decommissioning of the different schemes.

Cumulative Effects

6.6.12 The cumulative effects are considered at a high descriptive level and are not therefore quantified in the results.

6.6.13 GHG savings made today are more important than future savings because of the cumulative nature in which emissions build in the atmosphere. As per a discounted cash flow analysis a similar approach could be used to GHG emission savings analysis.

6.6.14 The major difference which could be considered when planning the timescales of projects which will emit carbon are built or decommissioned, particularly during the construction phase of the Severn Tidal Power project, is that in the future more advanced technologies and energy efficient means of construction or demolition may be available. Therefore, it could be prudent, if it was economically and environmentally viable, to delay appropriate projects. For example decommissioning projects could be delayed.

Consequential Development Effects

6.6.15 The consequential developments identified which are likely to affect GHG emissions during the operation of the option are described below but only qualitatively:

Energy intensive industry drawn to the area

6.6.16 Initially if the industry is drawn in from outside the UK where processes are still more energy intensive then if the industry moves into the UK there will be an overall Global emissions savings. The UK emissions savings in this scenario would be cancelled out by the new industry.

6.6.17 The second is that an existing industry in the UK moves to site near the Severn Tidal Power Option. The renewable energy would therefore be offsetting an existing source of power and therefore contribute to UK reduction targets.

6.6.18 Lastly, it is possible that a new industry would set up in the UK. This would therefore counteract any emissions savings with new UK emissions and could potentially increase UK emissions if the industry utilised more energy than the tidal power option could supply.

6.6.19 This has been highlighted here but would be an economic consideration outside the scope of this project.

Recreational usage of water bodies altered

6.6.20 It is considered that with an increasing size of Severn Tidal Power option there would be increasing recreational activity associated with it. It is likely nevertheless that the activities would involve non-motorised sports and therefore that increase in emissions would be proportional to increase in the number of visitors. This will however decrease per vehicle over the life of the project as Government policies on transport are brought to fruition.

Summary of Likely Significant Effects on the Environment

6.6.21 The following summarises the likely significant effects (direct, indirect, far-field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases. In addition the impacts of operational shipping diversion are presented for option B3.

6.6.22 Construction emissions have been generated from information provided by the engineering team at PB combined with assumptions used by the Air and Climatic Factors and the Resources and Waste Topic papers. The construction emissions relate directly to the physical size of the scheme and thus the resources, transportation and overall, embodied energy associated with each option. B3 is the physically largest scheme, followed by the two lagoon options with the smallest being B4 and B5.

6.6.23 The operational emissions released for maintenance are proportional to the number and size of turbines. Figure 6.1 below shows the base case cumulative emissions for each of the options. Operational emissions from estuarine changes are still very uncertain therefore these are incorporated into the range of results, which represents the low and high case. It should be noted that the potential variation on these curves is subject to the uncertainty in the quantities and effects, and the uncertainty in the carbon data, and this is reflected in the range for each option. The range for B3 is provided below in Figure 6.2 to illustrate the range. The cumulative emission lines show when each scheme becomes carbon neutral (but it does not give the full pay back period which is different due to the ongoing release of some emissions over the life of the project) and this is identified on the graph where each line crosses the x-axis. The emissions during construction may be a key criteria as they would be released at a time when the UK requires considerable emission reduction.

6.6.24 The result of the cumulative emissions in Figure 6.1 is, as previously discussed, highly sensitive to the displaced energy emission factors and therefore to UK policy success. Should policy exceed targets there would clearly be a decrease in cumulative emissions. However, should the policies to reduce carbon emissions of energy supply as summarised in Table 6.9 in Section 6.5.26 only be partly successful, this would result in increased emissions savings and thus increased cumulative emission savings. Figure 6.3 demonstrates the sensitivity of the displaced emissions by showing the current assumption alongside one which assumes slower reduction in emissions of energy supply. This is only included to illustrate the sensitivity of the results, the report answers are based upon the successful implementation of policy and the targets for carbon reduction being achieved.

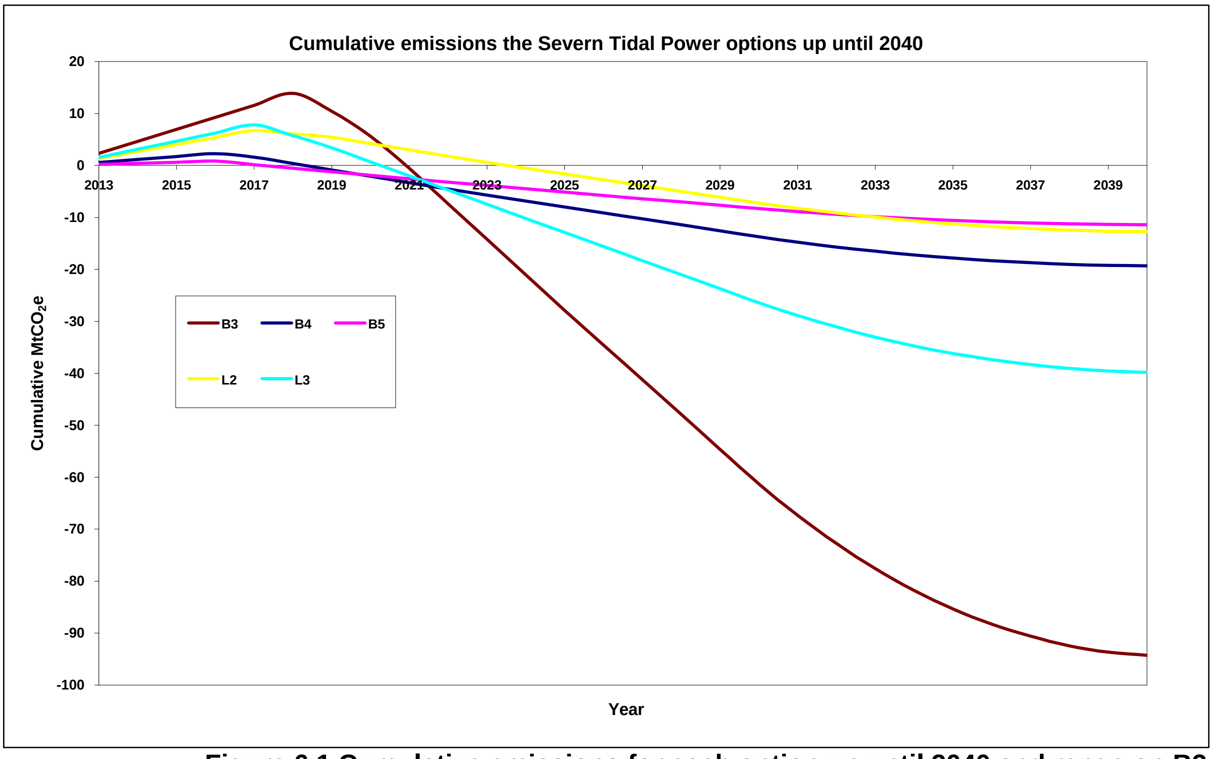

Figure 6.1 Cumulative emissions for each option up until 2040 and range on B3

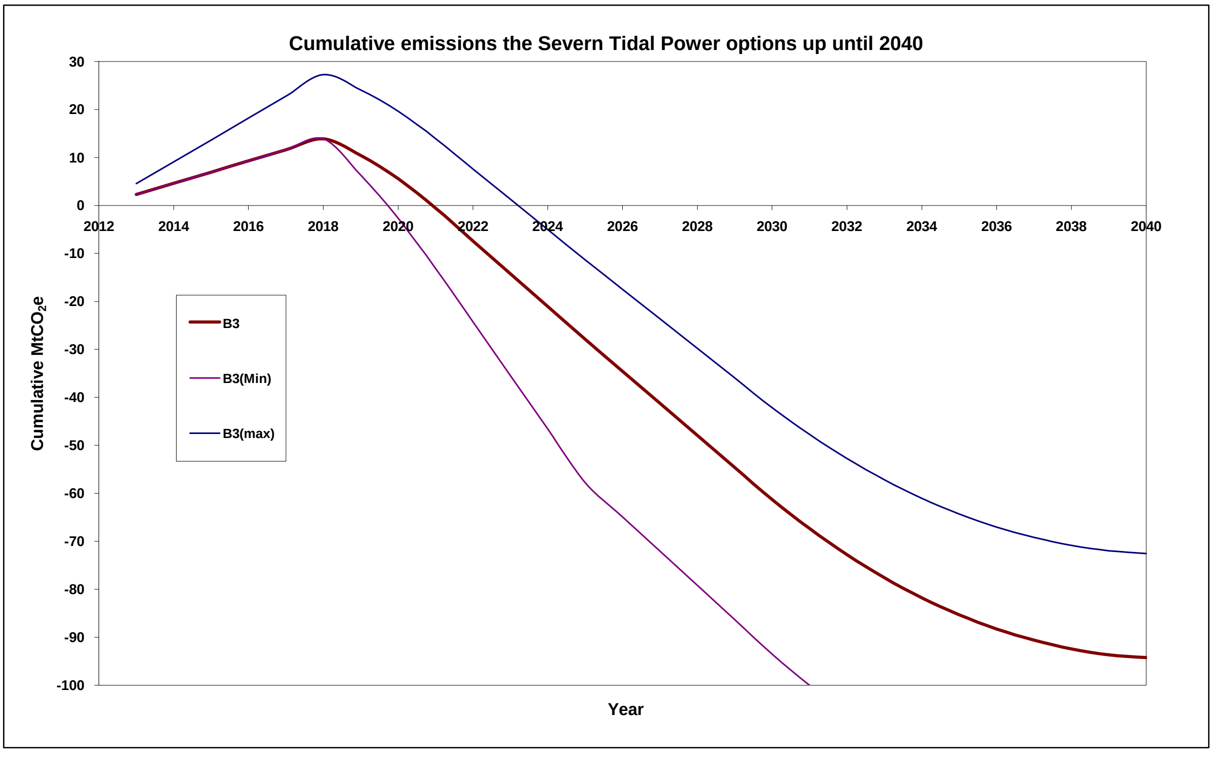

Figure 6.2 Cumulative emissions for B3 and associated range of uncertainty

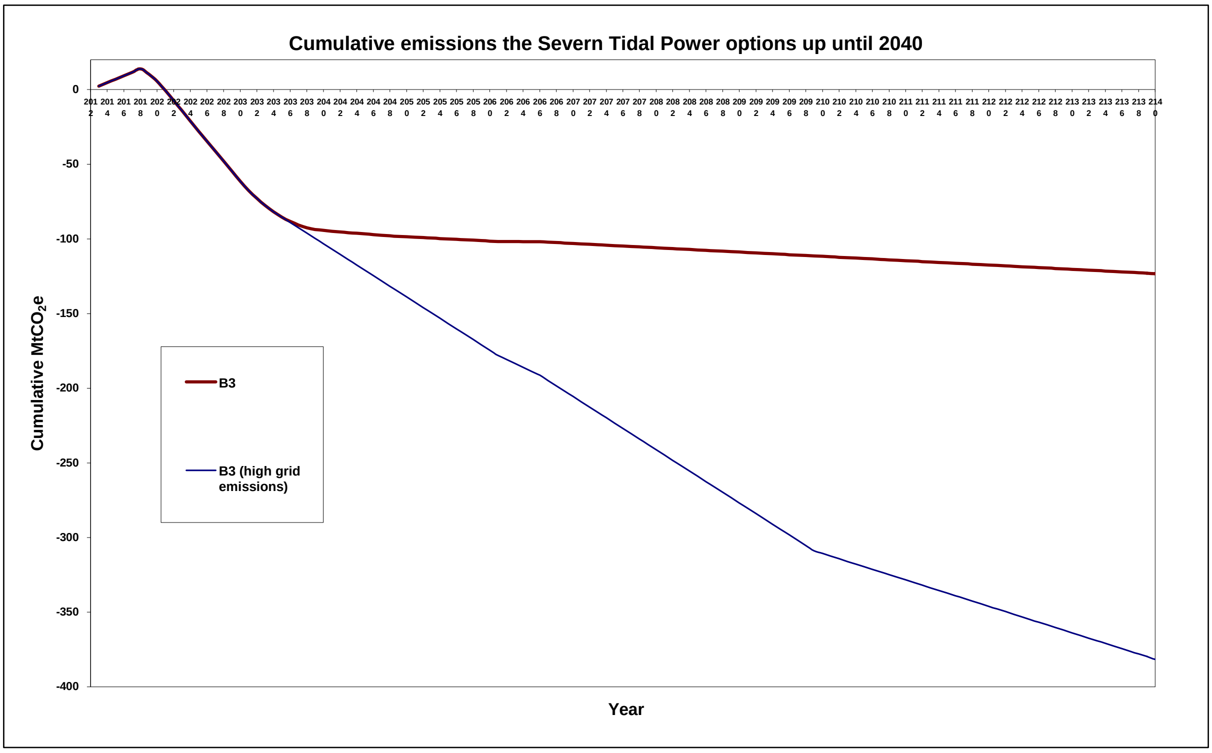

Figure 6.3: Cumulative emissions over lifetime of B3

6.6.25 The results are summarised in Table 6.18 and Table 6.19 below. Table 6.18 provides the range of emissions for construction, operation and decommissioning emissions.

Table 6.18.Summary of GHG Emissions for Construction, Operation and Decommissioning

Alternative	Construction (Mt CO_2)	Operation emissions (Mt CO_2)	Decommissioning (Mt CO_2)
B3 - Brean Down to Lavernock Point Barrage	14 to 28	-20 to 13.5	0.7 to 3
B4 – Shoots Barrage	2.3 to 4.5	-10 to 3.8	0.1 to 0.4
B5 – Beachley Barrage	0.8 to 1.6	-5 to 2.6	0.03 to 0.07
L2 - Welsh Grounds Lagoon	7 to 14	-12 to 2.6	0.4 to 0.75
L3d – Bridgwater Bay Lagoon	8 to 15	-1.5 to 4.8	0.3 to 0.7

Notes
- An error range has been provided on these results to provide an indication as to the level of uncertainty on the outputs.
- Operational emissions show a negative number due to the potential sequestration as a result of siltation (see Section 6.6.5).

Table 6.19 provides a detailed breakdown of the range of results for the Net emissions, the Unit CO_2 emissions, and the payback period.

Table 6.19: Summary of results

Alternative	Net emissions displaced (Mt CO_2)			Unit CO_2 emissions (kg CO_2/kWh)			Carbon Payback (yrs)		
	Low	Base	High	Low**	Base	High	Low**	Base	High
B3 - Brean Down to Lavernock Point Barrage	-147	-114	-78	-0.003	0.009	0.023	-0.8	2.6	7
B4 – Shoots Barrage	-34	-22	-16	-0.02	0.012	0.026	-6.3	3.5	7.8
B5 – Beachley Barrage	-20	-13	-9	-0.02	0.01	0.023	-5.7	2.8	7.7
L2 - Welsh Grounds Lagoon	-30	-17	-6.5	-0.02	0.022	0.05	-4.2	6.1	15
L3d – Bridgwater Bay Lagoon	-54	-47	-29	0.01	0.011	0.027	2.6	3.2	8.5

* Low, base and high cases are provided to present the range of potential results due to the uncertainty.
** The negative numbers are a result of the highest level of sequestration assumed due to siltation and result in carbon sequestration schemes. Further investigation into the potential sequestration of silt in the Severn is recommended to narrow reduce the uncertainty.

The range of input factors results in the variation in ranges for each option. The required level of construction and the resulting energy production impacts the range of results for each option. In addition, L3 has very little siltation and therefore the low uncertainty band for L3 is not as significant as the other options.

Figure 6.4 below shows the range of the payback period for each option (which shows the same pattern as the range of Unit CO_2 emissions). The red dot indicates the minimum scenario with baseline siltation assumptions and therefore shows the large potential impact that the siltation has on the low uncertainty band.

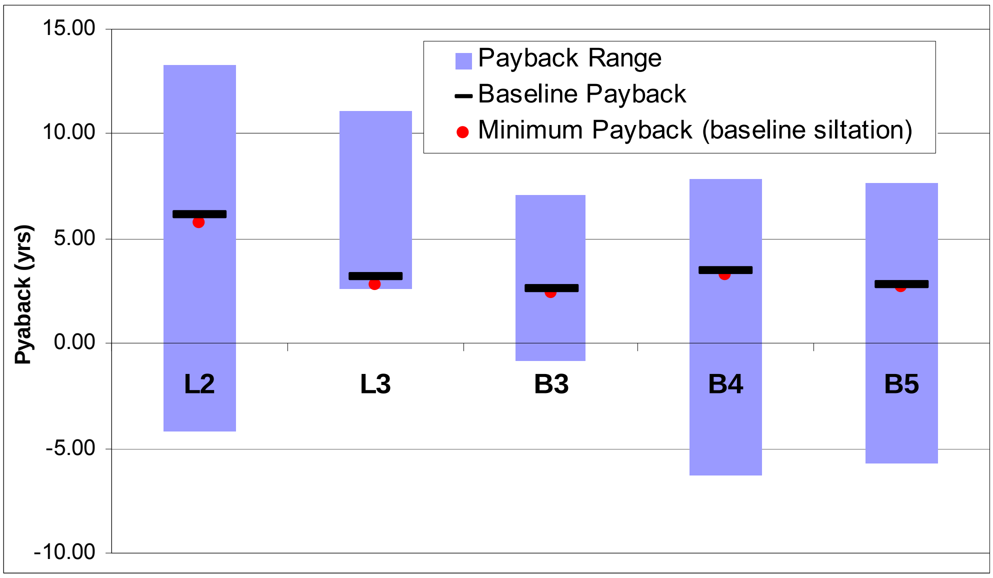

Figure 6.4: Payback range

6.6.26 Consideration of impact of shipping emissions on B3

The impact of additional emissions due to re-routing of vessels and the transportation of cargo from other port locations has been considered as an additional assessment on the B3 option which is likely to have the most substantial impact on vessel traffic. The results indicate that the operational emissions for the base case would increase by 100% with the assumptions utilised in this report. The payback period therefore increases to 3.1 years (from 2.6yrs) which is a c15% increase.

Assumptions, Limitations and Uncertainties

6.6.27 In the estimation of the carbon footprint for the different options a series of assumptions were made which impact the uncertainty on the carbon footprint assessment. Some of the information available limits the accuracy of the carbon footprint and therefore these assumptions have been documented fully in the above sections.

6.6.28 The assumed level of emissions that would be displaced has a significant impact on the net emissions for each option. The level of displaced emissions is dependent upon UK policy being achieved and the current energy supply being decarbonised. If the target levels of 0.43kgCO_2/kWh and 0.04kgCO_2/KWh are not achieved by the dates specified then this could contribute to Severn Tidal Power displacing significantly more emissions. These values are nevertheless applied to all energy project evaluation for the UK and therefore must be used to make the projects comparable.

6.6.29 Due to the high level of uncertainty on the results a sensitivity analysis has been completed for which the results have been incorporated into the range of results in Table 6.16.

Sensitivity analysis

6.6.30 A sensitivity analysis has been completed to identify the areas where, given an under or over estimation in a conversion factor or in the input data, one resource could have a significant impact on the total emissions.

6.6.31 To identify the components of the construction emissions which have the most significant effect on the overall emissions a 1000% increase has been applied. Based on this 1000% increase, in relation to total CO_2e emissions, we can identify which areas are of primary concern. Timber, Structural Concrete, Cement and Steel (Rebar) have the most significant (+50%) impact on the total CO_2e emissions however, individually they have an insignificant (<c.5%) effect in relation to the Net CO_2e emissions. All other construction, operation (maintenance) and decommissioning emissions do not show significant changes against the total and the net emissions.

6.6.32 It is possible that there are large uncertainties in the conversion factor data or in the quantities to which the conversion factors are applied. Therefore by doubling the construction emission data this accounts for an overall error in the conversion factors or a considerable under estimation in resources required. It is considered a worst case scenario for the construction emissions. This has been incorporated into the range of results presented.

6.6.33 The operational emissions associated with estuarine changes are highly uncertain. The baseline and the future baseline have been reviewed at a high level by the Water Quality and Marine Ecology Papers. We have completed a sensitivity analysis on the very high level numbers for methanogenesis and sequestration per Ha that we have estimated from previous sources of information. The data provided has a high level of uncertainty on the sites from which it was analysed (c.300%) therefore the application of a 1000% error band for a new location is reasonable. This assessment is based, as a worst case, on the fact that there would be a negative impact from sequestration and methanogenesis (i.e. the estuary would become a source rather than a sink). It is recognised nevertheless that there is a possibility, as has been experienced at La Rance, that productivity and thus sequestration could increase.

6.6.34 The carbon storage potential of siltation in the estuary given any of the options could be significant. The error band applied to the siltation is based on a minimal amount of storage across the estuary up to a maximum value which has been shown to occur in Estuaries in the USA. This maximum value has the potential to make some alternative options for Severn Tidal Power carbon negative (i.e. a sequestration scheme).

Table 6.20. Assessment summary for B3: Brean Down to Lavernock Point Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Global level of GHG emissions (Low and Low) **And** **UK level of GHG emissions (Low and Low)**	**Overall** Change in the overall GHG emissions associated with the B3 alternative.	Direct and indirect, GHG emissions generated during the different phases	High	Long Term. Continual effect during construction period (6 years), operation (120 years) and decommissioning (c. 3 years).	Irreversible/ permanent	Medium	Global effect and trans-boundary	Positive	High level of uncertainty in the carbon footprint due to layering of assumptions and data availability.	Yes
	Construction Increase of GHG emissions due to production and supply of raw materials, installation, dredging. Including impacts of transportation.	Direct	High	Medium term. Continual effect during construction period (6 years).	Irreversible/ permanent	Medium	Global effect and trans-boundary	Negative	Uncertainty associated with conversion data and quantities.	Yes
	Construction Construction of other large projects. Synergetic effects, i.e. increase in traffic density in the area.	Cumulative	Medium	Medium Term. Contribution to the continual effect during construction period (6 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Uncertainty in timing of projects.	No
	Operation Predicted decrease in emissions due to generation of electricity from a renewable source.	Direct	High	Long Term. Continual effect during the operational life of the project (120 years).	Irreversible/ permanent	Medium.	Global effect and trans-boundary	Positive	The displaced emissions calculated based on the kWh of renewable electricity produced are dependent upon the grid mix electricity going into the future. This is dependent upon successful policy implementation.	Yes (The percentage may seem small, the contribution of this scale of predictable and guaranteed renewable electricity supply is however significant).
	Operation Maintenance, dredging, shipping	Direct and indirect	Medium	Long Term. Continual effect during operation.	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Quantities uncertain	No
	Operation Development of other electricity generation projects in the area, could add to the GHG global effect in a positive or negative way	Cumulative	Medium	Long Term. Contribution to the continual effect during the operational life of project (120 years)	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Positive	Size and likelihood unknown but this would be considered by DECC at strategy level.	Yes, as this could either counteract or complement the emissions saved

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
	depending on the sustainability of these projects.									
	Decommissioning Assumed to be the same level as the emissions generated during construction, minus cement production and dredging. It also assumes that the plant would be primarily decarbonised by 2140.	Direct	Very Low	Short Term Continual effect during the decommissioning period (c. 3 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Predictions in 2140 are highly uncertain and it is likely that in reality that the structure would not be decommissioned.	No
	Decommissioning Decommissioning of other projects in the area during the same period.	Cumulative	Very Low	Short Term. Contribution to the continual effect during the decommissioning period (c. 3 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	If decommissioning can be delayed this increases the potential for more efficient plant.	No
	Other Indirect emissions due to positive economic impacts in the area.	Indirect	Medium	Long Term During construction (6 years) and operation (120 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Extremely difficult to predict the impacts and the carbon impacts of them.	No. However, if founded upon renewable electricity, it could decrease the significance.

Table 6.21. Assessment summary for B4: Shoots Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Global level of GHG emissions (Low and Low) **And** **UK level of GHG emissions (Low and Low)**	**Overall** Change in the overall GHG emissions associated with the B4 alternative.	Direct and indirect, GHG emissions generated during the different phases	High	Long Term. Continual effect during construction period (4 years), operation (120 years) and decommissioning (c. 2 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	High level of uncertainty in the carbon footprint due to layering of assumptions and data availability.	Yes
	Construction Increase of GHG emissions due to production and supply of raw materials, installation, dredging. Including impacts of transportation.	Direct	High	Short term. Continual effect during construction period (4 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Negative	Uncertainty associated with conversion data and quantities.	No
	Construction Construction of other large projects. Synergetic effects, i.e. increase in traffic density in the area.	Cumulative	Medium	Short term. Contribution to the continual effect during construction period (4 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Uncertainty in timing of projects.	No
	Operation Predict decrease due to generation of electricity from a renewable source.	Direct	High	Long Term. Continual effect during the operational life of the project (120 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	The displaced emissions calculated based on the kWh of renewable electricity produced are dependent upon the grid mix electricity going into the future. This is dependent upon successful policy implementation.	Yes (Although the percentage may seem small, the contribution of this scale of predictable and guaranteed renewable electricity supply is significant).
	Operation Maintenance, dredging, shipping	Direct and indirect	Medium	Long Term. Continual effect during operation.	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Quantities uncertain	No
	Operation Development of other electricity generation projects in the area, could add to the GHG global effect in a positive or negative way	Cumulative	Medium	Long Term. Contribution to the continual effect during the operational life of project (120 years)	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Positive	Size and likelihood unknown but this would be considered by DECC at strategy level.	Yes, as this could either counteract or complement the emissions saved

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
	depending on the sustainability of these projects.									
	Decommissioning Assumed to be the same level as the emissions generated during construction, minus cement production and dredging. It also assumes that the plant would be primarily decarbonised by 2140.	Direct	Very Low	Short Term Continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Predictions in 2140 are highly uncertain and it is likely that in reality that the structure would not be decommissioned.	No
	Decommissioning Decommissioning of other projects in the area during the same period.	Cumulative	Very Low	Short Term. Contribution to the continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	If decommissioning can be delayed this increases the potential for more efficient plant.	No
	Other Indirect emissions due to positive economic impacts in the area.	Indirect	Medium	Long Term During construction (5years) and operation (120 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Extremely difficult to predict the impacts and the carbon impacts of them.	No. However, if founded upon renewable electricity, it could decrease the significance.

Table 6.22. Assessment summary for B5: Beachley Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Global level of GHG emissions (Low and Low) **And** **UK level of GHG emissions (Low and Low)**	**Overall** Change in the overall GHG emissions associated with the B5 alternative.	Direct and indirect, GHG emissions generated during the different phases	High	Long Term. Continual effect during construction period (4 years), operation (120 years) and decommissioning (c. 2 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	High level of uncertainty in the carbon footprint due to layering of assumptions and data availability.	Yes
	Construction Increase of GHG emissions due to production and supply of raw materials, installation, dredging. Including impacts of transportation.	Direct	High	Short term. Continual effect during construction period (4 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Negative	Uncertainty associated with conversion data and quantities.	No
	Construction Construction of other large projects. Synergetic effects, i.e. increase in traffic density in the area.	Cumulative	Medium	Short Term. Contribution to the continual effect during construction period (4 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Uncertainty in timing of projects.	No
	Operation Predict decrease in emissions due to generation of electricity from a renewable source.	Direct	High	Long Term. Continual effect during the operational life of the project (120 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	The displaced emissions calculated based on the kWh of renewable electricity produced are dependent upon the grid mix electricity going into the future. This is dependent upon successful policy implementation.	Yes (Although the percentage may seem small, the contribution of this scale of predictable and guaranteed renewable electricity supply is significant).
	Operation Maintenance, dredging, shipping	Direct and indirect	Medium	Long Term. Continual effect during operation.	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Quantities uncertain	No
	Operation Development of other electricity generation projects in the area, could add to the GHG global effect in a positive or negative way	Cumulative	Medium	Long Term. Contribution to the continual effect during the operational life of project (120 years)	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Positive	Size and likelihood unknown but this would be considered by DECC at strategy level.	Yes, as this could either counteract or complement the emissions saved

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
	depending on the sustainability of these projects.									
	Decommissioning Assumed to be the same level as the emissions generated during construction, minus cement production and dredging. It also assumes that the plant would be primarily decarbonised by 2140.	Direct	Very Low	Short Term Continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Predictions in 2140 are highly uncertain and it is likely that in reality that the structure would not be decommissioned.	No
	Decommissioning Decommissioning of other projects in the area during the same period.	Cumulative	Very Low	Short Term. Contribution to the continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	If decommissioning can be delayed this increases the potential for more efficient plant.	No
	Other Indirect emissions due to positive economic impacts in the area.	Indirect	Medium	Long Term During construction (4 years) and operation (120 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Extremely difficult to predict the impacts and the carbon impacts of them.	No. However, if founded upon renewable electricity, it could decrease the significance.

Table 6.23. Assessment summary for L2: Welsh Grounds Lagoon

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Global level of GHG emissions (Low and Low) **And** **UK level of GHG emissions (Low and Low)**	**Overall** Change in the overall GHG emissions associated with the L2 alternative.	Direct and indirect, GHG emissions generated during the different phases	High	Long Term. Continual effect during construction period (5 years), operation (120 years) and decommissioning (c. 2 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	High level of uncertainty in the carbon footprint due to layering of assumptions and data availability.	Yes
	Construction Increase of GHG emissions due to production and supply of raw materials, dredging. installation, dredging. Including impacts of transportation.	Direct	High	Medium term. Continual effect during construction period (5 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Negative	Uncertainty associated with conversion data and quantities.	No
	Construction Construction of other large projects. Synergetic effects, i.e. increase in traffic density in the area.	Cumulative	Medium	Medium term. Contribution to the continual effect during construction period (5 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Uncertainty in timing of projects.	No
	Operation Predict decrease in emissions due to generation of electricity from a renewable source.	Direct	High	Long Term. Continual effect during the operational life of the project (120 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	The displaced emissions calculated based on the kWh of renewable electricity produced are dependent upon the grid mix electricity going into the future. This is dependent upon successful policy implementation.	Yes (Although the percentage may seem small, the contribution of this scale of predictable and guaranteed renewable electricity supply is significant).
	Operation Maintenance, dredging, shipping	Direct and indirect	Medium	Long Term. Continual effect during operation.	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Quantities uncertain	No
	Operation Development of other electricity generation projects in the area, could add to the GHG global effect in a positive or negative way	Cumulative	Medium	Long Term. Contribution to the continual effect during the operational life of project (120 years)	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Positive	Size and likelihood unknown but this would be considered by DECC at strategy level.	Yes, as this could either counteract or complement the emissions saved

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
	depending on the sustainability of these projects.									
	Decommissioning Assumed to be the same level as the emissions generated during construction, minus cement production and dredging. It also assumes that the plant would be primarily decarbonised by 2140.	Direct	Very Low	Short Term Continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Predictions in 2140 are highly uncertain and it is likely that in reality that the structure would not be decommissioned.	No
	Decommissioning Decommissioning of other projects in the area during the same period.	Cumulative	Very Low	Short Term. Contribution to the continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	If decommissioning can be delayed this increases the potential for more efficient plant.	No
	Other Indirect emissions due to positive economic impacts in the area.	Indirect	Medium	Long Term During construction (5 years) and operation (120 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Extremely difficult to predict the impacts and the carbon impacts of them.	No. However, if founded upon renewable electricity, it could decrease the significance.

Table 6.24. Assessment summary for L3d: Bridgwater Bay Lagoon

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Global level of GHG emissions (Low and Low) **And** **UK level of GHG emissions (Low and Low)**	**Overall** Change in the overall GHG emissions associated with the L3d alternative.	Direct and indirect, GHG emissions generated during the different phases	High	Long Term. Continual effect during construction period (5 years), operation (120 years) and decommissioning (c. 3 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	High level of uncertainty in the carbon footprint due to layering of assumptions and data availability.	Yes
	Construction Increase of GHG emissions due to production and supply of raw materials, installation, dredging. Including impacts of transportation.	Direct	High	Medium term. Continual effect during construction period (5 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Negative	Uncertainty associated with conversion data and quantities.	No
	Construction Construction of other large projects. Synergetic effects, i.e. increase in traffic density in the area.	Cumulative	Medium	Medium term. Contribution to the continual effect during construction period (5 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Uncertainty in timing of projects.	No
	Operation Predict decrease in emissions due to generation of electricity from a renewable source.	Direct	High	Long Term. Continual effect during the operational life of the project (120 years).	Irreversible/ permanent	Low	Global effect and trans-boundary	Positive	The displaced emissions calculated based on the kWh of renewable electricity produced are dependent upon the grid mix electricity going into the future. This is dependent upon successful policy implementation.	Yes (Although the percentage may seem small, the contribution of this scale of predictable and guaranteed renewable electricity supply is significant).
	Operation Maintenance, dredging, shipping	Direct and indirect	Medium	Long Term. Continual effect during operation.	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Quantities uncertain	No
	Operation Development of other electricity generation projects in the area, could add to the GHG global effect in a positive or negative way	Cumulative	Medium	Long Term. Contribution to the continual effect during the operational life of project (120 years)	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Positive	Size and likelihood unknown but this would be considered by DECC at strategy level.	Yes, as this could either counteract or complement the emissions saved

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
	depending on the sustainability of these projects.									
	Decommissioning Assumed to be the same level as the emissions generated during construction, minus cement production and dredging. It also assumes that the plant would be primarily decarbonised by 2140.	Direct	Very Low	Short Term Continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Predictions in 2140 are highly uncertain and it is likely that in reality that the structure would not be decommissioned.	No
	Decommissioning Decommissioning of other projects in the area during the same period.	Cumulative	Very Low	Short Term. Contribution to the continual effect during the decommissioning period (c. 2 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	If decommissioning can be delayed this increases the potential for more efficient plant.	No
	Other Indirect emissions due to positive economic impacts in the area.	Indirect	Medium	Long Term During construction (5 years) and operation (120 years).	Irreversible/ permanent	Very Low	Global effect and trans-boundary	Negative	Extremely difficult to predict the impacts and the carbon impacts of them.	No. However, if founded upon renewable electricity, it could decrease the significance.

6.7 Measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment

6.7.1 The SEA Directive requires that information is provided on the measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme (Annex I). These measures are considered within this topic, and will thereby inform an overall assessment of such measures within the SEA Environmental Report.

6.7.2 In this SEA, and in line with UK practice, these measures are split into those measures to prevent or reduce effects, and measures to as fully as possible offset any significant adverse effects on the environment.

6.7.3 As the carbon footprint assessment is highly dependent upon the results from other topic papers it is highly likely that where engineering or water quality changes for example implement measures to prevent, reduce and offset adverse effects on the environment, that these will directly alter the carbon footprint. It is suggested nevertheless that the carbon footprint is considered alongside these changes. Commonly the carbon footprint will improve with cost savings and environmental improvements, however this can now easily be monitored using the existing models.

6.7.4 Some specific considerations are described below which would, we believe, reduce the carbon impact from Severn Tidal Power on the environment.

<u>Measures to prevent or reduce effects</u>

6.7.5 The measures identified to prevent or reduce likely significant adverse environmental effects within this topic are described below. To identify the areas of most significant emissions contributions and therefore the areas with most potential for carbon reduction the results have been presented in Figure 6.5. The operational emissions include the sequestration and release of emissions due to estuarine processes and the increase due to operational dredging which is the major contributor. The lagoons which have zero (L2) and minimal (L3) dredging show considerably reduced operational emissions. The operational emissions are nevertheless a smaller proportion of total emissions in comparison to the construction emissions, which for all the options contribute more than 50%.

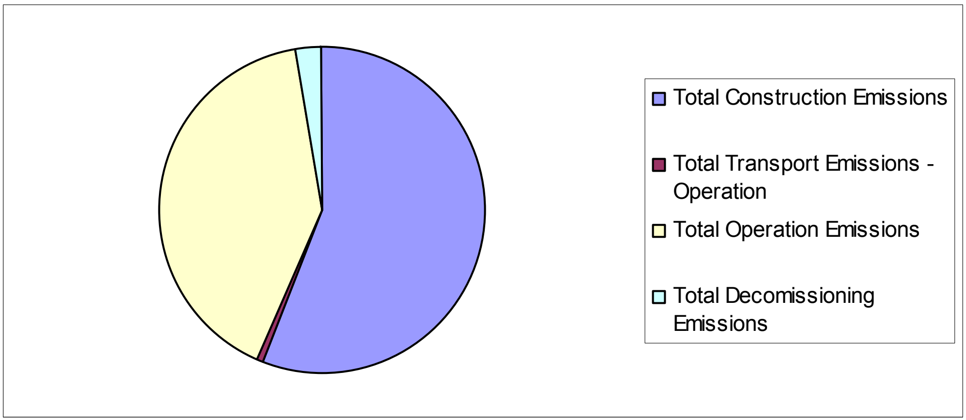

Figure 6.5: Major component breakdown of emissions

Construction

6.7.6 Figure 6.6 below gives the breakdown of the construction emissions for one of the tidal power options. For all options Steel (Rebar), cement, structural concrete and timber are large contributors. Armour stone and crushed rock also increase in significance depending on the option. The large contribution of these sources of material is related to the quantities required for each option. It is important therefore to consider the impact of the supply of these materials and how the carbon footprint can be reduced through careful procurement.

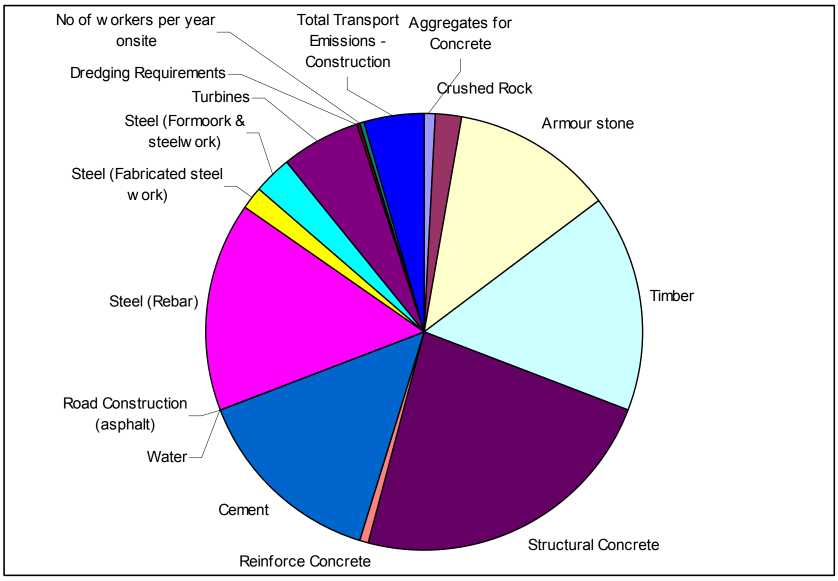

Figure 6.6 Breakdown of construction emissions

6.7.7 The Supply Chain Study (DECC, 2010) proposed the re-use of dredged materials on site as embankment materials, specifically sand and gravel and soft and hard rock. The remaining dredged material will be use in the construction of compensatory habitat in the estuary. This will require an efficient coordination between the dredging works and the embankment construction.

6.7.8 By re-using this valuable resource not only transportation and disposal cost will be reduced but the carbon footprint of extracting the replaced materials, and disposing the dredged materials, will be reduced.

6.7.9 Supply of materials and manufactured components should be in the UK where at all possible as the UK has efficient means of production and energy supply in addition to minimising transportation emissions. Where supply from outside the UK is required the most efficient means of production and transportation should be sought.

6.7.10 Another area of emission measures to prevent or reduce adverse effects is the optimisation of materials delivery to and on site. The delivery of materials direct to localised holding sites and final locations along the lagoon or barrage optimises the use of transportation on site. This would save transportation costs, emissions and it is likely that it would be considered for on site safety. In addition, 'Just In Time' scheduling should be used to avoid double handling on site. Similarly for the removal of waste, optimised site locations for pick up should be determined. For B3 and L2 it has been assumed that the existing dredging disposal sites will need to be moved to another dispersive location to enable continued dredging disposal by others. The new disposal site/s selected is/are also assumed to be used for the STP scheme's dredging, once operational. The distances involved in this are not quantifiable at this stage and therefore not included in the carbon footprint.

6.7.11 The remediation of quarry sites used to supply the materials for construction would provide a good means of mitigating effects.

6.7.12 The use of resources on site, for example water and energy should be minimised. Renewable energy (temporary or permanent) should be installed where possible to power on site accommodation and offices. Solar panels, small wind turbines biomass wood burners or Combined Heat and Power (CHP) options could be considered for heat and electricity.

Operation

6.7.13 The Navigation topic paper has highlighted a series of measures to reduce adverse effects. Once these measures are adopted the operation of barrages or lagoons will not have a significant impact on the navigation through the estuary, however it is still possible that there will be some vessel re-routing. These measures include:

- Scheduling of transit times through locks to avoid congestion;
- Sill-lowering at ports to avoid reduced access windows;
- Dredging locally to avoid loss of depth owing to sedimentation;
- For Beachley barrage it has been recommended that the lock structure is relocated to the west of the barrage to prevent vessels transiting in front of the turbine locks.

6.7.14 The size of the lock structures has been adjusted in order to accommodate the larger vessels especially post-Panama. Therefore, there will be only delays to transit time. It has been highlighted that further detailed analysis will be required to better understand risks to navigation from increased water velocity (particularly in close proximity to the barrage/lagoon structures) and sediment deposition in high risk areas.

6.7.15 In addition to the above measures suggested by Navigation it is believed that channelling the flow of water through the lagoon or barrage could save in costs and emissions that would be incurred as a result of dredging.

6.7.16 Renewable energy options that complement the tidal power option could be considered during the life of the project.

Measures needed to offset effects

6.7.17 The identification of offsetting measures is a requirement of the SEA Directive. For the purposes of this SEA, these are measures to as fully as possible offset any significant adverse environmental effects. Such measures make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. In this SEA, ‘compensation’, a subset of offsetting, is only used in relation to those measures needed under Directive 92/43/EEC (the Habitats Directive).

6.7.18 Compensation measures are even more indefinite in scope, being dependent on preceding tests within the Habitats Directive. Thus it will only be possible to describe the need for such measures under the Habitats Directive, rather than scope them in any detail. A separate Compensation Workstream has been tasked by DECC to consider compensation requirements as part of the Feasibility Study.

6.7.19 Offsetting is an option that many large scale projects are utilising in the UK and this could be considered for the construction phase of Severn Tidal Power. Land remediation for example could be completed as a compensating means.

6.7.20 The replacement of habitat under the Habitats Directive would also provide a means of offsetting sequestration lost in the Severn. It is acknowledged that the creation of replacement intertidal habitat could potentially impact the flux of GHG emissions and would therefore have a likely impact on the operational carbon footprinting. This analysis has not been included in this paper.

SECTION 7

ASSESSMENT AGAINST SEA OBJECTIVES – CARBON FOOTPRINTING

7 ASSESSMENT AGAINST SEA OBJECTIVES

7.1 Introduction

7.1.1 While not specifically required by the SEA Directive, the Practical Guide (ODPM et al., 2005) recommends that SEA Objectives are used to compare the effects of alternative options. The SEA Objectives, assessment criteria and indicators were drafted and consulted upon as part of the Phase 1 SEA scoping stage.

7.1.2 SEA Objectives reflect a desired direction of change. It therefore follows that these objectives may not necessarily be met in full by a given alternative option, but the degree to which they do will provide a way of identifying preferences when comparing alternative options.

7.1.3 This topic paper informs the Environmental Report and its assessment of alternative options against SEA Objectives. This is by providing an assessment specifically in relation to the topic's SEA Objectives. The Environmental Report will then consolidate each topic assessment to provide a description of the assessment in relation to all SEA Objectives.

7.2 Assessment Methodology

7.2.1 An SEA Objective compliance methodology requires judgements to be made on the performance of alternative options against each SEA Objective. The 'assessment criteria' and 'indicators' which accompany the SEA Objectives aid these judgements. The effects on receptors presented in section 3 are aggregated and related back to the SEA Objectives so that the environmental performance of each alternative option can be compared.

7.2.2 The SEA Objectives assessment summary table (table 4.1) shows how each alternative option performs over its entire life-cycle against each SEA Objective, and whether this is major or minor, positive or negative or a combination of the two. For instance, some receptors covered by an SEA Objective may benefit from an alternative option, whereas others would be adversely affected. Furthermore, the judgement of whether the alternative option performance is minor or major depends on the number or proportion of receptors for each objective that are significantly affected, and their value. In addition to the SEA Objectives assessment summary table, the SEA Objectives are also discussed in relation to assessment criteria and indicators.

7.2.3 It recognised that there is a degree of judgement related to alternative option performance, and the assessment criteria are intended as an aid to these judgements. This activity has also been informed by inputs from the Technical Workshops and the Environment and Regional Workstreams.

7.3 Objectives-led Assessment Summary

7.3.1 Table 7.3 sets out the summary of the SEA Objectives assessment which is described in detail below.

<u>SEA Objective CF1 - To maximise the opportunities for use of sustainable sources of energy for the UK</u>

7.3.2 This objective relates to the level of renewable energy produced and thus the annual energy output of each of the options. The unit CO2 emissions per kWh produced are also used as an indicator for this objective. The most effective way of comparing the options' overall impact on GHG emission levels over the lifecycle of the project is by looking at the CO_2 per unit of energy produced which has been estimated throughout this project and which could be readily compared to other forms of energy generation. The range (due to uncertainty) of unit emissions and the carbon payback period are summarised in Table 7.1 below for comparison. It is noted that the carbon payback period is different to the time required for the scheme to become carbon neutral.

Table 7.1: CO_2 per unit of energy produced

Alternative	Unit CO_2 emissions (kg CO_2/kWh)	Carbon Payback (years)
B3 - Brean Down to Lavernock Point Barrage	0 to 0.023	-0.8 to 7
B4 – Shoots Barrage	-0.02 - 0.026	-6.3 to 7.8
B5 – Beachley Barrage	-0.02 - 0.023	-5.7 to 7.7
L2 – Welsh Grounds Lagoon	-0.02 - 0.05	-4.2 to 15
L3d – Bridgwater Bay Lagoon	0.01 - 0.027	2.6 to 8.5

SEA Objective CF2 - To avoid adverse effects from GHG emissions over the lifecycle of the project

7.3.3 This Objective refers to the avoidance of GHG emissions into the atmosphere and thus the total CO_2 emissions released as a result of each phase of the option, and the net emissions over the life of the project. Section 6.5 describes all the likely environmental effects (changes to GHG emission levels) and importantly, includes the assumptions and uncertainty associated with the impact on carbon emissions of a Severn Tidal Power alternative option.

Table 7.2: Net CO_2 emissions and total CO_2 emissions per phase

Alternative	Net emissions displaced (Mt CO_2)			Construction (Mt CO_2)	Operation emissions (Mt CO_2)	Decommissioning (Mt CO_2)
	Low	Base	High			
B3 - Brean Down to Lavernock Point Barrage	-147	-114	-78	14 to 28	-20 to 13.5	0.7 to 3
B4 – Shoots Barrage	-34	-22	-16	2.3 to 4.5	-10 to 3.8	0.1 to 0.4
B5 – Beachley Barrage	-20	-13	-9	0.8 to 1.6	-5 to 2.6	0.03 to 0.07
L2 - Welsh Grounds Lagoon	-30	-17	-6.5	7 to 14	-12 to 2.6	0.4 to 0.75
L3d – Bridgwater Bay Lagoon	-54	-47	-29	8 to 15	-1.5 to 4.8	0.3 to 0.7

Assumptions, Limitations and Uncertainty

7.3.4 In undertaking the assessment of the alternative options against the SEA objectives, there are assumptions, limitations and uncertainties, particularly as there is a degree of judgement related to option performance. These issues are discussed for this topic below. The uncertainty on the carbon footprint is significant for the various options due to the conversion factors, data input from other topic areas, data gaps, and numerous assumptions made for the strategic comparison.

Table 7.3 SEA Objective Assessment Summary Table

Key

Performance is based on number or proportion of receptors linked to each SEA Objective for which significant effects have been predicted, and informed by consideration of SEA Assessment Criteria.			
Major negative performance against SEA Objective	--	Major positive performance against SEA Objective	++
Minor negative performance against SEA Objective	-	Minor positive performance against SEA Objective	+
No Effects	0	Uncertain	Applies to all

SEA Objective	Relevant Receptors	Alternatives Performance against SEA Objectives over entire life-cycle				
		Alternative Option B3: Brean Down to Lavernock Point Barrage	**Alternative Option B4: Shoots Barrage**	**Alternative Option B5: Beachley Barrage**	**Alternative Option L2: Welsh Grounds Lagoon**	**Alternative Option L3d: Bridgwater Bay Lagoon**
CF1 To maximise the opportunities for use of sustainable sources of energy for the UK	Renewable energy supply	++	+	+	+	+
		Significant contribution of **17TWh** per year of renewable energy over the lifetime of the project.	Contribution of **2.9TWh** per year of renewable energy over the lifetime of the project.	Contribution of **1.4TWh** per year of renewable energy over the lifetime of the project.	Contribution of **2.8TWh** per year of renewable energy over the lifetime of the project.	Contribution of **6.3TWh** per year of renewable energy over the lifetime of the project.
	GHG emissions on a per unit of electricity produced ($kgCO_2e/kWh$)	++	++	++	++	++
		0 – 0.023 $kgCO_2e/kWh$ Max case is c.50% of $0.04kgCO_2/kWh$ 2040 target as set by DECC.	-0.02 – $0.026kgCO_2e/kWh$ Max case is c.50% of $0.04kgCO_2/kWh$ 2040 target as set by DECC.	-0.02 – $0.023kgCO_2e/kWh$ Max case is c.50% of $0.04kgCO_2/kWh$ 2040 target as set by DECC.	-0.02 – $0.05kgCO_2e/kWh$ Max case is equal to 2040 target of $0.04kgCO_2/kWh$ as set by DECC.	0.01 – $0.027kgCO_2e/kWh$ Max case is c.50% of 2040 target of $0.04kgCO_2/kWh$ as set by DECC.
	Carbon payback period (years)	++	+	+	+	+
		-0.8 to 7	-6.3 to 7.8	-5.7 to 7.7	-4.2 to 15	2.6 to 8.5
CF2 To avoid adverse effects from GHG emissions over the lifecycle of the project	Net GHG emissions displaced against the baseline	++	+	+	+	+
		-147 to -78 MtCO2	-34 to -16 $MtCO_2$	-20 to -9 $MtCO_2$	-30 to -9 $MtCO_2$	-54 to -29 $MtCO_2$
	Total emissions per phase are summarised in Table 7.2 above.	--	-	-	-	-
		Highest level of total emissions displaced due to size of project.	As the physically smallest schemes B4 and B% offer the lowest total emissions.	As the physically smallest schemes B4 and B% offer the lowest total emissions	Lagoon options are lower than B3 in terms of total emissions release but higher than B4 and B5.	Lagoon options are lower than B3 in terms of total emissions release but higher than B4 and B5.

SECTION 8

PLAN IMPLEMENTATION

8 PLAN IMPLEMENTATION

8.1 Introduction

8.1.1 This section assesses whether each alternative may be compliant with existing legislation and policy relevant to this topic as set out in section 2.3. This section also sets out suggestions for the framework for the monitoring of the plan against the predicted effects within this topic. It will thereby inform the development of the overall monitoring suggestions contained within the SEA Environmental Report.

8.2 Legislation and policy compliance

8.2.1 Identification of compliance with existing legislation and policy is not a requirement of the SEA Directive but will assist with suggestions to Government by DECC. The assessment considers legislation and policy relevant to this topic; and does not consider the overall consenting route that would apply to alternative options. Consenting is the subject of a separate Feasibility Study workstream.

Air Quality

Alternative Option B3: Brean Down to Lavernock Point Barrage

8.2.2 Barrage option B3 complies with current UK legislation on air quality and emissions to atmosphere. There is a slight risk that the UK Air Quality Strategy 2007 objectives could be exceeded due to emissions from construction traffic close to residential dwellings.

Alternative Option B4: Shoots Barrage

8.2.3 Barrage option B4 complies with current UK legislation on air quality and emissions to atmosphere. There is a slight risk that the UK Air Quality Strategy 2007 objectives could be exceeded due to emissions from construction traffic close to residential dwellings.

Alternative Option B5: Beachley Barrage

8.2.4 Barrage option B5 complies with current UK legislation on air quality and emissions to atmosphere. There is a slight risk that the UK Air Quality Strategy 2007 objectives could be exceeded due to emissions from construction traffic close to residential dwellings.

Alternative Option L2: Welsh Grounds Lagoon

8.2.5 Lagoon option B5 complies with current UK legislation on air quality and emissions to atmosphere. There is a very slight risk that the UK Air Quality Strategy 2007 objectives could be exceeded due to emissions from construction traffic close to residential dwellings.

Alternative Option L3d: Bridgwater Bay Lagoon

8.2.6 Lagoon option L3d complies with current UK legislation on air quality and emissions to atmosphere. There is a slight risk that the UK Air Quality Strategy 2007 objectives could be exceeded due to emissions from construction traffic close to residential dwellings.

Carbon Footprinting

8.2.7 There are legally binding targets in place to reduce our national emissions therefore the plans are part of on going consideration by DECC to consider Severn Tidal Power.

8.3 Monitoring of significant environmental effects

8.3.1 The SEA Directive requires that monitoring measures are described within the environmental reporting. Monitoring allows the actual significant environmental effects of implementing a Severn Tidal Power alternative option to be tested against those predicted.

8.3.2 The Severn Tidal Power Feasibility Study SEA alone does not identify a preferred alternative option, but supports the wider decision making framework. Thus the monitoring is not prejudicial on the implementation of any alternative option. Below is a high level framework for monitoring, which can be applied to all of the Severn Tidal Power Schemes under consideration. The framework for this topic includes a brief description of monitoring proposed and the relationship between proposed monitoring, predicted likely significant environmental effects and receptors affected.

Air Quality

8.3.3 In order to assess the potential contribution to local air quality within the SEA study are it is recommended that air quality monitoring of NO_2, PM_{10} and SO_2 is undertaken at the landfall areas for a minimum period of 6 months prior to the barrage construction being undertaken and throughout the period of its construction. In addition survey and analysis of existing air quality monitoring stations is recommended to be undertaken throughout the construction period of the barrage.

Carbon Footprinting

8.3.4 National GHG emissions monitoring requirements specific to the plans are summarised in Table 8.1 however national GHG emissions will continue to be monitored for Government as part of the monitoring of targets.

Table 8.1 Monitoring of significant environmental effects

Significant Effect	Relevant receptor	Description of monitoring
Design changes	UK GHG emissions	Design review changes should be assessed in relation to the carbon footprint effect on construction , operation and decommissioning;
Construction emissions	Global and UK GHG emissions	Gate monitoring of transportation and all materials entering and leaving site. Transportation and fuel consumption should also be monitored.
Estuarine changes	Global and UK GHG emissions	Due to the high level of uncertainty the monitoring completed as part of the Water Quality and Marine Ecology papers should be used to consider the impacts on emissions cycles (carbon, methane and nitrogen in particular).,

SECTION 9

GLOSSARY

9 GLOSSARY

Term	Definition
Ancillary development	Other works beyond a Severn Tidal Power scheme but are needed to build or operate the scheme, including measures to prevent, reduce or as fully as possible offset significant environmental effects, e.g. dredging, bypasses etc.
Appropriate Assessment	A process required by the Habitats Regulations to avoid adverse effects of plans, programmes and projects on Natura 2000 sites and thereby maintain the coherence of the Natura 2000 network and its features. Formerly under the Conservation (Natural Habitats, &c.) Regulations 1994 (SI 1994/ 2716), from 1 April 2010, the regulations were replaced by The Conservation Of Habitats And Species Regulations, 2010.
Barrage	A manmade obstruction across a watercourse to retain a head of water on the rising tide, and then run the water through turbines when the tide level drops.
Bristol Channel	The area seaward of the headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast (see Severn Estuary and also Inner Bristol Channel and Outer Bristol Channel)
Bulb Kapeller type turbines	The Kapeller Bulb turbine is a turbine regulated only by its adjustable runner blades (single regulation). It has fixed wicket gates. It is adaptable to pumping as well as generation but only suited to one way generation. Kapeller Bulb turbine technology has largely been superseded by Bulb Kaplan turbines.
Bulb Kaplan turbines	The Kaplan turbine is a propeller-type water turbine that has adjustable blades and adjustable wicket gates (double regulation). It is adaptable to pumping as well as generation. Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The Kaplan turbine is suited to one or two way generation.
Bulb turbines	The generator is mounted in a bulb on the main turbine axis upstream of the runner blades for one way generation. Bulb turbines can be used for one or two way generation depending on the type (see above).
Caissons	Prefabricated concrete units used to construct parts of a barrage, lagoon or other offshore structures. Caissons can be used to house turbines, sluices or to construct navigation locks, or they may just be plain units used for impoundment construction.
Carbon Payback	Number of years that it takes for the emissions displaced from the production of renewable electricity to offset the carbon emissions released during construction, operation and decommissioning.
Coastal Squeeze	Process whereby the coastal margin is squeezed between a fixed landward boundary and the rising sea level.
Compensation	Measure which makes good for loss or damage to an SAC or SPA feature, without directly reducing that loss/damage. Only used in relation to the Habitats Directive (see offsetting, below).

Term	Definition
Consequential development	It is conceivable that a major tidal power scheme will facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as ‘consequential developments’.
Cumulative effects	Effects arise, for instance, where several developments each have insignificant effects but together have a significant effect, or where several individual effects of the plan have a combined effect.
Direct effects	The original effect as a result of an option (see indirect effects)
Ebb	When the sea or tide ebbs, it moves away from the coast and falls to a lower level.
Ebb mode	One way generation on ebb tides only i.e. during the period between high tide and the next low tide in which the sea is receding.
Ebb and flood mode	Two way generation during the ebb and flood tides
Effect	Used to describe changes to the environment as a result of an option (see also direct effects, indirect effects, far-field effects and cumulative effects)
Eutrophication	An increase in chemical nutrients (compounds containing nitrogen or phosphorus). This in turn can lead to ‘eutrophication effects’ – an increase in an ecosystem’s primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
Far-field effects	Effects that are felt outside the Severn Estuary study area.
Flood	The inward flow of the tide - This is the opposite of ebb. This refers to a mode of operation for a STP alternative option.
Future baseline	Baseline during construction (2014-2020) and operation (2020-2140), decommissioning and longer term trends.
Hydrodynamics / hydraulics	The science of physical forces acting on the water.
Impoundment	A body of water, such as a reservoir, made by impounding
Indicator	A measure of variables over time, often used to measure achievement of objectives.
Indirect effects	Those effects which occur away from the original effect or as a result of a complex pathway.
Irreversible	An effect that cannot be reversed. If the timescale for a receptor’s return to baseline condition is greater than 50 years then it will be considered irreversible.
Lagoon(s)/ Land-connected lagoons	A man-made enclosed body of water that retains a head of water on the rising tide and then runs the water through turbines when the tide level drops. A land connected lagoon uses the shoreline to make the enclosure.

Term	Definition
Long-listed options	All options identified in the SDC report, Call for Proposals and other strategically selected proposals as well as the Interim Options Analysis Report.
Measures to prevent or reduce effects	Measures to prevent or reduce any significant adverse effects on the environment.
Natura 2000	Natura 2000 is the European Union-wide network of protected areas, recognised as 'sites of Community importance' under the EC Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). The Natura 2000 network includes two types of designated areas: Special Areas of Conservation (SAC) and Special Protection Areas (SPA).
Negative effects	Changes which are unfavourable for a receptor. Can sometimes be referred to as 'adverse'.
Offsetting	Measures to as fully as possible offset any significant adverse effects on the environment. Such measures will aim to make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. Not used in relation to the Habitats Directive (see compensation, above).
One way generation	The operating mode whereby power is generated on only one phase of the tidal cycle. For Severn tidal power, one way generation is typically ebb mode.
Original scheme	The form of the scheme when it was shortlisted at the end of phase 1.
Permanent effect	An effect which will last at least for 50 years.
Phase 1	The current stage of the STP Feasibility Study - i.e. the Decision Making Assessment Framework (to develop a short-list of options) and SEA Scoping.
Phase 2	The second stage of the STP Feasibility Study - i.e. short-listed options appraisal and main assessment stage of the SEA.
Positive effects	Changes which are favourable for a receptor. Can sometimes be referred to as 'beneficial'.
Pumping	Operating turbines in reverse to pump water from lower to higher levels. Pumping can be used during one way generation to raise impounded water levels so that more energy can be generated when the ebb tide is receding.
Ramsar site	Ramsar sites are designated under the International Convention on Wetlands of International Importance 1971 especially as Waterfowl Habitat (the Ramsar Convention).
Receptor	An entity that may be affected by direct or indirect changes to an environmental variable.
Reversible	An effect that can be reversed. If the timescale for a receptor's return to baseline condition is less than 50 years then it will be considered reversible.
Scoping	The process of deciding the scope and level of detail of an SEA, including the environmental effects and alternatives which need to be considered, the assessment methods to be used, and the structure and contents of the

Term	Definition
	Environmental Report.
SEA objective	A statement of what is intended, specifying the desired direction of change in trends.
Seabed	The areas permanently covered by the sea, i.e. Lowest Astronomical Tide. Sometimes referred to as sub-tidal.
Severn Estuary	This is the physical extent of the Estuary and does not reflect the Study Area (see below) or nature conservation designations. Downstream limit - headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast passing through the small island features of Flat Holm and Steep Holm. Upstream limit – Haw Bridge, upstream of Gloucester on the River Severn (based on 1 in 100 year flood risk area and also used by Shoreline Management Plan (SMP) (Gifford, 1998) and Coastal Habitat Management Plan (CHaMP) (ABPmer 2006)). N.B. The tidal limit, which for the Severn is at Maisemore (West Parting) and Llanthony (East Parting) weirs, near Gloucester.
Severn Tidal Power Study Area	The general study area used for the project broadly extends downstream on the Estuary as far as Worm's Head to Morte Point. It includes the landward fringe and tributaries such as the River Wye and the River Usk. Study areas for individual topics for Phase 2 may extend beyond this area and these are defined separately according to topic.
Short-listed options	Options screened from long-listed options, to be taken forward for analysis in the SEA following the public consultation conducted in 2009.
Significant environmental effects	Effects on the environment which are significant in the context of a plan or programme. Criteria for assessing significance are set out in Annex II of the SEA Directive (2001/42/EC).
Site of Special Scientific Interest (SSSI)	Designated under the Wildlife and Countryside Act 1981, any land considered by Natural England to be of special interest because of any of its flora, fauna, or geological and physiographical features.
Sluice caissons	Prefabricated concrete structures placed into the water to house a sluice.
Special Area of Conservation (SAC)	Strictly protected site designated under the EC Habitats Directive 92/43/EEC. Article 3 of the Habitats Directive requires the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds).
Special Protection Area (SPA)	Strictly protected site classified in accordance with Article 4 of the EC Directive on the Conservation of Wild Birds (79/409/EEC), also known as the Birds Directive. They are classified for rare and vulnerable birds, listed in Annex I to the Birds Directive, and for regularly occurring migratory species.

Term	Definition
Straflo type turbines	A more compact turbine compared to Bulb turbine technology. Instead of containing the generator in a bulb, it is located and designed for ebb only operation and not suited to pumping.
Strategic Environmental Assessment (SEA)	Term used to describe environmental assessment as applied to policies, plans and programmes. 'SEA' is used to refer to the type of environmental assessment required under the SEA Directive.
Sub tidal	Areas (particularly with reference to habitats) that lie below the level of the lowest astronomical tide.
Synergistic effects	Effects which interact to produce a total effect greater than the sum of the individual effects, so that the nature of the final impact is different to the nature of the individual effects. Included within cumulative effects (see above).
Temporary effects	An effects which only lasts part of the project lifetime, e.g. is confined to the construction period.
The Shoots	The downstream boundary extends from Undy along the Welsh coast to Severn Beach along the English coast, just to the south of the M4 motorway crossing. The upstream limit extends just to the north of the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast.
Tidal bore	A tidal phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travel up a river or narrow bay against the direction of the current.
Tidal Prism	The difference between the mean high-water volume and the mean low-water volume of an estuary.
Transboundary Effects	An environmental effect upon another EU Member State.
Turbine caissons	Prefabricated concrete structures placed into the water to house turbines.
TWh/year	A unit used to describe how much energy generated, sold, consumed, etc. A terawatt-hour refers to generating or using power at a capacity of 1 terawatt (1012 watts) for one hour. A terawatt-hour per year means the equivalent amount of power sometime within the period of a year.
Two way generation	The operating mode whereby power is generated on both phases of the tidal cycle (ebb and flood)
Upper Severn Estuary	Upstream from the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast, to the tidal limit along the River Severn at Maisemere, Gloucestershire.

Term	Definition
Variant	A modified version of the original shortlisted scheme.

SECTION 10

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10 REFERENCES

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SECTION 11

APPENDICES

APPENDIX A

AIR QUALITY BASELINE RECEPTOR: VALUE, VULNERABILITY AND THRESHOLDS FOR MAGNITUDE OF EFFECT

Summary

The Strategic Environmental Assessment for the Severn Tidal Power Feasibility Study is founded on the assessment of effects upon receptors; to inform the identification of those effects which are likely to be significant.

In forming a judgement on effect significance, it is necessary to assign attributes to each receptor, some of the most important of these being their value and vulnerability. In addition, it is necessary to take the magnitude of effect into consideration. In advance of identifying the effects of the short-listed options, it is necessary to determine the thresholds for this magnitude of effect.

This document sets out the proposed levels of both value and vulnerability of those receptors under consideration during the Phase 2 assessment as well as proposed thresholds for magnitude of effect.

This document follows a Technical Workshop with statutory and key consultees, which was held to discuss the process and approach documented here. The feedback and discussion points provided during the Technical Workshop have been considered in this document.

1 OVERVIEW

1.1 Introduction

The Severn Tidal Power (STP) Strategic Environmental Assessment (SEA) is founded on the assessment of effects upon receptors; to identify those effects which are likely to be significant. A receptor is defined as an entity that may be affected by direct or indirect changes to an environmental variable.

In forming a judgement on effect significance, it is necessary to assign attributes to each receptor, some of the most important of these being their value and vulnerability. One purpose of this document is to set out the proposed levels of both value and vulnerability to those receptors under consideration during the Phase 2 assessment.

In addition, when forming a judgement of effect significance, it is necessary to take the magnitude of effect into consideration. In advance of identifying the effects of the short-listed options, it is necessary to determine the thresholds for this magnitude of effect. This document sets out the proposed thresholds for magnitude of effect for those receptors under consideration during the Phase 2 assessment.

1.2 Requirements of the Strategic Environmental Assessment Directive

When determining the likely significance of effects on the environment, the Annex II of the Strategic Environmental Assessment Directive includes the following criteria (as presented in Phase 2 SEA Env. 4 Process Note p11)[10]:

> Characteristics of the effects and of the area likely to be affected, having regard, in particular, to;
>
> (a) the probability, duration, frequency and reversibility of the effects;
> (b) the cumulative nature of the effects;
> (c) the transboundary nature of the effects;
> (d) the risks to human health or the environment (for example, due to accidents);
> (e) **the magnitude** and spatial extent **of the effects** (geographical area and size of the population likely to be affected);
> (f) **the value and vulnerability of the area likely to be affected due to** -
> (i) special natural characteristics or cultural heritage;
> (ii) exceeded environmental quality standards or limit values; or
> (iii) intensive land-use; and
> (g) the effects on areas or landscapes which have a recognised national, Community or international protection status.

For each receptor, an assessment will therefore be provided that reviews the effects against these criteria. In many cases this will be based on qualitative rather than quantitative information and where necessary make use of expert judgement. The findings will be reviewed at a Technical Workshop in each case.

[10] Parsons Brinckerhoff Ltd in association with Black & Veatch Ltd (2009) *Phase 2 SEA: Env. 4 Process Note*

1.3 Definitions of Value and Vulnerability

The Strategic Environmental Assessment Directive does not define value or vulnerability. For the purpose of the Severn Tidal Power Feasibility Study SEA, the following definitions are being used.

- **Value** the value of a receptor is based on the scale of the geographic reference, rarity, importance for biodiversity, social or economic reasons, and level of legal protection.
- **Vulnerability** the potential for a pathway for exposure of a receptor to a given environmental effect, together with the sensitivity of the receptor to that effect. (The sensitivity is the tolerance of a receptor to a given environmental effect and its ability to recover from that effect).

It is not readily possible to develop a 'one size fits all' definition that applies consistently to all topics of the STP SEA. Therefore specific definitions and judgements on receptor value and vulnerability have been developed for each topic in consultation with the relevant technical groups.
A guideline framework for these classifications is provided in Table 1.1 below:

Table 1.1 Guidelines for identifying receptor value and vulnerability

	Sample receptor definitions	
	Value	Vulnerability
High	e.g. receptor is rare, important for social or economic reasons, legally protected, of international or national designation.	e.g. potential pathways for environmental change exist between options (sources) and receptors, receptor is in declining condition, dependent on a narrow range of environmental conditions.
Moderate*	N/A	e.g. few pathways for environmental change exist between options (sources) and receptors, receptor is only expected to recover from disturbance over a prolonged period of time, if at all.
Low	e.g. receptor is common, of local or regional designation.	e.g. limited or no pathways from between options and receptors, receptor is in stable or favourable condition and dependent on a wide range of environmental conditions.
None	N/A	e.g. no pathways exist between environmental changes and receptors, receptor is insensitive to disturbance.

*'Moderate' vulnerability will only be assigned if analysis of receptors indicates that it is essential to make a further distinction between High and Low vulnerability attributes,

For each receptor, an assessment will therefore be provided that reviews the effects against these criteria. In many cases this will be based on qualitative rather than quantitative information and where necessary make use of expert judgement. The findings will be reviewed at a Technical Workshop in each case.

1.4 Summary of Value and Vulnerability for Air Quality

Tables 1.2 and 1.3 provide a summary of the value and vulnerability definitions for the Human Health population receptor and Habitats receptors respectively.
Discussion on the assigned receptor value, sensitivity and exposure are contained in the following sections.

Table 1.2 Summary of Air Quality Human Health receptor value and vulnerability

	Receptor definitions	
	Value	**Vulnerability**
High	UK Population, (protected under NEC emission ceiling & EU limit values)	Population currently at risk of exposure to air pollutants at or above UK Air Quality Objective values
	Population of South Wales & South West England (protected under EU limit values)	
	Local Population (protected under EU limit values)	
Low		Population exposed to current air quality well below UK Air Quality Objective values

Table 1.3 Summary of Air Quality Habitat receptor value and vulnerability

	Receptor definitions	
	Value	**Vulnerability**
High	International feature, e.g. SPA, SAC, Ramsar Site (protected under NEC emission ceiling, AQS and EU limit values, Habitats Directive)	Critical Load status affected for more than one habitat and more than one species
	National feature, e.g. SSSI (protected under NEC emission ceiling, AQS and EU limit values, Habitats Directive)	Majority of ecosystem known to be sensitive to acidification and eutrophication
		Minority of ecosystem known to be sensitive to both acidification & eutrophication & Critical Load status has been affected for one species
Low	Local feature, e.g. Environmentally Sensitive Area (protected under AQS and EU limit values)	Minority of ecosystem sensitive to either acidification or eutrophication and critical load status is either affected for one species. Minority of ecosystem sensitive to both acidification or eutrophication and critical load is altered but status not affected.

1.5 Definitions of Thresholds for Magnitude of Effect

The magnitude of the effect considers the receptor affected and categorises this as high, medium, low or very low. The Strategic Environmental Assessment Directive does not provide classification thresholds. Therefore specific definitions on classification thresholds for magnitude of effect have been developed for each topic receptor in consultation with the relevant technical groups.

Guidelines for determining thresholds for magnitude of effect are provided in Table 1.4 below. It should be noted that the thresholds may be quantitative or qualitative.

Table 1.4 Guidelines for determining thresholds for magnitude of effect

	Magnitude of effect			
Classification	**High**	**Medium**	**Low**	**Very Low**
Quantitative Guideline	90%+ of receptor or capacity of estuary to support receptor affected	50-90% of receptor or capacity of estuary to support receptor affected	10-50% of receptor or capacity of estuary to support receptor affected	<10% of receptor or capacity of estuary to support receptor affected
Qualitative Guideline (note that these are primarily focused on the natural environment and should be adapted for other topics as appropriate)	A permanent or long-term effect on the extent or size or integrity of a site, habitat, species assemblage or community, population or group. If adverse, this is likely to threaten its sustainability/favourable conservation status; if beneficial, this is likely to enhance its conservation status.	A permanent or long-term effect on the extent or size or integrity of a site, habitat, species assemblage or community, population or group. If adverse, this is unlikely to threaten its sustainability sustainability/favourable conservation status; if beneficial, this is likely to be sustainable but is unlikely to enhance its conservation status.	A permanent or long-term reversible effect on a site, habitat, species assemblage or community, population or group whose magnitude is detectable but will not threaten its integrity.	A short-term but reversible effect on the extent or size or integrity of a site, habitat, species assemblage or community, population or group that is within the normal range.

[NB: The guidelines are primarily focused on the natural environment and should be adapted for other receptors as appropriate.]

It should be noted that the thresholds for magnitude of effect may differ for each receptor or group of receptor further details of the proposed thresholds for magnitude of effect are given in Section 5 of this document.

2 RECEPTOR IDENTIFICATION

Air Quality impacts can occur at a number of spatial levels. For the purposes of the Severn Tidal Power SEA it is appropriate to consider receptors at a local level, i.e. those receptors in the vicinity of the short-listed options and susceptible to any localised impacts, and at a National (UK) level where any changes in air quality as a result of off-setting pollutant emissions from fossil power generation can be assessed.

2.1 Receptor Scale

Local level receptors for air quality comprise of both human populations and natural ecosystems, and are sensitive to the concentration of air pollutants. High concentrations of air pollution can have a direct impact upon human health as well as vegetation growth and biodiversity.

National receptors for air quality are also comprised of both human and natural habitats, where changes in national air pollutant emissions can lead to either a degradation or improvement in both human and habitat health.

2.2 Human Health Receptor

All selected receptors are legally protected under a variety of EU Directives and national environmental regulations. Human populations are protected under national air quality objectives and it is these standards to which the assessment of local human population receptors shall be assessed.

Though air quality objectives are also relevant to the national human population receptor, for the purposes of scale and lucidity a legally binding measure applied at the national scale, National Emission Ceilings Directive, shall be used. The national human population shall be assessed against the emissions ceilings limit, a strict standard of air pollutant emissions which the UK is not permitted to exceed and exists to protect both human and habitat health.

2.3 Habitat Receptor

Habitat receptors have been selected from those which fall under international, national protection and include a recognised local feature. All habitats are legally protected under EU Air Quality Directives and national air quality regulations.

Assessment of the local air quality impact on all of the habitat receptors at a local scale against air quality objectives is practicable and shall be undertaken against national air quality regulations and standards.

Impact of changes in air quality on all of habitat receptors at a national scale as a result of off-setting of pollutant emissions from fossil power generation shall be undertaken. Once again for the purpose of scale and lucidity a legally binding measure applied at the national scale, National Emission Ceilings Directive, shall be used to assess impacts upon all of habitat receptors at national scale.

3 ASSIGNING VALUE

3.1 Human Health Receptor Value

The Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland (DETR, 2007) set objectives for eight key air pollutants to protect health. The AQS objectives are equivalent to or more stringent than the mandatory EU limit values so achieving the objectives will ensure that the EU limit values are also complied with. In addition to AQS objective limits an Air Quality objective exposure reduction approach has been adopted for $PM_{2.5}$ with a target of 15% reduction by 2020.

Road transport, a significant source of air pollutants, is one of the major sources of local air pollution, especially in UK towns and cities. In urban areas, emissions from road traffic, combined with occasions of poor atmospheric dispersion, can make a significant contribution to pollutant concentrations, whereas in smaller non-urban areas though of a high population density, e.g. coastal town, dispersion of air pollutants may occur more readily.
Large scale and transboundary impacts of air pollutants were identified within the UN-ECE Convention on Long-Range Transboundary Air Pollution.1979. This established actions on preventing the detrimental impacts of large scale pollution episodes occurring across national boundaries, in particular emissions from large-scale industrial facilities. Further to the Convention on Long-Range Transboundary Air Pollution the EU National Emission Ceilings Directive (2000/81/EC) set total emission ceilings on air pollutants which are to be achieved by 2010.

Based on the above guidance and information, Table 3.1 below sets out the proposed values for the Air Quality on Human Health receptors for the purpose of this SEA. Further discussion on the value assigned to each receptor is provided below.

Table 3.1 Human Health Receptor Value

Receptor	Value
UK Population	High
Local Population	High

Two indices of human health have been applied to assign receptor value for the Air Quality topic within the scope of this SEA. In order to assess impacts of pollutants emissions from both power generation and material manufacture the UK population has been considered a receptor and has been assigned a HIGH value. In addition in order to assess the impact of emissions from both transport and construction activities the Local Population has also been considered a receptor and has also been assigned a HIGH value. High values were assigned to both human health receptors as the improvement of air quality and the protection of human health are both requirements under the Air Quality Framework Directives, regardless of spatial extent and the size of population affected..

3.2 Habitats and Species

The UN-ECE Convention on Long-Range Transboundary Air Pollution 1979 established actions on preventing acidification (of surface waters and soils), eutrophication of soils and ground-level ozone and the emissions of sulphur dioxide, ammonia, nitrogen oxide and non-methane volatile organic compounds (NMVOC). For acidification and eutrophication the concept of critical loads was used.

The Ramsar Convention, 1971, an intergovernmental treaty is a framework for national action and international cooperation for the conservation and protection of wetlands. It aims to protect some 220 habitats and approximately 1,000 species which are of European interest

The Habitats Directive 1992, listed 89 habitats and 788 species which were to be protected by means of a network of sites known as Special Areas of Conservation (SACs), and in addition the EC Birds Directive assigned a network of protected areas known as Special Protection Areas (SPAs).

Further to the Convention on Long-Range Trans-boundary Air Pollution, the EU National Emission Ceilings Directive (2000/81/EC) set total emission ceilings on air pollutants which are to be achieved by 2010. Sites identified as either Ramsar or SPA sites are internationally recognised and statutorily protected.

The above Conventions and Directive provide the parameters within which the receptors values may be assigned. Therefore the Status of the Habitat protection and was introduced as the indices for Air Quality Habitat Health vulnerability within the scope of this SEA.

Based on the above guidance and information Table 3.2 below sets out the proposed values for the Habitat Health receptors. Further discussion on the value assigned to each receptor is provided below.

Table 3.2 Habitats Receptor Value

Receptor	Value
International feature, e.g. SPA, SAC, Ramsar Site	High
National feature, e.g. SSSI	High
Local feature, e.g. Environmentally Sensitive Area	Low

The indices applied to assign the habitat receptor value of the Air Quality topic within the scope of this SEA, are established along a sliding scale which reflects the level of the protection Status assigned to a particular habitat. As both international (e.g. RAMSAR, SAC, SPA) and national features are legally protected they have been assigned a HIGH value. (e.g. SSSI or SSSA) or locally protected (environmentally sensitive area).

4 ASSIGNING VULNERABILITY

4.1 Vulnerability of Human Health

Urban populations, particularly within areas of localised social deprivation, are known to be more vulnerable to changes in air quality than subsequent populations within areas of greater wealth, as described in Analysis of Air Pollution and Social Deprivation (DETR, 2000). Populations within areas of known social deprivation are considered to have far fewer available resources and less choice with which to promote and protect their own and their family's good health.

The Air Quality Strategy (AQS) set out objectives directly applied from EU air quality limit values. The AQS objectives where set in such a way to ensure that the EU air quality limit values are achieved.
These air quality objective limit values have been selected as relevant indices for the Air Quality human health exposure sensitivity criteria within the scope of this SEA.

For the purposes of sensitivity of human health where a population is currently exposed to air pollutants at or above the UK Air Quality Objective limit values then this population has been assigned a HIGH sensitivity due to their current heath risks. Conversely a population currently exposed to air pollutants below the UK Air Quality Objective limit values was assigned a LOW sensitivity,

Table 4.1 Human Health Impacts Sensitivity

Sensitivity Criteria	Sensitivity
Population exposed to current Air Quality at or above UK Air Quality Objective limit values	High
Population exposed to current Air Quality below UK Air Quality Objective values	Low

It is illustrated and supported throughout the National Air Quality Strategy (AQS) that exceedences of objective pollutants frequently occur at roadside locations and urban areas of high concentration density. Therefore the urban nature of a location and its population density were considered as relevant indices of exposure for Air Quality human health receptor within the scope of this SEA.

As no such situation arises in the UK where a population is critically and acutely affected by poor air quality there was no relevance in assigning a HIGH level of exposure. However a MEDIUM value of exposure was assigned to a population present within an urban area, and where a receptor population was present in a rural area then the receptor level of exposure was assigned a LOW value.

Table 4.2 Level of Exposure to Human Receptors

Exposure Criteria	Level of Exposure
Urban population	Medium
Rural Population	Low

4.2 Vulnerability of Habitat Receptors

Coal-fired power generation is considered to represent a significant source of pollutants responsible for trans-boundary acidification of sensitive habitats. In addition gas fired power generation and road transport are both known sources of pollutants which present some risk of nitrification to sensitive wetlands.

Therefore the extent of a habitat's sensitivity to more than one relevant pollutant were both considered as a relevant indices for Air Quality Habitat receptor vulnerability within the scope of this SEA.

In harmful deposition of acid pollutants onto sensitive species is measured as a 'Critical load'. Where the critical load of a particular species has been defined as

> *"A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge".*
> *(Nilsson and Grennfelt 1988)*

Critical load has been employed as the quantifiable indicator for the exposure criteria.

Table 4.3 Level of Exposure to Habitat Receptor

Exposure Criteria	Level of Exposure
Critical Load status affected for more than one habitat and more than one species	High
Critical Load status affected for one species	Medium
Acidification and or Eutrophication significantly altered but critical load status not affected	Low
No contribution to either acidification of Eutrophication	None

Based upon UK critical load mapping information (Monks Wood, 2004), where a given habitat contains more than one species in which the critical load status has been affected for more than one relevant pollutant then the exposure of this receptor is assigned is HIGH, should a habitat's contain species where the critical load status has been affected for one of its constituent species then the habitats exposure is assigned to be MEDIUM. Where acidification or eutrophication changes for any number of species within a particular habitat, then that habitats exposure is assigned to be LOW. And where neither acidification nor eutrophication occurs within a particular habitat then that habitats exposure is assigned to be NONE.

Sensitivity of a habitat with respect to Air Quality has for the purpose of this SEA been defined as the degree of that particular habitat's response to either acidification or Eutrophication.

Table 4.4 Level of Sensitivity to Habitat Receptor

Sensitivity Criteria	Level of Sensitivity
Majority of ecosystem known to be sensitive to more than one of the following; acidification eutrophication	High
Some minority of ecosystem known to be	Medium

Sensitivity Criteria	Level of Sensitivity
sensitive to either more than one of the following; acidification Eutrophication.	
Some minority of Ecosystem known to have some sensitivity to either acidification or eutrophication.	Low
Ecosystem not known to be sensitive to either acidification or eutrophication.	Not Sensitive

Should a given habitat contain an ecosystem of which a majority of which is known to be sensitive to both acidification and eutrophication then the level of sensitivity of that particular habitat is considered to be HIGH. Should a given habitat contain an ecosystem of which a minority of which is known to be sensitive to both acidification and eutrophication then the level of sensitivity of that particular habitat is considered to be MEDIUM. Where a given habitat contains an ecosystem of which a minority of which is known to be sensitive to only acidification or eutrophication then the level of sensitivity of that particular habitat is considered to be LOW. And where a given habitat contains an ecosystem of that is not affected by either acidification or eutrophication then the level of sensitivity of that particular habitat is considered to be NOT SENSITIVE.

4.3 Vulnerability Assessment

The final stage is to assign the vulnerability of the receptor to operations. This process involves an integration of both sensitivity and exposure. Where a receptor is both sensitive and exposed to a human activity will it be considered vulnerable.

The vulnerability of a receptor has been determined by combining the sensitivity and exposure assessments according to the vulnerability matrix below:

Vulnerability Matrix

		Sensitivity of the Receptor			
Exposure of the Receptor		High	Medium	Low	None
	High				
	Medium				
	Low				
	None				

Categories of Vulnerability	
High	
Low	
None	

4.3.1 Vulnerability Assessment of Human Receptors

Applying the vulnerability matrix to both the exposure and sensitivity criteria for human receptors within Tables 4.1 and 4.2, the following vulnerability categories for Human Health were derived (Table 4.5).

Table 4.5 Vulnerability of Human Receptors

Exposure & Sensitivity Criteria	Urban population	Rural Population
Population exposed to current Air Quality at or above UK Air Quality Objective limit values	High	High

Exposure & Sensitivity Criteria	Urban population	Rural Population
Population exposed to current Air Quality below UK Air Quality Objective values	Low	Low

4.3.2 Vulnerability Assessment of Habitat Receptors

Applying the vulnerability matrix to both the exposure and sensitivity criteria for human receptors within Tables 4.3 and 4.4, the following vulnerability categories for Human Health were derived (Table 4.6).

Table 4.6 Vulnerability of Habitat Receptors

Exposure & Sensitivity Criteria	Majority of ecosystem known to be sensitive to more than one of the following; acidification eutrophication	Some minority of ecosystem known to be sensitive to either more than one of the following; acidification Eutrophication.	Some minority of Ecosystem known to have some sensitivity to either acidification or eutrophication	Ecosystem not known to be sensitive to either acidification or eutrophication
Critical Load status affected for more than one habitat and more than one species	High	High	High	None
Critical Load status affected for one species	High	High	Low	None
Acidification and or Eutrophication significantly altered but critical load status not affected	High	Low	Low	None
No contribution to either acidification of Eutrophication	None	None	None	None

5 ASSIGNING THRESHOLDS FOR MAGNITUDE OF EFFECT

Magnitude of air quality impacts for the Human Receptor and Habitat Receptor were derived directly from limits values set out the Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland, National Emission Ceilings Directive 2000/81/EC and the UN-ECE Convention on Long-Range Transboundary Air Pollution.

The approach for magnitude of impacts for the UK population receptor was derived with regard to limitations on emissions within both the National Emission Ceilings Directive 2000/81/EC and the UN-ECE Convention on Long-Range Trans-boundary Air Pollution. Where the magnitude of the impact upon air quality for the UK population is assessed in terms of the scale of pollutants emissions. The scale of pollutants emissions is referenced against thresholds of current UK coal fired power station emissions of air pollutants.

An identical approach was taken for both local population and habitat receptors (**International & nationally protected and locally protected habitat receptors).** Objective limit values (Air Quality Strategy objective limit or critical load) and emissions ceiling limits were applied upon a sliding scale of probability, in addition weighting was given to the larger spatial area was affected, where the effects were greater in duration and irreversible. Where each of the above indices reached a lower level of impact the magnitude was reduced. Table 5.1 below outlines the Air Quality Magnitude of Effects for the purposes of this SEA.

Table 5.1 Thresholds for Magnitude of Effects

	Magnitude of Effect			
Receptors	**High**	**Medium**	**Low**	**Very Low**
UK Population	Greater than 5% change in UK power station air pollutant emissions	2 - 5% change in UK power station air pollutant emissions	0.5 -2% change in UK power station air pollutant emissions	< 0.5% change in UK power station air pollutant emissions
Local Population	Risk of change in Air Quality limit status or worsening breach for more than one objective pollutant.	Risk of change in Air Quality limit status or worsening breach for one objective pollutant.	Risk of change in emissions of more than one Air Quality objective pollutant, with no breach of Air Quality limit value.	Risk of change in emissions of one Air Quality objective pollutant, with no breach of Air Quality limit value
International nationally protected Habitat Receptors	Critical Load exceedance status affected, on national scale	Critical Load Exceedance status affected on regional scale.	Critical Load exceedance status affected at local scale for a short duration.	Change in Acidification or Eutrophication, local scale for a short duration.
Locally protected Habitat Receptors	Critical Load exceedance status affected, on national scale	Critical Load Exceedance status affected on a regional scale.	Critical Load exceedance status affected at local scale for a short duration.	Change in Acidification or Eutrophication, local scale for a short duration.

6 DOCUMENTS REVIEWED

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3. Clean Air for Europe (CAFÉ) (2001)
4. Strategic Environmental Assessment, Guidance for Practitioners SEA Topic: Air Countryside Council for Wales
5. The Pollution Prevention and Control Regulations.
6. The UK National Air Quality Information Archive: www.airquality.co.uk (data and statistics, Air Quality Management Areas)
7. National Atmospheric Emission Inventory: www.naei.org.uk
8. Regional air pollution background concentration maps; http://www.airquality.co.uk/laqm/tools.php?tool=background
9. APIS (2007) Air Pollution Information Service Website. http://www.apis.ac.uk/ Critical loads maps
10. Analysis of Air Pollution and Social Deprivation A report produced for Department of the Environment, Transport and the Regions, The Scottish Executive, The National Assembly for Wales and Department of Environment for Northern Ireland. Katie King, John Stedman,December 2000
11. Habitats Directive Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora
12. Habitats Regulations http://www.opsi.gov.uk/si/si2007/uksi_20071843_en_1
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14. National Emission Ceilings Directive 2000/81/EC
15. Nilsson, J. & Grennfelt, P. (Eds) (1988) Critical loads for sulphur and nitrogen. UNECE/Nordic Council workshop report, Skokloster, Sweden. March 1988. Nordic Council of Ministers: Copenhagen.
16. United Kingdom Critical Load exceedance maps 2007.UK National Focal Centre (UK NFC) CEH Monks Wood

APPENDIX **B**

VALUE VULNERABILITY AND MAGNITUDE OF EFFECTS – CARBON FOOTPRINTING

Briefing Paper Ref	Baseline Receptor: Value, Vulnerability and Thresholds for Magnitude of Effect
Status	Template for use in report writing
Subject	Severn Tidal Power – Baseline Receptor: Value, Vulnerability and Thresholds for Magnitude of Effect
Date	10th June 2009
Author	Lara Ball, Sian Wilson
Reviewer	Tom Matthewson, Delyth Toghill
Circulation	Topic Leads
File Name	121320 STP SEA Phase 2 Template for Value, Vulnerbaility & Thresholds for Magnitude.doc

Summary

The Strategic Environmental Assessment for the Severn Tidal Power Feasibility Study is founded on the assessment of effects upon receptors; to inform the identification of those effects which are likely to be significant.

In forming a judgement on effect significance, it is necessary to assign attributes to each receptor, some of the most important of these being their value and vulnerability. In addition, it is necessary to take the magnitude of effect into consideration. In advance of identifying the effects of the short-listed options, it is necessary to determine the thresholds for this magnitude of effect.

This document sets out the proposed levels of both value and vulnerability of those receptors under consideration during the Phase 2 assessment as well as proposed thresholds for magnitude of effect.

This document follows a Technical Workshop with statutory and key consultees, which was held to discuss the process and approach documented here. The feedback and discussion points provided during the Technical Workshop have been considered in this document.

1 OVERVIEW

1.1 Introduction

The Severn Tidal Power (STP) Strategic Environmental Assessment (SEA) is founded on the assessment of effects upon receptors; to identify those effects which are likely to be significant. A receptor is defined as an entity that may be affected by direct or indirect changes to an environmental variable.

In forming a judgement on effect significance, it is necessary to assign attributes to each receptor, some of the most important of these being their value and vulnerability. One purpose of this document is to set out the proposed levels of both value and vulnerability to those receptors under consideration during the Phase 2 assessment.

In addition, when forming a judgement of effect significance, it is necessary to take the magnitude of effect into consideration. In advance of identifying the effects of the short-listed options, it is necessary to determine the thresholds for this magnitude of effect. This document sets out the proposed thresholds for magnitude of effect for those receptors under consideration during the Phase 2 assessment.

1.2 Requirements of the Strategic Environmental Assessment Directive

When determining the likely significance of effects on the environment, the Annex II of the Strategic Environmental Assessment Directive includes the following criteria (as presented in Phase 2 SEA Env. 4 Process Note p11)[11]:

> Characteristics of the effects and of the area likely to be affected, having regard, in particular, to;
>
> (a) the probability, duration, frequency and reversibility of the effects;
> (b) the cumulative nature of the effects;
> (c) the transboundary nature of the effects;
> (d) the risks to human health or the environment (for example, due to accidents);
> (e) **the magnitude** and spatial extent **of the effects** (geographical area and size of the population likely to be affected);
> (f) **the value and vulnerability of the area likely to be affected due to -**
> (i) special natural characteristics or cultural heritage;
> (ii) exceeded environmental quality standards or limit values; or
> (iii) intensive land-use; and
> (g) the effects on areas or landscapes which have a recognised national, Community or international protection status.

For each receptor, an assessment will therefore be provided that reviews the effects against these criteria. In many cases this will be based on qualitative rather than quantitative information and where necessary make use of expert judgement. The findings will be reviewed at a Technical Workshop in each case.

[11] Parsons Brinckerhoff Ltd in association with Black & Veatch Ltd (2009) *Phase 2 SEA: Env. 4 Process Note*

1.3 Definitions of Value and Vulnerability

The Strategic Environmental Assessment Directive does not define value or vulnerability. For the purpose of the Severn Tidal Power Feasibility Study SEA, the following definitions are being used.

- **Value** the value of a receptor is based on the scale of the geographic reference, rarity, importance for biodiversity, social or economic reasons, and level of legal protection.
- **Vulnerability** the potential for a pathway for exposure of a receptor to a given environmental effect, together with the sensitivity of the receptor to that effect. (The sensitivity is the tolerance of a receptor to a given environmental effect and its ability to recover from that effect).

It is not readily possible to develop a 'one size fits all' definition that applies consistently to all topics of the STP SEA. Therefore specific definitions and judgements on receptor value and vulnerability have been developed for each topic in consultation with the relevant technical groups.

The classifications for the carbon footprint receptors are provided in table 1.1 below:

Table 1.1 Guidelines for identifying receptor value and vulnerability

	Sample receptor definitions	
	Value	**Vulnerability**
High	There is a recognised requirement for limiting and reducing emissions	The receptor is at a critical level
Moderate*	N/A	N/A
Low	There is no recognised requirement for limiting and reducing emissions.	The receptor is not at a critical level
None	N/A	N/A

*'Moderate' vulnerability will only be assigned if analysis of receptors indicates that it is essential to make a further distinction between High and Low vulnerability attributes,

For each receptor, an assessment will therefore be provided that reviews the effects against these criteria. In many cases this will be based on qualitative rather than quantitative information and where necessary make use of expert judgement. The findings will be reviewed at a Technical Workshop in each case.

1.4 Definitions of Thresholds for Magnitude of Effect

The magnitude of the effect considers the potential scale of a specific effect on the receptor and categorises this as high, medium, low or very low. The Strategic Environmental Assessment Directive does not provide classification thresholds. Therefore specific definitions on classification thresholds for magnitude of effect have been developed for each topic receptor in consultation with the relevant technical groups.

The thresholds for magnitude of effect have been adapted for the carbon footprint topic as appropriate and the specific carbon footprint thresholds are summarised below in Table 1.2.

It should be noted that the thresholds will be quantitative where possible but where necessary may be a qualitative comparison.]

The magnitude of effect, in terms of high, med, low or very low, can either be a positive or a negative effect on the overall receptor. The positive or negative nature will be defined in the final SEA paper in the presentation of results. The percentage effect represents the change in level of GHG emissions in relation to each baseline for the given receptors. Where quantitative information is not available the qualitative descriptions will be used to justify the magnitude of the individual effects.

Table 1.2 Guidelines for determining thresholds for magnitude of effect

	Magnitude of effect			
Classification	**High**	**Medium**	**Low**	**Very Low**
Quantitative Guideline	5-10%	2-5%	0.5-2%	< 0.5%
Qualitative Guideline (adopted for the carbon footprint topic)	Equivalent in scale to the emissions of a large power station.	Estimated to be equivalent to the emissions from a small power station.	Smaller but still significant contribution to change in emissions	Minimal change in emission levels

2 ASSIGNING VALUE

The initial research into the baseline has assisted in providing guidance and information on how to assign value. The baseline information has, at this time of assigning value been gathered primarily from the IPCC and UKCIP02. UKCIP09 has recently been released and therefore the baseline will be updated in line with that. This is not believed nevertheless to have an impact on assigning value.

Based on the above guidance and information Table 2.1 below sets out the proposed values for the carbon footprint receptors. Each receptor is considered to have a high value because globally and in the UK there is a recognised requirement for limiting and reducing GHG emissions.

Table 2.1 Receptor Value

Receptor	Proposed Value
Global level of GHG emissions	HIGH
UK level of GHG emissions	HIGH

3 ASSIGNING VULNERABILITY

Literature on climate change in addition to national and international commitments to reducing GHG emissions has informed this review of the vulnerability of the Global and UK level of GHG emissions.

Based on the above guidance and information Table 2.1 below sets out the proposed vulnerabilities for the carbon footprint receptors. Further discussion on the vulnerability assigned to each receptor is provided below.

Table 3.1 Receptor Vulnerability

Receptor	Proposed Vulnerability
Global level of GHG emissions	HIGH
UK level of GHG emissions	HIGH

The carbon footprint receptors; the level of GHG emissions, can only be defined as having a high vulnerability because of their impact on climate change and the combined critical level at which we now find GHG emissions. Should the current concentration of GHG emissions in the atmosphere be considerably lower the receptor would not be considered vulnerable.

4 ASSIGNING THRESHOLDS FOR MAGNITUDE OF EFFECT

The magnitude of effect has not been assigned to each of the contributors to the overall effect on the receptor at this stage. This is because the final outputs from the SEA assessment are required. The table below gives an indication as to the layout of expected results however this will be provided in more detail in the final results. The results are arbitrary at this time.

Based on the above guidance and information, Table 2.1 below sets out the proposed thresholds for magnitude of effect for the carbon footprint receptors. Further discussion on the thresholds assigned to each receptor is provided below.

Table 3.1 Thresholds for Magnitude of Effects

	Thresholds for Magnitude of Effect			
Classification	**High**	**Medium**	**Low**	**Very Low**
UK level of GHG emissions				
Option 1 – contributors to impact on receptor				
Construction emissions			negative	
Operational emissions - Impact on emissions through estuarine changes		negative		
Production of renewable energy		Positive		

At this stage it is not possible to say what the overall magnitude of effect on the receptors will be for each option.

APPENDIX C

AIR QUALITY LOCAL HABITAT IDENTIFICATION & CALCULATIONS

Local Area habitat Identification			
NAME	**AREA_GIS**	**HABNAME**	**COVER%**
Walmore common	52.85	Inland water bodies (standing water, running water)	1.00
Walmore common	52.85	Humid grassland. Mesophile grassland	34.00
Walmore common	52.85	Improved grassland	65.00
Severn Estuary	24662.98	Coastal sand dunes. Sand beaches. Machair	4.00
Severn Estuary	24662.98	Salt marshes. Salt pastures. Salt steppes	6.00
Severn Estuary	24662.98	Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins)	89.00
Severn Estuary	24662.98	Improved grassland	1.00
Somerset levels and Moors	6388.49	Broad-leaved deciduous woodland	4.00
Somerset levels and Moors	6388.49	Bogs. Marshes. Water fringed vegetation. Fens	5.00
Somerset levels and Moors	6388.49	Humid grassland. Mesophile grassland	52.00
Somerset levels and Moors	6388.49	Improved grassland	26.00
Somerset levels and Moors	6388.49	Inland water bodies (standing water, running water)	5.00
Somerset levels and Moors	6388.49	Non-Forest areas cultivated with woody plants (including orchards, groves, vineyards,	2.00
Somerset levels and Moors	6388.49	Other arable land	1.00
Somerset levels and Moors	6388.49	Other land (including towns, villages, roads, waste places, mines, industrial sites)	5.00

Local SAC					Total Area SAC Cover/ Ha
North Somerset and Mendip Bats	**NAME**	**AREA_GIS**	**HABNAME**	**COVER%**	Area
King's Wood and Urchin Wood	North Somerset and Mendip Bats	561.19	Broad-leaved deciduous woodland	30	168.357
Compton Martin Ochre Mine	North Somerset and Mendip Bats	561.19	Dry grassland. Steppes	27.5	154.32725
Banwell Caves	North Somerset and Mendip Bats	561.19	Heath. Scrub. Maquis and garrigue. Phygrana	22.5	126.26775
Brockley Hall Stables	North Somerset and Mendip Bats	561.19	Mixed woodland	19	106.6261
The Cheddar Complex	North Somerset and Mendip Bats	561.19	Other land (including towns, villages, roads, waste places, mines, industrial sites)	1	5.6119
Wookey Hole					
Banwell Ochre Caves					
	Dunraven Bay	6.47	Broad-leaved deciduous woodland	12.5	0.80875
Dunraven Bay	Dunraven Bay	6.47	Dry grassland. Steppes	18.5	1.19695
Southerndown Coast	Dunraven Bay	6.47	Humid grassland. Mesophile grassland	25	1.6175
	Dunraven Bay	6.47	Improved grassland	17.5	1.13225
	Dunraven Bay	6.47	Shingle. Sea cliffs. Islets	26.5	1.71455
Severn Estuary/ Môr Hafren	Severn Estuary/ Môr Hafren	73715.4	Salt marshes. Salt pastures. Salt steppes	1	737.154
Bridgwater Bay	Severn Estuary/ Môr Hafren	73715.4	Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins)	99	72978.246
Severn Estuary					

Upper Severn Estuary					
Glen Tanar	Glen Tanar	4180.09	Bogs. Marshes. Water fringed vegetation. Fens	10	418.009
Glen Tanar	Glen Tanar	4180.09	Coniferous woodland	55	2299.0495
	Glen Tanar	4180.09	Dry grassland. Steppes	5	209.0045
	Glen Tanar	4180.09	Heath. Scrub. Maquis and garrigue. Phygrana	30	1254.027
Cardiff Beech Woods	Cardiff Beech Woods	115.62	Broad-leaved deciduous woodland	99.5	115.0419
Garth Wood	Cardiff Beech Woods	115.62	Other land (including towns, villages, roads, waste places, mines, industrial sites)	0.5	0.5781
Cwm Nofydd					
Fforestganol, Tongwynlais					
Castell Coch Woodlands and Road Section					
Avon Gorge Woodlands	Avon Gorge Woodlands	152.35	Broad-leaved deciduous woodland	70	106.645
Avon Gorge	Avon Gorge Woodlands	152.35	Coniferous woodland	5	7.6175
	Avon Gorge Woodlands	152.35	Dry grassland. Steppes	4	6.094
	Avon Gorge Woodlands	152.35	Heath. Scrub. Maquis and garrigue. Phygrana	4	6.094
	Avon Gorge Woodlands	152.35	Humid grassland. Mesophile grassland	2	3.047
	Avon Gorge Woodlands	152.35	Inland rocks. Screes. Sands. Permanent snow and ice	10	15.235
Mendip Limestone Grasslands	Mendip Limestone Grasslands	417.47	Broad-leaved deciduous woodland	10	41.747

Uphill Cliff	Mendip Limestone Grasslands	417.47	Dry grassland. Steppes	38	158.6386
Brean Down	Mendip Limestone Grasslands	417.47	Heath. Scrub. Maquis and garrigue. Phygrana	45	187.8615
Crook Peak to Shute Shelve Hill	Mendip Limestone Grasslands	417.47	Inland rocks. Screes. Sands. Permanent snow and ice	7	29.2229
Blackmill Woodlands		71.01	Broad-leaved deciduous woodland	92.5	65.68425
Blackmill Woodlands	Blackmill Woodlands	71.01	Heath. Scrub. Maquis and garrigue. Phygrana	7.5	5.32575
Glaswelltiroedd Cefn Cribwr/ Cefn Cribwr Grasslands	Glaswelltiroedd Cefn Cribwr/ Cefn Cribwr Grasslands	58.35	Bogs. Marshes. Water fringed vegetation. Fens	1	0.5835
Waun-fawr, Cefn Cribwr	Glaswelltiroedd Cefn Cribwr/ Cefn Cribwr Grasslands	58.35	Broad-leaved deciduous woodland	25	14.5875
Caeau Cefn Cribwr	Glaswelltiroedd Cefn Cribwr/ Cefn Cribwr Grasslands	58.35	Heath. Scrub. Maquis and garrigue. Phygrana	10	5.835
Bryn Bach, Cefn Cribwr	Glaswelltiroedd Cefn Cribwr/ Cefn Cribwr Grasslands	58.35	Humid grassland. Mesophile grassland	64	37.344
Penycastell Cefn Cribwr					
Hestercombe House	Hestercombe House	0.08	Other land (including towns, villages, roads, waste places, mines, industrial sites)	100	0.08
Hestercombe House					
Holme Moor and Clean Moor	Holme Moor and Clean Moor	7.58	Bogs. Marshes. Water fringed vegetation. Fens	11	0.8338
Holme Moor and Clean Moor	Holme Moor and Clean Moor	7.58	Broad-leaved deciduous woodland	85	6.443
	Holme Moor and Clean Moor	7.58	Humid grassland. Mesophile grassland	4	0.3032
Mells Valley	Mells Valley	28.22	Broad-leaved deciduous woodland	10	2.822

Vallis Vale	Mells Valley	28.22	Humid grassland. Mesophile grassland	5	1.411
Old Ironstone Works, Mells	Mells Valley	28.22	Improved grassland	60	16.932
St Dunstan's Well Catchment	Mells Valley	28.22	Other land (including towns, villages, roads, waste places, mines, industrial sites)	25	7.055
Mendip Woodlands	Mendip Limestone Grasslands	417.47	Broad-leaved deciduous woodland	10	41.747
Cheddar Wood	Mendip Limestone Grasslands	417.47	Dry grassland. Steppes	38	158.6386
Ebbor Gorge	Mendip Limestone Grasslands	417.47	Heath. Scrub. Maquis and garrigue. Phygrana	45	187.8615
Rodney Stoke	Mendip Limestone Grasslands	417.47	Inland rocks. Screes. Sands. Permanent snow and ice	7	29.2229
Asham Wood					
Quants	Quants	20.29	Broad-leaved deciduous woodland	35	7.1015
Quants	Quants	20.29	Coniferous woodland	25	5.0725
	Quants	20.29	Dry grassland. Steppes	15	3.0435
	Quants	20.29	Mixed woodland	25	5.0725
				Total Area	79743.9725

SPA Local			2001			
Somerset Levels and Moors	% Cover	Area/ Ha	% Critical Load Acidity exceeded	Area Load Exceeded	% Critical Load N exceeded	
Bogs. Marshes. Water fringed vegetation. Fens	5.00	319.42	0.769	246	0.423	135
Broad-leaved deciduous woodland	4.00	255.54	0.691	177	0.978	250
Humid grassland. Mesophile grassland	52.00	3339.98	0.84	2806	0.587	1961
Improved grassland	26.00	1941.99	0	0	0.587	1140
Inland water bodies (standing water, running water)	5.00	319.95	0.232	74	0	0
Non-Forest areas cultivated with woody plants (including orchards, groves, vineyards,	2.00	127.77	0.602	77	0.958	122
Other arable land	1.00	63.88	0.602	38	0.587	37
Other land (including towns, villages, roads, waste places, mines, industrial sites)	5.00	319.42	0	0	0	0
Coastal sand dunes. Sand beaches. Machair	4.00	986.52	0.602	594	0.587	579
Salt marshes. Salt pastures. Salt steppes	6.00	1479.77	0.602	891	0.41	607
Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins)	89.00	21950.05	0.602	13214	0.587	12885
All habitats	Total	31104.30	0.50	**18116**	0.52	**17716**
				0.58		0.57
Local Exceedances SPAs in BAP Format			2001		2001	
Unmanaged woods						
Other habitats			17,694		17,331	
Conifereous Woodland						
Broadleaved Woodland			177		250	
Acid Grassland						
Dwarf Shrub Heath						
Bogs			246		135	
All habitats			**18,116**		**17,716**	

SPA Local	2020	2020	2020		2020	
Somerset Levels and Moors	Area Load Exceeded		% Critical Load Acidity exceeded		% Critical Load N exceeded	
Bogs. Marshes. Water fringed vegetation. Fens	126	154	41.00%	130.96	48.00%	153.32
Broad-leaved deciduous woodland	101	123	41.00%	104.77	48.00%	122.66
Humid grassland. Mesophile grassland	1316	1607	41.00%	1369.39	48.00%	1603.19
Improved grassland	765	934	41.00%	796.22	48.00%	932.16
Inland water bodies (standing water, running water)	126	154	41.00%	131.18	48.00%	153.58
Non-Forest areas cultivated with woody plants (including orchards, groves, vineyards,	50	61	41.00%	52.39	48.00%	61.33
Other arable land	25	31	41.00%	26.19	48.00%	30.66
Other land (including towns, villages, roads, waste places, mines, industrial sites)	126	154	41.00%	130.96	48.00%	153.32
Coastal sand dunes. Sand beaches. Machair	389	475	41.00%	404.47	48.00%	473.53
Salt marshes. Salt pastures. Salt steppes	583	712	41.00%	606.71	48.00%	710.29
Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins)	8648	10558	41.00%	8999.52	48.00%	10536.03
All habitats				**12753**		**14930**
Local Exceedances SPAs in BAP Format			2020		2020	
Unmanaged woods						
Other habitats			12,517		14,654	
Coniferous Woodland						
Broadleaved Woodland			105		123	
Acid Grassland						
Dwarf Shrub Heath						
Bogs			131		153	
All habitats			**12,753**		**14,930**	

Local SACs		2001			
Habitiat Name	Area Cover/ Ha	% Critical Load Acidity Exceeded	Area Land Exceeded Acidity	% Critical Load Nutrient N Exceeded	Area Land Exceeded Nutrient N
Shingle. Sea cliffs. Islets	2	60%	1	59%	1
Other land (including towns, villages, roads, waste places, mines, industrial sites)	13	0%	0	59%	8
Improved grassland	18	0%	0	59%	11
Humid grassland. Mesophile grassland	44	84%	37	59%	26
Inland rocks. Screes. Sands. Permanent snow and ice	74		0	59%	43
Mixed woodland	112	69%	77	96%	107
Bogs. Marshes. Water fringed vegetation. Fens	419	77%	323	42%	176
Broad-leaved deciduous woodland	571	69%	395	96%	547
Dry grassland. Steppes	691		0	59%	406
Salt marshes. Salt pastures. Salt steppes	737	60%	444	41%	302
Heath. Scrub. Maquis and garrigue. Phygrana	1773	60%	1068	42%	750
Coniferous woodland	2312	60%	1392	71%	1637
Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins)	72978	60%	43933	59%	42838
Total SAC Habitat Exceeded		0.55	**47668**	0.61	**46851**
			0.60		0.59
Total SAC Habitat	79744				
Local SACs in BAP Format					
2001					
Unmanaged woods	112	0.69	77	0.96	107
Other habitats	74,513	0.60	44,378	3.93	43,609
Conifereous Woodland	2,312	0.60	1,392	0.71	1,637
Broadleaved Woodland	571	0.69	395	0.96	547
Acid Grassland	44	0.84	37	0.59	26
Dwarf Shrub Heath	1,773	0.60	1,068	0.42	750

Bogs	419	0.77	323	0.42	176
All habitats	79,744		**47,668**		**46,851**
Local SACs			2020		2020
HABNAME		% Critical Load Acidity Exceeded	Area Land Exceeded Acidity / Ha	% Critical Load Nutrient N Exceeded	Area Land Exceeded N / Ha
Shingle. Sea cliffs. Islets	2	41%	1	48%	1
Other land (including towns, villages, roads, waste places, mines, industrial sites)	13	0%	0	48%	
Improved grassland	18	0%	0	48%	
Humid grassland. Mesophile grassland	44	41%	18	48%	21
Inland rocks. Screes. Sands. Permanent snow and ice	74		0	48%	35
Mixed woodland	112	41%	46	48%	54
Bogs. Marshes. Water fringed vegetation. Fens	419	41%	172	48%	201
Broad-leaved deciduous woodland	571	41%	234	48%	274
Dry grassland. Steppes	691		0		0
Salt marshes. Salt pastures. Salt steppes	737	41%	302	48%	354
Heath. Scrub. Maquis and garrigue. Phygrana	1773	41%	727	48%	851
Coniferous woodland	2312	41%	948	48%	1110
Tidal rivers. Estuaries. Mud flats. Sand flats. Lagoons (including saltwork basins)	72978	41%	29921	48%	35030
Total SAC Habitat Exceeded			**32369**		**37930**
Local Exceedances SACs in BAP Format					
			2020		2020
			Area Land Exceeded Acidity / Ha		Area Land Exceeded N / Ha

Unmanaged woods			46		54
Other habitats			29921		35108
Conifereous Woodland			948		1110
Broadleaved Woodland			225		274
Acid Grassland			234		332
Dwarf Shrub Heath			727		851
Bogs			172		201
All habitats			**32273**		**37930**

APPENDIX D

AIR QUALITY EMISSIONS ASSUMPTIONS

Emissions Offsetting

Power Generation Emissions Factors

	kT/MToe		
5	Coal	Gas	Oil
No2	4.13	10	14
Co2	430.5	3750	870
PM10	0.093	0.23	0.382
SO2	3.78	0.08	8
% Power generation	89.00%	8.60%	2.30%

Source NAEI Power Generation and BERR 2006 Power Fuel Mix

Option Annual Energy Output (TWh) were taken from from the Options Defintion Report Rev 1 (2009)

UK Power Generation and Carbon Dioxide Emissions were taken from the Low Carbon Transition Plan (DECC, 2009)

2005	1650	TWh	CO2	553	Mt
2050	1100	TWh	CO2	118.57	Mt

Projection of Greenhouse gases (GHG) - Central carbon scenario (DECC, 2009)				
	Assumptions	up to 2035 DECC numbers	0.43	mtCO2/TWh
		2035 - 2140 DECC	0.04	mtCO2/TWh

Materials Emissions Summaries

(Supply Chain Report, 2009)

	L2	L3	B3	B4	B5
Cement (tonnes)	510000	1470000	2910000	320000	160000
NO_x	1667700	4806900	9515700	1046400	523200
PM_{10}	109548	315756	625068	68736	34368
Steelwork	3350000	920000	1750000	235000	127000
	2312550	3953494	11149921	1513873	874061.4
	6048.309	10010.07	27050.46	3737.607	2112.906
Total Steelwork (tonnes)	3350000	920000	1750000	235000	127000
Kg					
NO_x	3840961	1054831	2006472	269440.5	145612.5
PM_{10}	7649.494	2100.757	3996.004	536.6063	289.9957
SO_2	1890387	519151	987515.5	132609.2	71665.41

Dredging Assumptions

	Fuel Capacity Trailing Suction Hopper dredger		
	Fuel Consumption		
	0.200	litres/ kW/ Hr	
	5,600	m3	
Total Power	2,370	kW	
Fuel Use	474	litres/Hr	
Fuel use	422	kg/ hr	
Rate dredging full load	1	hr Mud	
Rate dredging full load	2	hr/ Sand	
Rate dredging full load	4	hr/ Gravel	
Rate Dredging	5,600.000	m^3/hr Mud	5.6 tonne/hr Mud
	2,800.000	m^3/hr Sand	2.8 tonne/hr Mud
	1,400.000	m^3/hr Gravel	1.4 tonne/hr Mud
Assume 1000m^3 = 1 tonne			
Fuel use per tonne dredging	75	kg/tonne dredged Mud	0.07533 tonne fuel/tonne dredged Mud
Fuel use per tonne dredging	151	kg/tonne dredged Sand	0.15066 tonne fuel/tonne dredged Sand
Fuel use per tonne dredging	301	kg/tonne dredged Gravel	0.30133 tonne fuel/tonne dredged Gravel

Fuel Oil & Gas Oil Density (http://www.simetric.co.uk/si_liquids.htm) 890 kg/m3

Fuel Oil & Gas Oil Pollutant Emissions (www.naei.org.uk/emissions/)

	NOx	SO2	PM10
Fuel Oil	72.0 kg/ t fuel	53 kg/ t fuel	7.8 kg/ t fuel
Gas Oil	72.0 kg/ t fuel	20 kg/ t fuel	3.7 kg/ t fuel

		NO_x	SO_2	PM_{10}	
Emissions per tonne Mud	Fuel Oil	0.0024	0.0017	0.0003	kg/tonne dredging
	Gas Oil	0.0024	0.0007	0.0001	kg/tonne dredging
Emissions per tonne Sand	Fuel Oil	0.0047	0.0035	0.0005	kg/tonne dredging
	Gas Oil	0.0047	0.0013	0.0002	kg/tonne dredging
Emissions per tonne Gravel	Fuel Oil	0.0094	0.0070	0.0010	kg/tonne dredging
	Gas Oil	0.0094	0.0026	0.0005	kg/tonne dredging/

Information Source: 1) Frank Rimmel
2) (http://www.deme.be/equipment/Marieke_GB.pdf)
3) www.naei.org.uk/emissions/

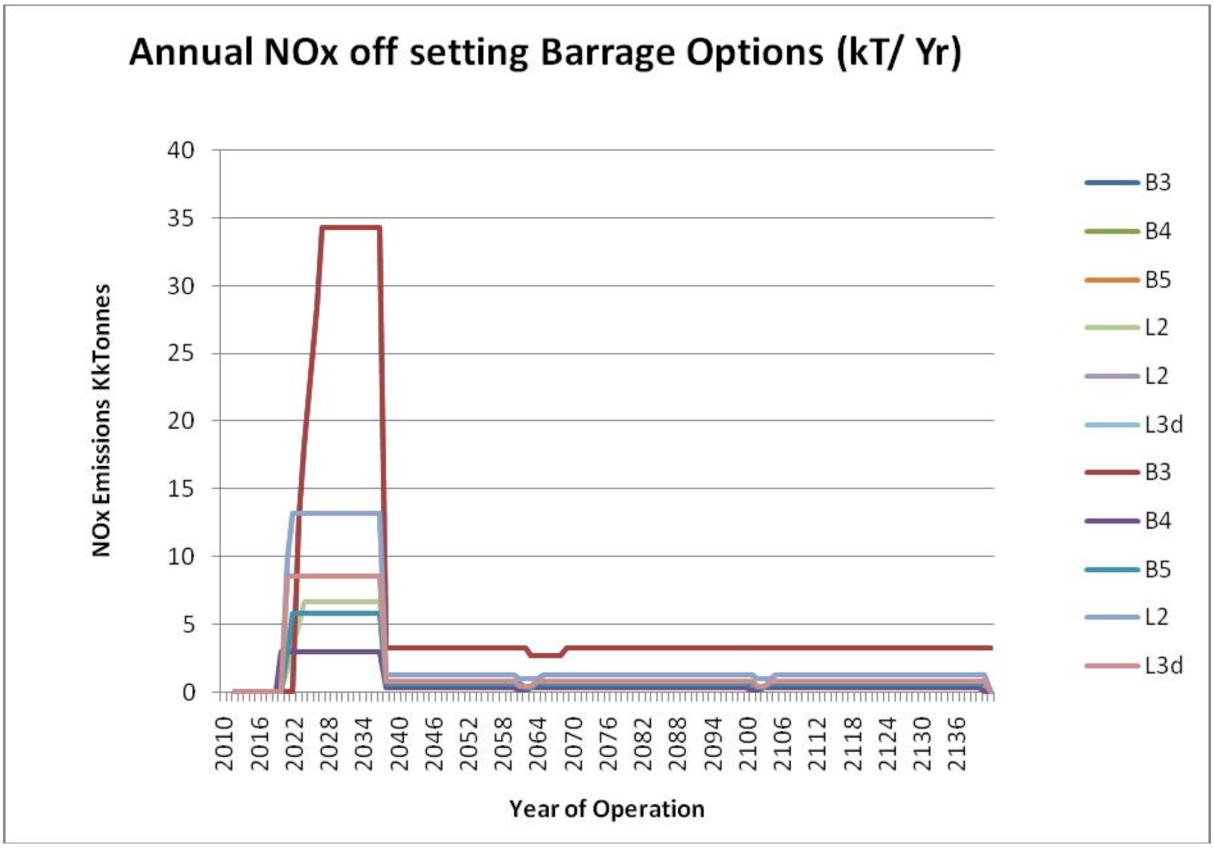
APPENDIX E

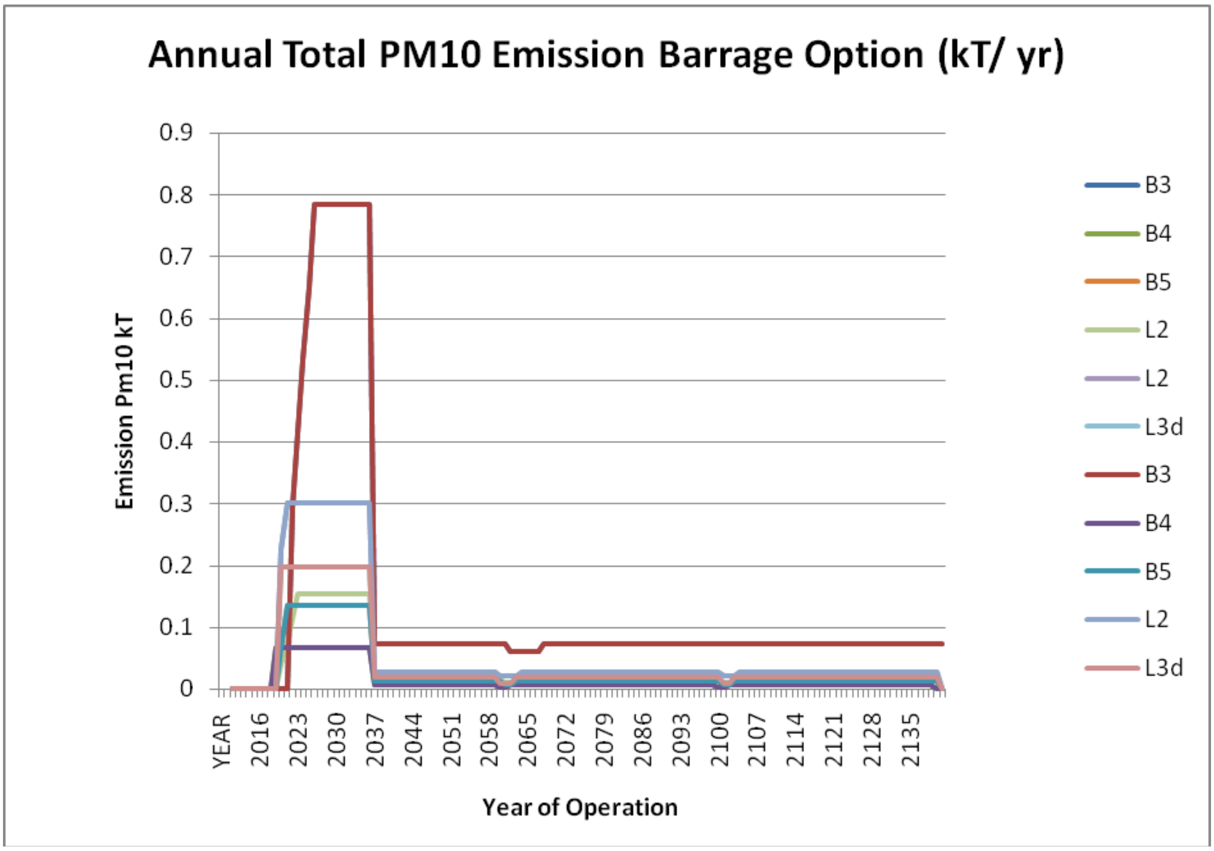
RAIL AND SHIPPING CAPACITY ASSUMPTIONS

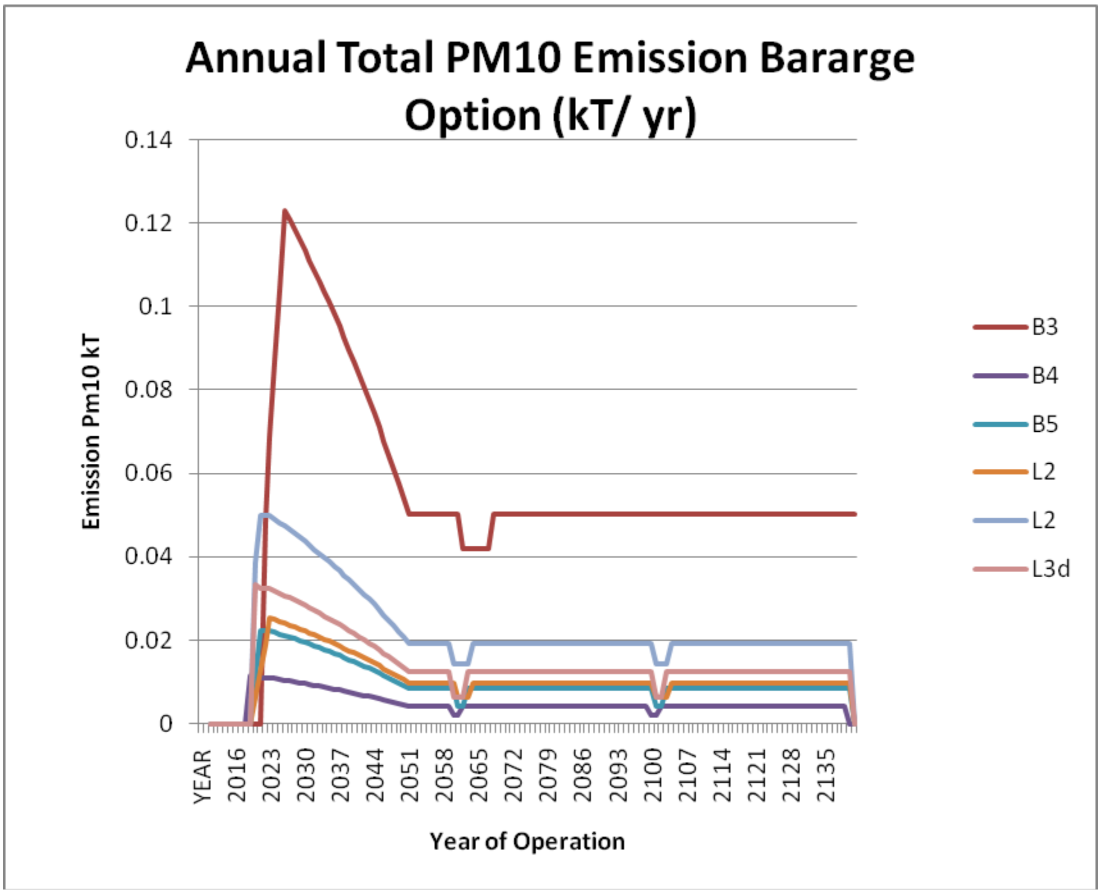
Rail				
Assumed rail classification	**Haulage Capacity Tonnes**	**Max Speed mph**	**Fuel consumption**	
66 class freight model	1800	75	200g/kWh	
Source: Strategic Rail Authority Rail emissions model November 2001				
Sea				
Bulk Vessel				
Source: lloydsmiu.com/miu/miuststa/htm				
Total UK Bulk Shipping Tonnage (DWT = Tonne)	450000000			
Number of Bulk Vessels in UK Fleet	8000			
Average UK Bulk Shipping Haulage capacity Tonnes	56250			
Typical Fuel consumption Bulk Tonnes/day	33.8			
Total Bulk Vessel Air Pollution Emissions per movement (kg/day)	**NOx** 1926.6	**PM10** 37.18	**SO2** 338	
Cargo Vessel				
Total UK General Cargo Tonnes	60000000			
Number of UK Cargo vessels in UK Fleet	17000			
Average UK General Cargo Haulage capacity Tonnes	3529			
Typical Fuel consumption Cargo Tonnes/day	21.8			
Total Cargo Vessel Air Pollution Emissions per movement (kg/day)	**NOx** 1242.6	**PM10** 23.98	**SO2** 218	
Number of days (assumed) each vessel in Regional study area				1
Source: eea.europa.eu/publication/EMEPcorinair4/B842Vs3.4pdf				

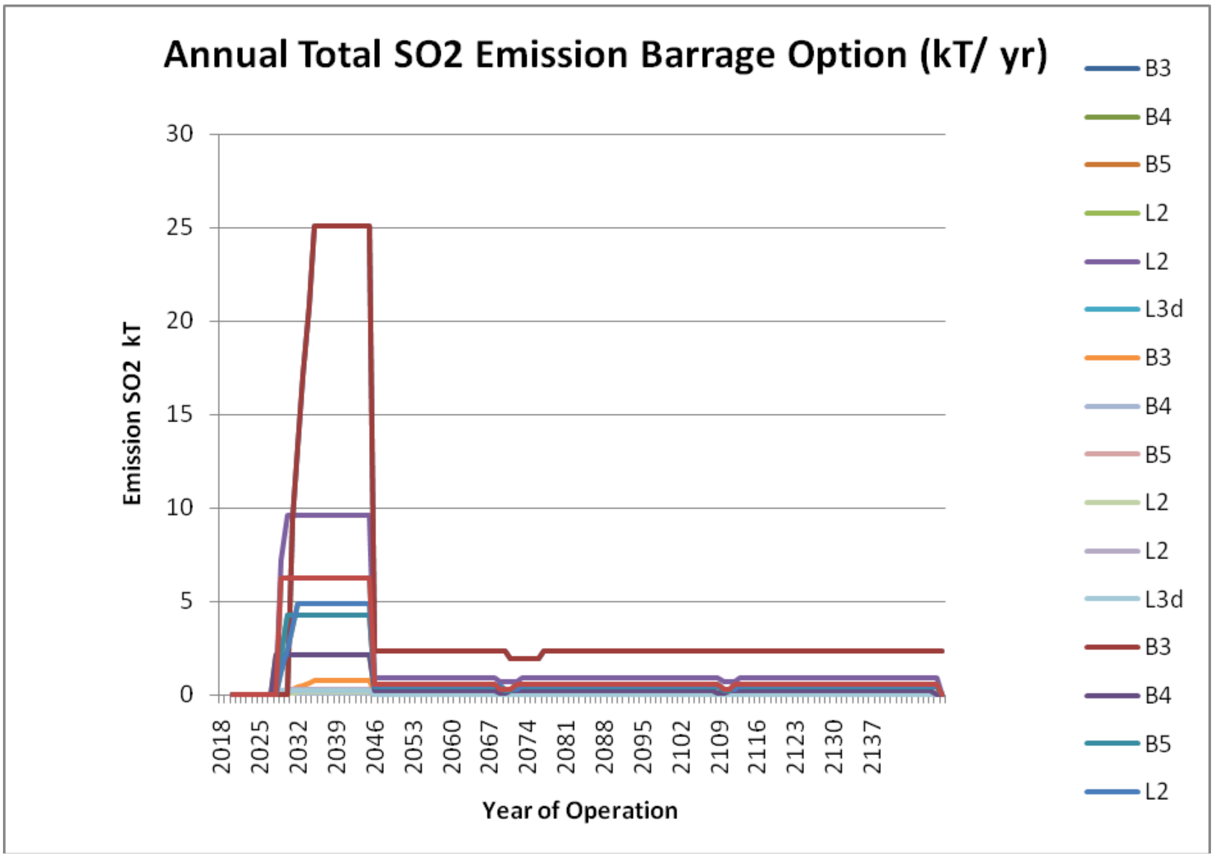
APPENDIX F

AIR QUALITY OFF-SETTING


Annual NOx off setting Barrage Options (kT/ Yr)
NOx Emissions KkTonnes
40
35
30
25
20
15
10
5
0
2010
2016
2022
2028
2034
2040
2046
2052
2058
2064
2070
2076
2082
2088
2094
2100
2106
2112
2118
2124
2130
2136
Year of Operation
B3
B4
B5
L2
L2
L3d
B3
B4
B5
L2
L3d

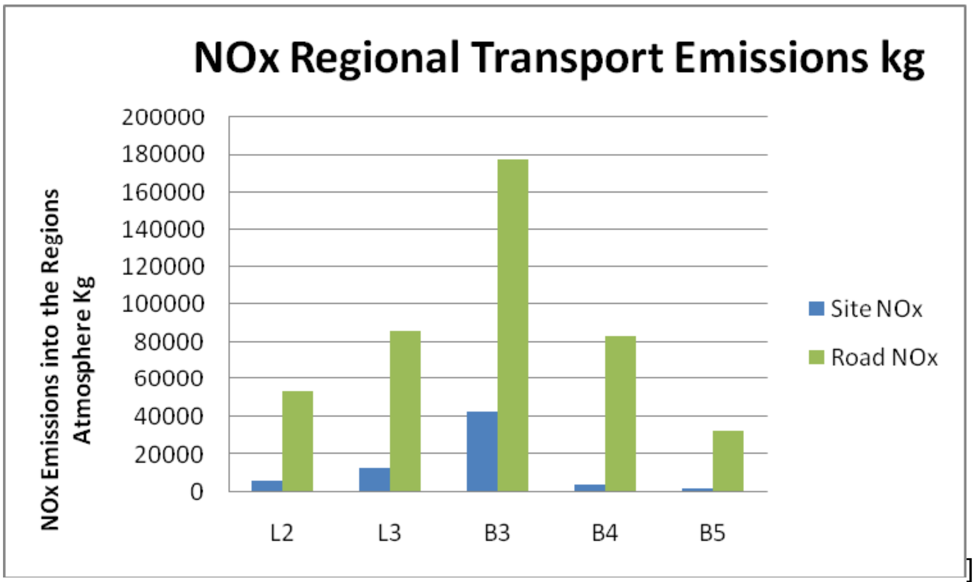

Annual Total PM10 Emission Barrage Option (kT/ yr)
Emission Pm10 kT
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
YEAR
2016
2023
2030
2037
2044
2051
2058
2065
2072
2079
2086
2093
2100
2107
2114
2121
2128
2135
Year of Operation
B3
B4
B5
L2
L2
L3d
B3
B4
B5
L2
L3d

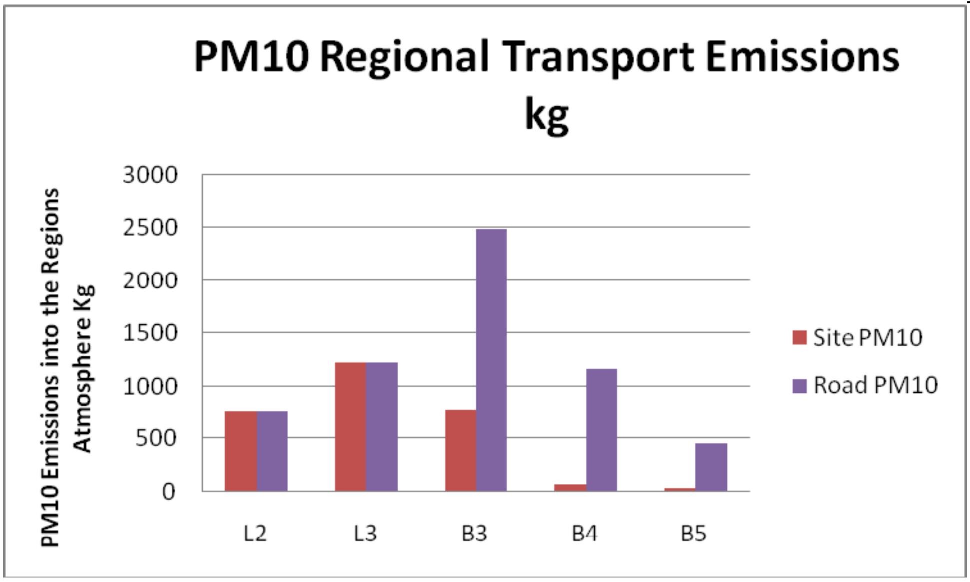

Annual Total PM10 Emission Bararge Option (kT/ yr)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Emission Pm10 kT
YEAR
2016
2023
2030
2037
2044
2051
2058
2065
2072
2079
2086
2093
2100
2107
2114
2121
2128
2135
Year of Operation
B3
B4
B5
L2
L2
L3d

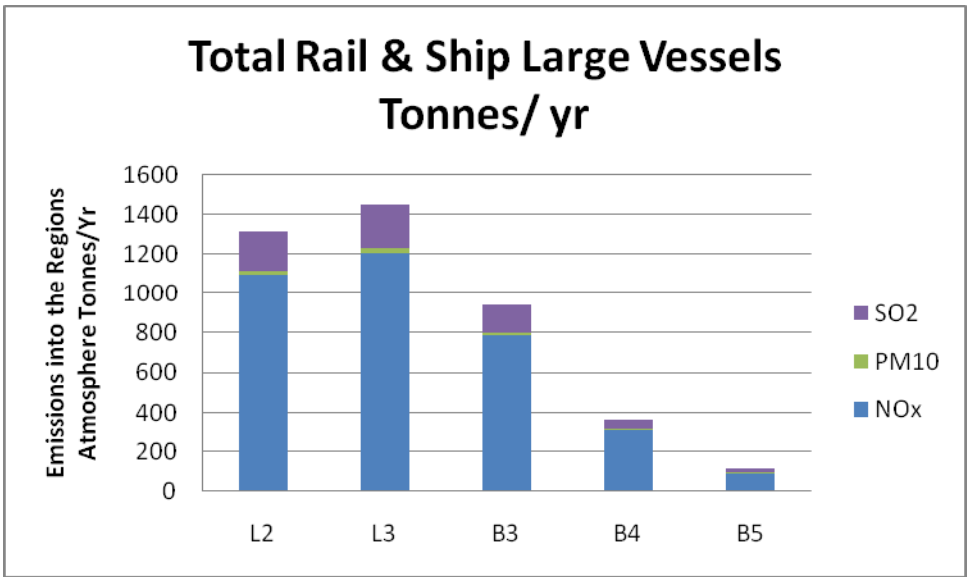

Annual Total SO2 Emission Barrage Option (kT/ yr)
Emission SO2 kT
30
25
20
15
10
5
0
2018
2025
2032
2039
2046
2053
2060
2067
2074
2081
2088
2095
2102
2109
2116
2123
2130
2137
Year of Operation
B3
B4
B5
L2
L2
L3d
B3
B4
B5
L2
L2
L3d
B3
B4
B5
L2

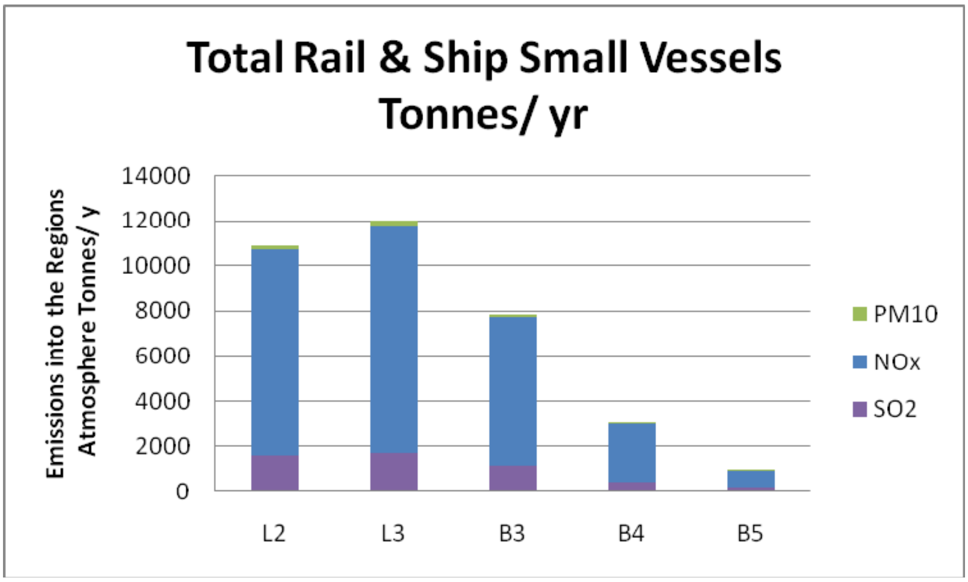
APPENDIX G

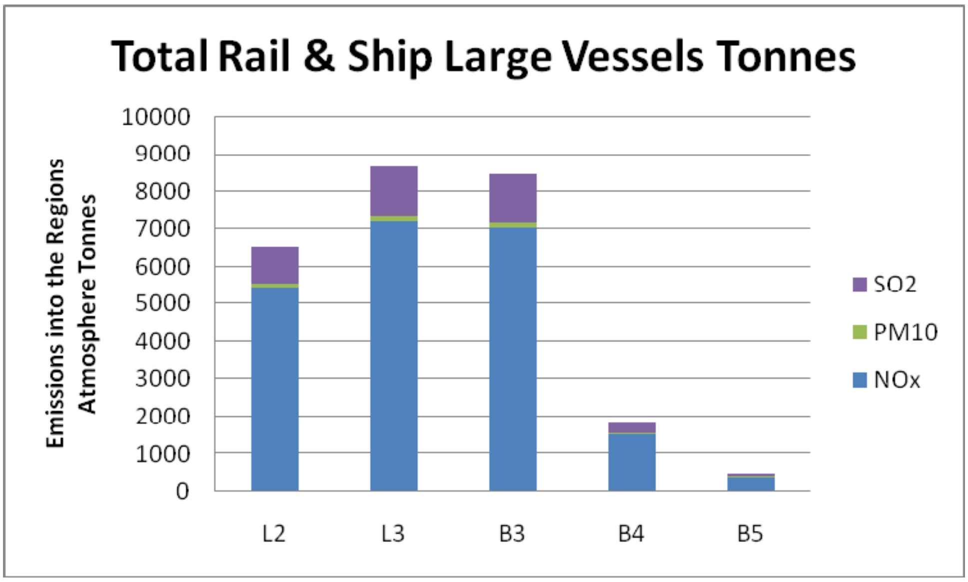
AIR QUALITY TRANSORT EMISSIONS

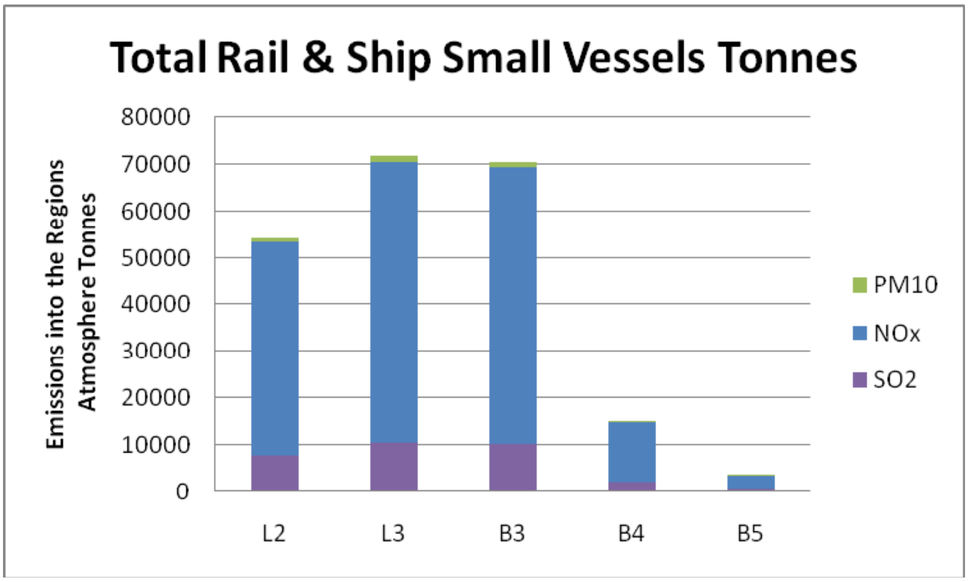

NOx Regional Transport Emissions kg
NOx Emissions into the Regions Atmosphere Kg
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
L2
L3
B3
B4
B5
Site NOx
Road NOx


PM10 Regional Transport Emissions kg
PM10 Emissions into the Regions Atmosphere Kg
3000
2500
2000
1500
1000
500
0
L2
L3
B3
B4
B5
Site PM10
Road PM10


Total Rail & Ship Large Vessels Tonnes/ yr
Emissions into the Regions Atmosphere Tonnes/Yr
1600
1400
1200
1000
800
600
400
200
0
L2
L3
B3
B4
B5
SO2
PM10
NOx

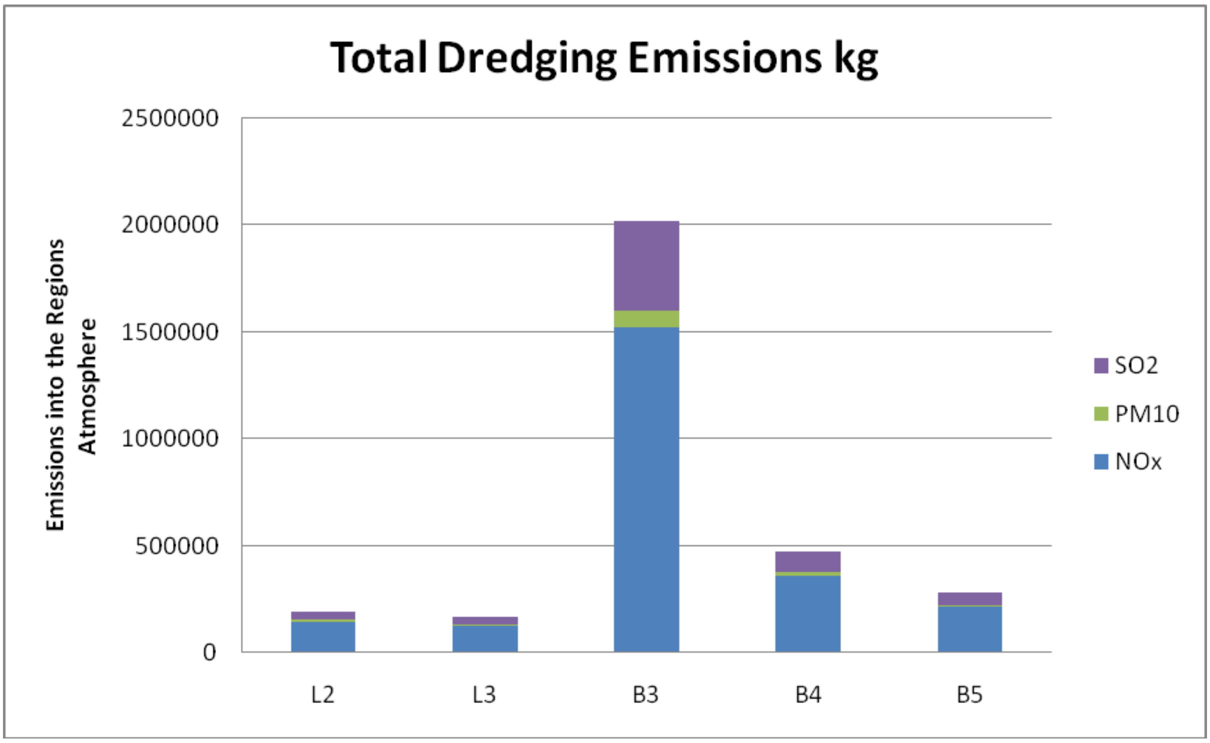

Total Rail & Ship Small Vessels Tonnes/ yr
Emissions into the Regions Atmosphere Tonnes/ y
14000
12000
10000
8000
6000
4000
2000
0
L2
L3
B3
B4
B5
PM10
NOx
SO2


Total Rail & Ship Large Vessels Tonnes
Emissions into the Regions Atmosphere Tonnes
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
L2
L3
B3
B4
B5
SO2
PM10
NOx


Total Rail & Ship Small Vessels Tonnes
Emissions into the Regions Atmosphere Tonnes
80000
70000
60000
50000
40000
30000
20000
10000
0
L2
L3
B3
B4
B5
PM10
NOx
SO2

APPENDIX H

AIR QUALITY TOTAL DREDGING EMISSIONS


Total Dredging Emissions kg
Emissions into the Regions Atmosphere
2500000
2000000
1500000
1000000
500000
0
L2
L3
B3
B4
B5
SO2
PM10
NOx