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SEVERN TIDAL POWER - SEA THEME PAPER

Air & Climatic Factors and Resources & Waste Effects and Interrelationships

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ABBREVIATIONS

ABBREVIATIONS

The following abbreviations are used in this Environmental Report:

BAP	Biodiversity Action Plan
CO_2	Carbon dioxide
cSAC	Candidate Special Area of Conservation
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
EIA	Environmental Impact Assessment
EC	European Commission
GHG	Greenhouse Gases
GIS	Geographical Information System
GW	Gigawatts
Hg	Mercury
HRA	Habitats Regulations Assessment
Mm^3	Million cubic metres
Mt	Million tonnes
MW	Megawatt
ODPM	Office of the Deputy Prime Minister
PM_{10}	Particulate matter (fine particles)
PPG	Planning Policy Guidance
SAC	Special Area of Conservation
SDC	Sustainable Development Commission
SEA	Strategic Environmental Assessment
SLR	Sea Level Rise
SO_2	Sulphur Dioxide
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
STP	Severn Tidal Power
TWh	Terrawatt hours
UKCIP	United Kingdom Climate Impacts Programme

NON TECHNICAL SUMMARY

NON TECHNICAL SUMMARY

Feasibility Study and Purpose of the SEA

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). 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.

The Feasibility Study has been split into two phases: Phase One examined 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 (the current stage) has involved work on environmental, regional, economic, commercial, technical and regulatory issues to inform the study conclusions including whether any of the potential schemes are feasible.

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.

Purpose of the Theme Papers

The SEA Directive requires that the likely significant effects on the environment and their interrelationships are described (SEA Directive Annex 1 (f)). The theme papers therefore summarise the interrelationships between related topics and thereby ensure that the many complex issues that are not self-contained within a given topic are recognised and their implications understood. Each theme paper also examines the interrelationships between this theme and other themes within the STP SEA. This is the Air & Climatic Factors and Resources & Waste theme paper. This paper covers the following topics:

- Air quality - in particular, emissions of sulphur dioxide (SO_2), particulate matter (PM_{10}) (fine particles) and nitrogen oxides (NOx) on humans and vegetation.
- Climatic factors – including emissions of greenhouse gases, particularly carbon dioxide (CO_2) throughout the life cycle of a STP scheme.
- Resources and waste – including sources of construction materials, energy, water, waste management facilities and potential waste sites.

Furthermore, the theme papers also assist the Environmental Report to meet the requirements of the SEA Directive by collating the difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information (SEA Directive Annex 1 (h)).

Each theme paper therefore provides an integrated summary across the theme, drawing on information presented in its topic papers. The theme paper also considers the likely significant effects on the environment of the variations of alternative options referred to as combination and multiple basin options.

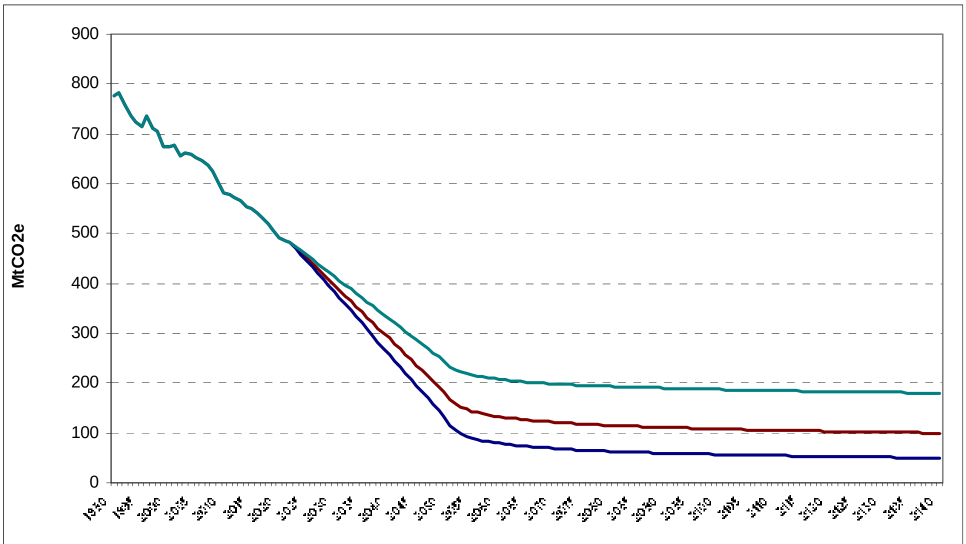
Air & Climatic Factors, Resources and Waste Baseline Environment and Significant Effects

<u>Baseline Environment 2009 -2140</u>

Air quality affects human health and vegetation, through deposition of nitrogen and acid. Air quality within the UK has generally been improving for the last 10 years, with poor air quality mainly present in urban areas and along major roads. This general trend is also reflected in the Severn Estuary, which is largely rural with good air quality; but some pockets of poor air quality, limited to urban areas and along major transport routes. There are significant improvements in air quality in the UK predicted between current levels and 2020, and these can be assumed to apply to the Severn Estuary. Predicted changes in air quality are based on existing legislation and energy targets, and upon estimated improvements in road vehicle technology. In the longer term, it is difficult to predict air quality, but it is assumed that with the use of low carbon technology and alternative energy, air quality would continue to improve.

Greenhouse gas emissions (expressed as million tonnes of carbon dioxide) have generally been falling in the UK for the last 10 years (Figure 1) but increasing globally. There are a number of future scenarios for greenhouse gas emissions predicted by the Intergovernmental Panel on Climate Change, and these mainly involve a steady rise followed by some decline, depending on factors such as industrialisation and adoption of policies to limit emissions. In the UK, on the other hand, emissions have been predicted to continue to decline. This is supported by the Renewable Energy Strategy (HM Government, 2009) which sets out how a target of 15% of electricity is to be generated from renewable sources by 2020, and the UK Low Carbon Transition Plan (DECC, 2009) which sets a target of 80% by 2050. Beyond 2050, the emissions projections rely upon the successful implementation of all current UK Policy, the detail for which may vary, but it is assumed by the project that these trends would continue.

Figure 1. Annual UK GHG emissions; observed and predicted



The UK is generally self-sufficient in its demand for aggregate and embankment materials. Some 280 million tonnes per year are consumed, from land and marine sources, as well as some 70 million tonnes of secondary and recycled aggregate. Wales and the South West of England produce in the order of 50 million tonnes per year.

The steel industry operates globally, with China producing 37% of the world's steel in 2007, and the UK only producing 1%.

The UK's energy consumption in 2008 was 165 million tonnes of oil equivalent, of which just 3 per cent was used by the construction industry. National energy policy, including the Renewable Energy Strategy, would affect the energy supply mix, although transport and construction are likely to continue to be predominantly fossil-fuel based at least until 2020, which includes the construction phase of an STP scheme.

Pressure on water supplies is increasing, through increased demand from population growth and seasonal reductions in availability as a result of climate change. Limited water is available for abstraction in proximity to the Severn Estuary and pressure on water resources is set to continue into the future.

Waste facilities include landfill (include hazardous, non-hazardous and inert waste landfills), waste incinerators and treatment facilities (recycling, composting, processing). There are no hazardous waste landfill sites available in Wales.

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 Strategic Environmental Assessment identifies likely significant effects on the environment, which can be either positive or negative. A number of effects were identified, some of which were significant. The construction and decommissioning emissions, use of resources and generation of waste are generally greatest for the physically larger schemes (as shown in the table above). The following effects were identified during construction:

- Use of raw materials and the emissions to air associated with their use and manufacture. The use of embankment materials was predicted to be significant for all options except the B5 Beachley Barrage, but other raw materials were not significant. Emissions to air.were generally not assessed as significant, with the exception of the greenhouse gas emissions associated with the B3 Brean Down to Lavernock Point Barrage.

- Effects on air quality and greenhouse gases from transportation of materials, workers and operation of machinery on site. There would also be some far-field effects from aggregates, embankment materials and steel as imported materials would be required. These effects were not predicted to be significant.

- Use of water and carbon emissions associated from its use, which affects UK greenhouse gas emissions. These effects were not predicted to be significant.

- Waste generated and effects on treatment and recycling of waste (e.g. steel), energy recovery for waste (e.g. timber), landfill facilities (e.g. hazardous waste), this was not assessed as significant.

- Cumulative effects on availability of aggregates and embankment materials from construction of proposed projects. These effects were assessed as significant.

The following effects were identified during operation:

- Significant positive effects from the use of renewable energy which does not produce emissions, resulting in a saving in emissions that would otherwise be produced by electricity. This would not be altered meaningfully by foreseeable maintenance programmes. The generation of renewable energy is greatest for the B3 Barrage and smallest for the B5 Barrage (as seen in the table above).

- Negative effects from maintenance and operations such as transportation, use of materials, energy and water (not significant). This also includes re-routing of vessels which would be required, particularly for the barrage options.

- Negative effects from energy use for navigational dredging and pumping to manage the effects of options, which are not predicted to be significant in terms of emissions, but sites would need to be found for the re-use or deposition of dredged material.

- Positive and negative effects from changes in the estuary which could release or provide a store for carbon due to changes in living material, such as intertidal habitat. There is some uncertainty as to the scale and significance of these effects.

During decommissioning of the alternative options, the effects are similar to those set out under construction. The main effect of significance is finding opportunities for recycling and re-use of materials in the structures, particularly aggregates.

There are several difficulties in predicting significant effects, particularly at a strategic stage. Assumptions must be made, based on project information on resource use, the source of materials, transportation distances and methods and the amount of waste generated. There are also uncertainties associated with predicting effects, particularly those in the future which must be based on information which is available today. Examples of uncertainties include whether policy would be successful in reducing future greenhouse gas and other emissions in the UK and globally; and how estuarine changes would affect the release or storage of carbon in living material.

Interrelationships

The main interrelationships between the Air & Climatic Factors and Resources and Waste topics can be summarised as follows:

- The type of resource or material used (e.g. aggregates, steel, water) and how it is processed would affect the quantity of emissions to air. For instance, embodied carbon emissions are higher for steel than concrete.
- The quantities and location of materials used would also affect emissions. This is not only due to the embodied emissions set out above, but this also affects the source and thus transportation of materials. For instance, The B4 Shoots and B5 Beachley Barrages require smaller quantities of concrete and it is assumed that aggregates can be sourced from Wales and the South West. Some materials, such as steel, would need to be sourced globally.
- The reuse or recycling of materials, which although requires some energy inputs, reduce the requirement for raw materials and their transportation. The main area for reuse is dredging material for construction of the options, in particular sand and gravel.
- The amount of waste generated and transport mode to waste treatment facilities would also affect greenhouse gas emissions and local air quality.

Interrelationships between the Air & Climatic Factors and Resources and Waste theme and other themes are summarised below:

- The construction of larger options (e.g. B3, L2, and L3d) would require either importing material, or increasing the capacity of existing UK sources or additional marine aggregate dredging licences. Although use of local sources reduces air emissions, it would have effects on local and UK dredging activity (Other Sea Uses Topic, Society and Economy Theme), marine ecology (Marine Ecology Topic, Biodiversity Theme) and landscape (Landscape and Seascape Topic).
- The size of the workforce (Communities Topic, Society and Economy Theme) would vary depending on the scale of construction required for each option. Their living accommodation and transportation would affect emissions.
- Impeded drainage due to reduction in the low tide level may require pumping to prevent flooding in some areas (Flood Risk and Land Drainage Topic within the Physicochemical Theme). Increased pumping would increase energy use and carbon emissions.
- All options would require increased maintenance dredging to keep shipping channels open (Navigation Topic, Society and Economy Theme). The greater the extent and frequency of

dredging, the greater the emissions to air during operation. There would also be waste management requirements to find sites for reuse or disposal of material.

- The feasibility study has identified measures to reduce or prevent significant effects on navigation, such that vessel re-routing to other ports is not anticipated. Nonetheless it is anticipated that the diversion of some vessels may occur, particularly for the B3 Barrage.

- There are a number of relationships are associated with estuarine and habitat changes and how these would affect the store or release of carbon dioxide and other greenhouse gases in organic material (Physicochemical and Biodiversity Themes).

Measures to Prevent, Reduce and as Fully as Possible Offset any Significant Adverse Effects

A number of measures to prevent or reduce environmental effects have already been incorporated into the design of the alternative options. These include reuse of dredged material and spoil onshore and navigation measures to reduce re-routing of vessels and prevent or reduce delays.

For both Air & Climatic Factors and Resources & Waste, the majority of potentially significant effects occur during the construction (and decommissioning phases), so additional measures which could be employed tend to focus on this phase:

- Use of a local supply of materials where possible.

- Use of the most efficient production and transport of materials.

- The identification of opportunities to use secondary and recycled materials.

- Waste management and minimisation (i.e. reuse, recycle, recovery, with landfill as the last resort).

- Use of renewable energy (temporary or permanent) where possible.

SEA Objective Compliance

The SEA Objectives were drafted and consulted upon as part of the Phase 1 SEA scoping stage. This theme paper identifies any interactions or inconsistencies between topics within this theme with regards to the assessment against SEA Objectives.

Overall, the performance of alternative options against SEA objectives for this theme is consistent with what would be expected, based on the interactions between air and climatic factors, resources and waste described above. For structures, the greater material and transport requirements during construction mean that more resources are used, waste is produced, and emissions to air are greater. This affects the local, national and international receptors. However, the greater the renewable energy produced, the better the performance over the life cycle of the project in relation to overall and operational emissions to air.

Implementation

Monitoring for significant environmental effects has been suggested for the implementation of a STP option, and comprises:

- Emissions of nitrogen dioxide, particulate matter and sulphur dioxide at key locations prior to and throughout construction.

- Monitoring of transportation and fuel consumption during construction.

Further studies could also be undertaken during more detailed design stages to reduce significant effects:

- Detailed design could be assessed in relation to the effect of the carbon footprint effect on construction, operation and decommissioning. This could include more detailed assessment of the effects of estuarine changes on carbon storage and release to reduce uncertainty of this effect, with a particular focus on the loss and creation of intertidal habitat,.

- The adequate supply and demand for aggregates and embankment materials for construction could be kept under review.

- Targets could be set for reuse of dredged materials and use of secondary and recycled aggregates. Other measures could be explored to minimise carbon use, such as embedding carbon minimisation into tender/contract documentation of any option.

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 Background

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 Any project to generate power form the tidal range of the Severn Estuary would need to meet the following objectives:

- To generate electricity from the renewable tidal range resource of the Severn Estuary in ways that will have an acceptable overall impact our environment and economy both locally and nationally, will meet our statutory obligations and provide benefit to the UK; and

- To deliver a strategically significant supply of renewable electricity, which is affordable and represents value for money compared to other sources of supply in the context of the UK's commitments under the forthcoming EU Renewable Energy Directive and Climate Change Act and our goal to deliver a secure supply of low-carbon electricity.

1.1.3 The Feasibility Study has been 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. This is the current stage.

1.2 Purpose of the SEA

1.2.1 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.

1.3 Purpose of the Theme Papers

1.3.1 The SEA Directive requires that 'the likely significant effects on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural and archaeological heritage, landscape and the interrelationship between the above factors' are described (SEA Directive Annex 1 (f)).

1.3.2 The theme papers therefore summarise the interrelationships between related topics – see Table 1.1 below – and thereby ensure that the many complex issues that are not self-contained within a given topic are recognised and their implications understood. This approach emerged from the SEA scoping phase to allow related topics to interact and interface more effectively. Each theme paper also examines the interrelationships between this theme and other themes within the STP SEA.

Table 1.1 SEA themes and topics

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

1.3.3 Furthermore, the theme papers will also assist the Environmental Report to meet the requirements of the SEA Directive by collating the difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information (SEA Directive Annex 1 (h)).

1.3.4 Each theme paper therefore provides an integrated summary across the theme, drawing on information presented in its topic papers. Each theme paper presents a review of the environmental baseline and considers the environmental effects for the topics within this theme, taking into account the interrelationships between them and identifying difficulties in compiling the information and uncertainties in the assessment. However, no substantive analysis is undertaken within each theme papers that is not already contained within its topics.

1.3.5 Each theme paper also considers the likely significant effects on the environment of the variations of alternative options referred to as combination and multiple basin options.

1.3.6 This theme paper covers Air & Climatic Factors and the Resources & Waste topics. The Air and Climatic Factors Topic covers two main areas, Air Quality and Carbon Footprinting. The Air Quality topic focuses emissions of sulphur dioxide (SO_2), particulate matter (PM_{10}) (fine particles) and nitrogen oxides (NOx). The assessment covers potential effects of Severn Tidal Power Options on local air quality and human health (i.e. South West and Wales), in addition to national contributions to air quality. The Carbon Footprinting topic focuses on greenhouse gas emissions (GHG), principally carbon dioxide (CO_2). The assessment considers potential changes in GHG emissions, in the UK and globally, as a result of a Severn Tidal Power option being implemented.

1.3.7 The Resources and Waste topic includes sources of construction materials, energy, water and waste management facilities[1]. The key environmental issues for resources relate to the types and quantities of resources required, the source of those resources, and the effects on the landscape from the use of natural resources and their transportation. Key issues for waste relate to the types and quantities of waste generated, how they would be managed, and where they would be disposed, treated, reused or recycled.

[1] These include sites for reuse opportunities (on-site or off-site), treatment and recycling facilities, energy recovery, and landfill.

SECTION 2

APPROACH

2 APPROACH

2.1 Overall approach adopted in the SEA

2.1.1 The assessment process involved the collection of information and the development of SEA objectives, definition of alternatives and identification of significant environmental effects. Measures to prevent, reduce and as fully as possible offset significant adverse effects on the environment were developed, and proposals reviewed in the light of identified significant environmental effects. A more detailed description of the purpose of each SEA task and the STP SEA approach is given in the Environmental Report (STP, 2010).

2.2 SEA Objectives

2.2.1 SEA Objectives are a recognised tool for comparing alternative options. SEA Objectives, and associated 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).

2.2.2 The SEA Objectives for this theme, as amended in response to the Scoping consultation, are set out in Table 2.1. The air quality assessment was extended in scope following phase 1 of the study, and due the inter-relationship between air quality and the other topics, there are some overlap between objectives for other papers (Communities and Terrestrial & Freshwater Ecology).

Table 2.1 SEA Objectives for Air & Climatic Factors and Resources & Waste

SEA Topic	SEA Objective
Air & Climatic Factors	To seek to maximise the opportunities for use of sustainable sources of energy for the UK.
Air & Climatic Factors	To avoid adverse effects from GHG emissions over the lifecycle of the project
Air & Climatic Factors	To avoid adverse effects on physical and mental health
Air & Climatic Factors	To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.
Air & Climatic Factors	To avoid adverse effects on valuable terrestrial and freshwater ecological networks.
Resources & Waste	To promote sustainable use of resources
Resources & Waste	To reduce waste generation and disposal, and achieve sustainable management of waste

2.3 Alternative Options for Tidal Power

2.3.1 At the beginning of Phase 2, five alternatives for the development of tidal power using the tidal range of the Severn Estuary were identified as the preferred candidates for more detailed study. The five options comprise three tidal barrages and two tidal lagoons (STP, 2010). These alternative options and key parameters associated with alternative options are set out in Table 2.2 and shown in Figure 2.1.

Figure 2.1 Severn Tidal Power Options

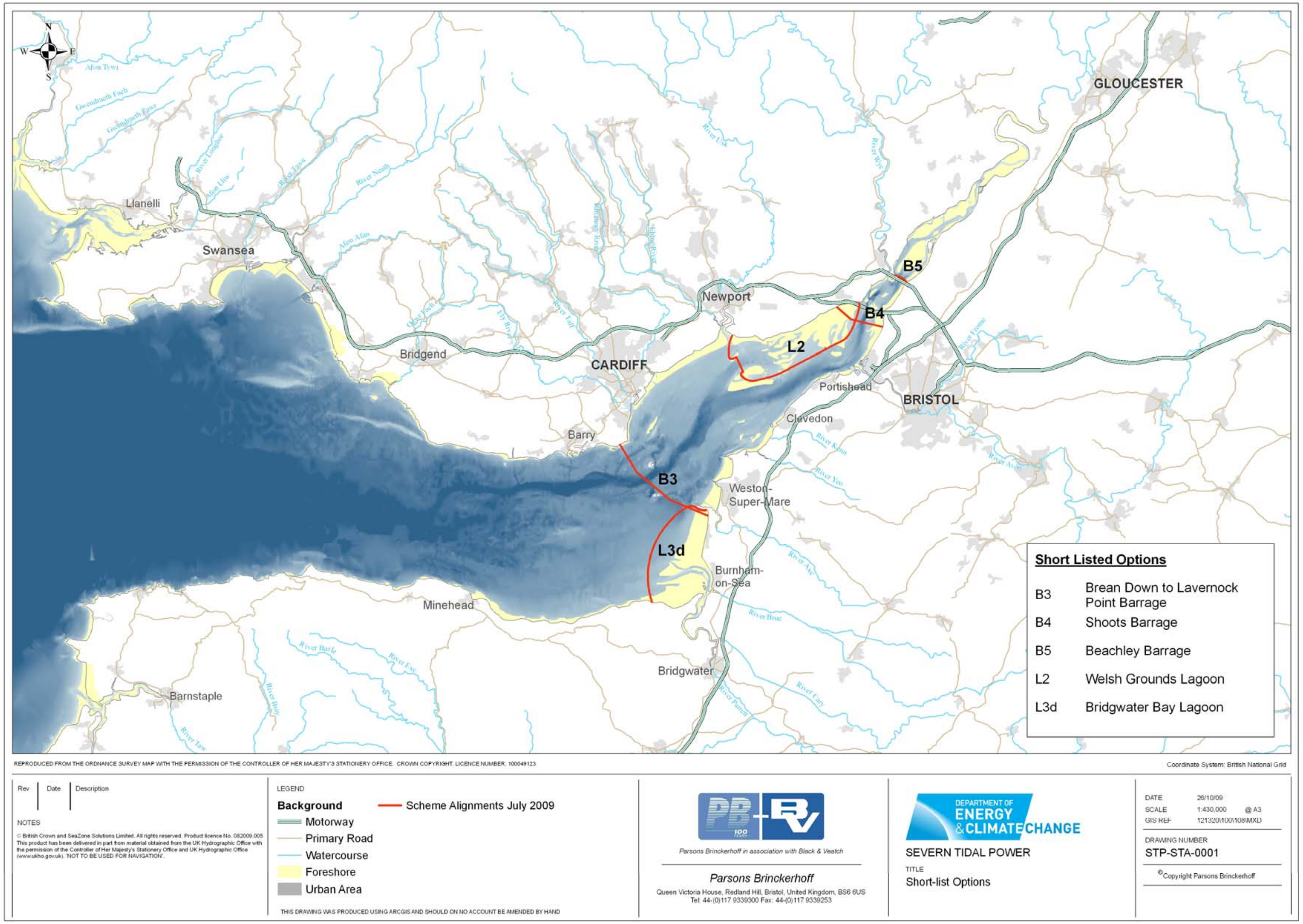


Table 2.2 Alternative options

Alternative	Location	Length (approx)	Operating mode	Turbine type	No. turbines	Annual energy output	Caissons	Locks
B3: Brean Down to Lavernock Point Barrage	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

2.3.2 Variations in the alternative options have also been considered. Whilst at this stage none of these constitute alternative options under the feasibility study, initial consideration has nonetheless been given to their potential effects. The variations considered included multiple basins and combinations of the five short-listed alternative options. Multiple basin variants are configured with the aim of providing continuous power to better align energy yield with peak demand.

2.3.3 Following an evaluation process (considering energy yield, costs, programme and opportunities for optimisation) one multiple basin and two combinations of options were identified for further high level review. This does not constitute the same level of detail as assessment of the short listed alternative options, but if any of the variations are found to have advantages over the alternatives, then further work would be required. The assessment of combination of options at this high level uses professional judgement to determine whether effects are likely to be equal to or greater than the combination of the assessment of the individual options.

2.3.4 The multiple basin option variant identified for high-level consideration of environmental effects is a double basin version of the L3d Bridgwater Bay lagoon (with pumping). The double basin concept splits the L3d lagoon into a high basin and a low basin using a rockfill dividing wall with its landfall at Berrow. The variant is then configured to provide a continuous cycle of water from the sea to the high basin, from the high basin to the low basin and then from the low basin to the sea. This variant employs two powerhouses, one between the high and low basins and a second between the low basin and the sea. Each basin would experience a tidal range, but the high basin water levels would always be kept above the low basin. Pumping is used to raise water levels in the high basin and lower them in the low basin to increase power output. The option variant would utilise single direction turbines (in contrast to the ebb/flood generation of the standard L3d alternative option).

2.3.5 Both of the potential combinations of options include the standard single basin L3d option, with the assumption that it would generating with an ebb/flood configuration. A combination of L3d (ebb/flood) with B3 Brean Down to Lavernock Point barrage (ebb only) has been shown to be worthy of further consideration; as has a combination of L3d (ebb/flood) with B4 Shoots barrage (ebb only).

2.3.6 L3d and B3 would be constructed sequentially due to the large amount of resources required to build either of these alternative options. Either option could be constructed first. L3d and B4 could be constructed either sequentially or concurrently. The operating rules and forms of construction for the combined options are assumed for the purpose of this high-level review to be the same as those for the individual alternative option.

2.4 Technical studies within the theme

2.4.1 A number of studies have contributed to this Theme Paper. These include baseline desk studies specific to topics, comprising:

- Review of existing and emerging legislation and policy which applies to air & climatic factors and resources & waste. Full details of legislation and policy which have been covered can be found within the topic papers as well as a summary within the Environmental Report.
- Current and future air quality predictions and energy requirements from sources such as National Atmospheric Emissions Inventory, National Air Quality Strategy (Defra, 2007) and the UK Low Carbon Transition Plan (DECC 2009c).
- Current and future levels of greenhouse gas information from DECC and the IPCC.
- Habitat information from sources such as the Centre for Ecology and Hydrology (CEH), the Joint Nature Conservation Committee (JNCC) and the Air Pollution Information System (APIS).
- Resources data such as aggregates, steel, energy and water was obtained from industry associations, water companies and government (such as Department of Communities and Local Government, Department of Trade and Industry and HM Revenue and Customs).

2.4.2 This data was used to predict effects for STP alternative options and performance against SEA objectives using information about options generated by the project including:

- Option Definition Report (Parsons Brinckerhoff, 2009)
- Onshore Infrastructure Paper (Parsons Brinckerhoff, October 2009)
- Supply Chain Survey (DECC, 2010)

Difficulties encountered, including uncertainty and risk

2.4.3 The Feasibility Study is strategic in nature and so are many of the methods used to predict effects. Some uncertainty is therefore carried through the assessment, from the project assumptions made to the use of standard conversion factors (e.g. quantity of concrete into amount of emissions generated). Although the results obtained are as realistic as possible, they do have a substantial error band on them, which are set out in individual topic papers and where relevant, in this theme paper. Examples of assumptions include source of construction materials; transport means and distances; workers accommodation; dredging material re-use; maintenance requirements; navigational dredging requirements during operation; estuarine changes (sequestration, methanogenesis, siltation and changes to the nitrogen) and emissions factors.

2.4.4 The assessment is limited to the best available data generated through the Feasibility Study. At this high level of study, every effort has been made to include effects within this theme arising from the STP options as set out in the Options Definition Report (STP, 2010) and SEA Topics. However, there are some elements of the study which cannot be included, either due to lack of detailed information or the certainty as to whether they would be included with an STP scheme. Examples of these include ancillary works such as grid connections, sites for construction and manufacture (e.g. caissons), and effects arising from some measures recommended to prevent or reduce effects such as topographic modification. At this stage of the study these aspects are not well enough defined in relation to source and quantity of materials and methods of transportation to include within the assessment. Table 2.1 below sets out what factors have and haven't been included within the carbon footprint as part of the feasibility study.

2.4.5 It has been assumed that improvements to air quality and emissions are made through existing and emerging legislation and policy. This includes reductions in emissions from the outcomes of the Government's Low Carbon Transition Plan (DECC, 2009c) and associated policies, estimated improvements in road vehicle technology leading to a reduction in vehicle emissions, and improvements to local air quality through Air Quality Management Areas. However, in some cases and in particular for long term predictions (see below), a margin of error was applied as there is some uncertainty on whether targets can be met. This assumption also affects the predicted displaced emissions which are also assumed to reduce over time.

2.4.6 For any future predictions, the nearer term predictions are more accurate than estimations into the future. 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, particularly in greenhouse gas reductions; future local air quality; critical load exceedences for habitats[2]; location and availability of resources and availability of waste management sites.

2.4.7 In some cases, the results of the assessment appear to be slightly different for inter-related topics. This is either due to the nature of the receptors or the assumptions on which the assessment is based. For example, air quality looks at emissions of SO_2, NOx and PM10 and the carbon footprinting paper looks at CO_2 emissions (among others). Although the sources of emissions are the same, air quality receptors are either within the UK, or in many cases, communities or vegetation more local to the alternative options, whereas carbon footprinting is on either a UK or global scale. This

[2] In this case the critical load is an estimated deposition of nitrogen and acid on vegetation and where this is potentially exceeded, there are harmful effects on the habitat.

means that the reporting of effects (direct, indirect, option comparison) is sometimes slightly different. In each case, the assumptions on which the assessment is based is clearly set out.

Table 2.1 Summary of STP Feasibility Study Carbon Footprint

Description	Info required for inclusion	Any exclusions or exceptions
Construction		
Embodied carbon footprint	Raw material quantities (kg) for example: concrete (type) cement (type) fine/coarse aggregate rebar grout rock/sand dredging sand or rock fill sand ballast armouring roadworks fabricated steel ship lock concrete/steel weight/spec of pumps weight/spec of any grates etc	No ancillary roadworks are included in the assessment as these were not quantified by the Engineering Team or in the Resources and Waste topic paper and assumed to be insignificant.
Embodied carbon footprint	Transportation (fuel consumption or transport type and distance/time on site) Construction plant usage (fuel consumption or transport type and distance/time on site) Dredging requirements (kg or days of operation) Waste disposal requirements	
Embodied carbon footprint	Disruption to traffic (shipping and road transport)	
Embodied carbon footprint	Travel to work (no of local/national workers) including additional accommodation requirements	
Operation		
Energy output received	Annual energy production (kWh)	
Area of new habitat creation obtained	Type of habitat and area	Unquantifiable at this stage of assessment.
Operational pumping	kWh of energy required or hours of pumping and pump rating	No construction pumping included
Operational (maintenance) dredging	Dredging requirements (kg or days of operation)	
Mitigation – back up generation	Motors – rating and hours of operation	Excluded – outside scope of SEA
Maintenance	Replacements required – yearly maintenance	
Shipping	Ongoing re-routing of ships (no of ships	

Description	Info required for inclusion	Any exclusions or exceptions
	impacted and re-routing distances)	
Estuarine ecosystem Methanogenesis, sequestration, direct CO2/NOx release	Loss/gain in emissions associated with the change in ecosystem. Area of intertidal area impacted – flooded or dried	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.
Operational workers	Travel to work (no of local/national workers)	
Decommissioning		
Recycling	Quantity of waste to be disposed of (worst case scenario total volume of material) – transportation distances	Incorporated into onsite/offsite vehicle use and transportation requirements.
Plant vehicle use	Onsite plant usage (fuel consumption or days on site and type)	
Estuarine ecosystem	Any changes that may occur as result of option being removed	Excluded
Cumulative effects and consequential development		
Cumulative and Consequential effects	Result of increase/decrease in emissions due to other large scale projects being commissioned at the same time as STP, and as a consequence of STP.	These effects are considered qualitatively only as not enough information available from cumulative and consequential works.

2.5 Consultation

2.5.1 Both the Feasibility Study and the SEA within it have included a programme of formal consultation and opportunities for informal input. 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 detailed in the topic papers and summarised in the Environmental Report (STP, 2010).

SECTION 3

AIR & CLIMATIC FACTORS AND RESOUCES & WASTE BASELINE ENVIRONMENT AND SIGNIFICANT EFFECTS

3 AIR & CLIMATIC FACTORS AND RESOURCES & WASTE BASELINE ENVIRONMENT AND SIGNIFICANT EFFECTS

3.1 Introduction

3.1.1 This section summarises the current state, characteristics and evolution of the environment for the topics within this theme.

3.1.2 This section also considers, within this theme, the likely significant effects on the environment for each alternative option and the interrelationships between these effects (SEA Directive Annex 1 (f)). These effects may arise from direct, indirect, far-field, cumulative and consequential development effects during construction, operation and decommissioning phases and may include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects (SEA Directive Annex 1 (f)).

3.1.3 This section also considers the difficulties encountered in compiling the required information (SEA Directive Annex 1 (h)) and the level of certainty in the assessment of effects.

3.2 Current state, characteristics and evolution of environment

3.2.1 Baseline information provides the basis for predicting and monitoring environmental effects. 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.

3.2.2 The characteristics of the environment for this theme are described at different geographic scales, which depend on the potential issues arising from the STP project identified for each topic:

- Local air quality in relation to population and ecosystems; waste management facilities, water and aggregate resources.
- National (UK) greenhouse gas emissions, and air quality in relation to populations and habitats, aggregate and energy resources.
- Global greenhouse gas emissions and international sources of steel.

Baseline environment (up to 2009)

3.2.3 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[3] were exceeded. Air quality within the UK is generally good, where the

[3] Objectives for air pollution are concentrations over a given time period that are considered to be acceptable in the light of what is known about the effects of each pollutant on health and on the environment. They can also be used as a bench mark to see if air pollution is getting better or worse. The objectives adopted in the UK are part of the Air Quality Strategy published by the Government in January 2000 (UK Air Quality Archive definition).

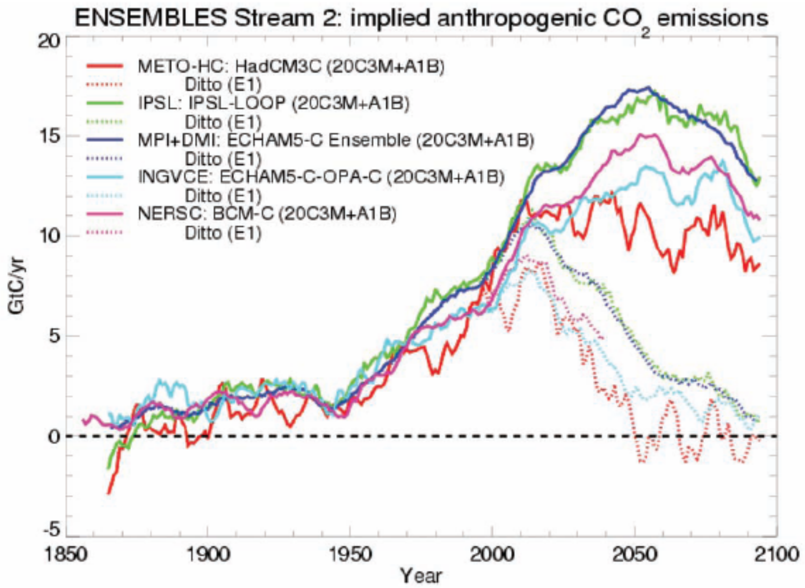
National Air Quality Information Archive mapped concentrations indicate large areas of the UK where air pollution levels are well below the national air quality objectives, and only large conurbations and major roads appear to have poor air quality.

3.2.4 This trend is reflected in the local study area. Up until 2009, it 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.

3.2.5 Air quality effects on vegetation vary. Mapping of exceedences of critical loads of habitats across the UK has indicated that between 23 - 86% of ecosystems within the broad Biodiversity Action Plan (BAP) category of habitats experienced an exceedance of critical load (CEH, 2004). This is also true of the local area with 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.

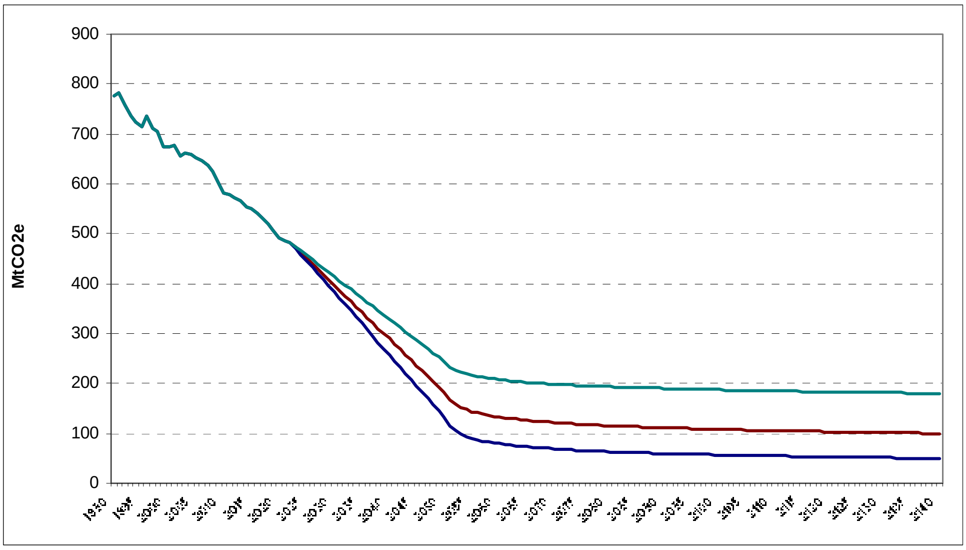
3.2.6 The global and UK emissions in 2009 and predicted increase is summarised in Figure 3.1 and Figure 3.2. It should be noted that the UK emissions includes reductions targets, but the steady increase in global emissions levels don't take account of international policies for reduction.

Figure 3.1 ENSEMBLES Global mitigated anthropogenic GHG emissions



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 3.2 Annual UK GHG emissions; observed and predicted



3.2.7 Aggregates are the most widely used construction material and account for around 85 per cent of non-energy mineral extraction in the UK (ISSB 2009). The aggregate and concrete market in the UK operates at a national level, with 100 per cent of aggregates coming from within the country (QPA 2009). There are three main sources for aggregates: marine dredged sand and gravel, land-won aggregates, and secondary or recycled sources[4].

3.2.8 Local aggregate markets are preferable for construction projects, as aggregates are heavy materials that are generally required in large quantities and therefore transport costs are a significant component of their cost. However, this preference for local sources is balanced by the requirement for the right types of aggregates in the right quantities, which may require sources from further afield. The choice of aggregate type and sources is also driven by purchasing policies, such as any targets for the secondary or recycled aggregates or more sustainable (non-road) transport methods.

3.2.9 Wales has 54 quarries and 14 wharves for marine-dredged aggregates and South West England has 70 quarries and 8 wharves. The two regions produce nearly 20 per cent of the UK's aggregates (QPA 2009).

3.2.10 The steel industry operates globally, with China producing 37% of the world's steel in 2007, and the UK only producing 1%. Four of the UK's 13 steelmaking and rolling mills are located in South Wales (UK Steel 2009). Steel is readily recyclable, with 5.2 million tonnes being recycled by UK steel.

3.2.11 The UK's energy consumption in 2008 was 165 million tonnes of oil equivalent, of which 3 per cent was used by the construction industry. The construction industry's energy use by fuel type was 31% petroleum products, 44% natural gas and 25% electricity.

[4] Recycled aggregates are reprocessed construction and demolition waste, e.g. recycled concrete from a demolition site. Secondary aggregates are by-products of industrial processes e.g. pulverised fuel ash from coal fired power stations, incinerator bottom ash from waste incinerators.

3.2.12 Water abstraction in Wales and the South West is predominantly from surface water supplies, and pressure on water supplies is increasing, through increased demand from population growth and seasonal reductions in availability as a result of climate change (Defra 2008). Environment Agency data indicate that there is limited water available for abstraction in the proximity of the Severn Estuary (EA 2009).

3.2.13 There are targets in both Wales and England to reduce and recycle waste (WAG, 2002; WAG, 2009, Defra, 2007). There are 137 landfills across Wales, South West England and the West Midlands (Environment Agency reporting areas), which include hazardous, non-hazardous and inert waste landfills. There are 289 treatment facilities which include a range of activities such as recycling, composting, processing, etc, some of which may be more relevant to the STP project than others.

3.2.14 In general across the UK, landfill void-space and projected landfill lifespan are in decline as existing landfill sites are filled, with very limited increases in capacity being developed or permitted. There is limited landfill availability in the regions local to the STP project. Note that there are no hazardous waste facilities available in Wales and only 3 in the South West/ West Midlands.

Baseline during construction (2014 – 2020)

3.2.15 There are significant improvements in air quality in the UK 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. It is assumed that these national improvements in air quality would extend to the local study area. Therefore, it is expected that some reduction in the number of AQMA's within the study area would occur, with potentially all of the AQMA's declared for NO_2 being revoked by 2020. In line with air pollutant concentrations in ambient air, pollutant deposition levels on vegetation are also predicted to decrease over time, both nationally and within the study area. Predictions rely heavily upon estimated improvements in road vehicle technology and reductions in emissions of NO_X.

3.2.16 Global greenhouse gas emissions are predicted to increase as shown in Figure 3.1 above, but UK emissions are predicted to decrease according to the Low Carbon Transition Plan (DECC, 2009).

3.2.17 Aggregates appear to be readily available in South Wales and South West England (South Wales RAWP 2008, South West RAWP 2008), and this can be expected to continue to be the case during the construction period (2014 to 2020), unless there is a significant shift in policy. Demand for recycled and secondary aggregates has been and would continue to be driven by environmental legislation[5].

3.2.18 The supply of steel during the construction phase of the STP project would be influenced by the domestic and global economies, which would affect steel prices and the time delay between order and delivery. The global steel industry accounts for '5 to 6 per cent of man-made carbon dioxide emissions' (FT 2009b) and therefore environmental legislation, such as carbon taxes, may affect cost. It is possible that the effects of such legislation could result in the scaling back of the UK steel industry, and therefore lead to an increase in imported steel.

3.2.19 National energy policy, including the Renewable Energy Strategy (HM Government 2009) which sets a target of 15 per cent renewable energy for 2020, would affect the energy supply mix, rather than its availability. Transport and construction operations

[5] E.g. EU Landfill Tax, Aggregates Levy.

are likely to continue to be predominantly fossil-fuel based during the construction phase. Climate change is likely to affect season availability of water in the future as well as demand.

3.2.20 The availability of waste management facilities and recent policy means that there is likely to be a reduction in waste going to landfill and an increase in other waste management options. The Welsh Assembly Government is proposing that by 2019/20, 90 per cent of nonhazardous and inert construction and demolition waste should be recycled, recovered, or reused. In addition, it is proposing that by 2015/16, there should be landfill diversion of 50 per cent of 2007 levels, and 75 per cent by 2019/20 (WAG 2009).

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

3.2.21 Insufficient data exist to robustly estimate future air quality between 2020 and 2140. However, air quality across the UK and in the study area is 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). These anticipated continued improvements in ambient pollutant concentrations would also lead to reductions in the levels of pollutant deposition on vegetation over time.

3.2.22 The global greenhouse gas emissions curve in Figure 3.1 has been based on IPPC predictions (A2 scenario) until 2100, and then is predicted to continue until 2140.

3.2.23 For the UK, Figure 3.1 has been assumed that there is a gradual decrease in emissions from 2022 towards the 2050 target of 80% reduction (DECC 2009). Error bands for an upper and lower estimate have been provided to take account of future uncertainty and are based on those provided in the Low Carbon Transition Plan (DECC, 2009c). The emissions assume that there is no Severn Tidal Power scheme as this could affect emissions (HM Government 2009). Beyond 2050 the emissions projections are most uncertain as they assume implementation of all current UK Policy and have been generated using logarithmic projections and incorporate wide error bands.

3.2.24 Although there is no policy to support predictions of resource availability during this period, if it would seem reasonable to assume that sustainability and climate change would continue to be key policy drivers, meaning that the following trends described above are likely to continue:

- increasing preference for secondary and recycled aggregates
- increase in steel prices and use of recycled steel
- fossil fuel use is expected to decrease, and renewable energy supplies increase.

3.2.25 The security of the UK's water supply is expected to worsen, as the impacts of climate change are more strongly felt. Annual average precipitation across the UK may decrease by up to 15% by the 2080s, and the seasonal distribution of precipitation would change, with winters becoming wetter and summers drier. The water industry will be undertaking work to embed the UKCP09 scenarios into its long term planning..

3.3 Significant environmental effects

3.3.1 This section considers, within this theme, the likely significant effects on the environment and the certainty of this assessment for each alternative option and the interactions between these effects. The full methodology for identifying these significant environmental effects is set out in the Environmental Report.

3.3.2 Consideration has also been given to the potential effects of combination options and multiple basin options although this has not been subject to the same level of detailed assessment as the individual shortlisted options. Alternative options are summarised in Table 2.2 and shown in Figure 2.1.

3.3.3 There are a number of effects that are common to all options. These are summarised and then discussed with reference to each option below:

3.3.4 Effects during construction comprise:

- Direct and indirect negative effects from use of raw materials and the emissions to air associated with their use and manufacture. This affects resources, national air quality, national and global greenhouse gas emissions. Assumptions on embodied carbon and other emissions are based on published sources[6]. The use of embankment materials was predicted to be significant for all options except the B5 Beachley Barrage, but other raw materials were not assessed as significant. Emissions to air. were generally not assessed as significant, with the exception of the greenhouse gas emissions associated with the B3 Brean Down to Lavernock Point Barrage. There are significant indirect effects arising from all options due to additional requirements for quarrying or dredging.

- Direct and indirect negative effects on air quality and greenhouse gases from transportation of materials. Transportation includes both road/rail traffic and shipping movements. Where smaller vessels would be required for movement of construction materials, emissions to air would be slightly elevated. This affects energy use, local and national populations and vegetation along traffic routes, in addition to UK greenhouse gas emissions. Assumptions have been made on the source of materials and this is set out in Table 3.1 below. There would also be some far-field effects from aggregates, embankment materials and steel production as imported materials would be required. These effects were not predicted to be significant.

- Direct and indirect negative effects on air quality and greenhouse gases due to transport and plant operation on site. These effects were not predicted to be significant.

- Direct negative effects from the use of water and carbon emissions associated from its use, which affects UK greenhouse gas emissions. These effects were not assessed as significant.

- Direct negative effects from waste generated and effects on treatment and recycling of waste (e.g. steel), energy recovery for waste (e.g. timber), landfill facilities (e.g. hazardous waste). There is some uncertainty in the quantities of waste produced for each option and so this is largely based on resource use. It is assumed that both dredged material and spoil would either be reused in

[6] University of Bath , 2008;

construction or for habitat creation. These effects were not assessed as significant.

- Cumulative negative effects on availability of aggregates and embankment materials from construction of proposed projects including nuclear and gas fired power stations, Severn Airport and Highways projects such as the new M4. No cumulative effects on air quality from building of four power stations within the area are anticipated. These effects were not assessed as significant.

Table 3.1 Assumptions of materials and sources

	Alternative Option				
Material	**B3**	**B4**	**B5**	**L2**	**L3d**
Aggregates for concrete	UK	Wales	South West	UK	UK
Sand/ gravel	UK	UK	UK	UK	UK
Crushed Rock	UK	UK	Wales	UK	UK
Armoured Stone	Scandinavia	Scandinavia	Scotland	Scandinavia	Scandinavia
Steel rebar	Overseas*	UK	UK	Overseas*	Overseas*
Steel Formworks	Overseas*	Overseas*	Overseas*	Overseas*	Overseas*
Timber	Scandinavia	Scandinavia	Scandinavia	Scandinavia	Scandinavia
Turbines	Far East	Far East	Far East	Far East	Far East

* Europe, Far East or US.

3.3.5 Effects during operation comprise:

- Direct positive significant effects from use of renewable energy, resulting in a saving in emissions that would otherwise be produced by other sources of electricity[7]. This reduces national and global greenhouse gas emissions and provides air quality improvements for the national population and vegetation through reduced fossil fuel combustion.

- Direct negative effects from maintenance and operations such as transportation, generation of waste, use of materials, energy and water. It is not expected that these would be significant demands in relation to resource use, although data is limited as to maintenance requirements at this stage. These effects were not assessed as significant.

- Replacement of turbines would have a small direct effect on national greenhouses gas emissions as there would be a temporary reduction in

[7] Note that these displaced emissions would decrease over the lifetime of the project as UK grid electricity, following UK Policy, will be decarbonised.

renewable energy generated. There would be far-field negative effects due to manufacture and transportation from overseas. These effects were not assessed as significant.

- Direct negative effects from dredging for navigation and pumping to maintain land drainage. This would affect national greenhouse gas emissions and sites which would need to be found for the re-use or deposition of dredged material. Effects arising from emissions were not predicted to be significant but disposal of dredgings was a significant effect.

- Indirect positive and negative effects from carbon sequestration (carbon stored within living material) due to changes in intertidal habitat, particularly saltmarsh, and organic content in sediment which would be deposited or water which would be impounded. It is not believed that loss of mudflat would cause sequestered carbon to be released due to siltation. There is some uncertainty related to these effects. Compensatory habitat (see section 5.3) has not been included within the carbon footprint as there is insufficient detail on the extent and type of habitat which could be created.

- Indirect positive and negative effects from methanogenesis, i.e. methane (a greenhouse gas) released from decomposition of organic matter when intertidal areas become permanently flooded, particularly mudflats. There is some uncertainty related to these effects.

Table 3.2 below provides a summary of the likely effects of changes to the areas of saltmarsh and mudflat immediately following the implementation of an STP option as estimated by the Marine Ecology Topic Paper. Likely effects 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 3.2 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
NB – Estimates for saltmarsh and mudflat are for immediate changes following STP implementation.					

3.3.6 Decommissioning effects include direct emissions from shipping and transportation. Although resource use would be low, there would be a significant quantity of recycled aggregates and other materials produced during decommissioning. There is uncertainty associated with decommissioning such as the extent of structure removal, and the predicted improvements in air quality and emissions in 2140.

Alternative Option B3: Brean Down to Lavernock Point Barrage (also known as Cardiff to Western)

3.3.7 B3 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. Key features include a total of 129 caissons. The central point includes a 778m long embankment The estimated annual energy output for the variant (including 5% outages) is 15.1 to 17.0 TWh/year.

3.3.8 The construction of B3 requires large quantities of raw materials, including aggregates, steel, energy and water (Table 3.3 below). However, there are opportunities for recycled materials, particularly sand and gravel from dredging, which are suitable for various uses within the structure and associated works. There are effects on air quality and climate associated with the production and transportation of raw materials, although none of these were predicted to be significant.

3.3.9 There are no significant effects on waste receptors during construction, although there would be the requirement to recycle steel and local energy recovery sites would take waste from timber and from offices and canteens. There would be a requirement for some landfill, although quantities are not assumed to be significant due to use of other waste management options, such as recycling.

3.3.10 This option produces the largest amount of renewable energy during operation, but also requires the largest amount of maintenance dredging for navigation. Nonetheless it offsets the greatest amount of emissions, with a fairly short carbon payback period[8] estimated at approximately two and a half years (Table 3.3, median of low and high estimates). There is some uncertainty associated with emissions offsetting and carbon payback, due to the range of assumptions on which calculations are based. In particular, is the uncertainty associated with estuarine changes and how carbon in ecosystems would be stored or released as a consequence. This is reflected by giving a range for results. For option B3 there is the greatest predicted decrease in saltmarsh (approximately - 210 ha) and other intertidal habitat, but an increase in sedimentation (approximately 500 Mm^3). This has been taken into account in carbon payback.

3.3.11 During operation there would be the requirement to find sites to re-use dredged materials and during decommissioning for recycled aggregates from removal of the structures.

Alternative Option B4: Shoots Barrage

3.3.12 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. The estimated annual energy output for the variant (including 5% outages) is 2.7 to 2.9 TWh/year.

[8] The carbon payback period is calculated by dividing the total emissions from construction, operation and decommissioning by the emissions which have been avoided through generation of renewable electricity.

3.3.13 Of the five alternative options, only the B5 Barrage is smaller than the Shoots Barrage, and it therefore generally requires fewer resources than the majority of options. However, it is still a sizeable structure and there is likely to be less opportunity to use recycled aggregates as the soft muds from dredging for this structure are less suitable than sand and gravels. As can be seen from Table 3.3, it is also assumed that some materials can be sourced locally, such as concrete from South Wales which reduces transportation distances. These factors reduce the overall emissions to air.

3.3.14 The types of effects arising from waste would be similar to the B3 Barrage described in paragraph 3.3.9, with a requirement for recycling and recovery during construction, as well as sites for re-use of dredged and structural materials during operation and decommissioning respectively.

3.3.15 The B4 Shoots Barrage produces less renewable energy than the majority of options and would require maintenance dredging for navigation during operation. As a smaller structure, it also requires fewer materials and produces fewer emissions during construction. It does not offset as much emissions as some of the other options, but carbon payback is at 3.5 years which is fairly similar to other options.

3.3.16 The B4 Barrage creates approximately 140ha of saltmarsh due to decreased inundation and is predicted to have approximately 300Mm^3 of siltation, both potential means of storing carbon.

Alternative Option B5: Beachley Barrage

3.3.17 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. There are a total of 31 caissons spread across approximately 1.5km of the length of the barrage and flanked by two embankments. The estimated annual energy output for the variant (including 5% outages) is 1.4 to 1.6 TWh/year.

3.3.18 The requirements for materials such as aggregates and steel are not surprisingly the lowest of all the options (Table 3.3). Like the Shoots Barrage, this means that more materials can be locally sourced (Table 3.3), which reduces emissions to air.

3.3.19 However, due to its location, it is assumed that the majority of maritime transportation and construction would be via small vessels. This increases emissions to air in comparison with use of fewer, larger vessels.

3.3.20 Effects arising from waste would be similar to the B3 Barrage, with a requirement for recycling and recovery during construction, as well as sites for re-use of dredged and structural materials during operation and decommissioning respectively. As the smallest structure, the quantities of waste for recycling and recovery are also likely to be smallest.

3.3.21 This structure would generate the smallest amount of renewable energy of all the STP options and also requires maintenance dredging for navigation and therefore potential for offsetting future emissions is lowest. However, due to the smaller amount of embedded carbon from smaller resource use and scale of construction, the payback period is also likely to be one of the lowest at 2.8 years (median of high/low estimates). The barrage is predicted to create approximately 80ha of saltmarsh due to decreased inundation and cause approximately 150Mm^3 from siltation.

Alternative Option L2: Welsh Grounds Lagoon

3.3.22 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. It has 32 caissons. The estimated annual energy output (including 5% outages) is 2.6 to 2.8 TWh/year.

3.3.23 The demand for aggregates is high for both the lagoon options, due to the length of the embankments and greater requirement for material in their construction. There is also limited opportunity for reuse of dredged materials, mainly due to the quality of dredged materials in the lagoon location (silts and mud, rather than sand, gravel and hard rock). Demand for other resources, including steel and water is similarly high (Table 3.3).

3.3.24 Due to high embodied emissions and greater emissions during transport and construction, emissions to air are also high for lagoon construction. However, this option would not require maintenance dredging for navigation meaning emissions during operation would be much lower. The lower energy output than barrage structures means that the carbon payback period is highest at 6.1 years. The Welsh Grounds Lagoon is predicted to create approximately 80ha of saltmarsh and cause approximately 300Mm^3 of siltation which has been taken into account.

3.3.25 Effects arising from waste would be similar to the B3 Barrage, with a requirement for recycling and recovery during construction, as well as sites for re-use of dredged and structural materials during operation and decommissioning respectively.

Alternative Option L3d: Bridgwater Bay Lagoon

3.3.26 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. Key features include a total of 42 caissons and approximately 12km of embankment. The estimated annual energy output for this variant (including 5% outages) is 5.6 to 6.6 TWh/year.

3.3.27 Demand for virgin aggregates is highest for the Bridgwater Bay Lagoon with limited opportunities for use of recycled materials due to the nature of the material dredged. There are also high demands for water and steel (Table 3.3).

3.3.28 Emissions to air are similarly high during construction, but low in relation to maintenance dredging for navigation. This option produces more renewable energy than the majority of other options and the carbon payback period is predicted to be about 3.2 years (median of high-low estimates). The Bridgwater Bay Lagoon would create approximately 250 ha of saltmarsh due to decreased inundation and cause approximately 45Mm^3 of siltation, both of which could store carbon and have been taken into account in the payback period.

3.3.29 Effects arising from waste would be similar to the B3 Barrage, with a requirement for recycling and recovery during construction, as well as sites for re-use of dredged and structural materials during operation and decommissioning respectively.

3.3.30 The use of multiple basins has also been considered for this option to better align energy yield and peak demands and provide the possibility of continuous power (see paragraph 2.3.4 above). Although this could improve energy generation, more resources would be required to construct the dyke and additional dredging would be required. There would be related effects on emissions to air from embodied emissions and transportation. The double basin design also relies upon pumping which would increase the carbon emissions arising compared to the standard L3d option.

Combinations

3.3.31 There are two possible combinations of options identified (paragraphs 2.3.5 - 2.3.6):

- B4 Shoots Barrage and L3d Bridgwater Bay Lagoon could be built together. These could either be constructed sequentially or concurrently.
- B3 Brean Down to Lavernock Point Barrage and L3d Bridgwater Bay Lagoon would need to be constructed sequentially due to the large resource requirements.

3.3.32 Both combinations would involve the resource requirements, and therefore embodied emissions described above. However, if construction of both options was happening at the same time there may be more opportunities to re-use waste materials from one structure in the other structure. This would, however, be limited in relation to aggregates for embankment materials which is probably the significant resource requirement due to the quality of dredgings.

3.3.33 For the concurrent construction of B4 and L3d scheme there may be opportunities for a reduction in carbon emissions and air pollutants arising from transportation of materials to site, due to the opportunities for bulking-up deliveries and/or using larger vehicles to deliver a greater pay-load. There may also be opportunities to use joint facilities, for example construction yards, equipment, workforce and these economies could reduce overall carbon footprint of the two options. The same would apply for decommissioning although it should be noted that there would be additional pressure on finding sites for re-use of waste materials.

3.3.34 For both combinations of options with the L3d Bridgwater Bay Lagoon, energy yields are likely to be lower than the sum of the individual energy yields due to a reduction in spring tides. This is likely to be in the order of 5% for L3d and B4 (Shoots Barrage) and 15% for L3d and B3 (Brean Down to Lavernock Point).

Table 3.3 Predicted Air & Climatic, Resources & Waste: Selected Statistics

Factor	Receptors	B3 Brean Down to Lavernock Point Barrage	B4 Shoots Barrage	B5 Beachley Barrage	L2 Welsh Grounds Lagoon	L3d Bridgwater Bay Lagoon
Construction						
Net annual demand for virgin aggregates and embankment materials (m tonnes) (proportion assumed to be from reused project dredging materials and not included in total) (note 1)	Resources, waste, national population, local population, protected habitats – local and national, UK and global greenhouse gas emissions	3.6 (61%)	3.1 (28%)	0.4 (50%)	13.9 (5%)	17.9 (0%)
Total steel demand: UK sourced (rebar) /International (m tonnes)	Resources, waste, national population, local population, protected habitats – local and national, UK and global greenhouse gas emissions	0.36/ 1.933	0.17/ 0.177	0.08/ 0.104	0.29/ 0.108	0.30/ 0.823
Total water use (m3)	Resources, national population, local population, protected habitats – local and national, UK and global greenhouse gas emissions	1,301,623	133,948	69,435	183,085	373,528
NOx emissions during construction period (Tonnes)	National population, local population, protected habitats – local and national	110,443	25,172	7,247	84,523	84,651
PM^{10} emissions during construction period (Tonnes)	National population, local population, protected habitats – local and national	2,345	514.3	152.1	1,089	1,672
SO^2 emissions during construction period (Tonnes)	National population, local population, protected habitats – local and national	27,615	5,582	1,949	16.708	16,708
GHG emissions during construction period (Mt CO_2)	UK and global greenhouse gas emissions	14 - 28	2.3 – 4.5	0.8 – 1.6	7 -14	8 - 15
Operation						
NO_2 Offsetting (kT) over lifespan of option (note 1)	National population, local population, protected habitats – local and national	1.8	-3.5	-1.1	2.9	1.7
PM_{10} Offsetting (kT) over lifespan of option (note 2)	National population, local population, protected habitats – local and national	-0.1	-0.2	-0.1	0.1	0.00

Factor	Receptors	B3 Brean Down to Lavernock Point Barrage	B4 Shoots Barrage	B5 Beachley Barrage	L2 Welsh Grounds Lagoon	L3d Bridgwater Bay Lagoon
SO_2 Offsetting (kT) over lifespan of option (note 3)	National population, local population, protected habitats – local and national	3.5	-0.7	-0.6	2.1	1.3
Dredging for navigation (Mm^3/yr)	Resources, local population, local protected habitats, UK greenhouse gas emissions	2	1.75	1	0	0.06
Base net emissions displaced (Mt CO_2) (low-high estimates) (note 2)	UK and global greenhouse gas emissions	-114 (-147, -78)	-22 (-34, -16)	-13 (-20, -9)	-17 (-30, -9)	-47 (-54, -29)
Base carbon payback (yrs) (low-high estimates)	UK and global greenhouse gas emissions	2.6 (-0.8, 7)	3.5 (-6.3, 7.8)	2.8 (-5.7, 7-7)	6.1 (-4.2, 13.3)	3.2 (2.6, .8.5)
Decommissioning						
GHG emissions (Mt CO2)	UK and global greenhouse gas emissions	0.7-3	0.1-0.4	0.03-0.07	0.4-0.75	0.3-0.7

(1) Includes for aggregates for concrete (structures, ballast and precast armouring) and primary aggregates for embankment & breakwater fill, sand ballast & seabed (sand, gravel & crushed rock)

(2) Offsetting was calculated using the Options Definition Report (STP, 2010), emissions factors for fossil fuel derived electrical power were used from the NAEI database, taking into account the gradual reduction of the fossil fuel mix of electrical power generation by ensuring that fossil fuel air pollution emissions remained proportionate to the CO^2 emissions from overall power generation (DECC, 2009b).

(3) i.e. Total emissions from construction/ operation and decommissioning / avoided emissions), the Climatic Factors Paper sets out a range to take account of 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

SECTION 4

INTERRELATIONSHIPS

4 INTERRELATIONSHIPS

4.1.1 The SEA Directive requires that the interrelationships between likely significant effects are described (SEA Directive Annex 1 (f)). This theme paper therefore summarises the interactions between related topics and thereby ensures that the many complex issues that are not self-contained within a given topic are recognised and their implications understood. Each theme paper also examines the relationships between this theme and other themes within the STP SEA.

4.2 Interrelationships between topics within Air & Climatic Factors and Resources & Waste theme

4.2.1 There are interrelationships between resources and emissions to air during construction. These comprise:

- The type of resource or material used (e.g. aggregates, steel, water) and how it is processed would affect the quantity of emissions. For instance, embodied carbon emissions are higher for steel than concrete.
- The quantities of materials used would also affect emissions. This is not only due to the embodied emissions set out above, but this also affects the source and thus transportation of materials. For instance, the B4 Shoots and B5 Beachley Barrages require smaller quantities of concrete and it is assumed that aggregates can be sourced from Wales and the South West, whereas for the other options, aggregates would sourced throughout the UK for concrete production.
- The location of materials also has an effect on air emissions due to transportation. For instance it has been assumed that armour stone would need to be imported from Scandinavia for all options with the exception of the B5 Beachley Barrage, which would be imported from Scotland .
- The type of transport and vehicle used for materials and waste also affects emissions to air. Use of many smaller vessels is less efficient than use of many larger vessels. Whether the road or rail transport is used affects air quality for communities and vegetation along main transport routes
- Reuse of materials, which although requires some energy inputs, does reduce the requirement for raw materials and their transportation. The main area for reuse is dredging material for construction of the alternative options, in particular sand and gravel. Another example is the re-use of steel formwork would reduce the requirement to import from the Far East and transport emissions associated with this.
- The amount of waste generated and transport mode to waste treatment facilities would also affect greenhouse gas emissions and local air quality.

4.2.2 The interrelationships during operation are mainly limited to materials, energy inputs and waste generated for the operation and maintenance of the option. This is comparatively small compared with the construction phase, and similarly to construction would have an effect on emissions to air through embodied emissions of raw materials and transportation to the site.

4.2.3 Turbines would need to be replaced periodically throughout the lifespan of each of the alternative options and in addition to sourcing the steel turbines from the Far East, there would be emissions in relation to their long distance transport and temporary reduction in renewable energy generated during installation.

4.2.4 Interrelationships during the decommissioning phase would be similar to those described under construction above.

4.3 Interrelationships between Air & Climatic Factors and Resources & Waste and other themes

4.3.1 There are several interrelations between this theme and other themes. Interrelationships during construction and operation are discussed below.

Construction

4.3.2 According to the Supply Chain Survey Report (2010), the current UK market could only provide enough materials for the B5 Beachley Barrage. Additional resources would be required for other options, such as imported material, increasing the capacity of existing UK sources or additional dredging licenses. For instance, the L3d Bridgwater Bay Lagoon would require a third of the UK's annual supply of aggregates. The cumulative demand of an STP project over and above usual supply would therefore be likely to require an expansion of dredging or quarrying activities. Although use of UK sources would reduce air emissions within this theme, it would have effects on local and UK dredging and quarrying activity. These effects are covered within the Other Sea Uses Topic within the Society and Economy Theme.

4.3.3 The size of the workforce would vary depending on the scale of construction required for each option, with a total of 43,500 workers predicted for the B3 Brean Down to Lavernock Point Barrage, 11,000 workers for the Shoots Barrage, 8,000 for the Beachley Barrage, 18,000 for the Welsh Grounds Lagoon, and 29,500 for the Bridgwater Bay Lagoon. Their living accommodation and transportation would affect emissions. For the Air and Climatic Factors Topic, assumptions were made on accommodation and commuting based on patterns of from other major construction projects. The effects of the workforce are covered in the Communities Topic within the Society and Economy Theme. The effects have been considered, but do not have a significant effect on the carbon footprint of each option.

4.3.4 The sources and use of materials during construction would affect the landscape and seascape, both through extraction from the source of materials and from the visual effect of the structure, and these are covered in the Landscape and Seascape Topic.

Operation

4.3.5 Impeded drainage due to reduction in the low tide level may require pumping to prevent flooding in some areas. The area of impeded drainage ranges from approximately 47km^2 for the L2 Welsh Grounds Lagoon to 372km^2 for the B3 Brean Down to Lavernock Point Barrage. This is covered under the Flood Risk and Land Drainage Topic within the Physicochemical Theme. Increased pumping would increase energy use and carbon emissions. The pumping requirements have been included in the carbon footprinting assessment.

4.3.6 Changes to the estuary due to operation of an STP option include elevated water levels outside of impounded areas (with the exception of the Bridgwater Lagoon) and increased erosion of the foreshore in some areas. The former would require raising of tidal defences by a maximum of 0.3m over about 60km for the B3 and B4 barrages, 95km for the B5 Barrage and 25km for the L2 Lagoon (no raising is required for the L3d Lagoon). In addition, revetment would be required to prevent erosion of the foreshore. The estimates for length of revetment vary from approximately 10km for the B5 Barrage and L2 Lagoon to up to 200km for the B3 Barrage. These additional works would have implications for use of resources, particularly aggregates as well as emissions to air, both through embodied emissions and transportation of materials. These effects have not been included within this assessment but can be clarified during detailed design (see section 7.2). The requirements for additional flood defence works are covered in the Flood Risk and Land Drainage Topic within the Physicochemical Theme.

4.3.7 The barrage options would require increased maintenance dredging to keep shipping channels open. The extent of dredging varies with each option but is greatest with the B3 Brean Down to Lavernock Point Barrage, the least dredging is required for the Lagoon options due to avoiding effects on navigational requirements within this structures. The greater the extent and frequency of dredging, the greater the emissions to air during operation. There is also the requirement to find sites for marine disposal of dredgings which relates to waste management.

4.3.8 There is potential for increased emissions due to possible changes in navigational requirements incurred by each option, which has been identified by the Phase 2 Regional Economic Impact Study (STP Regional Workstream, 2010). For example, re-routing of vessels or delay in delivery times would mean more fuel is used. The Navigation Topic, which is covered by the Society and Economy Theme, has assumed that measures would be put in place to reduce or prevent delays and reduce the requirement for vessels to be re-routed to other ports as far as possible (see section 5 below). No specific data has been produced to date on the actual tonnage which may still need to be diverted during operation of any of the STP options. However, it has been estimated that up to 40% of the cargo destined for Bristol Port could be rerouted to other ports for the B3 Barrage Option and would require rail transfer back to Bristol. This has been included in the carbon footprint assessment.

4.3.9 Employment of workers required during operation is small in comparison with the construction of STP options, ranging from 850 for the B3 Brean Down to Lavernock Point Barrage to 90 for the Beachley Barrage. It is expected that operational workers would be employed locally. This is covered by the Communities Topic (Society and Economy Theme). Transport emissions have been considered within the carbon footprint of each option but are not considered significant.

4.3.10 There are a number of relationships between the Physicochemical Theme, particularly the Hydraulics and Geomorphology topic, and climatic factors. These are associated with estuarine and habitat changes and how these would affect the sequestration or release of carbon dioxide and other greenhouse gases. Where possible, the carbon footprint has incorporated these effects (see Table 2.1) with some degree of uncertainty, although some processes such as dentrification, have not been quantified as part of this assessment.

4.3.11 Due to changes in the tidal range (i.e. reduced high tide and higher lower tides) upstream and downstream of barrage options and within impounded areas of lagoons, the extent of intertidal habitats would change. A gain in areas of saltmarsh above the new high tide levels, would mean increased carbon sequestration. Areas of intertidal mudflat would be lost as they would become permanently submerged, although it is thought that there would be no change to this carbon store. However, there would be an increase in methanogenesis due to anaerobic conditions generated by the subtidal environment.

4.3.12 Siltation is also predicted as a result of STP options and the build up of material behind a barrage or lagoon could lead to a build up of organic matter which would sequester carbon. De-nitrification may also occur in these circumstances, a process which releases nitrous oxide.

SECTION 5

MEASURES TO PREVENT, REDUCE AND AS FULLY AS POSSIBLE OFFSET ANY SIGNIFICANT ADVERSE EFFECTS

5 MEASURES TO PREVENT, REDUCE AND AS FULLY AS POSSIBLE OFFSET ANY SIGNIFICANT ADVERSE EFFECTS

5.1.1 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 (SEA Directive Annex I). These measures are considered within this theme paper in terms of the interrelationships between topics within this theme.

5.1.2 In this SEA, and in line with UK practice, these measures are split into those to prevent or reduce effects and measures to as fully as possible offset any significant adverse effects on the environment. Offsetting measures make good for loss or damage to the environment, without directly reducing that loss/damage.

5.2 Measures to prevent or reduce significant adverse effects

5.2.1 The measures that have been incorporated into the alternative options were the assumptions that:

- Dredged material would be used, where possible, in the permanent works, and material that could not be used for permanent works might be used for 'topographic modification' to provide new habitat as a prevent/ reduce measure.
- Onshore cut and fill work would be designed such that no spoil would need to be disposed of.
- In addition to use of HGVs, assumed transport plans for the barrage options have included non road vehicle methods for the transport of construction materials during the barrage construction phase.

5.2.2 During operation, measures which have been incorporated into option development to avoid or reduce navigational effects would also benefit emissions to air, such as:

- 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 B5 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.
- The size of the lock structures has been adjusted in order to accommodate the larger vessels especially post-Panama.

5.2.3 In terms of carbon emissions, the greatest proportion of total emissions occur during construction as seen in Figures 5.1 and 5.2 below. These are based on the Supply Chain Survey Report (2010) and therefore only include construction of a Severn Tidal Power Option, without including ancillary development and construction facilities at this stage. However, this illustrates the type of activities that produce high emissions and measures to further prevent or reduce effects should be focused on these activities.

Figure 5.1 Component breakdown of carbon emissions

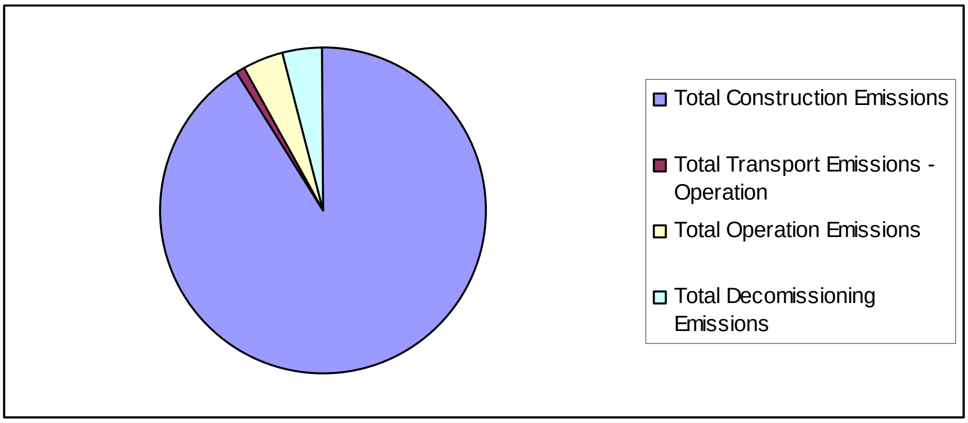
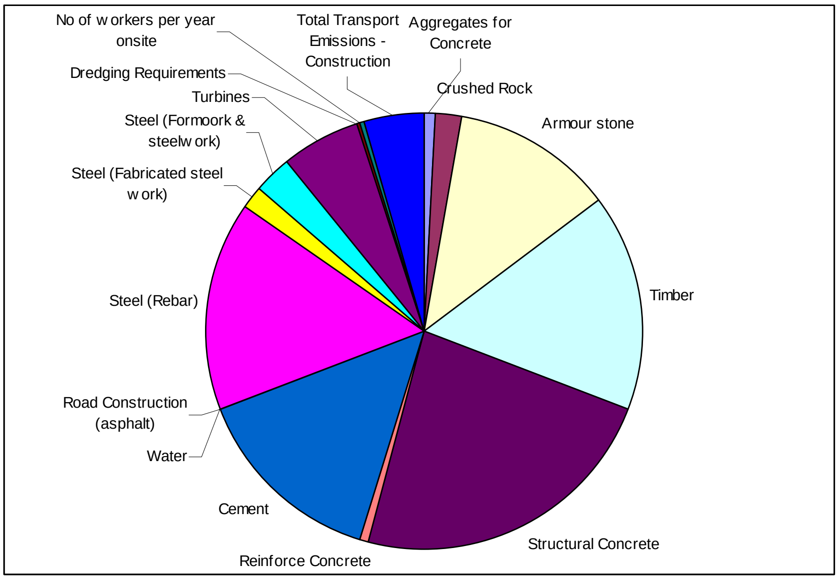


Figure 5.2 Breakdown of construction carbon emissions



5.2.4 Measures which could be incorporated into alternative options to reduce these effects on air emissions, through transport or use of materials, in addition to reducing the use of resources comprise:

- Supply of materials and manufactured components should be in the UK where at all possible.

- Where supply from outside the UK is required the most efficient means of production and transportation should be sought.

- Identification of opportunities to use secondary and recycled aggregates in place of virgin aggregates,

- Liaison with suppliers such as water companies, steel suppliers and aggregates bodies to secure supply.

- Manage each phase of work to minimise waste and manage the waste that is produced as high up the waste hierarchy as possible (i.e. reuse, recycle, recovery, with landfill as the last resort). This would be particularly beneficial for spoil arisings.

- Optimisation of materials delivery to and on site so that it is direct to localised holding sites and final locations. In addition, the removal of waste and optimised site locations for pick up.

- Introduction of a Sustainable Transport Plan during construction and promotion of the use of some carbon efficient forms of transport and construction, e.g. those which exclude forms of combustion.

- Use of larger vessels rather than smaller vessels would optimise the emissions to atmosphere.

- Renewable energy (temporary or permanent) could 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.

5.2.5 During operation it is believed that be channelling the flow of water through the lagoon or barrage may reduce the quantity of dredging in these areas and thus reduce some of the emissions associated with dredging. Renewable energy options that complement the tidal power option could be considered during the life of the project.

5.3 Measures to as fully as possible offset significant adverse effects

5.3.1 Although there are no particular offsetting requirements for this theme, it should be noted that provision of compensatory measures required by Directive 92/43/EEC (the Habitats Directive), should provide carbon sequestration function lost in the intertidal habitat for each option. The provision of compensatory habitat relates to the requirement to replace habitat designated under the Habitats Directive, in this case it is largely intertidal habitat and is covered with the Marine Ecology Topic Paper in the Biodiversity Theme.

5.3.2 It has not been possible to calculate the carbon footprint of compensatory habitat and similar offsetting measures, as the details relating to the extent and type of habitat that could be provided for each option has not been specified within this study. This requirement would need to be specified at a later stage of the Habitats Regulations Assessment process if a STP option were to be taken forward.

5.3.3 Nonetheless compensatory habitat would need to based on the type and extent of habitat lost for each option. In carbon sequestration terms, it would therefore be expected to at least provide carbon storage to that which was initially lost. As a guideline, the assessment of carbon emissions from loss of intertidal mudflat and saltmarsh for each option is given in Table 3.2, and this process would be reversed for where habitat losses are shown. It should be noted that other types of habitat are affected, but these are the most extensive in terms of carbon sequestration functions. It should also be noted that works required to create compensatory habitat and other offsetting or compensatory measures would also have a carbon footprint, but this would need to be calculated at a later stage of option development.

SECTION 6

SEA OBJECTIVE COMPLIANCE

6 SEA OBJECTIVE COMPLIANCE

6.1 Compliance with SEA objectives

6.1.1 The SEA Objectives which were drafted and consulted upon as part of the Phase 1 SEA scoping stage are set out in Section 2.2. This theme paper identifies any interactions or inconsistencies between topics within this theme with regards to the assessment against SEA Objectives.

6.1.2 The performance of the alternative options against SEA objectives for the Air & Climatic Factors and Resources and Waste Topics are summarised in Table 6.1 below.

Alternative Option B3: Brean Down to Lavernock Point Barrage

6.1.3 Although the B3 Barrage does not perform well in relation to SEA objectives for emissions to air (greenhouse gases and other emissions) during construction, it does perform highest against these objectives, both during operation and overall over the project life cycle (Table 6.1). This is because there are large inputs in relation resources and transportation during construction, but the energy generated would be greatest of all the alternative options. The demand for resources, in particular aggregates during construction means that this option does not perform well against SEA objectives for sustainable use of resources.

Alternative Option B4: Shoots Barrage

6.1.4 Table 6.1 shows that although the B4 Barrage performs better than large structures such as B3, L2 and L3d against SEA objectives for emissions to air during construction, it is still not meeting these objectives. However, it does perform well against SEA objectives for sustainable use of energy and emissions to air during operation and over the life cycle of the project. It does not perform as well as the B3 barrage in relation to maximising use of renewable energy as less power would be produced. It does not meet SEA objectives for sustainable use of resources due to the quantities required during construction and reduced opportunities for re-use of dredged materials..

Alternative Option B5: Beachley Barrage

6.1.5 The B5 Barrage does not meet SEA objectives for emissions to air (greenhouse gases and other emissions) during construction, it does perform better than larger structures due to less material and transport requirements. It does perform well against SEA objectives for sustainable use of energy and emissions to air during operation and over the life cycle of the project. It does not perform as well as the B3 barrage in relation to maximising use of renewable energy as less power would be produced. The smaller quantities of materials required means that there are no effects against SEA objectives for sustainable use of resources and waste management.

Alternative Option L2: Welsh Grounds Lagoon

6.1.6 The L2 Lagoon does not meet SEA objectives for emissions to air during construction, due to the quantities of materials and transportation required Table 6.1). It does, however, perform well against these objectives during operation and over the life cycle of the project. It does not perform as well as the barrage options in relation to greenhouse gas emissions over the project life cycle, due to both the resources required during construction and amount of renewable energy produced. The demand for resources, in particular aggregates, during construction means that this option does not perform well against SEA objectives for sustainable use of resources.

Alternative Option L3d: Bridgwater Bay Lagoon

6.1.7 The performance of the L3d Lagoon against SEA objectives for air and climatic factors, resources and waste, is similar to the L2 Lagoon. SEA objectives for air and climatic factors are not met for construction, but are met during operation and over the lifecycle of the project. The demand for resources during construction means that this option does not perform well against SEA objectives for sustainable use of resources (Table 6.1).

Summary

6.1.8 Overall, the performance of alternative options against SEA objectives for this theme is consistent with that expected due to the interactions between air and climatic factors, resources and waste as defined in Section 5. For structures, the greater material and transport requirements during construction mean that more resources are used, waste is produced, and emissions to air are greater. This affects the local, national and international receptors. However, the greater the renewable energy produced, the better the performance over the life cycle of the project in relation to overall and operational emissions to air.

Table 6.1 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				
		B3: Brean Down to Lavernock Point Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**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	++	+	+	+	+
		Significant contribution of **15.1 to 17.0 TWh** per year of renewable energy over the lifetime of the project.	Contribution of **2.7 to 2.9 TWh** per year of renewable energy over the lifetime of the project.	Contribution of **1.4 to 1.6 TWh** per year of renewable energy over the lifetime of the project.	Contribution of **2.6 to 2.8 TWh** per year of renewable energy over the lifetime of the project.	Contribution of **5.6 to 6.6 TWh** per year of renewable energy over the lifetime of the project.
To avoid adverse effects from GHG emissions over the lifecycle of the project	UK GHG emissions Construction and decommissioning	--	-	-	-	-
		Emissions released during c.8 yrs of construction between 14MTCO$_2$e and high estimate of 28MTCO$_2$e	Emissions released during c.5 yrs of construction between 2.4MTCO$_2$e and high estimate of 5MTCO$_2$e	Emissions released during c.4 yrs of construction between 0.8MTCO$_2$e and high estimate of 2MTCO$_2$e	Emissions released during c.6 yrs of construction between 7MTCO$_2$e and high estimate of 14MTCO$_2$e	Emissions released during c.7 yrs of construction between 8MTCO$_2$e and high estimate of 16MTCO$_2$e
	UK GHG emissions on a per unit of electricity produced. kgCO$_2$e/kWh	++/?	++/?	++/?	+/?	+/?
		0 – 0.021 kgCO2e/kWh Max case is c.50% of 0.04kgCO2/kWh 2040 target as set by DECC.	0 – 0.024kgCO2e/kWh Max case is c.50% of 0.04kgCO2/kWh 2040 target as set by DECC.	0 – 0.024kgCO2e/kWh Max case is c.50% of 0.04kgCO2/kWh 2040 target as set by DECC.	0 – 0.042kgCO2e/kWh Max case is equal to 2040 target of 0.04kgCO2/kWh as set by DECC.	0 – 0.022kgCO2e/kWh Max case is lower than 2040 target of 0.04kgCO2/kWh as set by DECC.
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

SEA Objective	Relevant Receptors	Alternatives Performance against SEA Objectives over entire life-cycle				
		B3: Brean Down to Lavernock Point Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
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
To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance	International/ national protected habitats - local	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
		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.
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
To promote sustainable use of resources	Aggregates and embankment materials; Steel; Energy; Water	-	-	0	-	-
		Aggregate demand during construction phase is still likely to be high, even with measures to prevent or reduce adverse effects in place.	Aggregate demand during construction phase is still likely to be high, even with measures to prevent or reduce adverse effects in place.		Aggregate demand during construction phase is still likely to be high, even with measures to prevent or reduce adverse effects in place.	Aggregate demand during construction phase is still likely to be high, even with measures to prevent or reduce adverse effects in place.
To reduce waste	Sites for reuse;	0	0	0	0	0

SEA Objective	Relevant Receptors	Alternatives Performance against SEA Objectives over entire life-cycle				
		B3: Brean Down to Lavernock Point Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
generation and disposal, increase reuse and recycling, and achieve the sustainable management of waste	Treatment and recycling facilities; Energy recovery; Landfill	Waste would be managed in accordance with the waste hierarchy and the greatest quantities of waste (dredged materials during construction and recycled aggregates from decommissioning) would be reused.	Waste would be managed in accordance with the waste hierarchy and the greatest quantities of waste (dredged materials during construction and recycled aggregates from decommissioning) would be reused.	Waste would be managed in accordance with the waste hierarchy and the greatest quantities of waste (dredged materials during construction and recycled aggregates from decommissioning) would be reused.	Waste would be managed in accordance with the waste hierarchy and the greatest quantities of waste (dredged materials during construction and recycled aggregates from decommissioning) would be reused.	Waste would be managed in accordance with the waste hierarchy and the greatest quantities of waste (dredged materials during construction and recycled aggregates from decommissioning) would be reused.

SECTION 7

IMPLEMENTATION

7 IMPLEMENTATION

7.1 Proposals for monitoring

7.1.1 The SEA Directive requires that measures to monitor the significant environmental effects 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.

7.1.2 This section sets out suggestions for the framework for the monitoring of the plan against the predicted significant effects within this theme which can be applied to all of the Severn Tidal Power Schemes under consideration. Table 7.1 includes a brief summary of monitoring proposed for this theme and identifies any interactions or inconsistencies between the topics within this theme.

Table 7.1: Potential Monitoring Summary

Monitoring proposal for significant environmental effects	Receptor	Topics covered	Comment
NO_2, PM_{10} and SO_2 at the landfall areas prior to and throughout option construction.	Local population and vegetation	Air Quality	-
Gate monitoring of transportation and all materials entering and leaving site. Transportation and fuel consumption.	Global and UK GHG emissions Local population and vegetation National population and vegetation Energy	Air Quality & Climatic Factors Resources and Waste	-
Estuarine changes - monitoring as part of the Water Quality and Marine Ecology Topic papers.	Global and UK GHG emissions	Climatic Factors	Used to consider the impacts on emissions cycles (carbon, methane and nitrogen)

7.2 Suggestions for further research

7.2.1 This section includes some suggestions for research to support further consideration of tidal power in the Severn Estuary. When further information on option definition and design becomes available, it is suggested that the following studies and refinements on this assessment are undertaken:

- Detail design and review should be assessed in relation to the effect of the carbon footprint effect on construction, operation and decommissioning. During subsequent design phases more detailed information would be available, for instance on the construction requirements for ancillary works (such as grid enhancements), source of materials, operational requirements and effects on other topics including navigation and requirement for measures such as flood defences. This would also include more detailed assessment of the effects of estuarine changes on storage and release of greenhouse gases to reduce uncertainty of these effects and include nitrous oxide, which like methane has greater global warming potential than carbon dioxide..

- The demand for aggregates and embankment materials should be under review during the detailed design of any of the alternative options to ensure adequate supply during construction.
- During detailed design, targets should be set for reuse of dredged materials and use of secondary and recycled aggregates. Sources of these materials should be investigated further. Other measures could be explored to minimise carbon use, such as embedding carbon minimisation into tender/contract documentation of any option.

SECTION 8

GLOSSARY

8 GLOSSARY

Term	Definition
Appropriate Assessment	A process required by the Habitats Regulations (SI 1994/ 2716) 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.
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 environment effects, e.g. dredging, bypasses etc.
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 Footprint	The total set of greenhouse gas (GHG) emissions caused by an organisation, event or product. Often expressed in terms of the amount of carbon dioxide, or its equivalent of other GHGs, emitted.
Carbon Sequestration	The long-term storage of carbon dioxide or other forms of carbon through biological, chemical or physical processes.
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

Term	Definition
	Directive (see offsetting, below).
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.
De-nitrification	Microbially facilitated process that may ultimately produce molecular nitrogen (N2) through a series of intermediate gaseous nitrogen oxide products. In general, it occurs in environments where oxygen consumption exceeds the rate of oxygen supply, such as wetlands and in seafloor sediments.
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.
Geomorphology	The study of the changing form of the estuarine environment and its components in relation to physical forcing.
Hydrodynamics / hydraulics	The science of physical forces acting on the water.
Impoundment	A body of water, such as a reservoir, made by impounding
Indirect effects	Those effects which occur away from the original effect or as a result of a

Term	Definition
	complex pathway.
Inner Bristol Channel	The downstream limit extends from Nash Point in Wales to the west of Minehead along the English coast. The upper limit extends from Swanbridge on the Welsh coast to Brean Down along the English coast.
Irreversible	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.
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.
Methanogenesis	The formation of methane by microbes known as methanogens. In most environments, it is the final step in the decomposition of biomass.
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.
Outer Bristol Channel	The outer limit extends from St. Govans Head in Pembrokeshire to Hartland Point in Devon, which traditionally defines the lower limit of the Bristol Channel. The upper limit extends from Nash Point in Wales to the west of Minehead along the English coast.
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.

Term	Definition
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	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 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.

Term	Definition
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.
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.
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 Prism	The difference between the mean high-water volume and the mean low-water volume of an estuary.

Term	Definition
Transboundary effects	An environmental effect upon another EU Member State
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.
Turbine caissons	Prefabricated concrete structures placed into the water to house turbines.
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.
Variant	A modified version of the original shortlisted scheme.

SECTION 9

REFERENCES

9 REFERENCES

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