Title: **Severn Tidal Power Feasibility Study- Phase 2**	Impact Assessment (IA)
Lead department or agency: DECC	**URN: 10D/812**
Other departments or agencies: Welsh Assembly Government South West Development Agency	**Date: 18/10/2010**
	Stage: Development/Options
	Source of intervention: Domestic
	Type of measure: Other
	Contact for enquiries: Andrew Jones Andrew.Jones1@decc.gsi.gov.uk

Summary: Intervention and Options

What is the problem under consideration? Why is government intervention necessary?

UK needs to move away from fossil fuels to counter climate change and meet environmental targets (80% emissions reduction by 2050, 15% renewable energy by 2020), while maintaining security of supply. Severn scheme is an indigenous source of renewable, low-carbon electricity. STP scheme likely to require Government intervention beyond existing renewables policy levers (EU ETS, RO, Grid reform) due to: private sector unfamiliarity with Compensatory Habitats requirements; limited innovation spillover benefits due to unique nature of Severn environment; market risks due to inflexible, variable output; upfront capital requirements unlikely to be raised through markets alone.

What are the policy objectives and the intended effects?

Severn scheme would produce low-carbon electricity, contributing towards energy and climate change goals and potentially improving security of supply. Feasibility Study aims to: assess costs/ benefits/ impacts of STP options; identify single preferred project (if appropriate); consider necessary Government measures to bring forward scheme that fulfils regulatory requirements; decide whether the Government could support a tidal power project in the Severn and on what terms. No specific policy to deliver a Severn project is considered here- there are therefore no regulatory impacts to be accounted for.

What policy options have been considered? Please justify preferred option (further details in Evidence Base)

1) Do Nothing Now- Government does not support Severn tidal deployment now, since current cost estimates indicate that there are more cost-effective ways of providing low-carbon electricity and ensuring security of supply. This makes it almost certain that a scheme will not come forward. Severn output replaced by some other form of generation.
2) Government supports one of 5 shortlisted Severn schemes:
- Cardiff-Weston: spanning estuary from Brean Down to Lavernock Point;
- Shoots Barrage: near Severn road crossings;
- Beachley Barrage: upstream of Shoots Barrage, and of Wye river;
- Welsh Grounds Lagoon: impoundment on Welsh shore between Newport and Severn road crossings;
- Bridgewater Bay Lagoon: impoundment on English shore between Hinkley Point and Weston-super-Mare.

When will the policy be reviewed to establish its impact and the extent to which the policy objectives have been achieved?	It will/will not be reviewed
Are there arrangements in place that will allow a systematic collection of monitoring information for future policy review?	Not applicable

SELECT SIGNATORY Sign-off For consultation stage Impact Assessments:

I have read the Impact Assessment and I am satisfied that, given the available evidence, it represents a reasonable view of the likely costs, benefits and impact of the leading options.

Signed by the responsible SELECT SIGNATORY: Charles Hendry ***Date:18 October 2010***

Summary: Analysis and Evidence

Policy Option 1

Description:

'Do Nothing'

Price Base Year 2009	PV Base Year 2010	Time Period Years 130	Net Benefit (Present Value (PV)) (£m)		
			Low: n/a	**High:** n/a	**Best Estimate:** **n/a**

COSTS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Cost** (Present Value)
Low	n/a		n/a	**n/a**
High	n/a		n/a	**n/a**
Best Estimate	n/a		n/a	**n/a**

Description and scale of key monetised costs by 'main affected groups'

Construction and operation of 'counterfactual' technologies assumed to replace Severn output if Severn scheme doesn't go ahead. Investment to replace capacity that reaches end of life within lifetime of Severn scheme. Level of Do Nothing costs depends on size of Severn scheme, ie greater for larger Severn schemes. Do Nothing costs therefore calculated for each Severn option, and incorporated into the Net Present Value of Severn options, rather than presented here.

Other key non-monetised costs by 'main affected groups'

Air/ noise pollution during construction phase of projects. Net ecosystem impacts associated with construction/ operation of power station. Finance costs (e.g. interest during construction) of building power stations.

BENEFITS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Benefit** (Present Value)
Low	n/a		n/a	**n/a**
High	n/a		n/a	**n/a**
Best Estimate	n/a		n/a	**n/a**

Description and scale of key monetised benefits by 'main affected groups'

Assume benefit of electricity produced is equal for counterfactuals and reference Severn schemes, and hence net zero.

Other key non-monetised benefits by 'main affected groups'

Electricity produced- we assume counterfactuals produce same amount of electricity as a Severn project, and that this electricity is of equal value. Security of supply benefits. Innovation benefits. Macroeconomic benefits to UK as a whole.

Key assumptions/sensitivities/risks | **Discount rate (%)** | GB

Counterfactual technologies are Advanced Supercritical Coal (ASC) with CCS, Offshore Wind and Nuclear. Best estimate of counterfactual costs is low carbon technology mix (Severn output replaced by 1/3 Coal with CCS, 1/3 Nuclear, 1/3 Offshore Wind). Counterfactual technologies produce same annual output as Severn scheme across the lifetime of Severn scheme. Counterfactual output of equal value to Severn output. Financing costs not included in Net Present Value. Optimism Bias uplift applied to Offshore Wind costs (at 24%) to Coal with CCS (at 60%) and to nuclear (at 15%).

Impact on admin burden (AB) (£m):			**Impact on policy cost savings (£m):**	**In scope**
New AB: n/a	**AB savings:** n/a	**Net:** n/a	**Policy cost savings:**	No

Enforcement, Implementation and Wider Impacts

<table>
<tr><td colspan="3">What is the geographic coverage of the policy/option?</td><td colspan="3">United Kingdom</td></tr>
<tr><td colspan="3">From what date will the policy be implemented?</td><td colspan="3">n/a</td></tr>
<tr><td colspan="3">Which organisation(s) will enforce the policy?</td><td colspan="3">n/a</td></tr>
<tr><td colspan="3">What is the annual change in enforcement cost (£m)?</td><td colspan="3">n/a</td></tr>
<tr><td colspan="3">Does enforcement comply with Hampton principles?</td><td colspan="3">Yes/No</td></tr>
<tr><td colspan="3">Does implementation go beyond minimum EU requirements?</td><td colspan="3">Yes/No</td></tr>
<tr><td colspan="3">What is the CO_2 equivalent change in greenhouse gas emissions?
(Million tonnes CO_2 equivalent)</td><td colspan="2">Traded:
n/a</td><td>Non-traded:
n/a</td></tr>
<tr><td colspan="3">Does the proposal have an impact on competition?</td><td colspan="3">Yes/No</td></tr>
<tr><td colspan="3">What proportion (%) of Total PV costs/benefits is directly attributable to primary legislation, if applicable?</td><td colspan="2">Costs:</td><td>Benefits:</td></tr>
<tr><td>Annual cost (£m) per organisation
(excl. Transition) (Constant Price)</td><td>Micro</td><td>< 20</td><td>Small</td><td>Medium</td><td>Large</td></tr>
<tr><td>Are any of these organisations exempt?</td><td>Yes/No</td><td>Yes/No</td><td>Yes/No</td><td>Yes/No</td><td>Yes/No</td></tr>
</table>

Specific Impact Tests: Checklist

Set out in the table below where information on any SITs undertaken as part of the analysis of the policy options can be found in the evidence base. For guidance on how to complete each test, double-click on the link for the guidance provided by the relevant department.

Please note this checklist is not intended to list each and every statutory consideration that departments should take into account when deciding which policy option to follow. It is the responsibility of departments to make sure that their duties are complied with.

Does your policy option/proposal have an impact on…?	**Impact**	**Page ref within IA**
Statutory equality duties[1] Statutory Equality Duties Impact Test guidance	Yes/No	
Economic impacts		
Competition Competition Assessment Impact Test guidance	Yes/No	
Small firms Small Firms Impact Test guidance	Yes/No	
Environmental impacts		
Greenhouse gas assessment Greenhouse Gas Assessment Impact Test guidance	Yes/No	
Wider environmental issues Wider Environmental Issues Impact Test guidance	Yes/No	
Social impacts		
Health and well-being Health and Well-being Impact Test guidance	Yes/No	
Human rights Human Rights Impact Test guidance	Yes/No	
Justice system Justice Impact Test guidance	Yes/No	
Rural proofing Rural Proofing Impact Test guidance	Yes/No	
Sustainable development Sustainable Development Impact Test guidance	Yes/No	

[1] Race, disability and gender Impact assessments are statutory requirements for relevant policies. Equality statutory requirements will be expanded 2011, once the Equality Bill comes into force. Statutory equality duties part of the Equality Bill apply to GB only. The Toolkit provides advice on statutory equality duties for public authorities with a remit in Northern Ireland.

Summary: Analysis and Evidence

Policy Option 2

Description:

Cardiff Weston Barrage

Price Base Year 2009	PV Base Year 2010	Time Period Years 130	Net Benefit (Present Value (PV)) (£m)		
			Low: -24,498	**High:** 21,384	**Best Estimate: -4,629**

COSTS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	Optional		Optional	**Optional**
High	Optional		Optional	**Optional**
Best Estimate				**35,437**

Description and scale of key monetised costs by 'main affected groups'

Construction Costs (Pre-construction, preliminaries, caissons, embankments, navigation locks, surface buildings, grid connection, turbine generators, Contingency). Operation costs (staff, taxes, insurance, Maintenance, Contingency, National Grid transmission tariffs). Refurbishment costs. Indicative compensatory habitats provision costs. Ancillary works e.g. sedimentation management. Measures to prevent/ reduce adverse environmental effects.

Other key non-monetised costs by 'main affected groups'

Lifecycle emissions during construction/ operation. Security of supply. Net ecosystem impacts. Noise/ air pollution during construction of barrage.

BENEFITS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	Optional		Optional	**10,940**
High	Optional		Optional	**56,821**
Best Estimate				**30,808**

Description and scale of key monetised benefits by 'main affected groups'

Avoided capital investment in other technologies (Coal with CCS, Nuclear), including investment to replace capacity that reaches end of life within lifetime of Severn scheme. Avoided running costs for other technologies. Avoided expenditure on carbon permits (relative to Coal with CCS only). Air Quality improvements (relative to Coal with CCS).

Other key non-monetised benefits by 'main affected groups'

nnovation spillovers. Macroeconomic benefits to UK society as a whole.

Key assumptions/sensitivities/risks | **Discount rate (%)** | GB

'Best estimate' of NPV is versus low carbon technology mix (Severn output replaced by 1/3 Coal with CCS, 1/3 Nuclear, 1/3 Offshore Wind). Sensitivities around counterfactuals' fuel, carbon and capital costs reflected in NPV range- low NPV versus nuclear (with low capital costs), high NPV versus Coal with CCS (with high carbon, fuel and capital costs). Counterfactual technologies produce same annual output as Severn scheme across the lifetime of Severn scheme. Counterfactual output of equal value to Severn output. Financing costs due to debt incurred in power station construction not included in Net Present Value. Optimism Bias plus Risk Assessment uplift of 47% applied to Severn costs. Optimism Bias applied to offshore wind at 23%, to Coal with CCS at 60% and to nuclear at 15%.

Impact on admin burden (AB) (£m):			Impact on policy cost savings (£m):	In scope
New AB: n/a	**AB savings:** n/a	**Net:** n/a	**Policy cost savings:**	No

Enforcement, Implementation and Wider Impacts

What is the geographic coverage of the policy/option?			United Kingdom		
From what date will the policy be implemented?			n/a		
Which organisation(s) will enforce the policy?			n/a		
What is the annual change in enforcement cost (£m)?			n/a		
Does enforcement comply with Hampton principles?			Yes/No		
Does implementation go beyond minimum EU requirements?			Yes/No		
What is the CO_2 equivalent change in greenhouse gas emissions? (Million tonnes CO_2 equivalent)			**Traded:** -73.0		**Non-traded:**
Does the proposal have an impact on competition?			Yes/No		
What proportion (%) of Total PV costs/benefits is directly attributable to primary legislation, if applicable?			**Costs:**		**Benefits:**
Annual cost (£m) per organisation (excl. Transition) (Constant Price)	**Micro**	**< 20**	**Small**	**Medium**	**Large**
Are any of these organisations exempt?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

Specific Impact Tests: Checklist

Set out in the table below where information on any SITs undertaken as part of the analysis of the policy options can be found in the evidence base. For guidance on how to complete each test, double-click on the link for the guidance provided by the relevant department.

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Does your policy option/proposal have an impact on…?	Impact	Page ref within IA
Statutory equality duties[2] Statutory Equality Duties Impact Test guidance	Yes/No	
Economic impacts		
Competition Competition Assessment Impact Test guidance	Yes/No	
Small firms Small Firms Impact Test guidance	Yes/No	
Environmental impacts		
Greenhouse gas assessment Greenhouse Gas Assessment Impact Test guidance	Yes/No	
Wider environmental issues Wider Environmental Issues Impact Test guidance	Yes/No	
Social impacts		
Health and well-being Health and Well-being Impact Test guidance	Yes/No	
Human rights Human Rights Impact Test guidance	Yes/No	
Justice system Justice Impact Test guidance	Yes/No	
Rural proofing Rural Proofing Impact Test guidance	Yes/No	
Sustainable development Sustainable Development Impact Test guidance	Yes/No	

[2] Race, disability and gender Impact assessments are statutory requirements for relevant policies. Equality statutory requirements will be expanded 2011, once the Equality Bill comes into force. Statutory equality duties part of the Equality Bill apply to GB only. The Toolkit provides advice on statutory equality duties for public authorities with a remit in Northern Ireland.

Summary: Analysis and Evidence

Policy Option 3

Description:

Shoots Barrage

Price Base Year 2009	PV Base Year 2010	Time Period Years 130	Net Benefit (Present Value (PV)) (£m) Low: -5,469	High: 3,033	Best Estimate: -1,717

COSTS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	Optional		Optional	**Optional**
High	Optional		Optional	**Optional**
Best Estimate				**7,605**

Description and scale of key monetised costs by 'main affected groups'

Construction Costs (Pre-construction, preliminaries, caissons, embankments, navigation locks, surface buildings, grid connection, turbine generators, Contingency). Operation costs (staff, taxes, insurance, Maintenance, Contingency, National Grid transmission tariffs). Refurbishment costs. Indicative compensatory habitats provision costs. Ancillary works e.g. sedimentation management. Measures to prevent/ reduce adverse environmental effects.

Other key non-monetised costs by 'main affected groups'

Lifecycle emissions during construction/ operation. Security of supply. Net ecosystem impacts. Noise/ air pollution during construction of barrage.

BENEFITS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	Optional		Optional	**2,136**
High	Optional		Optional	**10,638**
Best Estimate				**5,888**

Description and scale of key monetised benefits by 'main affected groups'

Avoided capital investment in other technologies (Coal with CCS, Nuclear), including investment to replace capacity that reaches end of life within lifetime of Severn scheme. Avoided running costs for other technologies. Avoided expenditure on carbon permits (relative to Coal with CCS only). Air Quality improvements (relative to Coal with CCS).

Other key non-monetised benefits by 'main affected groups'

Innovation spillovers. Macroeconomic benefits to UK society as a whole.

Key assumptions/sensitivities/risks | **Discount rate (%)** | GB

'Best estimate' of NPV is versus low carbon technology mix (Severn output replaced by 1/3 Coal with CCS, 1/3 Nuclear, 1/3 Offshore Wind). Sensitivities around counterfactuals' fuel, carbon and capital costs reflected in NPV range- low NPV versus nuclear (with low capital costs), high NPV versus Coal with CCS (with high carbon, fuel and capital costs). Counterfactual technologies produce same annual output as Severn scheme across the lifetime of Severn scheme. Counterfactual output of equal value to Severn output. Financing costs due to debt incurred in power station construction not included in Net Present Value. Optimism Bias plus Risk Assessment uplift of 45% applied to Severn costs. Optimism Bias applied to offshore wind at 23%, to Coal with CCS at 60%, and to nuclear at 15%.

Impact on admin burden (AB) (£m):			Impact on policy cost savings (£m):	In scope
New AB: n/a	**AB savings:** n/a	**Net:** n/a	**Policy cost savings:**	No

Enforcement, Implementation and Wider Impacts

What is the geographic coverage of the policy/option?	England and Wales				
From what date will the policy be implemented?	n/a				
Which organisation(s) will enforce the policy?	n/a				
What is the annual change in enforcement cost (£m)?	n/a				
Does enforcement comply with Hampton principles?	Yes/No				
Does implementation go beyond minimum EU requirements?	Yes/No				
What is the CO_2 equivalent change in greenhouse gas emissions? (Million tonnes CO_2 equivalent)	**Traded:** -12.7	**Non-traded:**			
Does the proposal have an impact on competition?	Yes/No				
What proportion (%) of Total PV costs/benefits is directly attributable to primary legislation, if applicable?	**Costs:**	**Benefits:**			
Annual cost (£m) per organisation (excl. Transition) (Constant Price)	**Micro**	**< 20**	**Small**	**Medium**	**Large**
Are any of these organisations exempt?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

Specific Impact Tests: Checklist

Set out in the table below where information on any SITs undertaken as part of the analysis of the policy options can be found in the evidence base. For guidance on how to complete each test, double-click on the link for the guidance provided by the relevant department.

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Does your policy option/proposal have an impact on…?	**Impact**	**Page ref within IA**
Statutory equality duties[3] Statutory Equality Duties Impact Test guidance	Yes/No	
Economic impacts		
Competition Competition Assessment Impact Test guidance	Yes/No	
Small firms Small Firms Impact Test guidance	Yes/No	
Environmental impacts		
Greenhouse gas assessment Greenhouse Gas Assessment Impact Test guidance	Yes/No	
Wider environmental issues Wider Environmental Issues Impact Test guidance	Yes/No	
Social impacts		
Health and well-being Health and Well-being Impact Test guidance	Yes/No	
Human rights Human Rights Impact Test guidance	Yes/No	
Justice system Justice Impact Test guidance	Yes/No	
Rural proofing Rural Proofing Impact Test guidance	Yes/No	
Sustainable development Sustainable Development Impact Test guidance	Yes/No	

[3] Race, disability and gender Impact assessments are statutory requirements for relevant policies. Equality statutory requirements will be expanded 2011, once the Equality Bill comes into force. Statutory equality duties part of the Equality Bill apply to GB only. The Toolkit provides advice on statutory equality duties for public authorities with a remit in Northern Ireland.

Summary: Analysis and Evidence

Policy Option 4

Description:

Beachley Barrage

Price Base Year 2009	PV Base Year 2010	Time Period Years 130	Net Benefit (Present Value (PV)) (£m)		
			Low: -4,188	**High:** 534	**Best Estimate: -2,104**

COSTS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Cost** (Present Value)
Low	Optional		Optional	**Optional**
High	Optional		Optional	**Optional**
Best Estimate				**5,375**

Description and scale of key monetised costs by 'main affected groups'

Construction Costs (Pre-construction, preliminaries, caissons, embankments, navigation locks, surface buildings, grid connection, turbine generators, Contingency). Operation costs (staff, taxes, insurance, Maintenance, Contingency, National Grid transmission tariffs). Refurbishment costs. Indicative compensatory habitats provision costs. Ancillary works e.g. sedimentation management. Measures to prevent/ reduce adverse environmental effects.

Other key non-monetised costs by 'main affected groups'

Lifecycle emissions during construction/ operation. Security of supply. Net ecosystem impacts. Noise/ air pollution during construction of barrage.

BENEFITS (£m)	**Total Transition** (Constant Price)	Years	**Average Annual** (excl. Transition) (Constant Price)	**Total Benefit** (Present Value)
Low	Optional		Optional	**1,187**
High	Optional		Optional	**5,909**
Best Estimate				**3,271**

Description and scale of key monetised benefits by 'main affected groups'

Avoided capital investment in other technologies (Coal with CCS, Nuclear), including investment to replace capacity that reaches end of life within lifetime of Severn scheme. Avoided running costs for other technologies. Avoided expenditure on carbon permits (relative to Coal with CCS only). Air Quality improvements (relative to Coal with CCS).

Other key non-monetised benefits by 'main affected groups'

Innovation spillovers. Macroeconomic benefits to UK society as a whole.

Key assumptions/sensitivities/risks **Discount rate (%)** GB

'Best estimate' of NPV is versus low carbon technology mix (Severn output replaced by 1/3 Coal with CCS, 1/3 Nuclear, 1/3 Offshore Wind). Sensitivities around counterfactuals' fuel, carbon and capital costs reflected in NPV range- low NPV versus nuclear (with low capital costs), high NPV versus Coal with CCS (with high carbon, fuel and capital costs). Counterfactual technologies produce same annual output as Severn scheme across the lifetime of Severn scheme. Counterfactual output of equal value to Severn output. Financing costs due to debt incurred in power station construction not included in Net Present Value. Optimism Bias plus Risk Assessment uplift of 44% applied to Severn costs. Optimism Bias applied to offshore wind at 23%, to Coal with CCS at 60%, and to nuclear at 15%.

Impact on admin burden (AB) (£m):			**Impact on policy cost savings (£m):**	**In scope**
New AB: n/a	**AB savings:** n/a	**Net:** n/a	**Policy cost savings:**	No

Enforcement, Implementation and Wider Impacts

<table>
<tr><td colspan="3">What is the geographic coverage of the policy/option?</td><td colspan="3">England and Wales</td></tr>
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<tr><td colspan="3">What is the CO_2 equivalent change in greenhouse gas emissions?
(Million tonnes CO_2 equivalent)</td><td colspan="2">Traded:
-7.0</td><td>Non-traded:</td></tr>
<tr><td colspan="3">Does the proposal have an impact on competition?</td><td colspan="3">Yes/No</td></tr>
<tr><td colspan="3">What proportion (%) of Total PV costs/benefits is directly attributable to primary legislation, if applicable?</td><td colspan="2">Costs:</td><td>Benefits:</td></tr>
<tr><td>Annual cost (£m) per organisation
(excl. Transition) (Constant Price)</td><td>Micro</td><td>< 20</td><td>Small</td><td>Medium</td><td>Large</td></tr>
<tr><td>Are any of these organisations exempt?</td><td>Yes/No</td><td>Yes/No</td><td>Yes/No</td><td>Yes/No</td><td>Yes/No</td></tr>
</table>

Specific Impact Tests: Checklist

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Does your policy option/proposal have an impact on…?	**Impact**	**Page ref within IA**
Statutory equality duties[4] Statutory Equality Duties Impact Test guidance	Yes/No	
Economic impacts		
Competition Competition Assessment Impact Test guidance	Yes/No	
Small firms Small Firms Impact Test guidance	Yes/No	
Environmental impacts		
Greenhouse gas assessment Greenhouse Gas Assessment Impact Test guidance	Yes/No	
Wider environmental issues Wider Environmental Issues Impact Test guidance	Yes/No	
Social impacts		
Health and well-being Health and Well-being Impact Test guidance	Yes/No	
Human rights Human Rights Impact Test guidance	Yes/No	
Justice system Justice Impact Test guidance	Yes/No	
Rural proofing Rural Proofing Impact Test guidance	Yes/No	
Sustainable development Sustainable Development Impact Test guidance	Yes/No	

4 Race, disability and gender Impact assessments are statutory requirements for relevant policies. Equality statutory requirements will be expanded 2011, once the Equality Bill comes into force. Statutory equality duties part of the Equality Bill apply to GB only. The Toolkit provides advice on statutory equality duties for public authorities with a remit in Northern Ireland.

Summary: Analysis and Evidence

Policy Option 5

Description:

Welsh Grounds Lagoon

Price Base Year 2009	PV Base Year 2010	Time Period Years 130	Net Benefit (Present Value (PV)) (£m)		
			Low: -7,968	High: 36	Best Estimate: -4,457

COSTS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	Optional		Optional	**Optional**
High	Optional		Optional	**Optional**
Best Estimate				**9,941**

Description and scale of key monetised costs by 'main affected groups'

Construction Costs (Pre-construction, preliminaries, caissons, embankments, navigation locks, surface buildings, grid connection, turbine generators, Contingency). Operation costs (staff, taxes, insurance, Maintenance, Contingency, National Grid transmission tariffs). Refurbishment costs. Indicative compensatory habitats provision costs. Ancillary works e.g. sedimentation management. Measures to prevent/ reduce adverse environmental effects.

Other key non-monetised costs by 'main affected groups'

Lifecycle emissions during construction/ operation. Security of supply. Net ecosystem impacts. Noise/ air pollution during construction of barrage.

BENEFITS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	Optional		Optional	**1,973**
High	Optional		Optional	**9,977**
Best Estimate				**5,485**

Description and scale of key monetised benefits by 'main affected groups'

Avoided capital investment in other technologies (Coal with CCS, Nuclear), including investment to replace capacity that reaches end of life within lifetime of Severn scheme. Avoided running costs for other technologies. Avoided expenditure on carbon permits (relative to Coal with CCS only). Air Quality improvements (relative to Coal with CCS).

Other key non-monetised benefits by 'main affected groups'

Innovation spillovers. Macroeconomic benefits to UK society as a whole

Key assumptions/sensitivities/risks | **Discount rate (%)** | GB

'Best estimate' of NPV is versus low carbon technology mix (Severn output replaced by 1/3 Coal with CCS, 1/3 Nuclear, 1/3 Offshore Wind). Sensitivities around counterfactuals' fuel, carbon and capital costs reflected in NPV range- low NPV versus nuclear (with low capital costs), high NPV versus Coal with CCS (with high carbon, fuel and capital costs). Counterfactual technologies produce same annual output as Severn scheme across the lifetime of Severn scheme. Counterfactual output of equal value to Severn output. Financing costs due to debt incurred in power station construction not included in Net Present Value. Optimism Bias plus Risk Assessment uplift of 44% applied to Severn costs. Optimism Bias applied to offshore wind at 23%, to Coal with CCS at 60%, and to nuclear at 15%.

Impact on admin burden (AB) (£m):			Impact on policy cost savings (£m):	In scope
New AB: n/a	**AB savings:** n/a	**Net:** n/a	**Policy cost savings:**	No

Enforcement, Implementation and Wider Impacts

What is the geographic coverage of the policy/option?			England and Wales			
From what date will the policy be implemented?			n/a			
Which organisation(s) will enforce the policy?			n/a			
What is the annual change in enforcement cost (£m)?			n/a			
Does enforcement comply with Hampton principles?			Yes/No			
Does implementation go beyond minimum EU requirements?			Yes/No			
What is the CO_2 equivalent change in greenhouse gas emissions? (Million tonnes CO_2 equivalent)			**Traded:** -12.0		**Non-traded:**	
Does the proposal have an impact on competition?			Yes/No			
What proportion (%) of Total PV costs/benefits is directly attributable to primary legislation, if applicable?			**Costs:**		**Benefits:**	
Annual cost (£m) per organisation (excl. Transition) (Constant Price)	**Micro**	**< 20**	**Small**	**Medium**	**Large**	
Are any of these organisations exempt?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	

Specific Impact Tests: Checklist

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Does your policy option/proposal have an impact on…?	Impact	Page ref within IA
Statutory equality duties[5] Statutory Equality Duties Impact Test guidance	Yes/No	
Economic impacts		
Competition Competition Assessment Impact Test guidance	Yes/No	
Small firms Small Firms Impact Test guidance	Yes/No	
Environmental impacts		
Greenhouse gas assessment Greenhouse Gas Assessment Impact Test guidance	Yes/No	
Wider environmental issues Wider Environmental Issues Impact Test guidance	Yes/No	
Social impacts		
Health and well-being Health and Well-being Impact Test guidance	Yes/No	
Human rights Human Rights Impact Test guidance	Yes/No	
Justice system Justice Impact Test guidance	Yes/No	
Rural proofing Rural Proofing Impact Test guidance	Yes/No	
Sustainable development Sustainable Development Impact Test guidance	Yes/No	

[5] Race, disability and gender Impact assessments are statutory requirements for relevant policies. Equality statutory requirements will be expanded 2011, once the Equality Bill comes into force. Statutory equality duties part of the Equality Bill apply to GB only. The Toolkit provides advice on statutory equality duties for public authorities with a remit in Northern Ireland.

Summary: Analysis and Evidence

Policy Option 6

Description:

Bridgewater Bay Lagoon

Price Base Year 2009	PV Base Year 2010	Time Period Years 130	Net Benefit (Present Value (PV)) (£m)		
			Low: -13,274	High: 6,120	Best Estimate: -4,765

COSTS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Cost (Present Value)
Low	Optional		Optional	**Optional**
High	Optional		Optional	**Optional**
Best Estimate				**18,055**

Description and scale of key monetised costs by 'main affected groups'

Construction Costs (Pre-construction, preliminaries, caissons, embankments, navigation locks, surface buildings, grid connection, turbine generators, Contingency). Operation costs (staff, taxes, insurance, Maintenance, Contingency, National Grid transmission tariffs). Refurbishment costs. Indicative compensatory habitats provision costs. Ancillary works e.g. sedimentation management. Measures to prevent/ reduce adverse environmental effects.

Other key non-monetised costs by 'main affected groups'

Lifecycle emissions during construction/ operation. Security of supply. Net ecosystem impacts. Noise/ air pollution during construction of barrage.

BENEFITS (£m)	Total Transition (Constant Price)	Years	Average Annual (excl. Transition) (Constant Price)	Total Benefit (Present Value)
Low	Optional		Optional	**4,780**
High	Optional		Optional	**24,175**
Best Estimate				**13,289**

Description and scale of key monetised benefits by 'main affected groups'

Avoided capital investment in other technologies (Coal with CCS, Nuclear), including investment to replace capacity that reaches end of life within lifetime of Severn scheme. Avoided running costs for other technologies. Avoided expenditure on carbon permits (relative to Coal with CCS only). Air Quality improvements (relative to Coal with CCS).

Other key non-monetised benefits by 'main affected groups'

Innovation spillovers. Macroeconomic benefits to UK society as a whole

Key assumptions/sensitivities/risks **Discount rate (%)** GB

'Best estimate' of NPV is versus low carbon technology mix (Severn output replaced by 1/3 Coal with CCS, 1/3 Nuclear, 1/3 Offshore Wind). Sensitivities around counterfactuals' fuel, carbon and capital costs reflected in NPV range- low NPV versus nuclear (with low capital costs), high NPV versus Coal with CCS (with high carbon, fuel and capital costs). Counterfactual technologies produce same annual output as Severn scheme across the lifetime of Severn scheme. Counterfactual output of equal value to Severn output. Financing costs due to debt incurred in power station construction not included in Net Present Value. Optimism Bias plus Risk Assessment uplift of 44% applied to Severn costs. Optimism Bias applied to offshore wind at 23%, to Coal with CCS at 60%, and to nuclear at 15%.

Impact on admin burden (AB) (£m):			Impact on policy cost savings (£m):	In scope
New AB: n/a	AB savings: n/a	Net: n/a	Policy cost savings:	No

Enforcement, Implementation and Wider Impacts

<table>
<tr><td colspan="3">What is the geographic coverage of the policy/option?</td><td colspan="5">England and Wales</td></tr>
<tr><td colspan="3">From what date will the policy be implemented?</td><td colspan="5">n/a</td></tr>
<tr><td colspan="3">Which organisation(s) will enforce the policy?</td><td colspan="5">n/a</td></tr>
<tr><td colspan="3">What is the annual change in enforcement cost (£m)?</td><td colspan="5">n/a</td></tr>
<tr><td colspan="3">Does enforcement comply with Hampton principles?</td><td colspan="5">Yes/No</td></tr>
<tr><td colspan="3">Does implementation go beyond minimum EU requirements?</td><td colspan="5">Yes/No</td></tr>
<tr><td colspan="3">What is the CO_2 equivalent change in greenhouse gas emissions?
(Million tonnes CO_2 equivalent)</td><td colspan="3">Traded:
-29.3</td><td colspan="2">Non-traded:</td></tr>
<tr><td colspan="3">Does the proposal have an impact on competition?</td><td colspan="5">Yes/No</td></tr>
<tr><td colspan="3">What proportion (%) of Total PV costs/benefits is directly attributable to primary legislation, if applicable?</td><td colspan="3">Costs:</td><td colspan="2">Benefits:</td></tr>
<tr><td>Annual cost (£m) per organisation
(excl. Transition) (Constant Price)</td><td>Micro</td><td>< 20</td><td>Small</td><td colspan="2">Medium</td><td colspan="2">Large</td></tr>
<tr><td>Are any of these organisations exempt?</td><td>Yes/No</td><td>Yes/No</td><td>Yes/No</td><td colspan="2">Yes/No</td><td colspan="2">Yes/No</td></tr>
</table>

Specific Impact Tests: Checklist

Set out in the table below where information on any SITs undertaken as part of the analysis of the policy options can be found in the evidence base. For guidance on how to complete each test, double-click on the link for the guidance provided by the relevant department.

Please note this checklist is not intended to list each and every statutory consideration that departments should take into account when deciding which policy option to follow. It is the responsibility of departments to make sure that their duties are complied with.

Does your policy option/proposal have an impact on…?	**Impact**	**Page ref within IA**
Statutory equality duties[6] Statutory Equality Duties Impact Test guidance	Yes/No	
Economic impacts		
Competition Competition Assessment Impact Test guidance	Yes/No	
Small firms Small Firms Impact Test guidance	Yes/No	
Environmental impacts		
Greenhouse gas assessment Greenhouse Gas Assessment Impact Test guidance	Yes/No	
Wider environmental issues Wider Environmental Issues Impact Test guidance	Yes/No	
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Health and well-being Health and Well-being Impact Test guidance	Yes/No	
Human rights Human Rights Impact Test guidance	Yes/No	
Justice system Justice Impact Test guidance	Yes/No	
Rural proofing Rural Proofing Impact Test guidance	Yes/No	
Sustainable development Sustainable Development Impact Test guidance	Yes/No	

[6] Race, disability and gender Impact assessments are statutory requirements for relevant policies. Equality statutory requirements will be expanded 2011, once the Equality Bill comes into force. Statutory equality duties part of the Equality Bill apply to GB only. The Toolkit provides advice on statutory equality duties for public authorities with a remit in Northern Ireland.

Evidence Base (for summary sheets) – Notes

Use this space to set out the relevant references, evidence, analysis and detailed narrative from which you have generated your policy options or proposal. Please fill in **References** section.

References

Include the links to relevant legislation and publications, such as public impact assessment of earlier stages (e.g. Consultation, Final, Enactment).

No.	Legislation or publication
1	STP Feasibility Study Phase 1- Partial Impact Assessment http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Renewable%20energy/Severn%20Tidal%20Power%20feasibility%20study/1_20090715085131_e_@@_PartialIAforPhaseOneConsultationSevernTidalPowerFeasibilityStudy.pdf
2	
3	
4	

+ Add another row

Evidence Base

Ensure that the information in this section provides clear evidence of the information provided in the summary pages of this form (recommended maximum of 30 pages). Complete the **Annual profile of monetised costs and benefits** (transition and recurring) below over the life of the preferred policy (use the spreadsheet attached if the period is longer than 10 years).

The spreadsheet also contains an emission changes table that you will need to fill in if your measure has an impact on greenhouse gas emissions.

Annual profile of monetised costs and benefits* - (£m) constant prices

	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
Transition costs										
Annual recurring cost										
Total annual costs										
Transition benefits										
Annual recurring benefits										
Total annual benefits										

* For non-monetised benefits please see summary pages and main evidence base section

Microsoft Office
Excel Worksheet

Evidence Base (for summary sheets)

Table of Contents

SUMMARY .... ERROR! BOOKMARK NOT DEFINED.

Methodology 3
Results 4
Conclusion 4

SECTION A: STRATEGIC OVERVIEW 5

Problem Under consideration: Fighting Climate Change, Ensuring Energy Security 5
Pathways to 2050 5
Severn Tidal contribution to UK emissions and renewable energy targets, security of supply 6
Rationale for Government Intervention 7
Policy Objectives 9
Options Considered 10
Identification of Counterfactual 12

SECTION B: METHODOLOGY 14

Appraisal Approach 14

SECTION C: COSTS & BENEFITS OF POTENTIAL OPTIONS 22

Summary of Phase 1 Results 22
Phase 2 Energy output and cost estimates for Severn Tidal Power Schemes 23
Comparing Severn Schemes' Costs against Counterfactual Technologies 25
Non-monetised benefits 29
Net Present Value 31
NPVs with Discount Rates excluding pure social time preference 32
Explanation of NPV differences between Phase 1 and Phase 2 IAs 33
Administrative Burden and Policy Savings Calculations 33

SECTION D: WIDER IMPACTS 34

Contribution to Emissions Reductions 34
Comparison with other renewable generation 35
Impact on renewable energy targets 36
Grid Impacts 37
Impacts on security of supply 37
Impact on Energy Bills 43
Impact on Devolved Administrations 44
Risks 44
Monitoring and Evaluation 44

SECTION E: SPECIFIC IMPACT TESTS 45

ANNEX 1: SENSITIVITIES FOR CAPITAL COSTS, FUEL AND CARBON PRICES **47**

Present Value of costs at Green Book rate 47

Net present Value at Green Book rates.. 52

Net Present Value at Reduced Discount rates 54

ANNEX 2: EXPLANATION OF DIFFERENCES IN NET PRESENT VALUE OF SEVERN SCHEMES BETWEEN PHASE 1 AND PHASE 2 .... **57**

ANNEX 3: LEVELISED COSTS.. **60**

Definition 60

Approach.. 61

Results 62

ANNEX 4: RISK ASSESSMENT AND OPTIMISM BIAS FOR SEVERN SCHEMES......................... **67**

Introduction 67

Risk Assessment... 67

Optimism Bias 69

ANNEX 5: TREATMENT OF FINANCING COSTS IN OTHER PUBLICATIONS **76**

Mott MacDonald, 'Electricity Generation Costs Update', June 2010 76

Renewable Energy Strategy (RES), Impact Assessment... 76

Framework for the Development of Clean Coal, Impact Assessment 76

SUMMARY

Methodology

1. We have appraised each of the 5 shortlisted Severn schemes (Cardiff-Weston, Beachley, Shoots, Welsh Grounds, Bridgwater Bay) by comparing their costs and benefits against those for other low-carbon generation technologies (Coal with carbon capture and storage (CCS), Nuclear, offshore wind), as well as against a 'Technology Mix' (one third of each of these technologies) – where these other technologies generate an equivalent annual amount of electricity to each Severn scheme over a 120-year time period.

2. The costs and benefits that have been monetised are construction (including Compensatory Habitats provision for Severn schemes) and operating costs (including charges for nuclear decommissioning and waste costs) , carbon emissions and air quality impacts. Key non-monetised costs and benefits relate to wider environmental impacts e.g. ecosystem impacts, security of supply, innovation spillovers and macroeconomic impacts.

3. Cost estimates for Severn schemes come from Parsons Brinckerhoff's 'Options Definition Report'. Costs for alternative technologies are based on assumptions in Mott MacDonald's 'UK Electricity Generation Costs Update'.

4. Cost estimates for CCS, nuclear and offshore wind are for Nth of a Kind (NOAK) plant rather than higher cost First of a Kind (FOAK) plant, even when costs are incurred before 2025 and construction begins in the next three years. This reflects the tendency to build fleets of plant, such that the risks around the first plant in the fleet are spread across the whole fleet – meaning that it is unlikely that any one plant will have truly FOAK costs. In addition, Severn schemes could potentially begin generation between 2018 and 2021 at the earliest, by which time learning will have generated cost reductions, and costs for these technologies may therefore be closer to NOAK. Sensitivities have been included to account for uncertainties around technology costs, fuel prices and carbon prices.

5. Optimism Bias uplifts have been estimated based on the strength of the costs information available. Optimism Bias has been estimated on a scheme-by-scheme basis for Severn schemes based on a risk assessment. Optimism Bias uplifts applied to Severn schemes are between 44% and 47%. Optimism Bias of 60% has been applied to Coal with CCS costs - this is based on an estimate in a previous Impact Assessment[7]. Optimism Bias has been applied at 24% to (Round 3) offshore wind costs to reflect the lack of contractual information relating to future offshore wind projects in deeper waters. Optimism Bias has been applied to nuclear at 15%, to reflect cost overruns on recent nuclear projects e.g. Okiluoto project in Finland. Financing costs are not included in the analysis. This reflects the fact that no delivery mechanism

[7] DECC, 'Impact Assessment of Coal and Carbon Capture and Storage requirements in 'A Framework for the Development of Clean Coal', November 2009.

for Severn has yet been proposed, meaning it is hard to form a view on what its financing costs will be. In addition, it is hard to foresee what the financing costs for any technology will be over the 120-year lifetime of a Severn scheme. Excluding financing costs tend to favour Severn schemes since they have the largest upfront capital costs relative to the other low carbon technologies.

Results

6. Under our central set of cost assumptions, no Severn schemes have a positive Net Present Value (NPV) against nuclear generation or the Technology Mix, either with or without Optimism Bias. Cardiff-Weston has a positive NPV against offshore wind, but only when Optimism Bias is excluded for both Cardiff-Weston and offshore wind. Cardiff-Weston, Shoots and Bridgwater Bay all have a positive NPV against Coal with CCS (although there are wider benefits, such as innovation, associated with CCS that have not been accounted for).

7. NPVs for each of the Severn schemes against alternative low-carbon technologies and a mix of these technologies are set out in the table below, with low and high sensitivities presented for alternative technologies' capital, fuel and (for CCS) carbon costs. Optimism Bias is accounted for.

NPV, £bn, OB included	Coal with CCS			Nuclear			Offshore Wind			Technology Mix		
	Low	Central	High	Low	Central	High	Low	Central	High	Low	Central	High
Cardiff-Weston	-3.9	9.9	21.4	-24.5	-21.5	-18.8	-9.3	-2.3	6.8	-12.6	-4.6	3.1
Shoots	-1.5	1.0	3.0	-5.5	-4.9	-4.4	-2.5	-1.2	0.5	-3.2	-1.7	-0.3
Beachley	-2.0	-0.6	0.5	-4.2	-3.9	-3.6	-2.6	-1.8	-0.9	-2.9	-2.1	-1.3
Welsh Grounds	-4.3	-1.9	0	-8.0	-7.4	-7.0	-5.2	-4.0	-2.4	-5.8	-4.5	-3.1
Bridgwater Bay	-4.4	1.4	6.1	-13.3	-12.0	-10.9	-6.7	-3.7	0.2	-8.1	-4.8	-1.5

Conclusion

8. Given the lack of a clear economic case for any of the Severn schemes - and the wider environmental legislation and financial barriers- a decision not to proceed with any Severn tidal power scheme at this time is recommended, although it should be left open as an option in the future.

SECTION A: STRATEGIC OVERVIEW

Problem Under consideration: Fighting Climate Change, Ensuring Energy Security

8. The UK currently has a number of targets with regards to climate change and energy policy.

9. The **Climate Change Act 2008** places in legislation a target of an 80% reduction in emissions by 2050, with an interim target of a 34% reduction by 2020 over 1990 levels. Under the Act, a system of legally-binding carbon budgets has been established to set the trajectory towards our long-term target. Each carbon budget lasts five years and the first three, covering the period 2008 to 2022, were set in May 2009. The fourth carbon budget, covering the period 2023 to 2027, will be set in legislation by June 2011.

10. In parallel to its emissions reduction targets, the UK also has a legally-binding **renewable energy target** (through the EU Renewable Energy Directive) to ensure that 15% of its energy comes from renewable sources by 2020. The lead scenario for the 2009 Renewable Energy Strategy (RES), suggested that renewables could provide more than 30% of our electricity by 2020[8]. More than two-thirds of this could come from onshore and offshore wind, with important additional contributions from hydro, sustainable bioenergy, marine sources and small-scale technologies.

11. 85% of UK greenhouse gas emissions are produced by burning fossil fuels to produce energy. Reducing emissions will therefore require a fundamental shift in the ways in which energy is produced and consumed. It is important that the UK maintains secure energy supplies while making this shift.

12. Key to helping to maintain energy security is having a diverse mix of low-carbon domestic energy sources. If the UK does not develop capacity to produce low-carbon energy domestically, then by 2050, we would become almost totally dependent on energy imports as our North Sea fossil fuel resources are exhausted. Overdependence on particular fuels would leave the UK vulnerable to geopolitical instability and to prices that may become higher or more volatile in response to supply uncertainties.

Pathways to 2050

13. In July this year, DECC published its '2050 Pathways Analysis'[9]. This described 6 illustrative pathways the UK could take to an 80% 2050 emissions reduction, ranging from a balanced pathway that requires significant effort across all sectors, a pathway where we fail to tackle energy efficiency, to pathways with only a minimal contribution from particular technologies in the future, such as renewables, biofuels, nuclear or carbon capture and storage.

14. Although these illustrative pathways differ substantially from one another, common messages emerge with regard to electricity generation. Firstly, a

[8] DECC, 'The Renewable Energy Strategy 2009', July 2009.
[9] DECC, '2050 Pathways Analysis', July 2010

substantial degree of electrification will be required in heating, transport and industry- failure to at least partially electrify heating and transport would make the emissions target undeliverable without very substantial demand reductions, technology breakthroughs, and extremely large amounts of bioenergy available. Consequently, electricity supply needs to be decarbonised, and may need to double, even as energy demand overall falls due to energy efficiency measures. This would require substantial, sustained investment in low-carbon technologies beyond current levels.

15. This largely supports scenarios which the Committee on Climate Change (CCC) has developed which envisage the decarbonisation of the UK power sector out to 2050. The CCC see emissions cuts in the electricity sector as being driven initially by increased deployment of wind in the period to 2020, followed by the deployment of a portfolio of low carbon technologies (nuclear, renewables and CCS) in the 2020s resulting in a largely decarbonised power sector by 2030[10].

Severn Tidal contribution to UK emissions and renewable energy targets, security of supply

16. The Severn is one of the few large-scale, untapped low-carbon renewable energy resources in the UK with the technology currently available to capture it. The largest of the shortlisted options provides around 5% of current UK total demand although more could potentially be generated from an even bigger scheme. Table 1 below shows the estimated capacity and annual output for the 5 Severn schemes that have been appraised in this Impact Assessment, together with the earliest dates when each of the schemes could begin generation assuming a 2010 project start date. The estimated annual outputs reflect the inclusion of mitigation measures to reduce environmental impact.

Table 1: Parsons Brinckerhoff estimates of Severn capacity, energy output and operational dates (assuming 2010 start date, Grid connection available on completion of construction, excluding Risk Assessment uplift))

	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
Capacity (MW)	8640	1050	625	1000	3600
Output (TWh / year)	15.60	2.70	1.50	2.60	6.30
Year of first generation (year)	2021	2018	2018	2019	2019
Year of last generation (year)	2141	2138	2138	2139	2139

17. As well as potentially contributing to the UK's emissions reduction and renewable energy targets, the Severn schemes could also potentially contribute to improving

[10] Committee on Climate Change, 'Meeting Carbon Budgets- The Need for a Step Change', October 2009 http://hmccc.s3.amazonaws.com/docs/21667%20CCC%20Report%20Chapter%204.pdf

security of energy supplies by increasing the diversity of the UK's energy supply mix and, as an indigenous source of energy, reducing dependence on imports.

18. As well as increasing the diversity of the UK energy mix in general, it would also increase the diversity of the UK's renewable electricity mix. The Severn schemes are based around tidal range generation which has a different output profile to wind: although it is intermittent, it is predictable as time and volume of generation is linked to the tides, but its output can fluctuate widely (between zero and maximum) over a short space of time. To the extent that a Severn scheme increases renewable diversity, these differences could make it easier to manage the risks posed by wind intermittency.

Rationale for Government Intervention

19. There are a number of justifications for Government action to address market failures in the renewable energy sector in general. The Stern Review[11] on the Economics of Climate Change identified three areas of market failures and barriers in tackling greenhouse gas (GHG) emissions reductions.

20. The first of these is the carbon externality where GHG emissions impose an external cost to society which is not reflected in the decision of a polluter to emit.

21. The EU has created the Emissions Trading Scheme (ETS) to introduce a specific traded carbon price that GHG emitters covered by the ETS – which includes large scale electricity generators - have to pay, thus internalising the cost of carbon in their decision making. The costs of low carbon generating technologies are typically higher than those of high-carbon technologies. The EU ETS has increased the cost of generating electricity using fossil fuels, going some way to reduce the cost differential between low and high-carbon generation. However, at current levels and without further international agreement, it is insufficient to alter fundamentally the relative economics of the different investments. Moreover, there are also limits to which the carbon price alone can be used to address climate change.

22. Even with a carbon price the market will undertake less investment in low carbon technologies than is socially optimal – for example, investment in R&D is subject to positive externalities in the shape of new knowledge and skills which spread beyond the investor. Therefore additional support for investment in low carbon technologies – the second element of Climate Change measures identified by Stern – is also needed. The EU Renewable Energy Directive does this by committing the EU to meet 20% of its energy needs from renewable sources by 2020, with the UK's share agreed at 15%. By increasing the amount of energy generated from indigenous sources the directive may also help strengthen national energy security, which the market wouldn't fully consider when making investment decisions. In the UK, the main incentive mechanism driving the necessary increase in large-scale renewable electricity generation is the Renewables Obligation (RO), which requires electricity suppliers to source a

[11] HM Treasury, 'Stern Review on the Economics of Climate Change' http://www.hm-treasury.gov.uk/sternreview_index.htm

specific and increasing amount of electricity from renewable sources. The RO has recently been expanded and extended to help ensure that the UK can deliver around 30% renewable electricity by 2020.

23. The third area identified by Stern is the need to tackle other market failures and non-financial barriers. A relevant example here is lack of grid infrastructure for low carbon technologies. In the RES the Government outlined how it planned to tackle this in order to allow renewable projects to connect to the Grid when they need and on the terms they need, through mechanisms such as a Grid National Policy Statement, appropriate investment incentives for grid companies, a new offshore transmission regime, and a 'connect and manage' approach to Grid access.

24. However, despite the existing policy mechanisms that are in place to drive increased levels of renewable electricity generation, Government intervention over and above this may be necessary to deliver any of the various Severn schemes as a result of certain key characteristics of the schemes which distinguish them from other forms of renewable generation.

25. Firstly, a Severn scheme would need to meet the objectives and legal requirements of the EU Habitats Directive through the provision of compensatory habitat measures ('Compensatory Habitats'). Given the large environmental impact of a Severn scheme, the delivery plan for Compensatory Habitats would underpin planning approval for the project. However, market testing carried out as part of Phase 2 of the Feasibility Study has indicated that potential private sector participants in a Severn scheme were concerned about the cost and complexity of developing Compensatory Habitats in the absence of planning approval, and over the deliverability of planning approval. Such uncertainty surrounding Compensatory Habitats might necessitate a higher level of Government involvement in scheme delivery relative to other renewables projects.

26. Secondly, a Severn scheme would only have limited innovation spill-over benefits for an investor relative to other renewable technologies. Both within the UK and elsewhere, there are a limited number of potential tidal range project locations where the knowledge gained in constructing a Severn project could be put to use. However, since the Severn Feasibility Study began, a number of other feasibility studies have been launched to investigate the tidal range potential of other UK estuaries and bays, e.g. the Mersey, Solway and Duddon. It is possible that the varied geographic characteristics of other tidal range resources mean that a solution that is optimal in the Severn estuary is not necessarily applicable elsewhere. This is in contrast to, say, wind, which can be used to generate power in a large number of locations and whose technology is replicable from one location to another. (However, one spin-off benefit of the Severn study has been the development of some innovative tidal range or hybrid tidal range/stream technologies under the Severn Embryonic Technologies Scheme (SETS). These technologies, if developed fully, could have wider applicability in the UK and further afield.)

27. Thirdly, the size, generating characteristics and longevity of a Severn scheme mean that it may not come forward under the RO. The RO regime only extends to

2037, meaning that RO support for a Severn scheme would be available for less than 20 years of a scheme's 120-year operational life. The inflexible nature of Severn output means that there will be periods when it is producing large levels of output at times of low demand. This exposes a Severn scheme to revenue risk (since wholesale prices will be low at times of low demand) or even off-take risk (a Severn scheme will not be able to sell its electricity at any price). The RO mechanism has both a market based support element and an element that is exposed to electricity price risk, meaning that it is only appropriate where the level of off-take risk is perceived to be manageable: this is unlikely to be the case for larger Severn schemes such as Cardiff-Weston Barrage and Bridgwater Bay Lagoon.

28. Fourthly, private sector investors are only likely to value output from a scheme over a 35-40 year period – for example, the higher discount rates used in private sector project appraisal mean that any returns much beyond this point are largely insignificant in Present Value terms – meaning that their decisions will not appropriately take account of the value that society attaches to the low-carbon, low marginal cost electricity generated by a Severn scheme beyond this point.

29. Finally, the upfront capital investment required to build a larger Severn scheme such as Cardiff-Weston or Bridgwater Bay is so great that, even if the revenue risk were reduced, it is unlikely that the necessary sums of money could be raised by the private sector through the markets. Market testing carried out by DECC as part of Phase 2 of the Feasibility Study indicates that up to £5bn could potentially be raised towards financing the construction of a scheme. This only covers all of the capital required for the smallest Severn scheme (Beachley Barrage) once Optimism Bias (see p22 below) is taken into account. The larger schemes present major risk management difficulties for the private sector, since their sheer size means that a single fixed price construction contract is unlikely to be achieved, and it is hard to see any agent other than Government who could bear the risk associated with the integration of the various construction packages. This means that risk transfer to the private sector could only be partial, and as a result, Government intervention would be required to provide additional sources of finance.

Policy Objectives

30. The overarching objective of a Severn Tidal Power scheme is to produce low-carbon electricity which contributes towards achieving climate change and energy goals and improves security of supply. The Stern Review of the economics of climate change made it clear that action is needed now to reduce the risks of dangerous climate change, for economic as well as moral reasons.

31. The objective of the Severn Feasibility Study has been to:

- assess, in broad terms, the costs, benefits and impact of a project to generate power from the tidal range of the Severn Estuary, including environmental, social, regional, economic, and energy market impacts;
- if applicable, identify a single preferred tidal range project (which may be a single technology/location or a combination of these) from the number of options that have been proposed;

- consider what measures the Government could put in place to bring forward a project that fulfils regulatory requirements, and the steps that are necessary to achieve this;
- decide, in the context of the Government's energy and climate change goals and the alternative options for achieving these, and after public consultation, whether the Government could support a tidal power project in the Severn Estuary and on what terms.

32. Over the course of the second Phase of the Study, a number of studies to consider the costs, impacts and risks of a Severn tidal power project have been carried out. This includes work on:

- How to build a Severn tidal power scheme
- The commercial risks associated with building a Severn tidal power scheme
- How the Estuary would change with a Severn tidal scheme, what effect this would have on the people and economy of the surrounding areas and the wildlife too
- How negative impacts could be reduced

33. Phase 2 has also looked at how shortlisted schemes could be improved in terms of output, costs and environmental impact. It follows on from the first phase of the study which identified the scope of the study going forward and the schemes to be studied.

34. This Impact Assessment (IA) accompanies the Phase 2 Feasibility Study Conclusions document that the Government is publishing. The numbers set out in this IA represent Government's current best estimates on the costs and benefits of different Severn scheme options. All estimates are subject to uncertainty around a range of key variables including: technology costs, fossil fuel prices, carbon prices, economic growth and energy demand.

Options Considered

Do Nothing

35. If the Government does nothing to support a Severn tidal scheme, then for the reasons set out above, it is very unlikely that the private sector would deliver a scheme in the foreseeable future. Instead some other form(s) of generation capacity would be built, with the exact type of generation built dependent on the prevailing market conditions and policy framework.

Government supports one of the five Shortlisted Severn Tidal Schemes

36. This essentially involves five different options. For each option the Government would undertake the measures necessary to support delivery of one of the five Severn schemes described below with the schemes entering operation as soon as is practically possible.

37. Originally ten proposals to generate electricity from the Severn Estuary came forward from a public Call for Proposals in May 2008 and a strategic review of

existing options. A public consultation considered which of the proposals should be studied further. The aim of short-listing was to identify scheme proposals that are not feasible, and eliminate them from further investigation. Several factors were used to determine feasibility:

- technical risk
- construction cost and the cost of energy produced
- how this cost compared to other ways of meeting our energy and climate change goals
- affordability – burden on taxpayers and energy consumers, role that Government would have to play in delivering the project

38. The following criteria were used to judge whether more costly schemes presented benefits that justified further study:

- Environmental impact – high-level view on schemes' environmental impact using predicted habitat loss as an indicator of severity
- Regional impact – high level view on impacts on ports, fishing and employment.

39. The short-listing process did not attempt to establish whether the harm caused to the environment or the regional economy was unacceptable or made a scheme unfeasible.

40. The schemes short-listed at Phase 1 and considered in this IA are:

- **Cardiff-Weston Barrage –** spanning the Estuary from Brean Down to Lavernock Point
- **Shoots Barrage –** near the Severn road crossings
- **Beachley Barrage –** slightly smaller and further upstream than the Shoots barrage, and upstream of the Wye.
- **Welsh Grounds Lagoon –** impoundment on the Welsh shore of the Estuary between Newport and the Severn road crossings.
- **Bridgwater Bay Lagoon –** impoundment on the English shore between Hinkley Point and Weston Super Mare.

41. As part of the Feasibility Study engineering consultants Parsons Brinckerhoff ('PB') have prepared an Options Definition Report (ODR)[12] which has defined each of the above schemes to a common level of detail in order to inform the inform the Feasibility Study of estimates of the scheme costs, energy yields, construction programmes and energy costs.

42. The form of the schemes as shortlisted at the end of Phase 1did not necessarily represent the optimal form taking into account cost, energy yield and

[12] Parsons Brinkerhoff, 'Strategic Environmental Assessment of Proposals for Tidal Power Development in the Severn Estuary- Options Definition Report', April 2010

environmental and regional effects. Therefore, in Phase 2, the schemes have been taken through a preliminary optimisation process to enable the Strategic Environmental Assessment to focus on the most appropriate form of each scheme.

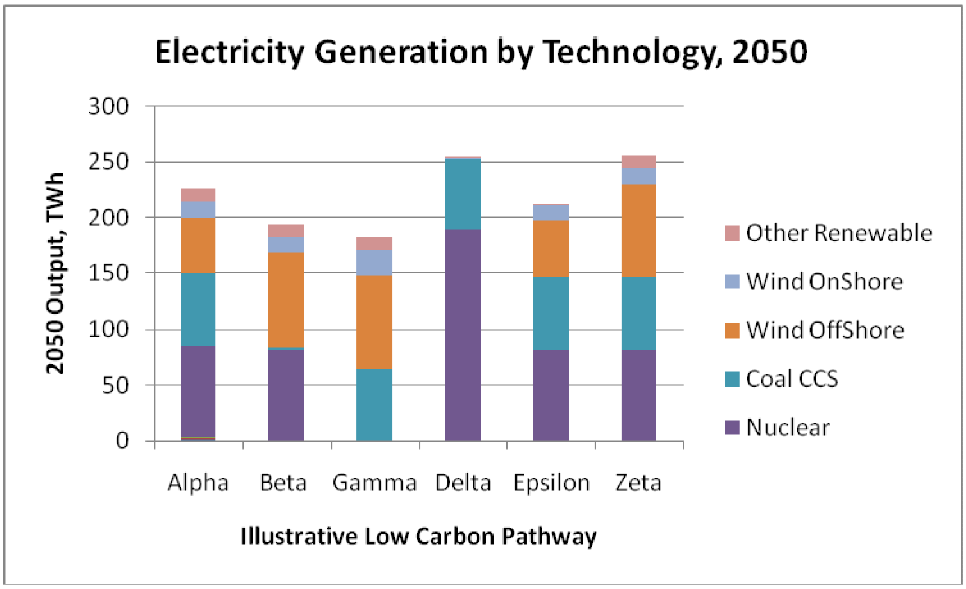
43. As a result of this process, the characteristics of some schemes have changed significantly between Phase 1 and Phase 2, most notably Bridgwater Bay Lagoon. In Phase 1, this option was assumed to have a generating capacity of 1360MW. In its current form Bridgwater Bay has a generating capacity of 3600MW.

Identification of Counterfactual

44. In the case of the "Do Nothing" option it is assumed that some other form(s) of generation will be built to provide the electricity supply that the Severn schemes would have supplied over their lifetime. Given that each of the Severn schemes would generate electricity for at least 120 years it is very uncertain what generation would be built instead over the entire lifetime.

45. DECC's 2050 Pathways work suggests that given the UK's emissions reduction targets CCS, nuclear and wind will be the principal electricity generating technologies in the UK in 2050. However, the actual shares of these main technologies vary a great deal between the illustrative low-carbon pathways developed by DECC, as is demonstrated by Chart 1 below:

Chart 1: UK Electricity Output in 2050 by technology in illustrative low-carbon pathways used in DECC '2050 Pathways' Report



46. Beyond 2050, uncertainty about the composition of the UK electricity mix increases further. This makes it difficult to choose an appropriate counterfactual technology for a very long-lived project like a Severn scheme.

47. To reflect this uncertainty we have therefore chosen to appraise the Severn options against the following low-carbon technologies across the life of a Severn project:

- Coal with Carbon Capture and Storage (CCS);
- Nuclear;
- Offshore Wind.

48. Over the time scale of the operation of the Severn schemes these represent the most likely low carbon technologies that would be built instead while they also provide a wide range of generation costs against which the Severn schemes can be compared.

49. In addition, we assess Severn schemes against a hybrid, low-carbon ‘technology mix’ counterfactual, where we assume that a third of a Severn scheme’s output would be replaced by nuclear, a third by offshore wind and a third by coal with CCS.

50. <u>The value of a Severn scheme against the technology mix counterfactual represents a ‘central’ value</u> which captures the uncertainty surrounding what technologies a Severn scheme would actually replace.

SECTION B: METHODOLOGY

Appraisal Approach

Counterfactual

51. In the Phase 1 Partial Impact Assessment (final version published February 2009), Severn scheme options were assessed against CCGT (gas) generation as the main counterfactual. The use of CCGT reflected the recommended approach in appraisal guidance at the time. However, to account for the uncertainty over the type of electricity generation technology that might constitute the marginal plant being built in the longer term, the schemes were also assessed against two 'hybrid' counterfactuals, which assumed a Severn scheme would displace:

    - CCGT up to 2030, then nuclear until the end of the Severn scheme's economic life (around 2140);
    - CCGT up to 2050, then nuclear.

52. CCGT is not used as a counterfactual in the Phase 2 IA. This reflects the fact that the UK's electricity generation mix will need to become increasingly low-carbon in the decades ahead. In addition, CCGT has very different generation properties to a Severn scheme in that it is flexible, and can respond during periods when supply is low relative to demand. In line with updated appraisal guidance[13], consistent with the UK's long-term emissions targets, Severn schemes have therefore been assessed against a wider range of low carbon counterfactuals: coal with CCS and offshore wind in addition to nuclear. As well as being low carbon, nuclear, CCS and offshore wind are significantly less flexible than CCGT. Severn schemes are assessed against each counterfactual technology across the whole of a Severn scheme's economic life – i.e. the counterfactual does not change over time.

53. Using this range of counterfactuals provides a wide range of possible outcomes for the value of each of the Severn options to society. This range reflects the uncertainty around the type of capacity which would replace a Severn scheme over the course of its operational life.

Cost Estimates

54. Cost estimates for Severn schemes come from Parsons Brinckerhoff's (PB) 'Options Definition Report'[14] which has updated the cost estimates used in Phase 1. More information on the design implications and costs of reducing environmental and regional effects of the schemes has been included. In addition, PB have moved from estimating costs via a 'fair basis' methodology at

[13] DECC, 'Valuation of Energy Use and Greenhouse Gas Emissions in appraisal and eveluation' January 2010 http://www.decc.gov.uk/media/viewfile.ashx?filepath=statistics/analysis_group/1_20100122170400_e_@@_valuationenergyuseggemissions.pdf&filetype=4
[14] Parsons Brinckerhoff, 'Options Definition Report', September 2010

Phase 1[15] using the common information that could be applied to all schemes, to using scheme specific information (including that available from previous studies) to establish more robust costs, designs and impacts for each scheme[16].

55. Assumptions underlying Mott-MacDonald's recent report on electricity generation cost estimates[17] have been used to generate costs for CCS, nuclear and offshore wind[18].

56. 'Nth of a Kind' (NOAK) cost estimates for CCS, nuclear and offshore wind have been used in preference to higher 'first of a kind' (FOAK) cost estimates even for capacity that would begin construction in the next few years. It is uncertain whether costs for these technologies would ever be at true FOAK levels . This is partly because FOAK costs are typically spread across a fleet of plant, meaning that no one plant's costs would necessarily be at FOAK levels. In addition to extra costs of undertaking the first projects, the risk/contingency premium will also be higher for FOAK. As a result the FOAK price can be substantially above the actual cost of build. In addition, the dates at which Severn projects come into operation (2018 to 2021 at the earliest) mean that learning benefits can be realised for the other technologies which will reduce costs and likely make them closer to NOAK than FOAK levels.

57. In comparison to Phase 1, the estimated costs of nuclear generation have increased significantly reflecting updated assumptions about the costs of key materials. Nuclear levelised cost estimates (based on a 10% discount rate) have increased from £38/MWh in Phase 1 to £69/MWh in this Phase 2 IA for plants beginning generation around 2020 [19].

Risk Assessment and Optimism Bias

58. According to HM Treasury Green Book guidance, Optimism Bias is 'the demonstrated systematic tendency for appraisers to be over-optimistic about key project parameters', and must be accounted for explicitly in all appraisals[20].

59. In Phase 1, Optimism Bias was applied to Severn scheme costs at 66%, the upper bound as recommended in Green Book guidance for non-standard civil engineering projects. Optimism Bias was also applied to nuclear costs at 66%.

60. For Phase 2, foreseeable risks to the delivery of a Severn project have been accounted for through a Risk Assessment exercise. Expert participants at a

[15] This entailed the estimation of fairly detailed unit costs for Cardiff Weston and Shoots Barrages, which were then applied to produce high level cost estimates for the other barrages (including Beachley). High level cost estimates for Welsh Grounds and Bridgwater Bay lagoons were also made.
[16] Full description of Phase 2 cost estimation methodology available Parsons Brinckerhoff, ibid.
[17] Mott MacDonald, 'Electricity Generation Costs Update', June 2010
[18] Costs for counterfactual technologies are based on assumptions developed for Mott-MacDonald report, 'UK Electricity Generating Costs Update', June 2010. Throughout this Impact Assessment, 'Coal with CCS' refers to advanced supercritical (ASC) coal plant with flue gas desulphurisation and carbon capture and storage. 'Nuclear' refers to pressurized water reactor nuclear plant. 'Offshore wind' refers to UK Round 3 offshore wind projects.
[19] £69/MWh is calculated using Mott MacDonald assumptions..
[20] HM Treasury, *The Green Book,* p85

series of workshops were asked to provide an assessment as to how 50 pre-identified risks would impact on project costs and duration, and the likelihood of these risks transpiring. This information was used to calculate an expected value for the impact of these risks on project duration and cost, and to derive a 'Risk Assessment Uplift' to apply to base costs to account for this. More details on the Risk Assessment process can be found at Annex 2.

61. An appropriate residual Optimism Bias uplift to apply on top of the Risk Assessment uplift (in order to account for residual uncertainty about project costs) has been calculated in accordance with Green Book Supplementary Guidance[21]. The Risk Assessment and residual Optimism Bias uplifts are combined to give an overall 'Optimism Bias' uplift.

62. Our Risk Assessment and Optimism Bias estimates for Severn projects are shown in the table below. Risk Assessment uplifts range between 15 and 20%, reflecting that the impact of particular risks would vary according to the Severn scheme in question. Optimism Bias uplifts are approximately the same for all schemes, ie residual uncertainty around scheme costs is similar for all schemes once risk assessment is taken into account.

63. A separate Optimism Bias uplift of 60% has been applied to Compensatory Habitats costs (see below). This represents the upper bound for Optimism Bias for flood and coastal defence schemes as detailed in Defra guidance[22]. Due to uncertainties about the actual form Compensatory Habitats will take, the 60% cost uplift has not been reduced. With Optimism Bias, unit cost estimates for Compensatory Habitats are £72,000/ha. The Optimism Bias for Compensatory Habitats has been incorporated into the total Optimism Bias uplifts presented below.

64. Mott MacDonald's nuclear cost assumptions are based on contractual information from recent/ current nuclear projects in regions with similar regulatory regimes to the UK (for example, Western Europe, North America). Firms are incentivised not to understate costs in contracts as they will bear the risk of the project coming in at above the quoted cost- cost assumptions that come from contractual information should not therefore need to be corrected for optimism bias. This is not the case for the other counterfactual technologies, where costs are based on engineering data. For this reason, optimism bias arguably need not be shown for nuclear in this instance. However, in order to reduce as far as possible the possibility of cost underestimates, particularly in light of recent experience of cost overruns in the nuclear sector (for example, with the Okiluoto project in Finland), we have applied Optimism Bias to nuclear costs at 15%. This reflects the percentage difference between central and high nuclear cost estimates in the Mott MacDonald report.

65. Although there is a considerable body of contract information for Offshore Wind, this generally relates to projects in the most favourable geographical sites, i.e. those which are closest to shore/ in shallower water. However, because we are considering new generation in 2018-2021, cost estimates are instead for Round 3

[21] HM Treasury, 'Supplementary Green Book Guidance: Optimism Bias' http://www.hm-treasury.gov.uk/d/5(3).pdf
[22] http://www.defra.gov.uk/environment/flooding/documents/policy/guidance/fcdpag/fcd3update0303.pdf

of the development of UK offshore wind capacity. There is no contract information as yet relating to Round 3 projects, and previous offshore wind projects do not necessarily provide a reliable guide to Round 3 costs, since Round 3 projects are expected to be in deeper water further from the coast than previous offshore wind farms. Consequently, given that:

- Wind farms can be classified as standard civil engineering;
- The basic technological solution (wind turbines) will not change for Round 3 projects;
- There is uncertainty about how costs will escalate in more challenging geographical conditions;

an Optimism Bias of **24%** has been applied to offshore wind cost estimates. This represents the midpoint of the recommended lower bound optimism bias for standard civil engineering projects (3%) and the maximum Optimism Bias uplift for Standard Civil Engineering (44%). It also approximates to the difference between central and high cost estimates in the Mott MacDonald report.

66. Our Coal CCS Optimism Bias uplift is based on those estimated for the Impact Assessment for the implementation of a policy framework to drive the development and deployment of clean coal[23]. Here Optimism Bias was applied to the main elements of expenditure as follows:

- Power plant: 0%
- CO2 capture: 200%
- CO2 pipelines: 66%
- CO2 storage: 200%

67. These were weighted by the proportion of overall expenditure comprised by each of these elements to give an overall Optimism Bias uplift of **60%**.

68. Optimism Bias uplifts for Severn and alternative technologies are summarized in the table below:

[23] DECC, *Consultation on a framework for the development of clean coal,* Impact Assessment, November 2009.

Table 2: Optimism Bias uplifts, Severn schemes and counterfactual technologies

	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon	Coal with CCS	Nuclear	Offshore Wind
RA uplift to costs (%)	17	14	13	13	14	n/a	n/a	n/a
OB uplift to costs (%)	30	31	31	31	30	60	15	24
Total Optimism Bias Uplift (%)	47	45	44	44	44	60	15	24

Comparing Costs

69. In Phase 1, overall scheme costs for Severn schemes were calculated by:

- Calculating a levelised cost of generation (in £/MWh) over a 35-year 'financing period' (i.e. the 35 years after an Severn scheme starts generation over which it repays the debts incurred in construction) using a central discount rate of 8% to reflect a commercial cost of capital;
- Multiplying a Severn scheme's annual output in each year of the financing period by the levelised cost to give an annual cost;
- Assuming annual costs post-financing period equal annual Operation and Maintenance expenditure.
- Discounting the stream of annual costs at Green Book discount rates to produce an estimate of the total present value of costs.

70. Costs for counterfactual technologies were calculated in a similar manner, using levelised cost estimates for those particular technologies and the same levels of annual output as for the Severn schemes.

71. In Phase 2, <u>cost streams</u> for both Severn schemes and counterfactual technologies have been constructed according to when particular categories of cost are incurred for each technology, e.g. construction costs occur in the years when construction actually takes place rather than being spread over the financing period as in Phase 1. The change in costing approach has been facilitated by more detailed information on the costs of alternative generating technologies from Mott MacDonald's electricity generating costs report[24]. Moreover by valuing costs in the year when resources are actually used, this method of comparing costs more accurately reflects costs as incurred by UK society as whole. These cost streams are discounted at Green Book rates.

72. Unlike for Phase 1, where the use of an 8% discount rate to calculate levelised costs reflected commercial costs of capital, financing costs (such as interest

[24] Mott MacDonald, 'UK Electricity Generation Costs Update', June 2010

repayment on debt financing) **have been excluded** from the cost and benefit appraisal in Phase 2. We have excluded financing costs since no mechanism has been proposed for delivering a Severn scheme, which means there is uncertainty around what the cost of capital for a Severn scheme would be, and because there is great uncertainty as to what a suitable cost of finance would be for any technology over the 120 year lifetime of a Severn project.

73. Some of the financing costs of our counterfactual technologies have been accounted for in previous DECC publications, as well as in Mott MacDonald's update of electricity generation costs[25]. This means that our figures for the costs of counterfactual technologies will be lower than those previously published.

74. For a given cost of capital **excluding financing costs is likely to favour Severn schemes against counterfactual technologies** because Severn schemes have higher upfront capital costs. This means that a conclusion that a Severn scheme delivers lower net benefits than other technologies is likely to be robust to assumptions about financing costs. The costs of financing a Severn scheme are however reflected in our indicative 'Energy Bills Impacts' analysis below.

75. As in Phase 1, the costs of counterfactual technologies are based on the assumption that they will replicate the annual output of each Severn scheme over its 120 year operating life.

76. The capacity of counterfactual technologies necessary to replicate the annual output from each of the Severn schemes is set out in the table below. Less capacity is needed for these alternative forms of generation because they are available to generate for a greater number of hours than Severn schemes.

Table 3: Counterfactuals capacity required to produce the same output as the reference Severn Scheme

	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
Output (TWh)	**15.60**	**2.70**	**1.50**	**2.60**	**6.30**
Capacity (MW)	8,640	1,050	625	1,000	3,600
Coal with CCS capacity (MW)	2,636	456	253	439	1,064
Nuclear capacity (MW)	2,438	422	234	406	984
Offshore Wind capacity (MW)	4,818	834	463	803	1,946

[25] Details of approaches to accounting for the costs of finance in the Renewable Energy Strategy, Mott MacDonald's 'Electricity Generation Costs Update' and the Impact Assessment for UK CCS policy are included at Annex 5.

77. Because counterfactual technologies have shorter lifetimes than the Severn schemes, counterfactual costs include investment in replacing capacity as it reaches the end of its operational life. The assumed operational lifetimes are based on Mott Macdonald's electricity generation cost report, and are as follows:

a. Coal with CCS: 38 years

b. Nuclear: 60 years

c. Offshore Wind: 24 years

78. Monetary values shown are expressed in 2009 Q1 prices (in Phase 1 they were expressed in 2008 prices). Costs and benefits are discounted back to 2010 at Green Book rates (discounting was also back to 2010 in Phase 1 analysis).

Compensatory Habitats Provision

79. *C*ompensatory Habitat costs in Phase 1 were based on a report by ABPMer which DECC commissioned for the feasibility study[26]. The Phase 1 cost estimate of £65k/ha was based on a review of recent managed realignment schemes, with an uplift applied to account for the unprecedented scale of Compensatory Habitats which might be necessary for a Severn scheme.

80. In Phase 1, 2 hectares of Compensatory Habitat for every 1 hectare of inter-tidal habitat lost was assumed to be the central rate of Compensatory Habitat provision used to generate central cost estimates for Compensatory Habitat. Sensitivities for Compensatory Habitat costs were generated using a 1:1 replacement ratio (i.e. 1 hectare for every hectare lost) and a 3:1 ratio.

81. In Phase 2 unit cost estimates for Compensatory Habitats from a further ABPmer study on managed realignment have been used[27] ABPmer used a case study approach to generate data on the range of possible costs that might apply to scaling up managed realignment. This involved an itemised costing of 'hypothetical projects' through modelling and desk-based research. A range of scenarios was created to account for different intervention levels.

82. A unit cost for Compensatory Habitats (before optimism bias) of £45k/ha has been applied. This represents the average of the 11 'hypothetical projects' as detailed in the ABPmer managed realignment report. These cover a range of size of managed re-alignments between 500ha and 11,500ha (5 sq km to 115 sq km).

83. When considering the absolute costs of the shortlisted Severn schemes, we present them with sensitivities around the ratio for Compensatory Habitat provision (1:1, 2:1, 3:1). However, when appraising the costs and benefits of

[26] Rupp-Armstrong S, Scott C, Nicholls R, 'Managed Realignment and Regulated Tidal Exchange in Northern Europe- Lessons learned and more', (based on the OMReG database: http://abpmer.net/omreg/).
[27] DECC, 'Feasibility of Managed Large Scale Realignment', April 2010.

Severn schemes against alternative technologies, costs for Compensatory Habitats are calculated using only the 2:1 ratio.

84. It is important to note that there remains a large element of uncertainty over the cost of Compensatory Habitat measures. Possible Compensatory Habitats have been quantified for inter-tidal habitat creation for the purposes of the feasibility study. Other Compensatory Habitats for other Natura 2000 features will be required but cannot be robustly quantified within the feasibility study. There is also uncertainty about whether compensatory measures beyond the requirements of the EU Habitats Directive and EU Water Framework Directive would be required, and how these would be implemented.

85. Given this, the cost of inter-tidal habitat creation should be taken as indicative of the scale of cost associated with compensatory measures not the exact cost. The cost of other measures such as those for fish is likely to be proportionally greater for the smaller options which have lower intertidal habitat loss but similar fish compensation requirements.

SECTION C: COSTS & BENEFITS OF POTENTIAL options

Summary of Phase 1 Results

86. In Phase 1, Parsons Brinkerhoff produced cost estimates for each of the long-listed schemes, including the 5 schemes that were taken forward into Phase 2, with different levels of Compensatory Habitat provision. Their estimates for construction costs (including sensitivities for different levels of Compensatory Habitat provision and including Optimism Bias adjustments) for the shortlisted schemes are summarised in the table below:

Table 4: PB Phase 1 Construction Capital Cost Estimates.

Construction Capital Costs, £m	Cardiff Weston	Shoots Barrage	Beachley Barrage	Fleming Lagoon	Bridgwater Bay Lagoon
No Comp Habitat, inc Opt Bias	26,375	3,699	2,660	4,580	4,408
1:1 Comp Habitat, inc Opt Bias	28,274	4,163	2,990	5,189	4,924
2:1 Comp Habitat, inc Opt Bias	30,173	4,627	3,320	5,799	5,440
3:1 Comp Habitat, inc Opt Bias	32,072	5,091	3,650	6,409	5,956
2:1 Comp Habitat, exc Opt Bias	20,903	3,205	2,300	4,018	3,769

87. The discounted costs and benefits from producing each Severn scheme's electrical output were netted off against those that would have resulted had the electricity been generated by alternative technologies in the counterfactual scenarios. In this way, a value for the Net Present Value ('NPV') of each Severn scheme against each counterfactual scenario was calculated. The 5 shortlisted Severn schemes all showed a negative NPV when appraised against each of the 3 main counterfactuals (CCGT, CCGT to 2030 then nuclear, CCGT to 2050 then nuclear). The results (including Optimism Bias) are summarised in the table below.

Table 5: Severn Tidal Cost Estimates, Phase 1

NPV of Severn Tidal, central cost estimates, incl Opt Bias, £bn	Cardiff Weston	Shoots Barrage	Beachley Barrage	Fleming Lagoon	Bridgwater Bay Lagoon
Vs CCGT @ £40/MWh	-27.1	-3.5	-3.2	-9.7	-4.5
Vs CCGT @ £40/MWh to 2029, then Nuclear @ £38/MWh	-40.4	-5.7	-4.4	-10.2	-7.0
Vs CCGT to 2049, then Nuclear	-35.6	-4.9	-4.0	-10.0	-6.1

Phase 2 Energy output and cost estimates for Severn Tidal Power Schemes

88. Updated estimates of Severn scheme specifications and costs have been provided by PB in the Options Definition Report (ODR)[28]. PB estimate that each Severn scheme would produce the following electricity outputs on an annual basis taking into account measures to mitigate environmental impact. As a result, estimates of output for some schemes including Cardiff-Weston have decreased.

Table 6: Severn capacity and energy output[29].

	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
Capacity (MW)	8640	1050	625	1000	3600
Output (TWh / year)	15.60	2.70	1.50	2.60	6.30
Year of first generation (year)	2021	2018	2018	2019	2019
Year of last generation (year)	2141	2138	2138	2139	2139

89. PB's undiscounted estimates for the capital expenditure[30] and annual operating cost of the shortlisted Severn options are set out in the tables below. For reference, Phase 1 costs, and the difference between Phase 1 and Phase 2 costs, are also shown. Capital expenditure (CapEx) is shown both with and without Risk Assessment/ Optimism Bias uplifts, and with and without Compensatory Habitats provision (at 2:1 ratio).

90. PB's base estimates for capital expenditure (ie without Risk Assessment/ Optimism Bias or Compensatory Habitat provision) have increased considerably for all schemes between Phase 1 and Phase 2. In the case of Bridgwater Bay, this is due largely to a considerable increase in generation capacity of the scheme. For other schemes, it is hard to point to general reasons why costs have increased: several cost elements which have increased in size for some schemes have decreased for others. Those capital cost elements for which PB estimates have increased for all schemes between Phase 1 and Phase 2 are: pre-construction; preliminaries and site overheads; caissons; navigation locks; design; contractor's oncosts, insurance and profit.

91. By contrast, Phase 2 estimates of the cost of Compensatory Habitat provision and Risk Assessment/ Optimism Bias uplift are lower than those estimated in Phase 1. However, the increase in capital costs more than offsets the reduction

[28] Parsons Brinkerhoff, ibid.
[29] 'Year of First Generation' assumes that a Grid Connection would be available at that date.
[30] Capital Expenditure includes pre-construction costs, civil engineering costs, mechanical and electrical equipment costs, ancillary works, measures to prevent/ reduce adverse effects,

in Compensatory Habitat costs and Risk Assessment/Optimism Bias uplift, meaning that total cost estimates have increased.

Table 7: Severn Scheme Cost Estimates, Feasibility Study Phase 1

STP Costs, Phase 1, £m	Cardiff Weston Barrage	Shoots Barrage	Beachley Bay Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
CapEx, no Compensatory Habitats, no RA & OB	15,889	2,228	1,602	2,759	2,655
CapEx, 2:1 Comp Habitats, no RA & OB	20,903	3,205	2,300	4,018	3,769
CapEx, 2:1 Comp Habitats, with RA & OB	30,173	4,627	3,320	5,799	5,440
Annual Operation Costs	315	44	32	55	52

Table 8: Severn Cost estimates, Phase 2

STP Costs, Phase 2, £m	Cardiff Weston Barrage	Shoots Barrage	Beachley Bay Barrage	Welsh Grounds Lagoon[31]	Bridgwater Bay Lagoon
CapEx, no Compensatory Habitats, no RA & OB	21,935	4,455	3,221	6,128	11,782
CapEx, 2:1 Comp Habitats, no RA & OB	23,199	4,743	3,450	6,771	11,971
CapEx, 2:1 Comp Habitats, with RA & OB	34,322	7,048	5,149	10,090	17,652
Annual Operation Costs	286	53.75	32	56	111.3

Table 9: Differences between Phase 2 and Phase 1 Cost Estimates

STP Costs, Difference between Phase 1 and Phase 2, £m	Cardiff Weston Barrage	Shoots Barrage	Beachley Bay Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
CapEx, no Compensatory Habitats, no RA & OB	6,046	2,227	1,619	3,369	9,127
CapEx, 2:1 Comp Habitats, no RA & OB	2,296	1,538	1,150	2,753	8,202
CapEx, 2:1 Comp Habitats, with RA & OB	4,149	2,421	1,829	4,291	12,212
Annual Operation Costs	-29	9.75	0	1	59

Comparing Severn Schemes' Costs against Counterfactual Technologies

92. Table 10 sets out the discounted present value (PV) of the costs of each Severn scheme and each corresponding counterfactual technology (excluding CO_2) for central cost estimates of each technology. It also shows the PV of costs adjusted by risk (RA) and optimism bias (OB). The table shows that the costs of all Severn schemes are higher than those for nuclear, offshore wind and "technology mix" counterfactuals. Cardiff-Weston barrage has lower costs than coal with CCS when risk adjustment and optimism bias are taken into account, but other Severn schemes have higher costs. When risk adjustment and optimism bias are excluded, Cardiff-Weston is also lower cost than offshore wind.

93. Costs with sensitivities for fuel and carbon prices and capital costs is set out in Annex 3 for each of the counterfactual technologies, and compared to Severn costs.

Table 10: Present Value of costs in 2010 (Q1 2009 prices)

Present Value of Costs	Severn	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Cardiff-Weston Barrage					
PV excl. RA & OB (£m)	23,980	24,115	12,158	26,718	20,997
PV incl. RA & OB (£m)	35,437	38,585	13,981	33,130	28,565
Shoots Barrage					
PV excl. RA & OB (£m)	5,215	4,638	2,350	5,137	4,042
PV incl. RA & OB (£m)	7,605	7,420	2,703	6,370	5,498
Beachley Barrage					
PV excl. RA & OB (£m)	3,691	2,576	1,306	2,854	2,245
PV incl. RA & OB (£m)	5,375	4,122	1,502	3,539	3,054
Welsh Grounds Lagoon					
PV excl. RA & OB (£m)	6,876	4,311	2,181	4,776	3,756
PV incl. RA & OB (£m)	9,941	6,898	2,508	5,922	5,110
Bridgwater Bay Lagoon					
PV excl. RA & OB (£m)	12,511	10,447	5,285	11,573	9,101
PV incl. RA & OB (£m)	18,055	16,715	6,078	14,350	12,381

Non-Monetised costs

94. There are a number of costs that are not included in the quantified cost analysis for either Severn schemes or counterfactual technologies.

95. These include costs that would be necessary to compensate for some of the habitats and species that might be lost under the Habitats Directive, such as fish; and other costs associated with complying with other legislation where other features are impacted upon. Other costs not included are the cost of monitoring and maintaining compensatory measures, and the cost of monetary compensation for fisheries. Net ecosystem service impacts that result from changes in the environment associated with the construction and operation of a power station, or the ecosystem service costs and benefits of compensatory measures, are also excluded. These ecosystem service impacts are likely to be particularly significant in relation to Severn schemes: the Severn estuary plays host to many internationally important habitats and species, whose habitat would change as a result of a tidal power project. Some of these impacts are reflected indirectly through the costs of Compensatory Habitat provision, which estimates what the costs of replacing lost Severn habitats in another location would be. However, Compensatory Habitats do not represent a direct valuation of the loss of ecosystem services in the Severn itself due to a project and they focus only on

the features that are protected. In line with our treatment of Severn schemes, we do not include any costs of this nature for counterfactual technologies.

96. Preliminary research on the economic value of the net ecosystem changes due to changes associated with the five shortlisted Severn options was undertaken[32]. Likely impacts on intertidal, salt marsh and grasslands are included in the analysis. The review of economic valuation evidence covered wetland values associated with flood control services, water quality, climate change, commercial and recreational fishing, other recreation, and biodiversity. However, the conclusions highlighted that significant caveats make the results insufficient (on their own) as an input to final decision making and that the results reported were significant under-estimates for a number of reasons detailed in the report. Further work would be required including a recommendation to undertake a stated preference study which would be better able to capture non-use values and the affected population that holds these values.

97. In addition, cost estimates do not include the air and noise pollution impacts during the construction phase of power projects.

Monetised Benefits

98. The principal benefit of any power project is the value of the electricity produced. However, for this appraisal we do not explicitly value the electricity produced as a benefit, as we assume that Severn schemes and counterfactual technologies produce an identical amount of electricity annually over an identical number of years (i.e. the economic life of a Severn project), and that the electricity produced by Severn schemes and by counterfactual technologies is of equal value.

99. This is a simplifying assumption and does not reflect the fact that although total generation per year is the same, the profile of this generation over the course of the year will differ between the different Severn schemes and also the counterfactual generation technologies. Society will value electricity output more or less highly during different periods of the day and year. Some of the counterfactual technologies are more flexible than the Severn schemes i.e. they can increase their output to coincide with periods when demand is higher, and therefore when society's need for it is greater, meaning that the electricity they produce might be more valuable.

100. However, monetising this across the economic life of a Severn tidal project is difficult, as it would require long-term assumptions about the different values society attaches to electricity produced at different points of the day, ie the difference between peak and off-peak wholesale electricity prices. It is impossible to predict with certainty what this differential might be in the future, since we do not know what the impact on the shape of the electricity demand profile will be of developments such as greater electrification of vehicles and heating, or increased levels of electrical storage. Given this uncertainty, we have not attempted to incorporate this into our analysis.

[32] Eftec: 'Economic valuation of the effect of the shortlisted tidal options on the ecosystem services of the Severn Estuary:, Report for DECC', April 2010.

101. The main monetary benefit of a Severn scheme estimated in this IA is the avoided CO_2 emissions generated by burning fossil fuels, and hence avoided UK carbon costs (in the form of avoided purchase of EU Emissions Trading Scheme (EU ETS) allowances). This benefit has been monetised by calculating the emissions produced by Coal with CCS in order to replicate a Severn scheme's output. These emissions have then been multiplied by the traded carbon value in that year, (taken from the latest DECC/ HMT IAG guidance[33] out to 2100). The value for the carbon value post-2100 is held constant at 2100 levels in real terms.

102. Even assuming that Coal with CCS plants co-fire biomass (assumed to constitute 5% of fuel burnt), monetised carbon benefits form a very significant component of Severn schemes' Net Present Value against a Coal with CCS counterfactual. The carbon value increases rapidly out to a 2075 peak of £308/tCO2 (central value), and remains at levels many times greater than the current price throughout the Severn scheme's operational lifetime.

103. An additional benefit of a Severn scheme relative to Coal with CCS is improved air quality. These benefits are incorporated into our NPV analysis.

104. Annual benefits are then discounted at Green Book rates to give a present value of benefits. The present value of benefits for each scheme are set out in Table 11 below with sensitivities for high and low carbon price values. The table shows that all schemes produce positive CO_2 and air quality benefits in comparison to coal with CCS generation. Since there are no avoided carbon or air quality costs relative to offshore wind or nuclear generation, Severn schemes have zero benefits relative to these counterfactuals. Severn schemes have positive benefits relative to the 'technology mix' counterfactual since this includes some CCS generation.

[33] DECC/ HMT: 'Valuation of energy use and greenhouse gas emissions for appraisal and evaluation' January 2010

Table 11: Present value of Benefits, discounted at Green Book rates.

Present value of Benefits	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Cardiff-Weston				
Low carbon price (£m)	2,945	0	0	982
Medium carbon price (£m)	6,727	0	0	2,242
High carbon price (£m)	10,524	0	0	3,508
Shoots Barrage				
Low carbon price (£m)	515	0	0	172
Medium carbon price (£m)	1,171	0	0	390
High carbon price (£m)	1,826	0	0	609
Beachley Barrage				
Low carbon price (£m)	285	0	0	95
Medium carbon price (£m)	650	0	0	217
High carbon price (£m)	1,014	0	0	338
Welsh Grounds Lagoon				
Low carbon price (£m)	494	0	0	165
Medium carbon price (£m)	1,125	0	0	375
High carbon price (£m)	1,757	0	0	586
Bridgwater Bay Lagoon				
Low carbon price (£m)	1,197	0	0	399
Medium carbon price (£m)	2,726	0	0	909
High carbon price (£m)	4,257	0	0	1,419

Non-monetised benefits

105. Although we monetise the benefit a Severn scheme creates relative to the CCS counterfactual in the form of avoided purchase of EU ETS allowances during the generation period, we do not value embedded or lifecycle emissions associated with Severn schemes or with counterfactual technologies. For Severn schemes, PB have estimated lifecycle emissions factors (per unit of electricity

produced) as part of the Strategic Environmental Assessment (SEA)[34]. However, it is not possible to fully separate out those contributory factors to the lifecycle emissions factor whose carbon impact has been costed by PB (e.g. materials whose cost includes the price of EU ETS permits required for their manufacture) and those factors whose carbon impact has not been costed (e.g. changes in the Severn estuary's characteristics as a 'carbon sink' due to a tidal power project). It is important to note that that the indirect carbon impacts of the schemes are relatively small, and that there are significant uncertainties involved in estimating the lifecycle emissions associated with a Severn scheme, especially surrounding the impact on Greenhouse Gas emissions from estuarine changes, such as sequestration, methanogenesis, impacts on the nitrogen cycle and most importantly siltation. The wider emissions impacts of a Severn scheme are discussed further in the 'Impacts- Carbon Footprint' section below.

106. In addition, the security of supply impacts of the Severn tidal schemes relative to counterfactual technologies have not been directly monetised. The security of supply impacts of a Severn project are likely to be ambiguous. On the one hand, a Severn scheme would increase the diversity of the UK's renewable generation mix. This would help mitigate the risks associated with renewables intermittency, as periods of low output from wind would not be correlated with periods of low output from tidal power. Furthermore, to the extent that a Severn scheme replaced fossil fuel-based generation, it would reduce the UK's dependency on imported fuels – to the extent that the security of supply benefits associated with this are not reflected in assumptions about future fossil fuel prices, then these benefits are not accounted for. However, the output from a Severn project would vary greatly (from zero to maximum output) over a short space of time, which could pose short-term system balancing challenges (discussed more in Section D).

107. The innovation spill-over benefits associated with a Severn scheme relative to counterfactual technologies have also not been monetised . The innovation benefits of Severn schemes are likely to be limited compared to the other low carbon technologies considered here as there are only a limited number of sites that are suitable for tidal power projects in the UK, and it is likely that the differing geographical characteristics of each site will require distinctive technological solutions.

108. Any macroeconomic benefits (or costs) that might accrue to the UK economy as a whole from a Severn scheme have also not been estimated. Again, these are likely to be small, as a Severn project would displace other economic activity at a national level. Regional impacts of a Severn scheme are presented below in the 'Distributional Impacts' section.

109. The improved flood defences which a Severn scheme will result in (see 'Impacts on the Environment- Flood Risk and Land Drainage below) are also not monetised.

[34] Parsons Brinkerhoff, 'SEA Topic Paper- Air and Climatic Factors' April 2010

Net Present Value

110. The Net Present Value (NPV) of a Severn scheme is the difference between the Present Value of the costs of the counterfactual generation technology (computed as explained in the Section above) and the Present Value of costs of the Severn scheme, plus any benefits the scheme provides relative to the counterfactual.

111. Table 12 sets out the NPV of each Severn scheme and the corresponding counterfactuals. Negative values indicate where a Severn scheme has a negative NPV compared to the relevant counterfactual technology, ie the Severn scheme has lower net benefits than alternative electricity technologies. Positive values indicate a positive NPV compared to the relevant counter factual technology.

112. NPV with sensitivities around fuel and carbon prices and capital costs for counterfactual technologies are set out in Annex 5. Counterfactual sensitivities form the lower (Nuclear) and upper (Coal with CCS) range for NPVs presented in the IA Front Sheets.

Table 12: Net Present Value for Severn schemes versus counterfactuals.

Net Present Value	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Cardiff-Weston				
PV excl. RA & OB (£m)	6,863	-11,822	2,738	-741
PV incl. RA & OB (£m)	9,875	-21,456	-2,307	-4,629
Shoots Barrage				
PV excl. RA & OB (£m)	593	-2,865	-78	-784
PV incl. RA & OB (£m)	986	-4,902	-1,235	-1,717
Beachley Barrage				
PV excl. RA & OB (£m)	-465	-2,385	-837	-1,229
PV incl. RA & OB (£m)	-603	-3,874	-1,836	-2,104
Welsh Grounds Lagoon				
PV excl. RA & OB (£m)	-1,439	-4,695	-2,100	-2,744
PV incl. RA & OB (£m)	-1,918	-7,433	-4,019	-4,457
Bridgwater Bay Lagoon				
PV excl. RA & OB (£m)	661	-7,226	-938	-2,501
PV incl. RA & OB (£m)	1,386	-11,977	-3,705	-4,765

NPVs with Discount Rates excluding pure social time preference

113. The Stern Review (2006) concluded that it was not ethically defensible to apply the pure social time preference rate to future cost-benefit calculations where this involved significant, and for practical purposes irreversible wealth transfers from future to present. This applied to the 0.5% pure social time preference element of the standard Green Book discount rate.

114. Treasury Green Book guidance states that for projects that involve significant, irreversible intergenerational wealth transfers, cost-benefit analysis should use discount rates that exclude pure social time preference as a sensitivity.

115. In Table 13 below we show the NPVs for Severn schemes versus counterfactual technologies that result if we use these alternative discount rates. Using the lower discount rate is favourable for the Severn schemes in NPV terms against all technologies but nuclear. This is because the lower discount rate causes the long-term low operating cost generation of the Severn schemes to be discounted less heavily. However, in only one instance (Shoots against Offshore Wind without Optimism Bias/ Risk Assessment) does the use of the lower discount rates cause a Severn scheme to switch from a negative to a positive NPV.

Table13: Net Present Value calculated at reduced Green Book discount rates.

Net Present Value	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Cardiff-Weston Barrage				
PV excl. RA & OB (£m)	11,072	-12,194	4,946	1,275
PV incl. RA & OB (£m)	15,744	-22,577	-71	-2,301
Shoots Barrage				
PV excl. RA & OB (£m)	1,316	-2,938	299	-441
PV incl. RA & OB (£m)	2,004	-5,099	-846	-1,313
Beachley Barrage				
PV excl. RA & OB (£m)	-104	-2,466	-668	-1,079
PV incl. RA & OB (£m)	-97	-4,041	-1,679	-1,939
Welsh Grounds Lagoon				
PV excl. RA & OB (£m)	-827	-4,849	-1,823	-2,500
PV incl. RA & OB (£m)	-1,054	-7,739	-3,764	-4,186
Bridgwater Bay Lagoon				
PV excl. RA & OB	2,276	-7,468	-136	-1,776

(£m)				
PV incl. RA & OB (£m)	3,665	-12,531	-2,901	-3,923

Explanation of NPV differences between Phase 1 and Phase 2 IAs

116. Severn scheme NPVs are generally much higher than at Phase 1. The reasons for the difference are discussed in greater detail at Annex 5, using the example of Cardiff-Weston. The main reasons for the higher NPVs can be summarized as follows:

a. Increased counterfactual generation costs (including optimism bias uplifts);
b. Lower Optimism Bias uplifts for Severn schemes at Phase 2 than at Phase 1;
c. Changes in methodology, principally exclusion of financing costs

Administrative Burden and Policy Savings Calculations

117. The costs of a Severn tidal project in administrative terms cannot be fully appraised until a delivery and funding structure has been put in place. For example, if a Severn scheme could be subsidised within the existing RO, there would be little additional administrative cost. If a Severn scheme required its own bespoke funding mechanism, greater administrative costs would be incurred in establishing and running this.

SECTION D: WIDER IMPACTS

Contribution to Emissions Reductions

118. The role a Severn scheme can play in helping the UK to reduce carbon dioxide emissions will depend on the counterfactual adopted, i.e. which technology a Severn tidal scheme would displace.

119. A Severn project would enable the UK to make significant CO_2 savings relative to a scenario where a Severn scheme's output was replaced by coal with CCS. We calculate these savings assuming that Coal with CCS would co-fire biomass at 5%. In addition, we show the 'unit cost' of abatement relative to the Coal with CCS counterfactual , calculated by dividing the PV of a Severn scheme's costs by the total CO_2 saved.

Table 14: CO2 saved, plus abatement cost per tonne of CO2 saved, across economic life of Severn schemes, relative to Coal with CCS counterfactual (assuming CCS burning 5% biomass)

vs Coal with CCS, assuming 5% cofiring with biomass	Cardiff Weston	Shoots	Beachley	Fleming Lagoon	Bridgwater Bay Lagoon
PV(Costs) exc OB, £m	23,980	5,215	3,691	6,876	12,511
PV(Costs) inc OB, £m	35,437	7,605	5,375	9,941	18,055
CO2 Saved (Mt CO2)	219	38	21	36	88
£/ tonne of CO2 saved, exc OB	**109**	**137**	**176**	**191**	**142**
£/ tonne of CO2 saved, inc OB	**162**	**200**	**256**	**276**	**205**

120. These calculations may overstate the value of CO_2 savings relative to coal with CCS if Severn intermittency means that additional thermal plant is required to generate when a Severn scheme is not producing electricity. A Severn project, like other intermittent technologies, may make flexible fossil fuel generation more attractive than inflexible, low-carbon generation in the short-term, which would offset CO_2 savings to some extent.

121. Nuclear and offshore wind do not produce any CO_2 during generation, so there are no carbon dioxide savings for a Severn scheme relative to either of these counterfactuals during generation.

122. Following DECC/ HMT guidance[35] we have also calculated a Traded Cost Comparator for Severn abatement which can be used to assess the cost effectiveness of the Severn schemes.

[35] *Valuation of Energy Use and Greenhouse Gas Emissions in Appraisal and Evaluation,* DECC, January 2010

123. We calculated these as follows for the 5 Severn options[36]:

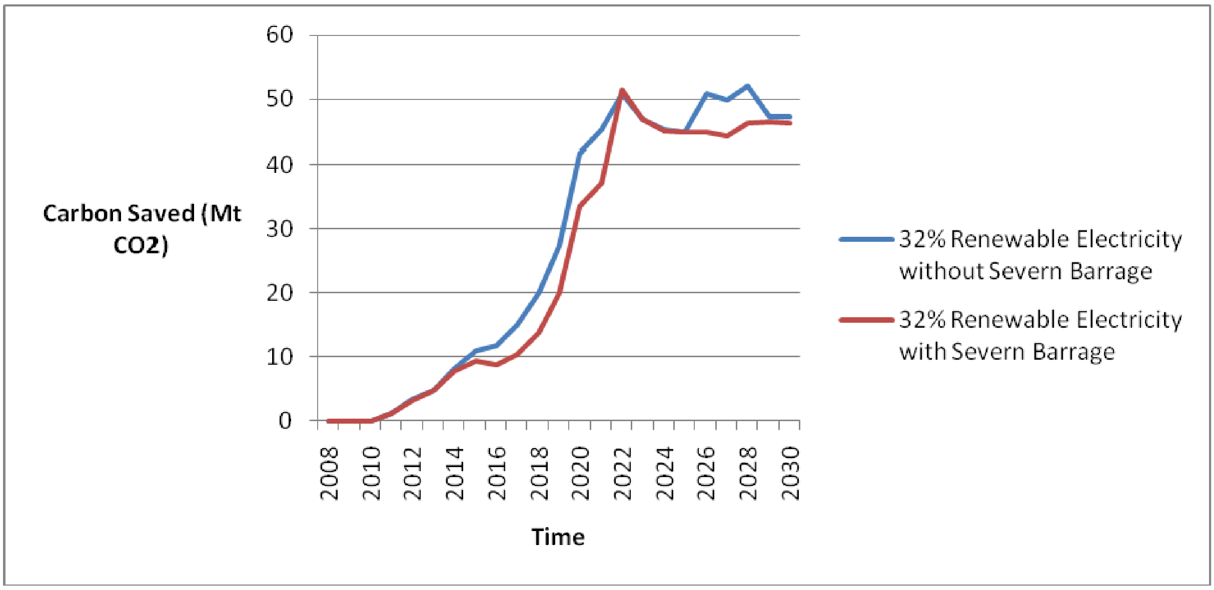
- Cardiff-Weston: £30/ tCO_2
- Shoots Barrage: £31/ tCO_2
- Beachley Barrage: £31/ tCO_2
- Welsh Grounds Lagoon: £30/ tCO_2
- Bridgwater Bay Lagoon: £30/ tCO_2

124. Since the cost per tonne of CO_2 saved for all Severn schemes for Coal with CCS is greater than these Traded Cost Comparators, none of the Severn schemes is cost-effective when considered purely as a carbon abatement option.

Comparison with other renewable generation

125. Redpoint modelling commissioned by DECC as part of the Renewable Energy Strategy Consultation analysis[37] looked at carbon savings when 32% of UK large-scale electricity is generated by renewable sources in scenarios with and without a Cardiff-Weston Barrage. As the graph below shows, the amount of emissions avoided to 2030 are slightly lower in the case where Cardiff-Weston is not built (approximately 60 million tonnes less CO_2 are saved up to 2030 if Cardiff-Weston is built).

Chart 2: Carbon Saved with 32% renewable share in 2020, with and without Severn Barrage (Redpoint 2008)



[36] Slightly different cost comparators are due to schemes' different emissions profiles.
[37] Redpoint et al, 'Implementation of the EU 2020 renewable target in the UK: Electricity Sector renewable support schemes', 2008

Impact on renewable energy targets

126. It would be very challenging for any of the shortlisted Severn schemes to begin generation in time to help meet the 2020 EU renewables target once the need for Compensatory habitats to ensure compliance with EU Birds and Habitats Directives is taken into account. Cardiff-Weston is scheduled to begin operation after 2020 even in PB's base estimate of construction period duration ie with a 2010 project start date, and so is not considered further in this section.

127. Treasury guidance states that Optimism Bias should be applied to project duration as well as costs.

128. As part of the Risk Assessment exercise, uplifts were estimated for project duration (pre-construction and construction) as well as costs to reflect the impact of foreseen risks on the timescales for the construction phase of a Severn project. Risk Assessment uplifts for project duration are shown in the table below:

Table 15: Severn scheme Project Duration (in months) uplifted to account for Risk Assessment Uplifts (excludes Cardiff-Weston)

	Shoots	Beachley Bay	Welsh Grounds	Bridgwater Bay
Project Duration (Pre-Construction and Construction phases, excl Risk Assessment)	108	120	148	150
Risk Assessment Uplift	25	24	30	29
Project Duration (incl Risk Assessment)	133	144	178	179

129. Given that our Risk Assessment uplifts add more than two years to the duration of each scheme. This makes it doubtful that any of the schemes could be ready in time to make a contribution to the UK's 2020 target, even if pre-construction could begin in 2010.

130. Moreover, planning approval for a scheme will only follow once compensation against the environmental impacts of the scheme (e.g. Compensatory habitats) is assured. The construction phase of a Severn project could only begin once the necessary Compensatory Habitats measures had been put in place. Since it is not clear at this stage what form Compensatory Habitats will take, and therefore when they would be considered 'assured' for the purposes of the planning process, it is therefore highly uncertain when work on a Severn scheme could start, and when it would be ready to begin generating electricity.

131. However, given the Risk Assessment uplifts estimated, and the need for Compensatory Habitats to be assured before work on a project begins, it is not

thought that a Severn scheme compliant with enivonmental legislation could be built in time to generate electricity by 2020.

Grid Impacts

132. National Grid are confident of being able to provide a viable connection solution for all options studied, subject to the changing generation background and gaining the required consents. The scale (and cost) of grid reinforcement work required is very dependent on the size of the scheme in output terms. For the Cardiff-Weston barrage the new substations and new and uprated overhead lines are likely to cost between £2 billion and £2.5 billion, whereas for the smaller barrages and lagoons the cost would be between £300,000 and £500,000. The costs of connecting the generating asset to a Grid substation would be borne by the project developer, but the capital costs of any transmission connection or reinforcement works would normally be borne by National Grid and recovered from all generators via the locational transmission tariffs, and would therefore not be included in the capital cost of the tidal generation project. However, they are accounted for through scheme operation costs, which include National Grid transmission charges. National Grid consider that the grid connection and reinforcement work could be accommodated within the construction programmes for the various schemes, thus not leading to any project overruns.

133. Grid connection and National Grid transmission tariffs are also included in costs for alternative technologies against which Severn schemes are appraised.[38]

Impacts on security of supply

134. This analysis assumes the continuation of the current market framework in the UK. However, Government has recognised that the current system may not provide investors with the right signals to invest in extra capacity and other mechanisms needed to provide security of supply during the 2020s, when there is increased intermittent and inflexible generation[39]. This may necessitate changes to current market arrangements, which may in turn alter what the security of supply impacts of a Severn scheme would be.

135. A Severn Tidal project will increase the diversity of the UK's electricity mix. Having a diverse electricity mix reduces dependence on particular types of generation, meaning that supply and price risks around individual generation types need not translate into supply interruptions or price spikes for the electricity system as a whole.

136. A Severn project would also increase the diversity of the UK's renewable electricity mix. Sinden, in a paper prepared for the Carbon Trust in 2005, notes that diversification reduces the variability of the total output from renewable generators, such that the contribution of the renewable portfolio as a whole to security of supply increases considerably[40].

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[38] For more details on grid impact of a Severn scheme, see, DECC, 'Indicative Impact of a Severn Tidal Power scheme on the National Electricity Transmissions System' April 2010

[39] HM Treasury, 'Energy Market Assessment' March 2010, http://www.hm-treasury.gov.uk/d/budget2010_energymarket.pdf

[40] Sinden G, 'Variability of Wave and Tidal Stream Energy Resources', 2005

137. Relative to the Coal with CCS counterfactual, a Severn project reduces the UK's dependency on imported fossil fuels as shown in the table below.

Table 16: Fossil Fuel use avoided annually, versus Coal with CCS counterfactual **.**

Fossil Fuel use avoided annually, Million tonnes of oil equivalent	Cardiff Weston	Shoots	Beachley	Fleming Lagoon	Bridgwater Bay Lagoon
Relative to Coal with CCS	4.55	0.78	0.35	0.75	1.80

138. However, Severn schemes also pose specific challenges to security of supply, as output is linked to the tides and these do not always coincide with peaks in demand for electricity. Periods where high Severn output coincides with unanticipated low demand would put downward pressure on wholesale prices, and could make them generally more volatile. (However, it is important to consider that Severn output would be predictable and known well in advance, such that other participants in the electricity market could factor it in to their output decisions to ensure demand met supply in general without significant price volatility). If wholesale prices did become lower/ more volatile, there could be less investment in new generating capacity, which would in turn reduce system capacity margins.

139. Against a renewables counterfactual, the impact on security of supply is more mixed. As part of the analysis for the RES Consultation, Redpoint modelled the impact of a Cardiff-Weston scheme relative to a counterfactual where the UK meets its 2020 renewables target using other technologies. Redpoint assumed that the Cardiff-Weston scheme began operation at full capacity in 2022, and contributed to an overall renewable share of capacity of 32%. While this timeframe may not be feasible, the conclusions related to Cardiff-Weston's impact on capacity margins remain relevant.

140. Margins become tighter during the Cardiff-Weston construction period (2015 to 2022) as the scheme displaces investment in other, smaller technologies that can be delivered more quickly. Predictions of margins after the scheme begins operation are more mixed.

141. These findings are illustrated in Chart 3 below. It shows capacity margins in three scenarios:

- **Status quo**: business as normal scenario where renewables target is not met;
- **32% Severn Barrage (RO32 no SB)**: 32% renewable energy level is partly met through construction of a Cardiff-Weston barrage;
- **32% no Severn Barrage (RO32 SB)**: 32% level is met through cheapest alternative renewable technologies without a Severn scheme.

Chart 3: De-rated Capacity Margins where 32% level of renewables achieved with and without Cardiff-Weston barrage (from Redpoint RES analysis) **.**

142. Redpoint have also produced a report for the British Wave Energy Association (BWEA) which sets out the positive impact a Severn scheme (or other marine power) could have in a renewables mix that was dominated by wind. The report estimates that for the first 10% of wind output that is replaced by marine power (assuming initial wind output of 120TWh) 1.35GW less back-up capacity is required to manage renewable intermittency[41].

Distributional Analysis- Regional Impacts

143. As part of Phase 2 of the Feasibility study, a re-working of the Phase 1 regional economic impact assessment has been conducted, taking appropriate account of methodological and data issues raised by the independent external peer review, and updating the regional economic impact estimates to reflect revised financial and construction information produced since Phase 1.

144. The figures below show the net impact on the regional economy of Wales and South West England. The net figures are the sum of impacts from the construction, ports, marine aggregates, tourism and commercial fisheries sectors.

145. This analysis follows the format of Phase 1 in terms of presenting the results as a central estimate with sensitivity testing through high and low impact cases. Given the uncertainty that is inherent in projects of this magnitude there are no probability estimates attached to these different cases – the central case is based on a moderate set of assumptions some of which are then tested in the sensitivity analysis. The results of this analysis are summarised below:

[41] Redpoint, 'The benefits of marine technologies within a diversified renewables mix- A report for the British Wind Energy Association', 2009

- **Cardiff-Weston** - The large barrage is expected to generate a net regional benefit in terms of Gross Value Added (GVA) of £2.4bn (with a range between £6.1bn and -£0.8bn). Should the Deep Sea Container Terminal (DSCT) proceed then the likely range is £5.9bn to -£1.5bn with a central estimate of £2.1bn. In terms of employment, the central estimate is for 840 net additional jobs per year during construction (+5,500 to -1,600) and 120 during operation (+800 to -2,000). The impact of DSCT on employment is, as for GVA, to reduce the positive impact with annual employment changes during construction at +440 (+5,300 to -2,200) and operation -80 (+700 to -2,500).

- **Shoots** - the central estimate is for a net GVA benefit of £0.9bn (£2.0bn to £0.3bn) with an annual employment gain of 1,300 during construction (4,000 to 600) and 100 during operation (250 to -100).

- **Beachley** - the central estimate is for a net GVA benefit of £0.5bn (£1.3bn to £0.1bn) with an annual employment gain of 1,000 during construction (2,000 to 600) and no change during operation (+150 to -150).

- **Welsh Grounds** - the central estimate is for a net GVA benefit of £1.2bn (£2.7bn to £0.4bn) with an annual employment gain of 1,800 during construction (5,000 to 600) and 100 during operation (+250 to -100).

- **Bridgwater Bay** is the largest of the lagoon options and is the most-revised from phase 1. For Bridgwater Bay the central estimate is for a net GVA benefit of £2.3bn (£4.6bn to £0.5bn) with an annual employment gain of 3,300 during construction (7,000 to 1,000) and 350 during operation (+700 to -250).

Impact on the Environment

146. Any Severn scheme would be the largest brought forward in a protected area in the UK. We have used a Strategic Environmental Assessment (SEA) to assess the environmental impacts of a Severn scheme as part of the Feasibility Study. However, there are significant uncertainties around environmental impacts which mean that they cannot be predicted with total confidence at this stage.

Air Quality

147. Air quality issues are principally associated with the construction phase of a project, in particular emissions from construction vehicles which could cause localised deteriorations in air quality. These impacts would increase with the size of a Severn project.

148. However, there is considerable uncertainty over what the air quality impacts at construction phase would be. The greater use of small boats in construction would tend to increase air quality impacts, while the use of larger boats would decrease them.

149. Once in operation, Severn schemes will also result in an improvement in air quality relative to the Coal with CCS counterfactual. These benefits have been monetised, and are included in the NPV analysis.

Carbon Footprint

150. Although a Severn scheme does not directly cause CO_2 emissions through generating electricity, it can, like other construction projects, still cause emissions indirectly, during the construction phase (e.g. due to the traffic of works vehicles), during operation (e.g. if a scheme alters the characteristics of its local environment in such a way that its ability to act as a 'carbon sink' is in some way impaired) and during decommissioning.

151. The cost of some of these indirect emissions are captured in the cost estimates of the materials used in construction - e.g. where the businesses producing the materials are within the EU ETS. However, other emissions are not accounted for.

152. One of the major areas of uncertainty for Carbon Foot-printing is establishing the impacts on emissions from estuarine changes, including sequestration, methanogenesis, impacts on the nitrogen cycle and most importantly siltation. This means that the impact of estuarine processes on a Severn scheme's carbon footprint is highly uncertain.

Flooding

153. A Severn scheme will change water levels and their profile. Without mitigation, this would lead to both increases and decreases to the flood risk. As a scheme holds back water before generating electricity, the mean water levels will rise and land would take longer to drain in the event of heavy rain and high tides. This as well as the potential for a speedier erosion of existing defences will increase fluvial flood risk. Cardiff-Weston could therefore potentially affect an estimated 370 km^2 of land containing 45,000 residential properties, 3,400 non residential properties and 28 critical infrastructure assets.

154. Scheme costings include extensive mitigation measures to both maintain existing protection levels for land on both sides of the Estuary and to bring back land drainage systems to existing service levels and improve flood defences. As the flood defences have been improved they will last longer than the existing ones but may need further investment over the course of the 120 year lifetime of a scheme. Land upstream of barrages will benefit from a lower risk of tidal storm surges as the highest tides are reduced e.g. 1.5m for Cardiff-Weston, 0.3m for Shoots. These improved flood defences will mitigate the impacts of predicted sea level rises.

155. Water levels will be affected beyond the Estuary itself. Cardiff-Weston, as the largest energy scheme, is likely to have the greatest impact, with a predicted increase in high tide levels on the largest Spring tides of up to 30cm along parts of the West Coast of Wales, as far north of the Llyn Peninsula and along the North Devon coastline, and below 10cm off parts of the East coast of the

Republic of Ireland. Costs for reducing these impacts in the UK through raising sea defences have been included in the cost of a Cardiff-Weston scheme.

156. The costs of additional flood defences are included in the capital costs of Severn schemes.

Habitat

157. Predictions of inter-tidal habitat loss range between 2,450-16,000ha depending on the scheme. Studies have shown that compensatory habitats could be feasibly provided for the protected intertidal area lost, although for options other than Bridgwater Bay this could not be achieved within the Severn area so would involve creating potentially substantial areas of habitat elsewhere in the UK. The scale is unprecedented at 6 to 60 times greater than the largest existing compensation project.

Birds

158. The Severn Estuary is designated as an internationally important site for a population of over 72,000 overwintering waterfowl recognised through its designation, under the Birds Directive, as a Special Protection Area (SPA) and as a Ramsar Wetland of International Importance.

159. For all tidal power options, habitats where these birds feed and roost would be reduced, which would lead to declines in the numbers of birds they can support. Models predict that Cardiff-Weston would also affect bird populations in three/four nearby SPAs. There is a risk that all options might affect populations both inside and outside the Severn due to migration patterns and bird flyways.

Fish

160. Within the Severn and its tributaries migratory fish, including Atlantic salmon, allis and twaite shad, and two species of lamprey, are designated as species of community importance by the Habitats Directive, and their presence is part of the reason for designation of the Severn Estuary designated sites and the Rivers Wye and Usk Special Areas of Conservation (SACs). Some of these species support fisheries with significant economic, social and cultural value. Species such as Atlantic salmon currently do not meet their conservation targets and the Environment Agency is investing in their recovery.

161. Relatively little is known about how these fish move and behave within the Estuary, tributary rivers (Wye and Usk) and out to sea. Therefore there is great uncertainty about predicting both the impacts on fish, and the effects of possible measures to mitigate harm. The majority of these mitigation measures are predicted to not have a substantial positive effect and, as they are new ideas, would require testing. Even with these measures, there is expected to be substantial residual damage that would require compensation under the Habitats Directive.

162. Predictions from modelling show a risk of extinction of twaite shad as a breeding species in the UK (most of the UK population occurs in the Severn

Estuary and Wye and Usk Rivers). For all options there is potential for population collapse, and effectively extinction, of genetically distinct salmon populations; in particular within the Rivers Wye and Severn. Local extinctions or population collapses within the area have been predicted for three other designated fish species as well as significant population declines. Bridgwater Bay has the potential to have the lowest risk of extinctions for designated fish populations.

163. All options would reduce the number of eels returning to the sea from the Estuary area, which could represent population reductions and place compliance with the EU Eel regulations at risk. Reductions in the populations of other marine and estuarine fish using the Severn Estuary are also predicted.

Impact on Energy Bills

164. As the NPV analysis shows, Severn schemes are generally higher cost than other individual counterfactual technologies, and are always higher cost than a low-carbon technology mix. However, since no delivery mechanism for a Severn project is proposed at this stage, it is not possible to estimate what a developer's costs of finance would be, or over what period the debt would have to be repaid, or indeed who the additional cost of a Severn scheme would fall on (taxpayers or electricity consumers). It is therefore not possible accurately to estimate what the impact of a Severn scheme would be on bills.

165. Instead, **for illustrative purposes only,** we have made an indicative estimate of what impact on bills a Severn scheme might have in a single year of operation (2025) over and above that of offshore wind in generating the same amount of output[42], assuming that all subsidy costs are passed on to electricity consumers, and spread equally across all electricity consumption.

166. Assuming that a Severn project was financed at a 10% cost of capital over a 35-year financing period, and given a projected wholesale electricity price of £101.50/MWh in 2025[43] we estimate that the impact on bills of each Severn scheme over and above that of offshore wind for generating the same amount of electricity would be as follows:

[42] Given a projected Renewables Obligation Certificate (ROC) price (2014 onwards) of £39.34, ROC banding of 2.0, and a Levy Exemption Certificate (LEC) price of £4.85.
[43] DECC, Updated Energy Projections, June 2010

Table 17: Impact of a Severn scheme on bills, net of offshore wind support

Severn Scheme	Average Domestic Bill Impact		Average Non-Domestic Bill Impact	
	2025 Bills Impact (£)	**% increase (2025)**	**2025 Bills Impact (£)**	**% increase (2025)**
Cardiff Weston	31	5%	76,252	5%
Shoots	7	1%	16,434	1%
Beachley	6	1%	14,908	1%
Welsh Grounds	14	2%	33,662	2%
Bridgwater Bay	18	3%	43,937	3%

Impact on Fuel Poverty

167. If a Severn scheme was funded through a subsidy mechanism where costs were passed on to consumers' bills, this could potentially create challenges for reducing levels of fuel poverty.

Impact on Devolved Administrations

168. As part of Phase 2, the Welsh Assembly Government (WAG) has updated the Phase One DTZ study into the regional economic impact of a Severn scheme. WAG, the South West Regional Development Agency and other regional partners have been closely linked in to the project via the Regional Workstream, which considers the interests of, and impacts on regions and regional bodies.

Risks

169. As part of Phase 2, a Severn-specific Risk Assessment exercise has been carried out. PriceWaterhouseCoopers (PWC) began the process by drawing up a list of risks to the delivery of a Severn project. Two Risk Workshops added other risks to the PWC list, and considered the likelihood of these risks transpiring, and their impact on project costs and delivery time should they occur. The information from the workshops fed into the calculation of Risk Assessment uplifts for each Severn project. These represent the expected impact of anticipated risks on Severn project cost and delivery time. More detail on the Risk workshops and the process by which risk assessment uplifts were calculated is available at Annex 2.

Monitoring and Evaluation

170. Even if a decision not to build a Severn scheme now is taken, it will be necessary to monitor energy market and technological developments in order to ascertain whether and when to review a 'don't build now' decision.

Section E: Specific Impact Tests

171. Given that no final regulation/ legislation is being proposed, we have not carried out the tests below in full. Below we discuss those areas where evidence of potential impacts in the relevant areas has come out of the Strategic Environmental Assessment (SEA) process.

Statutory Equality Duties Impacts

172. No assessment of the impact of a Severn scheme on statutory equality duties has been made.

Competition Impacts

173. No assessment of a Severn scheme's impact on competition has been made.

Small Firms Impacts

174. No assessment of a Severn scheme's impact on small firms has been made.

Greenhouse Gas Impacts

175. The reductions in direct CO2 emissions that a Severn scheme would lead to (versus a Coal with CCS counterfactual) are monetised and incorporated into the cost-benefits analysis. However, the SEA indicated that a Severn scheme might also affect Greenhouse gas levels by altering the ability of the Severn Estuary to act as a 'carbon sink'.

Wider Environmental Impacts

176. The environmental impacts of a Severn scheme have been explored through the Strategic Environmental Assessment (SEA) process[44] and are summarised in Section D above.

Health/ Wellbeing Impacts

177. The SEA process indicated that the construction of a Severn project will lead to increased levels of air and noise pollution on a very localised basis. When a Severn scheme is in operation, it will have positive air quality impacts against a Coal with CCS counterfactual- these have been monetised and incorporated into the cost-benefit analysis.

Human Rights Impacts

178. No assessment of a Severn scheme's impact on human rights has been made.

Justice Impacts

179. No assessment of a Severn scheme's impact on the justice system has been made.

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[44] Parsons Brinkerhoff for DECC, 'Severn Tidal Power, SEA Environmental Report' April 2010

Rural Proofing

180. The Highways Agency have highlighted the likely adverse impact on local roads during the construction phase of a Severn scheme. The in-migration of temporary construction workers is unlikely to have a significant impact on housing, facilities and services in the affected rural areas.

Sustainable Development

181. Once the costs of a Severn scheme's construction have been repaid, it will provide low-cost, zero-emission electricity for a long period. The environmental impacts of a Severn scheme have been explored through the SEA process and are summarised in Section D above.

SECTION F: SUMMARY AND PREFERRED OPTION

182. Once Risk Assessment and Optimism Bias are taken into account, all Severn schemes have a negative Net Present Value against a mix of alternative low carbon technologies across their economic life. Based on this, the preferred option is the **'Do Nothing'** option, where electricity demand is met, and the electricity system decarbonised, through investment in other forms of low-carbon electricity generation.

183. However, it will be necessary to continue monitoring costs of other technologies in relation to costs of Severn electricity generation (both shortlisted schemes and innovative new schemes that come forward in future) as it may be the case that a Severn scheme becomes more cost-effective in the future.

ANNEX 1: SENSITIVITIES FOR CAPITAL COSTS, FUEL AND CARBON PRICES

Present Value of costs at Green Book rate

Table 18: Present Value of Costs for Cardiff Weston and its counterfactuals

	Cardiff-Weston Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario					
PV (£m)	23,980	17,895	9,513	21,054	16,154
PV incl. RA & OB (£m)	35,437	28,632	10,940	26,107	21,893
PV incl. CO2 (£m)	23,980	20,557	9,513	21,054	17,041
PV incl. RA & OB and CO2 (£m)	35,437	31,294	10,940	26,107	22,780
Medium Scenario					
PV (£m)	23,980	24,115	12,158	26,718	20,997
PV incl. RA & OB (£m)	35,437	38,585	13,981	33,130	28,565
PV incl. CO2 (£m)	23,980	30,561	12,158	26,718	23,145
PV incl. RA & OB and CO2 (£m)	35,437	45,030	13,981	33,130	30,714
High Scenario					
PV (£m)	23,980	28,936	14,477	34,102	25,838
PV incl. RA & OB (£m)	35,437	46,297	16,649	42,286	35,078
PV incl. CO2 (£m)	23,980	39,178	14,477	34,102	29,252
PV incl. RA & OB and CO2 (£m)	35,437	56,539	16,649	42,286	38,492

Table 19: Present Value of Costs for Shoots and its counterfactuals

	Shoots Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario					
PV (£m)	5,215	3,480	1,857	4,094	3,144
PV incl. RA & OB (£m)	7,605	5,569	2,136	5,076	4,260
PV incl. CO2 (£m)	5,215	3,946	1,857	4,094	3,299
PV incl. RA & OB and CO2 (£m)	7,605	6,034	2,136	5,076	4,415
Medium Scenario					
PV (£m)	5,215	4,638	2,350	5,137	4,042
PV incl. RA & OB (£m)	7,605	7,420	2,703	6,370	5,498
PV incl. CO2 (£m)	5,215	5,758	2,350	5,137	4,415
PV incl. RA & OB and CO2 (£m)	7,605	8,541	2,703	6,370	5,871
High Scenario					
PV (£m)	5,215	5,507	2,762	6,507	4,926
PV incl. RA & OB (£m)	7,605	8,812	3,177	8,069	6,686
PV incl. CO2 (£m)	5,215	7,284	2,762	6,507	5,518
PV incl. RA & OB and CO2 (£m)	7,605	10,588	3,177	8,069	7,278

Table 20: Present Value of Costs, Beachley and its counterfactuals

	Beachley Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario					
PV (£m)	3,691	1,934	1,032	2,274	1,747
PV incl. RA & OB (£m)	5,375	3,094	1,187	2,820	2,367
PV incl. CO2 (£m)	3,691	2,192	1,032	2,274	1,833
PV incl. RA & OB and CO2 (£m)	5,375	3,352	1,187	2,820	2,453
Medium Scenario					
PV (£m)	3,691	2,576	1,306	2,854	2,245
PV incl. RA & OB (£m)	5,375	4,122	1,502	3,539	3,054
PV incl. CO2 (£m)	3,691	3,199	1,306	2,854	2,453
PV incl. RA & OB and CO2 (£m)	5,375	4,745	1,502	3,539	3,262
High Scenario					
PV (£m)	3,691	3,060	1,535	3,615	2,736
PV incl. RA & OB (£m)	5,375	4,895	1,765	4,483	3,714
PV incl. CO2 (£m)	3,691	4,046	1,535	3,615	3,065
PV incl. RA & OB and CO2 (£m)	5,375	5,882	1,765	4,483	4,043

Table 21: Present Value of Costs, Welsh Grounds Lagoon and its counterfactuals

	Welsh Grounds Lagoon	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario					
PV (£m)	6,876	3,223	1,716	3,792	2,910
PV incl. RA & OB (£m)	9,941	5,157	1,973	4,702	3,944
PV incl. CO2 (£m)	6,876	3,670	1,716	3,792	3,059
PV incl. RA & OB and CO2 (£m)	9,941	5,604	1,973	4,702	4,093
Medium Scenario					
PV (£m)	6,876	4,311	2,181	4,776	3,756
PV incl. RA & OB (£m)	9,941	6,898	2,508	5,922	5,110
PV incl. CO2 (£m)	6,876	5,389	2,181	4,776	4,115
PV incl. RA & OB and CO2 (£m)	9,941	7,976	2,508	5,922	5,469
High Scenario					
PV (£m)	6,876	5,138	2,575	6,065	4,593
PV incl. RA & OB (£m)	9,941	8,220	2,961	7,521	6,234
PV incl. CO2 (£m)	6,876	6,847	2,575	6,065	5,162
PV incl. RA & OB and CO2 (£m)	9,941	9,929	2,961	7,521	6,804

Table 22; Present Value of Costs, Bridgwater Bay and its counterfactuals

	Bridgwater Bay Lagoon	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario					
PV (£m)	12,511	7,811	4,157	9,188	7,052
PV incl. RA & OB (£m)	18,055	12,497	4,780	11,393	9,557
PV incl. CO2 (£m)	12,511	8,893	4,157	9,188	7,412
PV incl. RA & OB and CO2 (£m)	18,055	13,579	4,780	11,393	9,917
Medium Scenario					
PV (£m)	12,511	10,447	5,285	11,573	9,101
PV incl. RA & OB (£m)	18,055	16,715	6,078	14,350	12,381
PV incl. CO2 (£m)	12,511	13,057	5,285	11,573	9,972
PV incl. RA & OB and CO2 (£m)	18,055	19,325	6,078	14,350	13,251
High Scenario					
PV (£m)	12,511	12,449	6,239	14,696	11,128
PV incl. RA & OB (£m)	18,055	19,918	7,175	18,223	15,105
PV incl. CO2 (£m)	12,511	16,590	6,239	14,696	12,509
PV incl. RA & OB and CO2 (£m)	18,055	24,060	7,175	18,223	16,486

Net present Value at Green Book rates

Table 23: Cardiff-Weston, NPV vs Counterfactuals

Cardiff-Weston Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-3,141	-14,467	-2,926	-6,845
NPV incl. RA & OB (£m)	-3,861	-24,498	-9,331	-12,563
Medium Scenario				
NPV, excl RA & OB (£m)	6,863	-11,822	2,738	-741
NPV incl. RA & OB (£m)	9,875	-21,456	-2,307	-4,629
High Scenario				
NPV, excl RA & OB (£m)	15,480	-9,502	10,122	5,367
NPV incl. RA & OB (£m)	21,384	-18,788	6,849	3,148

Table 24: Shoots, NPV versus Counterfactuals

Shoots Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-1,220	-3,358	-1,122	-1,900
NPV incl. RA & OB (£m)	-1,521	-5,469	-2,529	-3,173
Medium Scenario				
NPV, excl RA & OB (£m)	593	-2,865	-78	-784
NPV incl. RA & OB (£m)	986	-4,902	-1,235	-1,717
High Scenario				
NPV, excl RA & OB (£m)	2,118	-2,453	1,292	319
NPV incl. RA & OB (£m)	3,033	-4,428	464	-310

Table 25: Beachley, NPV versus Counterfactuals

Beachley Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-1,472	-2,659	-1,416	-1,849
NPV incl. RA & OB (£m)	-1,996	-4,188	-2,555	-2,913
Medium Scenario				
NPV, excl RA & OB (£m)	-465	-2,385	-837	-1,229
NPV incl. RA & OB (£m)	-603	-3,874	-1,836	-2,104
High Scenario				
NPV, excl RA & OB (£m)	383	-2,156	-76	-616
NPV incl. RA & OB (£m)	534	-3,610	-892	-1,323

Table 26: Welsh Grounds Lagoon, NPV versus Counterfactuals

Welsh Grounds Lagoon	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-3,158	-5,160	-3,084	-3,801
NPV incl. RA & OB (£m)	-4,289	-7,968	-5,240	-5,832
Medium Scenario				
NPV, excl RA & OB (£m)	-1,439	-4,695	-2,100	-2,744
NPV incl. RA & OB (£m)	-1,918	-7,433	-4,019	-4,457
High Scenario				
NPV, excl RA & OB (£m)	19	-4,301	-811	-1,698
NPV incl. RA & OB (£m)	36	-6,980	-2,421	-3,121

Table 27: Bridgwater Bay, NPV vs Counterfactuals

Bridgwater Bay Lagoon	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-3,503	-8,354	-3,323	-5,060
NPV incl. RA & OB (£m)	-4,361	-13,274	-6,662	-8,099
Medium Scenario				
NPV, excl RA & OB (£m)	661	-7,226	-938	-2,501
NPV incl. RA & OB (£m)	1,386	-11,977	-3,705	-4,765
High Scenario				
NPV, excl RA & OB (£m)	4,195	-6,272	2,185	36
NPV incl. RA & OB (£m)	6,120	-10,880	169	-1,530

Net Present Value at Reduced Discount rates

184. The Green Book recommends using reduced discount rates to compute the Net Present Value as a sensitivity if a policy involves large , irreversible intergenerational wealth transfers[45]. NPVs with the reduced discount rates recommended in the Green Book are presented here.

Table 28: Cardiff-Weston's Net Present Value against its counterfactuals

Cardiff-Weston Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-1,224	-15,210	-1,596	-6,010
NPV incl. RA & OB (£m)	-972	-26,046	-8,183	-11,734
Medium Scenario				
NPV, excl RA & OB (£m)	11,072	-12,194	4,946	1,275
NPV incl. RA & OB (£m)	15,744	-22,577	-71	-2,301
High Scenario				
NPV, excl RA & OB (£m)	21,630	-9,523	13,568	8,558
NPV incl. RA & OB (£m)	29,707	-19,506	10,620	6,940

[45] HMT, 'Green Book'

Table 29: Shoots Net Present Value against counterfactuals.

Shoots Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-889	-3,493	-894	-1,758
NPV incl. RA & OB (£m)	-1,013	-5,737	-2,326	-3,025
Medium Scenario				
NPV, excl RA & OB, (£m)	1,316	-2,938	299	-441
NPV incl. RA & OB (£m)	2,004	-5,099	-846	-1,313
High Scenario				
NPV, excl RA & OB (£m)	3,185	-2,467	1,876	865
NPV incl. RA & OB (£m)	4,483	-4,557	1,110	345

Table 30: Beachley Net Present Value against counterfactuals.

Beachley Barrage	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-1,329	-2,774	-1,331	-1,811
NPV incl. RA & OB (£m)	-1,773	-4,396	-2,501	-2,890
Medium Scenario				
NPV, excl RA & OB (£m)	-104	-2,466	-668	-1,079
NPV incl. RA & OB (£m)	-97	-4,041	-1,679	-1,939
High Scenario				
NPV, excl RA & OB (£m)	934	-2,204	208	-354
NPV incl. RA & OB (£m)	1,280	-3,741	-592	-1,018

Table 31: Welsh Grounds Net Present Value against counterfactuals.

Welsh Grounds Lagoon	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-2,925	-5,375	-2,951	-3,750
NPV incl. RA & OB (£m)	-3,919	-8,344	-5,162	-5,808
Medium Scenario				
NPV, excl RA & OB (£m)	-827	-4,849	-1,823	-2,500
NPV incl. RA & OB (£m)	-1,054	-7,739	-3,764	-4,186
High Scenario				
NPV, excl RA & OB (£m)	963	-4,398	-331	-1,255
NPV incl. RA & OB (£m)	1,317	-7,220	-1,913	-2,605

Table 32: Bridgwater Bay Net Present Value against counterfactuals

Bridgwater Bay Lagoon	Coal with CCS	Nuclear	Offshore Wind	Technology Mix
Low Scenario				
NPV, excl RA & OB (£m)	-2,808	-8,743	-2,868	-4,806
NPV incl. RA & OB (£m)	-3,278	-13,998	-6,289	-7,855
Medium Scenario				
NPV, excl RA & OB (£m)	2,276	-7,468	-136	-1,776
NPV incl. RA & OB (£m)	3,665	-12,531	-2,901	-3,923
High Scenario				
NPV, excl RA & OB (£m)	6,614	-6,375	3,481	1,240
NPV incl. RA & OB (£m)	9,409	-11,275	1,584	-94

Annex 2: Explanation of Differences in Net Present Value of Severn schemes between Phase 1 and Phase 2

185. In the Impact Assessment for Phase 1 of the Feasibility Study, all shortlisted options were uncompetitive with the 3 counterfactuals (CCGT throughout Severn operational life, CCGT to 2029 then nuclear, CCGT to 2049 then nuclear).

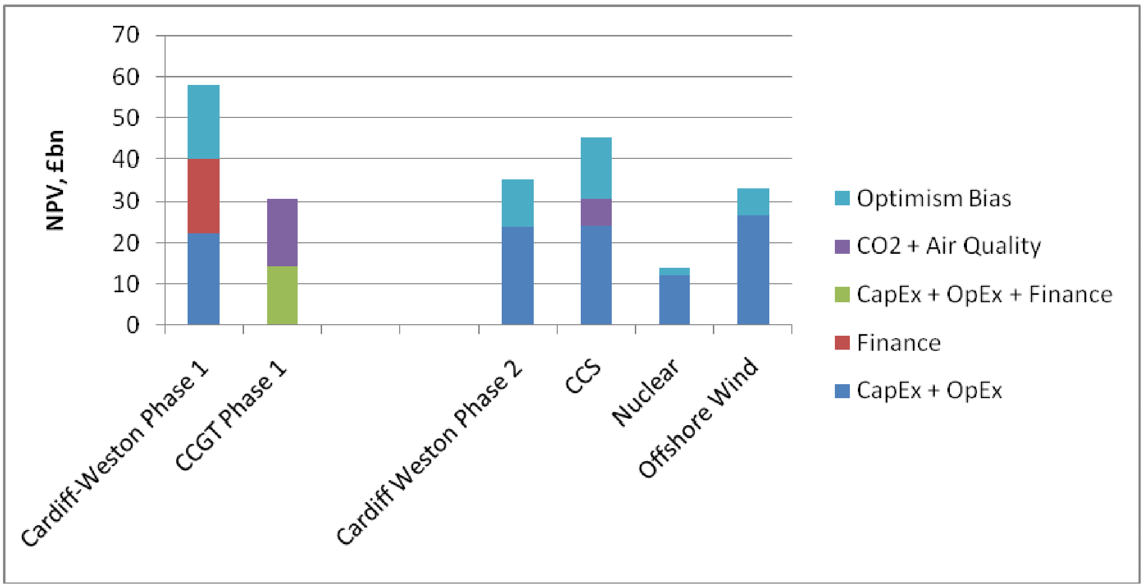
186. At Phase 2, three of the schemes (Cardiff-Weston, Shoots and Bridgwater Bay) have a positive NPV against Coal with CCS. Cardiff-Weston also has a positive NPV against offshore wind when Optimism Bias is not applied.

187. There are several possible reasons why this change could have occurred:

a. Costs of Severn schemes (CapEx and OpEx) have decreased;
b. Costs of counterfactual technologies have increased;
c. Benefits of Severn schemes (improved air quality, avoided CO2 emissions) are valued more highly;
d. Optimism Bias uplift has decreased for Severn schemes;
e. Optimism Bias uplift has increased for counterfactuals;
f. Phase 2 methodology is more favourable to Severn schemes than that employed at Phase 1.

188. We look at these possible explanations in turn for Cardiff-Weston, with reference to the following summary graph showing how Cardiff-Weston and counterfactual costs (in Present Value terms) have changed between Phase 1 and Phase 2. The figure below presents the Present Value of costs for Cardiff-Weston and the different counterfactuals used in Phase 1 and 2.

Chart 4: Composition of Net Present Value for Cardiff-Weston and counterfactuals, Phase 1 and Phase 2



Severn Scheme Costs

189. Parsons Brinkerhoff estimates of CapEx (including Compensatory Habitats) and OpEx have remained approximately the same between Phase 1 and Phase 2. This is therefore not a contributory factor to Cardiff-Weston's higher NPV.

Counterfactual Costs

190. Estimates of Coal with CCS and Offshore Wind CapEx and OpEx are considerably higher than CCGT cost estimates at Phase 1. We should note that CCGT cost estimates include the costs of finance: if finance costs were excluded, the difference would be even greater. This is therefore a significant contributory factor to Cardiff-Weston's higher NPV. (It is worth noting that estimates of CCGT costs have also risen considerably since the time of the Phase 1 IA.)

Benefits of Severn Schemes

191. The air quality benefits of a Severn scheme have been monetised in Phase 2 but not at Phase 1. However, they are only worth approximately £280m in Present Value terms, and are therefore not a significant contributory factor to Cardiff-Weston's higher NPV.

192. The benefits of Cardiff-Weston in terms of avoided CO2 emissions were much greater relative to CCGT at Phase 1 than to lower or zero carbon counterfactuals at Phase 2. This is therefore not a contributory factor to Cardiff-Weston's higher NPV.

Optimism Bias

193. In Phase 1, Optimism Bias was applied at 66% to Severn costs including the costs of finance. At Phase 2, a Risk Assessment and Optimism Bias uplift has been applied to CapEx and OpEx only at lower rates (44-47%). As the summary graph shows, the size of the Optimism Bias uplift is substantially greater at Phase 1 than Phase 2 for Cardiff-Weston. This is therefore a significant contributory factor to Cardiff-Weston's higher NPV.

194. At Phase 1, Optimism Bias was not applied to CCGT. At Phase 2, it was applied to CCS at 60%, and offshore wind at 24%, and at 15% to nuclear. This is therefore a significant contributory factor to Cardiff-Weston's higher NPV against CCS and wind.

Changes in Methodology

195. In Phase 1, financing costs were to some extent accounted for in the NPV calculations through using levelised cost estimates calculated at commercial discount rates. Due to its high construction costs, Cardiff-Weston had much higher financing costs than the CCGT counterfactual. Indeed, Cardiff-Weston's financing costs were greater than CCGT's CapEx, OpEx and financing costs combined.

196. At Phase 2, financing costs have been excluded from NPVs. If financing costs were included, they would be much higher for Cardiff-Weston than for any of the counterfactuals because of its higher upfront construction costs (which would likely have to be financed mostly through debt). The exclusion of financing costs is likely to be a significant contributory factor to Cardiff-Weston's higher NPV.

Summary

197. The following factors therefore contribute to Cardiff-Weston's much higher NPVs at Phase 2:

a. Increased counterfactual costs (including optimism bias uplifts) e.g. CCS counterfactual costs at Phase 2 are £10bn more than CCGT costs at Phase 1;
b. Lower Optimism Bias uplifts for Cardiff-Weston: £6bn lower at Phase 2;
c. Changes in methodology, ie exclusion of financing costs

198. These contributory factors will apply equally to other Severn schemes.

ANNEX 3: LEVELISED COSTS

Definition

199. The **Levelised Cost ('LEC')** of an energy project is calculated by dividing the sum of the scheme's **discounted costs** by the sum of the scheme's **energy output,** also discounted to account for when production of energy occurs. Formally:

$$Levelised\ Costs = \frac{Discounted\ costs}{Discounted\ energy} = \frac{\sum_{t=1}^{T} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{T} \frac{E_t}{(1+r)^t}}$$

200. where:

- I_t = Investment expenditures in year t;
- M_t = Operations and maintenance expenditures in year t;
- F_t = Fuel expenditures in year t;
- E_t = Electricity generation in year t;
- r = Discount rate; and
- n = Life of the system.

201. LECs can be interpreted as the per unit price of electricity which an investor would need to receive in order to **break even** on his investment**,** ie to have a Net Present Value of zero.

202. However, even for project with a given profile of expenditure and energy generation, the break-even price, and hence LEC, will vary depending on:

- the time period over which the investor must break even. In the equation above, we can vary this through *n.*
- an investor's cost of capital, and hence what rate of return he requires for the project to break even. In the equation above, we can vary this through *r.*

203. For a higher *n,* a project can break even over a longer period of time, meaning a lower LEC. If we increase *r,* an investor requires a higher rate of return for the project to break even, meaning a higher LEC.

204. Although a Severn scheme involves a large amount of capital outlay during its construction phase, once it is built it produces low marginal cost electricity over a much longer period than alternative energy technologies. If levelised costs are

based on a short break-even period, and/ a high cost of capital (and hence discount rate), a Severn scheme is likely to look unattractive in levelised cost terms relative to other technologies with lower upfront costs and shorter lifetimes, but higher marginal costs.

Approach

205. We calculate LECs for Severn projects and counterfactual technologies on the basis that a project must break even over its **economic lifetime,** ie until the asset ceases generation46. Severn projects and counterfactuals each have their own economic lifetime- we estimate them as follows47: Severn Tidal Schemes: 120 years (from start of generation)

- Coal with CCS; 38 years
- Nuclear: 60 years
- Offshore Wind: 24 years

206. We use a range of different discount rates to calculate LECs to provide both a private sector and a 'societal' perspective on the attractiveness of Severn projects as an investment relative to alternatives. These are:

- **10%:** to reflect an indicative cost of capital/ rate of time preference of a private sector investor;
- **Green Book discount rates[48]:** to reflect society's rate of time preference. This reflects the attractiveness of Severn schemes and counterfactual technologies from a 'societal' perspective.

207. We calculate LECs for Severn schemes at these different discount rates both with and without Risk Assessment and Optimism Bias. To calculate the Risk and Optimism Bias-adjusted LEC, we simply multiply the unadjusted LEC by the Risk Assessment plus Optimism Bias uplift estimated for each Severn scheme. We also calculate Severn scheme LECs for different levels of Compensatory Habitat provision.

208. It should be noted that LECs for Severn schemes do not correspond exactly with those in the ODR. This is due to the fact that we have distributed construction costs across the construction period to reflect the actual years in which particular costs were incurred, whereas in the ODR PB spread costs equally across the construction period.

46 An alternative approach is to assume that a project must break even over a 'financing period' which represents an investor's time horizon, ie the maximum time over which a project must break even. If a technology/ project's economic lifetime is shorter than the financing period, the project must still break even over its economic life (it cannot continue to earn revenue once it is out of operation). If a technology/ project has an economic life longer than the financing period, the project must break even before it ceases production.

47 Source for Severn lifetimes: Parsons Brinckerhoff Options Definition Report for Severn Tidal Power Feasibility Study. Counterfactual lifetimes come from Mott-Macdonald's 'UK Electricity Generation Costs Update', June 2010

48 Severn LECs calculated at Green Book rates, ie declining over time. Counterfactual LECs calculated using 3.5%, Green Book discount rate for period from now until 2040.

209. Severn LECs are based on the assumption that work on the project starts in 2010. This means they would begin generation 2018-2021.

210. To provide a comparison between Severn LECs and those of alternative energy technologies, we also show LECs for the counterfactual technologies used in our NPV analysis above. As in the NPV analysis, levelised costs for counterfactual technologies are calculated based on information developed by Mott-MacDonald as part of their recent report on UK electricity generation costs[49].

211. It should be noted that the levelised cost estimates for counterfactual technologies do not correspond exactly with those published in Mott-Macdonald's report. We have used nth of a kind (NOAK) technology cost estimates, together with a generation start date of 2020, in order to provide the most reasonable point of comparison with Severn levelised costs, given the longevity of Severn schemes, and given that Severn schemes' generation start dates range from 2018 to 2021. In the Mott-MacDonald report, NOAK costs are only published for projects starting generation later than 2020.

Results

10% Discount Rate

Table 34: LECs for Severn Schemes, 10% Discount Rate, for 2010 project start date.

LEC at WACC 10%	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
No Comp. Hab., no RA & OB (£/MWh)	199	215	267	320	238
1:1 Comp. Hab., incl. RA & OB (£/MWh)	303	325	404	489	346
2:1 Comp. Hab., incl. RA & OB (£/MWh)	312	335	419	515	349
3:1 Comp. Hab., incl. RA & OB (£/MWh)	321	345	433	541	352
2:1 Comp. Hab., no RA & OB (£/MWh)	211	229	287	355	242

[49] Mott MacDonald, 'UK Electricity Generating Costs Update', June 2010.

Table 35: LECs for Counterfactuals, 10% Discount Rate, assuming generation starts in 2020.

LEC at 10% discount rate	Coal with CCS	Nuclear	Offshore Wind
Excluding OB (£/MWh)	110	69	129
Including OB (£/MWh)	176	79	160

Chart 5: Levelised costs at WACC 10% discount rate without Risk Assessment and Optimism Bias

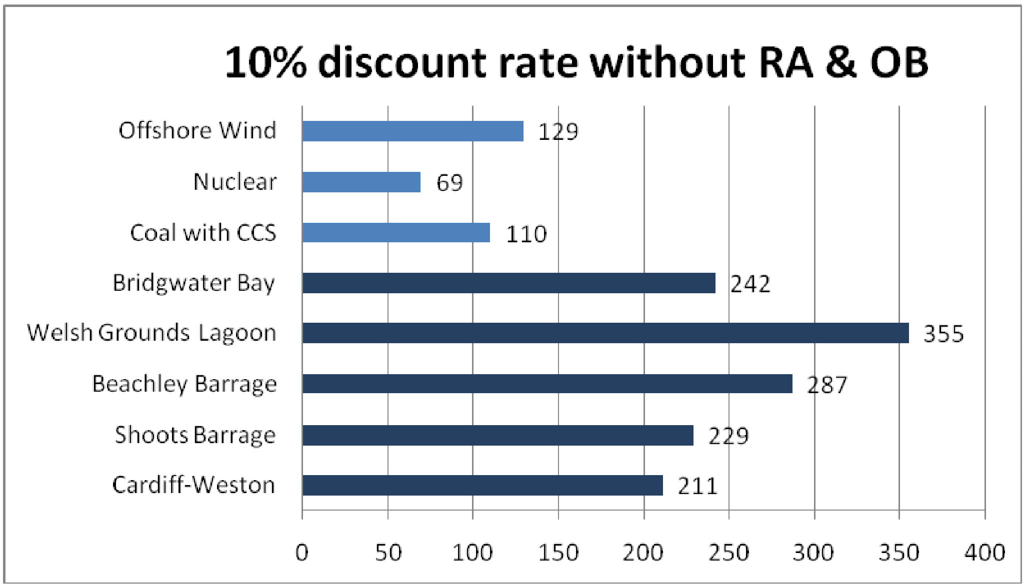
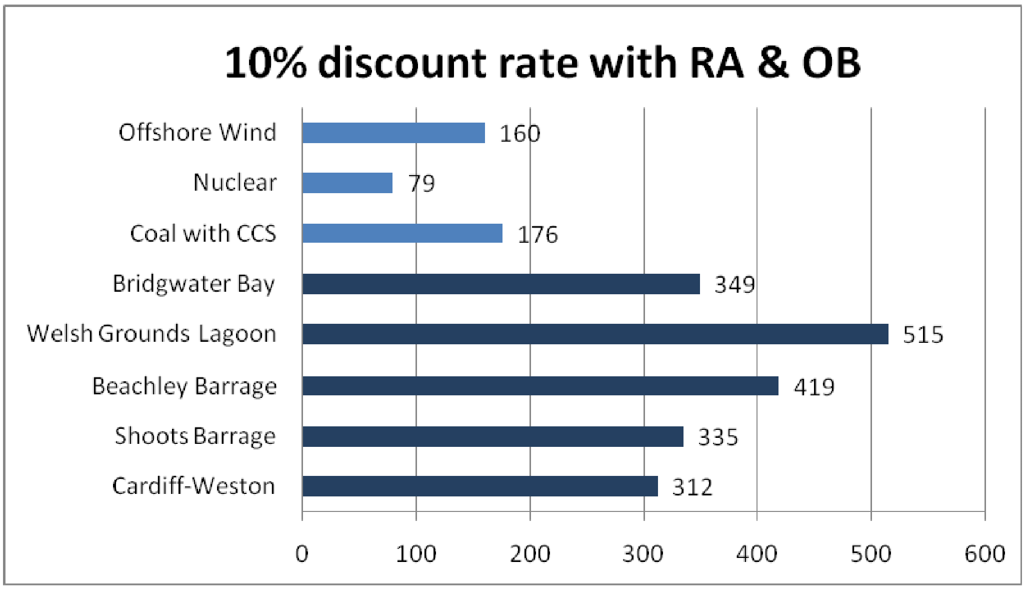


Chart 6: Levelised costs at WACC 10% discount rate with Risk Assessment and Optimism Bias.



Green Book Discount Rates

Table 36: LECs for Severn Schemes, Green Book Discount Rates.

LEC at GB rates	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
No Comp. Hab., no RA & OB (£/MWh)	70	79	98	108	86
1:1 Comp. Hab., incl. RA & OB (£/MWh)	106	118	147	162	125
2:1 Comp. Hab., incl. RA & OB (£/MWh)	108	121	151	169	126
3:1 Comp. Hab., incl. RA & OB (£/MWh)	110	123	155	176	126
2:1 Comp. Hab., no RA & OB (£/MWh)	73	83	104	117	87

Table 37: LECs for Counterfactuals, Green Book Discount Rate, assuming generation start in 2020.

LEC at GB rates	Coal with CCS	Nuclear	Offshore Wind
Excluding OB (£/MWh)	83	36	82
Including OB (£/MWh)	133	41	102

Chart 7: Levelised costs at Green Book discount rate without Risk Assessment and Optimism Bias.

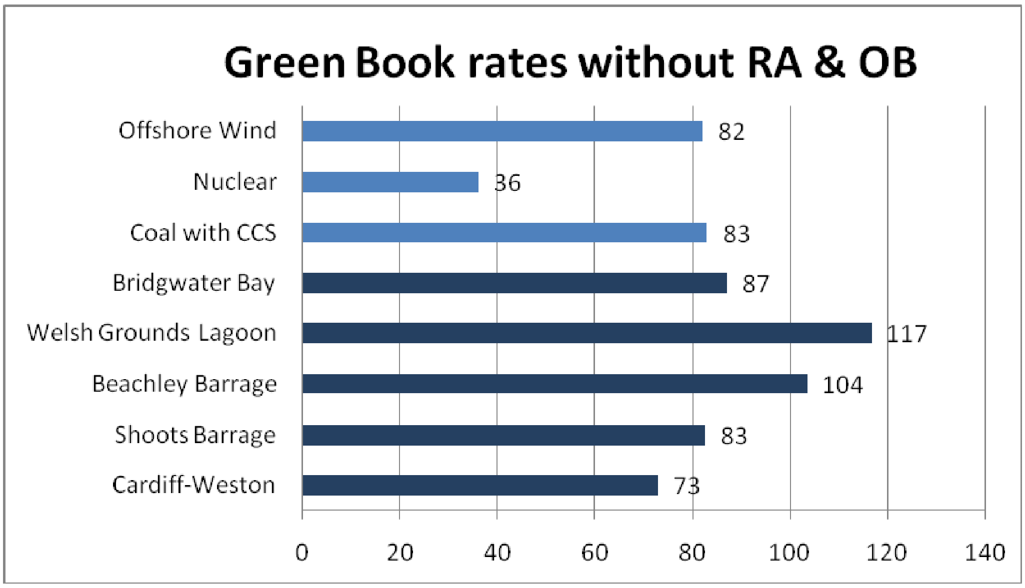
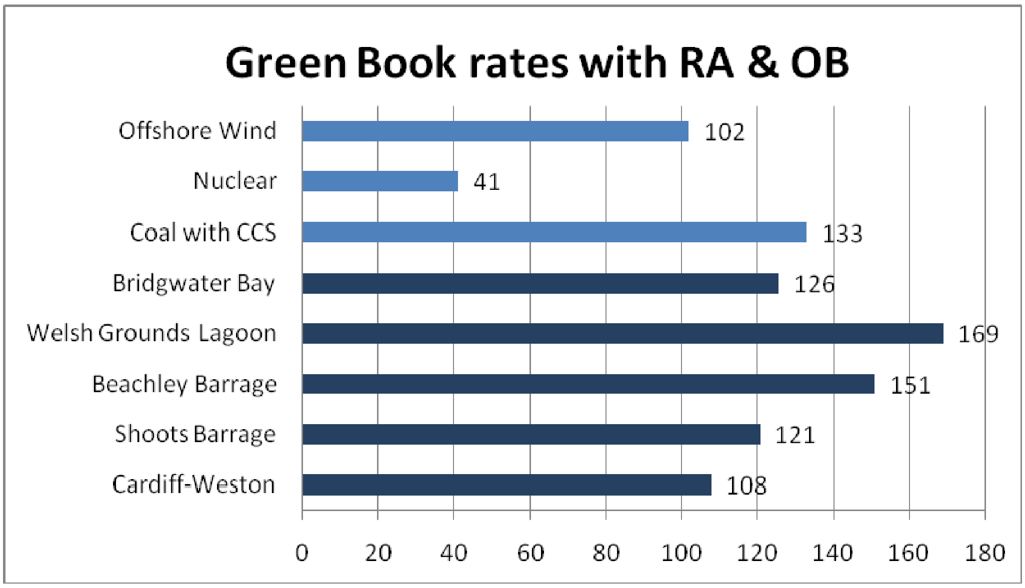


Chart 8: Levelised costs at Green Book discount rate with Risk Assessment and Optimism Bias.



ANNEX 4: RISK ASSESSMENT AND OPTIMISM BIAS FOR SEVERN SCHEMES

Introduction

212. The HMT Green Book ('the Guidance') refers to the difference between the actual expenditure for a project and its appraised total cost as 'Optimism Bias' (OB), which is due (according to the Guidance) to "a demonstrated, systematic, tendency for project appraisers to be overly optimistic". It requires that in project appraisal, cost estimates are uplifted to account for this tendency.

213. As part of the Severn Tidal Feasibility Study, specific risks that could affect project delivery have been assessed. For each risk, its expected impact on project cost and duration has been estimated.

214. However, it is impossible to assess ex ante all possible risks to project delivery, so there remains residual uncertainty about the ultimate cost of a project, and how long it will take to deliver.

215. The appropriate uplift to apply to Severn projects has been estimated in two phases. In our Risk Assessment exercise, we assess the likely impacts to project delivery from specific risks that can be anticipated in advance. Then, we estimate the appropriate residual uncertainty ('Optimism Bias') that should apply, given the risks we have already accounted for.

216. Whereas a Risk Assessment uplift is estimated for both project costs and project duration, Optimism Bias uplifts are only given for project costs. This is due to uncertainties around how project timelines will interact with the need to put environmental compensatory measures in place, meaning it is hard to arrive at a meaningful estimate of a date for final project delivery.

Risk Assessment

217. According to the Guidance, Risk Management or Risk Assessment "is a structured approach to identifying, assessing and controlling risks that emerge during the course of the policy, programme or project lifecycle. Its purpose is to support better decision-making through understanding the risks inherent in a proposal and their likely impact".

218. The aim of the Risk Assessment is to estimate the expected value of the cost increases and time delays due to a set of specific, identified risks relative to the initial cost estimates provided by PB. The expected cost of a certain risk is the cost increase caused by the occurrence of that risk (should it occur) multiplied by the probability that it will actually occur. Equivalently, the expected time delay is the time delay caused by the occurrence of the risk multiplied by the probability of its occurrence.

219. PricewaterhouseCoopers (PwC) identified a list of 50 risks that were deemed critical for the Severn Tidal Projects. In particular, the risks identified were organised in the following groups:

Group A: Project-Management risks;

Group B: Pre-construction risks;

Group C: Construction risks;

Group D: Operation and Management risks;

Group E: Subsidy risks.

220. In order to quantify the importance of the main risks for each scheme, two workshops were organised, during which every risk was assessed against a zero (0), low ("L"), low-medium ("L/M"), medium ("M"), medium-high ("M/H"), high ("H") scale. All projects were assessed separately and an assessment was provided for each risk pre- and post- the adoption of mitigation strategies that were identified during the workshops themselves.

221. Four components of risks were assessed:

- The **likelihood** of occurrence.
- The impact on **time**, should it occur.
- The impact on **costs**, should it occur, as percentage of a defined scope of cost increase.
- The **scope of cost increase**, i.e. the costs that would change, should the risk arise (e.g. construction costs, all costs, etc).

222. The workshop assessments were then used to generate a probability distribution for expected cost increases and time delays for every group of risks. The mean of the distribution was then taken as an estimate of the expected costs and time delays.

223. The 'interaction' between different risks has not been studied. In particular, two or more risks may:

i. **Overlap**, i.e. two or more risks account for the same type of uncertainty, such that the assessment overestimates the risk to the extent that these overlap.

ii. **Be correlated**, i.e. the occurrence of one risk could be correlated with the occurrence of another risk.

224. The expected cost and time delays are added on top of PB cost estimates according to the formula below.

$$'Costs + RA' = C * (1 + RA\%) = C + RA$$

225. Where C is the cost estimate provided by PB (which doesn't account for uncertainty) and RA ($RA\%$) is the final uplift (%) provided by the Risk Assessment. Results are shown in the tables below.

Table 38: Risk Assessment Uplifts for Severn Schemes

	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
RA uplift to costs (%)	17%	14%	13%	13%	14%

Table 39: Total expenditure (capex) corrected by Risk Assessment.

	Total Capex [A] + [B]	PB Cost Estimate [A]	Risk Assessment [B]
Cardiff-Weston Barrage (£m)	26,955	23,199	3,756
Shoots Barrage (£m)	5,506	4,743	763
Beachley Barrage (£m)	4,002	3,450	552
Welsh Grounds Lagoon (£m)	7,821	6,771	1,049
Bridgwater Bay Lagoon (£m)	13,989	11,971	2,018

Optimism Bias

226. This section describes how we estimate an appropriate Optimism Bias uplift to account for residual uncertainty around Severn scheme costs, taking into account the risks we have already accounted for through the Risk Assessment.

227. The Guidance sets out a five-steps procedure to calculate the correct Optimism Bias uplift to add on top of costs. The five steps are:

- **Step 1:** Decide which project type(s) to use;

- **Step 2:** Always start with the upper bound;
- **Step 3:** Consider whether the optimism bias factor can be reduced;
- **Step 4:** Apply the optimism bias factor;
- **Step 5:** Review the optimism bias adjustment.

228. This approach applies to all cost estimates computed by PB except for compensatory habitat costs, to which Defra Guidance[50] suggests to apply a 60% Optimism Bias.

Step 1: Decide which project type(s) to use

229. Severn Tidal Projects are Civil Engineering projects. The Guidance differentiates between 'Standard' and 'Non-Standard' Civil Engineering projects. In particular, the Guidance suggests, where more appropriate, to split a project's components into standard and non-standard components and to assess them as separate projects.

230. Some Severn components are non-standard, due either to their nature (particularly sophisticated components, for example) or to the dimension of the projects (even the smaller ones). PB identified some components for each project that could be more appropriately classified as 'Standard Civil Engineering'.

231. Each project has been split into a Standard Civil Engineering project and a Non-Standard Civil Engineering one. The final OB percentage uplift to add on top of cost estimates is the weighted average of the percentage uplift calculated for the two separate parts. The weights are reported in the Table below.

Table 40: Percentage split between 'Standard' and 'Non-Standard' cost components.

	Standard	Non-standard
Cardiff_Weston	25%	75%
Shoots	20%	80%
Beachley	15%	85%
Welsh Grounds	20%	80%
Bridgwater Bay	25%	75%

232. In determining the split, the following principles have been applied:

- All construction facilities are non-standard;
- All work carried out in the Estuary is non-standard;
- All caisson fabrication is standard;
- All M&E work is non-standard;

[50] Defra, 'Revisions to Economic Appraisal Procedures arising from new HM Treasury Green Book', March 2003.

- All ancillary works are non-standard;
- All measures to prevent/reduce adverse effects are non-standard;
- All surface buildings are non-standard;
- Connections to public roads are standard;

Step Two: Always start with the upper bound

233. The upper bound uplift to apply to each category is provided by the Guidance. In particular, the uplift is:

- Standard Civil Engineering: 44%;
- Non-Standard Civil engineering: 66%.

234. Upper bound uplifts represent the maximum uplift that should be added on top of costs to account for uncertainty. Uncertainty, in turn, is determined by the effect of a set of 'Contributory factors'. The stronger the effect of these factors, the higher the uncertainty about the final cost of the project, the higher the Optimism Bias uplift to add on top of costs.

235. Contributory factors are set out in Table . Contributory factors have different effects on the final uplift and are different for Standard and Non-Standard projects. The (relative) importance in generating the final uplift is set out in column 'Contribution to OB'.

Table 41: Contributory Factors and their relative importance (source: Green Book Supplementary Guidance).

	Max uplift	Contributory factors name	Contribution to OB
Standard	44%	Late Contractor Involvement in Design	3%
		Dispute and Claims Occurred	21%
		Environmental Impact	22%
		Other	18%
		Inadequacy of the Business Case	10%
		Poor Project Intelligence	7%
		Public Relations	9%
		Site Characteristics	3%
		Economic	7%
Non-Standard	66%	Other (additional procurement costs due to change in stakeholders requirements)	2%
		Design Complexity	8%
		Degree of Innovation	9%
		Environmental Impact	5%
		Inadequacy of the Business Case	35%
		Funding Availability	5%
		Project Management Team	2%
		Poor Project Intelligence	9%
		Site Characteristics	5%
		Economic	3%
		Legislation / Regulations	8%
		Technology	8%
		Other	1%

Step Three: Consider whether the optimism bias factor can be reduced

236. The Guidance then states that the upper bound uplift identified in Step 2 must be reduced "according to the extent to which the contributory factors have been managed". In particular, "[t]he main strategies for reducing Optimism Bias are:

- Full identification of stakeholder requirements (including consultation);
- Accurate costing; and
- Project and risk management".

237. In line with the Guidance, a 'mitigation factor' (between 0 and 1) is estimated for each contributory factor which expresses how well each contributory factor is being managed within the context of the Severn Project. The better a contributory factor is being managed, the higher the mitigation factor, and the lower the overall OB uplift. These mitigation factors are equal between schemes, such that

any differences in OB uplift between schemes can be explained by differences in schemes' standard/ non-standard cost split.

238. The main arguments justifying our mitigation factors are set out below.

Full identification of stakeholder requirements:

239. All major stakeholders have been consulted during phase 1 over the option that were shortlisted for phase 2.

240. There is little risk of changes in project scope, given that the only purpose of a Severn scheme is to produce electricity.

Accurate costing:

241. The design concepts are adaptations of a preliminary design prepared by Severn Tidal Power Group for Cardiff-Weston Barrage (Project B3).

242. Both PB and Corderoy are experienced in estimating the cost of major infrastructure schemes. Costs have been peer reviewed by a panel of expert engineers who have experience on this kind of projects.

243. PB carried out an appraisal of the accuracy of all cost estimates (excluding environmental impact mitigation and compensatory habitat costs) and identified intervals for each project within which costs tend to vary. Final cost estimates correspond to the value at the higher end of the cost range i.e. they are conservative.

Project and risk management:

244. A comprehensive list of risks has been produced by PricewaterhouseCoopers (PwC, hereinafter), which have been separately assessed during two workshops by a panel of experts. Many risks overlap with contributory factors for the Optimism Bias; therefore, to avoid double-counting, the elements of uncertainty that have been accounted for during the Risk Assessment must not be included in the Optimism Bias.

245. An assessment has been made of how each of these arguments apply to each of the contributory factors. Based on this, the contribution of each mitigating factor to the overall OB uplift has been reduced accordingly, to give final uplifts for non-standard (26%) and standard (20%) elements of the Severn schemes.

Step Four: Apply the optimism bias factor

246. The final Optimism Bias factor to add on top of cost estimates is the weighted average of the final uplifts for Standard and Non-Standard projects (20% and 26% respectively).

247. Final uplifts for each scheme are set out in Table.

Table 42: Optimism Bias final uplifts.

	OB final uplift
Cardiff-Weston	30%
Shoots	31%
Beachley	31%
Welsh Grounds	31%
Bridgwater Bay	30%

248. The final uplift must then be added on top of costs. However, since part of the uncertainty has been accounted for in the Risk Assessment, also the uplift for the latter must be added on top of costs. Risk Assessment uplifts (in percentage) for each project are set out in Table 38 above.

249. For each project, the adjusted costs, which include Risk Assessment and the Optimism Bias uplifts, is computed as follows:

$$'Costs + RA + OB' = C * (1 + RA\% + OB\%) = C + RA + OB$$

250. Where C is the cost estimate provided by PB (which doesn't account for uncertainty) RA ($RA\%$) is the final uplift (%) provided by the Risk Assessment, and OB ($OB\%$) is the final uplift (%) provided by the Optimism Bias. Results are shown in the table below:.

Table 43: Risk Assessment, Optimism Bias, and Total Upift to be applied to Severn project costs

	Cardiff-Weston Barrage	Shoots Barrage	Beachley Barrage	Welsh Grounds Lagoon	Bridgwater Bay Lagoon
RA uplift to costs (%)	17%	14%	13%	13%	14%
OB uplift to costs (%)	30%	31%	31%	31%	30%
RA plus OB (%) (to be applied to Severn scheme costs)	**47%**	**45%**	**44%**	**44%**	**44%**

Table 44: Total expenditure (capex) corrected by Risk Assessment and optimism Bias.

	Total Capex [A] + [B] + [C]	PB Cost Estimate [A]	Risk Assessment [B]	Optimism Bias [C]
Cardiff-Weston Barrage (£m)	34,322	23,199	3,756	7,367
Shoots Barrage (£m)	7,048	4,743	763	1,542
Beachley Barrage (£m)	5,149	3,450	552	1,147
Welsh Grounds Lagoon (£m)	10,090	6,771	1,049	2,269
Bridgwater Bay Lagoon (£m)	17,652	11,971	2,018	3,663

Step Five: Review the optimism bias adjustment

251. The Optimism Bias adjustments depend on the stage a project is at, ie as a project moves through the delivery phase, uncertainty about costs and duration will reduce, meaning the Optimism Bias uplift can also be reduced. If a Severn project was taken forward at some point in the future, it would be important to keep any future assessment of Optimism Bias under review.

ANNEX 5: TREATMENT OF FINANCING COSTS IN OTHER PUBLICATIONS

Mott MacDonald, 'Electricity Generation Costs Update', June 2010

252. Mott calculate levelised costs for each technology using a central real discount rate of 10%, and sensitivities using 7.5%. These discount rates therefore provide an approximate reflection of the finance costs faced by investors.

Renewable Energy Strategy (RES), Impact Assessment

253. In its report for DECC that fed into the RES Impact Assessment,[51] Redpoint calculated the cost of capital for each investment on a risk-adjusted basis for each type of investor (vertically integrated companies, independent developers, consortia) and technology. This was done by simulating the gross margin of each asset over its lifetime taking into account risks on both the cost and revenue side such as: policy risk, subsidy risk, electricity price risk, project risk. Overall costs, including these finance costs, are then calculated annually and on a Net Present Value basis for 2009-2030 using the Green Book discount rate of 3.5%.

Framework for the Development of Clean Coal, Impact Assessment

254. In its report for DECC that fed into the Impact Assessment[52], Redpoint calculated the cost of capital by estimating a risk premium for each CCS demonstration project, and applying this on top of a base cost of capital of 10%, which is a benchmark weighted average capital return (across debt and equity) for CCGT plant. It then annualised these costs and discounted them at Green Book rates.

[51] Redpoint/ Trilemma, 'Implementation of the EU2020 renewables target in the UK electricity sector: RO reform', June 2009.
[52] Redpoint, 'Carbon Capture and Storage Demonstration: analysis of policies on coal/ CCS and financial incentive schemes', November 2009.

Annexes

Annex 1 should be used to set out the Post Implementation Review Plan as detailed below. Further annexes may be added to provide further information about non-monetary costs and benefits from Specific Impact Tests, if relevant to an overall understanding of policy options.

Annex 1: Post Implementation Review (PIR) Plan

A PIR should be undertaken, usually three to five years after implementation of the policy, but exceptionally a longer period may be more appropriate. A PIR should examine the extent to which the implemented regulations have achieved their objectives, assess their costs and benefits and identify whether they are having any unintended consequences. Please set out the PIR Plan as detailed below. If there is no plan to do a PIR please provide reasons below.

Basis of the review: [The basis of the review could be statutory (forming part of the legislation), it could be to review existing policy or there could be a political commitment to review]; .
Review objective: [Is it intended as a proportionate check that regulation is operating as expected to tackle the problem of concern?; or as a wider exploration of the policy approach taken?; or as a link from policy objective to outcome?]
Review approach and rationale: [e.g. describe here the review approach (in-depth evaluation, scope review of monitoring data, scan of stakeholder views, etc.) and the rationale that made choosing such an approach]
Baseline: [The current (baseline) position against which the change introduced by the legislation can be measured]
Success criteria: [Criteria showing achievement of the policy objectives as set out in the final impact assessment; criteria for modifying or replacing the policy if it does not achieve its objectives]
Monitoring information arrangements: [Provide further details of the planned/existing arrangements in place that will allow a systematic collection systematic collection of monitoring information for future policy review]
Reasons for not planning a PIR: [If there is no plan to do a PIR please provide reasons here] Since no specific policy is being proposed, therefore no requirement for a monitoring process. Developments in the electricity sector e.g. technology costs will form basis of any decision to consider building Severn scheme in the future.

Add annexes here.