European Commission

SOCIO-ECONOMIC STUDIES IN THE FIELD OF THE INTEGRATED MARITIME POLICY FOR THE EUROPEAN UNION

The economics of climate change adaptation in EU coastal areas

Summary report

"Socio-economic studies in the field of the Integrated Maritime Policy for the European Union"

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The economics of climate change adaptation in EU coastal areas

Summary report

Directorate-General for Maritime Affairs and Fisheries

Study done on behalf of the European Commission

Directorate-General for Maritime Affairs and Fisheries
MARE.C.1 «Maritime Policy: Atlantic, Outermost Regions and Arctic»
European Commission
B-1049 Brussels
Tel: +32 2 295 01 61
e-mail: MARE-C1@ec.europa.eu

Executed by Policy Research Corporation (in association with MRAG)

Office Belgium:
Jan Moorkensstraat 68
2600 Antwerp
Tel: +32 3 286 94 94
fax: +32 3 286 94 96
e-mail: info@policyresearch.be
website: www.policyresearch.be

Office The Netherlands:
Parklaan 40
3016 BC Rotterdam
Tel: +31 10 436 03 64
fax: +31 10 436 14 16
e-mail: info@policyresearch.nl
website: www.policyresearch.nl

INTRODUCTION

This study on *'The economics of climate change adaptation in EU coastal areas'* provides insights in the state-of-play and the financial dimension of the actions undertaken to prepare Europe's coastal zones, including the Outermost regions, to the effects of climate change. Consequently, the different climate change adaptation aspects observed in the field are compared with the latest insights stemming from dedicated scientific literature. From this comparison and gap analysis recommendations are made to enhance the basis for policy-making on climate change adaptation in coastal zones. Thereby, this study has to be seen as 'part of the puzzle' of climate change adaptation in Europe, focusing primarily on the *actual* status of climate change adaptation across Europe's coastal zones and the related expenditure at European, national and sub-national level.

The most recent IPCC report (2007)[1] underlines that climate-related changes over the 21st century will include an acceleration in Sea Level Rise (SLR), further rise in sea surface temperature, more extreme weather events and storm surges, altered precipitation and ocean acidification. Within coastal zones these climate-related changes can be expected to have a range of impacts. Rising sea levels will increase the flood-risk and erosion along the coast but may also impact freshwater availability or result in an accelerated loss of coastal eco-systems. Climate experts emphasise the importance of adapting to these potential effects of climate change by developing and implementing coastal protection and adaptation strategies. Nevertheless, to date, little is known about the *actual* climate change adaptation practices and related investments made by the different member states to protect and adapt their coastal areas against the effects of climate change.

This summary provides an overview of the main insights of the study on the economics of climate change adaptation in EU coastal areas. Complementary to the summary and the final report, the insights per country are detailed in dedicated country fiches which can be downloaded from the European Commission's website[2].

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1 Intergovernmental Panel on Climate Change, Working Group II, 2007, *IPCC fourth assessment report on impacts, adaptation and vulnerability*.

2 http://ec.europa.eu/maritimeaffairs/climate_change_en.html

STUDY METHODOLOGY

In this study, the economics of climate change adaptation in EU coastal areas are explained from an empirical perspective and are benchmarked with the latest insights stemming from scientific literature.

Empirical information has been collected for the 22 EU coastal member states and the EU Outermost regions both at national and sub-national level through desk and internet research, contacts by telephone as well as field research. Field research has been carried out in 15 member states. On average 6-8 key players were visited per field trip, complemented with additional meetings by telephone. Besides the interviews to collect country specific information, there have been discussions with relevant academics and European associations and institutions to be able to integrate specific inputs and reflections from the research side as well. All information gathered has been extensively validated in conjunction with the interviewees. In addition, the final report was sent to three experts for a peer review.

In the empirical investigation, information was systematically collected on:

- Climate change *vulnerability* of European coastal areas;
- Level of *responsibility and key actors* (e.g. national and sub-national authorities, private stakeholders, research institutes);
- Adaptation *plans and practices* in European coastal areas at *(sub-) national level*;
- Coastal protection and climate change adaptation *expenditure* in European coastal areas at *(sub-) national level* for the period 1998-2015.

For the majority of countries national as well as sub-national authorities have been able to provide the (proximate) investment in coastal protection and climate adaptation for the entire period 1998-2015. Figures are as much as possible based on (sub-) national financial accounts. For six countries certain past or future expenditures have been extrapolated to receive a complete financial picture. For Bulgaria and Greece national and sub-national authorities could not provide sufficient details on the expenditure. For these countries, the expenditure has been calculated based on an extrapolation of the expenditure of neighbouring countries which apply similar policies and practices. In the final report and the country fiches the collection and analysis of data is further detailed for each country.

THE ECONOMICS OF CLIMATE CHANGE IN EU COASTAL AREAS

The value of the economic assets within 500 m of the coastline is estimated at € 500-1000 billion. In addition, 35% (€ 3.5 trillion) of the total GDP of the 22 European coastal member states is generated in the area within 50 km of the coast, an area which hosts moreover 1/3rd of the EU population. Policy makers do not question the vulnerability of coastal zones to climate change, but uncertainty remains when it comes to adapting to climate change, especially with regard to the financial side: what investments are needed, where and when, and which options (intervention versus no intervention as well as the type of intervention) are economically most viable?

Main risks for coastal zones: flooding, erosion, loss of eco-systems and freshwater shortage

The projected changes in climate which are relevant for coastal zones are among others a rise in sea level, changes in temperature, the direction and the power of waves, wind, precipitation and ice-cover as well as an increase in extreme weather events. To date, however, studies and reports dedicated to climate change adaptation in coastal zones focus in first instance on SLR. By the end of this century, sea level is likely to rise by 0.18m-0.59m (IPCC, 2007)[1]. SLR can cause flooding, coastal erosion and the loss of flat and low-lying areas, it magnifies landward intrusion of saltwater and endangers coastal eco-systems (EEA, 2008).

European marine basins differ in their vulnerability to climate change

Each European coastal member state is exposed differently to these climate changes, but trends can be observed per marine basin:

- *Baltic Sea*: Along the Baltic coastline, the overall vulnerability to coastal flooding and erosion due to SLR is expected to be low, most climate change impacts are projected for marine species as migration from the semi-enclosed Baltic Sea will be difficult when the sea surface temperature rises;
- *North Sea*: Significant SLR expectations, storm surges, many low-lying areas (more than 85% in BE and NL) and high economic and population concentrations make flood-risk a major concern for the North Sea countries;
- *Atlantic Ocean:* In the Atlantic marine basin, the main climate risk is flooding due to SLR and changes in both the direction and the power of waves; southern countries could become more exposed to freshwater shortage in the future due to prolonged and more intense periods of drought;

[1] At the recent international Copenhagen-conference on climate change ('Climate Change: Global Risks, Challenges & Decisions', 10-12 March 2009, Copenhagen), leading climate change scientists warned that the IPCC SLR scenarios are likely to yield an underestimation; on the basis of the most recent estimates (accounting also for the melting of the ice caps), scientists claim that the SLR scenarios by 2100 range between 0.5 m and 1 m or even more.

- *Mediterranean Sea:* Medium SLR is projected for the Mediterranean marine basin where few parts of the coastline are situated below 5 metre elevation; the area is however highly exposed to erosion; freshwater shortage is the most significant issue in the Mediterranean; large areas are affected by salt water intrusion and dry periods projected to increase in length and frequency put additional pressure on freshwater availability;
- *Black Sea:* Erosion is at present the most significant climate related problem for the Black Sea marine basin; furthermore, the area is vulnerable to the impacts of SLR on intertidal habitats and eco-systems due to the low intertidal range and limited scope for on-shore migration;
- *Outermost regions*: The characteristics of the Outermost regions such as the high concentration of population and socio-economic activities along the coastline, remoteness from the mainland, insularity, small size, difficult topography and economic dependence on a few products and sectors (often tourist related) in combination with their sensitivity to different extreme weather conditions (e.g. cyclones, drought, floods and volcanic eruptions) make these islands particular vulnerable to climate change; for some islands, also the loss of biodiversity is a major concern.

Uncertainty hampers proactive policy development for climate adaptation or coastal protection

In order for policy makers to take appropriate action where and when need be, it is important to grasp the specific vulnerability at the local level to each of the different climate change threats. Nevertheless, current scientific research results are not always supportive enough to develop climate adaptation strategies and coastal protection plans and decide on the optimal adaptation measures. Even in countries more advanced in climate change research, the uncertainties with respect to meteorological changes cause severe discrepancies between estimates given by different institutions and thus hamper accurate policy development.

Climate change adaptation has come to the agenda in almost all member states, yet being at different stages

Despite the remaining uncertainties, long-term strategic climate adaptation questions are being put on the political agenda throughout Europe. More and more countries tend to investigate how a more integrated approach to climate change adaptation in coastal zones can be followed to capture various climate change effects and streamline actions across different, but related, policy fields. This is not surprisingly, seeing the enormous economic values at stake. The estimated annual cost of inaction aggregated at EU level and primarily linked to coastal flood-risk and erosion is close to 6 billion in 2020, and is expected to further increase by 2080, depending on the rise in sea level[2].

[2] This cost of inaction comprises sea flood costs, salinity intrusion costs and migration costs; these figures are derived from the study performed by Richards and Nicholls in the framework of the wider PESETA (2009) study. Richards and Nicholls (2009) See: http://peseta.jrc.ec.europa.eu/docs/Costalareas.html

Countries more advanced in coastal protection and climate adaptation are in general those that are most affected and that have experienced some severe weather events in the past. This phenomenon can be observed especially in the North Sea countries for what concerns flood-risk. The coastal protection and climate adaptation activities in Spain confirm this observation when it comes to counteracting the problem of intense drought and freshwater shortage.

In most EU member states climate risks are however not approached from a coastal zone perspective. The majority of EU coastal member states start with a study of the projected changes in climate. Most of these changes rarely have an impact solely on coastal areas (with the exception of flood-risk and erosion). As a result, an over-arching climate change adaptation plan or strategy covering many areas and sectors is usually the result. Protection against the effects of climate change for coastal zones in particular may be included in such a wider climate change adaptation plan but hardly ever results in specific coastal zone adaptation plans. The problems of freshwater along the Mediterranean and flood-risk in the Netherlands illustrate this observation.

Spain – Actions to counteract water stress

In *Spain*, actions to counteract water stress are aimed at increasing the public water supply in order to overcome peaks in demand. Drought management plans together with considerable water infrastructure aimed at increasing water resources and reducing water loss (in 2005, Spain had already more than 700 desalination facilities and over the period 2005-2009 over 20 desalination facilities are to be built in addition) have overcome drought in the past few years. Although the Spanish Mediterranean Sea areas are in first instance eligible for national support, measures are undertaken throughout the entire country.

Malta – National Storm Water project

In the past few years *Malta* has suffered from intense flooding events. In September 2003, heavy storms and flash floods caused severe disruption of Malta's economic activities and damage of infrastructure throughout the island. Consequently, the government of Malta engaged in the development of a *National Storm Water Project*. The aim of the project is 'to manage water away from where it is a hazard to where they are short of it' as freshwater shortage is another important issue for Malta. At present, a *Storm Water Master Plan* is being formalised. The actual site works are projected to start by the end of 2010.

The Netherlands – National Water Plan, Delta Law and Delta Programme

Following different national studies and commission advices, the Dutch State Secretary for Public Works and Water Management has published the first National Water Plan in December 2008. The National Water Plan outlines the future water policy in the Netherlands and concerns the entire Dutch water system including amongst others surface water, groundwater, primary and secondary weirs and shores. The plan describes the measures to be taken to ensure the future safety of the Dutch population as well as how to make most of the different opportunities water offers. The plan is to a large extent based on the advice of the Delta Commission of September 2008 and is currently open for consultation. In the course of 2009, a Delta Law, a Delta Programme as well as the financial means that will be put forward will be presented.

Risk reduction and climate change adaptation are broadly supported at the EU level

The EU supports risk reduction and climate change adaptation through different directives and communications (e.g. Integrated Maritime Policy) as well as the Integrated Coastal Zone Management (ICZM) recommendation. The 'White Paper on adapting to climate change' constitutes the main reference document for future EU action[3]. The EU provides moreover financial support to climate change adaptation by means of dedicated priority themes under the Structural and Cohesion Funds and supports research into climate change under the different EU Research Framework Programmes. Overall, every twenty-fifth Euro (4%) of the normal coastal protection expenditure is borne by the EU.

The Flood Directive, stimulating the awareness and management of flood-risk in all member states, can also be considered as an important EU policy tool to protect the coastal areas against rising sea levels. With regard to water scarcity the European Commission published the Water Framework Directive in 2000 which specifies the EU requests for the protection of inland surface waters, transitional waters, coastal waters and groundwater. Following this Directive, the European Commission published in addition a set of policy options to increase water efficiency and saving in a dedicated communication on water scarcity and droughts (2007) and specific measures to boost disaster prevention have been put forward in the communication on the prevention of natural and man-made disasters (2009).

To protect against flooding and erosion, most European coastal member states mainly opt for 'protective' coastal measures

Despite the strategic climate change adaptation efforts currently undertaken in the majority of European member states, additional work is needed to turn strategic thinking into comprehensive adaptation policies and operational actions.

Although different climate changes and impacts are relevant for coastal zones[4], flooding and erosion in relation to SLR, are in general the issues mostly dealt with in scientific studies as well as in practice. The remainder of this summary will primarily focus on the elements of flooding, erosion and SLR. Other issues such as the direction and power of waves, wind, and precipitation are mentioned briefly.

One of the most common categorisations of related operational actions was introduced by the IPCC in 1990 and has been applied by many other authors since then (protect, accommodate and retreat). This categorisation is presented in *Table S-1*.

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3 The 'White Paper on adapting to climate change' was adopted on the 1st of April, 2009.

4 Besides flooding and erosion, water stress is also a key climate change risk; in literature, adaptation measures in the water sector are mainly categorised as measures boosting supply (e.g. extra reservoirs) or reducing demand (e.g. raising awareness); especially for the Mediterranean countries, the specific actions undertaken to counteract freshwater shortage are further detailed in the country fiches and final report.

Table S-1: Adaptation measures to SLR, flooding and erosion

	Protect = effort to continue use of vulnerable areas	***Accommodate*** = effort to continue living in vulnerable areas by adjusting living and working habits	***Retreat*** = effort to abandon vulnerable areas
Hard	Dikes, seawalls, groins, breakwaters, salt water intrusion barriers	Building on pilings, adapting drainage, emergency flood shelters	Relocating threatened buildings
Soft	Sand nourishments, dune building, wetland restoration or creation	New building codes, growing flood or salt tolerant crops, early warning and evacuation systems, risk-based hazard insurance	Land use restriction, set-back zones

Source: Policy Research Corporation

Such adaptation measures to SLR, flooding and erosion have different consequences for coastal eco-systems. In order to sustain the ecology of the coastal zones, accommodation or retreat options are advisable over protective measures as they allow eco-systems such as wetlands to migrate landwards in response to SLR. Protective measures tend to cause a 'coastal squeeze', trapping eco-systems between the sea and coastal constructions.

To date, mainly protective measures are undertaken to safeguard Europe's coastal zones from flooding and erosion. Nevertheless, 'accommodate' and 'retreat' are increasingly being examined as alternative strategies by EU coastal member states. Notwithstanding the differences at the national level which are described in more detail in the final report and country fiches, the main coastal protection approach per marine basin can be summarised as follows:

- *Baltic Sea*: In the Baltic Sea area coastal risk reduction measures mainly relate to spatial planning;
- *North Sea*: North Sea countries mostly use a mixture of hard and soft protective measures;
- *Atlantic Ocean*: Some countries implement protective measures, other countries combine 'protect' and 'accommodate' in the Atlantic Ocean area;
- *Mediterranean Sea*: In the Mediterranean area countries mostly rely on ad-hoc hard defences;
- *Black Sea*: In the Black Sea area countries mostly rely on ad-hoc hard defences;
- *Outermost regions*: Outermost regions mostly combine hard and soft protective measures.

Deciding on (additional) adaptation measures rarely involves a cost-benefit assessment

In general one would expect that decisions regarding (additional) coastal protection and climate change adaptation measures are based on a cost-benefit analysis (CBA) to evaluate if the benefits of (additional) measures outweigh the costs from a socio-economic point of view. In practice, most decision makers do not investigate the option of 'doing nothing' when deciding on risk reduction or climate adaptation measures. Especially in coastal zones where the socio-economic consequences of an extreme weather event would be enormous decision makers do not take the option of 'inaction' into account. Hence, most cost-benefit assessments tend more towards a cost-assessment: measuring which actions are optimal from a technical and financial point of view to ensure the safety of the area at risk.

Also in scientific literature, the benefits of adaptation or the cost of inaction are rarely monetised. They are mainly expressed as the potential value of assets at risk in case of no adaptation. At present, two tools, the Climate Framework for Uncertainty, Negotiation and Distribution (FUND) and the Dynamic Interactive Vulnerability Assessment (DIVA), are the most referred to for calculating the financial and economic impact of SLR with and without adaptation. Although these tools do not quantify all the benefits of adaptation in monetary terms, they provide a first basis for exploring the impact of different adaptation strategies.

The benefits of adaptation outweigh the costs

Within the PESETA (2009) study, Richards and Nicholls compared the cost of adaptation (based on the most optimal level of protection in terms of costs versus benefits) with the cost of inaction at EU level using the DIVA model. The different economic costs presented are:

- Damage cost (or cost of inaction): Sea flood costs, salinity intrusion costs and migration costs;
- Adaptation cost: Sea dike costs and beach nourishment costs[5];
- Residual damage cost: Damage costs that still remain after adaptation.

By 2020, the net-benefit of adaptation – defined as the damage cost without adaptation *minus* the cost of adaptation *minus* the residual damage cost with adaptation – ranges between € 3.8 billion (low SLR) and € 4.2 billion (high SLR)[6]. By 2080, this net-benefit is expected to further increase.

Although the analysis carried out in the PESETA study provides a good insight into the possible benefits of adaptation, one has to bear in mind that the estimations provided are projections based on a theoretical model. Consequently, the estimates do not entirely correspond to the actual situation but highly depend on the input parameters used and the values attributed to them. Furthermore, it is important to note that coastal protection and climate change adaptation is not just a question of measuring the level of financial costs versus financial benefits at an aggregated level; also sociological aspects, the value of eco-systems services (to for example human health and well-being) as well as the 'allocative' versus the 'distributive' aspects of adaptation should be considered.

The benefits of adaptation, according to PESETA (2009) are visualised in *Figure S-1*.

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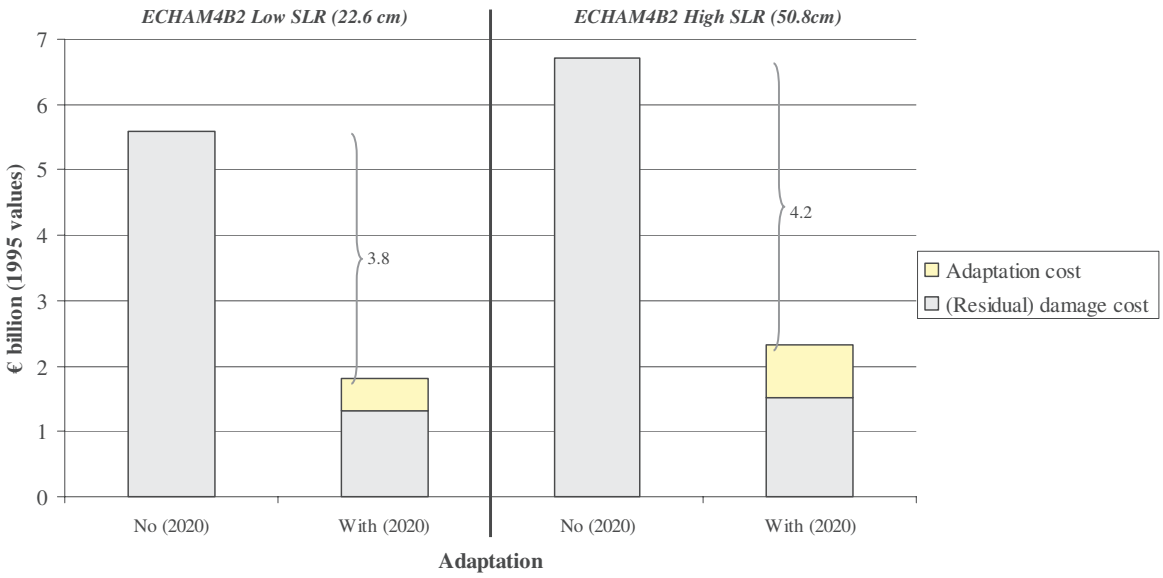
5 PESETA (2009) only considers 2 adaptation options: namely beach nourishments and the increase in flood defence dike heights; accommodation or retreat measures have not been considered in the estimates.

6 Richards and Nicholls (2009) See: http://peseta.jrc.ec.europa.eu/docs/Costalareas.html

Figure S-1: Cost of adaptation versus cost of inaction for Europe (under low and high SLR)



Source: Policy Research Corporation based on PESETA (2009)

The following paragraphs provide an overview of the *real* coastal protection and climate change adaptation expenditure of the EU coastal member states and Outermost regions. Unlike the scientific estimations presented in the previous paragraphs which are based on a theoretical model, these figures represent the actual expenditure by public and private actors to maintain and adapt their coastal zones. For the majority of countries national as well as sub-national authorities have been able to provide the (proximate) investment in coastal protection and climate change adaptation for the entire period 1998-2015. Figures are as much as possible derived (sub-) national financial accounts.

Over the period 1998-2015, Europe's total expenses to coastal protection amount to € 15.8 billion

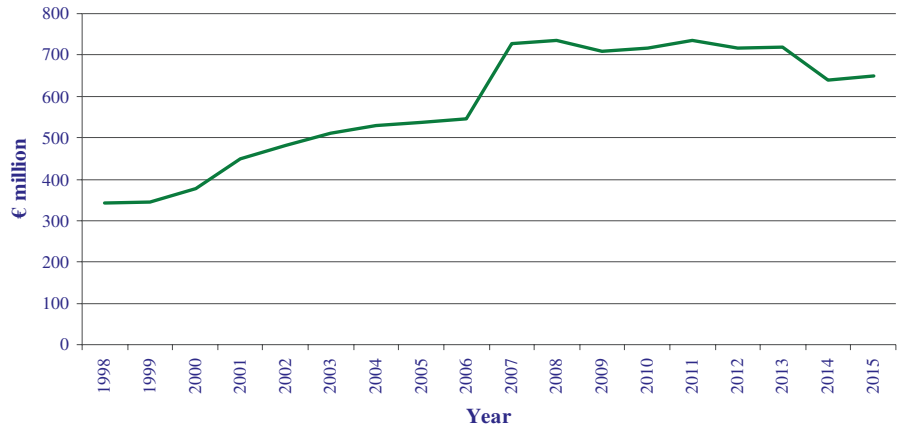
The total coastal protection and climate change adaptation expenditure to safeguard Europe's coastal zones from flooding and erosion (including the Outermost regions) amounts to € 15.8 billion over the period 1998-2015 (or on average € 0.88 billion per year). This total amount can be split between the 'normal' coastal protection expenditure and the amounts spent on specific 'hot-spots'. The normal expenditure includes the amounts spent on maintenance, new construction and extra-ordinary expenditure to protect against flooding and erosion. For the period 1998-2015 this represents € 10.47 billion or 2/3rd of the total. The hot-spot expenditure includes the expenditure to protect exceptional cities or singular eco-systems, accounting for the remaining 1/3rd of the total.

Coastal protection and climate change adaptation activities for coastal zones are highly intertwined. In countries which are not yet taking a climate change scenario explicitly into account, the coastal protection activities are still relevant to consider as – indirectly – they might also protect against more extreme weather related events. In countries which explicitly account for climate change, it is often difficult if not impossible to indicate which part of the investment is solely made in relation to climate change adaptation. In addition, some member states have defined climate change adaptation measures, but have not devoted a separate plan or allocated a specific budget to them. Consequently, adaptation measures are undertaken together with the ordinary coastal protection activities[7]. As a result, both climate-related and non-climate-related coastal protection expenditures have been considered for all countries when defining the actual coastal protection and climate change adaptation expenditure.

Normal coastal protection and climate adaptation expenditure steadily increases over time

Over the period 1998-2015, the accumulated normal expenses will amount to € 10.47 billion. A detailed look at the evolution of normal coastal protection and adaptation expenditure over this period reveals that in general, the annual normal coastal protection and climate adaptation expenditure increases over time. The evolution is presented in *Figure S-2*.

Figure S-2: Evolution of annual normal coastal protection expenditure (1998-2015)



Source: Policy Research Corporation

To better understand this evolution, one needs to analyse the underlying differences between the different marine basins. Most of the *North Sea* countries have been defending their coasts since decades. Therefore, their current and future coastal protection and climate adaptation expenditures are

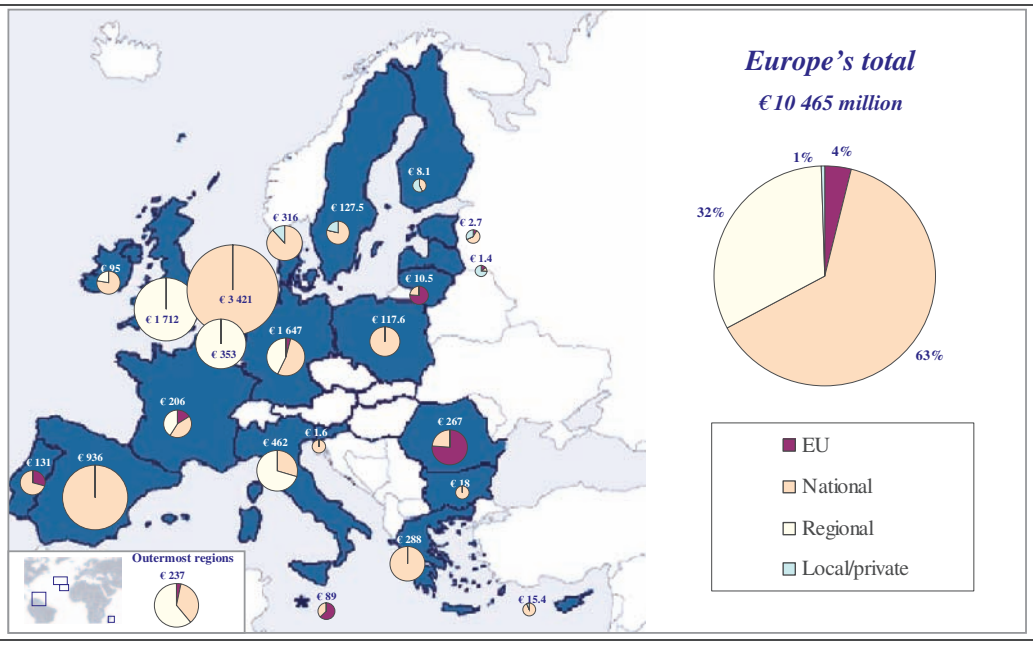
[7] In Germany, every coastal state has its own Coastal Defence Master Plan; each of these master plans takes a certain SLR scenario into account but without indicating the specific financial implications; in other words, the actions undertaken and budget foreseen are partly related to climate change and partly to the normal coastal protection activities; in the Netherlands on the other hand, the final report of the Delta Commission explicitly mentions the financial implications of the proposed Delta Programme.

high but remain rather stable totalling € 6.4 billion for the period 1998-2015. In the *Atlantic Ocean*, the *Mediterranean* and the *Black Sea* marine basin, about half of the member states have recently slightly increased their coastal protection expenditure or foresee limited additional investments in the near future, yet in absolute terms this may be relatively low. Along the *Baltic Sea* coast, no (additional) expenditure has been made to date or is expected to be made in the near future. This is primarily related to the approach followed by these countries as they consider climate change still too uncertain to proactively invest in.

The majority of the normal coastal protection expenditure is borne by national authorities

Over the period 1998-2015, national authorities bear on average close to 63% of the normal coastal protection cost whereas 32% is taken care of by sub-national authorities, 1% by local and private actors and 4% by the EU. In many countries however, when the governance structure of the country gives high autonomy to the 'regions' for what concerns the protection of the coastal zone regional expenditure could as well be seen as equivalent to the national expenditure throughout. Overall, national and regional authorities bear on average 95% of the normal coastal protection expenditure whereas 1% is taken care of by local and private actors. An overview of the European, national, regional/local and private contributions per country is given in *Figure S-3*.

Figure S-3: Normal coastal protection expenditure at European, national and sub-national level (regional, local and private) across Europe in € million (1998-2015)



Source: Policy Research Corporation

Hot-spot protection represents 1/3rd of the total coastal protection budget and totals € 5.3 billion

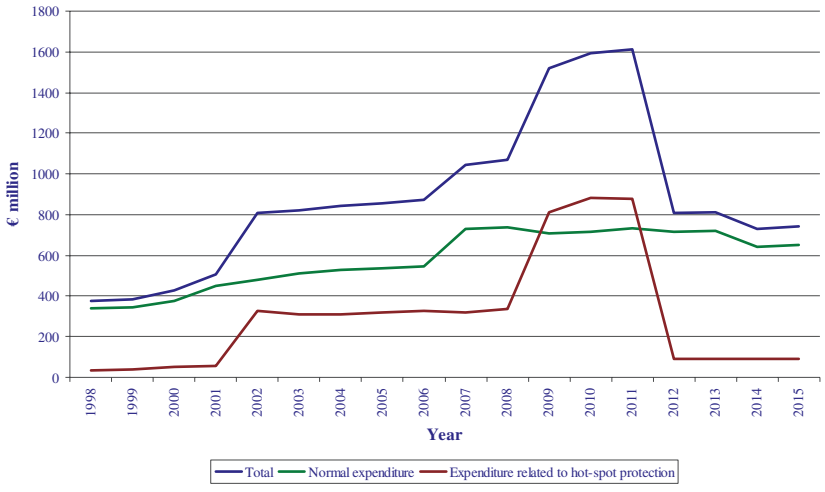
Over the period 1998-2015, additional investments are made to protect the following coastal hot-spots from flooding and erosion:

- Venice (Italy): € 4.2 billion (2002-2011);
- Hamburg (Germany): € 660 million (1998-2015);
- London (UK): € 380 million (2006-2015);
- Zwin and Ostend (Belgium): € 66 million (2002-2012);
- Danube Delta (Romania): € 45 million (2006-2015);
- Slovenian saltpan: € 20 million (2007-2013).

To a certain extent, the Netherlands may also be put in the list of hot-spot protection, in particular the comprehensive protection plan proposed by the Delta commission (2008). However as this plan has not yet been committed by the Dutch government and it is unlikely to come into effect before 2015 it has not been taken explicitly into account. The Delta Programme, currently being prepared, will define the financial means that will be put forward. The Delta Commission estimated that for the period 2010-2100 around € 1.0-1.5 billion per year will be needed to prevent the Netherlands from inland and coastal flooding and to ensure sufficient freshwater resources in the long run.

Comparing the evolution of the hot-spot related expenditure with the evolution of normal coastal protection expenditure makes clear that the expenditure for hot-spot protection concentrates over time and makes the total expenditure 'peak' in certain years. *Figure S-4* visualises this for the period 1998-2015.

Figure S-4: Normal versus hot-spot coastal protection expenditure in coastal member states



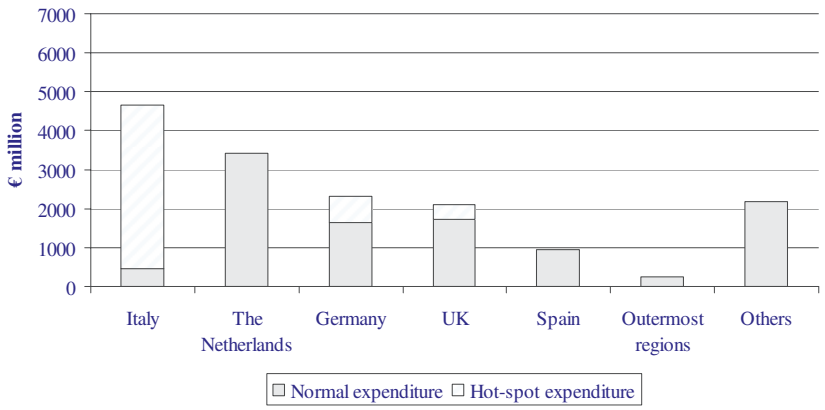
Year	*Total expenditure (€ million)*	*Hot-spot expenditure (% total)*
1998	375	9%
1999	384	10%
2000	427	12%
2001	507	12%
2002	809	40%
2003	821	38%
2004	843	37%
2005	857	37%
2006	873	38%
2007	1046	30%
2008	1072	31%
2009	1522	53%
2010	1597	55%
2011	1611	54%
2012	807	11%
2013	813	12%
2014	731	12%
2015	741	12%
1998-2015	***15837***	***34%***

Source: Policy Research Corporation

Close to 85% of total coastal protection expenditure is borne by five countries

When comparing the contribution of individual countries for the period 1998-2015, it turns out that the majority of coastal protection activities in financial terms is situated within five countries. The amounts spent to normal coastal protection and climate adaptation as well as to hot-spots by the top 5 countries is visualised in *Figure S-5*, together with comparative figures for the Outermost regions and the remaining countries. The Netherlands has by far the highest normal expenditure, whereas Italy has spent most in terms of hot-spot and overall expenditure.

Figure S-5: Top 5 countries in terms of cumulative coastal protection and climate adaptation expenditure (1998-2015)



Source: Policy Research Corporation

Expenditure to counteract freshwater shortage steadily increases between 1998 and 2015

Expenditure to protect the coastal zones against freshwater scarcity pops up primarily for the Mediterranean marine basin as the problem is the greatest in this area. In general, this expenditure is much higher compared to the amounts spent to counteract flooding and erosion. In Cyprus, for example, expenditure to freshwater supply and policy amounted to € 65.8 million in 2008. In Spain, close to € 3.8 billion is being invested over the period 2005-2009 to upgrade the water supply. Nevertheless, one needs to bear in mind that this cost is not one-to-one related to coastal zones and none of the Mediterranean countries takes climate change explicitly into account when defining actions to overcome the problem of freshwater shortage.

Estimation of the total present and future cost of adaptation based on a gap analysis between theoretical estimates and actual expenditure

Assessments within scientific literature on the annual adaptation cost to protect Europe's coastal zones against SLR range between $ 0.2 billion and € 5.4 billion. Based on a per country analysis, the PESETA (2009) study narrows the range of the annual adaptation cost for Europe's coastal zones to € 0.25-1 billion, depending on the socio-economic and corresponding SLR scenario.

The PESETA study – not published yet – is the most recent (exhaustive) report estimating the cost of adaptation that would be required to protect Europe's coastal zones against SLR and flooding on a country-by-country basis. Therefore, this study has been taken as benchmark to assess the gaps between the real expenditure and the theoretical estimated amount of coastal protection and climate adaptation[8]. The gap analysis focuses primarily on the risk of flooding and erosion. Comparison of the cost of adaptation needed to protect against the other climate related impacts relevant for coastal zones (freshwater shortage and saline intrusion, the loss of coastal eco-systems), cannot be made as such information is not available in scientific literature and actual expenditure is not one-to-one related to the coastal zones.

Comparison of the 'required' scientific estimates of PESETA (2009) with the actual expenditure yields the following[9]:

- The actual coastal protection expenditure in Europe, amounting to € 1.07 billion in 2008 (and on average € 0.88 billion per year for the period 1998-2015), corresponds with the upper-bound of the annual adaptation estimate of € 0.49 billion (22.6 cm SLR) and € 0.85 billion (50.8 cm SLR) presented in the PESETA study;
- Actual expenditure to protect Europe's coastal zones, excluding budgets dedicated to protect the hot-spots Venice and London as well as the Outermost regions as these have not been accounted for by PESETA (2009), amounts to € 0.61 billion; this brings the actual expenditure somewhat in between the high and low SLR scientific estimates;
- At a national level, the actual expenditure on coastal protection and climate adaptation for the five countries with highest expenditure is in line with or well above the theoretic figures from PESETA (2009); for the other countries in general the actual expenditure is well below the theoretic figures from PESETA (2009); differences are the largest for the Baltic Sea countries followed by the Mediterranean countries (with the exception of Spain).

An overview of the 'actual' total coastal protection and climate adaptation expenditure (normal and hot-spot expenditure) on a country level compared to the theoretical estimates of PESETA (2009) is provided in *Table S-2*. Countries have been ranked according to the actual cost of adaptation. The colours used in the table represent the safety level when comparing the *real* expenditure with the *theoretically estimated* investment that is needed to protect the human use of the coast, where green indicates that real expenditure is higher, red that it is lower and orange that it is somewhat in between.

[8] The information under the socio-economic scenario ECHAM4B2 has been used as benchmark as the related SLR scenarios of 22.6 cm (low SLR) and 50.8 cm (high SLR) correspond most to the 2007 IPCC SLR scenarios of 18-59 cm; the adaptation cost under this scenario ranges between € 0.49 billion (low SLR) and € 0.85 billion (high SLR). Richards and Nicholls (2009). See http://peseta.jrc.ec.europa.eu/docs/Costalareas.html

[9] Richards and Nicholls (2009). See http://peseta.jrc.ec.europa.eu/docs/Costalareas.html

Table S-2: Comparative analysis of scientific estimates of the annual cost of inaction and adaptation with the actual expenditure to coastal protection and climate change adaptation

	Scientific cost of inaction per annum in € million ECHAM4B2 (1995-2020)		*Scientific cost of adaptation per annum in € million ECHAM4B2 (1995-2020)*		*Actual average cost of adaptation per annum in € million (1998-2015)*
Country	*Low SLR (22.6 cm)*	*High SLR (50.8 cm)*	*Low SLR (22.6 cm)*	*High SLR (50.8 cm)*	*Annual normal and hot-spot related expenditure*
The Netherlands	3332	3776.7	54.3	88.1	190.1
Germany	498.6	593.9	50.0	101.0	128.1
UK	594.7	760.2	99.5	174.2	*116.3* (95)
Spain	36.3	52	20.7	40.7	51.5
Italy	93.6	269.4	29.7	49.8	*258.9* (25.6)
Belgium	584.8	590.7	2.0	2.5	23.3
Denmark	15.6	49.7	44.9	80.1	17.3
Romania	0.9	1.2	5.9	7.4	17.4
Greece	4.4	5.1	19.6	33.9	16.0
France	410.9	439.8	58.2	109.9	11.4
Portugal	8.7	9.1	10.6	21.8	7.3
Sweden	3.1	15.7	12.5	23.1	7.1
Poland	10.7	12.1	12.2	16.2	6.5
Ireland	25.9	72.9	26.7	45.8	5.3
Malta	0.4	0.5	0.2	0.3	5.0
Slovenia	0.1	0.1	0.1	0.2	1.2
Bulgaria	0.2	0.3	1.5	2.1	1.0
Cyprus	*n.a.*	*n.a.*	*n.a.*	*n.a.*	0.9
Lithuania	0.1	0.2	2.5	3.8	0.6
Finland	1.8	11.8	8.6	13.3	0.4
Estonia	0.2	0.3	21.2	28.9	0.2
Latvia	2.2	2.3	7.4	10.8	0.1
Outermost regions	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*(13.2)*
Europe's total	*5625.2*	*6664*	*488.3*	*853.9*	*879.1* (611.3)[10]

For the gap analysis it is important to bear in mind that:

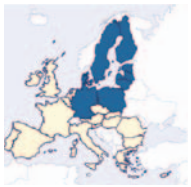
- PESETA (2009) estimates are theoretic figures which highly depend on the input parameters used and the values attributed to them
- The cost of adaptation calculated by PESETA (2009) is based on two specific adaption options: beach nourishments and the heightening of dikes
- The actual coastal protection and climate change adaptation is derived from information provided by (sub-) national authorities and based as much as possible on (sub-) national financial accounts

Red: low SLR > actual < high SLR
Orange: low SLR < actual < high SLR
Green: low SLR < actual > high SLR

Source: Policy Research Corporation partly based on Richards and Nicholls (2009)

In the next paragraphs, the results of the gap analysis are synthesised per marine basin[11].

Baltic Sea: Actual expenditure is much lower than the scientific estimates of PESETA



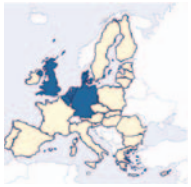
- The total coastal protection expenditure of the Baltic countries amounts to € 0.7 billion over the period 1998-2015; DE, SE, PL account for the majority of total expenditure;
- In the Baltic marine basin, the actual annual coastal protection and climate change adaptation expenditure over the period 1998-2015 for the countries concerned amounts to only **€ 38 million** whereas the cumulative theoretical estimates under a high and low SLR scenario lie between **€ 81 million** and **€ 128 million**;
- Baltic Sea countries focus primarily on accommodation and retreat measures by means of regional development and building regulations which have not been accounted for in the theoretical estimates of PESETA (2009);

[10] The total amount of € 611.3 million excludes the yearly expenditure made to the Thames Barrier (UK) and the Mose project (IT) as well as the expenditure in the Outermost regions.

[11] The theoretical estimates presented in the following paragraphs are extracted from the PESETA study. Richards and Nicholls (2009). See http://peseta.jrc.ec.europa.eu/docs/Costalareas.html

– In the Baltic marine basin, climate change scenarios are in general not yet considered in practice; most Baltic Sea countries consider climate change still too uncertain to proactively invest in and – implicitly – adopt a wait and sea approach; an exception is Poland which has implemented long-term coastal protection strategies since 1985 and within these has recently taken climate change (SLR) into account;

North Sea: Actual expenditure is similar or higher than the PESETA projected adaptation cost



– The North Sea countries will have spent in total € 7.6 billion to coastal protection over the period 1998-2015; the NL, DE and the UK account for the majority of total expenditure;

– Along the North Sea coast, the actual annual coastal protection and climate change adaptation expenditure over the period 1998-2015 for the countries concerned amounts to **€ 399 million** (**€ 420 million** including expenses to the Thames barrier) which is slightly above the cumulative theoretical estimate **€ 369 million** under a high SLR scenario, under a low SLR scenario the theoretical estimate is around **€ 208 million**;

– North Sea countries use primarily hard and soft 'protective' measures (beach nourishments, heightening of dikes) which corresponds to the measures taken into account in the theoretical estimates of PESETA (2009);

– The actual UK expenditure is close to the scientific investment under a low SLR scenario when also considering the additional hot-spot investment of the UK (London Thames Barrier); the Belgian, Dutch and German expenditures are much higher than the scientific estimated investment needed under a high SLR scenario but these countries defend their coasts since decades and are more advanced (and risk-averse) when it comes to the protection against increased flood-risk.

Atlantic Ocean: General tendency to spend less than the scientific estimates of PESETA

– The total coastal protection expenditure of the Atlantic Ocean countries amounts to € 1.2 billion over the period 1998-2015; the UK and ES account for the majority of the total expenditure;

– In the Atlantic Ocean marine basin, the actual annual coastal protection and climate change adaptation expenditure over the period 1998-2015 for the countries concerned amounts to **€ 67 million** whereas the cumulative theoretical estimates under a high and low SLR scenario amount to **€ 82 million** and **€ 148 million** respectively;

– France and Ireland spend less than the scientific investment; the gap might relate to the fact that both countries do not take a SLR scenario into account in current coastal protection operations; Ireland moreover tends to the use of accommodate and retreat actions in the future, which have not been accounted for by PESETA (2009); Portugal spends slightly less than the scientific amount under low SLR but, to date, a SLR scenario is taken into account in only 2-3 regional plans;

– Spain spends slightly more than the scientific estimate and is in general more advanced in climate adaptation than the other Atlantic Ocean countries.

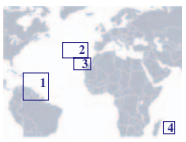
Mediterranean Sea: Expenditure is in range or slightly higher than PESETA estimates

- The Mediterranean countries will have spent over the period 1998-2015 close to € 5.8 billion to protect their coasts against flooding and erosion; much higher amounts are invested in freshwater but this expense is not one-to-one related to coastal zones;
- Along the Mediterranean coastline, the actual annual coastal protection and climate change adaptation expenditure over the period 1998-2015 for the countries concerned – excluding the Mose project in Venice – amounts to **€ 89 million** whereas the cumulative theoretical estimates under a high and low SLR scenario amount to **€ 110 million** and **€ 199 million** respectively;
- Although most Mediterranean countries are not yet advanced in climate change adaptation, the actual expenditure reaches almost the theoretical estimate; it is however apparent that protective actions are used both the actual and theoretical estimated amounts;
- Spain spends slightly more than the scientific amount under high SLR and Greece and Italy (excluding the Mose project) slightly less under a low SLR scenario; this correlates with the progress made in climate adaptation; Malta invests more than the theoretical estimated investment needed but the Storm Water Management Plan determining the annual expenditure concerns the entire country.

Black Sea: Expenditure is in range or slightly higher than PESETA estimates

- The total coastal protection expenditure of the Black Sea countries will have amounted to € 0.3 billion over the period 1998-2015;
- In the Black Sea marine basin, the actual annual coastal protection and climate change adaptation expenditure over the period 1998-2015 for the countries concerned amounts to **€ 18.4 million** whereas the cumulative theoretical estimates under a high and low SLR scenario amount to **€ 7.4 million** and **€ 9.5 million** respectively;
- In Bulgaria, actual expenditure corresponds to the scientific amounts both are very low; Romania is most active in coastal protection along the Black Sea coast and is especially focused on the problem of erosion, but not specifically in relation to SLR.

Outermost regions: Actual expenditure amounts to € 13.2 million per annum



(1) Martinique, Guyana Guadeloupe (FR)
(2) Azores, Madeira (PT)
(3) Canaries (ES)
(4) Reunion Island (FR)

- The actual annual coastal protection and climate change adaptation expenditure over the period 1998-2015 amounts to **€ 13.18 million**;
- Although the Outermost regions share many particularities, their institutional framework and progress made with regard to climate change adaptation highly differs; at present, the Canaries seem a forerunner as the Spanish national government includes the islands in the forthcoming Spanish National Strategy for Sustainable Coastal Management.

For the Outermost regions, no comparison with scientific estimates can be made as these have not been provided for in the PESETA study; as the Outermost regions cannot be compared with any of the EU islands such as Cyprus and Malta, extrapolation of data would give a wrong impression; it is clear that also from a scientific point of view, more efforts are needed to support the Outermost regions with adapting to climate change.

RECOMMENDATIONS FOR POLICY MAKERS

Based on the analysis carried out in the study and described in the previous sections, the following recommendations are worth considering:

- *Recommendation 1*: Take a leading and coordinating role in research into the effects of climate change at local level for all EU member states as well as for the Outermost regions;
- *Recommendation 2*: Ensure that the organisation and responsibility for coastal protection and climate change adaptation is clearly defined in each member state and list key actors per country;
- *Recommendation 3*: Stimulate the proactive involvement of national authorities in climate change adaptation and coastal protection;
- *Recommendation 4*: Make efforts to support cross-boundary cooperation in the field of climate change adaptation, foremost at marine basin level;
- *Recommendation 5*: Do not aim to rank coastal adaptation plans and programmes as 'one size does not fit all'; a handbook with practical guidelines supporting the development of a profound strategy and a clear-cut operational plan illustrating good practice examples across Europe could be published instead;
- *Recommendation 6*: Create a central database presenting the climate change adaptation strategies, plans, programmes and measures applied as well as investments made in the different member states.

European Commission

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