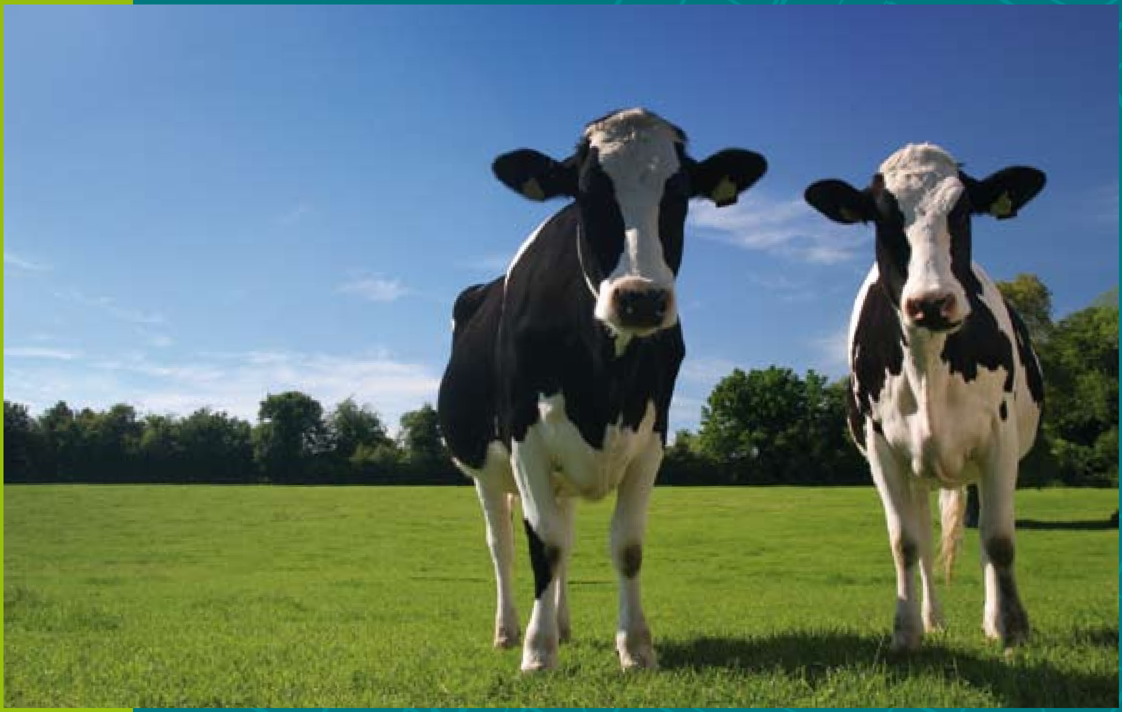
3

Routeplanner naar een klimaatbestendig Nederland

Adaptatiestrategiën



Routeplanner

2050

A qualitative assessment of climate adaptation options and some estimates of adaptation costs

Editors and authors
E.C. van Ierland, K. de Bruin, R.B. Dellink and A. Ruijs
Environmental Economics and Natural Resources, Wageningen UR

Co-authors

L. Bolwidt, RIZA, Institute for Inland Water Management and Waste Water Treatment

A. van Buuren, Department of Public Administration, Erasmus University Rotterdam

J. Graveland, RIKZ, National Institute for Coastal and Marine Management

R.S. de Groot, Environmental Systems Analysis, Wageningen UR

P. Kuikman, Alterra, Wageningen UR

E.E.M. Nillesen, Environmental Economics and Natural Resources, Wageningen UR

M. Platteeuw, RIZA, Institute for Inland Water Management and Waste Water Treatment

S. Reinhard, LEI, Wageningen UR & BSIK Leven met Water

V.C. Tassone, Environmental Systems Analysis, Wageningen UR

A. Verhagen, Plant Research International, Wageningen UR

R. Roetter, Alterra, Wageningen UR

S. Verzandvoort-van Dijck, Alterra, Wageningen UR

This study has been performed within the framework of the Netherlands Policy Programme ARK as Routeplanner projects 3, 4 & 5

Wageningen, February 2007.

Abstract

The Routeplanner project aims to provide a ‘systematic assessment’ of potential adaptation options to respond to climate change in the Netherlands in connection to spatial planning. The study is the result of a policy oriented project that took place between May and September 2006.

The aim of the current study is to provide a ‘qualitative assessment’ of the direct and indirect effects of adaptation options and to provide an assessment of some of the costs and benefits of adaptation options.

The present report presents and summarizes the results of all phases of the study: an inventory of adaptation options, a qualitative assessment of the effects of the adaptation options for the Netherlands in the long run, a database which allows to rank the various options according to a set of criteria and a relative ranking on the basis of these criteria. Finally the report also contains the best available information on costs and benefits of various adaptation options.

However, while conducting the study the project team observed that reliable information in this respect is in many cases still lacking and an urgent need exists for more detailed studies on costs and benefits of adaptation options and the design of the best options to cope with climate change.

Preface

In this report, we explore adaptation options in response to impacts of climate change in the Netherlands. Our aim is to assess the qualitative and quantitative characteristics of adaptation options and to provide a system to rank these options. Because the research on adaptation to climate change is still a relatively new domain, not so very many detailed estimates of costs and benefits are available in the literature and many estimates are based on rather crude assumptions. This makes that the results reported in this document need to be considered with caution until more detailed studies will provide better estimates.

We would like to thank all that have assisted in providing information relevant for writing this report, including KNMI, the Climate Centre, Aalt Leusink, Ralph Lasage and Piet Rietveld. All support was highly appreciated. With this report we wish to provide some further steps for a systematic socio-economic assessment of long run adaptation options in the Netherlands.

Ekko van Ierland, Karianne de Bruin, Rob Dellink and Arjan Ruijs (eds)
Environmental Economics and Natural Resources, Wageningen Universiteit

Contents

Abstract

Preface

1 Introduction ... 1

1.1 Adapting to climate change ... 1

1.2 Background ... 1

1.3 Rationale ... 2

1.4 Objective ... 4

1.5 Methodology ... 5

1.6 Outline of the report ... 5

2 Qualitative assessment ... 7

2.1 Categorising adaptation options by climate change characteristics ... 7

2.2 Interconnections between adaptation options ... 8

2.2.1 Overlap ... 10

2.2.2 Synergy and competition ... 13

2.3 Overview of adaptation options ... 18

3 Ranking adaptation options ... 28

3.1 Criteria for scoring adaptation options ... 28

3.2 Ranking with ordered criteria ... 29

3.3 Ranking with criteria weighting ... 34

4 Sorting options by climate change impacts ... 39

4.1 Sea level rise ... 39

4.2 River discharge ... 41

4.3 Groundwater level ... 43

4.4 Storms ... 44

4.5 Heat stress ... 46

4.6 Drought stress ... 48

4.7 Growth stress ... 50

5 A quantitative assessment of the options ... 52

6 Feasibility of adaptation options ... 68

7 Conclusion ... 74

References ... 79

Annex 1; Short description of adaptation options

Annex 2 – Synergy & Competition nature sector

Annex 3 – Expert Workshop

Annex 4 – Database overview – Agriculture sector

Annex 5 – Database overview – Nature sector

Annex 6 – Database overview – Water sector

Annex 7 – Database overview – Energy & Transport sector

Annex 8 – Database overview – Housing & Infrastructure sector

Annex 9 – Database overview – Health, Recreation & Tourism sector

List of tables

Table 1 Overview of adaptation options – climate characteristics and impacts
Table 2 Overview of adaptation options – implementation level and field of interest
Table 3 Ranking of options – Score-table
Table 4 Ranking according to focus on criteria
Table 5 Ranking with criteria weighting
Table 6 Sea level rise – ranking with ordered criteria
Table 7 River discharge – ranking with ordered criteria
Table 8 Groundwater level – ranking with ordered criteria
Table 9 Storms – ranking with ordered criteria
Table 10 Heat stress – ranking with ordered criteria
Table 11 Drought stress – ranking with ordered criteria
Table 12 Growth stress – ranking with ordered criteria
Table 13 Heat islands – Benefits and costs of green roofs in Toronto
Table 14 Heat islands – Green roofs comparison
Table 15 Criteria feasibility adaptation options
Table 16 Scoring and ranking of adaptation options regarding feasibility
Table 17 Overview synergies & competitiveness adaptation options nature sector
Table 18 Average Expert judgements on scoring adaptation options
Table 19 Database overview – Agriculture sector
Table 20 Database overview – Nature sector
Table 21 Database overview – Water sector
Table 22 Database overview – Energy & Transport sector
Table 23 Database overview – Housing & Infrastructure sector
Table 24 Database overview – Health, Recreation & Tourism sector

List of boxes

Box 1 Case-study Kampen – climate adaptation options that apply to the IJsseldelta-Zuid
Box 2 Case-study Biesbosch
Box 3 Environmental Cost Benefit Analysis

1 Introduction

1.1 Adapting to climate change

Possible consequences of climate change for the Netherlands have been documented in various reports, including the Environmental Balance (RIVM, 2004), the Climate Policy report commissioned by Parliament (Rooijers ***et al.,*** 2004) and the Climate report (KNMI, 2003). Most studies agree on the fact that climate change will take place, in spite of all mitigation efforts. Thus, while absolutely necessary, mitigation alone is not sufficient to cope with climate change. Some climate change impacts on water and ecosystems are already visible and have been accepted as being inevitable (VROM, 2005). It is necessary to start anticipating to these short and long term changes, and to develop new perspectives on how to deal with climate change. This includes developing and introducing new concepts for spatial planning and the design of infrastructure and cities.

For these reasons, adaptation to climate change is receiving increased attention in the scientific and policy debate, and is seen as complementary to mitigation (UNFCCC, 1997; McCarthy et al., 2001). Adaptation is defined as adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts' (Smit ***et al***., 1999). The related 'adaptive capacity' refers to the 'potential or ability of a system, region, or community to adapt to the effects or impacts of climate change' (Smit ***et al***., 2001; Smit and Piliposofa, 2003), mostly interpreted to reflect only adjustments to moderate potential damages, not to extreme scenarios. Progress towards a systematic assessment of adaptation in terms of technical, economic and institutional feasibility has been slow. For the Netherlands it is most strongly developed in the water sector. Adaptation to climate change can be reactive or pro-active. ***Reactive*** adaptation to climate change is a process of gradual coping. ***Pro-active*** adaptation involves planned action aimed at preparing for climate change and its possible adverse impacts, in an attempt to minimize those (Abramovitz ***et al***., 2002).

In this context innovation is essential and identifying innovations in an early stage offers scope for strengthening the international position of the Netherlands in terms of climate change adaptation. Such innovations can improve the opportunities to adapt smoothly, reduce climate vulnerability and/or increase the potential for cost-effective mitigation. If the Netherlands does not take the lead in innovation for climate change, other countries in the EU will pick the low hanging fruit and benefit from the opportunities. When environmental policies become stricter elsewhere, they would have comparative advantage; this is known as the first-mover incentive and is related to the Porter hypothesis that stringent environmental policy can strengthen the competitiveness of domestic producers (Xepapadeas and De Zeeuw, 1999).

1.2 Background

The Routeplanner project aims to provide a 'systematic assessment' of potential adaptation options to respond to climate change in the Netherlands in connection to spatial planning.

The systematic assessment includes the following aspects: 1) identification of adaptation options in the Netherlands; 2) a qualitative assessment of direct and indirect effects of the options; 3) identification and, where possible, a quantification of direct and indirect costs and benefits associated with the individual adaptation options; and 4) institutional aspects related to the implementation of adaptation options.

The present report contains and summarizes the results of all phases of the study: these aspects are identified in a database which allows ranking the various options according to a set of criteria and to obtain a relative ranking on the basis of these criteria. The report contains the best available information on costs and benefits of various adaptation options. However, we observe that the information in this respect is in many cases still lacking and an urgent need exists for more detailed studies on costs and benefits of adaptation options and the design of the best options to cope with climate change.

A warning to the reader is justified here: although we have tried to obtain the best information on costs and benefits, it needs to be emphasized that most of the values presented in this report should be considered as preliminary and the reliability often depends on the original sources of the information. They are rough estimates presented to obtain a first impression of the order of magnitude.

We also indicate that the study explicitly has been restricted to adaptation options in the Netherlands. This means that adaptation options for developing countries are not discussed in this report, although the authors are aware that adaptation in developing countries deserves special attention.

The project is coordinated and executed by the Environmental Economics and Natural Resources Group (Wageningen University) in collaboration with Plant Research International, Alterra and LEI (Wageningen Research Centre), responsible for the agricultural sector; RIZA (Institute for Inland Water Management and Waste Water Treatment) responsible for the water management and insurance sector; and the Environmental System Analysis group (Wageningen University) responsible for the input on adaptation options for ecosystems and nature. In addition to the overall implementation and coordination of the project, the Environmental Economics and Natural Resources Group has been responsible for the information on several adaptation options, including the options provided for the energy sector.

1.3 Rationale

Until recently, the mitigation agenda dominated climate change research, whereby analyses on greenhouse gas monitoring and reduction strategies received special attention. During the eighth session of the Conference of the Parties, within the United Nations Framework Convention on Climate Change (UNFCCC), especially developing countries have made a plea for paying more attention to adaptation. In the near future it is expected that there may be a trade-off between mitigation and adaptation measures despite the fact that they are complements rather than substitutes.
In order to make well-informed decisions on how to adapt to climatic change, besides a need to be informed on the expected changes in climate there is a need for information on adaptation options and the related effects including the costs and benefits. In this context the terms ‘climate proof’ and ‘robustness’ are used.

The concept 'climate proof' is defined as a function of robustness (relating to the variability of the present climate) and flexibility (relating to climate change) (see, Kabat et al., 2005). 'Robustness' is the capacity (of a system) to remain functioning well under extreme pressure/stress, for instance concerning drought, extreme precipitation, storms, etc. Flexibility is defined as the capacity (of the characteristics) of a system to adjust to changing circumstances.

There seems to be a huge discrepancy between what would be viable adaptation options from a scientific (technical) perspective and what policymakers perceive as being realistic measures to implement.

This discrepancy is often closely linked to the perceived costs and benefits, and clearly illustrates the lack of and need for reliable data and good insight in the associated costs and benefits. While some calculations are available for the costs of implementing adaptation measures, most notably investment costs, much less is known about (future) benefits which may be valued at avoided damage costs.

Optimal timing of adaptation measures

Comparing different options also requires due consideration of the timing of the adaptations. If sufficient mitigation will occur at the international level, the efforts for adaptation can remain restricted to those that are required at a temperature change of 2 degrees Celsius, which is the policy target of the EU. However, if international coordination of mitigation strategies will fail, then the need for stronger adaptation options increases. It is therefore necessary to carefully plan the adaptation measures, not only according to the regional scale, but also to the temporal scale and in the light of the mitigation actions. Over time, we will learn more about the effectiveness of mitigation strategies and we will get better insight in the impacts of climate change and their development over time. On the basis of a combination of scenario studies and this learning, an optimal timing of adaptation measures can be considered. In this context, it also need to be considered whether adaptation measures are planned in small incremental steps (for example various phases of small improvements of dikes), or in a limited number of larger steps (for example a big effort to strengthen dikes for a long period).

Policy issues

Systematic assessment of options that are technically, economically, and politically feasible will enable policymakers to make well-informed choices about different adaptation options. The challenge for the Netherlands is to harmonize a national adaptation policy with its spatial planning policy. The focus will be on developing more robust systems including technical solutions and improved control and risk management systems, and improved spatial planning. To make the Netherlands climate proof, a wide set of policy instruments can be used, ranging from financial instruments (e.g. taxes, subsidies or insurance arrangements) or command and control instruments (e.g. spatial planning or technology requirements) to institutional approaches (e.g. education, communication).

Stakeholders will be involved at different regional levels, from the international level, to national, regional and local level. Decisionmakers, consumers and producers will have their own responsibilities and task in adapting to climate changes and a careful coordination of the various activities needs to take place. In this context it is essential to make a consistent planning and a transparent distribution of tasks and responsibilities over the various institutions and stakeholders. This may call for new institutional arrangements.
A well-designed adaptation option will consider the risks involved, the irreversibilities (both of climate change and of investments in adaptation or mitigation), the learning processes over

time (e.g. how serious climate change is), and the role of the various stakeholders, such as the central government, the local authorities, business enterprises, universities and other knowledge institutes, specific sectors, NGO's or the citizens affected. Preparing for 'climate robustness' necessitates the development of early-warning systems, appropriate insurance arrangements, appropriate spatial planning and a harmonization across different policies.

In this context it is a must to analyze the role of the political system and public institutions in the Netherlands and in the EU. A crucial question is: are these institutions capable of handling the long term planning required for adequately adapting to climate change? Is the time horizon sufficiently long? Can the actions in the member states be coordinated? What are the costs and benefits of adaptation for the different sectors and to what extent does this create obstacles that prevent implementation of the necessary adaptation measures?

Are long term irreversible impacts, such as several meters of sea level rise, issues that can be handled adequately and efficiently by our current institutions? If so, how? If not, what alternatives or what mechanisms for improvement can be used?

Current experience shows that adaptation is easier to implement in sectors and systems where depreciation and capital replacement are high compared to those sectors that require long-term investments (e.g. the water sector, the housing sector/ city and infrastructure planning or general spatial planning). Because of long delays in planning, this study focuses on the period starting from 2050 and going beyond, in order to be well prepared for climate change through long term investment. Relevant questions are who should be held responsible for the costs of implementing the adaptation measures and what is the role of insurance companies in this respect? Another important aspect concerns the harmonization of adaptation and mitigation measures. As money can only be spent once, a trade-off needs to be made between mitigation for which benefits are expected mainly in the far future, and adaptation which generates immediate benefits, but which may be insufficient in the long run to prevent excessive future costs as a result of ongoing climate change impacts.

1.4 Objective

The objective of the Routeplanner project is to make an assessment of existing and promising new adaptation options to climate change for the Netherlands. The main issue at stake is how to make the Netherlands 'climate proof', especially in view of spatial planning, with a time horizon to 2050 and beyond. Adaptation options will be formulated, they will be evaluated on the basis of qualitative assessment criteria, and an inventory will be made of the existing knowledge on the associated incremental costs and benefits of the different options.1 The results can be used by policymakers to decide which adaptation options to choose from a socio-economic perspective. The Routeplanner project is subdivided in several subprojects. In the Routeplanner 3 project, the objective was to review the literature and to consult stakeholders to provide a systematic assessment and overview on adaptation options in the Netherlands, with special focus on spatial planning. Adaptation options identified include financial measures (taxes and insurance systems), legal interventions (spatial planning, command and control) and communication tools.

1 Incremental costs and benefits refer to those costs and benefits that are attributable to the adaptation measure only, and will not occur if the adaptation measure is not implemented.

The management of adaptation requires detailed monitoring of developments. Special aspects are risk management and disaster (and conflict?) management. In addition, attention is paid to infrastructure and housing and some of the health issues related to climate change.

The aim of the current study is to provide a 'qualitative assessment' of the direct and indirect effects of the adaptation options identified in the Routeplanner subproject 3, and augment the inventory where possible. The assessment is done by categorising, ranking and prioritising the identified adaptation options. Next we have made an inventory of the existing knowledge on the incremental costs and benefits and the environmental effects of the different adaptation options. This information complements the qualitative ranking, and will allow for a more elaborate choice of adaptation options by the policy makers once the estimates of costs and benefits will be complete and reliable (i.e. the existing gaps are filled by specific follow-up studies). We have already emphasized that still a lot of work needs to be done to improve the quality of the data and close the gaps.

1.5 Methodology

The project comprised the following parts:

1) A detailed review of sector-specific literature on climate change and related adaptation options including: general international and national policy documents; scientific and policy assessments published in academic reports and journal articles; non-academic reports by, government institutes, consultancy groups, and non-governmental organizations;
2) Construction of a database to summarize the identified adaptation options and the associated effects, and an inventory of institutional aspects related to their implementation, as far as available on the basis of existing studies;
3) The identification of relevant evaluation criteria for a qualitative assessment of the adaptation options;
4) The establishment of scores of the identified adaptation options in relation to the different evaluation criteria applied in the database, including the construction of tools to rank options based on (a) ordering of criteria and (b) weighted summation of criteria;
5) The (partial) validation of the scores and ranking of the adaptation options in a workshop with experts in the field of adaptation to climate change in the Netherlands;
6) An inventory of the incremental costs and benefits of adaptation options, in order to assess the order of magnitude of these in support of decision making on adaptation and to identify the knowledge gaps in this respect.
7) A final report containing the main findings and conclusions of this policy-oriented study.

1.6 Outline of the report

Chapter 2 presents the adaptation options, categorised by climate change characteristics, and a discussion of the interconnections between the various options, in terms of overlap, synergy and competition. In Chapter 3 the options are ranked according to their importance, urgency, the no-regret characteristics, the ancillary benefits to other sectors and domains, and their effect on climate change mitigation (mitigative effect); two types of ranking are applied: ordered criteria and criteria weighting. Chapter 4 provides a more detailed overview of the options, sorted by climate change impacts, namely: (i) sea level rise, (ii) river discharge, (iii) groundwater level, (iv) storms, (v) heat stress, (vi) drought stress and (vii) growth stress, all ranked with ordered criteria.

Chapter 5 deals with the quantitative assessment of the options and discusses the availability of estimates of the costs and benefits associated with the options. Next, Chapter 6 provides an evaluation of the feasibility of the different options in terms of the institutional opportunities as well as barriers for their implementation. Chapter 7 concludes by grouping the most important options with respect to different policy areas such as economic development, (human) security, living conditions, ecology, governance and costs and benefits; it also includes a discussion of the most important types of missing information.

2 Qualitative assessment

This chapter contains a first approach of a qualitative assessment of the adaptation options as identified in the Routeplanner subproject 3 “A preliminary inventory of options for climate adaptation in the Netherlands”. The qualitative assessment focuses on the ranking and prioritisation of the adaptation options. First, the options are categorised by climate change characteristic and climate change impact in order to evaluate the causal relationship between option and impact. Secondly, options are attributed with scores for a number of characteristics. On this basis, a first, preliminary ranking of the most urgent or most needed options can be made.

2.1 Categorising adaptation options by climate change characteristics

The adaptation options have been selected on the basis of a sectoral approach, in order to obtain the best inventory for the various sectors of the economy. Sectors included in the study are: agriculture, forestry, fisheries, water, energy and infrastructure. Some information is included on health, recreation and transport. Adaptation options were then categorised in two ways. First, we evaluated whether the adaptation options related to climate change characteristics such as temperature change, precipitation change, extreme weather events or others. Next, we indicated in more detail whether the option is relevant for the various impacts: 1. Sea level; 2. River discharge; 3. Groundwater level; 4. Storms; 5. Heat stress; 6. Drought stress and 7. Growth stress for plants and animals.

The resulting classification allows us to make a selection in the database to focus on the adaptation options that are relevant for the categories distinguished. We then can also rank these options according to the five criteria: (1) Importance, (2) Urgency, (3) No regret, (4) Ancillary benefits and (5) their contribution to Mitigation, as will be explained below.

Finally, we discuss the main adaptation options grouped according to their relevance for

- Adaptation and Economic sectors
- Adaptation and safety
- Adaptation and housing and living conditions
- Adaptation and ecology
- Adaptation governance and society

Sea level rise is related to thermal expansion of the seawater and to some extent to melting of icecaps. River discharge changes as a result of climate change due to changes in precipitation, effects on the melting of glaciers or increased periods of drought. The groundwater level may be affected due to changes in precipitation and evaporation and the need for irrigation water, process water or drinking water. Storms are an example of extreme weather events and it is likely that as a result of climate change more or even stronger storms may occur. Heat stress refers to the negative impacts of high temperatures to human beings, animals or plants. Drought stress refers to stress to human beings, animals or plants as a results of periods of drought that, according to the KNMI scenarios for the Netherlands, may occur in summer. Growth stress for plants and animals refers to combined impacts of climate change on the growth of plants and animals. It may be related to temperature (too hot or too cold) or to precipitation or water availability. If the conditions after climate change have a negative impact, we consider growth stress to occur. Adaptation can then be considered to reduce these negative impacts.

2.2 Interconnections between adaptation options

The different options cannot be seen in isolation. There are many ways in which these options are interconnected. This can involve (i) some overlap regarding the different options; (ii) synergies between options; and (iii) competition between options. In this paragraph Box 1 and 2 provide two case studies, namely the IJsseldelta project near Kampen and the spatial development of the Biesbosch, both focusing on the identification of adaptation options suitable for dealing with the impacts of climate change.

Some of the adaptation options identified are interlinked with each other. First, this interlinkage may concern overlap, meaning that one option relates to more sectors (typical examples of interlinkages exist between water and agriculture or nature). Secondly, it may also concern synergies between the options, meaning that the implementation of one option strengthens the effect caused by the implementation of the other option (e.g. adjusting cropping calendar increases effect of soil moisture conservation in agriculture). Thirdly, options may also be competing with each other, meaning that implementation of one option hinders other options. In this paragraph, the overlap, synergy and competition between the different options of the different sectors is briefly discussed.

Box 1. Kampen – climate adaptation options that apply to the IJsseldelta-Zuid

Introduction

The IJsseldelta area is located in the Netherlands just south of Kampen and belongs to the delta river IJssel, which flows into the IJsselmeer. Due to its geographic and low-lying position, the IJsseldelta is susceptible to flooding from the IJssel river and the IJsselmeer. Furthermore, the threat of flooding is expected to increase in the future because of climate change. Due to extreme high water events, the normative river discharge for extreme events was increased. The normative river discharge at Lobith (river Rhine) had to be increased from 15.000 m^3/s to 16.000 m^3/s. This was legally enforced in 2001. For the river IJssel, this results in an increase in the normative river discharge from about 2.400 m^3/s to about 2.700 m^3/s, and an increase of the normative high water levels with 10 to 50 centimetres. Furthermore, based on the results of climate models, it is expected that in time (2050-2100) the normative discharge at Lobith (river Rhine) will increase to 18.000 m^3/s due to climate change. For the river IJssel, this results in an increase in the normative river discharge to about 3.200 m^3/s, and an increase of the normative high water levels with 80 to 100 centimetres (Louters, et al., 2005).

IJsseldelta project

The aim of the IJsseldelta project is to develop an integral and viable plan to deal with the expected future challenges of the area. In search for possible solutions and ambitions the following conditions were adopted:

- The safety of Kampen and the IJsseldelta in case of extreme high water events must be improved significantly.
- The planned Hanzelijn railway, which should be in operation by the end of 2012, should not be delayed.

- Area must be reserved for 4.000 to 6.000 extra houses at the west side of Kampen.
- Attention must be paid to nature development between the IJssel river and the Drontermeer, taking into account the Ecological Structure in the Netherlands.
- The resulting scenario must receive broad support from authorities and the public.

The partners in the IJsseldelta project aim at an optimal spatial planning for the IJsseldelta area. The main parties involved are authorities like the ministries (national – Ministry of Housing, Spatial Planning and the Environment (VROM), Ministry of Agriculture, Nature and Food Quality (LNV) and Ministry of Transport and Public Works), the province (Overijssel), waterboards (Groot Salland) and the municipalities (Kampen, Zwolle and Zwartewaterland) and various other stakeholders (Louters, et al., 2005).

To develop an integral and viable plan several scenarios were identified that considered the following sectors, which can be linked to the identified adaptation options in this study:

- Transport: Road and rail – technical, procedural and legal aspects are considered, concerning adaptations to the Hanzelijn railway, accessibility of the area, constructional aspects and phasing possibilities for the construction phase. The following adaptation options relating to climate change could be considered in this sector: new design of large infrastructure, for railway and roads (option 92), design spatial planning, related to where to construct infrastructure (option 86) and 91. Water management systems: emergency revision, for tunnel railway and roads (option 91). Important to consider is the construction of the road and rail on dikes to create compartments (option 57).
- Water - Consideration of the required dimensions of the bypass, the safety against flooding, dike heights and structures, river dynamics and morphology, the water system, set water levels and water quality. Adaptation options such as the re-enforcement of dikes and dams, including ‘weak spots’ (option 55), adaptation of highways, secondary dikes to create compartments (option 57), protection of vital objects and infrastructure (option 58 and 59) and water management systems: options for water storage and retention in or near city areas (option 90) are important.
- Nature: Nature, landscape and cultural heritage – paying attention to the river management, maintenance of the nature area, archaeological and historical objects and locations, chances for birds and enhancement of the Ecological Structure in the Netherlands. The design and implementation of ecological networks, the establishment and management of protected areas and integrated nature and water management (options 28, 29 and 34) are all adaptation options that relate to climate change and nature management in the IJsseldelta.
- Agriculture – loss of agricultural grounds plays an important role, size of the operations.
- Recreation – recreation mainly focuses on water and nature recreation and possibilities for extensive recreation housing. Important aspects are navigability and attraction value of the area.
- Housing: Housing and working – emphasis is put on exploring the opportunities for the creation of unique living environments around the water, the interaction between housing and nature and the effects on the accessibility of living and working areas.
- Financial aspects: focus is put on determining direct and indirect costs and benefits of the civil works and spatial planning of the area.
- Other important issues are creating new institutional alliances with all institutions and partners involved in the project (relates to option 68) and the involvement of the public to provide input in the choice of scenario (relates to option 67 creating public awareness).

A cost-benefit analysis has been carried out for each identified scenario. In the costs, a distinction has been made between the civil costs and the design costs. The civil costs are the costs of all dikes and structures, and the costs of procurement of grounds. The design costs are the costs for the development and reinforcement of nature in the bypass (a new river branch created to the south of Kampen, which will connect the IJssel river to the lake Drontermeer). The total costs vary from scenario to scenario, and amount to several hundreds of millions Euro. Approximately 70-85% of these costs are civil costs. The analysis of direct and indirect benefits shows that especially the indirect benefits will determine the financial feasibility of the bypass. The financial contributions related to urban development, budget for the space for the river measures, and the future maintenance budget for the river management play a dominant role in making the project feasible (Project IJsseldelta, 2005).

The Masterplan, which was presented on 4 September 2006 to the minister of Transport, Public Works and Water Management, plan represents the preferred scenario for the IJsseldelta Zuid that relies on a wide support from authorities and the public. The total costs of the bypass amount 300 million euro, with a range of 20 percent. For this amount the entire bypass can be constructed, with facilities for nature, recreation and shipping. The costs are set up according to a modular structure. First the calculation of what the simple green bypass would cost is made, which is followed by the measures that can be added and their associated costs. In the fall of 2006 the social costs and benefits will be calculated for the development of the IJsseldelta Zuid.

The total cost of the bypass (300 million euro) has the following components:

- Construction of green bypass (land purchase, dikes, pastures between dikes, overpass in Hanzelijn and N50, with a simple inlet and outlet): € 193 mln
- Recreational shipping connection (2 meters depth), with a sluice for the recreational ships at the beginning and end: + € 14 mln
- Organisation of wet and dry nature: + € 11 mln
- Upgrading of the most simple in- and outlet to a in- and outlet with removable partitions: + € 13 mln
- Replacement of the current barricade near the Roggebotsluis by a new broad stormkering, and a new drawbridge as to create a “half open” bypass: + € 48 mln
- Additional costs, estimation: + € 21 mln
- Totale: € 300 mln
- 20 % range: € 240 - € 360 mln (Project IJsseldelta, 2006)

2.2.1 Overlap

Some of the adaptation options have a seeming or real overlap with each other. This makes sense as for example integrated nature and water management has effect on all sectors considered in this report. Moreover, both nature and the forestry sector benefit from a larger diversity of tree species. For some options, the apparent overlap does not exist as is shown by the explanation of the option. For some options, only some elements of the options are overlapping, whereas some options may be entirely overlapping with each other. In this section, we give a very brief overview of the possible overlap for the options of the sectors agriculture, nature and water.

Agriculture

The adaptation options of agriculture to climate change are a portfolio of measures comprising different activities. A land manager can select more than one option in response to climate change. The nested structure and relations between the various options are not further elaborated in this report. Some of the options within the agricultural sector seem to have a partial overlap with each other; this is elaborated in the next paragraph.

First, Option 10 (Changes in farming systems) includes structural changes in strategic planning, including consequent changes in strategic and tactical decision-making. Examples are: increased diversification (of production activities but also in spatial distribution of activities) or shifts in production orientation: moving from conventional to ecological farming or vice versa. There is no overlap with Option 1 (Adjusting crop rotation schemes and planting and harvesting dates) which focuses more on another type of (tactical) decision. Secondly, Option 15 (Land use change) has a partial overlap with Option 1 (Adjusting crop rotation schemes) and Option 10 (changes in farming systems). All three options have common elements as changing land use includes changes in land cover and changes in operational management. Thirdly, Option 21 (Acceptance of (gradual) ongoing changes in species composition in forests) has only partially overlaps with Option 17 (Increasing genetic and species diversity in forests) and 18 (Introduction of southern provenances of tree species and drought resistant species), there may even be synergy between these three options. Accepting, perhaps economic less attractive, species allows for gradual change in management. Inflexible species management not anticipating changes in species competition will prove to create adaptation problems in the light of climate change.

Nature

A number of the nature, agriculture and water options are supplementary to each other and therefore seem to be overlapping. For example, Option 30 (Artificial translocation of plants and animals) has some common elements but does not fully overlap with Option 17 (Increasing genetic and species diversity in forests) and 18 (Introduction of southern provenances of tree species and drought resistant species). Option 30 deals with artificial translocation of plants and animals. Options 17 and 18 deal only with plants and more precisely with forest plants. Option 30 deals with translocation of species and seeds from one area, not anymore suitable for species because of changing climate conditions, to another more suitable area. The focus of option 30 is preservation of species, in other words ensure the survival of existing species, whereas the focus of option 17 is to increase diversity in forests (this because monoculture forests are more sensitive to stress than mixed forests). Option 30 includes option 18 because artificial translocation may also imply translocation of southern species and drought resistance species. But option 30 goes beyond option 18 because it includes any translocation (plants and animals) from less suitable area to a more suitable area.

Secondly, Option 31 (Afforestation and mix of tree species) has common elements with Option 17 (Increasing genetic and species diversity in forests), but not a full overlap. There is overlap between option 31 and option 18 (Introduction of southern provenances of tree species and drought resistant species). Option 17 deals with the importance of diversifying species composition in forests. Option 31 focuses first of all on afforestation (i.e. planting a forest in areas where there was no forest before), this means that the focus is on increasing the amount of forest land in order to create new green areas. Then, when planting a forest, option 31 highlights the important of selecting suitable species and have mixed forests. This last concept (mixed forests) is the same one described in option 17.

Option 31 includes option 17 but includes also other aspects (such as increase the amount of forest land). There is however an overlap between option 32 "Adjustment of forest management" (not mentioned here) and option 17 and 18 because they are all dealing with management of already existing forests and they all focus on increasing diversity in forests and increasing resilience by introducing more suited species.

Thirdly, Option 34 (Integrated nature and water management) includes all possible options that combine creation of more space for water and other functions such as offering space to plant and animal species and thus maintaining/enhancing biodiversity. There are common elements but not necessarily an overlap with many other options. The focus of option 34 is to connect water and nature conservation and enhance of nature conservation values (e.g. wetland ecosystems). Option 40 ("More space for water") gives the accent on safety issues. Option 40 can also benefit nature, but in some cases more space for water can cause degradation of some ecosystems, for example, riverine forests that are considered a threat to water quality managers because they increase the roughness of the floodplain and thus enhance any occurring discharge peaks.

Fourthly, Option 35 (Integrated coastal zone management), includes all possible coastal options that increase safety and benefit coastal ecosystems. There is no overlap with Option 24 (Introduction of ecosystem management in fishery). That option deals with aquatic ecosystems. It deals with biodiversity conservation plans for freshwater and marine fish and shellfish. Option 35 deals with semi-terrestrial ecosystems. There exists, however, some overlap between option 24 and option 36 ("Restoration of ecosystems directly depending on water quantity and quality"). Option 36 in fact deals also (though not solely) with the management of aquatic ecosystems.

Water

As mentioned above, adaptation options for the sectors nature and water are often closely associated. Several adaptation options for nature exploit the possibilities provided by water management. Nature and water options could be taken together under the heading integral water management. However, we prefer to keep them separate because that allows us to specify more clearly that action is needed in terms of water management and nature management: nature does not get a free ride. Water management options providing protection against flooding often need to be modified to fully exploit he possibilities for nature restoration and conservation.

First, Option 34 (Integrated nature and water management) has an overlap with Option 40 ("More space for water"). Creating more space for the storage and retention of water (option 40) may benefit landscape and provide suitable habitat for flora and fauna. This option exploits the possibilities for nature conservation and restoration provided by option 40. Appropriate storage and retention may provide additional aquatic habitat and counteract drought, another consequence of climate change. A cautionary note: existing natural habitats may also disappear when faced with inundations that are too extreme in magnitude and frequency.

Secondly, Option 35 (Integrated coastal zone management) has an overlap with option 45 (Allow transgression of sea in wide dune areas, allow wash over of dikes) and 46 (Widening the coastal defence area). Re-establishment of the natural dynamics of the dunes, beaches and slacks in combination with safety measures implies the integration of safety policies and measures with nature restoration, recreational use and urban development.

As in option 34, this option means to exploit the possibilities for nature conservation and restoration that are provided by the water management options, in this case options 45 and 46. Such an integrated approach has already been applied since the early nineties, but locally, on a small scale and only in remote and scarcely populated areas. This general principle can be extended to larger scale measures that increase safety, natural values and recreational use, also in the vicinity of cities.

Thirdly, there is an overlap between Option 65 (Risk management as basic strategy) and option 41 (Risk based allocation policy), 44 (Compartmentation of low-lying parts of the Netherlands), 58 (Protection of vital objects) and 70 (Reduce waste water discharge during drought periods). The expected damage of flooding is defined as the probability of flooding multiplied by its impact (human life, damage). The size of the human population and of the economic value protected by our dikes has greatly increased in the last decades. The safety (probability of flooding) has been maintained on the same level, thus the risk of flooding has increased. In response to this, the Dutch water policy had adapted a new approach, a new line of thinking. In the evaluation of present uses, in the planning of adaptation measures, measures to reduce the probability of flooding are increasingly weighed against measures to reduce the impacts. This transition is already taking place, but is not yet fully adopted. Option 41 implements this approach in spatial planning in general. Options 44, 58, 59 and 70 are examples of impact reduction.

Fourthly, Option 90 (Water management systems: options for water storage and retention in or near city areas) is part of option 40 ("More space for water"). However, we treat it separately because the urban environment creates specific problems and changes. Problems are for example the large percentage of hard surface, limited storage capacity, limited sewer treatment capacity (options 64 and 89). Chances are the use of water storage for cooling, recreation, to separate sewer and rain water and, last but not least, to enlarge public awareness of the necessity and possibilities of climate adaptation (option 67).

Finally, there is an apparent overlap between option 48 (Fresh water storage to flush brackish water out during dry periods) and option 50 (Maintain higher water table to prevent salt water intrusion). However, this overlap is minimal as water stored at specific locations (say location A) can be used to flush brackish water out, or to prevent intrusion in, area B. This option can be used in combination with option 50.

2.2.2 Synergy and competition

There is a strong synergy between some of the options, where implementation of two (synergetic) options will result in a larger effect or a cheaper solution than when only one of the options is implemented. Likewise, some options are competitive, meaning that they must not be implemented jointly as that would result in a reduced effect. Conflicts and synergies of natural resources (land and water) and their use/management will most likely occur between agriculture, forestry, nature and the water sector. In this section we give an overview of the synergies of and competition/conflicts among a number of options.

Agriculture

First, water use or water management activities for agriculture will in many cases have a negative effect on adjacent nature areas. On the other hand, agricultural adaptation measures such as changes in farming systems and farm management can provide benefits for both water and biodiversity.

Secondly, biomass to substitute fossil fuels is a clear example of how agriculture and the energy sector can cooperate to mutual benefit. Adaptations of the agricultural sector are required to make biomass a feasible and profitable alternative to fossil fuels.

Thirdly, in the forestry and fishery sub-sectors, moving to management and exploitation options that are more in line with nature, can combine well with objectives in the nature and water sector. For example, making fisheries activities more sustainable has also positive effects on marine ecosystems.

Water

The nature and water sectors have many synergies but hardly any competition. Usefulness and urgency of some of the options depends on whether other options are implemented. For example, adaptation options that prevention flooding from taking place, reduce the urgency and magnitude of evacuation or compartmentation options.

As already mentioned in Section 2.2.1, there are large synergies between Option 16 (Adaptation strategies to salinization of agricultural land), 26 (Reallocation of mussel nursery plots), 27 (Aquaculture on former grassland) and 45 (Allow transgression of sea in wide dune areas, allow wash over of dikes). Moreover, also Option 28 (Design and implementation of ecological networks), 29 (Establishment and management of protected areas), 35 (Integrated coastal zone management), 36 (Restoration of ecosystems directly depending on water quantity and quality) and 46 (Widening the coastal defence area) show many synergies.

Nature

Obviously, adaptation options identified for the nature sector have many synergies with options from the other sectors. The table summarizing these synergies and competitions is presented in Annex 2. First, Option 28 (Design and implementation of ecological networks (The National Ecological Network - NEN)) may have synergies or compete also with Option 10, 12, 13 15, 16, 17, 18, 19, 20, 27, 40, 41, 45, 46, 52, 53, 54, 55, 62, 70, 86 and 96. Option 10 (Changes in farming systems) can support the development of the “National Ecological Network" by contributing to establishment of green corridors, increase the overall environmental quality and promoting a wildlife friendly environment. Option 12 (Regional adaptation strategies for the fen meadow areas) can improve retention of water in natural areas and reduce problems due of water-shortage. Option 15 (land use changes) can create opportunities for development of nature areas. Option 16 (Adaptation strategies to salinization of agricultural lands) can support to reduce salinity and thus increase/maintain the environmental quality of some nature areas. Option 17 (increasing genetic and species diversity in forest) can increase resilience of forest ecosystems, spread the risk of extinction, maintain/enhance biodiversity etc. Option 18 (Introduction of southern provenances of tree species and drought resistant species) can help to maintain/enhance biodiversity. Option 19 (Limiting the import of timber) can reduce the intensity of forest production and help in maintaining biodiversity. Option 20 (Retention of winter precipitation in forests) reduces drought problems. Option 40 (“More space for water”) can favour development of wetland nature. Option 41 (Risk based allocation policy) has a synergy with Option 28 as land use allocation policy may lead to more available space for nature in the lower part of the Netherlands. Option 52 (Reclamation of the southern North Sea) may lead to coastal ecosystems wetland development. Option 53 (Abandoning of the whole of low-lying Netherlands) leads to more available space for nature in the lower part of the Netherlands. Option 54 (Increase sand suppletions along the Dutch North Sea coast) offers opportunity for dune related nature development.

Option 62 (De-salinization) can reduce risk of damages to nature due to salinization. Option 70 (Reduce waste water discharge during drought periods) can reduce risk of damages to nature. Option 96 (Design infrastructure for recreation and tourism – coastal areas) has a synergy with Option 28 as sustainable tourism can favour nature values.

Option 28 also competes with some options. Option 13 (Relocation or mobilization of farms) can cause a competition, in terms of land availability. Option 20 (Retention of winter precipitation in forests) increases the sensitivity to storm damage. Option 27 (Aquaculture on former grassland) may compete because of reduced space for grassland. Option 40 ("More space for water") also competes as more space for natural rivers may lead to loss of some ecosystems for example riverine forests that are considered a threat to water quality managers since they increase the roughness of the floodplain and thus enhance discharge peaks. Next to being synergetic, Option 41 (Risk based allocation policy) also competes with Option 28 as the policy may lead to decreasing space for nature in the higher parts of the Netherlands. Option 46 (Widening the coastal defence area) can degrade existing semi-terrestrial ecosystems. Option 52 (Reclamation of the southern North Sea) may lead to loss of coastal marine ecosystems. Option 55 (Re-enforcement of dikes and dams) can damage nature conservation values. Option 86 (Design spatial planning, construct new housing and infrastructure) competes with nature in term of land availability. Next to synergies, Option 96 (Design infrastructure for recreation and tourism – coastal areas) also competes with Option 28 as non-sustainable tourism can actually decrease biodiversity

Option 29 (Establishment and management of protected areas), has synergies with Option 12, 15, 17, 18, 20, 40, 41, and 53 and competes with Option 13, 20, 40, 41, 55, and 86 for the same reasons as discussed above for Option 28.

Option 30 (Artificial translocation of plant and animal) and Option 31 (Afforestation and mix of tree species) have a synergy with Option 15 (Land use change) as they can create an opportunity for development of nature areas. They compete with Option 13 (Relocation or mobilization of farms) in terms of land availability.

Option 31 (Afforestation and mix of tree species) also has synergies with Option 17, 18, 21, 41 and 53. Option 17 (Increasing genetic and species diversity in forests) can increase resilience of forest ecosystems, spread the risk of extinction, maintain/enhance biodiversity etc. Option 18 (Introduction of southern provenances of tree species and drought resistant species) can help to maintain/enhance biodiversity. Option 21 (Acceptation of changes in species composition in forests) can favour the development of mixed forests. Option 41 (Risk based allocation policy) may lead to more available space for nature in the lower part of the Netherlands. Option 53 (Abandoning of the whole of low-lying Netherlands) leads to more available space for nature in the lower part of the Netherlands. It also competes with Option 41 (risk based allocation policy) as it may result to reduced nature areas in the higher parts of the country and Option 86 (Design spatial planning – construct new housing and infrastructure) in terms of land availability.

Option 32 (Adjustment of forest management) has synergies with option 17 (increasing genetic and species diversity in forest), 18 (Introduction of southern provenances of tree species and drought resistant species), 19 (Limiting the import of timber), 20 (Retention of winter precipitation in forests) and for option 21 (Acceptation of changes in species composition) for the same reasons as already mentioned for Option 28.

Option 33 (Implementation of effective agri-environmental schemes) has synergies with Option 4 (Soil moisture conservation practices), 5 (Irrigation), 7 (Water storage on farmland), and 16 (Adaptation strategies to salinization of agricultural land).

Option 4 and 5 can reduce drought problems for nature areas next to agricultural land. Option 7 may increase biodiversity and Option 16 can support to reduce salinity and thus increase/maintain the environmental quality of some nature areas.

Option 34 (Integrated nature and water management) has synergies with Option 14 (floating greenhouses) as the construction of floating areas could be used not only for the greenhouse horticulture but also for ecological development. It also has a synergy with Option 40 ("More space for water") as that option can develop wetland nature and Option 52 (Reclamation of the southern North Sea) as it may lead to coastal ecosystems wetland development.

Option 35 (Integrated coastal zone management) has synergies with Option 54, 61 and 96 and competes with Option 46 and 96. Option 54 (Increase sand suppletions along Dutch North Sea coast) can offer opportunities for dune related nature development. Option 61 (Artificial reefs along the coastline & development nature conservation values) can enhance marine biodiversity. Option 96 (Design infrastructure for recreation and tourism – coastal areas) can have synergies as sustainable tourism can favour nature values. It may be also competing as non-sustainable tourism can actually decrease biodiversity. Option 46 (Allow transgression of sea in wide dune areas, allow wash over of dikes) also competes with Option 35 as it can degrade existing semi-terrestrial ecosystems.

Option 36 (Restoration of ecosystems directly depending on water quantity and quality) has synergies with Option 12, 22, 23, 24, 25, 40, 46, 52, 54, 61, 62, 70 and competes with Option 27, 40, 45, 52. Option 12 (Regional adaptation strategies for the fen meadow area) can improve retention of water in natural areas and reduce problems due of water-shortage. Option 22 (Adjusting fishing quota) may reduce exploitation of marine resources. Option 23 (Adaptation of target species and fishing techniques) may reduce exploitation of marine resources. Option 24 (Introduction of ecosystem management in fishery) may contribute to maintenance of marine biodiversity. Option 25 (Eco-labelling and certification of fish) may support sustainable use of resources. Option 40 ("More space for water") can favour development of wetland nature. Option 46 (Widening the coastal defence area) can favour development of coastal ecosystems. Option 52 (Reclamation of the southern North Sea) may lead to coastal ecosystems wetland development. Option 54 (Increase sand suppletions along Dutch North Sea coast) offer opportunity for dune related nature development. Option 61 (Artificial reefs along the coastline & development nature conservation values) can enhance marine biodiversity. Option 62 (De-salinization) can reduce risk of damages to nature due to salinization. Finally, Option 70 (Reduce wastewater discharge during drought periods) can reduce risk of damages to nature

Option 27 (Aquaculture on former grassland) may compete with Option 36 because of a reduction of space for grassland. Option 40 ("More space for water") also competes with Option 36 as more space for natural rivers may lead to loss of some ecosystems for example riverine forests that are considered a threat to water quality manager since they increase the roughness of the floodplain and thus enhance discharge peaks. Option 45 (Allow transgression of sea in wide dune areas, allow wash over of dikes) can degrade existing semi-terrestrial ecosystems. Next to synergies, Option 52 (Reclamation of the southern North Sea) may also lead to loss of coastal marine ecosystems.

Finally, Option 37 (Monitoring nature, interpreting changes and informing), Option 38 (Educational programs) and Option 39 (Development of financing mechanisms) do have some synergies with Option 67 (Creating public awareness) and Option 68 (New institutional alliances).

Box 2. Case-study Biesbosch

Introduction

The Biesbosch – Haringvliet estuary is a green maze of several rivers, islands and a vast network of narrow and wide creeks. The movement of the water in the area is not only determined by the water level of the rivers but also by the tidal movement of the sea. During a storm and when the sea is whipped up, the Delta Works are closed and the stream of water can not exit into sea, then room is needed to temporarily store the water. In the Biesbosch and on the borders of the Haringvliet such space can be offered by turning large areas of polders into wetlands (in the Noordwaard, the island of Dordrecht and on polders along the Haringvliet).

Currently there are discussions ongoing about plans relating to safety, nature development, gas extraction, the construction of houses, recreation/tourism and the future of agriculture in the area. The area where the Biesbosch is located, which through the Haringvliet continues until the Voordelta, is part of a few areas in the Netherlands that are a perfect example for the development of a robust system that will be useful for the coming hundred years, even if climate change turns out to be more severe then expected. This area is also interesting because it is located between two city areas. The south part of the Randstad and the cities located in the province of Brabant are interested in exploring and organising their possibilities for recreation, water storage and drinking water supply for the years to come (Braakhekke, et al., 2005).

Project

The Biesbosch – Haringvliet estuary has been selected as a hotspot area within the Klimaat voor Ruimte programme. A concept project proposal has been developed by Staatsbosbeheer and Bureau Stroming. Currently they are contacting potential partners to discuss the development of specific project parts. The main issues are the spatial planning of the area relating to climate change. Special points of interest are the storage of water, the distribution of fresh water within and from this area, the saltwater intrusion and safety issues in the area concerning sea level rise and river discharge. Possible solutions are; turning large areas of polders into wetlands, with the possibility of combining nature and recreational functions for the area and in addition planting willow forests that partly can be used as biomass to generate energy. Part of the study is also to find out the possibilities for adaptive ways of housing (e.g. floating or on dwelling mounts). Since the project development is still in its starting-up phase it is not possible to present any costs and benefits of any suitable adaptation options (A. van Winden, 2006). However the following adaptation options, as identified in the Routeplanner project could relate to the Biesbosch - Haringvliet project:

- Agriculture sector: Development and growing of corps for biomass production (option 3 and option 88) and adaptation strategies to salinization of agricultural land (option 12);
- Nature sector: Integrated nature and water management (option 34);
- Water sector: Compartmentation of low-lying parts of the Netherlands (option 44), Relocation of fresh water intake points (option 51).
- Housing sector: Design spatial planning – construct new housing and infrastructure (option 86).

The following parties are involved in the project:

- Drinking water winning. The water winning companies want to be involved in the decision about where to locate future fresh water intake points.
- The city of Dordrecht. The city is located at the border of The Biesbosch and associates itself with the area. Future building plans can be integrated into the area.

- Waterschap Hollandse Delta. The waterschap is in charge of the maintenance of the dike rings and a large part of the inland-dike water and responsible for the fresh water supply to the agricultural and industrial sector.
- Shipping. Shipping will profit from a good connection between the harbours in the region and the rest of the country.
- Essent. Energy company Essent is interested to cooperate in the development of energy through biomass.
- Recreation. Possible individual entrepreneurs are able to find possibilities for the development of nature camping areas and nature lodges and offer possibilities for watersport in the area.
- Rijkswaterstaat. Rijkswaterstaat has taken the initiative for several projects in the area. A future perspective on water management for the coming years has not been developed yet.
- Dura Vermeer. Dura Vermeer is developing concepts for experimental building (e.g. floating and adaptive living). It is expected that with the change in watermanagement the demand for adaptive living wil increase).
- Staatsbosbeheer. Staatsbosbeheer is in charge of a large nature area in the National Park The Biesbosch and in the Haringvliet and involved in nature development projects in the region.

2.3 Overview of adaptation options

Table 1 gives an overview of the adaptation options and their relevant climate characteristics and impacts by sector. Table 2 presents an overview of the relevant level of implementation (international, national, regional, local and site level) and fields of interest as used in the Routeplanner project (economic development, security, living conditions, ecology and administration & society) for each identified adaptation option.

Table 1. Overview of adaptation options and their relevant (x) climate characteristics and impacts by sector

Sector	Subsector	Adaptation option		Temperature	Precipitation	Extreme weather events	Other	Sea level rise	River discharge	Groundwater level	Storms	Heat stress	Drought stress	Growth stress (plants - species)
		nr.	name											
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates		x	x					x	x	x	x
Agriculture	General	02	Choice of crop variety and genotype	x	x	x					x	x	x	x
Agriculture	General	03	Development and growing of crops for biomass production	x	x	x					x			x
Agriculture	General	04	Soil moisture conservation practices		x								x	x
Agriculture	General	05	Irrigation		x								x	
Agriculture	General	06	Self sufficiency in production of roughage				x							x
Agriculture	General	07	Water storage on farmland		x				x				x	
Agriculture	General	08	Subsoil drainage of		x					x			x	

Table 1. Overview of adaptation options and their relevant (x) climate characteristics and impacts by sector														
Sector	Subsector	Adaptation option		Temperature	Precipitation	Extreme weather events	Other	Sea level rise	River discharge	Groundwater level	Storms	Heat stress	Drought stress	Growth stress (plants - species)
		nr.	name											
			peatlands											
Agriculture	General	09	Insurance		x	x		x	x	x	x	x	x	x
Agriculture	General	10	Changes in farming systems	x	x	x			x		x	x	x	x
Agriculture	General	11	Water management and agriculture		x	x		x	x	x	x		x	
Agriculture	General	12	Regional adaptation strategies for the fen meadow area		x					x				
Agriculture	General	13	Relocation or mobilization of farms		x	x				x	x			x
Agriculture	General	14	Floating greenhouses		x	x			x	x	x			
Agriculture	General	15	Land use change	x	x	x					x	x	x	x
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	x	x			x						x
Agriculture	Forest	17	Increasing genetic and species diversity in forests	x	x	x						x	x	x
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species		x							x	x	x
Agriculture	Forest	19	Limiting the import of timber	x	x									x
Agriculture	Forest	20	Retention of winter precipitation in forests		x								x	
Agriculture	Forest	21	Acceptation of changes in species composition in forests				x				x	x	x	x
Agriculture	Fishery	22	Adjusting fishing quota	x								x		
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	x								x		x
Agriculture	Fishery	24	Introduction of ecosystem management in fishery	x								x		
Agriculture	Fishery	25	Eco-labelling and certification of fish	x										x
Agriculture	Fishery	26	Reallocation of mussel nursery plots	x		x					x			x
Agriculture	Fishery	27	Aquaculture on former grassland	x										x
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	x	x	x			x	x	x	x	x	x
Nature	Nature	29	Establishment and management of protected areas	x	x	x			x					x

Table 1. Overview of adaptation options and their relevant (x) climate characteristics and impacts by sector

Sector	Subsector	Adaptation option nr.	Adaptation option name	Temperature	Precipitation	Extreme weather events	Other	Sea level rise	River discharge	Groundwater level	Storms	Heat stress	Drought stress	Growth stress (plants - species)
Nature	Nature	30	Artificial translocation of plant and animal	x	x	x								x
Nature	Forestry	31	Afforestation and mix of tree species	x	x	x					x	x	x	x
Nature	Forestry	32	Adjustment of forest management	x	x	x					x	x	x	x
Nature	Agriculture	33	Implementation of effective agri-environmental schemes				x							x
Nature	Water management	34	Integrated nature and water management	x	x			x	x	x	x	x	x	x
Nature	Water management	35	Integrated coastal zone management	x	x			x	x	x	x			
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	x	x			x	x	x			x	x
Nature	Society	37	Monitoring nature, interpreting changes and informing	x	x	x		x	x	x	x	x	x	x
Nature	Society	38	Educational programs	x	x	x		x	x	x	x	x	x	x
Nature	Finance	39	Development of financing mechanisms	x	x	x		x	x	x	x	x	x	x
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention		x	x			x	x	x		x	
Water	Spatial concept	41	Risk based allocation policy		x			x	x					
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	x		x			x			x	x	
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	x		x			x		x	x	x	
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands		x	x		x	x	x	x			
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	x	x	x		x			x			
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	x	x	x		x			x			
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)		x	x		x	x		x			
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	x	x			x					x	
Water	Spatial	49	Higher water level	x	x				x				x	

Table 1. Overview of adaptation options and their relevant (x) climate characteristics and impacts by sector

Sector	Subsector	Adaptation option		Temperature	Precipitation	Extreme weather events	Other	Sea level rise	River discharge	Groundwater level	Storms	Heat stress	Drought stress	Growth stress (plants - species)
		nr.	name											
	concept		IJsselmeer											
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	x	x			x	x	x				
Water	Spatial concept	51	Relocation of fresh water intake points		x				x				x	
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	x				x						
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	x				x						
Water	Technological solution	54	Increase sand suppletions along coast	x		x		x			x			
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'		x	x		x	x	x	x			
Water	Technological solution	56	Adapted forms of building and construction	x	x	x		x	x	x	x	x		
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	x	x	x		x	x		x	x		
Water	Technological solution	58	Protection of vital objects		x	x		x	x		x			
Water	Technological solution	59	Protection of vital infrastructure		x	x		x	x		x			
Water	Technological solution	60	Enhancing capacity of sluices and weirs		x	x		x	x		x		x	
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	x		x		x			x			
Water	Technological solution	62	De-salinization	x	x			x						
Water	Technological solution	63	Reduction salt water tongue	x	x			x						
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	x				x	x					
Water	Social, policy	65	Risk management as basic strategy	x	x	x		x	x	x	x			
Water	Social, policy	66	Evacuation plans	x	x	x		x	X		x			
Water	Social, policy	67	Creating public awareness	x	x			x	x	x	x	x	x	x
Water	Social, policy	68	New institutional alliances	x	x			x	x	x	x		x	
Water	Social, policy	69	Private insurances against inundations and/ or drought related damages	x	x	x		x	x		x		x	
Water	Technological solution	70	Reduce wastewater discharge during drought periods			x							x	
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge	x					x			x	x	

Table 1. Overview of adaptation options and their relevant (x) climate characteristics and impacts by sector

Sector	Subsector	nr.	Adaptation option name	Temperature	Precipitation	Extreme weather events	Other	Sea level rise	River discharge	Groundwater level	Storms	Heat stress	Drought stress	Growth stress (plants - species)
			temperature is allowed											
Energy & Transport	Energy	72	Sluices	x		x			x		x		x	
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	x	x	x		x	x	x	x	x	x	x
Energy & Transport	Energy	74	Building stronger wind turbines			x					x			
Energy & Transport	Energy	75	Construct buildings differently in such a way that there is less need for air-conditioning/heating	x	x	x						x		
Energy & Transport	Energy	76	Constructing more stable overhead electricity transmission poles			x					x			
Energy & Transport	Energy	77	Adapt to mitigation strategies	x	x	x		x	x	x	x	x	x	x
Energy & Transport	Energy	78	Use improved opportunities for generating wind energy			x					x			
Energy & Transport	Energy	79	Use improved opportunities for generating solar energy			x	x							
Energy & Transport	Energy	80	Planting of biomass crops	x	x									x
Energy & Transport	Energy	81	Development of cooling towers	x		x			x			x	x	
Energy & Transport	Transport	82	Development of more 'intelligent' infrastructure that can serve as early warning indicator			x					x	x		
Energy & Transport	Transport	83	Improvement of vessels			x					x			
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent infrastructure		x	x			x		x			
Energy & Transport	Infrastructure	85	Increase standards for buildings as to make them more robust to increased wind speeds			x					x			
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure			x		x	x		x	x		
Housing & Infrastructure	Spatial	87	Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity	x		x					x	x		
Housing & Infrastructure	Design	88	Design houses with good climate conditions (control) – 'low energy'	x		x					x	x		

Table 1. Overview of adaptation options and their relevant (x) climate characteristics and impacts by sector

Sector	Subsector	Adaptation option nr.	Adaptation option name	Temperature	Precipitation	Extreme weather events	Other	Sea level rise	River discharge	Groundwater level	Storms	Heat stress	Drought stress	Growth stress (plants - species)
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system		x	x			x	x	x	x	x	
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas		x	x				x	x	x	x	
Housing & Infrastructure	Water management	91	Water management systems: emergency systems revision for tunnels and subways		x	x			x		x			
Housing & Infrastructure	Design	92	New design of large infrastructure		x	x			x		x			
Health		93	Improved air conditioning in nursery homes or hospitals	x	x	x						x		
Health		94	Measures for preventing climate related diseases	x	x							x		
Health		95	Improvement of health care for climate related diseases	x	x							x		
Recreation & tourism		96	Design infrastructure for recreation and tourism – coastal areas	x		x		x			x	x		

Table 2. Overview of adaptation options and their relevant implementation level and field of interest

Sector	Subsector	Adaptation option nr.	Adaptation option name	Implementation level I - International N - National R - Regional L - Local S - Site	Field of interest Ed - Economic development S - Security L - Living conditions E - Ecology A - Administration & society
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	R / L	Ed
Agriculture	General	02	Choice of crop variety and genotype	N / R	Ed
Agriculture	General	03	Development and growing of crops for biomass production	N / R / L	Ed
Agriculture	General	04	Soil moisture conservation practices	N / R	Ed
Agriculture	General	05	Irrigation	N / R	Ed
Agriculture	General	06	Self sufficiency in production of roughage	N	Ed
Agriculture	General	07	Water storage on farmland	R / L	Ed
Agriculture	General	08	Subsoil drainage of peatlands	R	Ed
Agriculture	General	09	Insurance	N	Ed

Table 2. Overview of adaptation options and their relevant implementation level and field of interest

Sector	Subsector	Adaptation option nr.	Adaptation option name	Implementation level I - International N - National R - Regional L - Local S - Site	Field of interest Ed - Economic development S - Security L - Living conditions E - Ecology A - Administration & society
Agriculture	General	10	Changes in farming systems	N / R	Ed
Agriculture	General	11	Water management and agriculture	R / L	Ed
Agriculture	General	12	Regional adaptation strategies for the fen meadow area	R	Ed
Agriculture	General	13	Relocation or mobilization of farms	N	Ed
Agriculture	General	14	Floating greenhouses	R	Ed
Agriculture	General	15	Land use change	N / R / L	Ed
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	R	Ed
Agriculture	Forest	17	Increasing genetic and species diversity in forests	N / R	E
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	N / R	E
Agriculture	Forest	19	Limiting the import of timber	N	Ed
Agriculture	Forest	20	Retention of winter precipitation in forests	N / R	E
Agriculture	Forest	21	Acceptation of changes in species composition in forests	N	E
Agriculture	Fishery	22	Adjusting fishing quota	R	Ed
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	R	Ed
Agriculture	Fishery	24	Introduction of ecosystem management in fishery	R	Ed
Agriculture	Fishery	25	Eco-labelling and certification of fish	R	Ed
Agriculture	Fishery	26	Reallocation of mussel nursery plots	R	Ed
Agriculture	Fishery	27	Aquaculture on former grassland	L	Ed
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	N / R	E
Nature	Nature	29	Establishment and management of protected areas	N / R	E
Nature	Nature	30	Artificial translocation of plant and animal	N / R	E
Nature	Forestry	31	Afforestation and mix of tree species	N / R	E
Nature	Forestry	32	Adjustment of forest management	N / R	E
Nature	Agriculture	33	Implementation of effective agri-environmental schemes	N / R	E
Nature	Water management	34	Integrated nature and water management	N / R	E
Nature	Water management	35	Integrated coastal zone management	N / R	E
Nature	Water management	36	Restoration of ecosystems directly depending on water	N	E

Table 2. Overview of adaptation options and their relevant implementation level and field of interest

Sector	Subsector	nr.	Adaptation option name	Implementation level I - International N - National R - Regional L - Local S - Site	Field of interest Ed - Economic development S - Security L - Living conditions E - Ecology A - Administration & society
			quantity and quality		
Nature	Society	37	Monitoring nature, interpreting changes and informing	N	E
Nature	Society	38	Educational programs	N	E
Nature	Finance	39	Development of financing mechanisms	N	E
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	N	S
Water	Spatial concept	41	Risk based allocation policy	N	S
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	N / L	Ed
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	N / L	Ed
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	R	S
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	N / R	S
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	N / R	S
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)	L	S / Ed
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	R	L
Water	Spatial concept	49	Higher water level IJsselmeer	N / R	L
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	R	E
Water	Spatial concept	51	Relocation of fresh water intake points	R / L	L
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	R	S
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	R	S
Water	Technological solution	54	Increase sand suppletions along coast	R	S
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	N / R	S
Water	Technological solution	56	Adapted forms of building and construction	S / N	L
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	N / R	S
Water	Technological solution	58	Protection of vital objects	R	S
Water	Technological solution	59	Protection of vital infrastructure	R	S

Table 2. Overview of adaptation options and their relevant implementation level and field of interest

Sector	Subsector	nr.	Adaptation option name	Implementation level I - International N - National R - Regional L - Local S - Site	Field of interest Ed - Economic development S - Security L - Living conditions E - Ecology A - Administration & society
Water	Technological solution	60	Enhancing capacity of sluices and weirs	N/ L	S
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	R	S
Water	Technological solution	62	De-salinization	R / L	Ed
Water	Technological solution	63	Reduction salt water tongue	R / L	E
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	R	Ed
Water	Social, policy	65	Risk management as basic strategy	N	S
Water	Social, policy	66	Evacuation plans	N	S
Water	Social, policy	67	Creating public awareness	N	S
Water	Social, policy	68	New institutional alliances	L / R / N / I	S / A
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	N	A
Water	Technological solution	70	Reduce wastewater discharge during drought periods	N / R	E
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature is allowed	N	A
Energy & Transport	Energy	72	Sluices	L	Ed
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	N	A
Energy & Transport	Energy	74	Building stronger wind turbines	N	Ed
Energy & Transport	Energy	75	Construct buildings differently in such a way that there is less need for air-conditioning/heating	S / N	L
Energy & Transport	Energy	76	Constructing more stable overhead electricity transmission poles	N	Ed
Energy & Transport	Energy	77	Adapt to mitigation strategies	N / I	E
Energy & Transport	Energy	78	Use improved opportunities for generating wind energy	N / R	Ed
Energy & Transport	Energy	79	Use improved opportunities for generating solar energy	N	Ed
Energy & Transport	Energy	80	Planting of biomass crops	N / R	Ed
Energy & Transport	Energy	81	Development of cooling towers	R	Ed
Energy & Transport	Transport	82	Development of more ‘intelligent’ infrastructure that can serve as early warning indicator	N	S
Energy & Transport	Transport	83	Improvement of vessels	N	Ed

Table 2. Overview of adaptation options and their relevant implementation level and field of interest

Sector	Subsector	nr.	Adaptation option name	Implementation level I - International N - National R - Regional L - Local S - Site	Field of interest Ed - Economic development S - Security L - Living conditions E - Ecology A - Administration & society
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent infrastructure	N	V
Energy & Transport	Infrastructure	85	Increase standards for buildings as to make them more robust to increased wind speeds	N / S	L
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	N / S	L
Housing & Infrastructure	Spatial	87	Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity	N / R / L / S	L
Housing & Infrastructure	Design	88	Design houses with good climate conditions (control) – 'low energy'	S	Ed
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	L	S
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	L	S
Housing & Infrastructure	Water management	91	Water management systems: emergency systems revision for tunnels and subways	L	S
Housing & Infrastructure	Design	92	New design of large infrastructure	N	S / Ed
Health		93	Improved air conditioning in nursery homes or hospitals	L	L
Health		94	Measures for preventing climate related diseases	N	L
Health		95	Improvement of health care for climate related diseases	N	L
Recreation & tourism		96	Design infrastructure for recreation and tourism – coastal areas	R	L

3 Ranking adaptation options

Ranking adaptation options can be done in several ways, depending on the importance of the different evaluation criteria considered. First, the criteria for ordering the adaptation options are introduced and discussed in Section 3.1. In the following sections, ranking will be carried out using ordering of criteria in Section 3.2 and using weighted summation in Section 3.3. Note that within these two broad types of ranking, many variations are possible, e.g. with respect to the order of the criteria or the weights given to the criteria. In this draft report, we adopt one alternative for each type of ranking. Though we feel that the ordering and weights used in this chapter bear relevance, which is confirmed by the expert workshop of 1 September 2006, we do not claim that these are fully objective and final. Nonetheless, as these ordering and weights represent the best expert judgement available, the ranking is very relevant.

3.1 Criteria for scoring adaptation options

The adaptation options have been given scores relating to (i) the importance of the option, (ii) the urgency of the option, (iii) the no-regret characteristics of the option, (iv) the ancillary benefits to other sectors and domains and (v) the effect on climate change mitigation. Note that in the table below, the adaptation options are ordered according to the sector (agriculture, nature, water, energy & transport, housing & infrastructure, health and recreation & tourism); this does not entail an implicit ranking of option. It should be emphasised that the scoring is tentative and based on subjective expert judgement.

The importance of an option reflects the level of necessity to implement the option. Important options can reduce major risks and/or preserve essential function provided by our surroundings. In principle, important options generate substantial benefits, though potentially at high costs.

The urgency of the option relates to the need of implementing the adaptation option immediately or whether it is possible to defer action to a later point in time. Long-lasting investments and conservation of the existing situation require early planning, and therefore a long period of waiting before implementing the option will render the option redundant (e.g. raising awareness), much more costly (e.g. for large infrastructure projects) or impossible (e.g. for conserving nature).

Note that a high score on urgency does not necessarily imply that the option is important.
It only means that postponing action may result in higher costs or irreversible damage.

In assessing the economic efficiency of various adaptation options a distinction is made between no-regret options and ancillary benefits options. No-regret options are those adaptation options for which non-climate related benefits, such as improved air quality, will exceed the costs of implementation; hence they will be beneficial irrespective of future climate change taking place. The United Kingdom Climate Impacts Programme (Willows and Connell, 2003) has defined no-regret adaptation options (or measures) as options (or measures) that would be justified under all plausible future scenarios, including the absence of human-induced climate change. A no-regret option could be one that is determined to be worthwhile (in that it would yield economic and environmental benefits which exceed its cost), and continue to be worthwhile, irrespective of any benefits of avoided climate damages.

Ancillary benefit options on the other hand are specifically designed to reduce climate-change related vulnerability while also producing corollary benefits that are not related to climate change (Abramovitz et al., 2002). Ancillary benefits thus concern external effects which have a positive impact on policy goals unrelated to climate change policy (Metroeconomica, 2004).

Finally, the options can be ranked according to their effect on mitigation. Certain adaptation options will also induce a reduction of greenhouse gas emissions, and thus score very high on mitigation effect (i.e. are complementary to mitigation policies), while other adaptation options are substitutes to mitigation and increase greenhouse gas emissions.

The ranking of the options has been done using the following score-table:

Table 3. Ranking of options - Score-table

	Score				
	5	4	3	2	1
Importance	The option has a **very high** level of importance	The option has a **high** level of importance	The option has a **medium** level of importance	The option has a **low** level of importance	The option has a **very low** level of importance
Urgency	The option has a **very high** level of urgency	The option has a **high** level of urgency	The option has a **medium** level of urgency	The option has a **low** level of urgency	The option has a **very low** level of urgency
No-regret characteristics	The net benefits are **very high**, irrespective of climate change	The net benefits are **high**, irrespective of climate change	The net benefits are **medium**, irrespective of climate change	The net benefits are **low**, irrespective of climate change	The net benefits are **very low**, irrespective of climate change
Ancillary benefits for other domains	The option generates a **very high** level of side effects	The option generates a **high** level of side effects	The option generates a **medium** level of side effects	The option generates a **low** level of side effects	The option generates a **very low or negative** level of side effects
Mitigation effect	The option has a **strong positive** effect on mitigation	The option has a **positive** effect on mitigation	The option has a **neutral** effect on mitigation	The option has a **negative** effect on mitigation	The option has a **strong negative** effect on mitigation

3.2 Ranking with ordered criteria

The first way of ranking adaptation options is by ordering the evaluation criteria. A relevant and often (implicitly) encountered ordering is that priority is given to options that score highest on (i) importance, (ii) urgency, (iii) no-regrets characteristics, (iv) ancillary benefits and (v) mitigation effect. 2 Through choosing a descending score order, starting with the mitigation effect, then ancillary benefits, then the no-regret characteristics, then the urgency and finishing with the importance of the strategies, a ranking is made that reflects this prioritisation of the options.

[2] This ordering is in line with the expert judgement as expressed in the expert workshop of 1 September 2006, but at some individual level discrepancies exist, as is documented in Annex 3.

Table 4 provides an overview of the prioritisation of all adaptation options identified earlier, ranked according to such an ordering of criteria.

From the ranking, it follows that the following adaptation options have the highest priority, as they score "very high" (5) on the four most important criteria:

- Integrated nature and water management (nr. 34);
- Integrated coastal zone management (nr. 35);
- "More space for water", "Water management 21st century" – water retention and storage (nr. 40);
- Risk based allocation policy (nr. 41);
- Risk management as basic strategy (nr. 65).
- New institutional alliances (nr. 68)

It is clear that these options will emerge among the highest ranked ones regardless of the way the criteria are ordered. Changing the order of the criteria will only affect options that score better on some criteria than on others. For instance, Water storage on farmland (nr. 07), scores very high on no-regrets and high on urgency and ancillary benefits, but only medium on importance and mitigation effect. Therefore, when importance is prioritised, this option has a rather low ranking, whereas it ranks just below the top when no-regrets characteristics are prioritised. It will always be below the top options mentioned above, however.

There are also some options that score (very) low on all criteria and therefore rank very low, regardless of the priority ordering of the criteria. These options are:

- Subsoil drainage of peatlands (nr, 08);
- Reclamation of (part of) southern North Sea (nr. 52);
- Abandoning of the whole of low-lying Netherlands (nr. 53);
- Self sufficiency in production of roughage (nr. 06).

What these options have in common is that they are relatively far-fetched and costly, and should only be implemented when climate damages turn out to be extremely high.

Table 4. Ranking according to focus on criteria

Sector	Subsector	Adaptation option nr.	Adaptation option name	Importance	Urgency	No regret	Ancillary benefits	Mitigation effect
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4
Nature	Water management	35	Integrated coastal zone management	5	5	5	5	4
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	5	5	5	5	4
Water	Spatial concept	41	Risk based allocation policy	5	5	5	5	4
Water	Social, policy	65	Risk management as basic strategy	5	5	5	5	4
Water	Social, policy	68	New institutional alliances	5	5	5	4	5
Water	Social, policy	66	Evacuation plans	5	5	5	3	3
Housing & Infrastructure	Spatial	87	Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity	5	5	4	5	4
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent	5	5	4	4	5

Table 4. Ranking according to focus on criteria								
Sector	**Subsector**		**Adaptation option**	**Importance**	**Urgency**	**No regret**	**Ancillary benefits**	**Mitigation effect**
		nr.	**name**					
			infrastructure					
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	5	5	4	3	4
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	5	5	3	3	3
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	5	5	3	3	1
Energy & Transport	Energy	75	Construct buildings differently in such a way that there is less need for air-conditioning/heating	5	4	5	4	5
Housing & Infrastructure	Design	88	Design houses with good climate conditions (control) – 'low energy'	5	4	5	3	5
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	5	4	5	1	3
Energy & Transport	Transport	82	Development of more 'intelligent' infrastructure that can serve as early warning indicator	5	4	4	4	5
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	4	4	3	3
Housing & Infrastructure	Design	92	New design of large infrastructure	5	4	4	3	3
Energy & Transport	Infrastructure	85	Increase standards for buildings as to make them more robust to increased wind speeds	5	4	4	1	3
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	5	4	3	4	3
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	5	4	3	3	3
Water	Spatial concept	51	Relocation of fresh water intake points	5	4	3	3	3
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	5	3	5	4	3
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	5	3	5	4	3
Energy & Transport	Energy	76	Constructing more stable overhead electricity transmission poles	5	3	4	1	3
Housing & Infrastructure	Water management	91	Water management systems: emergency systems revision for tunnels and subways	5	3	4	1	3
Energy & Transport	Energy	81	Development of cooling towers	5	3	3	4	3
Water	Technological solution	54	Increase sand suppletions along coast	5	3	3	1	3
Water	Spatial concept	49	Higher water level IJsselmeer	5	2	3	3	3
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	5	5	5	4
Agriculture	Forest	17	Increasing genetic and species diversity in forests	4	5	5	4	4
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	3	3
Water	Social, policy	67	Creating public awareness	4	5	4	3	5
Energy &	Energy	73	Lowering the discount factor for	4	5	3	3	5

Table 4. Ranking according to focus on criteria

Sector	Subsector	nr.	Adaptation option name	Importance	Urgency	No regret	Ancillary benefits	Mitigation effect
Transport			project appraisal					
Health		93	Improved air conditioning in nursery homes or hospitals	4	5	3	1	2
Agriculture	Fishery	24	Introduction of ecosystem management in fishery	4	4	5	5	3
Nature	Forestry	31	Afforestation and mix of tree species	4	4	5	4	5
Nature	Society	38	Educational programs	4	4	4	5	5
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	4	4	4	4	4
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	4	4	4	1	3
Water	Technological solution	56	Adapted forms of building and construction	4	4	3	5	4
Energy & Transport	Transport	83	Improvement of vessels	4	4	3	4	2
Agriculture	General	04	Soil moisture conservation practices	4	4	3	3	3
Water	Technological solution	60	Enhancing capacity of sluices and weirs	4	4	3	3	3
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	4	3	5	4	3
Agriculture	Forest	21	Acceptation of changes in species composition in forests	4	3	5	4	3
Nature	Forestry	32	Adjustment of forest management	4	3	5	3	3
Agriculture	General	10	Changes in farming systems	4	3	4	4	4
Health		95	Improvement of health care for climate related diseases	4	3	4	1	3
Recreation & tourism		96	Design infrastructure for recreation and tourism – coastal areas	4	3	4	1	3
Agriculture	General	11	Water management and agriculture	4	3	3	3	3
Energy & Transport	Energy	72	Sluices	4	3	1	1	3
Agriculture	General	15	Land use change	4	2	3	3	4
Agriculture	General	07	Water storage on farmland	3	4	5	4	3
Agriculture	General	02	Choice of crop variety and genotype	3	4	5	2	4
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	5	1	2
Nature	Nature	29	Establishment and management of protected areas	3	4	4	3	3
Nature	Agriculture	33	Implementation of effective agri-environmental schemes	3	4	3	4	5
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5
Agriculture	General	09	Insurance	3	4	3	2	3
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	3	4	3	1	4
Health		94	Measures for preventing climate related diseases	3	4	2	3	3
Water	Technological solution	70	Reduce wastewater discharge during drought periods	3	3	5	5	3
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	3	4	4	3

Table 4. Ranking according to focus on criteria

Sector	Subsector	nr.	Adaptation option name	Importance	Urgency	No regret	Ancillary benefits	Mitigation effect
Agriculture	General	12	Regional adaptation strategies for the fen meadow area	3	3	3	3	3
Agriculture	General	05	Irrigation	3	3	3	3	2
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	3	2	5	5	3
Water	Technological solution	58	Protection of vital objects	3	2	5	3	3
Water	Technological solution	59	Protection of vital infrastructure	3	2	5	3	3
Water	Technological solution	63	Reduction salt water tongue	3	2	5	1	3
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)	3	2	4	5	3
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	3	2	3	1	4
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature is allowed	3	2	3	1	1
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	2	3	5	4	4
Energy & Transport	Energy	74	Building stronger wind turbines	2	3	3	1	4
Agriculture	General	03	Development and growing of crops for biomass production	2	3	2	4	5
Energy & Transport	Energy	80	Planting of biomass crops	2	3	1	2	5
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3
Agriculture	Forest	20	Retention of winter precipitation in forests	2	2	3	4	3
Energy & Transport	Energy	78	Use improved opportunities for generating wind energy	2	2	1	2	5
Energy & Transport	Energy	79	Use improved opportunities for generating solar energy	2	2	1	2	5
Agriculture	Fishery	26	Reallocation of mussel nursery plots	2	1	3	2	5
Agriculture	General	14	Floating greenhouses	2	1	2	2	3
Agriculture	Fishery	22	Adjusting fishing quota	1	4	3	4	3
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	1	3	1	2	3
Agriculture	General	13	Relocation or mobilization of farms	1	3	1	1	3
Nature	Nature	30	Artificial translocation of plant and animal	1	3	1	1	3
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	1	2	3	4	3
Water	Technological solution	62	De-salinization	1	2	2	1	2
Agriculture	General	06	Self sufficiency in production of roughage	1	2	1	2	3
Agriculture	Forest	19	Limiting the import of timber	1	2	1	2	3
Agriculture	General	08	Subsoil drainage of peatlands	1	2	1	1	1
Agriculture	Fishery	27	Aquaculture on former grassland	1	1	3	3	3
Agriculture	Fishery	25	Eco-labelling and certification of fish	1	1	1	3	3
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	1	1	1	3	2

Table 4. Ranking according to focus on criteria

Sector	Subsector	nr.	Adaptation option name	Importance	Urgency	No regret	Ancillary benefits	Mitigation effect
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	1	1	1	2	2

3.3 Ranking with criteria weighting

A common tool in economic analysis when there are multiple objectives is Multi-Criteria Analysis (MCA). MCA uses the judgements of decision makers or experts on the importance of the various criteria to resolve the problem that the options can be ranked differently on the different criteria. In MCA, weights are given to each criterion that are supposed to reflect the preferences of the decision makers. The weighted sum of the different criteria is taken in order to get one single choice of option on the basis of which the options can be ranked. The main problem is choosing the appropriate weights. A natural candidate is equal weights; this mirrors an unweighted summation of the scores. Another relevant weighting is to give a higher weight to urgency, thereby indicating that this is the most important criterion.

Table 5 shows the ranked options according to a criteria weighting of (i) 40% weight for importance, (ii) 20% weight for urgency (iii) 15% weight for no-regrets characteristics (iv) 15% weight for ancillary benefits and (v) 10% weight for mitigation effect.[3] Note that we do not have to convert the scores of the different criteria as they all have the same dimension and all range from 1 to 5.

As indicated above, the choice of the weights does not affect the top options, as these score very high on most criteria and high on the other. The ranking just below that is, however, somewhat different. For instance, the strategy “Design and implementation of ecological networks (nr. 28)” is now higher ranked.

Table 5. Ranking with criteria weighting

[3] These weights are in line with the expert judgement as expressed in the expert workshop of 1 September 2006.

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Nature	Water management	35	Integrated coastal zone management	5	5	5	5	4	4.9
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	5	5	5	5	4	4.9
Water	Spatial concept	41	Risk based allocation policy	5	5	5	5	4	4.9
Water	Social, policy	65	Risk management as basic strategy	5	5	5	5	4	4.9
Water	Social, policy	68	New institutional alliances	5	5	5	4	5	4.9
Housing & Infrastructure	Spatial	87	Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity	5	5	4	5	4	4.8
Energy & Transport	Energy	75	Construct buildings differently in such a way that there is less need for air-conditioning/heating	5	4	5	4	5	4.7
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent infrastructure	5	5	4	4	5	4.7
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	5	5	5	4	4.5
Water	Social, policy	66	Evacuation plans	5	5	5	3	3	4.5
Energy & Transport	Transport	82	Development of more 'intelligent' infrastructure that can serve as early warning indicator	5	4	4	4	5	4.5
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	5	5	4	3	4	4.5
Housing & Infrastructure	Design	88	Design houses with good climate conditions (control) – 'low energy'	5	4	5	3	5	4.5
Agriculture	Forest	17	Increasing genetic and species diversity in forests	4	5	5	4	4	4.4
Nature	Forestry	31	Afforestation and mix of tree species	4	4	5	4	5	4.3
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	5	3	5	4	3	4.3
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	5	3	5	4	3	4.3
Agriculture	Fishery	24	Introduction of ecosystem management in fishery	4	4	5	5	3	4.2
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	5	4	3	4	3	4.2
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	5	5	3	3	3	4.2
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	4	4	3	3	4.2
Housing & Infrastructure	Design	92	New design of large infrastructure	5	4	4	3	3	4.2
Nature	Society	37	Monitoring nature, interpreting	4	5	5	3	3	4.1

Table 5. Ranking with criteria weighting

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
			changes and informing						
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	5	4	3	3	3	4
Water	Spatial concept	51	Relocation of fresh water intake points	5	4	3	3	3	4
Water	Technological solution	56	Adapted forms of building and construction	4	4	3	5	4	4
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	5	4	5	1	3	4
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	5	5	3	3	1	4
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Energy & Transport	Energy	81	Development of cooling towers	5	3	3	4	3	4
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	4	4	4	4	4	4
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	4	3	5	4	3	3.9
Agriculture	Forest	21	Acceptation of changes in species composition in forests	4	3	5	4	3	3.9
Energy & Transport	Infrastructure	85	Increase standards for buildings as to make them more robust to increased wind speeds	5	4	4	1	3	3.9
Agriculture	General	10	Changes in farming systems	4	3	4	4	4	3.8
Agriculture	General	07	Water storage on farmland	3	4	5	4	3	3.7
Nature	Forestry	32	Adjustment of forest management	4	3	5	3	3	3.7
Energy & Transport	Energy	76	Constructing more stable overhead electricity transmission poles	5	3	4	1	3	3.7
Energy & Transport	Transport	83	Improvement of vessels	4	4	3	4	2	3.7
Housing & Infrastructure	Water management	91	Water management systems: emergency systems revision for tunnels and subways	5	3	4	1	3	3.7
Agriculture	General	04	Soil moisture conservation practices	4	4	3	3	3	3.6
Nature	Agriculture	33	Implementation of effective agri-environmental schemes	3	4	3	4	5	3.6
Water	Spatial concept	49	Higher water level IJsselmeer	5	2	3	3	3	3.6
Water	Technological solution	60	Enhancing capacity of sluices and weirs	4	4	3	3	3	3.6
Water	Technological solution	70	Reduce wastewater discharge during drought periods	3	3	5	5	3	3.6
Agriculture	General	02	Choice of crop variety and genotype	3	4	5	2	4	3.5
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	4	4	4	1	3	3.5
Water	Technological solution	54	Increase sand suppletions along coast	5	3	3	1	3	3.5

Table 5. Ranking with criteria weighting

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Agriculture	General	11	Water management and agriculture	4	3	3	3	3	3.4
Nature	Nature	29	Establishment and management of protected areas	3	4	4	3	3	3.4
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	3	2	5	5	3	3.4
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4
Health		93	Improved air conditioning in nursery homes or hospitals	4	5	3	1	2	3.4
Agriculture	General	15	Land use change	4	2	3	3	4	3.3
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	3	4	4	3	3.3
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)	3	2	4	5	3	3.3
Health		95	Improvement of health care for climate related diseases	4	3	4	1	3	3.3
Recreation & tourism		96	Design infrastructure for recreation and tourism – coastal areas	4	3	4	1	3	3.3
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	2	3	5	4	4	3.2
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	5	1	2	3.1
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Water	Technological solution	58	Protection of vital objects	3	2	5	3	3	3.1
Water	Technological solution	59	Protection of vital infrastructure	3	2	5	3	3	3.1
Health		94	Measures for preventing climate related diseases	3	4	2	3	3	3.1
Agriculture	General	12	Regional adaptation strategies for the fen meadow area	3	3	3	3	3	3
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	3	4	3	1	4	3
Agriculture	General	05	Irrigation	3	3	3	3	2	2.9
Agriculture	General	03	Development and growing of crops for biomass production	2	3	2	4	5	2.8
Water	Technological solution	63	Reduction salt water tongue	3	2	5	1	3	2.8
Energy & Transport	Energy	72	Sluices	4	3	1	1	3	2.8
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	3	2	3	1	4	2.6
Agriculture	Forest	20	Retention of winter precipitation in forests	2	2	3	4	3	2.6
Agriculture	Fishery	22	Adjusting fishing quota	1	4	3	4	3	2.6
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Energy & Transport	Energy	74	Building stronger wind turbines	2	3	3	1	4	2.4

Table 5. Ranking with criteria weighting

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Energy & Transport	Energy	80	Planting of biomass crops	2	3	1	2	5	2.4
Agriculture	Fishery	26	Reallocation of mussel nursery plots	2	1	3	2	5	2.3
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature is allowed	3	2	3	1	1	2.3
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	1	2	3	4	3	2.2
Energy & Transport	Energy	78	Use improved opportunities for generating wind energy	2	2	1	2	5	2.2
Energy & Transport	Energy	79	Use improved opportunities for generating solar energy	2	2	1	2	5	2.2
Agriculture	General	14	Floating greenhouses	2	1	2	2	3	1.9
Agriculture	Fishery	27	Aquaculture on former grassland	1	1	3	3	3	1.8
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	1	3	1	2	3	1.8
Agriculture	General	06	Self sufficiency in production of roughage	1	2	1	2	3	1.6
Agriculture	General	13	Relocation or mobilization of farms	1	3	1	1	3	1.6
Agriculture	Forest	19	Limiting the import of timber	1	2	1	2	3	1.6
Nature	Nature	30	Artificial translocation of plant and animal	1	3	1	1	3	1.6
Agriculture	Fishery	25	Eco-labelling and certification of fish	1	1	1	3	3	1.5
Water	Technological solution	62	De-salinization	1	2	2	1	2	1.5
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	1	1	1	3	2	1.4
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	1	1	1	2	2	1.3
Agriculture	General	08	Subsoil drainage of peatlands	1	2	1	1	1	1.2

4 Sorting options by climate change impacts

The ranking of the adaptation options in the previous chapters gives good insight into those strategies that have good and bad overall characteristics. In some cases, however, it is more convenient to have more detailed information on promising options that relate to a certain climate impact.

In this chapter the adaptation options are sorted by climate change impacts, namely sea level rise, river discharge, groundwater level, storms, heat stress, drought stress and growth stress, after which each option is prioritised relating to the ordering of the criteria, in the same manner as in Section 3.2. This ranking per impact provides a more detailed overview of the adaptation options and prioritisation of the options for each type of impact.

4.1 Sea level rise

The main adaptation options relating to the sealevel rise are integrated nature and water management (34), integrated coastal zone management (35), risk based allocation policy (41), risk management as basic strategy (65) and creating new institutional alliances (68). Furthermore the development of evacuation plans (66), designing spatial planning as such that long term robustness for climate change will be established through the construction of new housing and infrastructure (86) and the re-enforcement of dikes and dams, including 'weak spots' (55) are important options.

Table 6. Sea level rise – ranking with ordered criteria

Sector	Subsector	Adaptation option		Importance	Urgency	No regret	Ancillary benefits	Mitigation effect	Weighted sum
		nr.	name	40%	20%	15%	15%	10%	
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Nature	Water management	35	Integrated coastal zone management	5	5	5	5	4	4.9
Water	Spatial concept	41	Risk based allocation policy	5	5	5	5	4	4.9
Water	Social, policy	65	Risk management as basic strategy	5	5	5	5	4	4.9
Water	Social, policy	68	New institutional alliances	5	5	5	4	5	4.9
Water	Social, policy	66	Evacuation plans	5	5	5	3	3	4.5
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	5	5	4	3	4	4.5
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	5	5	3	3	3	4.2
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	5	5	3	3	1	4
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	5	4	5	1	3	4
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	5	4	3	4	3	4.2
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	5	3	5	4	3	4.3

Table 6. Sea level rise – ranking with ordered criteria

Sector	Subsector	Adaptation option nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	5	3	5	4	3	4.3
Water	Technological solution	54	Increase sand suppletions along coast	5	3	3	1	3	3.5
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	3	3	4.1
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	4	4	4	1	3	3.5
Water	Technological solution	56	Adapted forms of building and construction	4	4	3	5	4	4
Water	Technological solution	60	Enhancing capacity of sluices and weirs	4	4	3	3	3	3.6
Recreation & tourism		96	Design infrastructure for recrea-tion and tourism – coastal areas	4	3	4	1	3	3.3
Agriculture	General	11	Water management and agriculture	4	3	3	3	3	3.4
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	3	4	3	1	4	3
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	3	4	4	3	3.3
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	3	2	5	5	3	3.4
Water	Technological solution	58	Protection of vital objects	3	2	5	3	3	3.1
Water	Technological solution	59	Protection of vital infrastructure	3	2	5	3	3	3.1
Water	Technological solution	63	Reduction salt water tongue	3	2	5	1	3	2.8
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)	3	2	4	5	3	3.3
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	3	2	3	1	4	2.6
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	1	3	1	2	3	1.8
Water	Technological solution	62	De-salinization	1	2	2	1	2	1.5
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	1	1	1	3	2	1.4
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	1	1	1	2	2	1.3

4.2 River discharge

The important adaptation options relating to the river discharge are integrated nature and water management (34), integrated coastal zone management (35), water storage and retention (40), risk based allocation policy (41), risk management as basic strategy (65) and making new institutional alliances (68). Also the development of evacuation plans (66), changing the modes of transport and development of more intelligent infrastructure (84), designing of spatial planning and the re-enforcement of dikes and dams (86), including 'weak-spots' (55) are relevant options.

Table 7. River discharge – ranking with ordered criteria

Sector	Subsector		Adaptation option	Importance	Urgency	No regret	Ancillary benefits	Mitigation effect	Weighted sum
		nr.	name	40%	20%	15%	15%	10%	
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Nature	Water management	35	Integrated coastal zone management	5	5	5	5	4	4.9
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	5	5	5	5	4	4.9
Water	Spatial concept	41	Risk based allocation policy	5	5	5	5	4	4.9
Water	Social, policy	65	Risk management as basic strategy	5	5	5	5	4	4.9
Water	Social, policy	68	New institutional alliances	5	5	5	4	5	4.9
Water	Social, policy	66	Evacuation plans	5	5	5	3	3	4.5
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent infrastructure	5	5	4	4	5	4.7
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	5	5	4	3	4	4.5
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	5	5	3	3	3	4.2
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	5	5	3	3	1	4
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	5	4	5	1	3	4
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	4	4	3	3	4.2
Housing & Infrastructure	Design	92	New design of large infrastructure	5	4	4	3	3	4.2
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	5	4	3	3	3	4
Water	Spatial concept	51	Relocation of fresh water intake points	5	4	3	3	3	4
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	5	3	5	4	3	4.3
Housing & Infrastructure	Water management	91	Water management systems: emergency systems revision for tunnels and subways	5	3	4	1	3	3.7
Energy & Transport	Energy	81	Development of cooling towers	5	3	3	4	3	4
Water	Spatial concept	49	Higher water level IJsselmeer	5	2	3	3	3	3.6

Table 7. River discharge – ranking with ordered criteria									
Sector	Subsector		Adaptation option	Importance	Urgency	No regret	Ancillary benefits	Mitigation effect	Weighted sum
		nr.	name	40%	20%	15%	15%	10%	
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	5	5	5	4	4.5
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	3	3	4.1
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	4	4	4	1	3	3.5
Water	Technological solution	56	Adapted forms of building and construction	4	4	3	5	4	4
Water	Technological solution	60	Enhancing capacity of sluices and weirs	4	4	3	3	3	3.6
Agriculture	General	10	Changes in farming systems	4	3	4	4	4	3.8
Agriculture	General	11	Water management and agriculture	4	3	3	3	3	3.4
Energy & Transport	Energy	72	Sluices	4	3	1	1	3	2.8
Agriculture	General	07	Water storage on farmland	3	4	5	4	3	3.7
Nature	Nature	29	Establishment and management of protected areas	3	4	4	3	3	3.4
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	3	4	3	1	4	3
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	3	4	4	3	3.3
Water	Technological solution	58	Protection of vital objects	3	2	5	3	3	3.1
Water	Technological solution	59	Protection of vital infrastructure	3	2	5	3	3	3.1
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)	3	2	4	5	3	3.3
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature is allowed	3	2	3	1	1	2.3
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	2	3	5	4	4	3.2
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Agriculture	General	14	Floating greenhouses	2	1	2	2	3	1.9

4.3 Groundwater level

The key adaptation options relating to the groundwater level are integrated nature and water management (34), integrated coastal zone management (35), water retention and storage (40), risk management as basic strategy (65), and the creation of new institutional alliances (68).

Table 8. Groundwater level – ranking with ordered criteria

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Nature	Water management	35	Integrated coastal zone management	5	5	5	5	4	4.9
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	5	5	5	5	4	4.9
Water	Social, policy	65	Risk management as basic strategy	5	5	5	5	4	4.9
Water	Social, policy	68	New institutional alliances	5	5	5	4	5	4.9
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	5	5	3	3	3	4.2
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	4	4	3	3	4.2
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	5	3	5	4	3	4.3
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	5	5	5	4	4.5
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	3	3	4.1
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	4	4	4	4	4	4
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	4	4	4	1	3	3.5
Water	Technological solution	56	Adapted forms of building and construction	4	4	3	5	4	4
Agriculture	General	11	Water management and agriculture	4	3	3	3	3	3.4
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	3	4	4	3	3.3
Agriculture	General	12	Regional adaptation strategies for the fen meadow area	3	3	3	3	3	3
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Agriculture	General	14	Floating greenhouses	2	1	2	2	3	1.9
Agriculture	General	13	Relocation or mobilization of farms	1	3	1	1	3	1.6
Agriculture	General	08	Subsoil drainage of peatlands	1	2	1	1	1	1.2

4.4 Storms

One of the most important extreme weather events connected to climate change is the expected increase in storm damage. Several adaptation options are targeting at this aspect. The important adaptation options relating to storms are integrated nature and water management, integrated coastal zone management (35), water storage and retention (40), risk management as basic strategy (65) and creating new institutional alliances (68).

Table 9. Storms – ranking with ordered criteria

Sector	Subsector	Adaptation option		Importance	Urgency	No regret	Ancillary benefits	Mitigation effect	Weighted sum
		nr.	name	40%	20%	15%	15%	10%	
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Nature	Water management	35	Integrated coastal zone management	5	5	5	5	4	4.9
Water	Spatial concept	40	“More space for water”, “Water management 21st century” - water storage and water retention	5	5	5	5	4	4.9
Water	Social, policy	65	Risk management as basic strategy	5	5	5	5	4	4.9
Water	Social, policy	68	New institutional alliances	5	5	5	4	5	4.9
Water	Social, policy	66	Evacuation plans	5	5	5	3	3	4.5
Housing & Infrastructure	Spatial	87	Make existing and new cities robust - avoid ‘heat islands’, provide for sufficient cooling capacity	5	5	4	5	4	4.8
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent infrastructure	5	5	4	4	5	4.7
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	5	5	4	3	4	4.5
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	5	5	3	3	3	4.2
Housing & Infrastructure	Design	88	Design houses with good climate conditions (control) – ‘low energy’	5	4	5	3	5	4.5
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	5	4	5	1	3	4
Energy & Transport	Transport	82	Development of more ‘intelligent’ infrastructure that can serve as early warning indicator	5	4	4	4	5	4.5
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	4	4	3	3	4.2
Housing & Infrastructure	Design	92	New design of large infrastructure	5	4	4	3	3	4.2
Energy & Transport	Infrastructure	85	Increase standards for buildings as to make them more robust to increased wind speeds	5	4	4	1	3	3.9
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	5	4	3	4	3	4.2
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	5	4	3	3	3	4

Table 9. Storms – ranking with ordered criteria

Sector	Subsector	Adaptation option nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Energy & Transport	Energy	76	Constructing more stable overhead electricity transmission poles	5	3	4	1	3	3.7
Housing & Infrastructure	Water management	91	Water management systems: emergency systems revision for tunnels and subways	5	3	4	1	3	3.7
Water	Technological solution	54	Increase sand suppletions along coast	5	3	3	1	3	3.5
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	5	5	5	4	4.5
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	3	3	4.1
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Nature	Forestry	31	Afforestation and mix of tree species	4	4	5	4	5	4.3
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	4	4	4	4	4	4
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	4	4	4	1	3	3.5
Water	Technological solution	56	Adapted forms of building and construction	4	4	3	5	4	4
Energy & Transport	Transport	83	Improvement of vessels	4	4	3	4	2	3.7
Water	Technological solution	60	Enhancing capacity of sluices and weirs	4	4	3	3	3	3.6
Agriculture	Forest	21	Acceptation of changes in species composition in forests	4	3	5	4	3	3.9
Nature	Forestry	32	Adjustment of forest management	4	3	5	3	3	3.7
Agriculture	General	10	Changes in farming systems	4	3	4	4	4	3.8
Recreation & tourism		96	Design infrastructure for recre-ation and tourism – coastal areas	4	3	4	1	3	3.3
Agriculture	General	11	Water management and agriculture	4	3	3	3	3	3.4
Energy & Transport	Energy	72	Sluices	4	3	1	1	3	2.8
Agriculture	General	15	Land use change	4	2	3	3	4	3.3
Agriculture	General	02	Choice of crop variety and genotype	3	4	5	2	4	3.5
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	5	1	2	3.1
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	3	4	3	1	4	3
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	3	2	5	5	3	3.4
Water	Technological	58	Protection of vital objects	3	2	5	3	3	3.1

Table 9. Storms – ranking with ordered criteria

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
	solution								
Water	Technological solution	59	Protection of vital infrastructure	3	2	5	3	3	3.1
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)	3	2	4	5	3	3.3
Energy & Transport	Energy	74	Building stronger wind turbines	2	3	3	1	4	2.4
Agriculture	General	03	Development and growing of crops for biomass production	2	3	2	4	5	2.8
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Energy & Transport	Energy	78	Use improved opportunities for generating wind energy	2	2	1	2	5	2.2
Agriculture	Fishery	26	Reallocation of mussel nursery plots	2	1	3	2	5	2.3
Agriculture	General	14	Floating greenhouses	2	1	2	2	3	1.9
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	1	3	1	2	3	1.8
Agriculture	General	13	Relocation or mobilization of farms	1	3	1	1	3	1.6

4.5 Heat stress

Relating to heat stress, integrated nature and water management (34) and making existing and new cities robust, by avoiding 'heat islands' and to provide for sufficient cooling capacity (87) are important adaptation option, as well as the design of spatial planning (86) and the construction of buildings in such a way that there is less need for air-conditioning and heating (75).

Table 10. Heat stress – ranking with ordered criteria

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Housing & Infrastructure	Spatial	87	Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity	5	5	4	5	4	4.8
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	5	5	4	3	4	4.5
Energy & Transport	Energy	75	Construct buildings differently in such a way that there is less need	5	4	5	4	5	4.7

Table 10. Heat stress – ranking with ordered criteria

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
			for air-conditioning/heating						
Housing & Infrastructure	Design	88	Design houses with good climate conditions (control) – 'low energy'	5	4	5	3	5	4.5
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	5	4	5	1	3	4
Energy & Transport	Transport	82	Development of more 'intelligent' infrastructure that can serve as early warning indicator	5	4	4	4	5	4.5
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	4	4	3	3	4.2
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	5	4	3	3	3	4
Energy & Transport	Energy	81	Development of cooling towers	5	3	3	4	3	4
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	5	5	5	4	4.5
Agriculture	Forest	17	Increasing genetic and species diversity in forests	4	5	5	4	4	4.4
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	3	3	4.1
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Health		93	Improved air conditioning in nursery homes or hospitals	4	5	3	1	2	3.4
Agriculture	Fishery	24	Introduction of ecosystem management in fishery	4	4	5	5	3	4.2
Nature	Forestry	31	Afforestation and mix of tree species	4	4	5	4	5	4.3
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	4	4	4	4	4	4
Water	Technological solution	56	Adapted forms of building and construction	4	4	3	5	4	4
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	4	3	5	4	3	3.9
Agriculture	Forest	21	Acceptation of changes in species composition in forests	4	3	5	4	3	3.9
Nature	Forestry	32	Adjustment of forest management	4	3	5	3	3	3.7
Agriculture	General	10	Changes in farming systems	4	3	4	4	4	3.8
Health		95	Improvement of health care for climate related diseases	4	3	4	1	3	3.3
Recreation & tourism		96	Design infrastructure for recre-ation and tourism – coastal areas	4	3	4	1	3	3.3
Agriculture	General	15	Land use change	4	2	3	3	4	3.3
Agriculture	General	02	Choice of crop variety and genotype	3	4	5	2	4	3.5
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	5	1	2	3.1
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4

Table 10. Heat stress – ranking with ordered criteria

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Health		94	Measures for preventing climate related diseases	3	4	2	3	3	3.1
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature is allowed	3	2	3	1	1	2.3
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	2	3	5	4	4	3.2
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Agriculture	Fishery	22	Adjusting fishing quota	1	4	3	4	3	2.6
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	1	2	3	4	3	2.2

4.6 Drought stress

The main adaptation options relating to drought stress are integrated nature and water management (34), water storage and retention (40) and the creation of new institutional alliances.

Table 11. Drought stress – ranking with ordered criteria

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	5	5	5	5	4	4.9
Water	Social, policy	68	New institutional alliances	5	5	5	4	5	4.9
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	4	4	3	3	4.2
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	5	4	3	3	3	4
Water	Spatial concept	51	Relocation of fresh water intake points	5	4	3	3	3	4
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	5	3	5	4	3	4.3
Energy & Transport	Energy	81	Development of cooling towers	5	3	3	4	3	4
Water	Spatial concept	49	Higher water level IJsselmeer	5	2	3	3	3	3.6
Nature	Nature	28	Design and implementation of ecological networks (The	4	5	5	5	4	4.5

Table 11. Drought stress – ranking with ordered criteria

Sector	Subsector	nr.	Adaptation option name	Importance 40%	Urgency 20%	No regret 15%	Ancillary benefits 15%	Mitigation effect 10%	Weighted sum
			National Ecological Network - NEN)						
Agriculture	Forest	17	Increasing genetic and species diversity in forests	4	5	5	4	4	4.4
Nature	Society	37	Monitoring nature, interpret-ting changes and informing	4	5	5	3	3	4.1
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Nature	Forestry	31	Afforestation and mix of tree species	4	4	5	4	5	4.3
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	4	4	4	4	4	4
Agriculture	General	04	Soil moisture conservation practices	4	4	3	3	3	3.6
Water	Technological solution	60	Enhancing capacity of sluices and weirs	4	4	3	3	3	3.6
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	4	3	5	4	3	3.9
Agriculture	Forest	21	Acceptation of changes in species composition in forests	4	3	5	4	3	3.9
Nature	Forestry	32	Adjustment of forest management	4	3	5	3	3	3.7
Agriculture	General	10	Changes in farming systems	4	3	4	4	4	3.8
Agriculture	General	11	Water management and agriculture	4	3	3	3	3	3.4
Energy & Transport	Energy	72	Sluices	4	3	1	1	3	2.8
Agriculture	General	15	Land use change	4	2	3	3	4	3.3
Agriculture	General	07	Water storage on farmland	3	4	5	4	3	3.7
Agriculture	General	02	Choice of crop variety and genotype	3	4	5	2	4	3.5
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	5	1	2	3.1
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	3	4	3	1	4	3
Water	Technological solution	70	Reduce wastewater discharge during drought periods	3	3	5	5	3	3.6
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	3	4	4	3	3.3
Agriculture	General	05	Irrigation	3	3	3	3	2	2.9
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature	3	2	3	1	1	2.3

Table 11. Drought stress – ranking with ordered criteria									
Sector	**Subsector**		**Adaptation option**	**Importance**	**Urgency**	**No regret**	**Ancillary benefits**	**Mitigation effect**	**Weighted sum**
		nr.	**name**	**40%**	**20%**	**15%**	**15%**	**10%**	
			is allowed						
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	2	3	5	4	4	3.2
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Agriculture	Forest	20	Retention of winter precipitation in forests	2	2	3	4	3	2.6
Agriculture	General	08	Subsoil drainage of peatlands	1	2	1	1	1	1.2

4.7 Growth stress

The most important adaptation option relating to growth stress is integrated nature and water management (34).

Table 12. Growth stress – ranking with ordered criteria									
Sector	**Subsector**		**Adaptation option**	**Importance**	**Urgency**	**No regret**	**Ancillary benefits**	**Mitigation effect**	**Weighted sum**
		nr.	Name	40%	20%	15%	15%	10%	
Nature	Water management	34	Integrated nature and water management	5	5	5	5	4	4.9
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	5	5	5	4	4.5
Agriculture	Forest	17	Increasing genetic and species diversity in forests	4	5	5	4	4	4.4
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	3	3	4.1
Water	Social, policy	67	Creating public awareness	4	5	4	3	5	4.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	5	3	3	5	4
Nature	Forestry	31	Afforestation and mix of tree species	4	4	5	4	5	4.3
Nature	Society	38	Educational programs	4	4	4	5	5	4.3
Agriculture	General	04	Soil moisture conservation practices	4	4	3	3	3	3.6
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	4	3	5	4	3	3.9
Agriculture	Forest	21	Acceptation of changes in species composition in forests	4	3	5	4	3	3.9
Nature	Forestry	32	Adjustment of forest management	4	3	5	3	3	3.7
Agriculture	General	10	Changes in farming systems	4	3	4	4	4	3.8
Agriculture	General	15	Land use change	4	2	3	3	4	3.3
Agriculture	General	02	Choice of crop variety and	3	4	5	2	4	3.5

Table 12. Growth stress – ranking with ordered criteria									
Sector	**Subsector**		**Adaptation option**	**Importance**	**Urgency**	**No regret**	**Ancillary benefits**	**Mitigation effect**	**Weighted sum**
		nr.	Name	40%	20%	15%	15%	10%	
			genotype						
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	5	1	2	3.1
Nature	Nature	29	Establishment and management of protected areas	3	4	4	3	3	3.4
Nature	Agriculture	33	Implementation of effective agri-environmental schemes	3	4	3	4	5	3.6
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	4	3	3	5	3.4
Agriculture	General	09	Insurance	3	4	3	2	3	3.1
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	3	4	4	3	3.3
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	3	2	3	1	4	2.6
Agriculture	General	03	Development and growing of crops for biomass production	2	3	2	4	5	2.8
Energy & Transport	Energy	80	Planting of biomass crops	2	3	1	2	5	2.4
Nature	Finance	39	Development of financing mechanisms	2	2	4	3	3	2.6
Agriculture	Fishery	26	Reallocation of mussel nursery plots	2	1	3	2	5	2.3
Agriculture	General	13	Relocation or mobilization of farms	1	3	1	1	3	1.6
Nature	Nature	30	Artificial translocation of plant and animal	1	3	1	1	3	1.6
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	1	2	3	4	3	2.2
Agriculture	General	06	Self sufficiency in production of roughage	1	2	1	2	3	1.6
Agriculture	Forest	19	Limiting the import of timber	1	2	1	2	3	1.6
Agriculture	Fishery	27	Aquaculture on former grassland	1	1	3	3	3	1.8
Agriculture	Fishery	25	Eco-labelling and certification of fish	1	1	1	3	3	1.5

5 A quantitative assessment of the options

In this chapter, a description is made of the costs and benefits of the adaptation options which are also presented in the database 'Adaptation to Climate Change in the Netherlands' in Annex 4 - 9. For each option, the cost and benefit items are indicated and for some of them estimate ranges are presented. The costs and benefits of the adaptation options are computed based on Cost Benefit Analysis (CBA) methodology. CBA is a social-economic evaluation method based on welfare economics. Within a CBA all effects of a project are listed in a structured manner and they are (as much as possible) put under one heading: they are monetary valued. For every large investment in infrastructure in the Netherlands a CBA is compulsory. Also for many projects and policy planning a CBA is carried out in order to get insight in the costs and benefits (e.g. the water directive). In case of a CBA, the objective is to have insight in all costs and benefits for the society as a whole. For a CBA, variants have to be compared with the autonomous development. This means that part of the adaptation is already factored in, namely ongoing adaptation to changes in policy, market and environment. Only the additional effort related to climate change should be taken into account. In this study the situation in which climate change occurs without adaptation options is compared to the situation with climate change and with adaptation options.

In the framework for climate adaptation the following steps are distinguished in the CBA analysis. 1) Climate change impacts; 2) Adaptation strategy; 3) Effects; 4) Quantification of effects; 5) Monetarisation of effects; 6) Computation. The estimates provided here are only rough estimates of especially the direct implementation costs of the option. Detailed estimates, including indirect economic and environmental costs and benefits, can only for some of the options be presented. As explained in Box 3, much information that is needed for doing a proper social cost-benefit analysis is not available and detailed research is needed to produce the estimates. We present here for each of the sectors considered in this report the information that is available at the moment and how that information is used to make cost and benefit estimates.

Box 3. Environmental Cost Benefit Analysis

In this report, preliminary and incomplete estimates are presented of the adaptation options for the different sectors. **Estimates are not yet final as many data are missing to produce more reliable and complete estimates.** Ideally, a Social Cost-Benefit Analysis (SCBA) should be performed for each of the options. In this box, it will be briefly explained what should ideally be done.

In order to make decision making procedures more transparent, the Dutch government decided in the year 2000 to use for public projects the 'Onderzoeksprogramma Effecten Infrastructuur' (OEI) guidelines to assess the costs and benefits of those projects. These guidelines present a social cost-benefit analysis that allows for the estimation of the net benefits of a project not only on the basis of the direct costs and benefits of such projects but also by considering the indirect or external effects in order to be able to assess the total welfare effects of public projects. The information provided by a SCBA is useful within the process of policy decision making. For the adaptation options presented in this report, the OEI guidelines can also be used to assess their direct and indirect costs and benefits.

Essential in this respect is that first, an inventory is made of the direct and indirect effects of the project, including for example direct costs but also indirect unemployment effects and environmental effects. Secondly, the costs of the option should be evaluated. These include preparation costs, investment costs, exploitation costs and replacement costs over the entire planning period of the project. When timing of the different cost elements is known, the net present value of the costs can be determined. Call PVC_t the present value of the costs and C_t the nominal costs of a cost item in year t. Call r the discount rate. If the term of the project would be T years, the net present value of costs is determined as follows:

$$NPV_c = \sum_{t=1}^{T} PVC_t = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

The present value of benefits can be determined in the same way. For the discount rate a value of 4% is adopted. This value is also used in the OEI guidelines. If annual exploitation costs are the same in each year and the planning period is long, the Net Present Value of the exploitation costs amounts for a discount rate of 4% approximately 26 times the annual costs (for a planning period of 50 years, the Net Present Value of the exploitation costs is approximately 22.5 multiplied by the annual costs).

Important in a SCBA is that also indirect effects are valued in monetary terms. These include indirect positive and negative effects on society, e.g. effects on unemployment, effects on other economic sectors and activities, effects on tax revenues and subsequent welfare effects. These also include opportunity costs of the project, i.e. foregone benefits of alternative use of the invested money, like for example foregone revenues of a tax cut. Next to the indirect economic effects, also the environmental effects are of importance for the adaptation options discussed in this report. This refers to environmental effects in its broadest sense, including effects on emissions of polluting substances in the air, water and soil, horizon pollution, noise pollution, and effects on nature areas' size and quality. Making precise and reliable estimates of these external effects may be an arduous task.

As an example, for adaptation option number 55 (re-enforcement of dikes and dams), it is possible to estimate preparation, investment and maintenance costs of re-enforcing a certain dike at a certain location. The indirect effects of this option include a reduced risk of flooding and possibilities for small scale nature development. Economic and environmental effects of a reduced risk of flooding include the expected reduction of flood damage, increased economic activity in the area due to a reduced risk of flooding, increased tourism activities in the new nature areas. Environmental effects include environmental stress due to construction activities, horizon pollution due to higher dikes, and increased biodiversity due to new nature development. Estimating these indirect effects may be more difficult than estimating the direct costs. The reduced flood damage costs are the reduced probability of flooding multiplied by the damage per flooding event. For predicting the increase of economic activity, economic models should be used in which this reduced flooding risk has been taken into account and in which a distinction is made between economic growth that would take place without and with the option to be taken. For estimating the environmental effects, first, the physical effects should be known before this can be turned into a monetary value by using environmental valuation techniques.

Much of the information that is needed for a proper SCBA of the adaptation options is not available. For the option discussed above, some of the direct costs can easily be estimated. For options like 'Integrated Nature and Water Management' (no. 34) or 'Land Use Change' (no. 15) estimating the direct implementation costs is already difficult. Much information is especially missing on the indirect and external economic and environmental effects of the options. Detailed additional research about the economic and environmental effects is needed in order to improve the rough estimates presented in this report.

Agriculture sector

For the agricultural sector, the climate change impacts are distinguished into 6 categories. The climate change categories are listed below, together with the relevant risk area and the corresponding agriculture areas as listed in LEI (2006).

1. Sea level rise - salt water intrusion (western lower regions; Bouwhoek en hogeland, westelijk Holland, Waterland/Droogmakerijen, Hollands en Utrechts weidegebied, Zuidwestelijke akkerbouwgebied=537,000 ha)
2. River discharge - flooding (western lower region; westelijk Holland, Waterland/Droogmakerijen, Hollands en Utrechts weidegebied, Rivierengebied, Zuidwestelijke akkerbouwgebied=531000 ha)
3. Groundwater level - wetter Spring and Autumn (western lower regions; westelijk Holland, Waterland/Droogmakerijen, Hollands en Utrechts weidegebied, Rivierengebied=336,000 ha)
4. Heat stress
5. Drought stress in Summer (eastern sandy region; Oosterlijk weidegebied, centraal weidegebied, Zuidelijk veehouderijgebied=628,000 ha)
6. Growing stress

In the database of adaptation options in Annex 4-9, a long list of possible adaptation options is presented. Most options are a response to counter the negative effects of climate change and do not include positive action to exploit emerging and new opportunities related to climate change. For each option of the agricultural sector, the possible direct impacts are summarized in the database. The effects can be distinguished into on-site effects and off-site effects. If only on-site effects are relevant the actor that uses the land will incur the costs and have the benefits. The actor (land user) will only apply the option if the benefits exceed the costs. When off-site effects exist benefits can be gained by other actors than the ones that pay the costs. An option that is profitable for society will not be implemented automatically.

To quantify the effects it is necessary to assess the acreage on which the option will be applied. We distinguish three relevant acreages.

a. the risk area (area that suffers the climate change impact the options is aimed for)
b. the acreage (within the risk area) the option will be applied to without climate change (autonomous development). Options that are applied in the autonomous development are not regarded as adaptation strategies.
c. the acreage (within the risk area) on which the option will be applied in case of climate change.

These three different acreages are given per option in the database. For most options the acreages can only been given by rough approximation. To quantify the adaptation options the relevant acreage is C-B (the area the options is applied with climate change minus the autonomous development).

To assess the total costs and benefits the relevant acreage is multiplied with the estimated costs and benefits per hectare. To compute the costs and benefits of the options, information is needed on the costs and benefits per hectare. In this analysis we do not compute indirect effects and second order effects because the necessary information to calculate these effects is lacking. In the next stage of the CBA models should be used to compute these effects.

The costs and benefits per hectare (related to the effects presented above) are summarized in the database. The costs and benefits are given in costs and benefits per year, because the time horizon of the computations is not known yet. Investments are transformed into year costs, based on the depreciation period of the investment and a discount rate of 4%. Off-site benefits are related to the acreage of the option they are related to. The purpose of the calculations is to assess the additional costs and benefits of adaptation strategies. Hence only the difference between the acreage under climate change and in the autonomous development is taken into account. This acreage is multiplied with the benefits and costs. For some options only the net costs are known (the difference between costs and benefits).

Nature sector: Costs and Benefits of adaptation options for ecosystems

Currently there is a lack of studies focusing on the monetary valuation of adaptation options for ecosystems. The issue is that adaptation strategies for ecosystems are basically strategies that would be implemented anyhow even if climate change would not take place. For example the national ecological network is implemented in order to restore ecosystems lost due to human impacts, protected areas are established under policy programs (e.g. EU Birds and Habitats Directive) in order to maintain biodiversity (lost because of human actions, infrastructure etc), agri-environmental schemes are implemented in order to reduce environmental degradation, water management strategies are often implemented with the main objective of increasing safety, and so on. Hence the investment, operation and maintenance costs of the strategies (when available) are not representative of the costs of the adaptation strategy for ecosystem under climate change. The same applies to the benefits (or avoided damage) of the strategy.

In order for these strategies to be effective under climate changes scenarios there are some changes within the strategy, mainly in terms of management, that need to take place. As mentioned in the Routeplanner sub-project 3 (A preliminary inventory of options for climate adaptation in the Netherlands) current research is focusing on analyzing and identifying in details these management strategies. Costs and benefits of climate adaptation options for ecosystems can therefore be estimated only once this information will be available.

Rough estimation of costs and benefits

In Annex 5 the costs and benefits of adaptation options for ecosystems are indicated in qualitative terms and for some options also quantified in monetary terms. The monetary data reported (nominal prices, not discounted) are rough estimates meant only to give an idea of the magnitude of costs and benefits and should therefore be used with caution. Additional socio-economic studies are needed in order to assess with accuracy the actual costs and benefits. An explanation of the rough estimates reported in the database is provided below:

Option 28 (Design and Implementation of 'climate proof' National Ecological Network (NEN))
According to an analysis done for the period 1999-2001 and 2003 by CBS (CBS, 2005) the costs for landscape conservation and management in Netherlands fluctuate between 800 mln Euro/yr and nearly 1 billion mln Euro/yr. These costs cover the costs for landscape and nature design and management, information, education, research and operating costs (the annual net cost of activities to preserve nature and landscape plus the difference between paid and received subsidies and financial contribution). We use an average of these costs, 900 mln. Euro/yr, as representative for the costs for the implementation of the NEN. The governmental budget is however much less than the required costs and varies slightly every year. For example in 2006 the budget allocated for the NEN is 357 million Euro only (for an overview of the governmental budget allocated see: Ministerie LNV, 2005).

In order to roughly estimate the costs related to the implementation of a 'climate proof' NEN we assume that the 30% of 900 mln. Euro represents the additional costs that would occur when implementing a NEN that takes into account climate change. The costs for implementing the NEN under climate change scenarios are therefore, very roughly, equal to 270 mln. Euro/yr. Assuming these yearly costs are constant and with a discount rate of 4%, Net Present Value is approximately equal to 7 000 mln Euro. Benefits are expected to be higher than the costs, but these are extremely difficult to assess.

Option 29 (Establishment/relocation of 'climate proof' protected areas)
If we consider that the average costs for the implementation of the NEN are equal to 900 mln. Euro/yr (see previous strategy for a more detailed explanation) and if we assume that 15% of these costs are intended for establishment/relocation of 'climate proof' protected areas then we obtain a rough value of 135 mln. Euro/yr or a Net Present Value of 3 500 mln Euro. Benefits are expected to be higher than the costs.

Option 31 (Afforestation and mix of tree species)
Afforestation costs will include several costs such as acquisition of land, soil preparation, selection of species when taking into account climate change, purchasing and transportation of species, bedding plants installation (or seeds). We assume that afforestation will take place by converting agricultural land into plantation forest. The average price of land in Netherlands (2001 prices) is about 37 000 Euro/ha (CBS, 2003). We assume that average afforestation costs are equal to 6 000 Euro/ha. We estimate therefore that the implementation of this strategy has a rough cost of 43 000 Euro/ha (37 000 + 6 000 Euro/ha). We are however not taking into account the opportunity costs of land represented by the foregone income from agricultural activities. Benefits are expected to be higher than the costs, but again very difficult to assess in monetary terms.

Option 37 (Monitoring nature, interpreting changes and informing)
According to VOFF (Vereniging Onderzoek Flora en Fauna) the amount of money spent on monitoring nature, interpreting changes and informing (not specifically related to climate change) corresponds to about 65 mln. Euro/yr (VOFF, 2006). A large number of organizations are involved in these activities (e.g. the Particuliere Gegevensbeherende Organisaties (PGO's), Rijkswaterstaat, the Water Boards). Given the expected large impacts of changes in climate on ecological systems, we assess that 20% of this amount, equal to 13 mln. Euro/yr (or a Net Present Value of 338 mln Euro), would be needed to monitor, interpret and communicate climate change induced ecological changes. The money available to carry out these activities only in the context of the Nature's Calendar project (Natuurkalender) in 2006 is about 400 000 Euro (Vliet, 2006). The Natuurkalender focuses on the monitoring, analysis, forecasting and communication of the timing of yearly recurring natural events in the context of changes in weather and climate. Roughly, 60% of the money is spent on communication and dissemination. The Natuurkalender only increases the knowledge on a very small selection of species. Furthermore, all other ecological impacts like changes in geographic distribution, species interactions, productivity and population sizes are not taken into account in the Natuurkalender project. Target audience of the Natuurkalender range from scientists to the general public and includes a wide variety of stakeholders in sectors like human health, agriculture, nature conservation and gardening (more info can be found at http://www.natuurkalender.nl/). The above costs of 400 000 Euro/yr include all activities mentioned above, which are carried out by 15 organizations, about 40 employees (all part-time) and 600,000 volunteers.

For the other nature related adaptation options there are not enough elements available to roughly estimate the costs and benefits involved.

Water sector

For the water sector, rough estimates can be given for most of the adaptation options presented. Reliability of the estimates, however, differs substantially for the different options. Reliability (high, medium or low) is given in between brackets for each option.

Option 40 (More space for water; MEDIUM)
The program WB21 is primarily focussed on the regional water problems. It covers the investments necessary to accommodate or to prevent surpluses or shortages of (fresh) water. It applies to the regional and urban water systems, water shortages and water table. The estimated investments to adapt to climate chance, soil compaction and subsidence and increase in hardened surface are 2.5 000 mln € for 2003-2015 (to meet present standards) and an additional 16 000 mln € in 2003-2050 for new standards in relation to climate change. NBW (2003) and Decembernota (2005) concluded that the main water system (rivers, IJsselmeer, the major Delta region water systems) can cope with present discharges from the regional and urban water systems, with the exception of the necessary enlargement of the discharge capacity of the Afsluitdijk sluices (see option 60), and taking into account the Room for Rivers program (see below). The Decembernota 2006 will provide insight in to what extent that applies to the future. WB21 includes regional and local retention or storage areas that cost 10 - 100 million per unit, depending on size, present occupation etc. Maintenance costs are € 10 000 to several 100 000 € per year. Additionally, to meet the new standards, the sewer system, groundwater storage and surface water storage in the urban environment each demand an investment of about 1 000 mln €, 3000 in total. That also covers the costs for options 89 and 90. The complete replacement of the sewer system, would that be necessary, has a price tag of 58 000 mln €.

The PKB package "Room for Rivers" (RvR) is not formally part of WB21 but has the same general approach, for the main flood plains. Implementation of the PKB measures will cost 2 100 mln €. These options are meant to accommodate a discharge of up to 16000 m3/s for the Rhine and 3800 m3/s for the Meuse. 50-70% of that amount is already in anticipation of long term climate change. To accommodate 18000 and 4600 m3/s for Rhine and Meuse, respectively, additional options are needed: enlargement of the Rhine flood plain or stronger dikes or both. Costs of dike enforcement: see option 55. For the Rhine, enlarging the flood plain costs approximately 2 600 mln € with a yearly maintenance of 0.4% of this amount. For the Meuse the enlargement of the flood plain costs approximately 2 000 mln €, with a yearly maintenance of 0.5% of this amount.

Enlarging the flood plain may also consist of the creation of emergency flood storage areas. This option is presently being investigated in the framework of Rampenbeheersingsstrategie Rijn en Maas (RBSO), as an option in addition tot RvR. Cost per unit of polder vary from 50 to 450 mln € depending on size, present infrastructure and use. Additional costs to compensate damages to commercial enterprises etc. may be considerable but have not been estimated. Maintenance costs are 0.7%/year.

Summarizing, retention, storage and other adaptations in regional water systems amount to 15 - 20 000 mln Euro, sewer and urban water system amount to 3 000 mln Euro Enlarging the flood plains of the Rhine and Meuse, in addition to Room for the Rivers, amount to 5 500 mln Euro.

Option 41 (Risk based allocation policy: MEDIUM)
This option mainly consists of another line of thinking in policy development and a change in legislation. It may result in changes in land use, but these changes are already considered under the other options. Direct costs (political discussion, adaptation of legislation) are 0 - 10 mln €.

Option 42 (Moving powerplants to coast: MEDIUM)
Implementation is not urgent, and moving existing power plants is extremely expensive. This adaptation will probably gradually take place as part of the regular and planned replacement of obsolete power plants. Therefore, the additional costs because of adaptation to climate chance are minor: higher costs for transportation of electricity, relocation of personnel etc. Costs are approximately 50 mln €.

Option 43 (Spatial planning of locations for powerplants)
Concentration of power plants may actually reduce costs, since safety and infrastructure options can be shared. However, it may require additional costs for the transportation of electricity (new power lines etc). Additional research has to be done to make reliable estimates.

Option 44 (Compartmentation of low-laying parts of the Netherlands: LOW)
Costs apply to dike construction, sluices etc. Uncertainties about the real benefits may make and investment of more than 1 000 mln € unlikely. A rough estimate of the total costs are 100 – 1 000 million Euro, depending on size, occupation etc. of areas. Costs per area: 5-270 million Euro. Maintenance costs are 1.1% per year. Reference: Syntheserapport Onderzoeksprogramma Rampenbeheersingsstrategie Overstromingen Rijn en Maas

Option 45 (Allow transgression of the sea in wide dune areas, allow wash over of dikes: LOW)
Costs vary greatly depending on the type of option. Allowing the sea to enter wide dune areas may actually save (maintenance) costs. At the other side of the spectrum, construction of a second dike behind an existing dike (see EU-project Comcoast) is costly, in particular if additional costs are involved to compensate farmers etc. Based on data for Perkpolder (Zeeland), a Comcoast approach would approximately cost 5 mln € per km of dike. There is no information available about the size of areas/dike length where this option is feasible or attractive. Implementation along 50 km of coastline (including Oosterschelde and Westerschelde) would cost 250 mln €.

Option 46 (Widening coastal defense: MEDIUM)
Reinforcement of the coastal defence in response to climate change is already partly incorporated into the present coast policy or recognized as a necessary feature for the future. It consists of three parts: extra sand supplementations (option 54), Zwakke Schakels and spatial reservation behind narrow dunes and sea walls. Most of the proposed protection options in “Zwakke Schakels” (weak spots) imply a seaward defence mainly using sand. Approximated costs are 2/3 of the total estimated costs of 750 mln €.
The spatial reservation is considered necessary to be able to cope with a maximum scenario of sea level rise (85 cm/100 years + 10% wind effect) during 200 years (Derde Kustnota 2000, Nota Ruimte 2005). The proposed width of the reservation zone is 200 m and the total area 1000 ha. Large scale nature restoration projects give some clues of the costs. The project Deltanatuur (Haringvliet) costs 140 x 106 € for 3000 ha. 600 ha of estuarine nature along the Westerschelde costs 200 mln €, including compensation for farmers, adaptation of relocation of sea dikes etc. With these figures we arrive at 0.3 – 0.5 mln € per ha, and 300-500 million Euro for 1000 ha. The costs of 1 km of new sea dike are estimated at 6 million Euro, including stone coverage of 2.5 million Euro per km.

Option 47 (Reconnecting water systems: MEDIUM)
One project is already in progress at the Haringvliet sluices: “Kier/Getemd Getij”. The total investment, including relocation of fresh water inlet points (35 mln €) is 135 mln €, of which a third applies to safety. Connecting Volkerak-Zoommeer and Oosterschelde would cost 300 mln €, for development of an alternative fresh water supply for agriculture, adaptation of sluices in Oesterdam (100 mln €) and Philipsdam (100-200 mln €). New and larger sluices and or siphons in the Brouwersdam and Flakkese Spuisluis would cost 150 mln €. Adaptation of the storm surge barrier in the Oosterschelde, to better accommodate river discharge, would costs approximately 100 mln €. Summarizing, the investment per sluice/dam is roughly 100 – 200 mln €. Assuming that adaptation at two points is sufficient, the total investment amounts to 200 – 400 mln €.

Option 48 (Fresh water storage to flush out brackish water)
Storage areas for surplus water in periods of heavy rainfall or high river discharges (option 40) can also be used to store water that can be used to flush out, or to prevent intrusion of, brackish or salt water. Therefore, this option requires no additional investment if option 40 is selected.

Option 49 (Maintaining higher water levels in IJsselmeer)
It would mean reinforcement of the dikes along the IJsselmeer (433km). At 1 - 2 million Euro per km that amounts to 500 - 1000 million Euro. That does not take into account enforcements that may be necessary along the Markermeer (350 km), the Ketelmeer en the IJssel mouth.

Option 50 (Maintain higher water levels to prevent salt intrusion)
It may affect agriculture, infrastructure, housing etc. The project “Waarheen met het Veen”? is estimating these costs, but no data is available now.

Option 51 (Relocation of fresh water intake points)
Costs for present relocations in Haringvliet are 35 mln €. By doing it gradually in the process of regular replacement, the additional costs are probably limited. 50 – 100 mln €.

Option 52 (Reclamation of parts of the southern North Sea)
The costs are very high, obviously. The necessary finances need to be generated by a PPS construction, mainly by industrial or urban development. Public financing will be approximately 1000 - 5000 mln €.
See for example www.progressiefwestland.nl/briefmin.pdf.

Option 54 (Increase of sand suppletions)
The present suppletions yearly cost 44 mln €, for a suppletion of 12 mln m3. To compensate for the effect of sea level rise (max scenario of 85 cm/century), the sand suppletions will have to increase to 23 million m3. Estimated additional yearly costs: 20 - 40 mln €. At a discount rate of 4%, Net Present Value equals 520 – 1040 mln €. New insights show that the sand suppletion is expected to increase to 28 million m3 per year and possibly leading to 58 million m3 per year in the next century. The price per m3 sand suppletion amounts around 2 – 4 €, whereby 20 percent of the price is determined by the costs of stookolie which has increased rapidly over the past years. This option could also be related to the construction of large scale dwelling mounds, to be combined with option 44, the compartmentation of low lying parts or as alternative for option 53 (Abandoning of the whole of low-lying Netherlands).

Option 55 (Reinforcement of dikes and dams)
The PKB Room for Rivers will accommodate 16000 m3/s discharge for Rhine, For the future, 18000 and 4600 m3/s discharge for the Rhine and Meuse, respectively, need to be accommodated, by stronger dikes, enlargement of the floodplain, or both. The costs for dike enforcement are as follows: Rhine 1 100 mln € with a yearly maintenance of 0.2% and Meuse 800 mln € with a yearly maintenance of 0.2%. Zwakke Schakels (weak spots) coast (see also option 46) costs in total 750 mln €. About 30% is for dike enforcement, 250 mln €. Net Present Value of total investment plus annual costs are 2 250 mln €.

Option 58 (Protection of vital objects)
This option can be combined with compartmentation (option 44) and with protection of infrastructure (option 59). Estimated costs are 100 – 1 000 mln €.

Option 59 (Protection of vital infrastructure)
This option can be combined with compartmentation (option 44). Estimated costs are 100 – 1 000 mln €.

Option 60 (Enlarging capacity of sluices, weirs)
The enlargement of the capacity of the Afsluitdijk sluices will cost 250 mln €. Small agricultural weirs for water level regulation in ditches are 6000 € a piece, with a 30% bandwidth. Maintenance costs are 50 €/year. Weirs in small canals are 30000 € a piece, with a 25 % bandwidth. Weirs in main canals cost 500000 €, with a bandwidth of 40 %.

Option 61 (Artificial reefs in North Sea)
Three alternatives have been studied, differing in length, number and distance from shore. Such reefs are primarily a safety measure, but may also be used for nature restoration, recreation. Cost estimates are 500 – 4 000 mln €
(see: www.veero.info/Archief/2005/050715kunstrif.htm)

Option 63 (Reduction of salt water tongue)
This option can be accomplished by reducing the dredging effort. Thus, there are no direct costs but it may cause economic damage to shipping.

Energy & Transport sector

For this sector, many of the costs and benefits can not be estimated yet. However, for all adaptation options an indication is given of the cost and benefit items. Additional cost benefit analyses are necessary in order to produce reliable estimates.

Option 71 (Adapt regulations such that a higher cooling water discharge temperature is allowed)
Costs include policy development and adaptation of the regulation. This has been done by the Commissie Integraal Waterbeheer (CIW), which in 2005 introduced a new regulation system regarding water discharge. The guidelines are used to regulate heat release by industry and power plants. For environmental reasons the Directorate-General for Public Works and Water Management's guidelines impose a maximum temperature of 30°C upon discharged cooling water. The action plan for cooling water restrictions can be put into operation as soon as the temperature of the surface water at Lobith (where the river Rhine enters the Netherlands) structurally exceeds 23°C. This temperature cap implies that any water to be discharged after use will sooner reach the environmental threshold of 30°C. An electricity plant adds an additional 7°C on average to the temperature of the water (Tennet, 2006). There is no information available on the costs of adapting a new regulation.

There are however external effects on the environment of higher cooling water discharge temperature that should be included into the cost-benefit analysis, this relates especially to the impact on the aquatic environment.

Benefits are that cooling water can be discharged, resulting in a more stable supply of energy and leading to avoided damages. Following the KEMA report about the influence of the cooling water temperature on the power production and efficiency for different power stations in the Netherlands the value of not delivered electricity is approximately 30 to 50 €/ MWh (Ploumen and Van Rijen, 2004). When the surface water temperature is above 23°C, the power plants have a problem with discharging their cooling water, this may lead to 10 % less electricity produced (Werven, 2003). In the summer of 2003 (June, July and August) the total net electricity production was 22035 mln kWh (CBS, 2006). The value of 10% not delivered electricity has a bandwidth of 6.6 – 11 mln €. This option is linked to option 81, the development of cooling towers.

Option 72 (Sluices)
The structure of the sluices is organised in such a way that there is sufficient cooling water available for electricity plants in dry periods. This option implies the construction of sluices and enhancing the capacity of the sluices and weirs and is directly related to option 60 (Enhancing the sluices and weirs). Benefits of the option are that more water is available to be used as cooling water during dry periods and thus results in a more stable supply of energy. See option 71 for the indication of avoided damage costs. More information needs to be obtained.

Option 73 (Lowering the discount factor)
The lowering of the discount rate will result in a higher net present value. When the discount rate is lowered from 4% to 3.5%, and the costs and benefits do not change, the net present value increases with approximately 14%. A discount rate of 3% will result approximately in a 32% increase of the net present value. A lower discount rate implies that present values of future costs and benefits are larger and therefore have a larger impact on the NPV. Present values of future damages of delaying the implementation of adaptation options become larger if the discount rate is lower and therefore lowering the discount rate better takes into account future effects of projects. The benefit of this option is that the lowering of the discount factor for project appraisal places a higher weight on climate change effects.

Option 74 (Building stronger wind turbines)
Costs are the development of wind turbines which are less prone to extreme winds. There will be investment in the design and construction of the turbines. The knowledge centre of ECN and TU Delft carries out research on the materials, component and structures of wind turbines. www.kc-wmc.nl. An assumption was made that strengthening existing wind turbines will amount to 10% of the construction (investment) costs. For onshore wind power, the 1000 MW barrier of wind power was passed in 2004. Investment costs range from 875 – 1250 €/kW. This results in a bandwidth of 87.5 – 125 M€ for strengthening existing onshore wind turbines. For offshore wind power, in 2003 the installed capacity was 19 MW. Investment costs range from 1546 – 2428 €/kW. This results in a bandwidth of 2.9 – 4.6 M€ for strengthening existing offshore wind turbines. (Sources: Noord, et al., 2004 / Dril, et al., 2005 /Beurkens and Noord, 2003)

Benefits include reduced losses in energy production due to higher wind speeds. There is a strong alternative energy supply, thus less demand for electricity from power plants and less problems with the discharge of cooling water.

On average during 2% of the time (approximately 1 week per year) a wind turbine is not producing due to technical malfunction and maintenance. With higher wind speeds and more storms this percentage will increase. More information needs to be obtained.

Option 75 (Construct buildings differently in such a way that there is less need for airconditioning or heating)
Ecofys has conducted a research about cost effective energy savings and climate protection. The isolation of existing houses will reduce the demand for heating and airconditioning. Using data about the number of houses, the surface of houses subject to isolation measurements and related costs, a rough estimate of 23349 M€ over 6 809 581 houses in 2004 is calculated (Ecofys, 2005).

The design and construction of new houses can be based on the principle of passive house technology. The original definition of a passive house is 'A building in which a comfortable interior climate can be maintained without active heating and cooling systems'. In the definition of passive houses the upper limit of primary energy is 15 kWh per m2 of living area per year for heating of space and ventilation air and 120 kWh (total primary energy demand per m2 of living are per year, including appliances). Examples from Germany and Austria show that the building costs are on average 10% higher then for conventional houses (Boer, B. de, et al., 2005). An example of the houses built on the principles of passive house technology is a building project in Sliedrecht - sustainable solar housing. One of the main objectives of the solar project was to prove that solar houses, designed and based on passive house technology, can compete in the housing market in the Netherlands, in price, quality and comfort. The building costs of the 12 passive solar houses were 4.7% higher compared to Dutch standard building costs for conventional houses in Sliedrecht built on the same site at the same time in the same housing project (ECBCS, 2006).

Benefits of this option are that there is a lower energy demand. For the building project in Sliedrecht the annual total primary energy demand is 117.1 kW/m2. More information needs to be obtained. Not that this option is linked with option 88 (Housing & Infrastructure – Design houses with good climate conditions (control)-low energy).

Option 76 (Constructing more stable overhead electricity transmission poles)
Tennet has developed a new kind of transmission pole. The new transmission poles result in a smaller magnetic field. This is because part of the pole is made of plastic. However the new transmissions poles are quite expensive. For the current lines the government pays on average 1 Million € per km, it is expected that the new lines and transmissions poles are twice as expensive. It will take some time before all the old transmission poles are replaced, because the current poles still have a lifespan of approximately 50 years (Algemeen Dagblad, 2005). Benefits of this option relate to avoided power cuts and avoided danger of transmissions poles breaking down.

Option 77 (Adapt to mitigation strategies)
Stimulate the supply of and demand for energy-saving products and increase consumer awareness to save energy. Costs relate to public awareness campaigns financed by the government and benefits relate to less energy demand of consumers and the avoidance of purchasing carbon emission permits. More information needs to be obtained.

Option 78 (Wind energy)
To determine the costs for onshore wind energy, it has been assumed that in 2050 there will be a realistic potential of 1.5 - 3.2 GW. Adjusted for the already installed onshore wind energy potential (in 2004 the 1000 MW barrier was passed (Dril, et al., 2005), the investment costs and operation and maintenance costs range from 1026 – 7795 M€ (Noord, et al., 2004).

To determine the costs for offshore wind energy, it has been assumed that in 2050 there will be a realistic potential of 6 - 30 GW. Adjusted for the already installed onshore wind energy potential (in 2003 the installed capacity of offshore wind farms amounted to 19 MW (Beurkens and De Noord, 2003). The investment costs and operation and maintenance costs range from 25733 – 268116 M€ (Noord, et al., 2004). Benefits include a reduction in the demand for electricity generated by power plants.

Option 79 (Solar energy)
The realisable potential for solar PV in 2050 is 49 GWpiek. The investment costs range from 5 to 8 €/Wpiek and investment costs are 1 – 3% of the investment /year. The lifetime of the solar PV is 25 years. NPV ranges from 439 040 – 907 970 M€ (Noord, et al., 2004). The NPV has not yet been corrected for the already existing solar energy generated. Benefits include a reduction in demand for electricity generated by power plants.

Option 80 (Biomass)
For this option several types of biomass installations are described.
First, with-burn of biomass; is adding biomass to the existing combustion process in coal- or gas plant. The only pre-treatment concerns the grinding of the biomass, in case of solid biomass and adding the biomass to the combustion process. In this analysis wood pallets are the reference fuel. For the burning with wood pallets alongside in a coal plant, the investment costs are 585 €/kWe (200€/ kWth). The maintenance costs included the maintenance and operation of the installation and additional costs relating to the burning of the biomass alongside, such drainage of residues. The total maintenance and operation costs amount 1.2 ct/kWhe.

Secondly, by-burn of biomass, biomass is vaporized, which is then added to the combustion process. This is possible in coal- as gas plants. The industrial process needs to be modified for by-burning of biomass. The investment costs are estimated at 2380 €/KWe (750 €/KWth). The maintenance and operation costs are estimated at 3.1 ct/KWh.

Thirdly, small scale independent biomass installations are installations smaller than 50 MWe (small scale fermentation installation, small wood installation or small scale bio-oil installations). Large scale installations are larger than 50 MWe, and generally aimed at the production of electricity. It is assumed that investment costs amount of 2900 €/KWe. The maintenance costs are estimated at 250€/kWe (Verrips, A., et al., 2005).

Benefits include a reduced demand for electricity generated by power plants. This option is linked with option 3 (the planting biomass crops).

Option 81 (Development of cooling towers for stable supply of electricity)
For the future demand of electricity it is advised to build new electricity plants in the coastal areas, so that seawater can be used for the discharge of cooling water. Plants near rivers in the lower-lying western parts of the Netherlands benefit from the new cooling water regulations that allow for higher temperatures of discharge water. The other plants, located more inland will benefit from the development of a cooling tower (Intermediair, 2006). The costs of building a cooling tower is estimated at 55 M€ (ECN, 2005). The costs range from 5 – 10 cooling towers, a bandwidth of 275 – 550M€. Benefits include avoided power cuts. This option is linked with option 71 (Adapt regulation regarding discharge cooling water) and with option 42 (Moving power plants to the coast).

Option 82 (Development of more 'intelligent' infrastructure that can serve as early warning indicator)
This option is specifically related to increased wind speed. More information needs to be obtained in order to make reliable estimates. Costs include knowledge/development of innovative vehicles and infrastructural design, or innovative emergency systems like for example adapting bridges in such a way that traffic is not blocked due to high wind speeds. Benefits include a reduction of accidents (avoided material damage and less traffic deaths)

Option 83 (Improvement of vessels relating to high wind speeds at sea)
Research has been conducted to create barges of aluminium or plastic, which are lighter in weight and therefore use less fuel. Most important is that the boats draw less deep in shallow a channel which is an advantage with low water levels that occurs more in large rivers. It is expected that dry summers that lead to an economic loss of 10 to 20 % are no longer rare. The project 'Inbiship' (innovative barge, a project financed by Brussels with 24 European partners) is aimed at developing a new type of barge with special diesel electric propulsion that makes a different ship-layout and more cargo space possible. Furthermore research is conducted on a system with 'air lubrication' to decrease the hull resistance and thus the fuel consumption (Financieele Dagblad, 2006).

Option 84 (Change modes of transport and develop more intelligent infrastructure (specifically related to flooding))
Costs include the innovative technological design of new infrastructure. Changing the mode of transport from the road/train to air/water transport, it concerns costs for new design of vehicles and infrastructure and enhancing the capacity of airplanes and ships.
Relating to the capacity of ships, see option 83. The project 'Inbiship' (innovative barge, a project financed by Brussels with 24 European partners) is aimed at developing a new type of barge with special diesel electric propulsion that makes a different shiplayout and more cargo space possible. Benefits relate to the avoided costs of delays due to flooding. More information needs to be obtained.

Option 85 (Increase standards for buildings as to make them more robust to increased wind speeds)
Costs include the design of new houses/building incorporating regulations to prevent damage caused by increased wind speeds. Implementing regulations for existing houses and buildings. Example is a different kind of roofing that is more storm robust. Benefits include the avoided damage. More information needs to be obtained. This option is linked with options identified for the Housing & Infrastructure sector, but this relates specifically to wind speed.

Sector Housing & Infrastructure

Option 86 (Design spatial planning – where to construct new housing and infrastructure)
Costs include the design of spatial planning takes into account the impacts of climate change, namely sea level rise. Within "Water management 21st century", the watertoets assesses the spatial planning on the possible consequence for the water system. This option is linked with option watersector 41– risk based allocation policy. Benefits include the reduction of people who die due to flooding, and the prevention of economic damage.

Option 87 (Make existing and new cities robust for climate change – avoid 'heat islands')
For Heat Island Effects, see http://www.epa.gov/heatisland/strategies/index.html. There are a number of steps that communities can take to lessen the impacts of heat islands. These "heat island reduction strategies" include:

- installing cool or vegetated green roofs;

- planting trees and vegetation; and (this is already applied in many cities in the Netherlands)
- switching to cool paving materials

As an example, the example of green roofs in Toronto is discussed. The city of Toronto has conducted studies to identify the citywide benefits of green roofs. Benefits were determined as initial cost saving related to capital costs or an amount of annually recurring cost savings. Table 13 shows the benefits and costs of green roofs in Toronto, which were identified in the green roof technology study.

Table 13. Heat islands - Benefits and costs of green roofs in Toronto

Category of benefit	Initial cost saving	Annual cost saving
Benefits from Stormwater flow reduction	Can $ 118 000 000 (€ 84 877 400)	
Benefits for Combined Sewer Overflow	Can $ 46 600 000 (€ 33 519 380)	Can $ 750 000 (€ 539 475)
Air quality benefits		Can $ 2 500 000 (€ 1 798 250)
Reduced Building energy consumption	Can $ 68 700 000 (€ 49 415 910)	Can $ 21 560 000 (€ 15 508 108)
Reduction Urban heat island	Can $ 79 800 000 (€ 57 400 140)	Can $ 12 320 000 (€ 8 861 776)
Total	Can $ 313 100 000 (€ 225 212 830)	Can $ 37 130 000 (€ 26 707 609)

Converter - 1 Can $ - British pound 0.493 (20 November 2005) - 1 Can $ - 0.71930 EUR – 20 November 2005 - (www.oanda.com)

These benefits were calculated based on the assumption that 100% of available green roof area be used across the city. The available green roof area included flat roofs on buildings with more than 350 m2 of roof area and assuming at least 75% of the roof area would be greened. The total available green roof area city-wide was determined to be 5000 hectares (50 million m2), which is 8% of the total land area.
The study also considered the costs of green roof implementation, which are primarily borne by private building owners. Based on work by the City of Waterloo, the incremental cost of re-roofing with an extensive green roofing system were found to be of the order of $ 75 to 90$ /m2 of roof (54 – 65 €/m2), over and above the cost of a traditional roof. The costs identified at the municipal level were costs for programmes to promote green roofs. No other costs were identified at the municipal level in relation to green roof implementation (London Climate Change Partnership, 2006).

Table 14 shows a rough comparison between Toronto and Amsterdam and Rotterdam. The total land area of the cities is compared (assumed that 8% of the total land area is available green roof area).

Table 14. Heat islands – Green roofs comparison Toronto, Amsterdam and Rotterdam

	Toronto	Amsterdam	Rotterdam
Total benefits: Initial cost saving	225 M€	59 M€	75 M€
Total benefits: annual cost saving	26 M€	7 M€	9 M€
Costs of green roof	54 – 65 €/m^2	?	?

Maintenance costs of green roofs in Amsterdam. A collective private green roof of 1600 m2, build on a parking garage. Maintenance costs are € 2250 per year (Gemeente Amsterdam, 2004).

Option 88 (Design houses with good climate condition at low energy consumption)

This option has a link with option 75, constructing buildings differently in such a way that there is less need for air-conditioning/heating).

Option 89 (Water management system in cities – revision of sewer system)
Costs include management of the sewer system and enlarging the capacity of the sewer system. In the Netherlands there is 100.000 km public sewer system, with a replacement value of 58 M€ (Het Parool, 2006). Benefits include a reduction of economic damage due to flooding of the sewer system caused by excessive rainfall. More information needs to be obtained.

Option 90 (Water management system in cities – options for water storage and retention in or near city areas)
This option has a strong link with option 40 identified for the water sector (water storage and retention). It concerns the spatial planning of cities, with the possibility for temporary water storage under buildings, or using water storage for recreation purposes. Costs include construction of buildings that can temporary store water, possibly changing land use functions near cities for water retention. Benefits include a reduction of economic damage due to flooding, creation of indirect benefits for recreation sector. More information needs to be obtained.

Option 91 (Water management system in cities – emergency system revision for tunnels and subways)
An emergency system is linked to options 65 (Risk management system) and 66 (evacuation plans). This option is specifically targeted at tunnels and subways. Costs of installing an emergency system can be calculated by multiplying the number of km subway systems and km of tunnels for both cars and trains exist that requires an emergency system and the costs of such a system, as well as the revision of the sewer system in both tunnels and subways. Benefits relate to the avoided delay due to non accessible tunnels or non functioning subways systems. More information needs to be obtained. This option has a link with option 89, a revision of the sewer system in tunnels and subways will enhance the capacity of the sewer system to deal with flooding.

Option 92 (New design of large infrastructure – reduce risk of flooding)
The option implies a new design of large infrastructure to reduce the risk of flooding. New tracks or highways are built on a dike, thereby becoming part of the compartmentation of an area to reduce the risk of flooding. In spatial planning this needs to be taken into consideration when designing infrastructure. When construction highways/tracks it is important to build new drainage systems that reduces flooding and land-slides that are caused by increase precipitation. The option is linked with option 44, the compartmentation of low-lying parts of the Netherlands. More information needs to be obtained.

Sector Health

Options presented for this sector, recently received a lot of media attention. Estimating the costs, however, is still difficult. More research is needed in order to give good estimates of the costs of benefits of the different components.

Option 93 (Improved airconditioning in nursery homes or hospitals)
Costs include the number of nursery homes and hospitals and the costs of investing in improved airconditioning systems. Benefits are a reduction in the mortality due to heatwaves. More information needs to be obtained in order to make reliable estimates.

Option 94 (Options for preventing climate related diseases (mitigation))
Costs include options to prevent climate related diseases such as government campaigns to inform the public about the existence and prevention of climate related diseases (such as Lyme disease and Legionnaires' disease). Benefits are a reduced mortality caused by climate related diseases. More information needs to be obtained.

Option 95 (Improvement of health care for these specific climate related diseases (adaptation))
Costs are a gain in knowledge about treatments (develop new medicine). Benefits are a reduction of mortality. More information needs to be obtained.

Sector Recreation & Tourism

Option 96 (Design infrastructure for recreation and tourism – coastal area)
The design of infrastructure for recreation and tourism in the coastal area relates to construction roads to access the coastal areas (prevention of congestion) and creating a sufficient amount of parking spaces. Benefits include increased economic activity due to increased recreation and tourism. More information needs to be obtained.

6 Feasibility of adaptation options

Criteria for assessing the feasibility of adaptation strategies

Erasmus University Rotterdam, Department of Public Administration, Chair Complex Decision-making and Process Management (prof.dr.ing. G.R. Teisman)

Authors: Drs. Arwin van Buuren, Dr. Jurian Edelenbos, Ir. Jasper Eshuis, Dr. Erik-Hans Klijn, Drs. Sibout Nooteboom, Prof.dr.ing. Geert Teisman

Introduction

We have chosen to assess the administrative feasibility of the different adaptation strategies, by making an analysis of the technical, societal and institutional complexity that accompanies the implementation of the proposed measures.

Technical complexity:

These are the technical difficulties and challenges which accompany the realization of the adaptation option:

- the technical facilities that have to be realized or mobilized;
- the technological uncertainties which accompany the implementation;
- the uniqueness of the operation and its risks.

Societal complexity:

That involves the diversity of values which are at stake when the option will be implemented, the changes which are necessary in the perceptions of stakeholders, the necessity of their cooperation and so on. This complexity expresses itself in:

- the amount of parties which have a stake at the option (or its effects);
- the diversity in normative views of the concerned parties;
- the degree to which the option is controversial and generates resistance;
- the necessity to generate consensus and frame convergence.

Institutional complexity:

As the institutional complexity of implementing an adaptation grows, there are more adjustments of the official, bureaucratic organizations, existing procedures and arrangements necessary, more cooperation between institutional separated domains and thus there is a bigger tension with existing practices and structures. Elements of institutional complexity are:

- clashes between institutional rules (for example because different departments use different sets of rules or make different demands on procedures and process arrangements which can be used in implementation trajectories);
- the organizational consequences of the option;
- the cooperative relations or associations which are necessary for the implementation;
- the degree of renewal of the option in relation to existing arrangements.

Table 15 presents the different criteria for the feasibility of the strategies and contains a five-point scale which we use for measuring the complexity of their realization. Table 16 presents the scores and ranking according to the selected weights of the adaptation options.

Table 15. Criteria feasibility adaptation options					
	Score				
	5	4	3	2	1
Technical Complexity	Realizing the strategy is technically very complex.	Realizing the strategy is technically complex.	Realizing the strategy is technically medium complex.	Realizing the strategy is technically moderate complex.	Realizing the strategy is technically hardly complex.
Social complexity	There are fundamental different opinions and perceptions about the option. Consensus is very difficult to realize.	There are substantial different opinions and perceptions about the option. Consensus is difficult to realize.	There are different opinions and perceptions about the option. Realizing consensus requires some effort.	There are some different opinions and perceptions about the option. Consensus is relatively easy to realize.	There are hardly different opinions and perceptions about the option. Consensus is easy to realize.
Institutional complexity	Realizing the option requires radical institutional changes and adjustments.	Realizing the option requires substantial institutional changes and adjustments.	Realizing the option requires a couple of institutional changes and adjustments.	Realizing the option requires some institutional changes and adjustments.	Realizing the option requires hardly if any institutional changes and adjustments.

Weighting

We propose to weight these types of complexity as follows:
Technical complexity: 20%
Societal complexity: 40%
Institutional complexity: 40%

Table 16. Scoring and ranking of adaptation options regarding feasibility

Sector	Subsector	nr.	Adaptation option name	Technical complexity 20%	Social complexity 40%	Institutional complexity 40%	Weighted sum
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	4	5	5	4.8
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	4	5	5	4.8
Water	Spatial concept	47	Re-connecting water systems - Overschelde: connection Oosterschelde - Westerschelde	4	5	5	4.8
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	4	5	5	4.8
Agriculture	General	15	Land use change	3	5	5	4.6
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	3	5	5	4.6
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	3	5	5	4.6

Table 16. Scoring and ranking of adaptation options regarding feasibility							
Sector	**Subsector**		**Adaptation option**	**Technical complexity**	**Social complexity**	**Institutional complexity**	**Weighted sum**
		nr.	**name**	**20%**	**40%**	**40%**	
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	3	5	5	4.6
Agriculture	General	12	Regional adaptation strategies for the fen meadow area	4	5	4	4.4
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	4	4	5	4.4
Water	Spatial concept	41	Risk ("Watertoets") based allocation policy	4	4	5	4.4
Agriculture	General	13	Relocation or mobilization of farms	3	5	4	4.2
Nature	Water management	34	Integrated water management	3	4	5	4.2
Nature	Water management	35	Integrated coastal Management	3	4	5	4.2
Agriculture	General	11	Water management and agriculture	4	4	4	4
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	4	4	4	4
Nature	Agriculture	33	Implementation of effective agri-environmental schemes	4	4	4	4
Nature	Finance	39	Development of financing mechanisms	4	3	5	4
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	4	4	4	4
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	4	4	4	4
Water	Social, policy	66	Evacuation plans	2	4	5	4
Water	Social, policy	68	New institutional alliances	2	4	5	4
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent infrastructure	4	4	4	4
Housing & Infrastructure		86	Design spatial planning – construct new housing and infrastructure	4	4	4	4
Agriculture	Fishery	24	Introduction of ecosystem management	3	4	4	3.8
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	4	4	3.8
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	3	4	4	3.8
Water	Spatial concept	50	Maintain higher water table to salt water intrusion	3	4	4	3.8
Water	Technological solution	70	Reduce wastewater discharge during drought periods	3	4	4	3.8
Housing & Infrastructure		90	Water management systems: options for water storage and retention in or near city areas	3	4	4	3.8
Agriculture	General	08	Subsoil drainage of peatlands	4	4	3	3.6
Nature	Nature	30	Artificial translocation of plant and animal	4	4	3	3.6
Housing & Infrastructure		92	New design of large infrastructure	4	4	3	3.6
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	2	4	4	3.6
Water	Technological solution	56	Adapted forms of building and construction	4	3	4	3.6
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	2	4	4	3.6
Recreation &		96	Design infrastructure for recreation and	2	4	4	3.6

Table 16. Scoring and ranking of adaptation options regarding feasibility

Sector	Subsector	nr.	Adaptation option name	Technical complexity 20%	Social complexity 40%	Institutional complexity 40%	Weighted sum
tourism			tourism – coastal areas				
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	3	3.4
Agriculture	General	02	Choice of crop variety and genotype	3	4	3	3.4
Agriculture	General	07	Water storage on farmland	3	4	3	3.4
Agriculture	General	10	Changes in farming systems	3	4	3	3.4
Agriculture	Fishery	27	Aquaculture on former grassland	3	3	4	3.4
Nature	Nature	29	Establishment and management of protected areas	3	4	3	3.4
Water	Spatial concept	49	Higher water level IJsselmeer	3	4	3	3.4
Water	Technological solution	59	Protection of vital infrastructure	3	3	4	3.4
Agriculture	General	03	Development and growing of crops for biomass production	2	4	3	3.2
Agriculture	General	05	Irrigation	4	3	3	3.2
Agriculture	General	09	Insurance	2	3	4	3.2
Agriculture	Forest	19	Limiting the import of timber	2	4	3	3.2
Agriculture	Fishery	26	Reallocation of mussel nursery plots	2	3	4	3.2
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	2	3	4	3.2
Water	Social, policy	65	Risk management as basic strategy	2	3	4	3.2
Water	Social, policy	67	Creating public awareness	2	3	4	3.2
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal to take predicted long-term effects of climate change into account (place a higher weight on these effects)	3	3	3	3
Housing & Infrastructure		87	Make existing and new cities robust - avoid ‘heat inlands’, provide for sufficient cooling capacity	3	3	3	3
Agriculture	Fishery	22	Adjusting fishing quota	1	4	3	3
Agriculture	Fishery	25	Eco-labelling and certification of fish	1	4	3	3
Agriculture	General	14	Floating greenhouses	2	3	3	2.8
Agriculture	Forest	17	Increasing genetic and species diversity in forests	2	3	3	2.8
Nature	Forestry	31	Afforestation and mix of tree species	2	3	3	2.8
Water	Technological solution	54	Sand suppletions along Dutch North Sea coast	2	3	3	2.8
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	2	3	3	2.8
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature is allowed	2	3	3	2.8
Energy & Transport	Energy	80	Planting of biomass crops	2	3	3	2.8
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	2	4	2	2.8
Water	Technological solution	63	Reduction salt water tongue	4	3	2	2.8
Agriculture	General	06	Self sufficiency in production of roughage	3	3	2	2.6
Nature	Forestry	32	Adjustment of forest management	3	3	2	2.6
Nature	Society	37	Monitoring nature, interpreting changes and informing	3	2	3	2.6

Table 16. Scoring and ranking of adaptation options regarding feasibility

Sector	Subsector	nr.	Adaptation option name	Technical complexity 20%	Social complexity 40%	Institutional complexity 40%	Weighted sum
Water	Technological solution	58	Protection of vital objects	3	2	3	2.6
Energy & Transport	Energy	74	Building stronger wind turbines	3	3	2	2.6
Energy & Transport	Energy	75	Construct buildings differently in such a way that there is less need for air-conditioning/heating	3	3	2	2.6
Energy & Transport	Energy	78	Improved opportunities for generating wind energy	3	3	2	2.6
Energy & Transport	Energy	81	Development of cooling towers	3	3	2	2.6
Energy & Transport	Transport	82	Development of more ‘intelligent’ infrastructure that can serve as early warning indicator	3	2	3	2.6
Agriculture	General	04	Soil moisture conservation practices	4	2	2	2.4
Agriculture	Forest	21	Acceptation of changes in species composition	2	3	2	2.4
Water	Spatial concept	51	Relocation of fresh water intake points	2	3	2	2.4
Energy & Transport	Energy	77	Adapt to mitigation strategies	2	3	2	2.4
Housing & Infrastructure		88	Design houses with good climate conditions (control) – ‘low energy’	2	2	3	2.4
Housing & Infrastructure		89	Water management systems: revision of sewer system	2	3	2	2.4
Health		94	Measures for preventing climate related diseases	4	2	2	2.4
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	3	2	2	2.2
Agriculture	Forest	20	Retention of winter precipitation in forests	3	2	2	2.2
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	3	2	2	2.2
Energy & Transport	Energy	72	Sluices	3	2	2	2.2
Energy & Transport	Energy	76	Constructing more stable overhead electricity transmission poles	3	2	2	2.2
Housing & Infrastructure		91	Water management systems: emergency systems revision for tunnels and subways	3	2	2	2.2
Health		95	Improvement of health care for these specific diseases	3	2	2	2.2
Nature	Society	38	Educational programs	2	2	2	2
Water	Technological solution	60	Enhancing capacity of sluices and weirs	2	2	2	2
Water	Technological solution	62	De-salinization	4	2	1	2
Energy & Transport	Energy	79	Improved opportunities for generating solar energy	2	2	2	2
Energy & Transport	Infrastructure	85	Increase standards for buildings as to make them more robust to increased wind speeds	3	2	1	1.8
Energy & Transport	Transport	83	Improvement of vessels	2	2	1	1.6

Table 16. Scoring and ranking of adaptation options regarding feasibility							
Sector	**Subsector**		**Adaptation option**	**Technical complexity**	**Social complexity**	**Institutional complexity**	**Weighted sum**
		nr.	**name**	**20%**	**40%**	**40%**	
Health		93	Improved air conditioning in nursery homes or hospitals	1	1	1	1

Conclusion

The feasibility analysis shows that many important and significant adaptation options encounter huge institutional complexity. That underlines the necessity of investing in more institutional pliability. Existing institutional cleavages horizontal as well as vertical as well as between different activity domains have to be pulled down in order to make integrated and coordinated action possible. A search towards new, flexible and temporal institutional arrangements is necessary to make an effective and smoothly implementation of adaptation options possible.

The social complexity is often high because of the many different values of stakeholders and the diverging interpretations of the problem and the preferred solution. More sense of urgency is necessary to make collective action for climate adaptation possible. But also investments in interaction between actors with divergent interests and values are necessary as well as more space for involvement of actors in policy-making and implementation to generate the requisite support for painful measures. Serious involvement of those who have a direct concern with adaptation options (farmers, fishermen, citizens) can enhance the support and facilitates the execution of the measures.

There seems to be a slightly relation between the feasibility of adaptation options and their ranking on importance, urgency, no regret, ancillary benefits and mitigation effect. We see the more significant and fundamental options generate more complexity than the less significant options. But also some very important and urgent options (like educational programs (38) and some more technical measures) are relatively well feasible and generate little social and institutional complexity, compared to some less important and urgent options (abandoning of low-lying Netherlands (53), relocation of farms (13), Reclamation of (part of) southern North Sea (52)) who are very complex to implement. So, in every case a specific analysis is necessary regarding the conditions for implementation.

Some adaptation options are technical relatively easy to implement. However, that does not say anything about the social and institutional complexity their implementation brings about. And these forms of complexity are much more difficult to handle. Implementing the adaptation options therefore requires a careful scan of the social and institutional environment in which they have to take place. A one-sided technocratic approach in climate policy is without doubt undesirable.

7 Conclusion

This report has shown that the Netherlands inevitably has to adapt itself to the effects of climate change and that there is a large number of adaptation options available for this. A good adaptation policy requires a timely planning and a choice for robust measures, i.e. measures that are useful in different climatic circumstances and that can be adapted in a later stage if deemed necessary. In addition to assessing the cost and benefits of adaptation options it is necessary to carefully plan the financing of the various options.

In this study, the adaptation options are inventarised on the basis of the sector they are most strongly related to, but they can also be classified in several other ways. Below we summarize the most important options for several fields of interest as used in the Routeplanner project.

Adaptation and economic development

Adaptation of traffic infrastructure is necessary to reduce the number of climate related disturbances (84). Possibilities are measures to reduce inundation of tunnels, facilities to deal with problems related to low river water levels, or measures to reduce disturbances of public transport due to extreme weather events. Also important are adaptations in the agricultural sector, forestry and fisheries. It concerns among other things adaptation of production systems (10, 32), changes in crop and variety choice (17, 18, 21, 31), improvements in water management (4), including irrigation and spreading risk for example by developing new insurances and improving ecosystem management in the fisheries sector.

For the transport sector, infrastructure for road, railway and inland navigation needs to be improved. Separate measures are required for air traffic and shipping in order to garantee safe transport also under extreme weather situations (83).

Adaptations in the recreation sector are required but they are expected to be taken by private sector entrepreneurs. When temperatures rise, coastal recreation will offer more opportunities due to which infrastructure has to be adapted. For these adaptations, a sea level rise of 20 to 80 cm by the year 2100 should be considered.

Industry should take into account changes in temperature, precipitation and weather extremes and especially the more risky industries (refineries, petrochemical and chemical industry, etc.) should take into consideration the risks caused by these climatic changes in order to avoid calamities. Responsibility of taking action lies both with the private parties as with authorities providing the licenses.

Also the agricultural and forestry sector will need to adjust to the changes in temperature and precipitation.

Special attention deserves the issue of insurance against the impacts of climate change. New arrangements and a clear distribution of tasks between the private and the public sector is required and transparant information needs to be provided to the relevant stakeholders, in order to be capable of making adequate decisions.

Adaptation and Security

Risks of flooding

If adaptation options are ranked according to importance, it is observed that options dealing with security (including water management) require much attention (34, 35, and 40). Also a shift towards risk management is of eminent importance (41, 65). A good coastal protection and protection against river flooding demands for adaptations that will become more important in the future (55). The already started policy measures in this field are a good starting point, but when sea levels and precipitation patterns change even more additional adaptation measures are necessary.

For security, it is necessary to improve evacuation plans and evacuation routes in order to reduce the effects of possible calamities (66) and also compartmentation of vulnerable regions can be considered in order to reduce damages (57).

It is important already in the short term to make the Dutch infrastructure climate proof and to take into consideration into spatial planning the effects of climate change and of flooding risks that are related to a sea level rise and changes in river discharge (86). This means that infrastructure in the coastal zone and along the rivers has to be adapted in such a way that the risks are reduced sufficiently. It has to be investigated in detail which measures will be most appropriate for this. For this purpose, a sound social cost-benefit analysis has to be set up in which the interactions between the different fields of policy and sectors are considered. In such an analysis, also the effects of which a monetary value can not be estimated easily should be considered. Only on the basis of such a study, it can be concluded which options are most suitable. Detailed studies of hotspots and watersheds should be set up in which the different alternatives can be compared.

Security of public utilities

For security also the public utilities are important, for example due to a possible shortage of cooling water in periods with high temperatures and low precipitation. As a result electricity generation can be in danger, which can result in additional security risks. To reduce these risks, it should be considered to use cooling towers instead of river water for cooling (81). Furthermore, for electricity generation, it is important that overhead electricity transmission poles and high-tension cables are sufficiently strong and able to resist extreme weather events (e.g. storm and freezing rain) (76).
Water management needs to be adapted in order to secure safe and sufficient drinking water. A possibility is increasing the water level of the IJsselmeer (48, 49) or to create more fresh water storage capacity.

Health

For public health, heat stress is an important risk. To reduce these risks, it is important to improve air conditioning in hospitals and nursing homes (93) and to improve provision of good information.
Attention should also be given to preventing negative effects of toxic algae and an increase of diseases (like Lyme disease).

Adaptation of living conditions (incl. spatial planning)

In the long run, the spatial division of the Netherlands should be reconsidered as well as plans to build in areas vulnerable for floods (64).

In order to reduce the envisaged increase in electricity demand that is related to the use of more air conditioning, it is important to consider in new construction and city plans possibilities of natural cooling and preventing unnecessary high temperatures. This requires a more climate oriented design of houses and offices (75, 86, 88). In city plans, it is important to prevent the existence of so-called heat islands and to construct enough green areas so that cities remain agreeable also when temperatures are high, without the need to use air conditioning.

For water storage along rivers, it is useful to reserve space in an early point in time and also in coastal areas, space should be reserved in order to enable a good coastal defence in the long run (86).

To prevent water problems during heavy rainfall, improvements of the sewage system and/or decoupling water discharge via the sewage system are important adaptation options (89).

Adaptation and Ecology

For ecology, strengthening the National Ecological Network (28) and integrated water management remain important (34). The increasing pressure on ecosystems due to climate change can be compensated by strengthening the National Ecological Network in order to support stability and resilience of the ecosystems concerned. As a result, species can adapt themselves better to changing climate zones and can use the resilience of ecosystems in an optimal way.

When nature management opts for planting hedges and trees, it is important to make a deliberate choice of climate proof species in order to prevent higher mortality in case of subsequent climate changes (17). Also monitoring carefully environmental changes (37) is important in order to be able to adapt policies in time and to adjust where possible.

Adaptation and Administration and Society

An adaptation of the administrative structure is advisable in order to reach good solutions for issues that require harmonization and coordination between different policy making and executing institutions (68). This includes as a clear example water management but also issues that require coordination between institutions dealing with spatial planning, agriculture, recreation, infrastructure and water management. It is important to strengthen existing initiatives and develop new alliances, as well as making a clear division and coordination of the different tasks.

Communication and conscious-raising is important to prepare the Dutch society to climate change (67). Well informed actors can on the basis of their own judgment look for the best adaptation options in the public as well as in the private sectors. On the basis of a systematic analysis of the different adaptation options a future-oriented strategy can be realized in which the government can accomplish an optimal adaptation policy in close collaboration with private parties: new possibilities created by climate change will be utilized and damage caused by climate change can be prevented as much as possible by making an appropriate choice from the adaptation options.

Important aspects in social cost-benefit analysis are the use of the correct discount rate and the possible irreversibility of long term effects (73). A reconsideration of the correctness of the discount rate of 4% that is actually used in social cost-benefit analyses is necessary.

Finally, it is very important to create transparency on the responsibilities and tasks of the various authorities and stakeholders, and to make clear what the role of the various authorities, producers, consumers and other stakeholders are in dealing with the impacts of climate change.

Costs and benefits of adaptation options

The overview of costs and benefits shows that adaptation policies will cost many billions of euros. Especially security policies require many billions of euros in order to assure that water management fulfills the desired security norms. Furthermore, also within the field of spatial planning billions of euros have to be invested to reserve for space, possibly to compartment parts of the country and make infrastructure climate proof.
Also within the private sector, investments are important to prepare the Dutch economy for the envisaged climatic changes. These investments have to be fit within the ongoing investment trajectories of the different economic sectors and the costs will differ considerably between the different sectors.

Adaptation options involving relatively high costs are typically those for maintaining safety against flooding, but it is not easy to assess which parts of the costs are required for maintenance of the existing safety standards and which part of the costs are explicitly related to changes induced by climate change. Many factors are interacting in determining sea level and river discharge and the exact role of climate change is difficult to determine.

Another category involving high costs is the adaptation of housing and buildings in order to cope with higher temperatures. This will involve several tens of billions of euros in the coming decades.

For the ecological network additional costs would be involved if an expansion of the network would be required to cope with the impacts of climate change.

Knowledge gaps

When writing this report, it turned out that the costs and benefits of the adaptation options can be estimated with a reasonable precision only for a limited number of options. For the majority of the options, the data are missing or the reliability of the data is insufficient. This means that it is difficult to compare the costs and benefits of the different policy alternatives and the different adaptation options. Additional research is therefore needed in order to improve and expand the database of adaptation options in such a way that it can be used for determining cost effective policies. As the costs and benefits depend on location specific circumstances and the exact phasing of the measures, detailed studies in so-called hotspot areas are indispensable. Only based on a detailed scenario study of the possible adaptation options, it can be indicated in detail which costs and benefits can be expected.

Also the specific administrative aspects of the different adaptation options need to be considered. They will differ for the different policy fields and for the private parties involved. This requires an analysis on the level of specific adaptation options in their administrative context, on a local, regional, national and international level, or on the level of the relevant ecosystems.

In this context also further studies are needed to analyze how individual will respond to the impacts of climate change and which policies are needed to assist in optimizing these responses.

Finally: Adaptation and Mitigation

Adaptation is absolutely necessary. Obviously, this does not mean that the mitigation efforts will become less important. If mitigation is insufficient, in the long run no suitable adaptation options will be available at acceptable costs. If that situation would occur, then climate policy (the combined mitigation and adaptation policies) would have failed completely. It is therefore of unrelenting importance to reach a solid international mitigation policy. Only then, costs of adaptation options can be limited correspondingly.

References

Abramovitz, J., T. Banuri, P. Girot, B. Orlando, N. Schneider, E. Spanger-Siegfried, J. Switzer and A. Hammill. 2002. Adapting to climate change natural resource management and vulnerability reduction. Background paper to the taskforce on climate change adaptation and vulnerable communities. International Institute for Sustainable Development, Canada: Manitoba.

Algemeen Dagblad, 2005. Nieuwe mast heeft geen likje verf nodig. 20 May 2005

Beurkens, L.W.M. and M. de Noord, 2003. Offshore wind power developments. An overview of realisations and planned projects. ECN Beleidsstudies (ECN-C-03-058)

Boer, B. de, H. Kaan, I. Opstelten, M. Elswijk, C. Boonstra, L. Joosten, 2005. Passiefhuizen: minder energie, meer comfort. Energiebesparing. ECN, DHV Bouw en Industrie.

Braakhekke, W., A. van Winden, W. Helmer and G. Litjens, 2005. Klimaatverandering – probleem of kans? Ruimtelijke oplossingen en mechanismen voor de Nederlandse delta. Een eerste verkenning. Bureau Stroming, Stichting ARK, Klimaat voor Ruimte

CBS, 2003. Web magazine, 24 February 2003. Centraal Bureau voor de Statistiek.

CBS, 2005. Web Magazine, 8 November 2005. Centraal Bureau voor de Statistiek.

CBS, 2006. CBS – Statline (statline.cbs.nl)

Decembernota KRW/WB21 2050. Toelichting. Ministerie van Verkeer en Waterstaat. Januari 2006

Derde Kustnota, 2000. Ministerie van Verkeer en Waterstaat.

Dril, A.W.N. van, L.W.M. Beurkens, Y.H.A. Boerakker, M.G. Boots, B.W. Daniels, R. Harmsen, H. Jeeninga, P. Kroon, T.J. de Lange, M. Menkveld, M.J.J. Scheepers, A.J. Seebregts, C.H. Volkers, J.R. Ybema and H. Elzenga, 2005. Reference projections energy and emissions 2005-2020, ECN Beleidsstudies ECN-C--05-089

ECBCS – Energy conservation in buildings and community systems (www.ecbcs.org)

ECN, 2005. Energie Verslag Nederland 2005. Elektriciteits- en gasmarkt - http://www.energie.nl/dossier/markt2005.pdf

Ecofys, 2005. Kosteneffectieve energiebesparing en klimaatbescherming. De mogelijkheden van isolatie en de kansen voor Nederland. Ecofys

Financieele Dagblad, 2006. Smeermiddel voor Hollandse Glorie 22.08.2006

Gemeente Amsterdam, 2004. Handleiding daktuinen. Gemeente Amsterdam Dienst Ruimtelijke Ordening

Heat Island Effect, website http://www.epa.gov/heatisland/strategies/index.html

Het Parool, 2006. Veel water? Wen er maar aan; ’50 tot 150 euro voor droge voeten is niet veel’. 23 August 2006

Hotspots project, 2006. Definitiestudie hotspots.

Ierland, E.C. van, R.S. de Groot, P.J. Kuikman, P. Martens, B. Amelung, N. Daan, M. Huijnen, K. Kramer, J. Szönyi, J.A. Veraart, A. Verhagen, A. van Vliet, P.E.V. van Walsum and E. Westein, 2001, ***Integrated assessment of vulnerability to climate change and adaptation options in the Netherlands***, NRP-CC.

Intermediair, 2006. Warmwatervrees: onze rivieren worden te warm. Intermediair 30 (27-07-2006)

Kabat, P, W. van Vierssen, J. Veraart, P. Vellinga and J. Aerts, 2005. Climate proofing the Netherlands. Nature, Vol. 438, Issue 7066, p. 283-284

KNMI 2003. De toestand van het klimaat in Nederland. Bilthoven:KNMI 2003.

KNMI 2006. Klimaat in de 21^{e} eeuw, vier scenario’s voor Nederland. Bilthoven: KNMI 2006.

LEI, 2006. Land- en tuinbouwcijfers 2006, Den Haag, LEI.

London Climate Change Partnership, 2006. Adapting to climate change: Lessons for London. Greater London Authority, London.
Louters, T., J. Pierey, T. van Ellen and A. Otten, 2005. Future of the IJsseldelta: an example of modern River Basin Management. DHV
McCarthy, J.J. Canziani, OF, Leary, N.A., Dokken, D.J. and White, K.S. (eds.), 2001. ***Climate Change 2001: Impacts, Adaptation, Vulnerability.*** Cambridge University Press, Cambridge, UK.
Metroeconomica, 2004. Costing the impacts of climate change in the UK: overview of guidelines. UKCIP Technical Report. UKCIP, Oxford.
Ministerie LNV, "Report on the implementation of the Pan-European - Ecological Network", The Netherlands, 2005
NBW, 2003. Het Nationaal Bestuursakkoord Water. Den Haag
Noord, M. de, L.W.M. Beurskens, H.J. de Vries, 2004. Potentials and costs for renewable electricity generation, a data overview. ECN (ECN-C--03-006) (share – lit energy)
Nota Ruimte, 2005. Ministeries van VROM, LNV, VenW en EZ.
Oanda.com, the currency site www.oanda.com
Ploumen, P.J. and S.P.N. van Rijen, 2004. Invloed van de koelwatertemperatuur op vermogen en rendement voor een STEG-, kolengestookte en Combi-eenheid. KEMA Power Generation & Sustainables, Productnummer 50331003.CL.303P3.11.4 (29)
Project IJsseldelta, 2005. Scenario's bypass Kampen. Provincie Overijssel, DHV and H+N+S Landschaparchitecten
Project IJsseldelta, 2006. Veilig wonen, werken en recreëren in IJsseldelta Zuid, Masterplan. Provincie Overijssel en Friesland, Gemeente Kampen, Zwolle, Dronten en Oldebroek en Waterschap Groot Salland (www.ijsseldelta.info)
RIVM, 2004. Milieubalans 2004. Het Nederlandse milieu verklaard. RIVM rapport 251701057, 200p., Bilthoven.
Rooijers, F. I. de Keizer, S. Slingerland, J. Faber, R.C.N. Wit, J. Verbeek, R. van Dorland, A.P. van Ulden, R. Hutjes, P. Kabat, E.C. van Ierland, 2004 Klimaatverandering Klimaatbeleid. Inzicht in keuzes voor de Tweede Kamer. Hoofdrapport september 2004. Rapport 3748.
Smit, B., I. Burton, R.J.T. Klein, and R. Street, 1999. The science of adaptation: a framework for assessment. Mitigation and Adaptation Strategies for Global Change 4: 199-213
Smit, B., O. Pilifosova, I. Burton, B. Challenger, S. Huq, R. Klein and G. Yohe, 2001. Adaptation to climate change in the context of sustainable development and equity. In Climate Change 2001 – Impacts, Adaptation and Vulnerability – Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change , McCarthy, J., Canziana, O., Leary, N., Dokken, D. and K. White, eds. Cambridge University Press, Cambridge, United Kingdom. 877-912
Smit, B. and Pilifosova, O. 2003. From adaptation to adaptive capacity and vulnerability reduction. In: Smith, J.B., Klein, R.J.T and Huq, S. (eds.). Climate change, adaptive capacity and development. Imperial College Press. London.
Tennet, 2006. Website www.tennet.org
UNFCCC, 1997. Kyoto Protocol to the United Nations Framework convention on Climate Change.
Verrips, A., H. de Vries, A. Seebregts and M. Lijesen, 2005. Windenergie op de Noordzee. Een maatschappelijke kosten-batenanalyse. CPB
Vliet, A. van, 2006. Natuurkalender- personal communication, Sept. 7, 2006
VOFF, 2006, personal communication, September 7, 2006
VROM, 2005. Netherlands Report on Demonstrable Progress under article 3.2. of the Kyoto Protocol. The Hague, The Netherlands.
Werven, M.J.N. van, 2003. Monitoren van de voorzieningszekerheid in de elektriciteitsmarkt met behulp van indicatoren. Technische Bestuurskunde, TU Delft, ECN Beleidsstudies Gas- en elektriciteitsmarkten

Willows, R.I. and R.K. Connell (Eds.), 2003. Clilmate adaptation: Risk, uncertainty and decision-making. UKCIP Technical Report. UKCIP, Oxford.
Winden, A. van, 2006. Personal comments 22.09.2006
Xepapadeas, A. and A. de Zeeuw, 1999. Environmental policy and competitiveness: The Porter hypothesis and the composition of capital. Journal of Environmental Economics and Management, Vol. 37, Issue 2, p. 165-182

Annex 1; Short description of adaptation options

Sector – Agriculture

1. ***Adjusting crop rotation schemes and planting and harvesting dates***
   This option is based on the selection of crop rotation schemes and timing of planting and harvesting to respond to local changes in environmental conditions. The effects of the adjustment of crop rotation schemes and planting and harvesting dates are to minimize production losses and avoid decreased workability and trafficability in early spring and autumn.

2. ***Choice of crop variety and genotype***
   Future climate features can be included in breeding and selection options and genetic manipulation through the choice of crop variety and genotype. Effects are to preserve the productivity of crop land by growing crops or trees which better resist saline conditions, wetness, drought, pests, diseases, frost and a shorter growing season. The choice of crop variety and genotype is considered the most important adaptation option to climate change in the agricultural sector.

3. ***Development and growing of crops for biomass production***
   This is a special case that combines adaptation and mitigation in one option. Using crops and crop residues for industrial processes and fuel is not new, but when markets for renewable energy grow and markets for conventional products are decreasing biomass production may be a viable alternative. Using existing crops but also the development of starch, sugar and oil crops which are resistant to salt, drought or wetness may contribute to the production of biomass for the production of energy and raw materials. The growing of stress resistant crops will remain limited in the Netherlands. The opportunities for the Dutch agricultural and business sectors in this field are mainly in the development of high quality genetic material and in the added value of the production and sale of seeds for the production of stress resistant crops at international scale.

4. ***Soil moisture conservation practices***
   Soil moisture conservation practices may serve as adaptation options to reduced rainfall during the summer period. In conservation tillage, some or all the previous season's crop residue is left on the soil surface. This may protect the soil from wind and water erosion and retain moisture by reducing evaporation and increasing infiltration. Increased soil organic matter will not only improve the water holding capacity but also improve soil structure.

5. ***Irrigation***
   Irrigation is required for the profitable growing of fruit trees, vegetable crops and flower bulbs. Due to climate change irrigation demand is expected to increase. Irrigation management practices include irrigation scheduling and the monitoring of soil moisture status. Irrigation scheduling is the tuning of the timing and amount of water.

6. *Self sufficiency in production of roughage*

The aim of this option is to create self-sufficiency in roughage by locally produced roughage, instead of relying on insecure availability of roughage from abroad due to climate change.

7. *Water storage on farmland*

Water storage on farmland is defined as the storage of excess water either in the soil under low groundwater conditions in open water like ditches, water courses, lakes and ponds or on the soil surface in case the soil and open water offer insufficient storage capacity. Water storage on farmland refers to overflow polders and retention areas, where the land remains property of the farmer and is used for temporary water storage. Overflow polders are put to service when the water storage system ('boezem') cannot discharge the water and needs to be unburdened. Retention areas are meant to receive the peak discharge of rivers to prevent flooding elsewhere. Emergency retention areas allocated along the major rivers to receive large quantities of water in extreme conditions to prevent life-threatening situations and large damage elsewhere in e.g. urban or agricultural areas.

8. *Subsoil drainage of peatlands*

Subsoil drainage is a recently introduced adaptation option to combat subsidence and oxidation of peat related to lowering of groundwater tables during periods of drought. Drainage tubes are laid out in the field perpendicularly to ditches, below the water level in the ditches. The water from ditches infiltrates into the subsoil with the purpose to increase the groundwater level.

9. *Insurance*

Insurance is the most important anticipating adaptation option. Damage due to storms and floods are expected to be the largest loss-making items. Due to the unknown effects of climate change on weather extremes it is difficult to adjust insurance contributions to increased risks. Currently, farmers can only insure damage due to rain and hail storms, not due to snow storms.

10. *Changes in farming systems*

In many regions of Europe, including the Netherlands, farms have, in response to policy and market incentives, become highly specialized enterprises. Farms can also adapt to the constraints of climate change to the productivity by replacing part of their production activities by alternative, income generating activities like nature management and development, biological farming in water extraction areas, processing and sale of products on the farm, agro-tourism and health care.

11. *Water management and agriculture*

Groundwater levels are kept low in agricultural land and high in natural areas, which creates a scattered pattern of groundwater levels and gradients from natural areas to polders. Water level management involves the increase of ditch and groundwater levels. Wetting of farmland can be realized through structural or periodical wetting. Structural wetting involves the raising of ditch bottoms or the lowering of the drainage depth in combination with an increase of the drainage density. Periodical wetting involves the increase of the groundwater water level in fields with or without water supply from ditches.

12. *Regional adaptation strategies for the fen meadow area*

The fen meadow area of the Netherlands is characterized by scattered groundwater levels because groundwater levels are kept low in agricultural land and high in natural areas. This results in the sinking down of water from natural areas in polders due to the gradient between natural and agricultural areas with soil subsidence in the agricultural areas, and water shortage in summer in both the agricultural and natural areas. The subsidence can be prevented by creating water basins between the polders and the natural areas.

13. *Relocation or mobilization of farms*

Relocation or mobilization of farms and greenhouses are adaptation options related to problems like soil subsidence, decreased accessibility of farmland for cattle and machinery, and damage from high and saline groundwater. The relocation of farms and greenhouses involves the displacement of entire farms or enterprises to other parts of the Netherlands, where the mentioned problems do not occur.

14. *Floating greenhouses*

Floating greenhouses are greenhouses on the water surface, which move up and down with the water level, while offering space for water storage in low-lying polders. Floating greenhouses are an integrated and flexible adaptation option to the increased need of space for the storage of water under climate change and to changing groundwater levels.

15. *Land use change*

Land use change substitutes the productivity loss of crops with shortening growing seasons and overproduction of wheat by economic value of new urban, recreational land, forest, or land for bioenergy crops.

16. *Adaptation strategies to salinization of agricultural land*

Sealevel rise will cause an increase of the salt water seepage in the coastal zones of the Netherlands, and an increase of the salt water intrusion in the main rivers in combination with lower river discharges in summer. Both types of salinization can harm salt sensitive crops in agriculture and horticulture. Adaptation options to salinization of agricultural land are; improving the efficiency of freshwater use in areas subject to salinization, the growing of halophyte, the growing of macro- and micro algae, the growing of bait for fish in saltwater basins on the land, the conversion of salted arable land to grassland, nature or sea culture parks, irrigation using brackish water, use or design of salt tolerant crops, and changing land use.

17. *Increasing genetic and species diversity in forests*

Promoting broad genetic variation and diversified species composition in forests are appropriate options to spread the risk of extinction of species and to increase the resilience of production forests. Diverse forests are stable and less susceptible to storms and pest and diseases, and have a higher value for nature and recreation.

18. *Introduction of southern provenances of tree species and drought resistant species*

The introduction of tree provenance of more southern origin and the planting of drought tolerant species may be appropriate adaptation options to a reduced natural regeneration of forests due to drought stress in summer.

19. *Limiting the import of timber*

The northbound spread of pests and diseases from southern regions can be slowed by restricting import of fresh timber from areas with pests.

20. *Retention of winter precipitation in forests*

Winter precipitation retained in forests may be used to relieve drought stress during dry summers.

21. *Acceptation of changes in species composition in forests*

The acceptation of changes in species composition with respect to the natural, recreational and production functions of forests seems an unavoidable option to adapt to climate and the change in species composition is also part of the natural process of forest development.

22. *Adjusting fishing quota*

Current insights have shown the important influence of climate change on the decreasing fish stocks in the North Sea besides unsustainable fishing. Therefore fishing quota should not only be based on the actual levels of fish stocks and fish capture, but also on the expected shifts in species ranges.

23. *Adaptation of target species and fishing techniques*

Adaptation of target species and techniques in the fishing industry may help to prevent the loss of productivity as a result of the reduction in current target species. Moving away from the single-species stock assessment and allocations to species groups or assemblages will provide the fishing industry with more flexibility.

24. *Introduction of ecosystem management in fishery*

The introduction of ecosystem management in the fisheries sector will enable a more active and direct participation of the fishing industry. The fishing and aquaculture industries have a long-term self-interest in integrated coastal and marine developments, and regularly collect information on the local aquatic climate, which could be of help to managers.

25. *Eco-labelling and certification of fish*

Eco-labelling and certification are adaptation options on the demand side of the fisheries sector, which aim to raise recognition by policy makers and the public at large of the necessity of sustainable use of fish resources.

26. *Reallocation of mussel nursery plots*

The dynamic reallocation of mussel nursery plots after storms avoids loss of productivity. Synergies occur when offshore windmill parks offer another possibility to locate mussel nursery plots. The underwater foundation of offshore windmill has proven to be a suitable place to grow mussels, analogous to the pending mussel culture. This option offers the possibility to combine mussel production with the production of electricity.

27. *Aquaculture on former grassland*

Fish production by means of aquaculture in seawater basins on former grassland may increase the economic value of otherwise inundated grassland. This is an adaptation option to undesired changes in species ranges on sea.

28. Design and implementation of ecological networks (The National Ecological Network - NEN)

Without special measures, extinctions of local populations are very likely to increase. Often due to the isolation of most nature areas, migration and adjustment of distribution ranges will be difficult for most species. The establishment of green corridors and ecological zones are very important to support adaptation of species especially those with low migration capabilities. The creation of the NEN can enhance the adaptation capacity of species to climate change

29. Establishment and management of protected areas

In combination with the development of a robust Ecological Network, the location, surface area and management of protected areas should be screened on their suitability under changing climatic conditions. In general, climate change will lead to more instability in nature, which requires more "adaptive management" and more space for species to allow them to adjust their distribution and/or phenology to changing environmental conditions.

30. Artificial translocation of plant and animal

Networks may have limited effects as migration of species along the corridors may not be able to keep pace with the climatic changes. Propose artificial translocation of plants and animals as a way of preserving species under climate change. Emphasize the importance of using various management approaches according to specie's climatic tolerances and dispersal abilities. For example, for the conservation of many mammals, artificial translocation may be more useful than the creation of large-scale migration corridors; whereas wind-dispersed plants may be best conserved in disjunctive reserves aligned in the direction of projected climate change.

31. Afforestation and mix of tree species

As often the dispersal rates of trees is very slow compared to the expected speed of climatic changes, corridors may not be able to counteract the negative effects on some tree species, calling for active afforestation measures. When planting a forest particular attention should be given to the selection of species and to the establishment of mixed forests. Afforestation can contribute to create new green areas and increase the robustness of existing forest ecosystems. New forest areas will also counteract the loss of forest caused by excessive drought in summer.

32. Adjustment of forest management

Adjustment of forest management can occur in already existing forests for the main purpose of decreasing the vulnerability of the ecosystem. For example a switch from single-stand to mixed forests, a switch from drought sensitive species to more resistant species and the use of a more broad range of species will help to spread the risk of possible negative effects. Pest control measures should be taken into account in order to counteract the increase of pests and contain diseases.

33. *Implementation of effective agri-environmental schemes*

Farmers are paid to modify their farming practice in order to protect wildlife and habitats and increase the environmental quality of their agricultural land by reducing the nutrient and pesticides emission. Agri-environmental schemes could contribute in maintaining a variety of valuable semi-natural habitats, maintaining or increasing species richness and thus enhancing the resilience of the natural system against climate change.

34. *Integrated nature and water management*

Creating more space for water, besides increasing the water storage capacity and benefiting landscape, can offer space to plant and animal species. Appropriate water management can allow adequate storage of water from heavy rains and can help in counteracting drought, both likely consequences of climate change. However, it should be realized that existing natural habitats are likely to disappear when faced with increasing incidence and/or magnitude of inundations.

35. *Integrated coastal zone management*

The integration of safety measures, nature conservation/restoration, urban and recreationall development. Re-establishment of the natural dynamics of the shoreline, where possible, is an important ingredient.

36. *Restoration of ecosystems directly depending on water quantity and quality*

Restoration of natural aquatic and wetland ecosystems as well as terrestrial ecosystems that directly depend on water quantity or quality, its aim being “to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater”. Contributes to mitigating the effects of floods and droughts”. Moreover, it also aims at “preventing further deterioration and protecting and enhancing the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems.

37. *Monitoring nature, interpreting changes and informing*

Monitoring nature is essential to understand the dynamics of the natural systems and their reactions to climatic changes. Monitoring activities have the objective of detecting impacts of climatic changes and the response from the natural environment.

38. *Educational programs*

In recent years the considerable losses due to extreme weather events, have increased public interests in climate change as well as public awareness of potential and actual risks associated with climate and extreme weather. Educational programs could be delivered in schools, institutions, or to a broader public for instance through radio, television, newspapers or road signs. Educational programs are actually raising an interest and involving citizens in the protection of the environment.

39. *Development of financing mechanisms*

Although most adaptation measures will require additional funding, most measures build on already existing activities aiming at increasing the robustness of Dutch natural ecosystems (even without climate change) and taking the climate change dimension into account can thus be done in a rather cost-effective manner. In addition to government funding, new financial mechanisms should be identified in order to involve all sectors in society in the implementation of actions to allow ecosystems to adapt naturally to climate change.

Sector - Water

40. "More space for water", "Water management 21st century" - land retention and storage

This option consists of the designation of selected areas of land for retention and storage of surplus freshwater originating from either excessive rainfall and/or peak river discharges. Thus, by means of the enhancement of storage capacity where needed (e.g. in polders), it is the intention to avoid inundations and other forms of water nuisance in areas where this is unwanted, as well as to build up reserves of stored freshwater that might be used during the periods of prolonged drought that are also likely to occur with increasing frequency. The mean principle in this option consists of a focus on retaining and storing freshwater surpluses in a controlled way, before thinking of discharging water surpluses as quickly as possible towards the sea.

41. Risk based allocation policy

In spatial allocation of different types of (terrestrial) land use in the Netherlands, it is still common use not to take into account considerations concerned with water-related risks. Based on careful risk-management analyses, which account for risks in the appropriate way by multiplying probability with potential impact, it should be possible to identify those areas within the Netherlands where risks are highest and where they are lowest, in order to subsequently allocate water-sensitive types of land use or activities much more prominently to the areas with the lowest risks. In the meantime, the policies should also attempt to discourage existing forms of water-sensitive land use in high-risk areas and stimulate their transference towards higher and safer regions.

42. Moving powerplants to coast (cooling water)

Power plants along our rivers already experience problems during periods of drought and high temperatures because the temperature of their discharge water is higher than allowed (see also option 71). Cooling with sea water is an effective solution.

43. Spatial planning of locations for powerplants (nuclear in particular)

Powerplants along the coast suffer a risk of flooding. To reduce the risk, in particular when the number of powerplants along the coast is likely to increase (option 42), careful spatial planning is called for. This applies in particular to nuclear powerplants. One possible adaptation is the concentration of several powerplants on specific locations, surrounded by a dike or situated at +5 NAP (see option 58). Another option is limiting the construction of power plant to areas with lower flooding risks than along the North Sea, such as the Westerschelde.

44. Compartmentation of low-lying parts of the Netherlands

Presently one dike ring (no. 14) comprises almost the whole of the province of Zuid-Holland. Flooding may affect up to 4.5 million people and amount to 290 billion € in damages. The present infrastructure (high ways, railroads) and dams make it unlikely that the area will be flooded completely and at once, and thus reduce the actual damages. However, further compartmentation, through adaptation of existing structures or new construction, may greatly reduce adverse affects of flooding. Possibilities are presently being examined within the WV21 program. More information (in Dutch) on www.projectvnk.nl and www.rijnland.net.

45. Allow transgression of sea in wide dune areas, allow wash over of dikes

In the past, the outer dunes were managed as dikes: erosion damage was prevented by constructions or poles, reed en cord grass plantations. Since the beginning of the nineties 'dynamic coastline management' was introduced. Where necessary, the coast fundament is preserved by beach and bank (under water) nourishment. Locally, where the dunes are wide enough and where there is no human occupation or commercial activity, dune maintenance has been reduced or stopped and the sea was allowed to invade former dune slacks, with "De Kerf" as largest example. This option "meegroeien met de zee" combines safety, nature restoration and recreation. This option holds great promise for the future. It does not increase safety, but it maintains the safety level at reduced costs and while increasing the value for nature and recreation. A similar option applies to dikes. Instead of making the existing dikes stronger to compensate for higher water levels and wave attack, one may build a new and lower dike behind the existing dikes. That makes it possible to allow (limited) wash over of the present dikes. Again, this solution can be combined with other functions, such as nature restoration, aquaculture (options 7, 11, 16, 27). In the EU-project Comcoast, this option is being tried out near Perkpolder (Zeeland) en Basel-Kruibeke-Rupelmonde (Vlaanderen).

46. Widening the coastal defence area (in combination with urbanisation and nature)

Widening the coastal defence by e.g. adding more lines of dunes, either inland or offshore, will evidently enhance the safety level and counteract the increasing threat of the rising sea. The effects of widening the coastal defence will be that either inland or along the original coastline extra sand dunes will be erected.

47. Reconnecting water systems in Delta area (e.g. Volkerak Zoommeer and Oosterschelde)

Sluices, but also dikes and dams limit the water flow and may thus increase the risk of flooding. Reconnecting water systems reduces the risk of flooding and may increase the natural values of the areas involved. This line of thinking has been the base for the Integrale Visie Deltawateren of the provinces of Zeeland, Zuid-Holland and Noord-Brabant. Examples are reconnecting the Volkerak Zoommeer with the Oosterschelde and or the Grevelingen. Surplus Rhine water can thus be diverted to the Delta, preventing the flooding of part of the northern delta and lower Rhine areas. The reintroduction of tidal influence will increase marine and estuarine biodiversity and reduce the blue algae blooms in Volkerak Zoommeer. There are also negative effects, however. Without additional measures, the availability of fresh water for agriculture will be reduced and salt intrusion may increase. Also, the present recreational infrastructure in lake Grevelingen and elsewhere is not sufficiently adapted to the introduction of tidal influence.

48. Fresh water storage to flush brackish water out during dry periods

This option creates benefits for the storage of drinking water, the storage of surplus water during flood periods and nature restoration.

49. Higher water level IJsselmeer

Storing more water in the IJsselmeer may prevent damages, for the northern part of the country due to extended periods of drought (desiccation, salt intrusion). It would be a costly operation, since all the dikes along the IJsselmeer (and the Ketelmeer and possibly the Markermeer) would have to be reinforced. It may require a somewhat higher sluice capacity in the Afsluitdijk. That is already covered by the planned doubling of the sluice capacity (see options 40, 60).

50. *Maintain higher water table to prevent salt water intrusion*

The benefits of maintaining higher water table to prevent salt water intrusion is the reduction of soil compaction and peat oxidation and the reduction of water shortage in nature reserves.

51. *Relocation of fresh water intake points*

Sea level rise, soil subsidence and compaction and more frequent periods of drought increase the risk of salt water intrusion. This may make it necessary for the water companies to move their intake points upstream/east. This is already taking place in the northern part of the delta region, as part of the policy decision ("Kierbesluit") to partly open the Haringvliet sluices for sea water at high tide.

52. *Reclamation of (part of) southern North Sea*

All along the Dutch North Sea coast, the majority of the countryside behind the strip of coastal dunes is potentially vulnerable to inundations provoked by a breakthrough of the sea through any part of dunes or dikes. A very drastic potential measure would be the reclamation of one or a few gigantic polders in the southern North Sea, parallel to the coast. These polders would have to be protected from the remaining part of the sea by huge and strong dikes in order to keep the rising sea out of it for a prolonged period of time.

53. *Abandoning of the whole of low-lying Netherlands*

Another very drastic adaptation option would be to actually evacuate the low-lying parts of The Netherlands, at least as far as the functions most vulnerable to water and/or salt damage are concerned. In fact, this would actually be the most sensible and natural adaptation option possible, were it not for the immense amount of energy, money and emotional stress involved in actually effectuating this option.

54. *Increase sand suppletions along coast*

Since the nineties, sand suppletions have become the most important measure to maintain the safety levels along the Dutch coast, in addition to the reinforcement of dikes and dams. Sand suppletions are aimed at preserving the same amount of sand in the 'Kustfundament'. Calculations over a period 200 (!) years from now have shown that supplementations will remain the most appropriate adaptation measure for the future. They will have to be increased to compensate for sea level rise, but the North Sea contains sufficient sand to exploit. For this space needs to reserved for large scale sand mining in the North Sea.

55. *Re-enforcement of dikes and dams, including 'weak spots'*

By far the most traditional and usual way of human society to cope with (increasing) flood and/or inundation-related risks consists of the construction of dikes and dams, designed to strictly separate the space designated for water bodies from that designated for human uses such as agriculture, urbanisation or infrastructure.

56. *Adapted forms of building and construction*

By construction of new houses, urbanisation or even entire cities on floating facilities, it is easily imaginable that these new investments will be safe from any threat imposed by the expected water table changes that climate change may be causing in future. These constructions will have to be robust enough to allow both significantly higher water tables during periods of excessive precipitation and/or peak river runoff and periods of prolonged drought, during which the floating supports would actually be resting on firm ground.

57. *Adaptation of highways, secondary dikes to create compartments*

Adaptation relates to the adjustment of highways and tracks and creating secondary dikes to create compartments.

58. *Protection of vital objects*

It may be effective to provide additional protection to vital objects, such as power plants, refineries, and large cities. Locally such adaptations are already reality: the Maasvlakte is situated at +5 m NAP.

59. *Protection of vital infrastructure*

As relating to option 58. One may think of Betuwelijn, High Speed Line, specific highways, for instance those selected as adequate evacuation routes (strategy 66).

60. *Enhancing capacity of sluices and weirs*

By enhancing the capacity of sluices and weirs, the amount of water that can be safely stored is enhanced as well. The effects of enhancing the capacities of sluices and weirs are that at any time the water storage capacity of the land will be significantly increased. This would enable the country to cope with higher peaks of both precipitation and river discharges.

61. *Artificial reefs along the coastline & development nature conservation values*

The construction of spatially carefully distributed reefs on strategic points along the Dutch coastline is likely to help reduce the wave action of the sea when it reaches the actual coastline. By this reduction of wave action the erosion of the coastline by the sea can be so drastically reduced, that even a rise in sea level may well be compensated for.

62. *De-salinization*

More efficient techniques are becoming available to desalinize salt water. In particular when with the use of surplus heat energy of powerplants (strategy 42) and of industrial activity this may become a viable adaptation option. This option may also generate economic value since increasing scarcity of fresh water is a worldwide phenomenon and techniques can be exported.

63. *Reduction salt water tongue*

The depth of the channel in the Nieuwe Waterweg has gradually been increased by dredging, to improve access to the harbour of Rotterdam for larger ships. The salt water tongue has therefore also moved east during the last decade. Sea level rise will increase this phenomenon. The harbour of Rotterdam is gradually moving west, for easier access by larger ships in the future, and because Rotterdam wants to use the docks for urban development. This westward movement provide an opportunity to gradually reduce the depth of the channel, in order to reduce the salt water intrusion.

64. *Stimulate economic activity in other (eastern and western) parts of the Netherlands*

Risk is chance times consequence. This equation is the basis for a new line of thinking in the decision making process about safety levels. Reducing the consequences of flooding gets more attention (WV21, see also options 44, 58, 59, 66 etc). The consequences may be reduced by gradually moving or spreading economic activities. This is a long term process. It may not be feasible and profitable to actually move existing factories etc. Instead, the strategy will mainly consist of breaking down factories and infrastructure that become obsolete, and build new factories outside the low-lying parts of the Netherlands.

This option also included the stimulation of activities that do not depend on access to sea or rivers, such as ICT and financial services, or that are better situated near our eater and southern borders, such as EU-related activities.

65. *Risk management as basic strategy*

Risk management concerning flooding, due to sea level rise. Including focusing on differentiating the risks of flooding and the possible consequences as well as maintaining of the risk levels, indicating the reduction of the consequences due to compartmentation, floating houses etc.

66. *Evacuation plans*

Traditionally, our national safety policy has concentrated on prevention. In WV21 the emphasis has shifted in the direction of ‘coping’. To reduce the adverse consequences of flooding, evacuations plans and associated measures are vital. Scenarios studies for flooding of several parts of the Netherlands are carried out to get a feeling for the scope of the problem and for possible solutions. Clear responsibilities, robust communication lines, solid infrastructure (option 59) and large concentrations of people: the challenge is considerable. Evacuation plans are also valuable from a communication/awareness (option 67) point of view: road signs with “evacuation route” provide a direct way to communicate that we have ‘live with water’.

67. *Creating public awareness*

The creation of public awareness is, within the context of modern democratic society, crucial to achieve any change of any magnitude. Thus, even when scientific evidence clearly indicates the need of adopting adaptation options for coping with the expected climate change impacts, it will still be necessary to inform the public of both the need and the consequences of any option proposed.

68. *New institutional alliances*

In order to actually make innovative and effective adaptation options really happen, the organisation of new institutional alliances is likely to be instrumental. These would have to include, among others, alliances between water boards and municipalities, between water boards and private parties (citizens, farmers) and among national, provincial and municipal authorities and water boards as well as international alliances. At the same time, ties and alliances between municipalities, as well as between towns and countryside (multi-governance) are necessary, e.g. to avoid the natural tendency of local or regional communities to solve their problems by spatially transferring them to other localities or regions. The new organisation structure also aims at improving the communication between the public and the private sector, making it both more accessible and less ‘political’ (more honest).

69. *Private insurances against inundations and/or drought related damages*

At present, it is impossible in The Netherlands to insure properties against the risks of flooding or drought. Theoretically this could be changed by creating this possibility. Negotiations between the authorities and the private insurance companies might lead to possibilities for a more appropriate and equalised spread of the financial risks involved in these type of water-related damages.

70. *Reduce wastewater discharge during drought periods*

Increased drought and higher temperatures will cause an increase in nutrient concentrations, eutrophication, and blue algae blooms. Enlargement and improvement of water treatment plants, storage capacity and separation of rain water and sewer are possible adaptations to reduce waste water discharge and thus prevent an increase in water quality problems.

Sector Energy and transport

71. *Adapt regulations such that a higher discharge temperature is allowed*

A possible adaptation option to solve the problem of unstable energy supply due to cooling water discharge constraints can be solved by relaxing the law imposing a restriction of cooling water discharge. The effects of a relaxation may be that ecosystem values may be affected negatively due to increased surface water temperatures, and drinking water may need additional treatments, which will lead to extra costs. Benefits of the adaptation measure include a stable supply of electricity that may be valued at avoided damage costs of a power cut.

72. *Sluices*

The structure of sluices is organised in such a way that there is sufficient cooling water available for electricity plants in dry periods.

73. *Lowering the discount factor for project appraisal*

Lowering the discount factor for project appraisal to take predicted long-term effects of climate change into account (place a higher weight on these effects).

74. *Building stronger wind turbines*

Increased wind speeds may also require stronger wind turbines to be developed. This will require knowledge about how to develop turbines that are less prone to extreme winds and investment in stronger material.

75. *Construct buildings differently in such a way that there is less need for air-conditioning/heating*

This requires spatial adjustment and technical development of new type of buildings. To reduce consumer demand for cooling and heating purposes by developing intelligent constructions on houses and buildings that provide for a constant temperature year round, without needing additional cooling or heating devices.

76. *Constructing more stable overhead electricity transmission*

Improvement of overhead electricity transmission poles would be a possibility to adapt to the increased risk of windstorms.

77. *Adapt to mitigation strategies*

A large set of options for mitigation strategies exist, such as energy-saving products including for example, energy-saving light bulbs, rechargeable batteries, technical devices (e.g. refrigerators, t.v.'s etc.) or to increase consumer awareness to save energy through government campaigns.

78. Use improved opportunities for generating wind energy

The development of wind turbines off-shore will contribute to increased production of sustainable energy. This will also have a mitigating effect as Carbon emissions may be reduced.

79. Use improved opportunities for generating solar energy

Increased hours of sunshine will enhance the potential of sustainable energy production through solar energy. Analogous to wind energy, this adaptation measure will also have a mitigating aspect, as it will reduce Carbon emissions and decrease the demand for tradable permits.

80. Planting of biomass crops

Climate change may induce farmers to grow other crops with a shorter rotation period, including biomass crops. In addition, it may be used as a mitigation option to reduce carbon emissions and decrease demand for tradable permits.

81. Development of cooling towers

Insufficient water that can be used for cooling purposes, development of cooling towers for stable supply of electricity.

82. Development of more 'intelligent' infrastructure that can serve as early warning indicator

Due to increased wind speeds there is a need to develop more 'intelligent' infrastructure like for example road and vehicle sensors that can serve as an early warning indicator and provide for adjustments in driving.

83. Improvement of vessels

An important aspect of increased risk of storms at sea leading to a decrease of fishing days necessitates the improvement of vessels, making them "storm-proof".

84. Change modes of transport and develop more intelligent infrastructure

The danger of increased flooding leading to a higher level of corrosion of vehicles, trains and infrastructure provides an opportunity to change modes of transport and develop more intelligent infrastructure. Increasing air- and over water transport would cause some relief of the high pressure on the current road network. The action needed to implement the option includes increased knowledge on new types of vehicle and infrastructural design and increase the load capacity of airplanes and container ships. In addition, this requires careful spatial planning in the long term that may be in conflict with other spatial planning policies.

85. Increase standards for buildings as to make them more robust to increased wind speeds

Increased standards for buildings to make them more robust to increased wind speeds would be an important option to consider for the built (urban) environment. This would require up-to-date knowledge on the vulnerability of buildings to wind storms.

Sector Housing and Infrastructure

Climate change will require adjustment in infrastructure and housing in order to reduce the negative impacts of climate change and to exploit the new opportunities that are provided. In the context of the risk of long term sea level rise, it is not only necessary to adjust to small and gradual change of the climate, but is also necessary to think strategically about long term spatial planning in order to reduce the risk related to long term sea level rise, in case mitigation of climate change will be insufficient.

86. ***Design spatial planning – construct new housing and infrastructure***

To construct new housing and infrastructure and how to design spatial planning as such that long term robustness for climate change will be established.

87. ***Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity***

It is essential to make existing and new cities robust for the impacts of climate change in terms of temperature management. This needs detailed spatial planning in order to avoid 'heat islands' and to provide for sufficient cooling capacity.

88. ***Design houses with good climate conditions (control) – 'low energy'***

Design of houses with good climate conditions at low energy consumption is urgently needed, followed by policies to implement 'low energy' houses and offices, with good climate control.

89. ***Water management systems: revision of sewer system***

For dealing with increased precipitation in cities the water management system needs to be adjusted and better facilities for dealing with excessive rain water are needed. This includes a revision of the sewer system.

90. ***Water management systems: options for water storage and retention in or near city areas***

For dealing with increased precipitation in cities the water management system needs to be adjusted and better facilities for dealing with excessive rain water are needed. This includes options for water storage and retention in or near city areas.

91. ***Water management systems: emergency systems revision for tunnels and subways***

For dealing with increased precipitation in cities the water management system needs to be adjusted and better facilities for dealing with excessive rain water are needed. This includes revision of emergency systems for instance for tunnels and subways.

92. ***New design of large infrastructure***

Synergies exist where the new design of large infrastructure also provides opportunities to reduce the risk of flooding.

Sector Health

Climate change has an impact on health through changes in temperature and moisture. In addition to direct heat stress, it affects the spread and occurrence of various diseases, such as malaria, or diseases related to other insects, like tics (Lyme disease, Legionnaires disease). Adaptation options include:

93. ***Improved air conditioning in hospitals***

94. ***Measures for preventing climate related diseases***

95. ***Improvement of health care for climate related diseases.***

Sector Recreation & tourism

96. *Design infrastructure for recreation and tourism – coastal areas*

Higher temperatures would in principle allow for more outdoor recreation and tourism in the Netherlands. Particularly the coastal areas provide new opportunities. Long term planning would allow to design the infrastructure for recreation and tourism as such that it is climate robust and that it can stand substantial sea level rise without further adjustment. This requires a revision of regulations and guidelines for the design of this type of infrastructure.

Annex 2 – Synergy & Competition nature sector

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
			Adap-tation option	Design and implementation of ecological networks (The National Ecological Network - NEN)	Establish-ment and management of protected areas	Artificial translocation of plant and animal	Afforestation and mix of tree species	Adjustment of forest management	Implementation of effective agri-environmental schemes	Integrated nature and water management	Integrated coastal zone management	Restoration of ecosystems directly depending on water quantity and quality	Monitoring nature, interpreting changes and informing	Educational programs	Development of financing mechanisms
Agri-culture	General	04	Soil moi-sture conservation prac-tices						SYNERGY: strategy 4 can reduce drought problems for nature areas next to agricultural land						
Agri-culture	General	05	Irriga-tion						SYNERGY: strategy 5 can reduce drought problems for nature areas next to agricultural land						
Agri-culture	General	07	Water storage on farmland						SYNERGY: strategy 7 may increase biodiversity						
Agri-culture	General	10	Changes in farming systems	SYNERGY. Changes in farming systems can											

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
				support the development of the "National Ecological Network" by contributing to establishment of green corridors, increase the overall environmental quality and promoting a wildlife friendly environment											
Agri-culture	General	11	Water management and agriculture												
Agri-culture	General	12	Regional adaptation strategies for the fen meadow area	SYNERGY: Strategy 12 can improve retention of water in natural areas and reduce problems due of water-shortage	SYNERGY: Strategy 12 can improve retention of water in natural areas and reduce problems due of water-shortage							SYNERGY: Strategy 12 can improve retention of water in natural areas and reduce problems due of water-shortage			
Agri-culture	General	13	Relocation or mobilization of farms	COMPETITION: Strategy 13 can cause a competition, in terms of land availability	COMPETITION: Strategy 13 can cause a competition, in terms of	COMPETITION: Strategy 13 can cause a competitio	COMPETITION: Strategy 13 can cause a competitio								

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.															
Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Natur e	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water manageme nt	Water management	Societ y	Societ y	Societ y
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
					land availability	n, in terms of land availability	n, in terms of land availability								
Agri-culture	General	14	Floating greenhou ses							SYNERGY: the construction of floating areas could be used not only for the greenhouse horticulture but also for ecological development.					
Agri-culture	General	15	Land use change	SYNERGY: Strategy 15 can create opportunity for development of nature areas.	SYNERGY: Strategy 15 can create opportunity for development of nature areas.	SYNERGY : Strategy 15 can create opportunity for developme nt of nature areas.	SYNERGY : Strategy 15 can create opportunity for developme nt of nature areas.								
Agri-culture	General	16	Adaptatio n strategies to salinizatio n of agricultur al land	SYNERGY: Strategy 16 can support to reduce salinity and thus increase/mainta in the environmental quality of some nature areas.					SYNERGY: Strategy 16 can support to reduce salinity and thus increase/mainta in the environmental quality of some nature areas.						
Agri-culture	Forest	17	Increasin g genetic and	SYNERGY: Strategy 17 can increase	SYNERGY: Strategy 17 can increase		SYNERGY : Strategy 17 can	SYNERGY: Strategy 17 can increase							

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
			species diversity in forests	resilience of forest ecosystems, spread the risk of extinction, maintain/enhance biodiversity etc.	resilience of forest ecosystems, spread the risk of extinction, maintain/enhance biodiversity etc.		increase resilience of forest ecosystems, spread the risk of extinction, maintain/enhance biodiversity etc.	resilience of forest ecosystems, spread the risk of extinction, maintain/enhance biodiversity etc.							
Agri-culture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	SYNERGY: strategy 18 can help to maintain/enhance biodiversity	SYNERGY: strategy 18 can help to maintain/enhance biodiversity		SYNERGY: strategy 18 can help to maintain/enhance biodiversity	SYNERGY: strategy 18 can help to maintain/enhance biodiversity							
Agri-culture	Forest	19	Limiting the import of timber	SYNERGY: Strategy 19 can reduce the intensity of forest production and help in maintaining biodiversity				SYNERGY: Strategy 19 can reduce the intensity of forest production and benefit maintaince of biodiversity							
Agri-culture	Forest	20	Retention of winter precipitation in forests	SYNERGY: reduce drought problems COMPETITION: increase sensitivity to	SYNERGY: reduce drought problems COMPETITION: increase			SYNERGY: reduce drought problems COMPETITION: increase							

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
				storm damage	sensitivity to storm damage			sensitivity to storm damage							
Agri-culture	Forest	21	Acceptation of changes in species composition in forests				SYNERGY Strategy 21 can favour the development of mixed forests	SYNERGY Strategy 21 can favour the development of mixed forests							
Agri-culture	Fishery	22	Adjusting fishing quota									SYNERGY : strategy 22 may reduce exploitation of marine resources			
Agri-culture	Fishery	23	Adaptation of target species and fishing techniques									SYNERGY : strategy 23 may reduce exploitation of marine resources			
Agri-culture	Fishery	24	Introduction of ecosystem management in fishery									SYNERGY : strategy 24 may contribute to maintenance of marine biodiversity			
Agri-culture	Fishery	25	Eco-labelling and certification of fish									SYNERGY: This strategy may support sustainable use of resources			
Agri-	Fishery	26	Reallocati												

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
culture			on of mussel nursery plots												
Agri-culture	Fishery	27	Aquaculture on former grassland	there may be COMPETITION because of reduced space for grassland								there may be COMPETITION because of reduced space for grassland			
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	SYNERGY: because strategy 40 can favour development of wetland nature. COMPETITION: more space for natural rivers may lead to loss of some ecosystems for example riverine forests that are considered a threat to water quality managers since they increase the roughness of the floodplain and thus enhance discharge peaks	SYNERGY: because strategy 40 can favour development of wetland nature. COMPETITION: more space for natural rivers may lead to loss of some ecosystems for example riverine forests that are considered a threat to water quality managers since they increase the roughness of the floodplain and thus enhance					SYNERGY: because strategy 40 can favour development of wetland nature.		SYNERGY: because strategy 40 can favour development of wetland nature. COMPETITION: more space for natural rivers may lead to loss of some ecosystems for example riverine forests that are considered a threat to water quality manager since they increase the roughness of the floodplain and thus enhance discharge peaks			

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
					discharge peaks										
Water	Spatial concept	41	Risk based allocation policy	SYNERGY: Land use allocation policy may lead to more available space for nature in the lower part of the Netherlands COMPETITION: the policy however may lead to decreasing space for nature in the higher parts of the Netherlands	SYNERGY: Land use allocation policy may lead to more available space for nature in the lower part of the Netherlands COMPETITION: the policy however may lead to decreasing space for nature in the higher parts of the Netherlands		SYNERGY: Land use allocation policy may lead to more available space for nature in the lower part of the Netherlands COMPETITION: the policy however may lead to decreasing space for nature in the higher parts of the Netherlands								
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	COMPETITION: strategy 46 can degrade existing semi-terrestrial ecosystems							COMPETITION: strategy 46 can degrade existing semi-terrestrial ecosystem	COMPETITION: strategy 46 can degrade existing semi-terrestrial ecosystems			

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
											s				
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	SYNERGY: strategy 46 can favour development of coastal ecosystems.								SYNERGY: strategy 46 can favour development of coastal ecosystems.			
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	SYNERGY: strategy 52 may lead to coastal ecosystems wetland development. COMPETITION: strategy 52 may lead to loss of coastal marine ecosystems						SYNERGY: strategy 52 may lead to coastal ecosystems wetland development.		SYNERGY: strategy 52 may lead to coastal ecosystems wetland development. COMPETITION: strategy 52 may lead to loss of coastal marine ecosystems			
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	SYNERGY: Strategy 53 lead to more available space for nature in the lower part of the Netherlands	SYNERGY: Strategy 53 lead to more available space for nature in the lower part of the Netherlands		SYNERGY: Strategy 53 lead to more available space for nature in the lower part of the Netherlands								
Water	Technol o0gical	54	Increase sand	SYNERGY: strategy 54							SYNERGY: strategy	SYNERGY: strategy 54			

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
	solution		suppletions along Dutch North Sea coast	offer opportunity for dune related nature development							54 offer opportunity for dune related nature development	offer opportunity for dune related nature development			
Water	Technol o-gical solution	55	Re-enforcement of dikes and dams, including 'weak spots'	COMPETITION: Strategy 55 can damage nature conservation values	COMPETITION: Strategy 55 can damage nature conservation values										
Water	Technol o0gical solution	61	Artificial reefs along the coastline & development nature conservation values								SYNERGY: This strategy can enhance marine biodiversity	SYNERGY: This strategy can enhance marine biodiversity			
Water	Technol o-gical solution	62	De-salinization	SYNERGY: strategy 62 can reduce risk of damages to nature due to salinization								SYNERGY: strategy 62 can reduce risk of damages to nature due to salinization			
Water	Social, policy	67	Creating public awareness										SYN-ERGY	SYN-ERGY	
Water	Social, policy	68	New institution												SYN-ERGY

Table 17. Overview of synergies and competitiveness of adaptation options of the Nature sector with other adaptation options.

Sector				Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature	Nature
	Sub-sector			Nature	Nature	Nature	Forestry	Forestry	Agriculture	Water management	Water management	Water management	Society	Society	Society
		nr.		28	29	30	31	32	33	34	35	36	37	38	39
			al alliances												
Water	Technological solution	70	Reduce wastewater discharge during drought periods	SYNERGY: strategy70can reduce risk of damages to nature								SYNERGY: strategy70can reduce risk of damages to nature			
Housing & Infra-struc-ture		86	Design spatial planning – construct new housing and infrastructure	COMPETITION: in term of land availability	COMPETITION: in term of land availability		COMPETITION: in term of land availability								
Recrea-tion & tourism		96	Design infrastructure for recreation and tourism – coastal areas	SYNERGY: sustainable tourism can favour nature values COMPETITION: non-sustainable tourism can actually decrease biodiversity							SYNERGY: sustainable tourism can favour nature values COMPETITION: non-sustainable tourism can actually decrease biodiversity				

Annex 3 – Expert Workshop

Summary report of expert-workshop

On September 1ste a workshop was conducted with experts from different sectors with the purpose of discussing the scoring and ranking of the adaptation options as identified, scored and ranked in Routeplanner sub-project 3 and 4. At first a short introduction of the ARK and Routeplanner-project was given, in which it was stressed that the Routeplanner-project provides the scientific support for the ARK strategy paper.

The experts were then asked to rank the identified options on their level of importance, with “5” indicating that an option has a very high level of importance and a score “1” indicating that an option has a very low level of importance. A discussion followed about the differences of prioritisation of the options scored by the experts and the scoring presented in the Routeplanner subproject 4. Suggestions were made to give priority to options relating to public awareness raising and information provision and increase the scoring of options that serve multiple uses such as water retention and agriculture.

For the ordering of the criteria the experts suggested the following order:

1. importance
2. urgency
3. ancillary benefit
4. no-regret
5. mitigation

It was overall concluded that the effect of an adaptation option on mitigation is of least importance, because the project relates to adaptation and some experts remarked that mitigation effects are part of the ancillary benefits. The criteria no-regret characteristic of the option was regarded as important, because it refers to the uncertainty about the right moment to implement an option and if this may lead to the misallocation of resources. However it can be seen as a conservative attitude to only implement options that are ranked highly on no-regret characteristics. Through sorting the options using the above ordering of criteria the top priority of options were identified and discussed by the participants. Several of the options relate to water management, especially for inland and coastal areas and the nature and agriculture sector. One important option “creating new institutional alliances” was further discussed. The experts mentioned that it should be carefully checked if the current institutions are able to cope with climate change and the implementation of the identified adaptation options and if they can be made climate proof. It is suggested that this can be done through the cooperation of institutions and stakeholders in new alliances, and through embedding institutions into existing structures. However, it is possible that problems arise when the urgency of the local and regional institutions differ from the national level. It is thus important that the national institutions have a coordinating role in the area of spatial planning, water and nature to guarantee an overall policy that is implemented in the same way at national, regional and local level.

The experts appointed the following weights to the criteria:

- 40% - importance
- 20% - urgency
- 15% - ancillary benefit
- 15% - no-regret
- 10% - mitigation

The experts suggested to cluster the identified options according to the sectors; economic development, security, living climate and policy and society and possibly cluster the options to the spatial scale level (international, national, regional, local and building) they relate to, and furthermore add information about the required policy effort to implement an option. Table 18 shows the average expert judgement on the scoring of the adaptation options, next to the scoring of the criteria done in this report. In total four experts scored the criteria, two experts scored all criteria and the other two experts scored only the criteria "importance".

There are some discrepancies between the average expert judgement and the scores shown in table 4 of this report. None of the adaptation options has scored "very high" on all the criteria. The following adaptation options have the highest priority regarding the "importance" criteria:

- Monitoring nature, interpreting changes and informing (nr. 37);
- Water management and agriculture (nr. 11);
- Design spatial planning – construct new housing and infrastructure (nr. 86);
- "More space for water", "Water management 21st century" – water retention and storage (nr. 40);
- Evacuation plans (nr. 66).

There are also some options that score low on the "importance" criteria, these are:

- Reallocation of mussel nursery plots (nr. 26);
- Abandoning of the whole of low-lying Netherlands (nr. 53);
- Relocation or mobilization of farms (nr. 13).

Table 18. Average Expert judgement on scoring adaptation options

Sector	Subsector	Adaptation option		Importance - report	Importance – average expert judgement	Urgency - report	Urgency – average expert judgement	No regret - report	No regret - average expert judgement	Ancillary benefits - report	Ancillary benefits - average expert judgement	Mitigation effect - report	Mitigation effect - average expert judgement
		nr.	name										
Agriculture	General	01	Adjusting crop rotation schemes and planting and harvesting dates	3	4	4	2	5	3	1	2	2	4
Agriculture	General	02	Choice of crop variety and genotype	3	4	4	2	5	4	2	2	4	3
Agriculture	General	03	Development and growing of crops for biomass production	2	3	3	3	2	4	4	3	5	3
Agriculture	General	04	Soil moisture conservation practices	4	3	4	3	3	3	3	3	3	3
Agriculture	General	05	Irrigation	3	3	3	3	3	3	3	3	2	3
Agriculture	General	06	Self sufficiency in production of roughage	1	3	2	3	1	3	2	3	3	3
Agriculture	General	07	Water storage on farmland	3	3	4	3	5	4	4	3	3	3
Agriculture	General	08	Subsoil drainage of peatlands	1	3	2	4	1	4	1	3	1	3
Agriculture	General	09	Insurance	3	4	4	4	3	4	2	3	3	3
Agriculture	General	10	Changes in farming systems	4	3	3	4	4	3	4	3	4	4
Agriculture	General	11	Water management and agriculture	4	5	3	4	3	3	3	4	3	4
Agriculture	General	12	Regional adaptation strategies for the fen meadow area	3	4	3	3	3	3	3	3	3	3
Agriculture	General	13	Relocation or mobilization of farms	1	2	3	3	1	2	1	3	3	2
Agriculture	General	14	Floating greenhouses	2	3	1	3	2	3	2	2	3	3
Agriculture	General	15	Land use change	4	4	2	4	3	4	3	4	4	4
Agriculture	General	16	Adaptation strategies to salinization of agricultural land	3	3	2	3	3	4	1	4	4	3
Agriculture	Forest	17	Increasing genetic and species diversity in forests	4	3	5	3	5	3	4	3	4	3
Agriculture	Forest	18	Introduction of southern provenances of tree species and drought resistant species	4	3	3	3	5	3	4	3	3	3
Agriculture	Forest	19	Limiting the import of timber	1	3	2	3	1	3	2	3	3	3
Agriculture	Forest	20	Retention of winter precipitation in forests	2	3	2	3	3	4	4	3	3	3
Agriculture	Forest	21	Acceptation of changes in species composition in forests	4	3	3	3	5	3	4	3	3	2
Agriculture	Fishery	22	Adjusting fishing quota	1	2	4	4	3	4	4	5	3	3
Agriculture	Fishery	23	Adaptation of target species and fishing techniques	1	2	2	3	3	3	4	5	3	3
Agriculture	Fishery	24	Introduction of ecosystem management in fishery	4	2	4	3	5	3	5	4	3	3
Agriculture	Fishery	25	Eco-labelling and certification of fish	1	2	1	3	1	3	3	3	3	2
Agriculture	Fishery	26	Reallocation of mussel nursery plots	2	1	1	2	3	2	2	3	5	2
Agriculture	Fishery	27	Aquaculture on former grassland	1	2	1	3	3	3	3	4	3	3

Table 18. Average Expert judgement on scoring adaptation options

Sector	Subsector	nr.	Adaptation option name	Importance - report	Importance – average expert judgement	Urgency - report	Urgency – average expert judgement	No regret - report	No regret - average expert judgement	Ancillary benefits - report	Ancillary benefits - average expert judgement	Mitigation effect - report	Mitigation effect - average expert judgement
Nature	Nature	28	Design and implementation of ecological networks (The National Ecological Network - NEN)	4	4	5	4	5	4	5	4	4	3
Nature	Nature	29	Establishment and management of protected areas	3	4	4	3	4	4	3	4	3	3
Nature	Nature	30	Artificial translocation of plant and animal	1	2	3	3	1	2	1	2	3	3
Nature	Forestry	31	Afforestation and mix of tree species	4	3	4	4	5	4	4	4	5	4
Nature	Forestry	32	Adjustment of forest management	4	3	3	5	5	5	3	5	3	4
Nature	Agriculture	33	Implementation of effective agri-environmental schemes	3	3	4	4	3	4	4	4	5	4
Nature	Water management	34	Integrated nature and water management	5	4	5	4	5	4	5	4	4	4
Nature	Water management	35	Integrated coastal zone management	5	4	5	4	5	3	5	3	4	4
Nature	Water management	36	Restoration of ecosystems directly depending on water quantity and quality	3	4	3	3	4	5	4	4	3	4
Nature	Society	37	Monitoring nature, interpreting changes and informing	4	5	5	4	5	5	3	4	3	5
Nature	Society	38	Educational programs	4	4	4	4	4	4	5	4	5	5
Nature	Finance	39	Development of financing mechanisms	2	3	2	4	4	4	3	3	3	4
Water	Spatial concept	40	"More space for water", "Water management 21st century" - water storage and water retention	5	5	5	4	5	3	5	3	4	4
Water	Spatial concept	41	Risk based allocation policy	5	4	5	3	5	5	5	4	4	4
Water	Spatial concept	42	Moving powerplants to coast (cooling water)	2	3	3	3	5	3	4	3	4	3
Water	Spatial concept	43	Spatial planning of locations for powerplants (nuclear in particular)	5	3	4	4	3	4	3	3	3	3
Water	Spatial concept	44	Compartmentation of low-lying parts of the Netherlands	4	3	4	3	4	3	1	3	3	3
Water	Spatial concept	45	Allow transgression of sea in wide dune areas, allow wash over of dikes	3	3	2	3	5	3	5	4	3	3
Water	Spatial concept	46	Widening the coastal defence area (in combination with urbanisation and nature)	5	3	4	3	3	3	4	3	3	3
Water	Spatial concept	47	Reconnecting water systems in Delta area (e.g.Volkerak Zoommeer and Oosterschelde)	3	3	2	4	4	4	5	3	3	4
Water	Spatial concept	48	Fresh water storage to flush brackish water out during dry periods	5	3	3	4	5	4	4	4	3	4
Water	Spatial	49	Higher water level	5	3	2	3	3	3	3	2	3	2

Table 18. Average Expert judgement on scoring adaptation options

Sector	Subsector	Adaptation option		Importance - report	Importance – average expert judgement	Urgency - report	Urgency – average expert judgement	No regret - report	No regret - average expert judgement	Ancillary benefits - report	Ancillary benefits - average expert judgement	Mitigation effect - report	Mitigation effect - average expert judgement
		nr.	name										
	concept		IJsselmeer										
Water	Spatial concept	50	Maintain higher water table to prevent salt water intrusion	5	3	3	3	5	3	4	3	3	2
Water	Spatial concept	51	Relocation of fresh water intake points	5	3	4	3	3	3	3	3	3	3
Water	Spatial concept	52	Reclamation of (part of) southern North Sea	1	2	1	3	1	2	3	2	2	3
Water	Spatial concept	53	Abandoning of the whole of low-lying Netherlands	1	2	1	2	1	3	2	3	2	3
Water	Technological solution	54	Increase sand supplетions along coast	5	4	3	4	3	3	1	3	3	3
Water	Technological solution	55	Re-enforcement of dikes and dams, including 'weak spots'	5	4	5	5	3	4	3	4	3	4
Water	Technological solution	56	Adapted forms of building and construction	4	4	4	5	3	4	5	5	4	5
Water	Technological solution	57	Adaptation of highways, secondary dikes to create compartments	5	4	4	4	5	4	1	3	3	4
Water	Technological solution	58	Protection of vital objects	3	4	2	4	5	4	3	3	3	4
Water	Technological solution	59	Protection of vital infrastructure	3	4	2	5	5	4	3	3	3	4
Water	Technological solution	60	Enhancing capacity of sluices and weirs	4	4	4	4	3	4	3	4	3	4
Water	Technological solution	61	Artificial reefs along the coastline & development nature conservation values	1	2	3	4	1	3	2	3	3	4
Water	Technological solution	62	De-salinization	1	2	2	3	2	3	1	2	2	3
Water	Technological solution	63	Reduction salt water tongue	3	3	2	3	5	4	1	2	3	3
Water	Social, policy	64	Stimulate economic activity in other parts (eastern and northern) of the Netherlands	5	4	5	4	3	3	3	3	1	3
Water	Social, policy	65	Risk management as basic strategy	5	4	5	3	5	3	5	4	4	4
Water	Social, policy	66	Evacuation plans	5	5	5	4	5	3	3	3	3	4
Water	Social, policy	67	Creating public awareness	4	4	5	4	4	3	3	3	5	4
Water	Social, policy	68	New institutional alliances	5	4	5	4	5	4	4	4	5	3
Water	Social, policy	69	Private insurances against inundations and/or drought related damages	3	3	4	3	3	3	1	3	4	3
Water	Technological solution	70	Reduce wastewater discharge during drought periods	3	3	3	3	5	3	5	3	3	2
Energy & Transport	Energy	71	Adapt regulations such that a higher discharge temperature is allowed	3	3	2	3	3	3	1	3	1	3
Energy & Transport	Energy	72	Sluices	4	3	3	3	1	3	1	3	3	3
Energy & Transport	Energy	73	Lowering the discount factor for project appraisal	4	2	5	2	3	3	3	3	5	2
Energy &	Energy	74	Building stronger wind	2	2	3	2	3	2	1	3	4	3

Table 18. Average Expert judgement on scoring adaptation options

Sector	Subsector	nr.	Adaptation option name	Importance - report	Importance – average expert judgement	Urgency - report	Urgency – average expert judgement	No regret - report	No regret - average expert judgement	Ancillary benefits - report	Ancillary benefits - average expert judgement	Mitigation effect - report	Mitigation effect - average expert judgement
Transport			turbines										
Energy & Transport	Energy	75	Construct buildings differently in such a way that there is less need for air-conditioning/heating	5	4	4	4	5	4	4	4	5	4
Energy & Transport	Energy	76	Constructing more stable overhead electricity transmission poles	5	3	3	3	4	3	1	3	3	3
Energy & Transport	Energy	77	Adapt to mitigation strategies	3	3	4	3	3	3	3	3	5	4
Energy & Transport	Energy	78	Use improved opportunities for generating wind energy	2	3	2	3	1	3	2	4	5	4
Energy & Transport	Energy	79	Use improved opportunities for generating solar energy	2	4	2	3	1	4	2	4	5	4
Energy & Transport	Energy	80	Planting of biomass crops	2	3	3	4	1	3	2	3	5	4
Energy & Transport	Energy	81	Development of cooling towers	5	3	3	3	3	3	4	2	3	3
Energy & Transport	Transport	82	Development of more 'intelligent' infrastructure that can serve as early warning indicator	5	4	4	5	4	4	4	3	5	4
Energy & Transport	Transport	83	Improvement of vessels	4	2	4	4	3	3	4	3	2	4
Energy & Transport	Transport	84	Change modes of transport and develop more intelligent infrastructure	5	4	5	4	4	3	4	4	5	4
Energy & Transport	Infrastructure	85	Increase standards for buildings as to make them more robust to increased wind speeds	5	3	4	3	4	3	1	3	3	2
Housing & Infrastructure	Spatial	86	Design spatial planning – construct new housing and infrastructure	5	5	5	4	4	4	3	4	4	4
Housing & Infrastructure	Spatial	87	Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity	5	4	5	4	4	4	5	4	4	4
Housing & Infrastructure	Design	88	Design houses with good climate conditions (control) – 'low energy'	5	4	4	4	5	4	3	4	5	4
Housing & Infrastructure	Water management	89	Water management systems: revision of sewer system	5	3	4	3	4	4	3	4	3	3
Housing & Infrastructure	Water management	90	Water management systems: options for water storage and retention in or near city areas	4	4	4	4	4	4	4	4	4	4
Housing & Infrastructure	Water management	91	Water management systems: emergency systems revision for tunnels and subways	5	3	3	3	4	4	1	4	3	3
Housing & Infrastructure	Design	92	New design of large infrastructure	5	3	4	3	4	3	3	3	3	3
Health		93	Improved air conditioning in nursery homes or hospitals	4	3	5	3	3	4	1	4	2	3
Health		94	Measures for preventing	3	3	4	3	2	4	3	4	3	3

Table 18. Average Expert judgement on scoring adaptation options

Sector	Subsector	nr.	Adaptation option name	Importance - report	Importance – average expert judgement	Urgency - report	Urgency – average expert judgement	No regret - report	No regret - average expert judgement	Ancillary benefits - report	Ancillary benefits - average expert judgement	Mitigation effect - report	Mitigation effect - average expert judgement
			climate related diseases										
Health		95	Improvement of health care for climate related diseases	4	3	3	4	4	5	1	4	3	3
Recreation & tourism		96	Design infrastructure for recreation and tourism – coastal areas	4	2	3	2	4	3	1	2	3	2

Annex 4 – Database overview – Agriculture sector

Table **19 A**

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
1	Agri-culture	Gene-ral	Soils too wet in spring and autumn	Adjusting crop rotation schemes and planting and harvesting dates	Minimize production losses and avoid decreased workability and trafficability in early spring and autumn Transport and trading sector: changes in delivery times of crops and produce		The loss of income and damage to the harvest de to extreme wet conditions in the Netherlands in 1998 amounted to 600 M€ [???ref??], this amount could be theoretically saved if planting and harvesting dates could be shifted in response to the soil moisture conditions in autumn and spring.		> 100 mln		> 100
2	Agri-culture	Gene-ral		Choice of crop variety and genotype	Preserve the productivity of crop land by growing crops and trees which better resist saline conditions, wetness, drought, pests, diseases, frost and a shorter growing season Effects are expected on the trading sector (through the changed demand and supply of agricultural products) and on the health sector (through the introduction of new food products)		Avoided damage costs of climate change Maize wortelkever - harvest losses of 6.5 to 13% - in the Netherlands an economic loss of 15 to 30 M€ on an annual base		> 50 mln		> 50
3	Agri-culture	Gen-ral	Salt water intrusion, water shortage during summer period, excess water (flooding) during spring and autumn period.	Development and growing of crops for biomass production	Using existing crops but also the development of starch, sugar and oil crops which are resistant to salt, drought or wetness may contribute to the production of biomass for the production of energy and raw materials	Combines adaptation and mitigation	A new cash crop could improve the income of farmers.				P.M.
4	Agricult ure	Gener al	Reduced rainfall during the summer period	Soil moisture conservation practices	Protect soil from wind and water erosion and retain moisture by reducing evaporation and increasing	Conservation tillage methods (some or all previous		Improved soil quality.	6 mln		6

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
					infiltration Improve water holding capacity and soil structure	season's crop residue is left on the soil surface)					
5	Agri-culture	Gene-ral		Irrigation		Irrigation scheduling (tuning of the timing and amount of water)Monitoring of soil moisture status	The increase in profit for the agricultural sector due to the reduction of water shortage, converted to the total area of agricultural land in the Netherlands was estimated at 4 billion euros per year.	Reduced costs for irrigation enable the farmer to stay within irrigation quotaincrease of crop production because situations of stress due to drought or salty conditions are avoided on timeCosts of maintenance are lower	RIZA study - increases in farm income		P.M.
6	Agri-culture	Gene-ral		Self sufficiency in production of roughage	To create self sufficiency in roughage by locally produced roughage, instead of relying on insecure availability of roughage from abroad due to climate change		Locally produced roughage instead of relying on availability from abroad	none			P.M.
7	Agri-culture	Gene-ral		Water storage on farmland		Conversion of grassland along the main rivers into (emergency) retention areas	Compensation to the farm for granting the blue service (annual compensation for damage to crops <u>or</u> a single benefit for the decrease of the value of land. Both depend on the probability of inundation.	Retention areas create additional income for farmers: - possibility to deploy these areas for recreation, nature development and management - as water stocks fro the fruit growing sector to combat night frost in spring - seepage areas used for growing crops which benefit from wet conditions			P.M.
8	Agri-culture	Gene-ral		Subsoil drainage of peatlands	reducing subsidence of peat soils in lowland and upland peat soils by maintaining high groundwater levels		maintaining groundwater levels in winter and summer, thus reducing decomposition of peat and drought stress, without negative effects on workability and trafficability		effect on farm income and the cost-effectiveness of investments in subsoil drainage are currently studied in the project		P.M.

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
									'Waarheen met het veen', sub-project 'Subsoil drainage', by Praktijkonderzoek ASG and Alterra.		
9	Agri-culture	Gene-ral	Extreme weather events	Insurance	Compensation for damage of weather extremes		Compensation				P.M.
10	Agri-culture	Gene-ral		Changes in farming systems	Increase resilience and reduce vulnerability to external shocks	Replacing part of their production activities by alternative, income generating activities (nature management and development, biological farming in water extraction areas, processing and sale of products on the farm, agro-tourism, health care)					P.M.
11	Agri-culture	Gene-ral	Fen-meadow areas:- subsidence of farmland- water shortage during the dry summer period- excess water during wet periods- salinization related to sea level riseGround water levels are kept low in agricultural land (resulting in accelerated oxidation of peat and soil subsidence) and high in natural areas - creating a scattered pattern of groundwater levels and gradients from natural areas to poldersFarmland on high areas on sandy soils: suffer from summer	Water management and agriculture		Increase in ditch and groundwater levels	1. Peak water discharges can be captured; 2. High groundwater levels can be maintained in adjacent nature areas; 3. A groundwater stock can be maintained at the start of the dry summer period; 4. Soil subsidence due to oxidation of peat is reduced		The increase in profit for the agricultural sector due to the reduction of water shortage, converted to the total area of agricultural land in the Netherlands was estimated at 1 billion € per year. A possible increase in the costs of damage due to the wetting of farmland is not taken into account in the		P.M.

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
			drought (causing yield loss and loss of income)						estimation of benefits.		
12	Agri-culture	Gene-ral		Regional adaptation strategies for the fen meadow area	Even out scattered groundwater levels	Creating water basins between the polders and the natural areas to prevent subsidence, and which can supply water in the summer					P.M.
13	Agri-culture	Gene-ral	Soil subsidence, decreased accessibility of farmland for cattle and machinery, and damage from high and saline groundwater	Relocation or mobilization of farms		Mobile milking stables					P.M.
14	Agri-culture	Gene-ral	Flooding and changing groundwater level	Floating greenhouses							P.M.
15	Agri-culture	Gene-ral		Land use change	Land use change substitutes the productivity loss of crops with shortening growing seasons and overproduction of wheat by economic value of new urban, recreational land, forest, or land for bioenergy crops						P.M.
16	Agri-culture	Gene-ral	Sea level rise - increase of the salt water seepage in the coastal zones, increase of the salt water intrusion in the main rivers in combination with lower river discharges in the summer	Adaptation strategies to salinization of agricultural land		Activities at the crop level and at the regional/national level:- improving the efficiency of freshwater use in areas subject to salinization- the growing of halophyte cultures- the growing of macro- and micro-algae- the growing of bait for fish in saltwater basins on the land- the conversion of	Irrigation using brackish water: For arable, vegetable and bulb-flower farms in Zeeland and western BrabantIncreases in farm income		Irrigation using brackish water:Increases in farm income:between €127 and €743 per ha per year for irrigation water with chloride concentrations between 300 and 600 mg/lbetween €102 and €722 per ha per year for irrigation water with chloride concentrations between 600 and		P.M.

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
						salted arable land to grassland, nature or sea culture parks- irrigation using brackish water- use or design of salt tolerant crops- changing land use			900 mg/l		
17	Agri-culture	Forest		Increasing genetic and species diversity in forests	Spread risks of extinction of species and to increase the resilience of production forests		Forests are stable and less susceptible to storms and pest and diseases, and have a higher value for nature and recreation				P.M.
18	Agri-culture	Forest		Introduction of southern provenances of tree species and drought resistant species	Reduced natural regeneration of forests due to drought stress in summer						P.M.
19	Agri-culture	Forest		Limiting the import of timber	Northbound spread of pests and diseases from southern regions slowed by restricting import of fresh timber from areas with pests						P.M.
20	Agri-culture	Forest		Retention of winter precipitation in forests	Relieve drought stress during dry summers		Could reduce drought related production losses				P.M.
21	Agri-culture	Forest		Acceptation of changes in species composition in forests			More natural and better adapted forests				P.M.
22	Agri-culture	Fishery		Adjusting fishing quota							P.M.
23	Agri-culture	Fishery		Adaptation of target species and fishing techniques	May help to prevent the loss of productivity as a result of the reduction in current target species. Moving away from the single-species stock assessment and allocations to species groups or assemblages will provide the fishing industry with more flexibility						P.M.
24	Agricult ure	Fishery		Introduction of ecosystem management in fishery	More active and direct participation of the fishing industry The fishing and aquaculture industries have a long-term self-interest in integrated						P.M.

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
					coastal and marine developments, and regularly collect information on the local aquatic climate						
25	Agri-culture	Fishery		Eco-labelling and certification of fish	Demand side of the fisheries sector, aims to raise recognition by policy makers and the public at large of the necessity of sustainable use of fish resources	Certification of fish The process of checking and verifying the sustainable manner of fisheries The advertisement of the certificate to the public					P.M.
26	Agri-culture	Fishery		Reallocation of mussel nursery plots	Avoids loss of productivity Windmill parks - offer the possibility to combine mussel production with the production of electricity		The benefits of mussel growing at € 10.000 per windmill are, however still limited compared to he benefits of the electricity production (€ 700.000 per year including subvention).				P.M.
27	Agri-culture	Fishery		Aquaculture on former grassland	Fish production by means of aquaculture in seawater basins on former grassland may increase the economic value of otherwise inundated grassland						P.M.

Table **19B**

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
1				< 100	low-medium	high, but it requires no action at higher scales			Farmers, contract workers, product boards, retail sector, transport and trading sector			
2				< 50	low-medium	high - requires change in research policies and specific investments at higher scales	Benefits of adaptation options critically depend on market development		Farmers, farmer organisations, product boards, consumers, national government, EU and international, national and local research organizations	National agricultural laws, EU CAP, cross-compliance measures, publicity and the capacity of the agricultural sector to adjust to the changes.	Strong link with biodiversity research.	
3				5-15	low	effect critically depends on management	Benefits of adaptation options critically depend on market development		Ministry of Economic Affairs (sustainable energy management based on biomass production), business sector, energy companies, research institutes, universities, other ministries, and the DEN-, BSIK- and NEO-programs Agricultural and agri-business are important actors as suppliers of biomass		Combination of agriculture with other land functions (water storage, erosion control, soil cleaning or the creation of attractive landscapes) The production of crops for biomass may contribute to the energy and industrial sectors and to the nature sector if combined with other land use functions	Negative effects on biodiversity and food supply are possible (o.a. Reinhard, 2006).
4				> 6	low-medium				Farmers		Positive effects on erosion reduction.	Negative impacts on water quality
5				> 200	low		The increasing difficulty for vegetable growers to meet quality demands given the expected increased frequency of dry summers and extreme rainfall events. The extension of the area of irrigated crops enabled by improved irrigation management may		Farmers, business sector and water boards		Spillover effects to water and nature (benefit through a reduced extraction volume of surface water for irrigation) are expected	

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
							result in an over-production of highly profitable crops, leading in turn to a decrease of their profitability.Automated irrigation management: necessity of the farmer to have a PC with continuous connection to internet					
6				1-5	low		In an open market it will be difficult to achieve self sufficiency	Exploit the Dutch expertise in primary production and subsequent stages in the processing and distribution chain	Farmers and product boards			
7				15-50	low		Bottlenecks in local markets for roughage (due to decreased possibilities for grazing) and upper limits to compensations for blue or green services		Farmers, water boards	Blue services require a legal agreement based on private law between the landowner and the water board	Water storage can be combined with the development of aquatic nature. Smaller inundation risk down stream.	Nutrient rich water could have negative effects on nature values. To have a storage capacity the area should not be wet throughout the year.
8	loss of income due to reduced grass production/quality yet to be examined	€ per ha		P.M.		of regional importance to the peat-grassland area	possibly reduced grass yield and/or quality; yet to be examined	reduce the emission of CO2, reduce the runoff of manure to the surface water by enabling the filling up of ditches, leveling of the soil surface and realising a dryer topsoil	farmers, water boards, local government	subsidies from the national government justifiable due to contribution to reduction of soil subsidence and CO2 emission	nature (through groundwater level regulation).Drained agricultural land will subside faster than surrounding nature, in the long run this will lead to drainage of the (higher situated) natural lands.	drainage of peatland will lead to release of carbon dioxide.
9				P.M.			Due to unknown effects of climate change on weather extremes it is difficult to adjust insurance contributions to increased risks					

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
10	P.M.	P.M.	P.M.	P.M.							effects will strongly depend on local setting and implementation.	effects will strongly depend on local setting and implementation.
11	P.M.	P.M.	P.M.	P.M.					Water boards, farmers			
12	P.M.	P.M.	P.M.	P.M.			Inflexibility of the urban area with regard to changing land use. The presence of expensive infrastructure and buildings. The resistance of farmers to a large scale reallocation of land. The difficulty to buy out landowners due to high land prices The financial losses and societal opposition to recent large infrastructural projects		national government, all land owners involved in land rearrangement	The mandatory rules from the European Union, such as the Water Framework Directive, the Bird Directive and the Habitat Directive	The creation of buffering water basins and the rearrangement of the peat-grassland area would have positive effects on the nature sector by improving the retention of water in natural areas within peat-grassland area.	
13	P.M.	P.M.	P.M.	P.M.								
14	P.M.	P.M.	P.M.	P.M.			Actual implementation depends on the willingness of water boards to allocate space to the greenhouses	Opportunity to combine crop production and aquaculture	Construction company, greenhouse product boards, provincial governments, water boards			
15	P.M.	P.M.	P.M.	P.M.				Opportunity to generate income by carbon credits for reduced CO2 emissions				
16	P.M.	P.M.	P.M.	P.M.			Irrigation using brackish water:Difficulty for farmers to comply with the high quality demands for vegetables and the risk for overproduction of highly profitable crops due to the extension of the irrigated areaHigher					Irrigation using brackish water:Salty diets can pose health risks

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
							rainfall intensities under future climate in combination with the use of brackish water may result in the decay of soil structure					
17	P.M.	P.M.	P.M.	P.M.							Nature and recreation sector Industrial sector through the supply of different timber species	higher costs for wood industry (paper, furniture)
18	P.M.	P.M.	P.M.	P.M.								
19	P.M.	P.M.	P.M.	P.M.			Policy would require a strong control by all actors Uncertain if such a import restriction will be accepted in a globalizing market, seems an unrealistic option.		national government, forest product boards, timber processing industry		Industrial sector	
20	P.M.	P.M.	P.M.	P.M.			For the lower parts of the Netherlands retention of winter precipitation in forests may increase the sensitivity to storm damage		Forest operators, water boards		The nature and recreational sectors in case the forest is used for these purposes The agricultural sector, in case the retention of winter precipitation influences water levels in adjacent farmland	higher costs for wood industry (paper, furniture)
21	P.M.	P.M.	P.M.	P.M.			New timber species may not fit the demands of the timber processing industry		Forest operators, tree nurseries, timber processing industry		Industrial sector, nature and recreation sectors related to the changed forest composition	
22	P.M.	P.M.	P.M.	P.M.							Biodiversity	Fishing industry
23	P.M.	P.M.	P.M.	P.M.			The adaptation of target species requires changes in consumer preference, away from traditional species like cod fish		Fishing industry, national government, European authorities	Changes in target fish species and techniques will have to comply with European legislation and agreements	Trade sector through the changing supply of fish species	
24	P.M.	P.M.	P.M.	P.M.					Fishing and aquaculture		Nature sector	

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
									industries, national government, nature organisations			
25	P.M.	P.M.	P.M.	P.M.				An increasing emphasis on product quality in terms of sustainability of the production process as opposed to quantity and price aspects will help fishermen to cope with scarcer resources and decrease waste of by catches	Retail, fish processing industry, trade			
26	P.M.	P.M.	P.M.	P.M.					For mussel plots in windmill parks: E-connection, mussel growers and administrators of windmill parks.			
27	P.M.	P.M.	P.M.	P.M.								

Annex 5 – Database overview – Nature sector

Table **20A**

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
28	Nature	Nature	Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability). Indirect impacts on the ecosystem (drought, flooding)	Design and implementation of ecological networks (The National Ecological Network - NEN)	Provide space for species, Decrease landscape fragmentation, facilitate migration of species	According to the Dutch Government the network should be completed by 2018 and 12 main ecological links will be realized. Currently some initiatives (e.g. PEEN) have been taken in order to establish a wide network of ecological areas within Europe.	Maintain biodiversity against climate change (by facilitating migration of species and increasing robustness of ecosystem)	Maintain biodiversity and restore ecosystems lost because of previous human impacts on landscape, improve air quality, enhance recreation, carbon sequestration, other regulation functions (e.g. water regulation, soil retention)			>7000
29	Nature	Nature	Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability)	Establishment and management of protected areas	Long term protection of species, contribute to the expansion and robustness of the NEN	The Dutch government has proposed and designated protected areas under the EU Birds and Habitats Directives. The government has announced new Habitats Directive areas.	Maintain biodiversity against climate change	Maintain biodiversity and restore ecosystems lost because of human impacts on landscape, support the development of the NEN, improve air quality, enhance recreation			>3500
30	Nature	Nature	Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability)	Artificial translocation of plant and animal	Provide habitats for species	Only research activities but no concrete actions	Maintain biodiversity against climate change	Commercial use of plants and animals in new areas, other services (e.g. biological control)			P.M.
31	Nature	Forestry	Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability). Indirect impacts on the ecosystem (e.g. drought and flooding)	Afforestation and mix of tree species	Development of new green areas, ensure refuge to several plants and animals, maintain and/or enhance genetic variation in the forest, increase robustness of forest ecosystems	The government plan is to add 40.000 ha of new woodland between 2000 and 2020. New woodland will be developed also in urban areas.	Enhance and maintain biodiversity against climate change	Support the development of the NEN, enhance recreation, carbon sequestration, timber production			>0.43 per ha
32	Nature	Forestry	Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability). Indirect impacts on the	Adjustment of forest management	Increase robustness of forest ecosystems, reduce risk of fire, enhance genetic variation in the forest	At a policy level, the main actions are taken to develop sustainable forestry, but very little is known with regard to adjusting forest management in	Maintain biodiversity against climate change	Reduced risk of fire, carbon sequestration, timber production			P.M.

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
			ecosystem (e.g.: drought, flooding)			order to take into account climate change.					
33	Nature	Agriculture	Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability)	Implementation of effective agri-environmental schemes	Maintain valuable habitats, create more space for species, increase environmental quality, decrease landscape fragmentation	Agri-environmental schemes are supported by the EU and have been implemented since 1992 as a result of EEC regulation 2078/92	Maintain biodiversity against climate change	Maintain biodiversity and restore ecosystems lost because of previous human impacts on landscape, support the development of the NEN, increase environmental quality			P.M.
34	Nature	Water management	Indirect impacts on the ecosystem (e.g. drought, flooding). Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability)	Integrated nature and water management	Protect and/or develop valuable habitats, create more space for nature	Possibilities of integrated water management are currently being considered by the Dutch Cabinet ("Spatial Planning key decision"). According to the policy document "Nature for People, People for Nature" the size and quality of wet landscape in and around the large rivers and large areas of (inland) water will be increased by 2010.	Maintain biodiversity (by increasing robustness of the riverine nature)	Contribute to the implementation of the NEN, counteract flooding and drought, safety, improve the landscape, enhance recreation			P.M.
35	Nature	Water management	Indirect impacts on the ecosystem (e.g. sea level rise, flooding). Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability)	Integrated coastal zone management	Protection of habitats, enhancement of the natural functions of the coastline.	Currently several solutions are investigated	Maintain biodiversity (by increasing robustness of the ecosystem)	Prevent and/or reduce potential ecological damages due to flooding and salt water intrusion, enhance recreation			P.M.
36	Nature	Water management	Indirect impacts on the ecosystem (e.g. drought, flooding). Direct impacts on ecosystem (e.g. changes in distribution, abundance of species, food availability)	Restoration of ecosystems directly depending on water quantity and quality	Conservation and restoration of natural aquatic, wetland and terrestrial ecosystems that depend on water	In 2000 the EU Water Framework Directive (WFD) was published, obliging all European Community member states to implement effective legislations.	Maintain biodiversity against climate change	Increase robustness of the ecosystem, support the development of the NEN, enhance of recreation			P.M.
37	Nature	Society	All direct and indirect impacts	Monitoring nature, interpreting changes and informing	Increase and spread knowledge about the impacts of climate changes on the ecosystem	Several organizations all over the world are supporting monitoring activities (e.g. Dutch Phenological Network)	Identify impacts of climate change on the ecosystem and spread knowledge	Use the acquired knowledge to: select suitable adaptation strategies for nature, identify mitigation strategies, adjust policy plans and improve daily planning of farmers, foresters, medical doctors, tourist organizations, nature lovers, photographers, etc.			>340
38	Nature	Society	All direct and indirect	Educational	Increase public	Education programs delivered	Citizens can	Citizens can contribute to			P.M.

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
			impacts	programs	awareness and involve public citizens in the protection of nature	in schools, institutions, or through radio, television, etc.	contribute to maintain biodiversity	sustainable use of recreation			
39	Nature	Finance	All direct and indirect impacts	Development of financing mechanisms	Involving enterprises and entrepreneurs in the protection of biodiversity	The Dutch government "Agenda for a living countryside" demands support from various stakeholders to contribute to nature development and protection of biodiversity	Increase financial contribution for biodiversity protection against climate change				P.M.

Table 20B

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
28				7000	low	high	Lack of knowledge about how to implement a climate change proof ecological network, lack of space, high costs of land, foregone income from previous land use, uncertainties about the effects, scarce environmental quality within the network, high fragmentation because of motorways, railways and waterways	Protection of biodiversity not only within the Netherlands but also in connection with other European country	Env. organization, researchers, ecologists, policy makers, landowners, farmers, managers, control institutions	Policy measures should give more attention to the role of the NEN in supporting species to adapt to changes in climate. The government demands more involvement of the private sector (landowners and farmers) however the latter did not provide yet a relevant contribution to the implementation of the NEN. In order to increase the robustness of the NEN, actions are also required at a broader, international level.	Nature, health, insurance, recreation	(reduced space) agriculture, infrastructure, industry
29				3500	low	high	Lack of space, high costs of land, foregone income from alternative land use, uncertainties about the effects, the isolation of most protected areas may hamper migration of species	Protection of threatened species	Env. organization, researchers, ecologists, policy makers, landowners, managers, control institutions	There are currently several European and national agreements: European Natura 2000 Network (EU Birds and Habitats Directives), the Flora and Fauna Act and the Nature Protection Act. There is the need to adjust these agreements in order to take more into account climate change.	Nature, health, insurance, recreation	(reduced space) agriculture, infrastructure, industry
30				P.M.		low	High investment costs, uncertainty about the results	Trading opportunities	Researchers, environmental organizations, ecologists, policy makers, managers,	P.M.	Nature, health, insurance, recreation	not known

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
									control institutions			
31				0.43 per ha	low	high	Lack of space, foregone income from previous land use, risk of fire	New opportunities for timber production and recreation	Policy makers, farmers, foresters, timber industries, managers	Lack of policy recommendation that take climate change into account	Forestry, health, insurance, recreation	(reduced space) agriculture, infrastructure, industry
32				P.M.		high	Changes in species composition may not be welcome, lack of knowledge about suitable forest management under climate change's scenarios.	New market opportunities	Policy makers, foresters, timber industries, managers	As above	Forestry	not known
33				P.M.		medium	The procedure to apply for the schemes is very complex and rigid, uncertainty about the results	Development of a more environmental friendly agriculture	EU and Dutch policy makers, farmers, landowners, control institutions	It is necessary to simplify the red tape	Nature, health, insurance, recreation	(reduced space) agriculture
34				P.M.		high	High investment costs, lack of space, storage of extra-water may cause degradation of some ecosystems (e.g. less eutrophic semi terrestrial ecosystems)	Nature can help in counteracting drought and flooding	Policy makers, ecologists, water managers, researchers	Careful planning at a policy level is necessary in order to avoid damages to the ecosystems	Safety, nature, water management, insurance, recreation	Reduced space for alternative land use
35				P.M.		high	Limited knowledge about suitable adaptation strategies for the ecosystems in important areas like the Wadden Sea, lack of space.	Nature can help in reducing risk of flooding and salt water intrusion	Policy makers, ecologists, water managers, researchers	More actions should be taken also at an international level to select suitable strategies to protect important ecosystem (e.g. Wadden Sea)	Safety, water management, recreation	reduced space for other sectors
36				P.M.		medium	Lack of knowledge about restoration plans under climate change's scenario		Policy makers, ecologists, water managers, researchers		Safety, insurance, water management, recreation	
37				340	low	high	The budget available for monitoring programmes is low, It is important to secure long-term commitment and funding to allocate time and funds to carry out monitoring activities with high standard.		Biologists, researchers, nature lovers, photographers, environmental organizations	To increase the effectiveness and quality of the monitoring programmes and to secure long-term commitment is necessary to allocate funds.	Forestry, health, recreation, agriculture	
38				P.M.		high	Some citizens may have resistances (e.g. not believing in climate change) and may be difficult to stimulate and enroll them in the protection of the environment	Simplify the life style and way of living of people	Environmentalists, teachers, journalists, citizens, etc.		Education, nature	

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
39				P.M.		high	It is not easy to identify what types of environmental services could be financed and whether a market could be created for these services	Development of a "green" market, which can provide additional benefits to the environment and to the economy	All types of stakeholders (e.g. entrepreneurs, land users, NGO's, insurance companies) that could benefit from "payment/reward for ecosystem services"	All types of stakeholders should be involved in the implementation of new financing mechanisms, whereas the government will act as a facilitator	Nature, marketing, recreation	

Annex 6 – Database overview – Water sector

Table **21A**

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
40	Water	Spatial concepts	Prolonged drought Locally excessive precipitation peaks Local water nuisance	More space for water: a: Regional water system b: Improving river capacity	More emphasis on spatial retention and storage of fresh water before discharge towards sea; lowering of risks of water-caused damages for acceptable costs; less local damages.	"More space for water"; "Water management 21st century" more efficient use of existing storage and discharge capacity by improving operational management of polders; expansion of storage capacity where necessary (e.g. in polders) disconnecting of draining ditches from main hydrological system + increase amount of ditches				specify benefits on different levels (individual, local, regional) and different disciplines (socio-economic, societal, spatial, financial, emotional)	P.M.
41	Water	Spatial concepts	Local water nuisance	Risk based allocation policy	spatial allocation of compartments for different use intensity over territory	better spatial policy, based on risk management, i.c. no constructions on lowest, most vulnerable parts	maintains investors-friendly conditions		risk-analysis: risk = sum(probabilit y*effect)		P.M.
42	Water	Spatial concepts		Moving powerplants to coast (cooling water)							P.M.
43	Water	Spatial concepts		Spatial planning of locations for powerplants (nuclear in particular)							P.M.
44	Water	Spatial concepts		Compartmentation of low-lying parts of the Netherlands							P.M.
45	Water	Spatial concepts		Allow transgression of sea in wide dune areas, allow wash over of dikes							P.M.
46	Water	Spatial concepts	Sea level rise	Widening the coastal defence area (in combination with urbanisation and nature)			increase of safe feeling for citizens decrease in stress/disquiet among people with respect to inundations willingness to pay generally proves to exceed the costs necessary to provide this				P.M.

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
							feeling of safety				
47	Water	Spatial concepts		Reconnecting water systems in Delta area (e.g. Volkerak Zoommeer and Oosterschelde)							P.M.
48	Water	Spatial concepts		Fresh water storage to flush brackish water out during dry periods							P.M.
49	Water	Spatial concepts		Higher water level IJsselmeer							P.M.
50	Water	Spatial concepts		Maintain higher water table to prevent salt water intrusion							P.M.
51	Water	Spatial concepts		Relocation of fresh water intake points							P.M.
52	Water	Spatial concepts		Reclamation of (part of) southern North Sea	decrease of inundation risk for lowest parts near sea		increase of safety low-lying Netherlands; continuation current land use generally possible, including further options for development				P.M.
53	Water	Spatial concepts		Abandoning of the whole of low-lying Netherlands	strictly terrestrial forms of land use restricted to highest eastern parts; increase in safety; lowering the threat of intrusion by the sea		enhancing safety; adapting spatial use to changing hydrological conditions; opportunities for very large-scale dynamic wetland nature in low parts of Netherlands				P.M.
54	Water	Technolog ical solution	sea level rise	Increase sand suppletions along coast	compensates for sand losses from sea defence due to increase of erosion caused by sea level rise		maintenance of legally determined safety level for coastal defence compensation for soil subsidence/ sea level rise with respect to dynamic sand banks and intertidal mudflats in Wadden Sea				P.M.
55	Water	Technolog ical solution	sea level rise	Re-enforcement of dikes and dams, including 'weak spots'	weakest and narrowest stretches of coastal sand dunes are re-enforced; there have been eight such spots identified		lessened risk of breakthroughs from sea possible opportunities for combination of small-scale nature development, e.g. salt water - freshwater transitions in sand dune area				P.M.

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
56	Water	Technological solution	Local water nuisance	Adapted forms of building and construction	floating buildings, suburbs or urbanisations; constructing without cellars or crawl spaces; installation of roof gardens on houses or industrial plants; raising infrastructure, ports, industries and urbanisations	maintains investors-friendly conditions					P.M.
57	Water	Technological solution		Adaptation of highways, secondary dikes to create compartments							P.M.
58	Water	Technological solution		Protection of vital objects							P.M.
59	Water	Technological solution		Protection of vital infrastructure							P.M.
60	Water	Technological solution	Increase in precipitation	Enhancing capacity of sluices and weirs							P.M.
61	Water	Technological solution	Sea level rise	Artificial reefs along the coastline & development nature conservation values			increase of safe feeling for citizens decrease in stress/disquiet among people with respect to inundations willingness to pay generally proves to exceed the costs necessary to provide this feeling of safety				P.M.
62	Water	Technological solution		De-salinization							P.M.
63	Water	Technological solution		Reduction salt water tongue							P.M.
64	Water	Technological solution		Stimulate economic activity in other parts (eastern and northern) of the Netherlands							P.M.
65	Water	Social, policy		Risk management as basic strategy							P.M.
66	Water	Social, policy		Evacuation plans							P.M.

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
67	Water	Social, policy		Creating public awareness	Dutch citizens have become more aware of their vulnerability with respect to water-related threats; they may be more disposed to comply with adaptation strategies; they may become more creative in developing strategies and in finding water linked solutions	Social learning, "vliegwieleffekt"	Increase of safety feeling for citizens decrease in stress/ anxiety among people with regards to inundations				P.M.
68	Water	Social, policy		New institutional alliances	All public and private stakeholders and parties otherwise concerned are entitled to execute the right act in a more flexible and interactive way in response to climate-related changes. But for the sake of common interest the provincial councils are endowed with the right to decide upon aims and targets, planning, coordinative management and recompensation schemes. The national government will continue to be responsible for setting up integrated knowledge of the water system, for international agreements on water quantity and quality, for maintenance and equipment of the main and internationally linked waterway network and for priority setting encompassing all water authorities.	Tell the true story, don't make a soap show of it Don't start talking about tax increase, but start discussion on a balanced approach: who has to carry the burden: the state representing the public interest, the tax payer or each a part of the bill?	Willingness to pay generally to provide this feeling of safety depends largely on the acknowledged reputation of public authorities responsible for water management				P.M.
69	Water	Social, policy		Private insurances against inundations and/or drought related damages	leveling out of remaining risks		security of households & companies; spread of costs damage reduction by loss-reducing incentives			risk-analysis: risk = sum(probability*effect)	P.M.
70	Water	Social, policy		Reduce wastewater discharge during drought periods							P.M.

Table 21B

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioriti sation	Barriers	Opportunities	Actors	Institution al aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
40				a. 19000 b. >7000	Medium				ministries of V&W, LNV, VROM, Water Boards, provinces, municipalities, agricultural organisations, nature managers, nature-NGOs Water Boards, municipalities, provinces			
41				0 - 10	Medium							
42				50	Low							
43				P.M.								
44				100 - 1000	low							
45				250	low							
46				1000	low							
47				200 - 400	Medium							
48				0								
49				>500								
50				P.M.								
51				50 - 100	Medium							
52				1000 - 5000	low							
53				P.M.								
54				750-1500	medium				RWS, LNV, coastal provinces, recreation-NGOs, nature NGOs			
55				>5000	Low				RWS, LNV, coastal provinces, recreation-NGOs, nature managers, nature NGOs			
56				P.M.								
57				P.M.								
58				100 - 1000	Low							
59				100 - 1000	Low							
60				> 250	Medium							
61				500 - 40000	Medium							
62				P.M.								
63				none								
64				P.M.								
65				P.M.								
66				P.M.								
67				P.M.				Public initiative and action, hearings	Citizens, municipality (1 desk for all public authorities), Minister of Water Management (V&W)		Agriculture, housing, recreation	
68				P.M.				Spatial planning and new planning guidelines may	Ministries, municipalities, provinces, water boards, farmers & citizens, urban regions, EU,		Agriculture, nature, recreation, housing,	

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioriti sation	Barriers	Opportunities	Actors	Institution al aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
								provide opportunities for improving safety conditions and avoiding safety risks	universities		transport	
69				P.M.					insurance branche, authorities		less costs for public sector; more risks for private insurance companies	
70				P.M.								

Annex 7 – Database overview – Energy & Transport sector

Table **22A**

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
71	Energy & Transport	Energy	Insufficient water that can be used for cooling purposes	Adapt regulations such that a higher discharge temperature is allowed	There may be a negative effect on ecosystems due to higher surface water temperatures.	The Commissie Integraal Waterbeheer has developed a new, more flexible methodology to deal with discharge of cooling water during hot summers.	Cooling water can be discharged, resulting in a more stable supply of electricity and avoiding damage relating to not delivered electricity		The value of not delivered electricity is approximately 30 to 50 €/ MWh (Ploumen and Van Rijen, 2004) The value of 10% not delivered electricity has a bandwidth of 6.6 - 11 M€	Avoided damage costs of power cuts Value of not delivered electricity	6.6 - 11
72	Energy & Transport	Energy	Insufficient water that can be used for cooling purposes	Sluices	The structure of the sluices is organised in such a way that there is sufficient cooling water available for electricity plants in dry periods.	Construct sluices and enhance the capacity of existing sluices	Sufficient cooling water is available in dry periods, providing more stable supply of electricity and avoiding damage relating to not delivered electricity		The value of not delivered electricity is approximately 30 to 50 €/ MWh (Ploumen and Van Rijen, 2004) The value of 10% not delivered electricity has a bandwidth of 6.6 - 11 M€	Avoided damage costs of power cuts Value of not delivered electricity	6.6 - 11
73	Energy & Transport	Energy		Lowering the discount factor for project appraisal to take predicted long-term effects of climate change into account (place a higher weight on these effects)	Future climate change effects are taken more into account when using a lower discount rate, thus projects that are generally being viewed as more sustainable in the long run, become more attractive.	The government will need to decide on a new discount rate to use for project appraisal	Projects for which benefits are not expected in the short, but in the long run, which are usually projects that take long-term projected environmental effects into account will become more attractive when using a lower discount rate	These type of projects are usually viewed as being more sustainable in the long run and put greater weight on environmental and natural concerns.	P.M.		P.M.
74	Energy & Transport	Energy	Severe winds may increase the risk of damage to wind turbines	Building stronger wind turbines	Adapted to avoid damage due to strong winds; generate more sustainable energy	Technical development of stronger wind turbines	Less loss in energy production due to higher wind speeds. Avoidance of purchasing carbon emission permits	Less demand for electricity from power plants, less need for cooling water and problems with discharging cooling water	P.M.	Avoided damage cost of strengthening existing wind turbines. Valuing at the market-price of carbon emission permits.	P.M.
75	Energy & Transport	Energy	Increased demand	Construct buildings differently in such a way	There will be less need for airconditioning or	Spatial adjustment and technical	Less demand for cooling/heating		P.M.	Difference between energy	P.M.

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
			for airconditioning and heating	that there is less need for air-conditioning/heating	heating	development of these new type of buildings				demand of a conventional house and a house built on the principles of passive house technology Valuing at the market-price of providing airco and cooling systems	
76	Energy & Transport	Energy	Damage to overhead electricity transmission due to wind storms	Constructing more stable overhead electricity transmission poles	Avoid power cuts and damage to houses/infrastructure	Technical development of stronger overhead electricity builds	Avoided damage due to power cuts and avoided danger of electricity poles coming down during storms.		P.M.	Avoided damage costs of power cuts and infrastructure	P.M.
77	Energy & Transport	Energy	Mitigation may affect production processes	Adapt to mitigation strategies		Stimulate demand of energy-saving products and increase consumer awareness to save energy	Reduce energy demand. Avoidance of purchasing carbon emission permits				P.M.
78	Energy & Transport	Energy	Increased wind speeds	Improved opportunities for generating wind energy	Generating more sustainable energy; increased flexibility as where to place wind turbines as due to increased wind speeds more locations become profitable	Constructing new wind turbines	Contribute to sustainable energy generation, less demand for electricity generated by power plants, avoiding purchase of carbon permits		P.M.	Valuing at the market-price for carbon permits	P.M.
79	Energy & Transport	Energy	Increased hours of sunshine	Improved opportunities for generating solar energy	Generating more sustainable energy	Development of solar energy farms	Contribute to sustainable energy generation, less demand for electricity generated by power plants, avoiding purchase of carbon permits		P.M.	Valuing at the market-price for carbon permits	P.M.
80	Energy & Transport	Energy	Insufficient water that can be used for cooling purposes	Planting of biomass crops	Change in land use		Contribute to sustainable energy generation, less demand for electricity generated by power plants, avoiding purchase of carbon permits		2005: reduced CO_2 eq. emission of 0.4-0.54 Mton/yr 2010: reduced CO_2 eq. emission of 1.3-1.7 Mton/yr	Valuing at the market-price for carbon permits	P.M.
81	Energy & Transport	Energy	Insufficient water that can be used for	Development of cooling towers	Decrease in landscape values; increased noise nuisance, avoided damage to freshwater	Construction of the cooling tower	Stable supply of electricity	Avoided damage to ecosystems	The value of 10% not delivered electricity has a bandwidth of 6.6 - 11 M€	Avoided damage costs of power cuts	6.6 - 11

	Sector	Sub-sector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
			cooling purposes		ecosystems						
82	Energy & Transport	Transport	Increased wind speed leading to more accidents	Development of more 'intelligent' infrastructure that can serve as early warning indicator	Better informed and therefore prepared drivers	Increase knowledge on new types of infrastructural and vehicle design	Less road accidents		P.M.	Avoided damage to infrastructure and less traffic deaths	P.M.
83	Energy & Transport	Transport	Increased wind speed leading to less days of fishing at sea Dry summers lead to less transportation possibilities over rivers	Improvement of vessels	Avoid damage to the fishery sector Avoid damage to inland transportation over rivers	Technical construction of safer vessels Construction of lighter vessels	Economic gains for fishermen Avoided economic damage during dry periods		P.M.	Valuing at market-prices of fish Avoided economic damage (estimated at 10 - 20% of total turnover during dry summers)	P.M.
84	Energy & Transport	Transport	Flooding leading to a higher level of corrosion of vehicles, trains and infrastructure	Change modes of transport and develop more intelligent infrastructure	Possibly more air traffic or transport over water	Increase knowledge on new types of infrastructural and vehicle design	Safer and more reliable (public) transport	Relief pressure of congested road traffic	P.M.	Avoided costs of delays	P.M.
85	Energy & Transport	Infrastructure	Storm damages to infrastructure	Increase standards for buildings as to make them more robust to increased wind speeds	Improved robustness to increased wind speeds	Increase knowledge on vulnerability of buildings to windstorms; development of these standards	Reduce vulnerability Avoided damage to infrastructure		Use the model developed by Dorland et al., adjusted to current wind speed predictions and economic growth rate scenarios	Use the model developed by Dorland et al., adjusted to current wind speed predictions and economic growth rate scenarios	P.M.

Table 22B

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
71	Damage to ecosystems (Non-market valuation)	P.M.	P.M.	P.M.	n.a.	high	Increasing the maximum tolerable temperature of cooling water discharge would be relatively easy to implement, a possible barrier could be severe societal opposition due to the possible negative effects on ecosystems	A 'quick fix' meaning that it is a relatively easy to implement solution to deal with severe electricity supply constraints during hot periods	National government; energy generating companies; nature organisations	Regulation on cooling water discharge needs to be adjusted	The industrial, agricultural and service sector will all benefit from a stable power supply	Ecosystems may experience negative effects: species may not be able to survive in warm water; increase of algae bloom
72	Maintenance costs			P.M.					National government			
73	none	n.a.	none	0	n.a.		There is a risk that when lowering the discount factor, projects become viable that may not be warranted. There is a risk for loss of capital.	Implementation of sustainable projects	The national government; private companies that implement these projects	It may be difficult to justify using a lower discount factor when long-term future effects remain uncertain, and therefore difficult to implement	The ecosystem sector may benefit as this will enhance the chance of having more sustainable projects being approved. Landscape values may be enhanced which may also affect housing prices.	The industry may experience negative effects, for example less roads or dikes may be built
74	P.M.		Strengthening existing onshore wind turbines: 87.5 - 125 M€ Strengthening existing offshore wind turbines: 2.9 - 4.6 M€	3 - 125	n.a.	high		Generate more sustainable energy and relieve the pressure of possible limitations in cooling water supply	The national government; electricity generating firms; private companies that construct these turbines			
75			The costs of isolating existing houses to reduce the demand for heating and airconditioning - 23349 M€ Construction of a passive house -	23000	low	high	Knowledge constraint on how to develop these buildings		The national government, local governments, (Technical) Universities, Spatial Planning experts			

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
			4,7% higher building costs compared to conventional houses									
76				P.M.	n.a.	high			The national and local governments, private companies constructing the electricity poles			
77				P.M.	n.a.				National government			
78	Decrease in landscape/scenic values		The NPV for onshore wind energy range from 1026 - 7795 M€. The NPV for offshore wind energy range from 25733 - 268116 M€.	P.M.	medium	high to comply with policy on sustainable energy production			The national and local governments, private sector, nature organisations			It may reduce landscape/scenic values leading to economic losses of recreation areas, housing prices
79			The NPV for solar energy (not yet corrected for the existing solar energy generated) ranges from 439040 - 907970 M€	P.M.	low	high to comply with policy on sustainable energy production	Uncertainty about whether hours of sunshine will really increase		National government manufacturers of solar energy, consumers	Provision of subsidies to make it more attractive to buy solar energy		
80				P.M.	n.a..	high to comply with policy on sustainable energy production	Competition on land that can be used to produce other (food) crops	This adaptation option can complement mitigation strategies	National government, farmers, owners of biomass plants	The option contributes to meeting the demands of the EC biofuel Directive	Agriculture; production of biomass crops may generate higher returns than producing other crops	Due to increased land use competition food prices may rise
81			Costs range from 5 - 10 cooling towers, amount 275 - 550 M€	275 - 550	low	high to prevent electricity shortages similar to summer 2003	House-owners may object against the building of cooling tower in their vicinity	Generates a stable supply of electricity without compromising ecosystem values	National government, local governments, society	Cooling towers need to comply with noise regulations	Ecosystems and the (fresh) water sector	Landscape values may decrease leading to a drop in house prices and therefore to economic losses
82				P.M.	n.a.	high	High investment costs and a long planning horizon	Development of highly innovative and safe infrastructure	The national government, universities, spatial planning experts, private companies involved in the technical development			

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
83				P.M.	n.a.				Fishery sector, companies building vessels			Possible danger of over-fishing and hence a negative effect on marine ecosystems
84				P.M.	n.a.		Long planning horizon and high investment costs	Relief pressure of congested road traffic		Requires huge changes in spatial planning	More reliable public transport will have a positive effect on the tourist sector as more people will be inclined to go on a journey, leading to economic gains	
85				P.M.	n.a.				National government, research institutes, construction companies	Requires changes in building laws		

Annex 8 - Database overview - Housing & Infrastructure sector

Table **23A**

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
86	Housing & Infrastructure	Spatial	Flooding due to sea level rise and river discharge	Design spatial planning – construct new housing and infrastructure	Less damage to houses and infrastructure	Design spatial planning	Avoided economic damage Less people die due to flooding				P.M.
87	Housing & Infrastructure	Spatial	Increased impact of storms and heat stress in city areas	Make existing and new cities robust - avoid 'heat islands', provide for sufficient cooling capacity	Sufficient cooling capacity in cities	Installing cool or green roofs planting trees and vegetation	Benefits from green roofs: reduction of stormwater flow, sever overflow, improved airquality, reduced buildings energy consumption		For the city of Toronto, the initial cost savings are 225 M€, the annual cost savings are 26 M€		> 225
88	Housing & Infrastructure	Design	Increased demand for airconditioning and heating	Design houses with good climate conditions (control) – 'low energy'	There will be less need for airconditioning or heating	Spatial adjustment and technical development of these new type of buildings	Less demand for cooling/heating				P.M.
89	Housing & Infrastructure	Water management	Excessive rainfall	Water management systems: revision of sewer system	Sewer system can cope with excessive rainfall	Revision of system	Less damage due to flooding of the sewer system				P.M.
90	Housing & Infrastructure	Water management	Due to the large percentage of hard surface in cities, the limited storage and sewer treatment capacity, excessive rainfall leads to flooding	Water management systems: options for water storage and retention in or near city areas	Less problems with flooding in cities	Create storage and retention areas	Less damage due to flooding	Water storage can be used as cooling water, or recreational purposes.			P.M.
91	Housing & Infrastructure	Water management	Excessive rainfall	Water management systems: emergency systems revision for tunnels and subways	Less delays due to closing of tunnels and subways	Install emergency system, construction of tunnels and subways	Less economic damage due to delays			Avoided costs of delays	P.M.
92	Housing & Infrastructure	Design	Flooding	New design of large infrastructure	Opportunity to reduce the risk of flooding	During the design of large infrastructure taking into account the impacts of climate change	Less economic damage due to flooding of important infrastructure (such as highways and train tracks)	New tracks and highways can be build on dikes, thus becoming part of the compartmentation of an area to reduce the risk of flooding			P.M.

Table 23B

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
86				P.M.	n.a.				National government, construction companies, architects			Competition with nature sector in terms of land availability
87	Yearly maintenance costs		For the city of Toronto: the costs of green roof per m2: 54 - 65 €	54 - 65 Euro per m2	medium				National government, local government			
88				P.M.	n.a.		Knowledge constraint on how to develop these buildings		National government, construction companies, architects			
89			Modernisation of the sewer system demand an investment of 3000 - 5000 M€ The replacement value of 100000 km public sewer system is 58000 M€	3000 - 5000	low				National government, local government			
90			Urban water system	3300	low				National government, waterboards			
91				P.M.	n.a.				National government			
92				P.M.	n.a.				National government, architects			

Annex 9 - Database overview - Health, Recreation & Tourism sector

Table **24A**

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
93	Health		Increase demand for airconditioning	Improved air conditioning in nursery and hospitals	Improved climate in hospitals and nursery homes		Less mortality due to heat waves				P.M.
94	Health		Increased spread and occurrence of climate related diseases	Measures for preventing climate related diseases	Control the spread and occurrence of climate related diseases	Prevention measures to control the spread and occurrence	Less mortality caused by climate related diseases				P.M.
95	Health		Increased spread and occurrence of climate related diseases	Improvement of health care for these specific diseases	Improved health care		Less mortality				P.M.

Table 24B

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
93	Maintenance of airconditioning systems			P.M.	n.a.				National government			
94				P.M.	n.a.				National government, research institutes			
95				P.M.	n.a.				National government			

Table 24C

	Sector	Subsector	Impacts of climate change	Adaptation option	Effects of adaptation option	Actions to apply the option	Direct **benefits**	Indirect **benefits** (qualitative description)	Monetary **benefits** (unit euro)	Methodology to estimate monetary **benefits**	**Net Present Value of Benefits for 2006 (million euro)**
96	Recreation & tourism		Increased number of tourists due to change in climate	Design infrastructure for recreation and tourism – coastal areas	Costal areas are climate robust and can stand sea level rise	Revision of regulations and guidelines	Increased economic activity due to increased tourism				P.M.

Table 24D

	Other **costs**	Unit euro	Total Other **costs**	**Net Present Value of Costs for 2006 (million Euro)**	Reliability (high-medium-low)	Prioritisation	Barriers	Opportunities	Actors	Institutional aspects	**Effects on other sectors** Spillover - positive effects on other sectors	**Effects on other sectors** Spillover - negative effects on other sectors
96				P.M.	n.a.				Tourism industry, national government		Synergy - tourism can favour nature values	Competition - rapid increase of tourism can decrease biodiversity

Colofon

Dit onderzoek is mogelijk gemaakt door bijdragen van de BSIK programma's Klimaat voor Ruimte, Leven met Water en Habiforum.

Klimaat voor Ruimte: KvR 004/2006 Adaptatiestrategiën
Leven met Water: P2054
Habiforum: H-C205

Auteurs: E.C. van Ierland, K. de Bruin, R.B. Dellink en A. Ruijs
Environmental Economics and Natural Resources, Wageningen UR
Met bijdragen van: L. Bolwidt (RIZA), A. van Buuren (EUR), J. Graveland (RIKZ), R.S. de Groot (WUR), P. Kuikman (Alterra), E.E.M. Nillesen (WUR), M. Platteeuw (RIZA), S. Reinhard (LEI, Leven met Water), V.C. Tassone (WUR), A. Verhagen (Plant Research International), R. Roetter (Alterra) en S. Verzandvoort-van Dijck (Alterra)

Fotografie: Vincent Basler, Wilma Manders en Habiforum
Ontwerp: insandouts communication and design

ISBN-10 90-376-0504-4
ISBN-13 978-90-376-0504-4

December 2006

klimaat voor ruimte
leven met water
Habiforum
landbouw, natuur en voedselkwaliteit
Ministerie van Economische Zaken
Ministerie van Verkeer en Waterstaat
Rijkswaterstaat
VROM

klimaat voor ruimte

leven met water

Habiforum

2010