



PBL Netherlands Environmental  
Assessment Agency

# Adaptation to climate change in the Netherlands

Studying related risks  
and opportunities





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Anchors for the Dutch National Adaptation Strategy

**Adaptation to climate change in the Netherlands – Studying related risks and opportunities**

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# Main findings

## Climate risks and adaptation deficit are increasing

The climate is changing worldwide, therefore also in the Netherlands. Temperatures are going up, it is getting dryer and heatwaves are occurring more frequently, while precipitation events are becoming more extreme and more intense. And the Netherlands, similar to many other countries, is also vulnerable to climate change.

With its new Delta Programme, the Dutch Government has made an important step forward towards national climate-resilience. However, the programme's adaptation strategy does not cover all the risks and opportunities for the Netherlands in relation to climate change; instead, it focuses mainly on flood protection, freshwater supply, and spatial adaptation to urban flooding and urban heat stress.

Our analyses show that, in addition to the Delta Programme, more attention is needed for the impact of climate on the Dutch economy, population and nature. The Netherlands is a well-organised country, but it is largely still attuned to the old climate.

The changing climate calls for adaptation in many sectors and on many scales. Without adequate adaptation measures, the 'adaptation deficit' will only increase over the coming decades.

## Society's increasing complexity also increases its vulnerability

The climate is not the only thing that changes; society is also changing and this has various consequences for the Netherlands' vulnerability to climate change. For example, both ageing and the increasing population density within cities will result in greater vulnerability to heat stress and infectious diseases.

An important trend is the increasing 'electrification' of society; citizens as well as public services and companies are becoming ever more dependent on the power grid and ICT networks. Moreover, these networks are becoming increasingly interwoven, also on an

international scale. Thus, if, for example, heavy rains or heatwaves cause a disruption in the power grid at a certain location, the consequences of this interrupted supply may be felt far beyond national borders. Such weather extremes are expected to increase in frequency and magnitude over the coming decades.

The power supply also calls for additional attention for another reason. The fuel mix used in power generation is changing in the decades to come; the share of renewable energy, such as wind and solar power, will grow. These resources will reduce the power supply's vulnerability to, for example, decreased availability of cooling water when river water levels are low, but may also cause vulnerability to increase in the case of wind energy, which is sensitive to weather extremes such as prolonged periods of no wind.

## Urgency on a national scale: climate resilience of critical infrastructure

In addition to the Delta Programme, the main points of urgency for adaptation to climate change concern investments in critical infrastructure and networks, i.e. the power grid and ICT and transport, and in spatial development. This is related to the social importance and the long lifespan and lifecycle of these infrastructures and the related low flexibility for adjusting them to climate change. Therefore, the choices and investments that will be made over the coming years, in part, determine the degree of climate resilience of the infrastructure and networks in the longer term.

Ensuring that the national and international infrastructures – power, ICT and transport – are climate resilient is the responsibility of the national government. This requires cooperation of the companies that manage these critical networks and infrastructural nodes – also on a European scale.

Awareness and knowledge of all possible climate effect is essential, for critical infrastructure to become more climate-resilient. The government can play a stimulating and coordinating role, at this point. For example, by having stress tests conducted in collaboration with power, ICT and transport companies. For the power grid, this could also be an effective instrument, on a north-western European scale, but possibly also for transboundary ICT and transport networks. Stress tests can be used to determine the stability and climate resilience of the power grid and other networks. Conducting these joint stress tests periodically could provide up-to-date overviews of the climate risks over time, which may also be used for determining whether additional measures should be taken and by whom. The government may use this knowledge to make binding agreements with the other authorities, companies and neighbouring countries involved to increase climate resilience.

## Urgency on regional and local scales; climate resilience of spatial development

Looking at the most urgent climate risks reveals that provinces, municipalities and water boards also have the task of seriously addressing climate resilience in their spatial planning. In recent years, the national government has made considerable investments in knowledge development. Now it is time to utilise this knowledge in projects of implementation on regional and local scales. Here, the national government's role could be one of facilitation, coordination and stimulation. It could, for example, share the experience obtained from pilot project more actively with other authorities, businesses and NGOs. Agreements could be made with provinces, municipalities and the business community about making road infrastructure, regional and local power grids and ICT networks more robust against climate impacts. Agreements with municipalities may involve urban redevelopment projects to reduce the impacts of urban heat. Rather than being compulsory, such agreements should rather be aimed to create a new, innovative playing field for companies and project developers. If, in practice, this would prove to have an insufficient effect, then regulation could be implemented to secure robustness requirements in spatial development.

## Opportunities for timely anticipation: connect to policy agendas and planned investments

Climate change adaptation currently is not always incorporated in policy agendas and development projects. And yet they do offer opportunities for affordable climate adaptation. Such opportunities arise in the preliminary process of development, during regular maintenance work, when critical infrastructure needs to be replaced, and when investments are made in urban housing development and redevelopment. Opportunities that are missed will take dozens of years to present themselves again, on all levels; nationally, regionally and locally.

It is also important that climate adaptation is awarded a more prominent position in foreign policy, such as in the fields of international safety, agriculture and urban development. Dutch companies, researchers and government officials are known abroad for their expertise in the field of water safety. This expertise has added value when it is coupled to other spatial challenges, such as those with respect to climate smart agriculture, water availability and biodiversity conservation.



# Introduction

The climate is changing and all countries will need to adjust to that fact. The Dutch Cabinet plans to have a national adaptation strategy in place by 2016. One of the main building blocks of this strategy is a report containing all the available knowledge on climate effects, providing the foundation for adaptation (PBL, 2015a). The current document describes the outline of that report.

## Climate change: unavoidable

All over the world, the realisation is growing that climate change is unavoidable – even if we would substantially reduce greenhouse gas emissions today. Global warming is continuing, sea levels will continue to rise and precipitation patterns continue to change. This means that the world will have to adjust to the expected changes (IPCC, 2014a,b).

In 2014, the Royal Netherlands Meteorological Institute (KNMI) updated its four climate scenarios for the Netherlands. Under all scenarios, the Dutch winters will become less cold and considerably wetter (Figure 1; KNMI, 2014). The summers will become warmer and probably also dryer. The duration and intensity of heat waves will increase, as will the intensity of extreme precipitation events in summer; hailstorms and thunderstorms will become heavier. And prolonged periods of drought will increase the risk of wildfires.

## Consequences for the Netherlands

The Dutch Cabinet plans to publish a National Adaptation Strategy (NAS) in the first half of 2016 (IenM, 2013). Starting point for the strategy is to address all the sectors that may be affected by climate change; from transport infrastructure to public health and nature. The European Commission has called for such a wide-ranging approach and has requested that all Member States have their adaptation strategies ready no later than by 2017 (EC, 2013). The need for a comprehensive approach of climate adaptation is emphasised in reports by the Netherlands Court of Audit and PBL (Netherlands Court of Audit, 2012; PBL, 2013b).

**Figure 1**  
**Changes in the Dutch climate, according to KNMI'14 climate scenarios**

	<b>General changes</b>	<b>Scenario differences and natural variations</b>
<b>Temperature</b> 	<ul style="list-style-type: none"> <li>• Temperatures will continue to rise</li> <li>• Mild winters and hot summers will occur more often</li> </ul>	<ul style="list-style-type: none"> <li>• Temperature differences differ between the four scenarios</li> <li>• Changes by 2050 and 2085 will be greater than the natural variations on a 30-year timescale</li> </ul>
<b>Precipitation</b> 	<ul style="list-style-type: none"> <li>• Precipitation and extreme precipitation in winter will increase</li> <li>• The intensity of extreme rainfall in summer will increase</li> <li>• Hail and thunderstorms will become heavier</li> </ul>	<ul style="list-style-type: none"> <li>• More dry summers in two of the four scenarios</li> <li>• Natural variety in precipitation is relatively large, which causes fewer differences between the scenarios</li> </ul>
<b>Sea level</b> 	<ul style="list-style-type: none"> <li>• Sea levels will continue to rise</li> <li>• The rate of sea level rise is increasing</li> </ul>	<ul style="list-style-type: none"> <li>• The rate of sea level rise strongly depends on global temperature increases</li> <li>• No differences between scenarios with different air mass circulation patterns</li> </ul>
<b>Wind</b> 	<ul style="list-style-type: none"> <li>• Changes in wind speed are small</li> </ul>	<ul style="list-style-type: none"> <li>• Westerly winds occur more often in two of the four scenarios</li> <li>• The wind and storm climate shows a large natural variety</li> </ul>
<b>Fog</b> 	<ul style="list-style-type: none"> <li>• The number of days of fog will decline and visibility will increase further</li> <li>• The amount of sunlight close to the earth's surface will increase slightly</li> </ul>	<ul style="list-style-type: none"> <li>• Natural variations differ for the various climate variables</li> </ul>

Source: KNMI 2014

*The KNMI'14 scenarios present four different futures for the Dutch climate. There are changes in climate that occur in all four scenarios, but there are also natural variations and differences between the scenarios.*

With its Delta Programme 2014, the Dutch Government already has developed important steps for three vital elements: protection against flooding, drinking water security of supply, and managing extreme heat or rainfall in cities (also see Text box 1).

The Ministry for Infrastructure and the Environment has requested PBL Netherlands Environmental Assessment Agency to gather the available knowledge, in addition to the Delta Programme, on possible other climate effects and indicate the entry points for adaptation strategy. The Ministry requested that attention would be paid not only to the climate effects within the Netherlands, but also to any consequences for the Netherlands related to climate effects elsewhere in the world (PBL, 2015d). The current document provides an outline of the resulting report.

## Reader

Knowledge on climate change is vital for drafting an adaptation strategy, but equally essential is that on societal developments and the country's governance system (Figure 2). These three components are addressed individually, in the following chapters. Chapter 2 describes the main climate effects and related risks within the Netherlands. Chapter 3 elaborates on the expected societal developments, such as those in socio-economic and technological areas. Chapter 4 shows the changing trend in governance, indicating a shift in the roles of national government and society. With these developments in mind, Chapter 5 derives the most urgent adjustments needed in the Netherlands. Finally, Chapter 6 presents a number of important foundations for the Dutch adaptation strategy.

### **Text box 1. Delta Programme**

The Netherlands is a low-lying country, vulnerable to flooding and other water-related risks. It needs to prepare for the impact of rising sea levels, land subsidence, reduced water availability and rising temperatures. However, this not only concerns the future; flood protection already is inadequate in some areas, today.

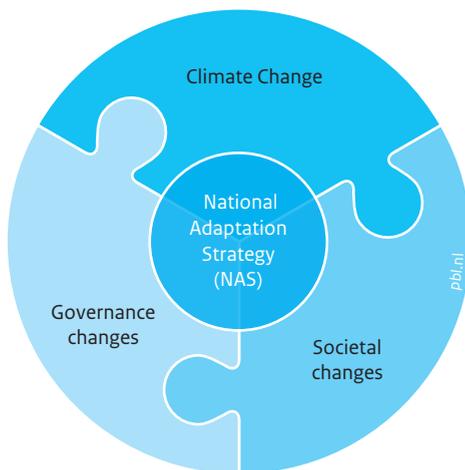
The government intends to protect the Netherlands against high water and secure a sufficient supply of fresh water now and in the future. For this reason, the Delta Programme is planning ahead, in collaboration with various authorities and other organisations. The plans are being drawn up under the direction of the Delta Programme Commissioner. The Delta Programme focuses on three issues:

- Setting new water safety standards.
- More reliable availability of fresh water for agriculture, industry and nature.
- More climate-proof and water-robust spatial planning.

The Delta Programme 2015 presents the strategic decisions on the above topics (the 'delta decisions'), based on a participative research and decision-making process between 2010 and 2014.

<http://www.government.nl/issues/delta-programme/>

Figure 2  
**Three changes are affecting each other**



Source: PBL

*An adaptation strategy cannot be worked out without taking the developments in climate, government and society into account.*

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# Climate change; a wide range of risks

The things that influence climate change in the Netherlands are varied and mostly already visible (PBL, 2013a). The Dutch research programme Knowledge for Climate (2009–2014) has greatly increased our knowledge about the possible effects of climatic changes. Climate change also offer opportunities for the Netherlands. This chapter elaborates on these opportunities, follows by the main risks.

## Opportunities for the Netherlands that are related to climate change

Climate change usually is referred to as involving risks and threats. However, it also delivers opportunities. The earth's warming, for example, may have some positive effects for the Netherlands. The milder winters are likely to reduce the numbers of people who perish due to extremely cold weather. This will have a positive impact on the general population death rate, because the likely increase in deaths due to heat spells is relatively smaller. These premature, season-dependent deaths are however affected by many factors, such as temperature variables (mean, extreme, thermic comfort, day-night differences), habituation, behaviour and housing. The exact relative influence of these factors is uncertain.

The increase in the greenhouse gas CO<sub>2</sub> and the rise in temperatures both have a positive impact on the production levels of most agricultural crops grown in the Netherlands. This is particularly the case for sugar beet (Schaap et al., 2014). The already relatively warm and dry southern part of Europe will be facing even greater drought in the future, due to climate change. Many of the agricultural crops will not thrive in those conditions. This presents opportunities for a relative competitive advantage for Dutch agriculture. Agriculture is a sector that is used to having to adjust to changing circumstances, and it is likely to also anticipate on that situation.



*Climate change could offer new opportunities for the Netherlands. It may, for example, make the country more attractive for tourism (photo on the left: Mediatheekrijksverheid/Tineke Dijkstra), and improve the growth levels of crops new to the Netherlands, such as grapes (photo on the right: Hollandse Hoogte/Flip Franssen).*

Milder winters will also deliver cost savings on energy use and road maintenance. Another positive effect is that the change in climate will make the Netherlands more attractive for tourism and recreation. Although weather extremes will increase, the summer season will be longer; spring and autumn both will have longer periods of pleasant weather. These effects of climate change thus offer economic opportunities for the Dutch sector of recreation and tourism (PBL, 2013b).

## Understanding the risks; probability and impact

Despite the possibly positive effects for the Netherlands, the negative effects of climate change may have serious consequences for the way the country functions. These negative effects are varied, affect various levels and scales, and their impact also varies enormously.

To be able to picture the main risks that the Netherlands is likely to face, a distinction has been made between those to the economy, to people, and to nature and the environment (Tables 1, 2 and 3). The risks are so different in character that it is difficult to capture them under one common denominator. Therefore, this study followed the advice of the Dutch Council for the Environment and Infrastructure (Rli) and the Scientific Council for Government Policy to make a distinction between these three risk dimensions (Rli, 2014; WRR, 2014). The impact of a certain climate effects thus has been classified in three categories, using semi-quantitative scoring, with different category boundaries per type of impact (economy, people, nature and the environment). The probability of climate risks was also classified in three categories: unlikely or unlikely to increase within this century, likely to increase within this century, and likely within this decade. Risks with a low probability and a small impact have been left out, as their urgency in the adaptation strategy will be only limited. The PBL report 'From risk assessment to adaptation strategy' ('Van risico-beoordeling naar adaptatiestrategie' (PBL, 2015b)) provides information on the method applied and the considerations used in the mutual comparison of risks. A brief summary is provided in Text box 2.

Table 1  
Economic impact per occurrence

	Unlikely in this century (up to 2100)	Likely in this century (up to 2100)	Likely in this decade (2010–2020)
Large (damage >100 million euros)	<ul style="list-style-type: none"> <li>• Flooding due to primary dyke failure</li> <li>• Epidemic of a disease that is new to the Netherlands</li> <li>• Agricultural damage due to plagues or animal diseases</li> <li>• Flooding in eastern Netherlands due to a dyke breach in Germany</li> </ul>	<ul style="list-style-type: none"> <li>• Failure in crucial parts of the power grid due to prolonged heat/drought or no wind</li> <li>• Yield losses due to consecutive periods of drought</li> <li>• Limited shipping due to extremely high or low water levels</li> <li>• Damage to buildings and mains due to additional ground subsidence</li> </ul>	
Medium (damage of 10–100 million euros)		<ul style="list-style-type: none"> <li>• Flooding due to secondary dyke breach</li> <li>• Disruptions in crucial ICT nodes elsewhere in the world due to extreme weather</li> <li>• Local power failure due to extreme weather</li> <li>• Disruptions to railway and road traffic due to storm damage or wildfires</li> <li>• Yield losses due to extreme weather</li> <li>• Increases in food prices due to prolonged drought in Europe</li> </ul>	<ul style="list-style-type: none"> <li>• Traffic disruptions due to extreme wind gusts and rainfall</li> <li>• Damage to water pipes caused by the pull of tree roots during wind gusts</li> <li>• Increase in medical costs and labour losses due to prolonged and more intense pollen season</li> </ul>
Small (damage of 1–10 million euros)			<ul style="list-style-type: none"> <li>• Local water drainage flooding due to extreme rainfall</li> <li>• Railway and road transport disruptions due to heat</li> <li>• Increase in power prices, on a European level, due to cooling water scarcity and/or no wind</li> <li>• Production losses Dutch companies due to climate effects abroad</li> <li>• Price fluctuations raw materials</li> <li>• Calls for emergency aid from abroad</li> </ul>

Risk

Small

Medium

Large

Source: PBL

Climate effects can lead to major economic damage. Both transport and traffic may become seriously disrupted by extreme rainfall, wind gusts or plain heat, and drought may cause large agricultural losses. In addition, the indirect damage caused by, for example, power failures, disrupted financial services, and failure to maintain public order can be very high. These types of cascade effects are trans-sectoral and, to date, have been neglected, but their economic and social impact may be large. Also additional soil subsidence may cause substantial damage to buildings and mains and cables (Hoogvliet et al., 2012). In addition to any great damage caused by a single event, the accumulated amount of damage from many small incidents can also add up. Water drainage flooding due to extreme precipitation is a typical example of this, as are the labour losses and medical expenses caused by an increase in the occurrence of hay fever and asthma.

Table 2  
Impact on people

	Unlikely in this century (up to 2100)	Likely in this century (up to 2100)	Likely in this decade (2010–2020)
Large (>100,000 affected and/or >10 deaths)	<ul style="list-style-type: none"> <li>• Flooding due to primary dyke breach</li> <li>• Epidemic of a disease new to the Netherlands</li> <li>• Consequences of political conflict elsewhere in the world</li> <li>• Flooding in eastern Netherlands due to dyke breach in Germany</li> </ul>	<ul style="list-style-type: none"> <li>• Failure in crucial parts of the power grid due to prolonged heat/drought or no wind</li> <li>• Large-scale disruptions in ICT due to disruptions in crucial ICT nodes elsewhere in the world</li> <li>• Large-scale disruptions in ICT services due to overheating</li> </ul>	<ul style="list-style-type: none"> <li>• Urban heat stress</li> </ul>
Medium (10,000–100,000 affected and/or 1–10 deaths)		<ul style="list-style-type: none"> <li>• Flooding due to breaches in secondary dykes on local/regional levels</li> <li>• Regional power failure due to extreme weather</li> <li>• Disruptions in railway and road traffic due to storm damage</li> <li>• Local disruptions in ICT and transport due to wildfires</li> </ul>	<ul style="list-style-type: none"> <li>• Prolonged and more intense pollen season (hayfever, asthma)</li> <li>• Increase in the number of Lyme patients</li> <li>• Infectious diseases caused by reduced water quality</li> <li>• Traffic accidents and disruptions due to extreme wind gusts and rainfall</li> <li>• Damage to water pipes caused by the pull of tree roots during wind gusts</li> <li>• Dutch casualties abroad due to extreme weather or infectious and other diseases</li> </ul>
Small (<10,000 affected and no deaths)			<ul style="list-style-type: none"> <li>• Local water drainage flooding due to extreme rainfall</li> <li>• Disruptions to railway and road transport due to heat</li> <li>• Local power failure due to storms or soil movement</li> </ul>

Risk

Low

Medium

High

Source: PBL

Failing of vital sectors can lead to deaths or other casualties among the affected population. Disruptions to the supply of energy, ICT, financial services or drinking water have a direct impact on people's daily lives and may affect large numbers of people at the same time. The greatest impact is expected by increased heat stress; the number of people affected compare to the number of inhabitants of a middle-sized Dutch town, such as Leiden or Deventer. It is one of the main risks for people living in cities; more frequent occurrences of heatwaves are expected to cause an increase in deaths among vulnerable groups of the population, such as the elderly. Although some other events, such as large-scale flooding or pandemics, may result in more casualties, these events are less likely.

Table 3  
Impact on nature and the environment

	Unlikely in this century (up to 2100)	Likely in this century (up to 2100)	Likely in this decade (2010–2020)
Large (national level and/ or irreversible)	<ul style="list-style-type: none"> <li>Species losses due to shifting climate zones</li> <li>Disappearing tidal marshes and mudflats due to flooding from the sea</li> </ul>	<ul style="list-style-type: none"> <li>Species and habitat losses due to extremely low water levels in river stretches and riverine wetlands</li> <li>Changing migration patterns of migratory animals</li> </ul>	
Medium (regional level and/ or not easily reversible)		<ul style="list-style-type: none"> <li>Temporary disruptions to habitats due to recurrences of extreme drought</li> <li>Disruptions of the soil and of previously undisturbed archeological sites due to increased ground subsidence</li> <li>Increased natural and environmental effects caused by desiccation and eutrophication</li> </ul>	<ul style="list-style-type: none"> <li>Deterioration of ecological water quality</li> <li>Decline in native species due to shifting climate zones</li> </ul>
Small (local level and/ or reversible)			<ul style="list-style-type: none"> <li>Local disruption of habitats due to extreme weather</li> <li>Additional CO<sub>2</sub> emissions due to increased ground subsidence</li> </ul>

Risk

 Small

 Medium

 Large

Source: PBL

The seriousness of climate impacts for nature and the environment is largely determined by their irreversibility. Certain animal and plant species and habitats, such as tidal marshes and mudflats, may disappear due to rising temperatures and sea levels and structural drought. In turn, this may cause migration patterns of migratory birds and fish to change. This would involve nationally or internationally unique or important nature, and therefore this impact was judged to be large. Another serious climate effect is the expected deterioration of water quality. This effect is insidious and is further exacerbated by the discharging of cooling water. It is highly probable that species will also disappear on local and regional scales due to regular occurring weather extremes. This effect is judged as less serious, because those species continue to occur elsewhere and therefore might return.



*Adaption of the European transport system to climate change, to date, has not received much attention from policymakers, according to the European Environment Agency (EEA) in one of their recent publications (EEA, 2014). Copenhagen, where the EEA is located, shortly after heavy rainfall (photo on the left, Hollandse Hoogte/Anadolu Agency). Amsterdam experienced a cloudburst on 28 July 2014. Over a short period of time, the enormous amount of rain caused parts of the A10 motorway to be closed off, flights were cancelled at Amsterdam Airport Schiphol, and the streets and canals changed their appearance (photo on the right, ANP/Evert Elzinga).*

## Wide range of climate risks – many on regional and local scales

The analyses show that the Netherlands may be faced with a wide range of climate risks, varying from less likely events with major consequences (particularly on a national scale) to more frequent events with more limited consequences (particularly on regional and local scales). Some of those risks have already been elaborated in the Delta Programme, namely those of flooding events, water drainage flooding and water shortages. The tables show that additional attention is needed for the level of robustness of power, ICT and transport networks, drinking water supply, possible consequences for agriculture (crop damages) and nature (reducing ecological quality), public health impacts (e.g. more frequently occurring infectious diseases) and the impact on traffic (e.g. from flooded roads).

The economic damage and risks to people particularly increase due to weather extremes, which will become more intense and will occur more frequently in the coming decades; these concern heat, drought, heavy rainfall and thunderstorms together with heavy wind gusts, and higher river discharges.

Violent storms constitute the main risk factor for failure of critical infrastructure (power, ICT, transport and drinking water supply networks), on both national, regional and local scales. Large-scale power failures may cause a cascade of effects with the risk of societal disruption (Vogel et al., 2014), as numerous functions and many people are dependent on power, for example, for ICT services, rail traffic, financial transfer systems and logistics. Vital services, such as hospitals and pumping stations, have emergency aggregates at their disposal, but these may not continue to work under extreme weather conditions and prolonged impacts, such as flooding. Extremely heavy rainfall and wind gusts are expected to cause damage, on multiple occasions, to traffic and buildings in the coming decade. The flooding of homes and businesses, traffic accidents and limited traffic capacity will lead to economic damage and may affect large shares of the population.

**Text box 2. Risk assessment method**

Climate change may cause the events that we are currently already facing to become more frequent and more intense (Figure 1). The gradual changes in climate (e.g. the rise in temperatures and sea levels) and the expected increase in weather extremes (drought, heavy rainfall in combination with wind gusts) both will lead to changes in the level of risk for people and nature. In collaboration with many other knowledge institutes, PBL has constructed an overview of the range of climate risks to the Netherlands. In doing so, a distinction was made between three risk dimensions: economic risk (damage), human risk (deaths, casualties), and nature and environmental risks (the disappearance of certain species and habitats). These risks were subsequently ranked according to probability and projected magnitude (Tables 1, 2 and 3). The magnitude and probability were ordered per risk dimension into three categories. The level of probability is related to the frequency at which already occurring events are likely to occur (more often, similar, less often), the reference being the occurrences over the past century. Assuming the most unfavourable KNMI '14 scenario for the Netherlands, we estimated the likelihood of the country experiencing more and more severe climate change impacts in the coming decades or century. For the risk assessment, we assumed the current spatial layout and size and composition of the Dutch population, and combined these with the climate change projected for 2050. This assessment, thus, effectively is an estimation 'in case of in-action'. The magnitude of the economic risks is indicated by the projected damage in euros and the personal risks in terms of numbers of deaths and/or casualties. Casualties are people who somehow have been exposed to the consequences of climate change. This may vary from people whose home has been flooded as a result of extreme rainfall or people who experience power cuts or disruptions to communication services, to those suffering from hay fever. The magnitude of nature risks is indicated on a local, regional or national scale, in combination with the degree of irreversibility of the consequences. The likelihood and magnitude of water-related risks has been derived from studies carried out for the Delta Programme. For the other risks, the magnitude and likelihood have been based on other studies on i) transport and infrastructure, ii) the power supply system, iii) ICT networks, iv) public health, v) nature, vi) agriculture, and vii) fishery. For each, this concerns the magnitude of the consequences within a certain sector. The related background reports can be downloaded from <http://www.ruimtelijkadaptatie.nl/nl/bouwstenen-nas>. The international risks for the Netherlands have been derived from PBL (2015d).



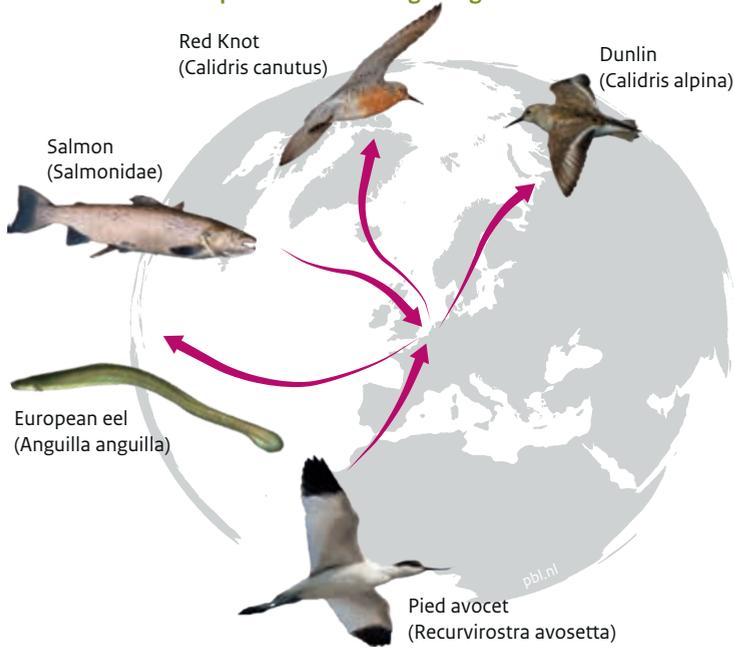
*A warmer climate is expected to lead to an increase in intensity and duration of the hay fever season (photo on the left, Hollandse Hoogte/Corbis) and to more infected ticks within a wider distribution area, during a longer annual period. This means an increased risk of Lyme disease and the meningitis that is transmitted by ticks: Tick-Borne Encephalitis (TBE) (photo on the right, Thinkstock).*

Heatwaves are relatively risky. Urban heat stress causes an increase in risk of disease and premature mortality, particularly among older people with serious afflictions and other vulnerable groups (Table 2). Heat and drought may also cause large-scale power failures, if power plants are unable to extract cooling water from the rivers. Drought and low water tables also affect shipping, agricultural crops and water quality (Cyanobacteria (blue-green algae)).

The gradual changes in climate also carry risks, among other things for public health (Table 2) and for nature and the environment (Table 3). Species distribution areas for both animals and plants are shifting, life cycles are changing and habitats are either changing or disappearing. This may also cause migration patterns to change (Figure 3). Rising sea temperatures lead to shifts in fish stocks. The prolonged growing season and the arrival of new species (such as the strongly allergenic *Ambrosia*) are expected to further increase the impact of hay fever in the Netherlands. Furthermore, Lyme disease is likely to spread further, due to the prolonged summer season (RIVM, 2014). These gradual changes particularly call for keeping a finger on the pulse. A typical example of this is the current monitoring system for infectious diseases and plagues, on national, European and global levels. In addition, plans of action should be drawn up, ready for when diseases or plagues manifest themselves.

Climate effects in Europe and elsewhere in the world may also pose a risk to the Netherlands. This concerns, for example, food price rises due to prolonged drought in Europe (Table 1; Figure 4), or increased political conflict in vulnerable regions, Dutch casualties abroad from extreme weather events or infectious diseases (Table 2). This is further elaborated in Chapter 3.

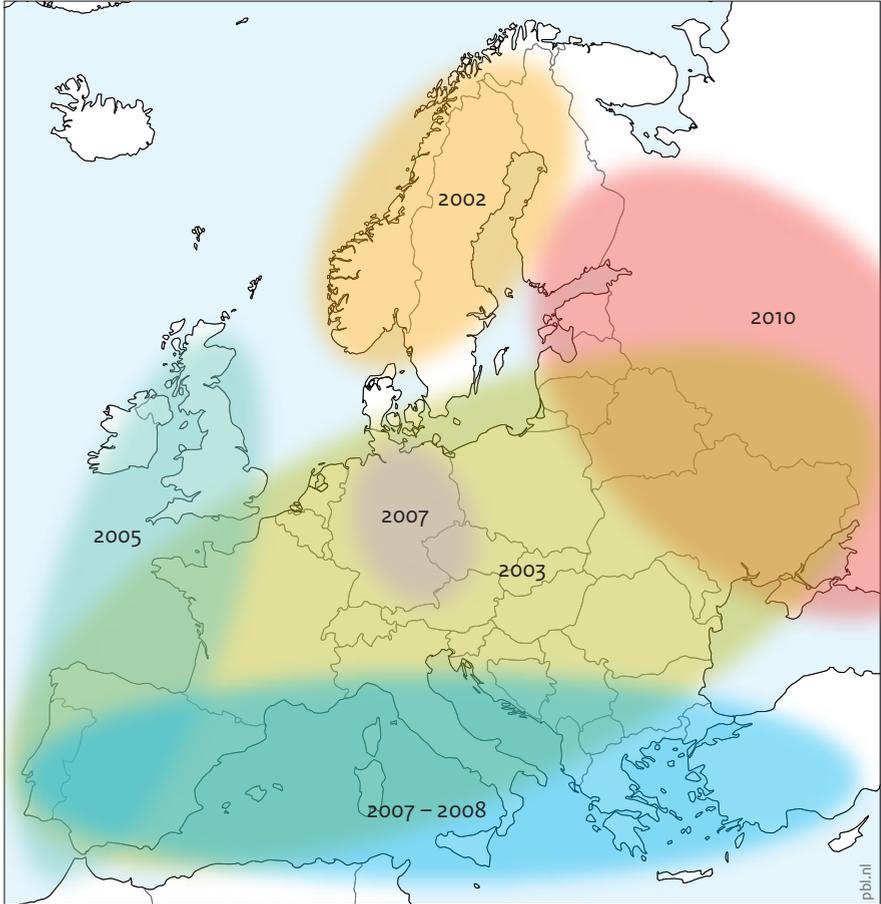
Figure 3  
**The Netherlands an important hub for migrating birds and fish**



Source: PBL; Imares

*With the Wadden Sea, the Ems Delta and the South-western Delta, the Netherlands is an important migratory junction for aquatic birds and fish. Climate change affects migration patterns, among other things when salt-marsh habitats and mudflats disappear.*

Figure 4  
**Main periods of drought in Europe, 2000–2010**



Source: SOER 2010; Barriopedro et al. 2011

During the first decade of this century, Europe was affected by multiple periods of prolonged drought. By 2050, climate change may cause a biennial repetition of the extreme drought of 2003, according to the KNMI 'business as usual' scenario.

# Society; more complex and vulnerable

## Changes in Dutch society

What will Dutch society look like in 2050? The so-called Delta scenarios provide four images of the future (Deltares, 2011). These scenarios were developed for the Delta Programme and were based on KNMI's climate scenarios (KNMI, 2006) and the scenarios from the study on Welfare, Prosperity and Quality of the Living Environment by PBL Netherlands Environmental Assessment Agency and CPB Netherlands Bureau for Economic Policy Analysis (CPB and PBL, 2006).

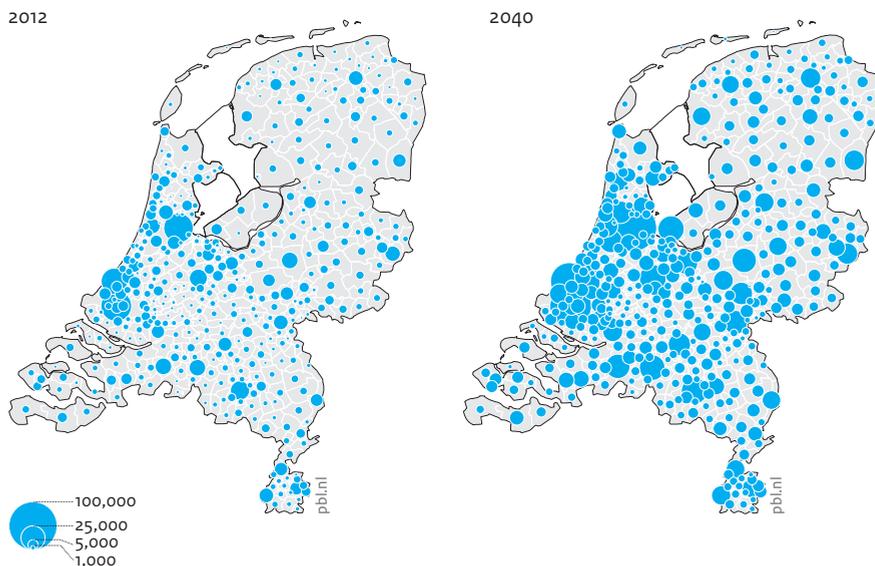
Under all the Delta scenarios, the population grows and so does the income per capita. Ageing is a definite for Dutch society and it features in all scenarios (Figure 5). It causes the population to become more vulnerable, for example to diseases and heat stress.

On urbanisation, however, the scenarios vary. Over the past decades, in times of extensive economic growth, increasing numbers of people have moved away from the larger cities. More recently, economic growth has been low and many people are moving back into the cities. The migration towards the larger cities in the west, among other things means that more people will be living in the low-lying areas of the country (which are partly below sea level). Dyke breaches in those areas may cause large-scale flooding with serious consequences. In addition, cities are more vulnerable to heat stress.

A notable development is the growing dependence of citizens and businesses on electricity, ICT and transport. Also many societal functions are becoming increasingly dependent on these services, such as financial transfer systems and transport, as well as air conditioning, the Internet and home electronics, things that are becoming more important as the population ages. Disruptions to the power or ICT networks affect a multitude of services.

Another important, related development is the change in energy mix. Currently, the Netherlands mainly uses fossil fuels (oil and natural gas) in its energy supply. However, in order to reduce greenhouse gas emissions as well as for geopolitical reasons, the share of sustainable resources, such as solar and wind energy, is increasing (Figure 6).

Figure 5  
Number of residents over the age of 75, per municipality



Source: PBL

*The number of people over the age of 75 will double to 2.5 million by 2040. Most of these people currently live in the Randstad, as they will in the future, although their numbers will also strongly increase in the larger municipalities outside the Randstad area.*

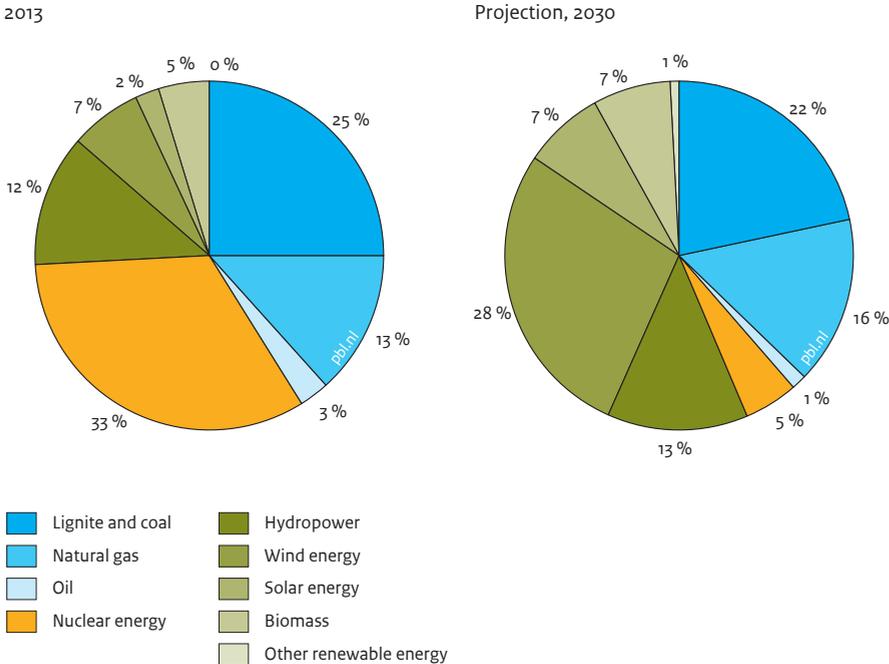
As the generation of solar and wind energy involves both highs and lows, this may cause overloaded or overcharged networks, in turn making them vulnerable to failure.

All scenarios also show increasing globalisation; the most under high economic growth. Globalisation leads to a complex interwovenness of functions and dependencies (see under 'European and global interwovenness' below).

## Vulnerability to climate change

It is difficult to predict what the long-term consequences will be of climatic changes in combination with the changes within society. Together, the scenarios lead to a large range of possibilities and uncertainties, featuring complex mutual influences and feedback mechanisms. A full picture of the risks calls for knowledge input from many different parties, including governments, businesses and NGOs. This study first conducted qualitative research on the long-term impact, with respect to vulnerability to climate change, of three developments: increasing dependence on electricity, increasing vulnerability to heat stress, and increasing globalisation.

Figure 6  
Fuel mix in power generation in north-western Europe



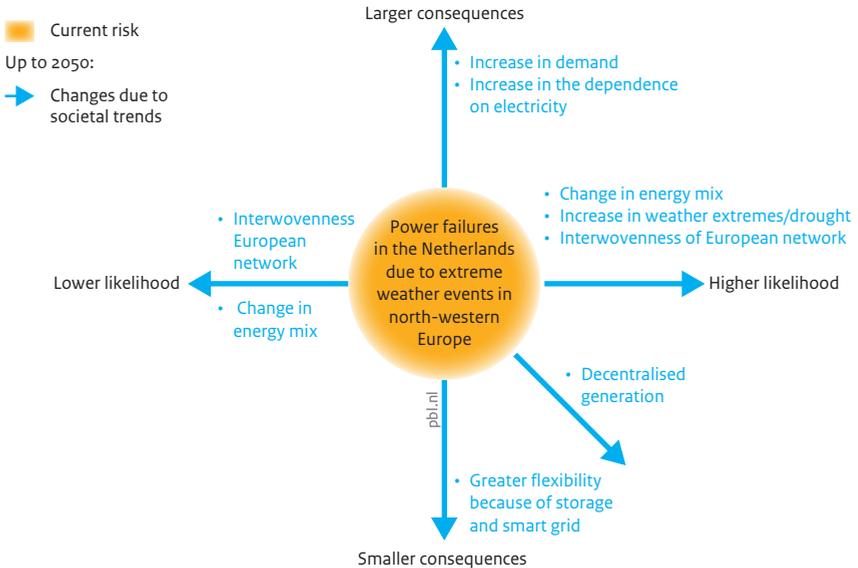
Bron: ECN/Eurelectric

*The shares of north-western European power generation sources (biomass, hydropower, solar and wind power) that are sensitive to extreme weather will increase from around 25% in 2013 to over 50% by 2030. Power generated by wind energy in particular will increase from 7% to 28% (north-western Europe: the Netherlands, the United Kingdom, Germany, Denmark, Norway, Belgium and France).*

## Increasing dependence on electricity

The increasing dependence on electricity increases the risks that are related to climate change (Figure 7). For example, the chances of power failure increase because violent storms and heatwaves occur more often, while the resulting impact of power failures on society increases. The change in energy mix also adds to the Netherlands' vulnerability to climate change and energy-supply disruptions. The amount of sun and wind that is available for power generation will hardly be affected by climate change, but wind-energy supply may fail when a heatwave occurs in combination with prolonged periods of no wind. Furthermore, the internationalisation of the power grid also increases vulnerability (see also below).

Figure 7  
**Forcefield analysis of the risk of power failures between 2015 and 2050**



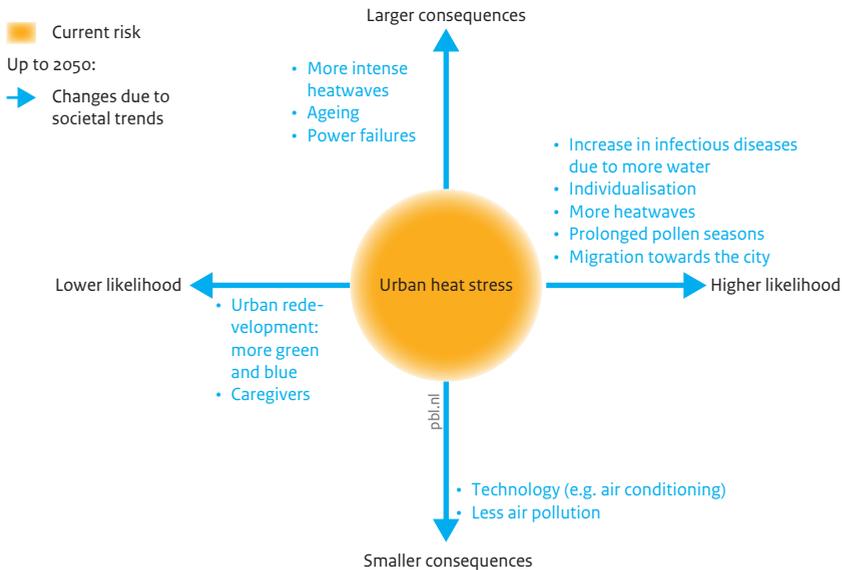
Source: PBL

*Future changes will have a variety of consequences in relation to the Netherlands' vulnerability to climate change. Climate change will increase the likelihood of power failures. Social developments, such as the increasing dependence on power, enlarge the impact of power failures. The power grids in Europe will become more interconnected. On the one hand, this will lead to more redundancies and greater flexibility, while power failures abroad may also have an impact in the Netherlands. Technological developments, for example, those related to storage and local power generation, may reduce this impact.*

## Increased vulnerability to heat stress

The ageing of the Dutch population also makes it more vulnerable to heat spells and infectious diseases (Figure 8). This is particularly the case if cities grow under the continued influx of young people. In cities, the impact of heat stress is greater and infectious diseases spread faster than in rural areas. Moreover, in summer, the frequency of extreme rainfall will increase, which means cities will be flooded more often. These flooded areas can easily turn into incubation sports for infectious diseases when temperatures are high.

Figure 8  
Forcefield analysis of the risk of urban heat stress between 2015 and 2050



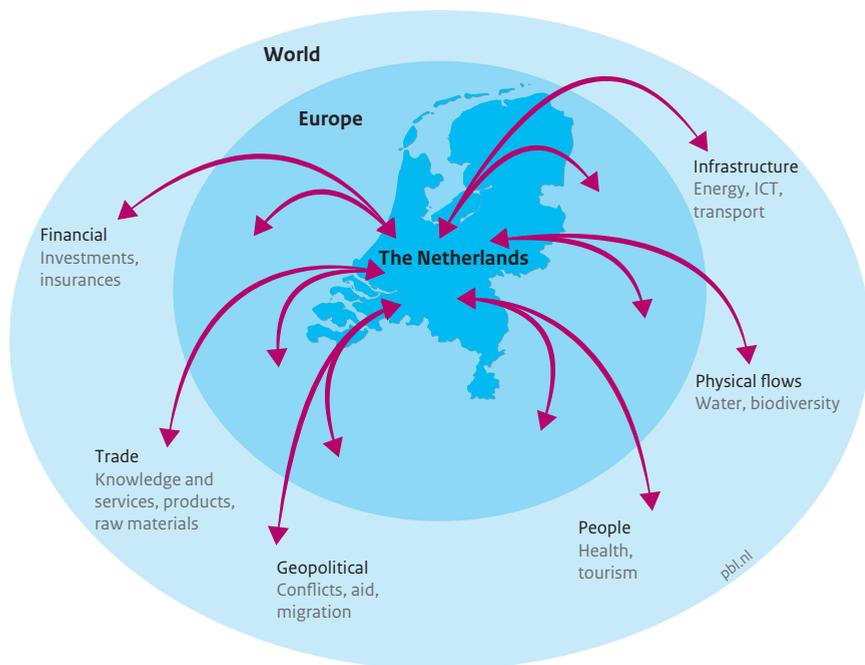
Source: PBL

In the coming decades, an increasing number of Dutch citizens will experience the impact of heat. Not only because heatwaves will occur more often and be more severe, but also because more people will be living in cities, where the degree of warming is stronger than in the countryside. Ageing will cause the population to become more vulnerable. Smart urban redevelopment (more space for 'green' and 'blue') may have a preventative effect. More 'blue' may have the negative effect of infectious diseases developing in ponds and lakes. Certain technology, such as air conditioning, may be able to limit some of the consequences, but could also falter when the power supply is interrupted. Air pollution may increase heat-related health effects. Measures that are aimed to reduce air pollution, thus, contribute to reduce the impact of heat stress.

## European and global interwovenness

The Netherlands is developing within a globalising world and the number of international relationships is increasing, both within and outside Europe. Thus, it is connected to many countries in many different ways; through critical infrastructure, trade relations, energy supply, immigration and emigration, international organisations and tourism (Figure 9). On a European level, power grids, ICT networks and other critical infrastructure are becoming more and more interconnected. This has the advantage that supply disruptions in one location can easily be solved by the supply from another location. However, there are also disadvantages, such as in case of power failures abroad also affecting the supply within the Netherlands (Figure 7).

Figure 9  
International relations of the Netherlands

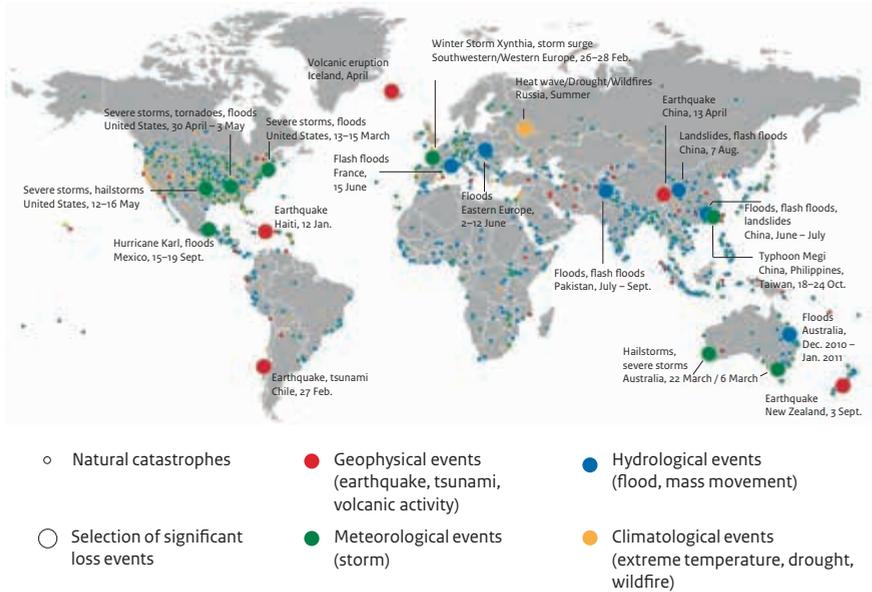


Source: PBL

*The Netherlands may be affected by global climate change, in a number of ways: by disruptions in trade chains or supply of resources, by financial damage to Dutch investments abroad, by damage to vital services such as energy and ICT, and by people travelling to and from countries that carry higher health risks. It may even be affected in a geo-political way, by conflicts or migration.*

On a global level, there are a large number of natural disasters, such as flooding events, drought, and landslides (Figure 10), and the damage they cause has increased substantially over the past decades (Munich RE, 2012). Natural disasters that have caused the most damage and human casualties are flooding events and tropical storms in coastal areas. River flooding as a result of extreme rainfall also occurs often, in particular within Europe. In addition to more economic damage and more casualties, these floods have also increased in frequency, mainly along the rivers. Tropical storms are increasing in intensity and, in coastal areas, they regularly cause large disasters, with many casualties and severe damage (Visser et al., 2012). The increase in climate risks elsewhere in the world also have an impact in the Netherlands.

Figure 10  
Natural catastrophes, 2010



Source: NatCat database, Munich RE (2011, pages 54-55)

*The number of natural disasters in the world is large. In 2010, some 960 disasters were reported; a large number of which concerned flooding events and storms. The damage and the number of casualties they cause is expected to increase strongly, as a result of urban growth and increasing economic activity in the more vulnerable areas. The risk of Dutch companies and citizens being affected by natural disasters elsewhere in the world is also increasing.*

From a global perspective, there are large regional differences in the nature and severity of the impact of climate change. The general perception is that regions already experiencing problems will be faced with even bigger ones. For examples, regions already affected by flooding must fear more damage. Vulnerability to climate risks, all over the world, is strongly affected by societal development. Important global trends, here, are population growth, migration towards cities, and economic growth. Currently, some 800 million people are living in flood-prone areas, around the world, 70 million of which in areas that are flooded nearly every year. In many river areas and delta regions, the risk of flooding is expected to increase substantially in the coming decades, particularly in Southeast Asia (IPCC, 2014b). Climate change is a threat to the global economy. A risk analysis by the World Economic Forum (2015) prominently features weather-related natural disasters and water crises. Climate change may also play a role in other risks, such as the dispersion of infectious diseases, international conflicts, extreme variations in energy prices, and disruptions to critical infrastructure. The World Economic Forum, therefore, considers globally failing adaptation to climate change a major risk (Figure 11).

Figure 11  
Top ten global risks in terms of likelihood and impact



Source: World Economic Forum 2015

*The World Economic Forum considers global failure of climate adaptation a major risk.*

This may have various consequences for the Netherlands, such as production losses for businesses, a greater appeal for aid by other countries, and large fluctuations in the price of, for example, resources and food. Climate change may also affect international security (Van Schaik et al., 2015). Simmering conflicts, such as those over the availability of agricultural land and fresh water, and the rights to newly available natural resources (e.g. in the Arctic Region) may escalate due to climate change. Conflict may increase migration, both national and international, and lead to great regional instability. The drought and food crises between 2005 and 2008, for example, may be seen as the sparks that lit the already present powder kegs in North Africa and the Middle East. To date, there are no indications of climate change leading to substantially increased migration from vulnerable regions to the Netherlands. It is more likely that climate-related migration takes place mainly to close-by regions, which in turn may exacerbate food stress, political conflict and increase the call for humanitarian aid (Van Schaik et al., 2015).

# Changing governance; new roles

Climate adaptation must be developed within a situation of changing governance. As in many other European countries over the past decades, public governance in the Netherlands became not only more focused on Europe, but also decentralised, partly privatised and to a certain extent more complex. This has its consequences for the roles of the national government and society.

## Active roles for government and society

The Dutch Government increasingly operates less from a hierarchical position and focuses more on collaboration and facilitation. The style of governance, thus, is shifting from a 'performing' and 'lawful' government towards one focused on 'networking' and 'participation' (Figure 12). The place of society is also changing; citizens and businesses have more responsibilities (the 'participatory society') and more often take the initiative to improve that surroundings (the 'energetic society').

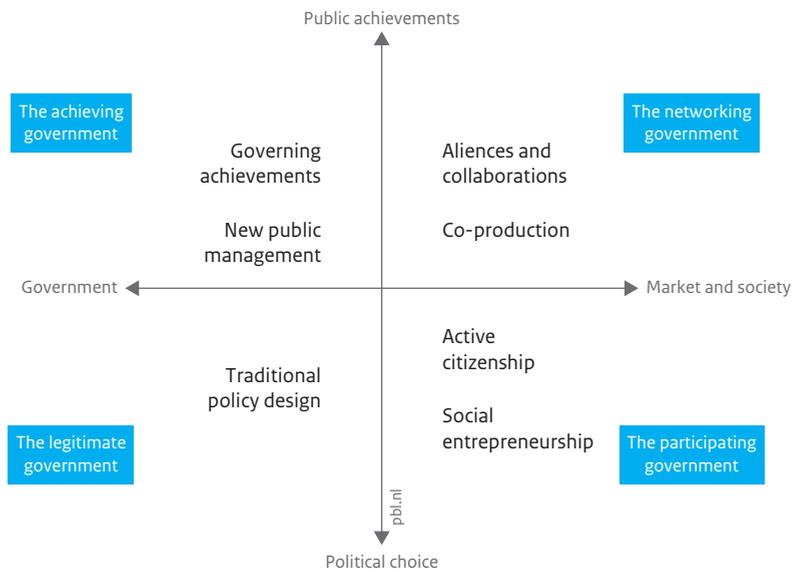
The national government has a 'systems responsibility' in terms of climate adaptation; they are responsible for the complete arena of climate adaptation, also on regional and local levels, as local or regional climate effects could grow into problems of national scale. And also because the method of adaptation may have certain consequences in the areas under the national government's responsibility, such as public order, public health, nature and the environment.

However, the national government is not the only actor in the field of climate adaptation. One of the challenges in effective adaptation to climate change concerns the engagement of others, such as local governments, government agencies, independent governing boards, the private sector and NGOs. The national government is to actively coordinate the collaborations between these parties. Not by involving itself in the tasks and their execution on regional and local levels, but by stimulating and organising the process of climate change adaptation. This type of approach fits an energetic society (Hajer, 2011; RMO, 2013).



Modern coastal fortification at the Hondsbosse sea wall. Example of an integral solution; collaborations between governments and NGOs has led to a plan that not only benefits water safety, but also serves other purposes, such as nature and recreation (photo Hollandse Hoogte/Siebe Swart).

Figure 12  
Four governance styles and characteristics



Source: NSOB and PBL 2014

*The changing relationships between government, market (companies) and society (citizens) (NSOB, 2013).*



*On the left, a sketch of Soesterhof 2013; this is an example of an initiative by the local population to design a greener and more climate-resilient neighbourhood (illustration Bewonersvereniging Soesterhof). On the right, Dutch Minister Plasterk of the Ministry of the Interior and Kingdom Relations (BZK) visiting the Soesterkwartier to observe citizen participation in practice (photo Vereniging Duurzaam Soesterkwartier; Source: Vereniging Duurzaam Soesterkwartier ([www.duurzaamsoesterkwartier.nl](http://www.duurzaamsoesterkwartier.nl))).*

Collaboration and discussion between various parties is needed, in order to gather all the knowledge and information with respect to climate adaptation (see also Chapter 3), to answer questions on the nature of the problem, the magnitude of the adaptation task, the options to increase climate resilience, and to determine who should do what. These questions cover many fields, such as power supply, freshwater supply, urban development, public health, nature development, and rural area development.

## Awareness is a precondition

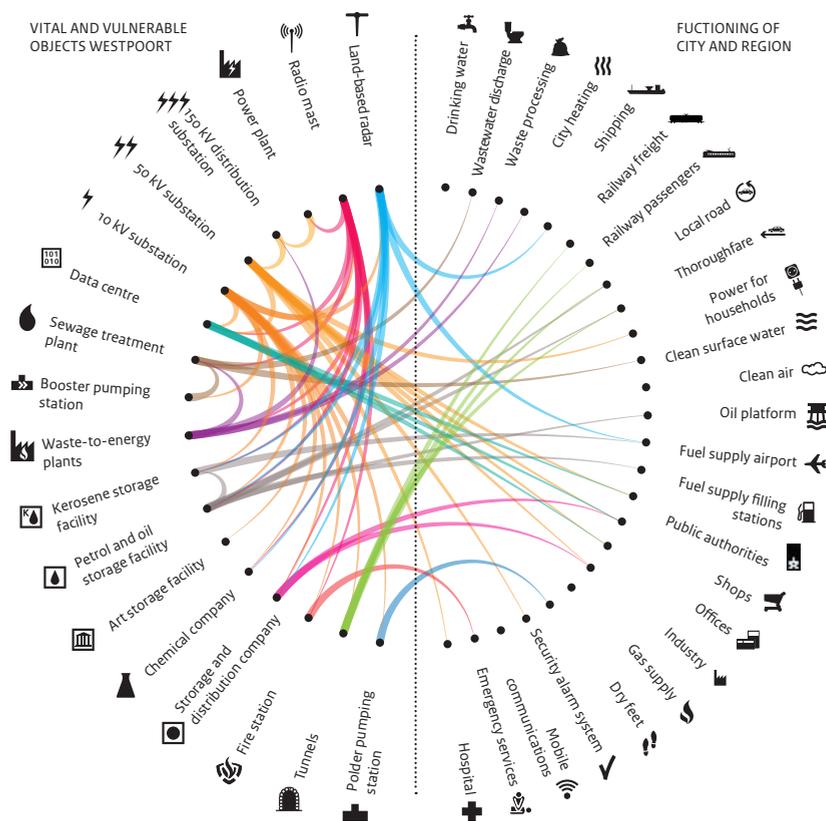
The first precondition for addressing climate adaptation is for governments, businesses and private citizens to become aware of climate change and its possible impact. One of the things that could greatly contribute to this awareness is the joint execution of a stress test, such as was done in Amsterdam in the port area of Westpoort (Figure 13). A near-disaster or smaller scale incident may also be an important impetus for awareness, such as the cloudburst that hit parts of the Netherlands – also Amsterdam – on 28 July 2014. A study by Runhaar et al. (2015) showed that awareness is growing. There are, for example, companies that explicitly include climate change in their strategic development.

The need for awareness not only applies to the Netherlands, but to all of Europe. Contacts with neighbouring countries have shown that few are aware of the increase in vulnerability of the European power grid to weather extremes, caused by the switch to other energy sources such as biomass, solar and wind power (Figure 7). Awareness should also be increased further on a global scale (World Economic Forum, 2015).



Overview of the port area of Westerpoot (photo on the left, Municipality of Amsterdam). Practicing simple solutions; an artist's impression of road markings that ensure companies remain accessible by truck (photo on the right, MUST Stedebouw).

Figure 13  
Chain effects in Westpoort and its region



Source: MUST stedebouw 2014

Example of one initiative on a local level. The municipality of Amsterdam and the water board Amstel Gooi, together with all parties involved in the port area of Westpoort, conducted a risk analysis.

# Adaptation to climate change

Dutch society, in general, will probably be able to adjust to the results of climate change. However, in certain areas, the capability to adapt is limited or uncertain. Spatial development, for example, have a long-term impact with consequences for multiple generations.

## Urgent adjustments

Over the past years, in the research programmes ‘Climate changes Spatial Planning’ and ‘Knowledge for Climate’, a large amount of knowledge was gathered on the possible effects of climate change and the resulting risks and opportunities. Further knowledge, undoubtedly, would deliver even greater insights. The real challenge, however, is to move from ‘knowing’ to ‘wanting’ to ‘acting’. The knowledge available today shows that in addition to the water-related challenges, climate adaptation is urgent, in particular in two areas: climate resilience of critical infrastructure and networks (national and international tasks) and spatial development (regional and local tasks).

The urgency in both cases concerns the long lifespan of these structures and the little flexibility to adapt them to climate change. The choices and investments that will be made in the short term will largely decide the level of climate resilience of the Netherlands in the long term. Today’s choices will also determine the available room for finding solutions and covering costs of adjustments if climate change goes faster or differently from expected.

### **National: climate resilience of critical infrastructure**

The analyses show that, on a national level, particularly the main infrastructure is vulnerable to climate change; the system of primary dykes and the energy, ICT and transport infrastructure. In the Netherlands, the national main infrastructure is the responsibility of the national government.

In executing the Delta Programme with the protection against flooding, the national government has made a step towards anticipating climate change. Also making the other parts of the national main infrastructure climate-resilient, requires a ‘stress test’ for each part (the energy, ICT and transport infrastructure). Such a test provide



*'Rebuild by design' or 'Build back better' are concepts that focus on the need for integrated spatial development that is aimed at reducing climate-related risks in rebuilding infrastructure and urban areas in the wake of natural disasters. In the development of new infrastructure and urban areas, climate change and the related risks should be anticipated. On the left, an example of how in the Netherlands rivers are given more room by broadening the floodplains, such as here near the city of Nijmegen, in order to adapt to the future climate risks of flooding (photo mediatheekrijksverheid-luchtfoto Siebe Swart). On the right, an example of a more local-scale redevelopment, where a former shunting yard in Rotterdam will be turned into a levee that also holds a city park and shops (artist impression Buro Sant en Co).*

information on the adaptation task and capacity for the various parties involved (companies, governments).

### **Regionally and locally: climate resilience in spatial development**

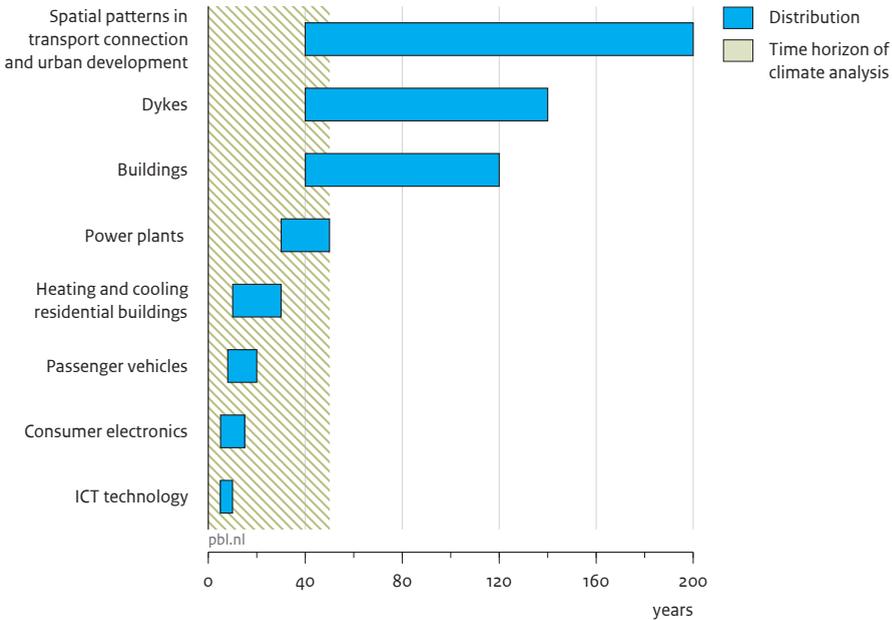
On provincial, municipal and water board levels, there are large tasks in making spatial planning more climate-resilient. Over the last years, the government made substantial investments in knowledge development. This knowledge should now be utilised in projects directed at implementation. Provinces, municipalities and companies will be able to ensure climate resilience for regional and local road, power and ICT networks, and municipalities can utilise redevelopment projects to reduce the heat impact within cities.

The national government can play a facilitating, coordinating and governing role; for example, by actively sharing pilot project experience with other government authorities, companies and NGOs. Stress tests may be the basis for negotiating agreements with these authorities, and rather than being compulsory, those agreements should create a new innovative arena for both businesses and project developers. If this should prove to be insufficiently effective, the government could consider implementing legal robustness requirements, thus placing a governance focus on spatial development.

## **Connecting to spatial development and infrastructural investments is crucial**

In order to achieve affordable climate resilience for infrastructure and spatial development, it is essential to connect to initiatives and investments that are already up and running. Current as well as planned initiatives can be utilised for climate adaptation, even if that is not their primary goal. For example, urban redevelopment, which mostly

Figure 14  
Lifetime of installations and infrastructure



Source: Philibert and Pershing 2002; edited by PBL

*Particularly for developments that have a long lifecycle, it is important to join climate-resilience enhancement projects.*

originates from a social need, may make a substantial contribution to climate adaptation by including more 'green' and 'blue'; in this way, not only will these urban areas become more pleasant to live in, they also will reduce heat stress. Other combinations can be found, for example, when building new data centres or renovating drinking water networks, and during extensive road and railway maintenance work. With some additional effort, these can be conducted in such a way that they also increase climate resilience. However, experience has learnt that such efforts are not automatically included. Most attention is usually paid to the short-term benefits, with not much eye for the long-term robustness to which climate resilience typically belongs.

Therefore, it is crucial for the parties responsible for climate adaptation to join in projects that have a long lifecycle, at an early stage, such as those of urban restructuring and the construction of dykes and infrastructure (Figure 14). If such opportunities are missed, it often takes decades for new similar opportunities to present themselves.



# Anchors of a national adaptation strategy

The transition towards becoming a more climate-resilient country is no easy feat for the Netherlands; the effects of climate change are still uncertain, the risks and opportunities very diverse and such transition requires input from many different parties. The diverse nature of the adaptation task also means that it is too early to present a fully detailed description of what should be the National Adaptation Strategy (NAS). What can be presented, however, are a number of anchors for such a strategy; thus, providing a framework for an effective approach.

## Broad input, compelling vision

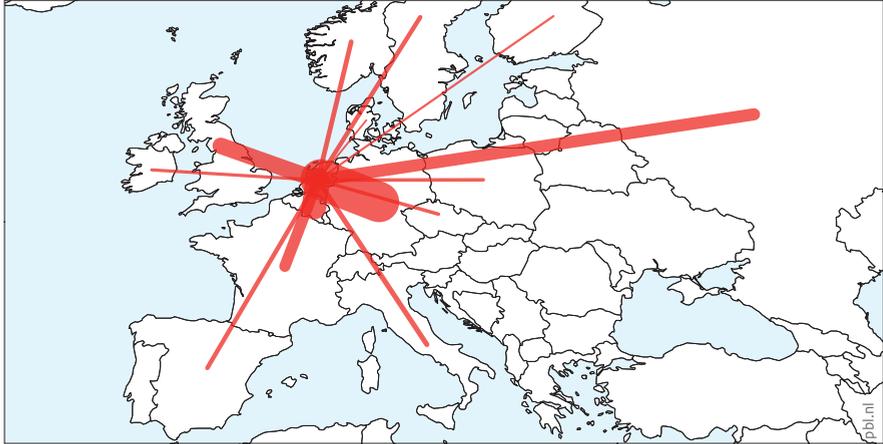
On the basis of current knowledge, the most urgent tasks seem to be to ensure the climate resilience of critical infrastructure and spatial development. However, obtaining a complete overview of all climate risks and related adaptation tasks is also important. This can only be achieved if all parties share their knowledge; government authorities, companies, citizens and NGOs.

The national government is responsible for the 'system' with respect to climate adaptation, and it is therefore its task to stimulate and support collaboration between all of those parties.

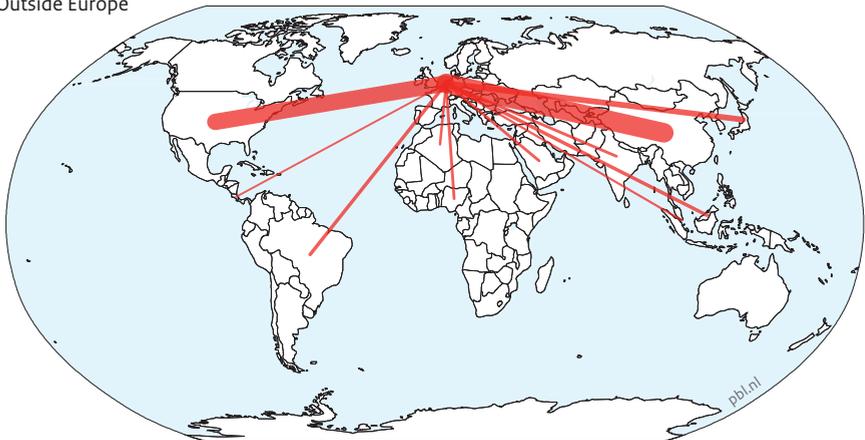
An active, facilitating government is one that has ambition, provides direction, is consistent and stays on course. Such a government utilises and involves society in the search for solutions, it is not afraid to experiment, stimulates initiatives and rewards frontrunners. It also focuses on changing certain unwritten rules, habits and everyday practices. This type of government does not take its lead from the power of vested interests; it invites dynamics by continuing to challenge and by utilising the power of dynamic regulation. It also invests in increasing its learning ability, scales up successful experiments and corrects undesirable side effects (NSOB and PBL, 2014).

Figure 15  
**Largest import flows to the Netherlands, 2012**

Within Europe



Outside Europe



Import flow (in billion USD)



Source: UN Comtrade

The Netherlands has many import relationships. In monetary terms, in 2012, it imported most goods from Germany, Belgium, China, the United States and the United Kingdom.

The main task is to ensure that climate adaptation becomes a structural element in people's thinking and actions. An inspiring and inviting government vision could be the starting point. The following actions could provide the framework for such a vision:

- Climate adaptation has an important, infrastructural agenda; identify climate resilience as an intrinsic quality in spatial design and infrastructural investment.
- Involve and mobilise provinces, municipalities, companies and NGOs.
- Create a stimulating and innovative environment for climate adaptation.
- Utilise and bring about moments of change.
- Stimulate the use of stress tests, on various scales and levels, including the European, to increase both knowledge and awareness.
- Include climate adaptation in international policy and international projects, and allow them to enhance each other.

## Keep a focus on Europe and the rest of the world

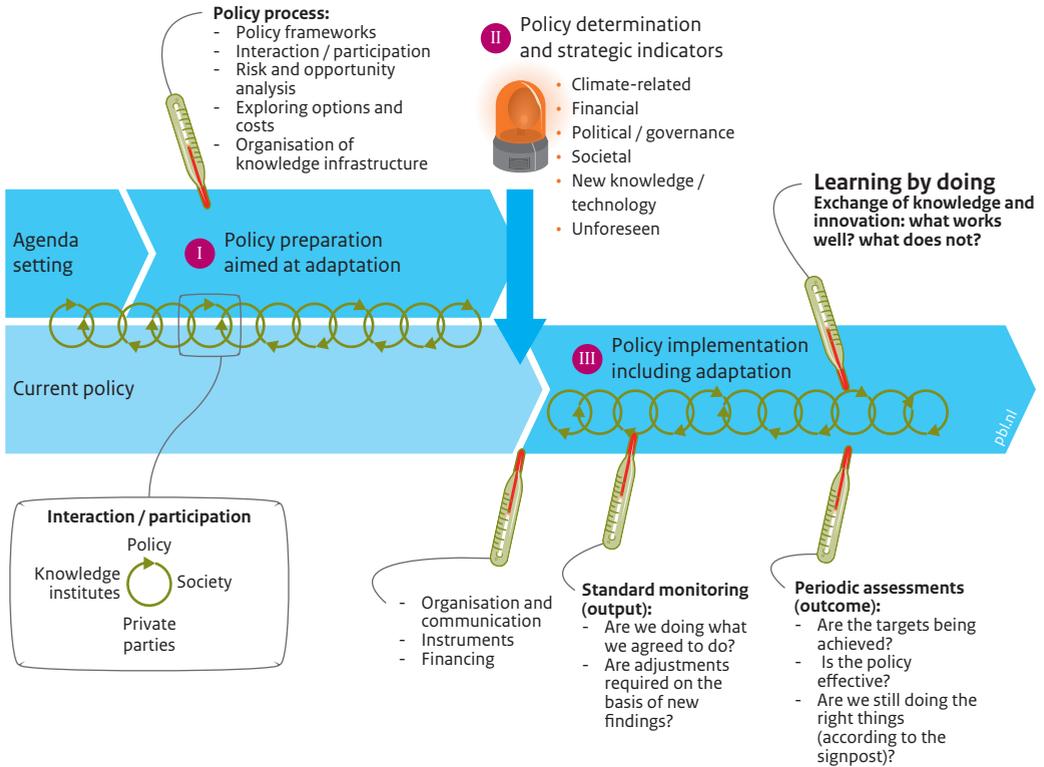
The adaptation efforts of the Netherlands in the area of critical infrastructure would be particularly effective if they are constructed in agreement with its neighbouring countries and the rest of Europa. The scale on which agreement should take place depends on the subject. For retaining water in the upper course of the Dutch rivers, for example, collaborations with its neighbouring countries would mostly suffice. But, for instance, for a more robust energy supply, would minimally require collaboration on a north-western European scale.

The Netherlands is connected to Europe and to the rest of the world through its trade flows (Figure 15). Climate change elsewhere in the world may pose a risk to the global economy (Figure 11) and specifically also to the Netherlands and Dutch companies if climate adaptation is not adopted at an early enough stage. This, for example, calls for greater alertness of companies whose trade flows depend on possible problem regions. The national government could also be affected, such as by increased calls for emergency aid by other countries.

The Dutch Government could stimulate climate adaptation in developing countries by explicitly including the subject in its foreign policy and in networks of internationally operating companies, NGOs and other countries. The focal points of 'water' and 'food' could be utilised even better than they are today, through a greater emphasis on climate adaptation.

Abroad, the Netherlands is known for its knowledge and expertise in the field of water management, and the country is renowned for its integrated approach. As climate-change related problems, such as in water safety, freshwater supply, and sustainable agriculture, will start to affect more countries, they will increasingly call on Dutch companies, turning Dutch expertise into an even larger export product.

Figure 16  
**Monitoring and assessment in policy development**



Source: PBL

Policy preparation aimed to contribute to adaptation is not separate from already implemented policy. Following policy preparation (I) and policy formulation (II), the adaptation objectives will be integrated into policy implementation (III). The strategic signposts are specifically for the adaptation policy. These signposts connect short-term efforts with long-term objectives, and they are also indicators used in monitoring and assessment; do new insights provide reasons for adjusting policy implementation or strategy?

## Learning by doing

There is not much experience available on climate adaptation, and there are hardly any practical data on the impact of adaptive measures. Although theoretical studies provide a certain amount of insight, most knowledge will have to be developed 'while doing'; starting by first determining what needs to change, choosing the required measures and implementing them, followed by monitoring and measuring the results and learning from these results. In other words: learning by doing.

Learning by doing can only succeed under a system of proper monitoring and assessment: the adaptation monitor. Because climate adaptation involves many different parties, joint fact finding is essential for such a monitor to be effective. The development of an adaptation monitor not only will lead to a broader knowledge base, but it will also stimulate collaboration and clarify the individual responsibilities of the parties involved.

PBL has developed a concept for adaptation monitoring, assuming the integration of climate adaptation into existing policy processes and a participatory development and implementation of policy (PBL, 2015c; Figure 16). The first step for this concept related to the themes of the Delta Programme (e.g. water safety and freshwater availability).

Further elaboration and implementation of a monitoring and assessment system and organisation will follow once the Dutch National Adaptation Strategy will be ready, in 2016.



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