6. VULNERABILITY ASSESSMENT, CLIMATE CHANGE IMPACTS, AND ADAPTATION MEASURES

The climate in the Netherlands is projected to undergo significant changes over the coming decades, which will have multiple consequences. The most pressing potential consequences are increasing heat stress in urban areas, increasing flood risks due to both more extreme river discharge and sea level rise, more frequent failure of vital infrastructure such as electricity and IT, more frequent damage to crops or production resources, an increased health burden and productivity loss, and changes in biodiversity. These conditions, in a country such as the Netherlands, give rise to climate change impacts that require risk assessments and decisions on timely and smart interventions.

The Sixth National Communication[131] described the National Programme for Spatial Adaptation to Climate Change (ARK)[132], which started in 2006 and ran until 2011, as the central programme for adaptation in the Netherlands. As described in the Seventh National Communication[133], the Dutch Delta Programme, which started in 2010, has since been the main vehicle for climate change adaptation planning in the Netherlands (see Box 6.1). The report by the Netherlands Court of Audit (2012)[134] recommended broadening the scope beyond the water domain. This challenge was taken up, resulting in the National Climate Adaptation Strategy 'Adapting with ambition' (2016)[135].The strategy broadened the scope of adaptation planning to include the effects of climate change within nine sectors: water and spatial management; nature; agriculture, horticulture and fisheries; health and welfare; recreation and tourism; infrastructure (road, rail, water and aviation); energy; IT and telecommunications; and public safety and security. Table 6.1 provides an overview of milestones in addressing climate adaptation over the past fifteen years (2006–2022).

[131] Available here: Sixth National Communication (2013)
[132] National Programme for Spatial Adaptation to Climate Change, Ministry of Housing, Spatial Planning and the Environment; Ministry of Transport, Public Works and Water Management: Ministry of Agriculture, Nature and Food Quality; Ministry of Economic Affairs, VROM 7222 / April 2007.
[133] Available here: Seventh National Communication (2018)
[134] Adaptation to climate change: National strategy and policy, Algemene Rekenkamer, 2012
[135] Adapting with ambition, National Climate Adaptation Strategy 2016 (NAS), Ministry of Infrastructure and the Environment, December 2016

Year	Action
2006	The Royal Netherlands Meteorological Institute (KNMI) publishes climate scenarios for the Netherlands for 2050 and 2100
2006–2011	National Programme for Spatial Adaptation to Climate Change (Adaptatieprogramma Ruimte voor Klimaat, ARK)
2007	National Adaptation Strategy 'Climate changes Spatial Planning' (Maak ruimte voor klimaat), with a focus on spatial adaptation
2008–2014	National Research Programme on Climate Change and Adaptation (Onderzoeksprogramma Kennis voor Klimaat)
2009	The Royal Netherlands Meteorological Institute (KNMI) updates its climate scenarios for the Netherlands for 2050 and 2100; scenarios from 2006 remain unchanged
2010–2014	Start of the Delta Programme, preparation phase: preparation of decisions on the protection against flooding, on climate-resilient urban areas and on adequate freshwater supply
2010 onwards	An updated Delta Programme is presented each year, as part of the annual government budget planning (available in English)
2012	EU Climate Adaptation Strategy
2012	The Netherlands Court of Audit advises in its report 'Adapting to climate change: strategy and policy' to broaden the scope to climate risks that have so far been insufficiently explored and mentions the sectors of health, energy, transport and recreation
2012	The Netherlands Environmental Assessment Agency (PBL) publishes the policy study 'Effects of Climate Change in the Netherlands' (Effecten van Klimaatverandering in NL), a study requested by the Dutch government and an important input for the National Climate Adaptation Strategy 2016. It contains, among other things, an inventory of effects on the sectors of water management, nature conservation, arable and livestock farming, human health and tourism
2013	The Netherlands Environmental Assessment Agency (PBL) publishes 'Adapting with tact, building blocks for an integrated vision on climate adaptation' (Aanpassen met beleid, bouwstenen voor een integrale visie op klimaatadaptatie), in which the inventory is extended with the sectors of fisheries, transport and infrastructure, energy, and information and communication technology, also including the consequences of climate effects abroad
2013	The National Climate Agenda (Klimaatagenda) integrates the advice from the Netherlands Court of Audit, covering both climate mitigation and climate adaptation
2014	Ratification of the five Delta Decisions including those on flood safety, freshwater supply and climate-resilient urban areas. One of these is the Delta Decision on Spatial Adaptation, which includes the ambition for the Netherlands to be flood resilient and climate robust in 2050. Start of the implementation phase of the Delta Programme

Year	Action
2014	The Royal Netherlands Meteorological Institute (KNMI) updates its climate scenarios for the Netherlands for 2050 and 2100
2015	The Netherlands Environmental Assessment Agency (PBL) synthesises the results of the National Research Programme on Climate Change and Adaptation in its report 'Adapting to climate change: recognising risks, seizing opportunities' (Aanpassen aan klimaatverandering: kwetsbaarheden zien, kansen grijpen), an important input for the National Climate Adaptation Strategy 2016
2016	Publication of the National Climate Adaptation Strategy 'Adapting with ambition', a result of the National Climate Agenda and the EU Climate Adaptation Strategy
2017	Delta Plan on Spatial Adaptation presented as part of the Delta Programme to enhance the implementation of the Delta Decision on Spatial Adaptation
2018	Publication of the Implementation Programme 2018–2019 of the National Climate Adaptation Strategy (NAS) of the Netherlands called 'Implementing with ambition'
2020	Publication of the NAS reporting 2017–2019, 'National perspective on Climate Adaptation; a growing challenge in a changing environment' (Nationaal perspectief klimaatadaptatie; Groeiende opgave in een snel veranderende omgeving)
2021	The Netherlands Environmental Assessment Agency (PBL) published a study 'Navigating towards a climate resilient country' (Navigeren naar een klimaatbestendig Nederland), describing options for short and long-term monitoring and evaluation of climate adaptation policies
2021	Climate Signal 2021, the Royal Netherlands Meteorological Institute (KNMI) published the latest insights in climate change in the Netherlands, based on the 2021 IPCC report and KNMI research
2022	Final report on the evaluation of the NAS

Table 6.1: Milestones in addressing climate adaptation over the past fifteen years

Box 6.1 The Delta Programme and Adaptive Delta Management

The Delta Programme's[136] aim is to ensure that our flood risk management, freshwater supply, and spatial planning will be climate proof and water resilient by 2050, so that our country will continue to be able to cope with the increasing weather extremes. The Delta Programme is a nationwide programme and has an advisory role towards the national government. The national government, provinces, municipalities, and regional water boards work together with input from social organisations, the business community, and knowledge institutes (Delta Commissioner 2013, www.deltacommissaris.nl). The Minister of Infrastructure and Water Management bears the responsibility. A Delta Commissioner was appointed to prepare and oversee the implementation of the Delta Programme. His main responsibility is to prepare an annual report that outlines progress and the steps that will be taken in the year ahead. Each year, the Minister of Infrastructure and Water Management presents the Delta Programme report to the House of Representatives as part of next year's national budget. The legal framework for the implementation of the current national adaptation strategy in the Netherlands is the 'Delta Act on flood safety and fresh water supply' (hereinafter: the Delta Act).The Delta Act is formally an amendment of the Water Act and anchors the Delta Programme, the Delta Fund, and the role of the Delta Commissioner. The Delta Act entered into force on 1 January 2012.

The Delta Programme is currently being developed in nine sub-programmes. Three sub-programmes apply to the whole of the Netherlands:

-Flood risk management (coastal and fluvial floods)

-Fresh water supply

-Spatial adaptation

The other six sub-programmes are regional:

-Rhine Estuary-Drechtsteden

-South-western delta

-IJsselmeer Region

-Rivers

-Coast

-Wadden Region

[136] More information on the Delta Programme can be found here: https://english.deltaprogramma.nl/

Administrative consultations regarding the three national sub-programmes take place within the so-called Administrative Umbrella Consultations. The six regional sub-programmes are discussed in regional high-level steering groups and administrative consultation bodies.

The Delta Programme uses an integrated approach when tackling the issues of flood risk management, water supply, and the role that spatial planning can play in resolving those issues. Key decisions regarding flood risk management, fresh water supply, and spatial adaption, as well as regional strategies were proposed to Parliament in September 2014. The implementation of the proposed policy and strategies has since commenced and will span several decades. E.g. new flood risk management standards have to be accomplished in 2050. The Delta Programme will take account of uncertainties about the future impact of climate change as well as spatial and socio-economic development (See the next section for the use of scenarios). For the Delta Programme, a new planning approach was developed, called 'adaptive delta management'. Key elements of adaptive delta management are:

-linking short-term decisions with long-term tasking around flood risk management and fresh water;

-incorporating flexibility in possible solution strategies (where effective);

-working with multiple strategies and moments to switch between them (i.e. adaptation paths);

-linking different investment agendas.

Preparing for future changes requires short-term measures that tie in with the long term, i.e. measures that expand our adaptability and increase the ability to withstand extreme situations. Finalising measures for impacts fifty to a hundred years ahead is difficult and in most cases not advisable. After all, solutions must be able to grow along with new insights and circumstances. On the other hand, it is essential that measures are taken now, considering that it took several decades to complete the Delta Works. Implementing adaptive delta management involves three steps:

-What short-term developments in other policy areas might interfere with water safety and fresh water supply measures?

-Insight into the flexibility of the possible solutions. For example, can the solutions be easily implemented on a step-by-step basis and adapted in case circumstances change?

-What decisions must be taken now in order to make the adaptive approach possible?

These three steps ensure that necessary measures are taken early, while at the same time keeping sufficient options open for additional measures required in the future to protect the Netherlands against flooding and to ensure a sufficient supply of fresh water. To enable this approach, monitoring, reporting, and evaluating schemes for refining adaptation are developed.

In the process, all relevant material, like results of research and knowledge programmes (Knowledge for Climate), experiences from international cooperation (International Water Programme, Delta Alliance, Connecting Delta Cities), and assessments by the Netherlands Environmental Assessment Agency (PBL 2011)[137] are taken into account.

This chapter reports on climate change and its effect on multiple sectors (Section 6.1), on assessments of the impacts and the way that urgencies are defined (Section 6.2), and on the resulting policies and measures (Section 6.3) in the Netherlands. For a more detailed description of national climate effects and implications, the reader is referred to the assessments by the Netherlands Environmental Assessment Agency (PBL 2012[138]; 2015[139]). Details on international cooperation and capacity building can be found in Chapter 7 (and in PBL 2016), while details of research activities and programmes are described in Chapter 8.

6.1 (A) Climate effects

This section summarises observed and projected changes in the climate (Subsection 6.1.1) and their effects on multiple sectors in the Netherlands (Subsections 6.1.2–6.1.9). It elaborates on the work coordinated by the Netherlands Environmental Assessment

[137] Climate Adaptation in the Dutch Delta, Strategic options for a climate-proof development of the Netherlands, PBL, 2011
[138] The effects of Climate Change in the Netherlands: 2012, PBL, 2012
[139] Adaptation to climate change in the Netherlands – Studying related risks and opportunities, PBL, 2015

Agency (PBL 2013[140]; 2015). The sectoral assessments[141] that have been performed in 2014–2015 were part of this work. All results form the basis of the National Climate Adaptation Strategy. The Delta Programme is based on research that has been carried out by the same organisations.

Figure 6.1 visualises the broader picture of climate effects and some of its sectoral implications in the Netherlands.

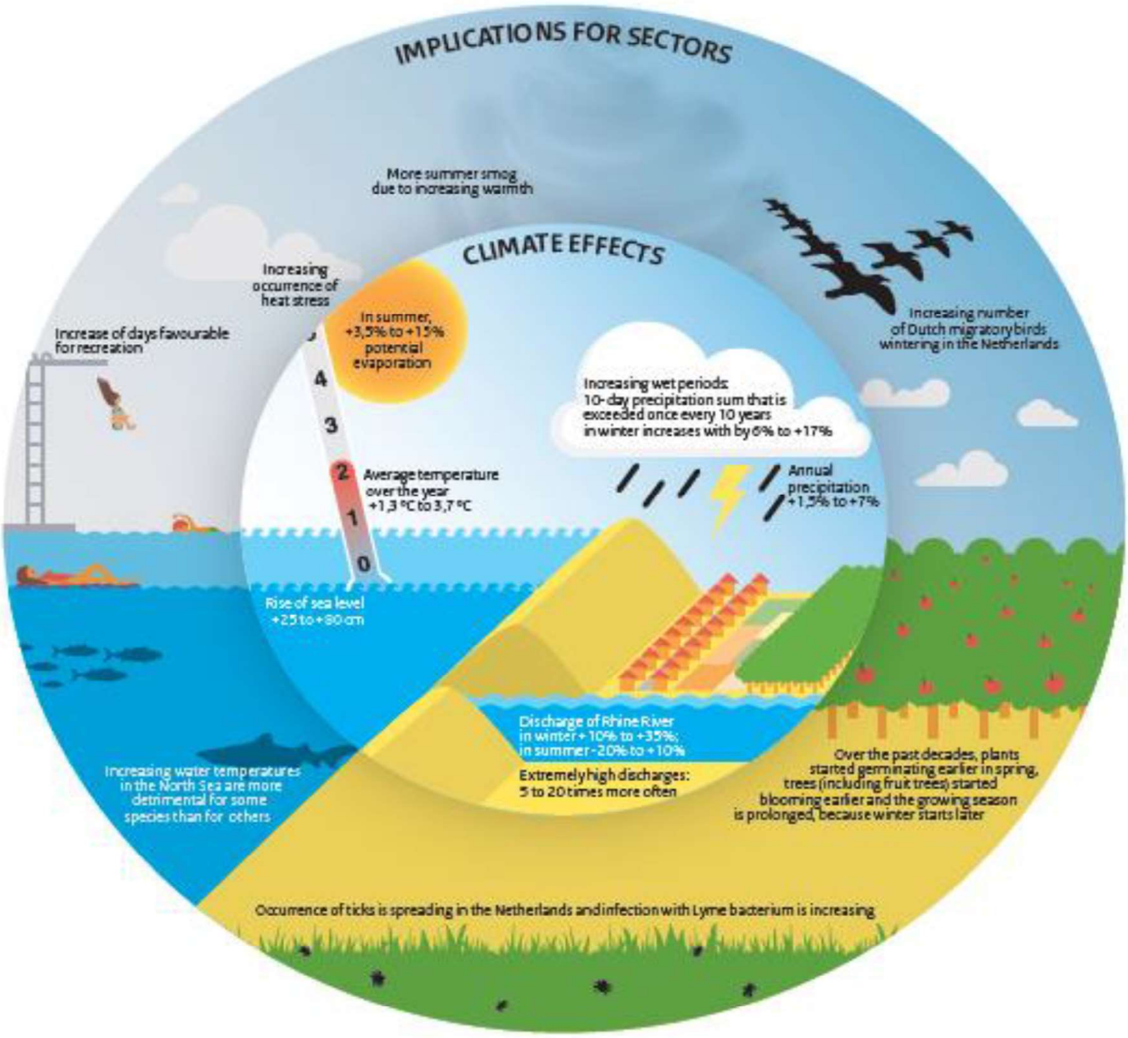

Figure 6.1 Overview of some climate effects and implications for sectors (source: Deltares 2015[142]; KNMI 2015[143]).

[140] Aanpassen met beleid. Bouwstenen voor een integrale visie op klimaatadaptatie, PBL, 2013
[141] More information on the sectoral assessments can be found here: https://klimaatadaptatienederland.nl/@188130/onderzoeksprogramma-kennis-voor-klimaat/
[142] Implications of the KNMI'14 climate scenarios for the discharge of the Rhine and Meuse, comparison with earlier scenario studies, Deltares, 2015
[143] KNMI'14 climate scenarios for the Netherlands, brochure - revised version, KNMI, 2015

6.1.1 Effects of climate change

The Netherlands has become warmer. Average temperatures in De Bilt increased by 2.3 °C between 1901 and 2020.[144] In all four scenarios that KNMI developed for the Netherlands, the temperature will increase further. The mean temperature increase in 2050 is the largest for winter (December, January, February) and the smallest for spring (March, April, May). Extreme precipitation in the Netherlands has increased as well and it is likely that it will further increase in future. This trend includes higher frequencies and intensities of extreme precipitation.[145] There are indications that higher humidity of the air from a warmer climate will result in larger clusters of showers, including 'supercells' that may cause both squalls – sudden sharp increases in wind speed – and hailstorms.

In 2014, the Royal Netherlands Meteorological Institute (KNMI) published its update of four climate scenarios for the Netherlands for around 2050 and 2085 (the first scenarios were published in 2006)[146]. These scenarios are based on a whole range of advanced global and regional climate models combined with information from time series of measured data, which allowed them to incorporate changes in air circulation patterns in their models. Each scenario provides a consistent picture of the changes in many climate variables, including temperature, precipitation, sea level and wind. Not only the changes in the mean climate are depicted, but also the changes in the extremes such as the coldest winter day and the maximum hourly precipitation per year. The changes are provided for two different time horizons: around 2050 and around 2085 (Table 6.2), relative to the reference period of 1981–2010.[147] The KNMI'14 scenarios are the four combinations of two possible values for the global temperature increase – 'Moderate' or 'Warm' – and two possible changes in air circulation patterns, 'Low value' (L) and 'High value' (H) (Figure 6.2). Together, they span the likely changes in the climate of the Netherlands according to the latest insights. In the H scenarios, more frequent westerly winds occur in winter. This change leads to mild and more humid weather compared to the L scenarios. In summer, high-pressure systems have a greater influence on the weather in the H scenarios. Compared to the L scenarios, these high-pressure systems cause more easterly winds, which implies warmer and drier weather for the Netherlands. The 2014 scenarios have since been supplemented by the 2021 climate signal which

[144] KNMI 2021: KNMI Klimaatsignaal'21: hoe het klimaat in Nederland snel verandert, KNMI, De Bilt.
[145] See the KNMI'14 scenarios for more information regarding the increased frequency of extreme precipitation and analysis of other types of extreme climatic events (e.g. temperature extremes, hail and thunderstorms) compared to past observations.
[146] For more information on these scenarios, see: www.climatescenarios.nl
[147] See the KNMI'14 scenarios (pp. 4–6) for the detailed tables comparing the trends in future climate with trends observed in the past (compared to the difference between the averages for 1951–1980 and the reference period of 1981–2010).

combines the insights of the sixth review cycle of the IPCC and the KNMI's own research on the effects of climate change on the Netherlands. New climate scenarios – which will replace the 2014 scenarios – are forecast to be published by 2023.

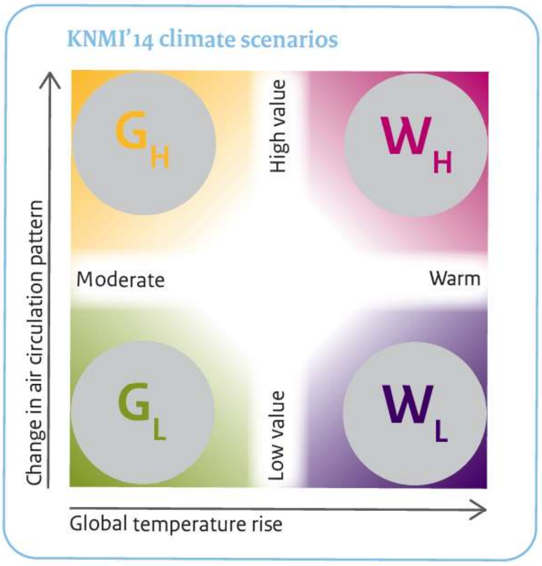

Figure 6.2 The four KNMI'14 scenarios (KNMI 2015)

	Climate reference (1981–2010)	**Climate around 2050**			
		G_L	**G_H**	**W_L**	**W_H**
Annual average temperature	10.1 °C	+1.0 °C	+1.4 °C	+2.0 °C	+2.3 °C
Annual average precipitation	851 mm	+4%	+2.5%	+5.5%	+5%
Potential evaporation (annual)	559 mm	+3%	+5%	+4%	+7%
Absolute sea level rise	+3 cm	+15 to +30 cm	+15 to +30 cm	+20 to +40 cm	+20 to +40 cm
Winter average temperature	3.4 °C	+1.1 °C	+1.6 °C	+2.1 °C	+2.7 °C
Coldest winter day per year	-5.9 °C	+2.0 °C	+3.6 °C	+3.9 °C	+5.1 °C
Average precipitation winter	211 mm	+3%	+8%	+8%	+17%
10-day amount exceeded once in 10 years	89 mm	+6%	+10%	+12%	+17%
Mean wind speed in winter	6.9 m/s	-1.1%	+0.5%	-2.5%	+0.9%
Highest average daily wind speed per year	15 m/s	-3%	-1.4%	-3%	+0%
Summer average temperature	17.0 °C	+1.0 °C	+1.4 °C	+1.7 °C	+2.3 °C
Warmest summer day per year	24.7 °C	+1.4 °C	+1.9 °C	+2.3 °C	+3.3 °C
Average precipitation summer	224 mm	+1.2%	-8%	+1.4%	-13%
Daily amount exceeded once in 10 years	44 mm	+1.7 to +10%	+2.0 to 13%	+3 to +21%	+2.5 to +22%
Maximum hourly precipitation in a year	15.1 mm/h	+5.5 to +11%	+7.0 to 14%	+12 to +23%	+13 to +25%
Potential evaporation (summer)	266 mm	+4%	+7%	+4%	+11%
Highest moisture deficit exceeded once in 10 years	230 mm	+5%	+17%	+4.5%	+25%

	Climate reference (1981–2010)	Climate around 2085			
		G_L	G_H	W_L	W_H
Annual average temperature	10.1 °C	+1.3 °C	+1.7 °C	+3.3 °C	+3.7 °C
Annual average precipitation	851 mm	+5%	+5%	+7%	+7%
Potential evaporation (annual)	559 mm	+2.5%	+5.5%	+6%	+10%
Absolute sea level rise	+3 cm	+25 to +60 cm	+25 to +60 cm	+45 to +80 cm	+45 to +80 cm
Winter average temperature	3.4 °C	+1.3 °C	+2.0 °C	+3.2 °C	+4.1 °C
Coldest winter day per year	-5.9 °C	+2.7 °C	+4.1 °C	+5.6 °C	+7.3 °C
Average precipitation winter	211 mm	+4.5%	+12%	+13%	+30%
10-day amount exceeded once in 10 years	89 mm	+8%	+12%	+18%	+25%
Mean wind speed in winter	6.9 m/s	-2.0%	+0.5%	-2.5%	+2.2%
Highest average daily wind speed per year	15 m/s	-2%	-0.9%	-1.8%	+2%
Summer average temperature	17.0 °C	+1.2 °C	+1.7 °C	+3.2 °C	+3.7 °C
Warmest summer day per year	24.7 °C	+2.0 °C	+2.6 °C	+4.2 °C	+4.9 °C
Average precipitation summer	224 mm	+1.0%	-8%	-5.0%	-23%
Daily amount exceeded once in 10 years	44 mm	+2.5 to +15%	+2.5 to 17%	+5.5 to +40%	+5 to +40%
Maximum hourly precipitation in a year	15.1 mm/h	+8 to +16%	+9 to 19%	+22 to +45%	+22 to +45%
Potential evaporation (summer)	266 mm	+3.5%	+8.5%	+9%	+15%
Highest moisture deficit exceeded once in 10 years	230 mm	+3.5%	+17%	+15%	+40%

Table 6.2: Climate scenarios for the Netherlands, projected values for 2050 and 2085 (KNMI 2015)

The overall trends in the KNMI’06 and KNMI’14 climate scenarios do not differ substantially, since the underlying scientific evidence on which these scenarios are based, the fourth and fifth assessment IPCC reports respectively, are quite similar for the individual emission scenarios, while the choices made for the KNMI climate scenarios were also almost identical. KNMI’14 adds more details and provides a richer picture of the future climate of the Netherlands than KNMI’06. The KNMI’14 scenarios include more climate variables and indicators than the KNMI’06 scenarios.

The KNMI scenarios describe the most likely range of future climate changes in the Netherlands. These scenarios have also been combined with socioeconomic scenarios (so-called WLO, Welvaart en Leefomgeving ‘Prosperity and Environment’) to form the Delta Scenarios.[148] These scenarios combine plausible views of future climate trends

[148] For more information on the Delta Scenarios, see: https://english.deltaprogramma.nl/delta-programme/knowledge-development/delta-scenarios

(slow/rapid) and socioeconomic developments (limited versus strong changes), looking ahead to 2050 and 2100.

The first set of Delta Scenarios was drawn up in 2012 and launched in 2013, with an update following in 2018.[149] Its hydrological conditions were based on the KNMI'06 scenarios, while its socioeconomic trends derived from WLO 2006.[150] The Delta Scenarios are the basis for the risk and vulnerability assessments that are developed in the Netherlands at the national and subnational level. A substantial part of the impacts relate to the issues addressed in the Delta Programme: protection against flooding, the supply of fresh water and spatial adaptation to flooding, and heat stress in the built environment.

The KNMI'14 climate scenarios were launched in 2014 and the socioeconomic scenarios received an update in 2015. Also in 2015, global agreements were set down in Paris on the restriction of global warming to a maximum of 2 degrees Celsius by 2100. In 2017–2018, these new insights into socio-economic trends and the Paris climate agreements were incorporated into an interim update of the Delta Scenarios. An assessment of these new scenarios and agreements for the Delta Scenarios concluded that the new insights fall within the bandwidth of the Delta Scenarios; as such, the Delta Scenarios are still a proper basis for the selection of measures. Table 6.3 summarises the most important risks and opportunities for various sectors as derived from the KNMI'14 scenarios.

Coastal impacts	Storm surges will show little change, but the sea level rise will continue; until now, the process of sea level rise is relatively slow. Coastal protection measures require continuous monitoring to detect the expected acceleration of the sea level rise in the near future
Flooding	Increased winter rainfall will increase peak discharge and flooding risks of the Rhine, Meuse and smaller rivers
Water resources	In two of the four scenarios, drought will increase in summer and lead to water shortages, water quality issues and salinisation; sea level rise will contribute to salt water intrusion
Health	Temperature rise will lead to reduced mortality during winter and increased mortality in summer; during hot summers, air quality will

[149] Deltascenario's voor de 21e eeuw, actualisering 2017. H.A Wolters, G.J. van den Born, E. Dammers, S. Reinhard, Deltares, 2018

[150] Welvaart en Leefomgeving, een scenariostudie voor Nederland in 2040. L.H.J.M. Janssen, V.R. Okker, J. Schuur; Centraal Planbureau, Milieu- en Natuurplanbureau en Ruimtelijk Planbureau, 2006

	deteriorate; there is great uncertainty about possible trends in infectious diseases; a further increase in the number of 'allergy days' due to the extension of the growing and flowering season
Mobility	Traffic disruption due to heavy showers may increase; slippery roads under icy conditions and damage to roads become less likely, but rutting will increase during summer heat waves
Energy	The energy demand for heating houses, factories and offices will decrease, but more energy will be required for air conditioning; the demand for inland cooling water for electricity production will reduce as fossil fuel-powered energy production will gradually phase out
Agriculture	Potential crop yields will increase with a longer growing season and higher CO_2 concentrations, but changes in precipitation and the prevalence of extreme events could threaten harvests; dry years will present a particular challenge; pests and diseases may increase
Nature	The risks are the greatest for ecosystems that depend on precipitation, e.g. heathlands, dry grasslands, rain-fed moorland pools and raised bogs; fens in nature reserves surrounded by deeply drained polders that depend on the inlet of surface water are also highly susceptible; increased risk of natural fires; climate zones are shifting and biodiversity will change
Recreation	The number of attractive recreation days increases

Table 6.3: Sectoral implications for the Netherlands (KNMI 2015)

The National Adaptation Strategy (2016) has its basis in the KNMI'14 scenarios and elaborates on the four climate trends ('Hotter', 'Wetter', 'Drier' and 'Rising Sea Level') to characterise the implications of climate change for nine sectors: water and spatial management; nature; agriculture, horticulture and fisheries; health and welfare; recreation and tourism; infrastructure (road, rail, water and aviation); energy; IT and telecommunications; and public safety and security.

6.1.2 Implications for water and spatial adaptation

The main impacts of climate change on water management, if insufficient countermeasures are taken, include the following:

- a raised likelihood of coastal erosion and flooding;

- an increase in peak discharges from the rivers in winter, raising the likelihood of flooding;
- more frequent flooding in urban areas after extreme rainfall events;
- a decrease of river discharges in summer, affecting transport capacities and freshwater availability (e.g. for irrigation);
- an increased chance of water quality deterioration caused by drought – combined with decreasing water volumes and dropping water levels – or by higher water temperatures;
- an increase in salt water intrusion into surface water bodies, impacting freshwater availability;
- an increase in concentrations of substances in water such as nutrients due to the evaporation of water.

Over the past 100 years, the sea level rose by about 20 cm and it is projected to increase further (Table 6.2). This rising sea level leads to coastal erosion, reduces safety along the coast, and leads to a need for increased pumping capacity for discharging excessive fresh water supply during peak periods into the sea. The climate scenarios also predict higher wind speeds, although this increase is small and lies within the current variability in wind speed from year to year. The expected higher precipitation in winter and reduced snowfall will make discharges in the Rhine and Meuse catchment more extreme. It is important to note that the actual discharges will also depend on factors such as water management of the upstream river basin, in addition to climate change. A critical flood situation can occur if spring tide, storm conditions and high river discharge coincide. As the sewage systems were designed to cope with less violent downpours, heavier summer storms will also mean more pluvial flooding in urban areas.

A national monitoring programme to assess the strength of the dykes has been implemented after it became clear that a number of dykes does not meet the safety standards. This third extended assessment round has generated the current picture of tasking for flood risk management. Flood protection projects have been prioritised on the basis of data from the National Flood Risk Analysis for the Netherlands (2015)[151], including new safety standards. The new standards entered into use in 2017. In 2050, when the flood defence system will meet these new standards, every citizen will have a level of protection against flooding equivalent to a fatality rate of 10^{-5} per year. In addition, a higher protection level may apply for areas in which flooding could lead to

[151] The National Flood Risk Analysis for the Netherlands, Rijkswaterstaat VNK Project Office, 2015

large groups of casualties or significant losses. A higher level of protection may also apply if so-called 'vital functions' are present.

Furthermore, the Delta Programme scenarios (see Box 6.1) have been used to assess the regional vulnerability of the freshwater supply in 2050. Specific vulnerabilities included the following:

- Freshwater may become increasingly scarce in our country as water consumption increases while the climate changes.
- In the coastal provinces, where salinisation can occur, a dry year means that no water of the desired quality can be withdrawn for long periods.
- On the higher, sandy part of the Netherlands, where there is no water supply from the rivers, bottlenecks can occur in an average year due to a lack of moisture in the soil and a drop in the groundwater level.
- The increase in periods of drought can cause irreversible damage to nature and can damage the infrastructure. Prioritisation of water use, for which a ranking is already in use, can diminish the possibilities to solve drought stress in agriculture through the water supply.
- In 2016, a study of the salt tolerance of agricultural crops generated more insight into salinisation and its impact.[152]

6.1.3 Implications for nature and biodiversity

Nature in the Netherlands is under pressure. Biodiversity has been declining for the past decades due to e.g. habitat loss and fragmentation as well as nitrogen deposition. Climate change exacerbates these problems. Significant effects of climate change on ecosystems and biodiversity are:

- an earlier start of the growing season as well as the breeding season;
- a decrease in species with the core area of distribution north of the Netherlands (cold-loving species);
- an increase in species with the core area of distribution south of the Netherlands (heat-loving species);
- changes in composition of species;
- changing bird migration patterns;

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[152] Inventarisatie en analyse zouttolerantie van landbouwgewassen op basis van bestaande gegevens, L C P M Stuyt, M Blom-Zandstra en R A L Kselik, Wageningen Environmental Research (Alterra), Wageningen Plant Research, oktober 2016

- loss of native species, while new species will establish themselves;
- more frequent dry periods in summer causing groundwater depletion, salinisation, and habitat loss of species that live in and near water;
- more frequent floods causing damage.

The annual average temperature in the Netherlands has increased by 2.3 °C between 1901 and 2020, with the summer warming the most.[153] This is twice the magnitude of global warming. Nature cannot keep up with the speed of temperature change: research shows that nature is adapting ten times too slowly.[154] This problem is only expected to get worse in the coming decades. Climate change has multiple impacts on nature and biodiversity in the Netherlands.

Firstly, climate change will allow some plant and animal species from warmer, more southerly regions to become established in the Netherlands. With the arrival of new heat-loving species to the Netherlands, the competitive relationships between species are changing. Little is known about the exact effects of this. However, some of these new species may pose a threat to biodiversity, economic activity, or human and veterinary health, as they also involve pest species or nuisance species. Examples include the oak processionary caterpillar and the western corn rootworm. At the same time, more cold-loving species, such as wheatears, black-tailed godwits, Linnaea borealis, arnica and burbots, are disappearing. This process has been observed already (Figure 6.3) and constitutes a natural process. It is often the weather extremes that cause rapid changes in nature. An extremely high maximum temperature, intense or prolonged drought, wildfires or a severe storm can cause major deaths among species or promote the establishment of new species. The extreme drought in 2018 and 2019, for example, had a very large effect on many nature reserves. This process of changing species abundance could be amplified by low spatial cohesion between the nature areas in the Netherlands and those of our neighbouring countries (species cannot follow shifting climate zones due to habitat fragmentation).

[153] Temperatuur in Nederland en mondiaal, 1907 - 2019 | Compendium voor de Leefomgeving (clo.nl)
[154] Van Swaay, C. A. M., van Turnhout, C. A. M., Sparrius, L. B., van Grunsven, R. H. A., van Deijk, J. R., van Strien, A. J., & Doornbos, S. (2018). Hoe onze flora en fauna veranderen door klimaatverandering. *De Levende Natuur*, *119*(6), 256-259.

Secondly, climate change also has an effect on the growing and flowering periods of plants[155] as well as on the breeding season of birds[156] (phenology). The increased temperatures are the main explanation for this shift. Climate change also affects the times when birds migrate, insects emerge, and mammals and amphibians hibernate. When some of these changes fail to coincide, food chains can become disrupted. If this situation occurs, the change in climate rises above the adaptive capacity of nature.

Third and finally, hydrological changes in groundwater and surface water – as well as temperature changes – are also putting increasing direct pressure on ecosystems such as forests, coasts and peat areas. Our aquatic and wet terrestrial ecosystems, such as the smaller and larger river systems, wetlands, wet heath and raised bog, are particularly sensitive to extremes in the weather.

Climate change will be advantageous for some plants and animals but disadvantageous for other species. The actual impact will be co-determined by non-climate factors such as the dispersal and adaptive capacity of species, or management issues such as an improvement in water quality and more robust ecological networks (PBL 2010[157]).

[155] See: https://www.naturetoday.com/intl/nl/observations/natuurkalender/sightings/annual-reports/jaaroverzicht-2001-2015
[156] See: https://www.clo.nl/indicatoren/nl1405-verloop-van-de-eilegdatum-van-zangvogels
[157] Adaptation strategy for climate proofing biodiversity, PBL, September 2010

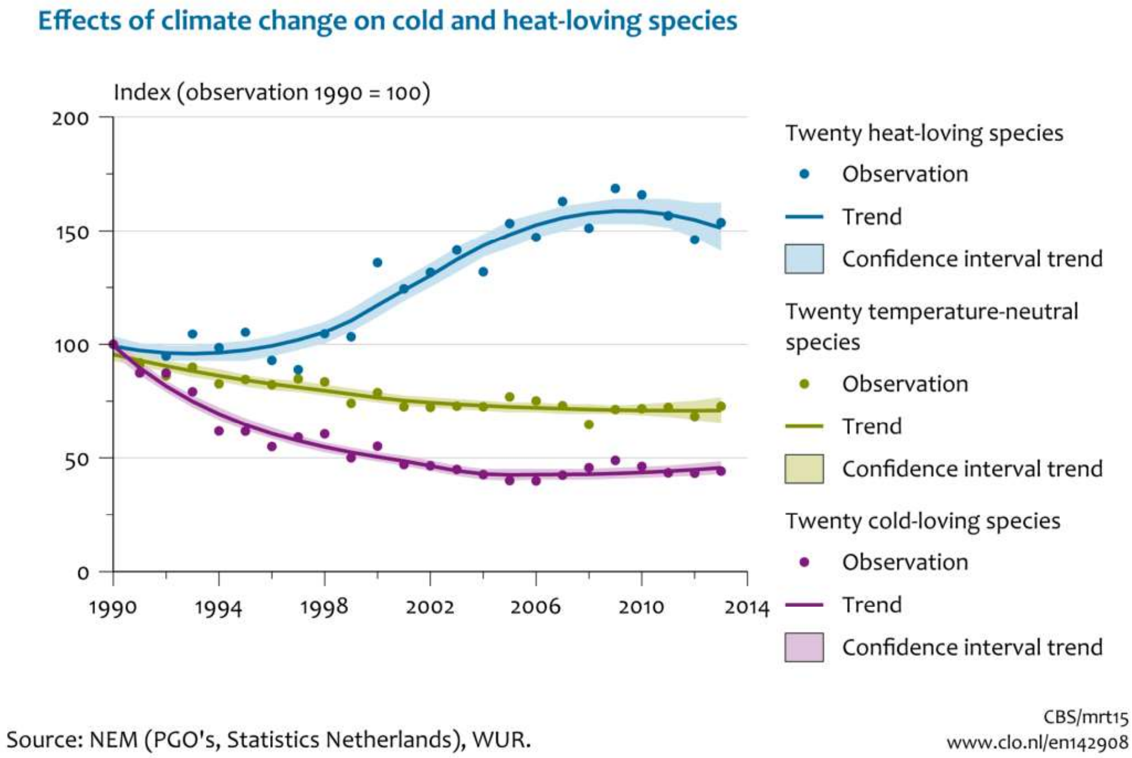

Figure 6.3: Climate change impacts on species in the Netherlands (Environmental Data Compendium 2015[158])

6.1.4 Implications for agriculture, horticulture and fisheries

The main effects of climate change on agriculture are:

- an increase in crop productivity and extension of the growing season due to the warmer climate;
- changes in the distribution, frequency, intensity and occurrence of pests and diseases affecting crops and livestock due to the warmer and wetter climate;
- a decrease in crop production and crop damage due to waterlogging caused by the increased intensity and/or duration of precipitation;
- crop damage from soil water deficits and/or brackish groundwater seepage;
- an increase in damage to buildings (e.g. greenhouses) and crops, and an increase in erosion in hilly areas due to the increased frequency and intensity of weather extremes (such as storms, heavy rain, hailstorms, heat, and night frost);

[158] Available from: Environmental Data Compendium 2015

- an increase in crop damage and crop production constraints due to the extended dry periods and increased frequency of droughts throughout the growing season and during harvest;
- an increase in crop damage and crop production constraints due to salinisation as a result of the rising sea level, in combination with droughts and land subsidence;
- an increase in livestock heat stress, affecting their well-being and production, due to extended dry periods and increased frequency of droughts.

Changes in the climate will generally improve the average climatic conditions for farming in the Netherlands, especially in comparison to southern European countries. Higher temperatures mean longer growing seasons and higher potential crop yields. Dutch agriculture can often react flexibly to changing climatic conditions. Losses due to smaller yields in dry years may often be counterbalanced by higher product prices, which results from scarcity throughout Europe. Potatoes and dairy production are examples of agricultural commodities where the competitiveness of the Netherlands is high.[159]

On the other hand, the agricultural sector regards climate change-related extreme weather events as one of the greatest challenges posed by climate change. Too much water (flooding and waterlogging) as well as too little water (drought) can result in yield loss and economic damage. Flooding of agricultural land in river areas and waterlogging due to increased rainfall damage agricultural soils and crops and decrease crop production, as was seen in the Limburg flood in 2021. Also, weather extremes such as storms, heavy rainfall and hail, which are expected to occur more frequently with climate change, damage crops. The drought risk is the highest in areas that have little or no access to water from rivers or ditches and in areas where the water table is low, such as the higher sandy soils in the east and south of the Netherlands. Periods of drought can severely damage crops and decrease crop production. In combination with droughts and land subsidence, sea level rise will also increase the salinisation in the coastal areas and the province of Flevoland in the Netherlands. Salinisation negatively impacts agriculture and horticulture, especially salt-sensitive cultivation such as tree cultivation and flower bulbs.

[159] Exploring the future of European crop production in a liberalised market, with specific consideration of climate change and the regional competitiveness, C.M.L. Hermans, I.R. Geijzendorffer, F. Ewert, M.J. Metzger, P.H. Vereijken, G.B. Woltjer f, A. Verhagen, Ecological Modelling Volume 221, Issue 18, 10 September 2010, Pages 2177-2187

In addition, the distribution, frequency, intensity and occurrence of pests and diseases may increasingly affect crops and livestock. Fungal diseases, insect pests and weed growth, especially for crops such as potatoes and onions, are expected to increase. Additionally, the warmer weather and increased droughts increase the chance of heat stress of livestock, which negatively impacts health and production, or decreases grazing time.

It is expected that higher water temperatures will result in shifts within the fish population of the North Sea. Southern (Lusitanian) species have increased in recent decades (sprat, anchovy and horse mackerel), especially at the northern limit of their distribution areas, while northern (Boreal) species have decreased at the southern limit of their distribution range but increased at the northern limit (cod). The yield of southern species is expected to increase, whereas the yield of northern species is expected to decrease in the Dutch part of the North Sea. This situation will affect the specialised fisheries in particular.[160] It is as yet unclear whether these shifts will lead to a change in the total yield. Possible increases in the North Sea area will be limited.

Ocean acidification as a result of higher CO_2 levels could have a population-scale impact on fish and shellfish, but this process is currently very difficult to predict. However, the present evidence suggests possible effects in the food web such as an enhanced sensitivity of calcifying plankton as well as effects on fish sensory systems, which may change behavioural patterns.[161] Other calcifying organisms like mussels and oysters can also be affected by ocean acidification. Mussels are an important food source and can have impaired growth and reduced structural integrity at higher concentrations of dissolved CO_2.[162]

In freshwater systems, mortality during summer could increase. There is a higher probability of diseases, pest algae and damage from storms, especially for shellfish. Overall, the implications of climate change for fisheries are still considered to be limited.

[160] Rijnsdorp, A.D., Peck, M.A., Engelhard, G.H., Möllmann, C., Pinnegar, J.K. (2009) Resolving the effect of climate change on fish populations. *ICES Journal of Marine Science* 66, 1570-1583.
[161] Heath, M.R., Neat, F.C., Pinnegar, J.K., Reid, D.G., Sims, D.W., Wright, P.J. (2012) Review of climate change impacts on marine fish and shellfish around the UK and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems* 22, 337-367.
[162] Fitzer, S., Phoenix, V., Cusack, M. et al. Ocean acidification impacts mussel control on biomineralisation. *Sci Rep* 4, 6218 (2014). https://doi.org/10.1038/srep06218.

6.1.5 Implications for health and welfare

The direct implications of climate change for public health are:

- an increase in morbidity and mortality during summer due to heat stress;
- an increase in mortality from flooding;[163]
- an increase in mental stress caused by increased pluvial flooding and flood threats.[164]

Indirect health consequences are:

- an increase of vector-transmitted diseases such as Lyme disease;
- an increase of diseases linked to air quality (ozone and particulates);
- an increase of allergies such as hay fever and house dust mite allergy;
- an increase of water-related diseases;
- a change in the occurrence of food-related diseases, due to the changing occurrence of pathogens;
- an increase of exposure to UV-related disorders.

Climate change is only one contributing factor which impacts human health and well-being. However, its consequences could potentially be severe, placing public health among the priorities of climate change policies in the Netherlands (see Sections 6.2 & 6.3). Senior citizens and people who suffer from respiratory or cardiovascular conditions are particularly susceptible to extreme temperatures. During a heatwave, mortality rises by approximately 13%, largely due to the aggravation of pre-existing conditions.[165] The frequency with which extreme temperatures occur in urban areas is higher than in rural areas. Urban areas retain more heat by day and lose less heat at night. Heat stress is exacerbated by atmospheric pollution (high levels of ozone and summer smog) and it is this combination that can trigger various respiratory diseases. It is not yet clear whether milder winters will reduce mortality.

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[163] Within the Delta Programme, measures are taken to keep the level of flood risk within the legal norms. With the adequate implementation of the Dutch flood protection programmes, flood risks will not increase.
[164] Idem.
[165] Effecten van klimaat op gezondheid : Actualisatie voor de Nationale Adaptatiestrategie [The effects of climate on health : Update for the National Adaptation Strategy], Wuijts S, Vros AC, Schets FM, Braks MAH, 2016, RIVM rapport 2014-0044

With higher average temperatures, the hay fever season may become longer in duration. An increasing length of droughts may render the season more intense. Exotic allergenic plant species such as ragweed (*Ambrosia artemisiifolia*) may establish themselves. At present, over two million people in the Netherlands take medication to relieve the symptoms of hay fever. This figure is expected to double.

The influence of climate change on public health must be considered alongside that of demographic developments such as population growth, population ageing, migration and urbanisation.[166] Warm and wet conditions will lead to problems with mosquitoes and other arthropods as well as the diseases that they spread (emerging zoonoses such as West Nile virus or malaria), which also result from more frequent travel abroad. In addition, people are projected to spend more time outside (more often and for longer periods) because it will become warmer on average, while they will also spend more time on outdoor leisure and recreation activities. Exposure to UV radiation, air pollution and pollen, water-borne diseases (e.g. cyanobacteria) and Lyme disease may increase as a result. The ozone layer above the Netherlands will probably recover more quickly from climate change, counteracting the exposure to UV radiation.

6.1.6 Implications for recreation and tourism

The implications of climate change for the recreation sector are:

- a longer tourist season due to higher temperatures in spring and summer;
- restrictions on water-based recreation, such as reduced navigability and more delays at bridges or locks, due to a higher frequency of falling water levels in summer;
- a decline in bathing water quality;
- an increase in the number of day trips;
- a rise in the number of foreign tourists;
- an increase in the erosion of beaches and dunes due to higher mean sea levels.

Depending on the climate scenario, the net spending in the recreation sector may rise by between 1% and 6%. However, no account has been taken of any changes in leisure and recreation behaviour. European studies show that, in the months of June, July and

[166] For a substantiation of this fact, see also: Climate change and public health policy: translating the science, Braks M, van Ginkel R, Wint W, Sedda L, Sprong H, Int J Environ Res Public Health. 2013 Dec 19;11(1):13-29.

August, the temperature in the traditional holiday regions around the Mediterranean could become too high for many tourists. In the more temperate climates, by contrast, conditions will become more favourable. The Netherlands will have a more distinguished reputation as 'the Netherlands Waterland' (since the popularity of water sports is growing). Numbers of foreign tourists coming to the Netherlands may rise and more people may remain in the Netherlands for their holidays.

The increasing popularity of recreation on and in the water means that more people will be exposed to water and the associated health problems.

6.1.7 Implications for infrastructure (road, rail, water and aviation)

The implications of climate change for infrastructure are:

- increased flooding and obstruction of facilities and roads caused by excessive rain, in case of insufficient drainage capacity;
- more erosion of road infrastructure and embankments by heavy rain and flooding, which results in more maintenance;
- more traffic congestion and less safety due to more extreme rainfall;
- changing groundwater levels. In periods of drought this may lead to increased soil subsidence. The rise of groundwater levels in wet circumstances increases the risk of uplift of tunnels;
- an increase in corrosion due to higher precipitation and higher temperatures;
- an increase of rutting on melting road surfaces (in case of dense asphalt, as porous asphalt is less vulnerable to heat), deformation of rail tracks, as well as failure of technical installations;
- due to higher temperatures waterway infrastructure / engineering structures, such as moveable bridges and lock gates, might jam or not close fully;
- more obstruction of traffic by roadside fires and safety hazards due to drought and heat, and subsequent threats to adjacent nature;
- drought impacts vegetation which increases the risk of erosion of embankments in case of rain after a dry period;
- reduced navigability of rivers in periods when water levels are too high or too low. Low water levels lead to reduced transport capacity for inland shipping, which increases pressure on rail and road transport capacity, increased transport costs, and consequently shortages of e.g. fuel and building materials. Shortage of water leads to problems with the availability of locks. In general extreme water levels reduce the capacity for transfer of goods in harbours;

- problems with low water are further increased by ongoing erosion in parts of the river bed. Low water in combination with erosion lead to a restriction of the space available for navigation;
- an increase in damage to oil rigs, high-voltage transmission lines, roads, bridges and vehicles from extreme storms (thunderstorms or tornado-like storms with extreme windspeeds; in general average wind is not expected to change significantly in the Netherlands due to climate change);
- fewer problems due to extreme winter conditions; e.g. fewer occasions when roads need to be salted, reduction in damage to rail tracks and roads by frost and salt, fewer constraints on water transport from ice cover and fewer travel delays;
- an increase in the probability of surface water pollution caused by sewerage overflow after heavy precipitation;
- increased vulnerability to extreme weather due to socioeconomic developments and new technologies such as smarter vehicles;
- increased vulnerability of transport to extreme weather due to increasing dependence on other sectors such as energy and IT.

A multitude of reports (e.g. OECD 2016)[167] state that the economic costs of extreme weather due to climate change, storms and floods are very high and are increasing. Increasing precipitation combined with higher temperatures may accelerate the corrosion and deterioration of viaducts, bridges and other infrastructure, while inspections and maintenance work will be needed more often. The relatively short depreciation periods for investments in the road haulage sector allow it to react flexibly to climate change. However, it is necessary to incorporate measures to prevent or mitigate the effects of climate change as early as possible into maintenance, renovation and construction, in order to prevent high costs due to damage that could have been prevented. Depending on the type of effect and its characteristics, climate change may cause high repair costs and/or user costs of infrastructure though, due to a lower availability of the infrastructure. Soil subsidence affects roads at a slow pace and therefore cause little user costs, but higher repair costs in the long term. Poor sight due to heavy rainfall will cause little to no repair costs, but higher user costs due to a lower availability of the infrastructure. Compared to the change in the levels of use (increased traffic, heavier vehicles), climate change contributes little to wear and tear of pavements, proceeding as it does at a slow pace compared to the frequency of regular maintenance work of road infrastructure.

[167] Adapting Transport to Climate Change and Extreme Weather: Implications for Infrastructure Owners and Network Managers, ITF Research Reports, OECD Publishing, Paris 2016

The impact on the availability of infrastructure due to extreme weather, and consequently on user costs, could be higher as well. The effects of low river discharges could become an important factor in water transport. A specific effect, which will demand action in the long run, is the constraints that shipping will suffer due to extreme high or low water. This development may push up prices for transport, and also impacts road and rail transportation indirectly. In the long run, this situation may lead to a shift in transport modality.

Investments in transport by rail and waterways require more time and the replacement periods of materials are much longer, thus making them more vulnerable. Infrastructure is also dependent on other sectors, e.g. electricity and telecom, whereas managing water risks requires cooperation between water managers. Awareness and knowledge of all possible climate effects is essential for critical infrastructure to become more climate resilient.

Opportunities resulting from climate change arise because costs are avoided (e.g. less winter maintenance), because future developments can accommodate known causes of climate change (e.g. integrated planning, smart vehicles suitable to adapt to climatic conditions), and because innovation with associated economic potential is required.

6.1.8 Implications for energy, IT and telecommunications

The implications of climate change for energy are:

- a decline in natural gas consumption in winter;
- an increase in electricity consumption during summer;
- an increase in the frequency of cooling water constraints for facilities such as power plants. This issue is a European problem, as the Dutch power plants have been moved to the sea;
- a reduction in the ice accretion on wind turbines;
- an increase in the damage to critical infrastructure from extreme storms.

An important trend is the increasing 'electrification' of society. Socioeconomic developments and new technologies continuously increase the demand for energy, while the dependence of other critical sectors on the energy and IT network increases the vulnerability of society. Moreover, these networks are becoming increasingly interwoven, not only in the Netherlands but also on the international scale. Finally, due to the increasing contribution of renewable energy sources such as solar and wind, the energy system in Europe – including the Netherlands – is becoming more vulnerable to climate and weather extremes as well (PBL 2017).[168]

As a result of these factors, a disruption of the energy supply due to climate change can have direct effects on all critical infrastructure such as IT and transport, leading to numerous cascading effects in other sectors as well. For example, if 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. In the end, a failing energy grid due to the effects of climate change can result in high societal and economic impact. The cost to prevent physical damage to infrastructure is several factors lower than the costs of not being able to add value through energy in all depending sectors of society, such as information and communication (IT), the industrial and transport sectors, and civil society at large.

In addition, the fuel mix used in power generation will change in the decades to come; the share of renewable energy such as wind and solar power has grown rapidly over the past years (Figure 6.4). These resources may reduce the power supply's vulnerability by reducing the dependence on cooling water, but they may also increase it; for example, in the case of wind energy, which is sensitive to weather extremes – specifically prolonged periods of windlessness.

[168] PBL (2017). Impact klimaat op robuustheid elektriciteitsvoorziening 2050 (Impact of climate on robustness of power supply 2050), eds. M. Vonk and H. Eerens. 41 pp., in press.

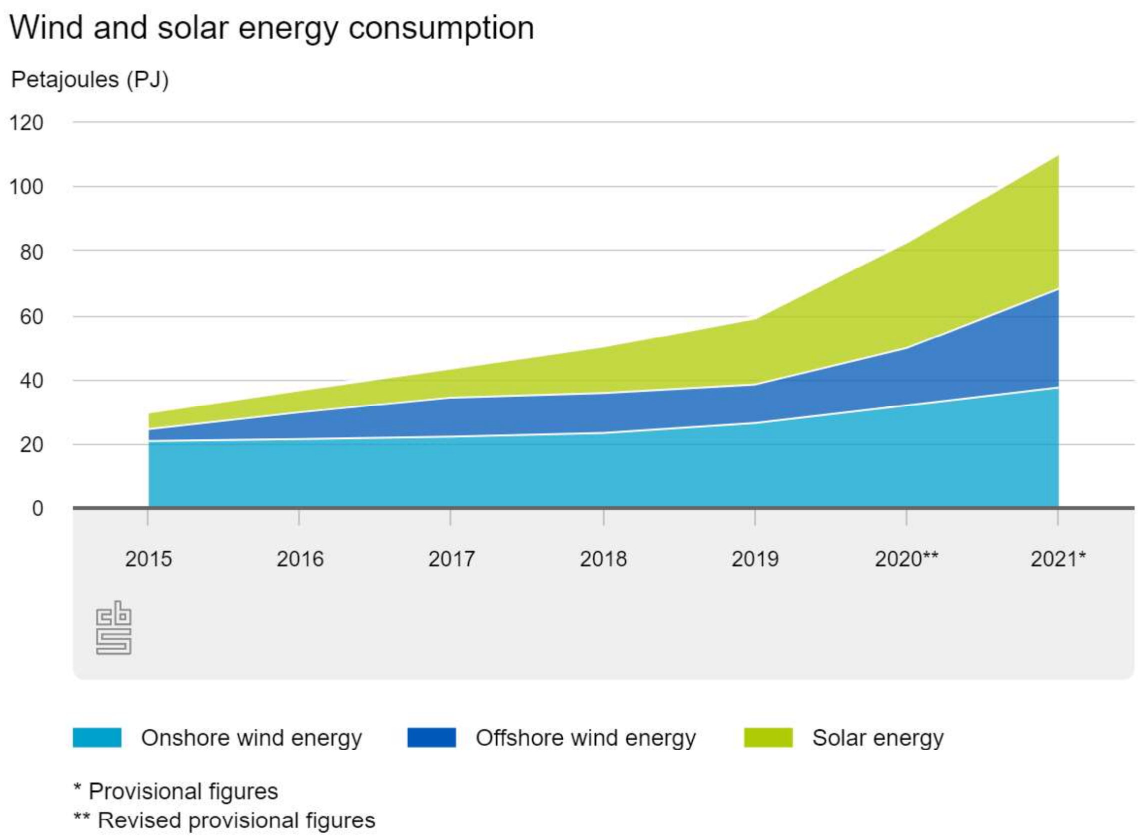


Figure 6.4 Wind and solar energy consumption (CBS, 2022)[169]

6.1.9 International context

Climate change does not respect national boundaries. Climate change in the world has multiple consequences for the Netherlands in terms of how the country functions. The Netherlands is home to a delta of four of Europe's major rivers (Rhine, Meuse, Scheldt, and Ems). Consequently, climatic risks to the country – both in terms of flooding and drought – can result from changes in upstream weather patterns (including increased precipitation, drought or the melting of Alpine glaciers) as well as adaptation and climate change policies of upstream countries. Additionally, as a country with an open economy, partially reliant on international trade and value chains for its wealth, the Netherlands is also vulnerable to climate change-associated economic shocks and instability abroad. The Netherlands is thus vulnerable to the effects of climate change elsewhere.

[169] Available from: https://www.cbs.nl/en-gb/news/2022/26/lower-renewable-energy-share-despite-more-solar-and-wind-energy

To get a clear picture of the nature of the international context of climate change vulnerability, the PBL published a report[170] on the risks and opportunities of international climate effects for the Netherlands. The report shows that the main risks for the Netherlands arise from weather extremes such as cyclones, extreme precipitation events, heatwaves and drought. It is expected that the probability and intensity of such weather extremes worldwide will increase due to climate change. The more gradual, but high impact, changes in the global climate also affect the Netherlands. These changes could include the melting of the polar ice, the shifting of climate zones and the related effects on the growing conditions for crops, and the warming of the oceans leading to the migration of fish stocks. Based on this, the PBL report outlines the main international risks for the Netherlands – differentiating between the European and the global level.

Risks on the European level

The 2015 PBL report distinguishes between climate risks and opportunities in an European context on the one hand and the global dimensions on the other hand. In Europe, the climate risks with the greatest impact for the Netherlands are related to (1) the international power grid and IT networks, (2) the water levels in the rivers and (3) public health.

Firstly, power supply and IT services form a challenge in the face of climate change. As grids and networks are becoming increasingly closely connected internationally, a disruption in just one of these networks and/or regions could trigger cascade effects. The probability that the Netherlands will be faced with a failure of the power grid or a collapse of IT networks due to weather extremes is small at the moment, but should it occur, the impact could be huge. At the same time, climate adaptation efforts on the part of the Netherlands to make the power supply and IT networks more robust will be most fruitful if they are undertaken in close cooperation with other countries in Europe; for example, by doing climate stress tests.

Secondly, the Netherlands has an extensive delta programme aimed at minimising the risk from climate change in regards to flooding. However, in July 2021, extreme rainfall caused regional flooding in Germany, Belgium and Luxembourg, and the Dutch province of Limburg, culminating in a crisis of unprecedented proportions in the Netherlands and

[170] Worldwide climate effects. Risks and opportunities for the Netherlands. Eds. M. Vonk, A. Bouwman, R. van Dorland & H. Eerens, PBL, 2015

neighbouring countries. Flooding from streams and high water levels in the Meuse resulted in a great deal of damage and misery for local residents, businesses and organisations in the stricken regions. Houses were left uninhabitable, possessions swept away, campsites flooded and harvests ruined – and that was not the worst of it. In neighbouring countries, lives were also lost. As the Netherlands is a delta county and thus vulnerable to climatic events occurring upstream in rivers like the Meuse, Rhine, Ems and Scheldt, transnational cooperation is crucial in adapting to increasingly frequent extreme weather events – such as the heavy precipitation causing the 2021 floods. Cooperation with upstream countries is institutionalised in the Meuse, Rhine, Ems, and Scheldt commissions. These commissions focus, amongst other topics, on flood prevention. As the floods of 2021 show, there is a needs to further strengthen resilience in these riverine areas. In response to the floods, the Netherlands has sought dialogue with German and Belgian national and regional authorities at various levels to improve the resilience of the riverine areas to extreme weather events.

Thirdly, climate change implications in terms of public health can be considered in direct impacts such as increased morbidity and mortality due to heat stress, but also indirect health consequences through emerging zoonoses such as West Nile virus or malaria and an increase of vector-transmitted diseases such as Lyme disease. The outbreak of COVID-19 has been a major public health threat and disrupted much of public life around the globe. In this regard COVID-19 has shown the importance of European cooperation in disease preparedness and response. Dutch systems for infectious disease preparedness will be evaluated and strengthened in light of the lessons drawn from the COVID-19 pandemic.

Risks on the global level

The most relevant risks of climate change impact on the Netherlands from a global perspective are related to (1) disruptions of economic chains and (2) international stability.

Firstly, regarding the economic chain, if weather extremes somewhere in the world lead to temporary shortages in and disruptions to the supply of raw materials, products and services, this situation can lead to increasing prices. As a result, the World Economic Forum recognises that climate change is posing a major risk to the functioning of the world economy. Although the impact of these disruptions per event would likely be small for the Dutch economy as a whole, this notion does not preclude the fact that it could be serious for individual companies or private citizens. For example, Dutch businesses and citizens in a disaster area could become directly affected. Of relevance in this regard is that the Netherlands has the ambition to change its economy from a linear economic system to a circular economic system. Goals have been set to reach 50% circularity in 2030 and 100% circularity by 2050. Increased circularity of the economic system helps reduce vulnerability to disruptions of the supply and distribution of raw materials, as it reduces the need for raw material input in the economy.

Secondly, the Netherlands could also become affected when climate change/extremes would affect international stability. Simmering conflicts, such as those surrounding the availability of agricultural land and water, could flare up as a result of climate change and lead to political instability. For example, higher food prices due to harvest failures after drought could have considerable consequences for the local population in the affected areas, eventually leading to increased tensions. The possible increase in tensions and natural disasters will lead to a greater demand for relief in other regions and a need for more humanitarian aid. In the Arctic region, tensions could mount concerning the rights to natural resources which would become extractable due to the melting polar ice. Although it is unlikely that this situation will lead to conflict, the impact could be major should it occur.

There are several ways in which the Netherlands may come to experience the consequences of global climate change; disruption of the business chains or the supply of raw materials, financial damage to Dutch investments abroad, damage to vital infrastructure such as energy or IT, damage to people travelling to countries with increased public health risks, or even geopolitical consequences such as conflict and migration.

6.2 (B) Impacts and urgencies

Section 6.1 comprised an inventory of climate change – observed and projected – and its implications for the Netherlands. This inventory has been gathered over the years, especially in the Knowledge for Climate (Kennis voor Klimaat) Research Programme. A wide range of implications have been identified. As a next step after these initial inventories, a risk assessment has been carried out in order to assess the risk of especially the negative implications (PBL 2015). PBL is currently working on an update of this assessment. The results of the assessment will be available in 2024 (regarding the current climate impact and risks) and 2025 (future impact and risks). The latter will be based on the revised climate scenarios for the Netherlands that the KNMI will publish in 2023.

6.2.1 Understanding risk: likelihood and impact

The negative implications of climate change may have a serious effect on the way that the country functions. They are varied, affect various levels and scales, and have an enormously varied impact as well. To picture the main risks that the Netherlands is likely to face, a distinction has been made between risks affecting the economy, those affecting people, and those affecting nature and the environment. The risks were subsequently ranked according to impact and likelihood.[171]

The impact of an occurrence of climate change was classified into three categories using semi-quantitative scoring, with different category boundaries per type of impact (i.e. economy, people, and nature and the environment).

The likelihood of an occurrence of climate change was also classified into three categories: unlikely to increase within this century, likely to increase within this century and likely to increase within this decade.

Three impact tables resulted from this analysis. In these tables, the negative implications of climate change were classified ranging from a low risk (low impact and low likelihood) to a high risk (high impact and high likelihood); see PBL 2015 or Appendix 1 of NAS 2016.

[171] In many publications the term 'probability' is used instead of 'likelihood'

Box 6.2. Risk assessment method (PBL 2015):

Climate change may cause the events that we are currently already facing to become more frequent and more intense. The gradual changes in climate (e.g. the rise in temperatures and sea levels) as well as the expected increase in weather extremes (drought, heavy rainfall in combination with wind gusts) will both lead to changes in the level of risk for people and nature. In collaboration with many other knowledge institutes, PBL 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* (likelihood) and *projected magnitude* (impact). The magnitude and probability for each risk dimension were classified into three categories. The resulting tables can be found in PBL 2015.

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 as well as the current size and composition of the Dutch population, combining these factors with the climate change projected for 2050. As a result, this assessment is effectively an estimation 'in case of inaction'.

The magnitude of the economic risks is indicated by the projected damage in euros as well as the personal risks in terms of the number of deaths and/or casualties. Casualties are people who have somehow been exposed to the consequences of climate change. This group may vary from people whose home has been flooded as a result of extreme rainfall to people who experience power cuts or disruptions to communication services and 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 were derived from studies carried out for the Delta Programme. For the other risks, the magnitude and likelihood were based on other studies of i) transport and infrastructure, ii) the power supply system, iii) IT networks, iv) public health, v) nature, vi) agriculture and vii) fishery. For each category, this estimate concerns the magnitude of the consequences within a certain sector. The related background reports can be downloaded from http://www.ruimtelijkeadaptatie.nl/nl/bouwstenen-nas. International risks for the Netherlands were derived from PBL (2015).

6.2.2 Visualising consequences of climate change and risk

When writing the National Climate Adaptation Strategy, it was decided to visualise all inventoried implications or consequences of climate change in four diagrams visualising each of the four major climate trends:

1. Temperatures are rising (it becomes warmer, see Figure 6.6a).
2. Precipitation is increasing (it becomes wetter, see Figure 6.6b).
3. Periods of drought are increasing in summer (it becomes drier, see Figure 6.6c).
4. The sea level is rising (see Figure 6.6d).

The results of the risk assessment described above have been included in these diagrams, adding bold uninterrupted and bold interrupted outer lines to indicate that the risk for sectors and systems is high. These diagrams will be further refined and updated with the results from the PBL study mentioned in the introduction of section 6.2. Based on these diagrams, further detailed diagrams were already developed in 2020-2021 specified for each of the following sectors: water management, nature, agriculture, health, recreation and tourism, infrastructure, energy, IT and telecommunications, safety, built environment and spatial planning.[172]

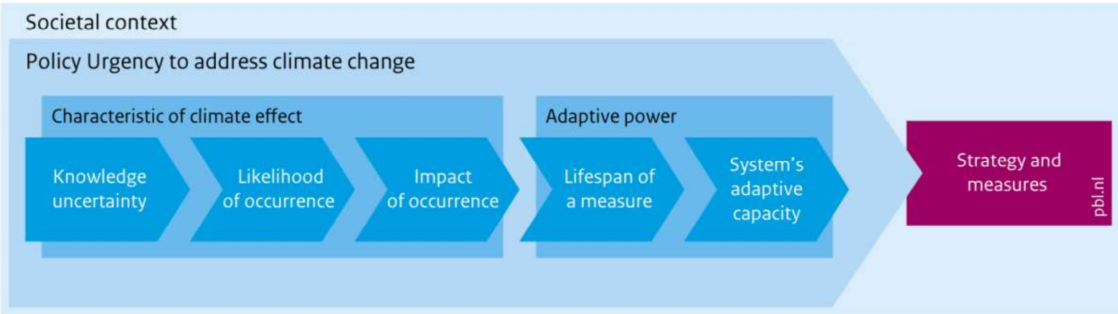
6.2.3 From risk assessment to adaptation strategy

The next step to be taken is to formulate an adaptation strategy counteracting the negative sectoral implications. In order to do so, we need to know where to start. Which one of the risks needs our attention? Which sector or system has already studied the implications of climate change and is addressing them already? Where could adaptation measures best be taken? Which should these measures be? And when should these measures be taken? Such questions need to be answered in order to determine where to start.

[172] Available diagrams per sector: https://klimaatadaptatienederland.nl/thema-sector/ (in Dutch)

To determine the issues that need to be addressed urgently, the Netherlands Environmental Assessment Agency (PBL) developed five criteria. Three of them define the character of climate change or a climate effect and two of them define the ability of an affected sector or system to adapt to the changing climate (see Figure 6.5).

Policy urgency defines the strategy for adaptation measures



Source: PBL

Whether or not a climate effect is considered to be urgent depends not only on the character of the particular climate effect but also on the adaptive capacity of society and the societal context.

Figure 6.5: Criteria to determine urgency.

First, three criteria that determine the character of a climate effect (the first two have already been explained above when defining different risks):

1. the likelihood of an effect;
2. the impact of an effect;
3. the knowledge uncertainty about the effect. Is it a gradual change which is often linear and as such relatively easy to predict, are we confronted with increasing extremes which is much more difficult to predict, or are we facing a system change?

Second, two criteria to define the ability of a sector or system to adapt:

1. the lifespan of a measure, depending among other things on the lifetime or replacement time of parts;
2. the capacity to adapt within a sector or a system, depending among other things on the culture.

Within PBL's standard methodology, these five criteria are used to identify the sectoral implications or consequences of climate change to which extra attention should be devoted, over and above those designated under the Delta Programme. As a result, the National Climate Adaptation Strategy focuses not only on issues suffering from a marked climate impact but also on vulnerable sectors and/or sectors with limited adaptive capacity. This approach has led to the following six issues demanding urgent action:

1. more heat stress leading to increased morbidity, hospital admissions and mortality, as well as reduced productivity;
2. more frequent failure of vital systems in energy, telecommunications, IT and transport infrastructures;
3. more frequent crop failures or other problems in the agricultural sector, such as decreased yields or damage to production resources;
4. shifting climate zones, whereby some flora and fauna species will be unable to migrate or adapt, leading to changes in biodiversity;
5. greater health burden and loss of productivity due to a possible increase in infectious diseases or allergic respiratory conditions such as hay fever;
6. cumulative effects, whereby a system failure in one sector or at one location triggers further problems elsewhere.

Figure 6.6a: Overview of climate trends in the Netherlands: temperatures are rising (available in higher resolution here: Climate Adaptation Knowledge Portal)

Figure 6.6b: Overview of climate trends in the Netherlands: precipitation is increasing (available in higher resolution here: Climate Adaptation Knowledge Portal)

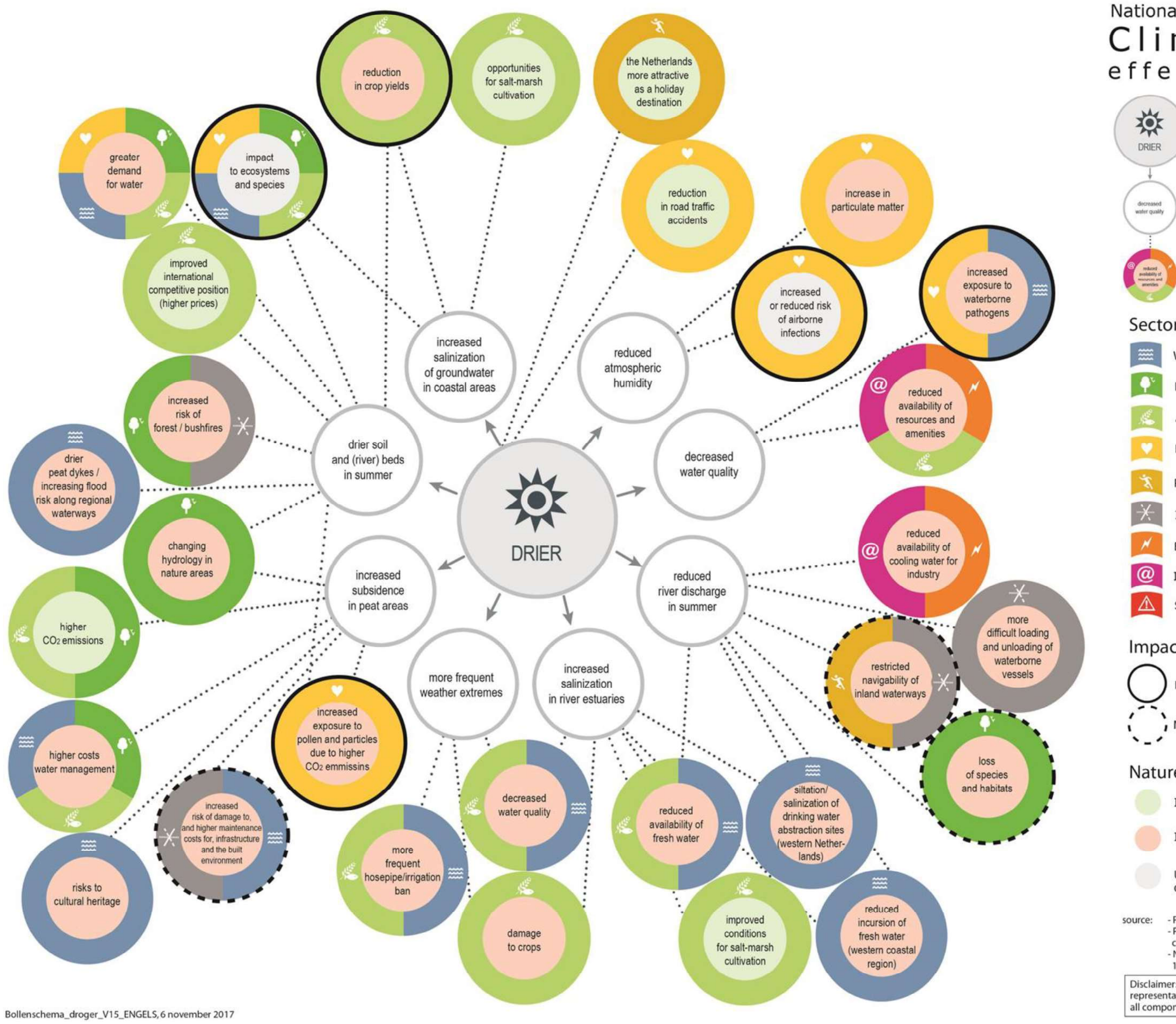


Figure 6.6c: Overview of climate trends in the Netherlands: periods of drought are increasing in summer (available in higher resolution here: Climate Adaptation Knowledge Portal)

Figure 6.6d: Overview of climate trends in the Netherlands: the sea level is rising (available in higher resolution here: Climate Adaptation Knowledge Portal)**6.3** (C) Policies and measures

We start this section with the general outline of climate adaptation policy and implementation. In the following subsections, we elaborate on sector-specific policies and measures.

The most important milestones in policy and measures for climate adaptation have been described in the introduction to this chapter. To summarise, the first National Adaptation Strategy (NAS) was published in 2007. The Delta Programme (DP) started in 2010 and its preparation phase ended with the ratification of the Delta Decisions by the Dutch Government in 2014. In 2016, the second NAS was published.

The NAS has a broad approach to climate adaptation, focusing on sectors and systems. For water and spatial adaptation, climate adaptation has a special programme in place: the Delta Programme (see Box 6.1 for general information about the DP; see Box 6.3 for general information about the NAS).

Box 6.3. National Climate Adaptation Strategy

Policy

The Netherlands was one of the first countries to develop a National Adaptation Strategy in 2007. In 2016, the Netherlands finalised a new National Climate Adaptation Strategy. This second NAS introduces various new initiatives and intends to accelerate the progress of ongoing initiatives. It encompasses the national Delta Programme, in which all authorities work together on the adaptation to sea level rise, more intensive rainfall, increased peak discharges of rivers, droughts and heat, though it focuses on the issues not dealt with in the Delta Programme. The formulation of the National Climate Adaptation Strategy 2016 was guided by the integral climate policy agenda for mitigation and adaptation, 'the Climate Agenda' (2014),[173] and it is based on recent insights into climate risks and vulnerabilities as well as socioeconomic developments. The National Climate Adaptation Strategy 2016 was presented to the House of Representatives. It also met the European Commission's request for Member States to produce a climate adaptation strategy no later than 2017.

The National Climate Adaptation Strategy 2016 builds on the analysis elaborated in the previous section, highlighting the six climate effects which call for immediate action (see 6.2). Notwithstanding the importance of addressing these six climate effects, the NAS underlines that action is needed on a wide variety of climate effects.

The NAS ascertains that 'climate proofing' is a joint undertaking for which not only the government but every member of Dutch society is responsible. For this reason, the

[173] Climate Agenda: resilient, prosperous and green. Summary, Ministry of Infrastructure and the Environment, September 2014

NAS intends to set out the course. The government stimulates and initiates projects and programmes in order to:

1. increase awareness of the necessity of climate adaptation;
2. encourage the implementation of climate adaptation measures;
3. develop and exploit the knowledge base;
4. address the six climate effects which call for immediate action;
5. embed climate adaptation within policy and legislation;
6. monitor the progress and effectiveness of the adaptation strategy.

The NAS also ascertains that the urgency of climate adaptation will only increase in the years ahead. Since it is impossible to plan everything in advance due to many unknown factors, the practice of 'learning by doing' underpins the activities set out on account of the NAS.

Measures

The National Climate Adaptation Strategy 2016 is the precursor to a Climate Adaptation Implementation Programme which is being developed at the moment. Its goal is mainstreaming climate adaptation in all policies, in all policy implementation and in all relevant activities of civil society, citizens and companies. Projects already confirmed in the NAS are also included, such as a study to determine the current status of government buildings and sites, the organisation of a dialogue on the insurability of climate risks, and the production of a climate adaptation guide to accompany the Multi-Year Programme for Infrastructure, Spatial Planning and Transport (MIRT).

In order to implement the National Climate Adaptation Strategy 2016, topical dialogues on climate adaptation have been initiated for the most pressing issues. Stakeholders are gathered around these issues to discuss and analyse the relevant elements, to define the role and responsibility of each of the stakeholders, and to formulate an action plan in which each stakeholder assumes certain responsibilities.

Coordinating role

National and international coordination of climate adaptation lies with the Ministry of Infrastructure and Water Management. The ministry also oversees the design of a monitoring system which is intended to enable the central government, regional and local authorities, water management authorities and other stakeholders to monitor the progress of the NAS implementation programme as well as their own contribution. The National Adaptation Strategy explicitly calls for broad participation of government departments, the business community and individual households. Figure 6.7 illustrates the approach taken in the National Climate Adaptation Strategy 2016 to climate-proof the Netherlands.

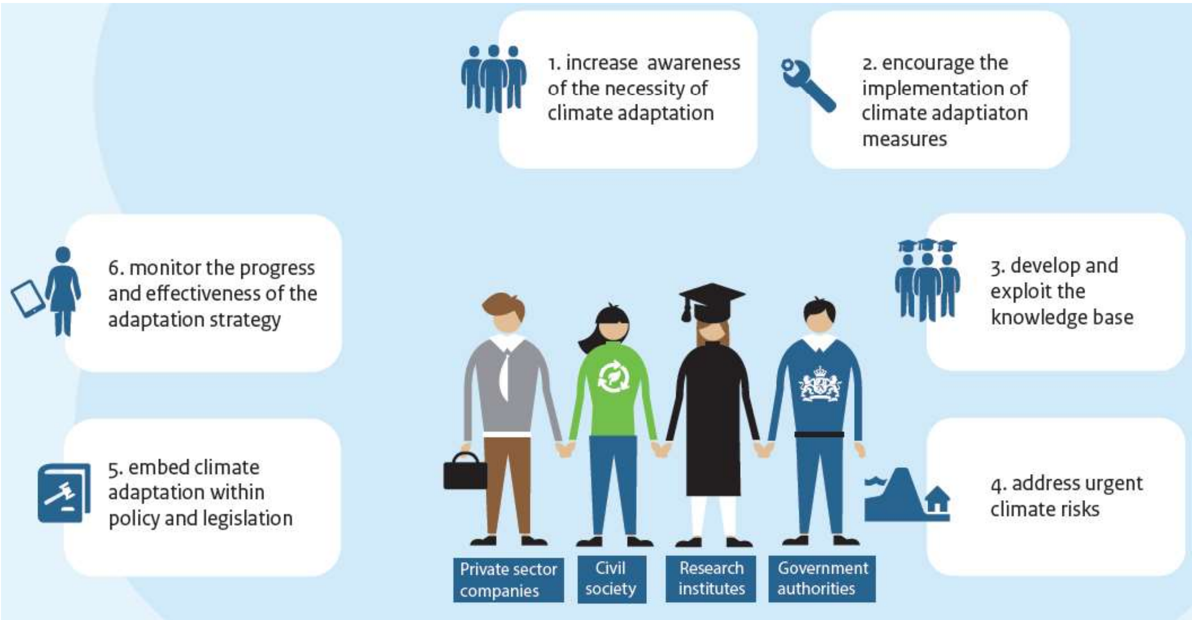


Figure 6.7: The approach of the National Adaptation Strategy to climate-proof the Netherlands

The following subsections summarise how the most affected policy sectors deal with climate adaptation, both in recent national policy plans and in implementation. Subsection 6.3.1 mainly falls within the scope of the Delta Programme, while the other subsections mainly fall within the scope of the NAS.

6.3.1 Water and spatial adaptation

In this subsection, we discuss the three components of the Delta Programme: flood risk management, freshwater supply and spatial climate adaptation. In Box 6.1, the general outline of the programme has been given. Complementary to the Delta Programme components, we discuss the international cooperation in preparing for adaptation.

Flood risk management

Overall national policy outline

Climate change and adaptation measures are strongly integrated into the water policy agenda. Increasingly extreme river discharges and the rise in sea levels are addressed in the Delta Plan on Water Safety.

New standards in flood risk management

From 1 January 2017, the new standards for flood risk management have entered into force.[174] These new standards are based on flood probabilities, whereas the old standards were based on probabilities of exceeding water levels. These new standards signify a major leap in flood risk management policy. New knowledge accompanies these new standards as well as new forms of organisation.

Dyke reinforcement continues to play the most important part in keeping the Netherlands safe from flooding. The Third Safety Assessment (2014) of the existing primary flood defence system acknowledged the importance of the considerable effort devoted to compliance with old, statutory flood protection standards. The implementation of reinforcement projects has been reprioritised on the basis of the new standard. Some of these projects will also be re-evaluated through the new standard. The first safety assessment based on the new standards will be published in 2023.

In addition to the reinforcement of dykes, other more integrated solutions are taken into consideration. An example is the Room for the River programme[175] (Ruimte voor de Rivier), where the river manager has cooperated closely with provinces and municipalities to find solutions not just for water safety but for multiple goals.

[174] For more information, see: https://www.helpdeskwater.nl/onderwerpen/waterveiligheid/primaire/nieuwe-normering/
[175] For more information on the Room for the River programme, see: https://www.rijkswaterstaat.nl/en/water/water-safety/room-for-the-rivers

The Delta Programme has adopted a risk-based approach. Not only the probability of flooding but also the consequences of flooding, such as fatalities, damage and disruption, are included in this approach. A tolerable individual risk level (i.e. a basic safety level for individual loss of life due to flooding) of 1/100,000 or 10^{-5} per year is set for everyone living or working in an area that is protected by dykes, dunes or dams (2013).[176] This risk-based approach results in differentiated levels of protection as an economically efficient method to reduce the risk. A risk-based approach also recognises opportunities offered by so-called multi-layered safety. In accordance with the European Flood Directive, the Delta Programme from 2013 onwards propagates a three-layer safety model:

1. The first level of safety is protection against flooding (dykes, dunes, barriers and dams), minimising the probability of a flood. This measure is and remains the basis of our safety during high water.
2. Spatial planning is the second layer of multi-layered safety and can limit the effects of flooding in the areas behind the dykes, thus contributing to water safety. A good spatial structure will provide physical protection of vital or vulnerable functions, which is an important component of the Delta Programme for Spatial Adaptation.
3. The third layer is emergency management. Adequate crisis management will limit the impact of a flood in terms of casualties and fatalities. This responsibility has been assigned to the Water Crisis and Flood Management Task Force (Stuurgroep Management Watercrises en Overstromingen), which includes representatives of all relevant parties, including ministries, water authorities, regional disaster management authorities and highway authorities. The Ministry of Justice and Security and the Security Council are working alongside partners in the water sector on the 'Water and Evacuation' project. This project recently produced guidelines for the regional disaster management authorities on the ways to integrate water safety into their practices and procedures.

Adaptation measures

Over the past decades, enormous investments have been made to improve the water safety of the Netherlands. Those investments are mainly policy driven: e.g. the new standards for flood protection, or better knowledge on failure of levees leading to a need

[176] Delta Programme 2014. Working on the Delta: Promising solutions for tasking and ambitions, Delta Commissioner 2013.

to reinforce. While reinforcing, climate change is taken into account, making for a 'future proof' design.

- Coastal zone*:* through 'The coast is growing', the Netherlands has opted for sand replenishment as the key solution for coastal defence. It enables the coastal foundation zone to grow concurrently with the rise in sea level. Where possible, this process occurs by distributing and transferring sand naturally along the coast (such as the 'Sand Motor' project, an artificial sand bank created off the coast of The Hague to let ocean currents, wind and waves gradually spread the sand[177]). In addition, the cabinet is opting for a cohesive approach to spatial development of the coastal zone which allows for a balanced development of nature, economy and accessibility in the existing coastal areas.
- Rivers: within the programmes for river widening under the Room for the River (Ruimte voor de Rivier) and the Meuse projects (Maaswerken), over 30 projects have been completed along the major rivers. Since 2015, the Rhine is able to handle a peak discharge level of 16,000 m^3/s and the Meuse a discharge level of 3,800 m^3/s. Where possible and cost-effective, measures are already being implemented to enable discharges of 18,000 m^3/s by the Rhine and 4,600 m^3/s by the Meuse. To anticipate these higher discharges, reservation zones for future flood protection or peak storage have been designated.
- Regional water authorities contribute on a structural basis to the current Flood Protection Programme. As part of an Administrative Agreement on Water Affairs (concluded on 23 May 2011), regional water authorities became co-financers of the investments needed to improve the primary flood defence systems which are operated and maintained by these authorities, since they fall within their jurisdiction. The co-financing is equally distributed between the water authorities and the Delta Fund. This agreement also mentions the need to cooperate on water management issues so as to increase effectivity.
- Sea level rise is an issue of specific interest for the Netherlands. The speed and amount of SLR after 2050 are highly uncertain, and determine the effort required to keep the Netherlands safe in the long run. This is why in 2019, a research programme on sea level rise was launched by the national government. In this programme, government authorities and knowledge institutes work together to develop knowledge relevant for future adaptation of the Netherlands. It addresses subjects like the effects of SLR of up to five meters on the current flood management and fresh water availability approach, and the development of possible alternative strategies for the more distant future.

[177] For more information, see: https://dezandmotor.nl/en/about-the-sand-motor/

Freshwater supply

Overall national policy outline

The Delta Decision on Freshwater Supply and the associated Delta Plan on Freshwater Supply are intended to foster sufficient freshwater supply in the Netherlands now and in future, an attractive living environment and a strong economic position. All over the Netherlands, measures aimed at the efficient use, retention, storage and supply of fresh water are in progress.[178]

Adaptation measures

The innovative approach in this domain is the so-called Smart Water Management, which aims at efficient operational water management by using IT and reaching across water management boundaries. New applications to this end, such as information screens, have proven their value in recent calamities. Tools to effect a cultural change, such as serious games, also prove effective. The use of a risk-based approach to freshwater availability in operational water management looks promising. Freshwater supply measures are increasingly linked to spatial adaptation measures, especially the ones involving drought issues. The measures set out in the Delta Plan on Freshwater Supply are being implemented according to schedule. For some measures, an integrated approach has been adopted.

To improve water quality in the Netherlands, responsible parties such as the national government, regional water authorities and other interested parties cooperate in the Delta Approach. Recently, this cooperation resulted in the Delta Approach Water Quality and Fresh Water, which intends to improve the water quality and to help avoid water quality problems in future.

Spatial climate adaptation

Overall national policy outline

The Delta Plan on Spatial Adaptation, launched in 2017, has been mentioned before. It focuses on spatial adaptation to more intense rainfall, drought and heat, as well as on

[178] As described in the year Delta Programme. See for instance: Delta Programme 2022, Every new development climate-proof, Delta Commissioner, September 2021

measures to reduce the impact of flooding through spatial planning should a flood occur. The realisation of a water-resilient and climate-proof design will be achieved by working on seven ambitions (steps in the process of becoming climate-proof) (Figure 6.8):

1. mapping out vulnerabilities;
2. conducting a risk dialogue and drawing up a strategy;
3. drawing up a programme of measures;
4. capitalising on opportunities for linkages with other spatial development initiatives;
5. improving the knowledge basis and encouraging and facilitating local governments and private parties (including network organisations);
6. regulating and embedding;
7. improving the responsiveness to calamities.

Figure 6.8: The seven ambitions for water-resilient and climate-proof spatial planning (Delta Plan on Spatial Adaptation 2018)

Regional policy outline

In urban areas, municipal authorities and regional water authorities are jointly responsible for reducing the risk of pluvial flooding (flooding as a result of heavy precipitation). Government authorities decide how they address water challenges. So-called Water Plans are developed at different scales and with different legal status; for example, a Water Plan at the level of municipalities, a Municipal Sewerage Plan (including rainwater collection), a Provincial Water Plan, a Water Management Plan of the water authorities and a country-wide National Water Plan.[179] These different water plans together offer opportunities for water-inclusive planning.

Measures coordinated by the Delta Programme

Each year a Delta Programme report is sent to the Dutch parliament containing an update on the actual situation with regard to climate adaptation and forecasting the programmes of measures (reports available in English). Concrete projects for climate change adaptation presently focus on mainstreaming and 'no regret' options. Implementation is often realised by regional and local authorities, especially where spatial developments are concerned. Coalitions of the willing for regional and local initiatives are on the increase (for example, see Box 6.4). The most important results continue be the Climate Agreements between the national government, the Association of Provinces of the Netherlands (IPO) and the Association of Netherlands Municipalities (VNG); the development and use of the National Climate Portal[180]; the Climate Impact Atlas[181]; and follow-up on the 'climate stress tests' carried out by regional governments, municipalities and network organisations between 2019 and 2020. Finally work is carried out through national and international cooperation between the business community and the international Delta Alliance (2013).

A number of municipalities have developed or have started to develop adaptation policies and even released local adaptation strategies; for example, the cities of Rotterdam (with its Rotterdam climate initiative) and Amsterdam (Amsterdam Rainproof[182]). Many more examples exist, as can be seen on the map showing examples of climate adaptation measures which is available on the national climate portal mentioned above. Several studies advise on the embedding of adaptive capacity in planning instruments such as the strategic socio-environmental assessment (planMER), Cost-Benefit Assessment,

[179] The National Water Plan 2016 – 2021, Ministry of Infrastructure and the Environment, Ministry of Economic Affairs, December 2015
[180] Available from: http://ruimtelijkeadaptatie.nl/english/
[181] Available from: http://www.klimaateffectatlas.nl/en/
[182] For more information, see: https://www.rainproof.nl/English

Water Assessment (Watertoets) and Building Act (Bouwbesluit) in technical standards and in the instruments that will become part of the new law on spatial planning, the Environment and Planning Act (Omgevingswet).

Box 6.4. Adaptation to climate change in the city of Amsterdam – Amsterdam Rainproof makes the most of rainwater

Amsterdam Rainproof is a partnership which aims to reduce the negative impact of the increasingly frequent heavy rainfall in the city. Rainwater represents a free resource. Rather than allowing it to simply run off into the drainage system, Amsterdam Rainproof wants to put it to good use.

In some places, the drainage system is simply not up to the task. Within the urban environment, much of the surface area is covered by buildings, asphalt or concrete where water accumulates and can cause significant damage.

Amsterdam Rainproof collates information, initiatives and ideas. Everyone can help to achieve its aims. While installing a water butt in the garden may not seem to make much of a difference, the 'rainproofing' of Amsterdam will be the combined result of all efforts large and small. Every drop counts! The project involves close cooperation between various partners, from water management authorities and research institutes to small companies and individual households.

https://amsterdamsmartcity.com/projects/amsterdam-rainproof | https://www.rainproof.nl/

Regional and local measures

Provinces and Regional Water Authorities are implementing adaptation measures in the regional water system. Most of the measures consist of creating 'space for water' in order to store precipitation water. In many cases, the parties involved prefer integrated solutions, combining water issues with other space-consuming issues (housing, leisure, biodiversity, farming, and so on) in order to create more value for society as a whole (see also Section 6.3.2).

The Association of Netherlands Municipalities (VNG) is monitoring its members' response to increasingly severe and protracted rainfall. Approximately one third of the investments in water management tasks at this level are intended to improve rainwater drainage. Measures focus on separating the precipitation run-off from sewage water. They include increased infiltration of precipitation, retaining groundwater at levels beneficial to the ecosystem and increased capacity to remove excess water. Municipalities are required to compensate for lost infiltration capacity. Large projects are subjected to a water assessment process.

International cooperation in preparing for adaptation

In addition to the cooperative actions at the national and regional levels, the Netherlands actively cooperates with other countries in low-lying delta areas that also face a challenging climate adaptation process. The aim is to learn from each other, to help others protect themselves against floods and to help them ensure sufficient amounts of clean water. In doing so, the Netherlands enters into long-term cooperation agreements. These partnerships are based on the existing Partners for Water (Partners voor Water) programme. Box 6.5 offers some examples from the Sustainable Water Fund (Fonds Duurzaam Water). Chapter 7 provides more extensive information on the Dutch support for climate action in developing countries.

Giving adaptation to climate change a more prominent place in foreign policy will also create international opportunities for the Netherlands; for example, in the fields of international stability, agriculture, and urban planning and development. The Netherlands is world-renowned for its experience and expertise in the field of water management. From New York to Vietnam, Dutch companies, academics and public officials are asked for advice. The growing demand for knowledge and experience on the subject of climate adaptation provides opportunities for Dutch expertise as an export product.

Box 6.5. Examples of adaptation cooperation with developing countries: Sustainable Water Fund

The Sustainable Water Fund (Fonds Duurzaam Water, FDW) is a Dutch subsidy programme facility stimulating public-private partnerships (PPPs) to accelerate support for water safety and water security in developing countries. FDW contributes to the achievement of SDG 6 (clean water and sanitation), SDG 8 (inclusive and sustainable economic growth, employment and decent work for all), and SDG 17 (global partnerships for sustainable development). To achieve the goals set by the programme and to deliver on comprehensive, well-planned climate change adaptation and mitigation, it is imperative to cooperate and collaborate closely with multiple stakeholders. FDW integrates this approach by working through PPPs that must include at least a government agency, a private partner, and an NGO but can also include a knowledge institution, of which at least one partner is Dutch. All partners contribute to inclusive, sustainable and extensible projects.

FDW has provided €150 million in subsidies since 2012. Partners are expected to co-finance 30–40%. With this budget FDW supported 42 PPP projects in 24 countries. These are projects within the fields of drinking water and sanitation (WASH), including waste; efficient water use in agriculture; and integrated water management (IWRM). Through these PPPs, the projects aim to contribute to climate change adaptation and mitigation, sustainable economic growth, self-reliance, and poverty reduction.

A few examples of how the Netherlands supports climate adaptation and mitigation through FDW include the following project cases:

Rwanda: Scaling universal access to safe and climate-resilient water services

In Rwanda, FDW co-finances a project to ensure sustainable water supply in the near future and strengthen awareness and capacities of central and district governments, the Water and Sanitation Corporation (WASAC), and urban communities on (the effects of) climate change. The project objectives are threefold. First, to support WASAC – the National Water and Sanitation service provider – to align its national master planning and investment programme for horizon 2050 with climate resilience investment planning through capacity building. Moreover, it will enhance the potential to take mitigating measures in a wide variety of water-related sectors in addition to water supply. This includes water provision for the agricultural sector and industry. Secondly, to develop and implement Water Safety Plans as a useful instrument for documentation and prioritising of climate change-related risks and hazards, hence strengthening adaptation to climate change in relation to water quality control. In addition, the project is introducing a risk-based framework to better inform and guide decision making for infrastructure management and rehabilitation based on climate change-related impacts. Last, the project will also endeavour to enhance water retention by introducing rainwater harvesting at schools.

India: Water Efficiency in Sustainable Cotton Production System

FDW supports a PPP on sustainable cotton production in India. In terms of adaptation, the project stimulates increased water efficiency and good agricultural practices in the production of organic cotton. This supports farmers in increasing their profits as well as making them more resilient towards the negative impacts stemming from climate change (including prolonged droughts). Additionally, the project introduces a social hydrologic model. This model aims to aid farmers to predict effects of introducing water efficiency interventions on their incomes. Moreover, this model helps the farmers to visualise the effects of the present decisions regarding farm management on future income on the organic cotton market, taking into account climate variability. Importantly, the introduction of technologies and techniques to harvest, conserve and re-use rain water will reduce the organic cotton footprint on groundwater abstraction/depletion. It is envisioned this will make farmers much more resilient to the expected risks of climate change in years to come.

Ethiopia: Improved water allocation and irrigation efficiency in Ziway-Shalla basin

The project contributes to adaptation in the Ziway-Shalla basin, an area facing particular water stress due to climate change and (recent) slow economic development. The project focuses on supporting climate adaptation by strengthening the capacity of the water authority in various regards. This helps achieve successful water management in order to combat the negative implications stemming from climate change, including prolonged droughts and deteriorating agricultural conditions. The project has the following end goals in strengthening the water authority: first, to develop a water allocation plan including permitting, licensing as well as the pricing of (irrigation) water; second, to increase water efficiency in the horticultural sector; and third, to take anti-erosion measures and watershed interventions.

Indonesia: Securing eroding delta coastlines, Building with Nature

FDW supports at-scale implementation of a 'Building with Nature' pilot, which provides coastal security and supports revitalisation of at least 6,000 ha of aquaculture ponds along a 20 km shoreline in Demak district (central Java). This enhances the resilience of 70,000 people living along the coast.

Northern Java's deltaic shorelines suffer from severe erosion and related flooding hazards, caused by mangrove conversion for aquaculture, groundwater extraction and infrastructure development. Over 30 million people in Java are at risk. The agricultural sector (mainly rice and aquacultures), an engine for economic growth, has suffered multi-billion dollar losses. Conventional hard-infrastructure solutions have been found to be ineffective, expensive and unable to adapt to climate change ('maladaptation'). Furthermore, they fail to bring back the economic, environmental and social benefits that healthy mangrove coastlines offer.

The project introduces the Building with Nature approach to accomplish resilience along eroding delta coastlines. This innovative approach combines civil engineering with mangrove rehabilitation to build safe and adaptive coastlines, while simultaneously introducing sustainable land use. The Building with Nature approach is mainstreamed in policies, plans and budget allocations for lowland development, disaster risk reduction, climate change adaptation and water safety in Indonesia. This helps ensure the sustainability of the project, thereby increasing the long-term resilience of the shoreline of the Demak district in central Java.

6.3.2 Implications for nature

Overall national policy outline

Climate change is likely to have a considerable impact on the realisation of the current conservation goals for biodiversity. This development requires a reassessment of aspects such as the foreseen extension and localisation of the Dutch National Ecological Network (now called 'Nature Network Netherlands') to meet climate change challenges. Solutions will often have a strong spatial impact on the already intensively used Dutch landscape.

Since 2016, various parties have been working on climate adaptation and nature within the framework of the National Climate Adaptation Strategy (NAS). Parallel to this, the Drought Policy Table was established after the dry summer of 2018. From this moment on an action programme for climate adaptation for both agriculture[183] and nature[184] has been worked on within the framework of the NAS. The Drought Policy Table has recommended including climate resilience of nature in the joint nature ambition of the central government and the provinces and linking it to the nature and development tasking.

The national government and the provinces have a major task in realising the obligations of the Birds and Habitats Directives (VHR). The Nature Pact and the Nature Programme, including the 'Nature Inclusive Agenda' are aimed at achieving this task. Climate-proof nature is the basis for realising that task. In general, the Dutch nature policy adapts by:

1. Achieving 70% of the VHR targets in and around the protected nature areas by 2030. This is done by focusing on more acreage for natural systems, creating robust connections and by improving conditions so that nature becomes more resilient.
2. Promoting the basic quality of nature in a broader sense by working together with other programmes towards a nature-inclusive society.

Examples of innovative strategies in this domain are the following broad types of adaptation:

- assessment of nature policy and biodiversity conservation goals in response to climate change (2013)[185];
- scenarios for nature-inclusive agriculture and a new 'collective' approach to agro-environmental schemes;

[183] For information on the agriculture action programme, see: https://www.rijksoverheid.nl/documenten/publicaties/2020/01/30/actieprogramma-klimaatadaptatie-landbouw
[184] For information on the nature action programme, see: https://www.rijksoverheid.nl/documenten/rapporten/2021/03/31/actielijnen-klimaatadaptatie-natuur
[185] MinEZ 2013. Natuurambitie Grote Wateren 2050 en verder [*Ambition for nature in large water bodies 2050 and beyond*]

- integration of nature objectives in water management and infrastructure;
- the Nature Inclusive Agenda.[186]

The Nature Inclusive Agenda stems from the ambition document 'Netherlands Nature Positive' (2019) and the Nature Programme that followed. This programme sets the stage for the restoration and strengthening of nature in and around protected nature areas and for the realisation of a nature-inclusive society in 2050.

The resilience of the natural environment is expected to increase through these innovations by creating larger interconnected nature areas and corridors, as well as a sufficient variety of favourable environmental conditions (High-Low Netherlands, green infrastructure, wet-dry and fresh-salt gradients, and so on). Increasing the adaptive capacity of nature calls for a fuller use of the possibilities within the existing framework of nature and biodiversity legislation and policy, with a view to a more development-oriented policy focused on natural dynamics. This policy should still respect global agreements on the protection and sustainable use of biodiversity as agreed in the Convention on Biological Diversity and the Sustainable Developments Goals. An important instrument in this respect is the creation of the 'Nature Network Netherlands' under the responsibility of the provinces.

Provincial policy outline

In 2012, many nature management tasks were devolved to the provincial level, with the existing budgetary reserves transferred to the Provinces Fund. The provincial authorities are now responsible for the management of existing nature areas as well as the realisation of the ecological network, for which 80,000 hectares are to be acquired. Within the physical domain, the central government has limited its own responsibility to the large bodies of water and to certain aspects of agricultural nature management, the latter being undertaken in association with the provinces.

Adaptation measures

In 1990, the government introduced the National Ecological Network, a concept intended to offset the impact of climate change by allowing more space for natural processes. It was hoped that the proposed infrastructure of interconnected nature areas would encourage vulnerable species to migrate; a form of 'managed relocation'. This principle

[186] https://agendanatuurinclusief.nl/de-agenda/#Agenda1

has been retained and now forms the basis of the policy document 'Natuurlijk verder' ('The Natural Way Forward').[187]

The climate buffer programme[188] was initiated in 2006 by collaborating nature organisations, later united in the Climate Buffer Coalition (CNK) in response to the consequences of climate change. Climate buffers are nature-based solutions that serve to reduce the risk of flooding and the effects of prolonged drought, while creating positive effects for living and housing, the landscape, cultural heritage and recreation. These climate buffers contribute to the climate-proofing of the Netherlands.

This initiative found a ready ear in politics. The Dutch House of Representatives awarded it a subsidy amounting to €15 million, which was meant to build climate buffers as an example for climate adaptation. Nature organisations were to be responsible for the implementation of the projects. In the subsidy conditions, the government included the provision that attention must be paid to public support and the dissemination of results. These climate buffer projects were used as best practices by the Delta Programme, which in turn led to further knowledge development and publicity.

The Climate Buffer programme ran until 2014, but a large part of the projects was completed later. These projects are permanent sources of inspiration. Thanks to the successes and the promising experience, a new start was made in 2017 and the coalition was expanded to include the Nature and Environmental Federations, now with financial support from the European LIFE IP programme (duration until 2022) and the Ministry of Agriculture, Nature and Food Quality. Six different types of climate buffers are designed:

- Ecosystem engineers: Use of organisms to establish sediment and/or slow down waves
- Carbon sinks: Carbon sequestration in organic material, formation of marshes and salt marshes
- Green air conditioning: Temperature reduction from wetlands in and around the city
- Natural sponge: Water retention in natural areas on higher ground
- Living coast: Natural dunes with shifting sand, sandbanks and expanding salt marshes as coastal protection

[187] Natuurlijk verder Rijksnatuurvisie 2014, Ministerie van Economische Zaken, 2014
[188] More information on the programme can be found here: www.klimaatbuffers.nl

- Room for nature and water management: Natural inundation areas store the water when there is heavy precipitation and peak discharge

Fig 6.9: Climate buffers in the Netherlands, with completed projects marked in blue and projects under development in yellow.[189]

6.3.3 Agriculture, horticulture and fisheries

Overall national policy outline

Dutch agriculture is likely to benefit from climate change more than agriculture in countries farther to the south or east. Higher temperatures may allow for longer growing seasons, higher yields and the introduction of new crops. If the effects of climate change elsewhere in Europe prove less propitious, the Netherlands will gain a competitive advantage. The increased frequency and intensity of weather extremes will nevertheless result in greater damage to crops and production resources.

[189] Details for each specific project can be found on the climate buffer website (in Dutch)

To prepare all Dutch entrepreneurs in agriculture and horticulture to deal with climate change sustainably and effectively, the Action Programme for Climate Adaptation in Agriculture was set up by the Ministry of Agriculture, Nature and Food Quality in 2020 in collaboration with stakeholders. Central to achieving this goal are the five pillars: water system, soil system, crops and cultivation systems, livestock farming, and supporting instruments, consisting of a regional approach, risk management, and knowledge and innovation.

Pillar 1. The water system encompasses climate adaptation actions aimed at increasing the resilience of the water system in order to be better prepared for drought, flooding and deterioration of water quality, such as salinity and nutrient pollution, now and in the future. National, regional and local cooperation minimises damage caused by climate change. In this pillar, there is structural cooperation with the Delta Programmes Freshwater and Spatial Adaptation, the Drought Policy Table, and the High Water and Flooding Policy Table and use is made of the experience of farmers and water boards.

Pillar 2. The soil system encompasses climate adaptation actions aimed at improving the health of agricultural soils by applying soil measures to, among others, increase the water storage, water infiltration, and the water purification capacity of the soil, as described in the National Programme for Agricultural Soils. In addition, improving soil quality (physical, chemical and biological) can support crops in coping with extreme weather conditions. Sustainable soil management can include, for example, using organic and green manure, lighter machines or drones, and permanent grassland.

Pillar 3. The crops and cultivation system encompasses climate adaptation actions aimed at making crops and cultivation systems more resilient to climate change as described in the Vision for the Future of Plant Protection by 2030. Climate-resilient crops are, for example, crops that are more resistant to diseases and pests, drought, salt or flooding, such as certain maize varieties, sorghum, cranberries and wine grapes. In 2022 the National Grow Fund funds the CROP-XR project to develop robust and extra-resilient agricultural crops.[190] In addition, this pillar aims to gain knowledge about adaptive

[190] For more information, see: Stand van zaken en vervolg Actieprogramma klimaatadaptatie landbouw

cultivation systems and, where necessary, to improve regulations that restrain measures, such as hail covers, to protect crops against frost and extreme showers.

Pillar 4. Livestock Farming encompasses climate adaptation actions *aimed at making livestock, such as dairy cattle, pigs and poultry, more climate-proof,* as described in the Benchmark for Sustainable Livestock Farming, the action plan for heat stress and the policy on new barn systems. Due to climate change, farm animals experience more heat and UV radiation. In addition, livestock gets exposed to new animal diseases due to climate change. Adaptation measures can include grazing and transport during the night, ventilators, and places with shadow in the meadow.

Pillar 5. Supporting Instruments consist of three supporting instruments: 1) a regional approach, 2) knowledge and innovation, and 3) risk management. These instruments cut across the four pillars and provide integral support for the objectives of these pillars. An example of a supporting instrument is the Broad Weather Insurance which agricultural entrepreneurs can use to insure against damage resulting from weather extremes.

Adaptation measures

The extreme weather events of the last couple of years have increased the urgency of implementing adaptation measures. For example, in 2016, high-intensity rainfall caused crop failure on many potato fields in South Brabant, in 2017 hail damaged crops and greenhouses, in the last five years droughts impacted agricultural productivity, and in 2021 the flooding in Limburg damaged agricultural fields. Most adaptation measures need to be implemented at the farm level, such as different cultivation methods, and measures to decrease water use or increase water retention and infiltration. However, a higher level of planning is also required for some measures, for example, farmers can adapt to high-intensity rainfall by improving drainage, but the impact on crop yields also depends on regional water management. Besides, farmers need to be assisted by research and innovation at the sector level, specifically for the development of heat-resistant or pest and disease-resistant varieties. Therefore, a dynamic knowledge agenda has been developed in collaboration with the sector on the basis of which knowledge projects are carried out and knowledge is disseminated to the agricultural and horticultural sectors and regional parties.

6.3.4 Health and welfare

Overall national policy outline

The Ministry of Health, Welfare and Sport is mindful of the possible effects of climate change, which it addresses within its regular policy. In 2007, a National Heat Plan was prepared as a preventive measure in a cooperative project between the Ministry of Health, RIVM, the Dutch Red Cross, ActiZ and the Regional Health Services GGD, and was updated in 2015.[191] It now offers a range of specific measures that can be taken locally by institutions and care providers to ensure that they are ready and act appropriately in periods of sustained heat. The National Heat Plan focuses on the residential care sector and the action to be taken when a formal heat wave warning is issued. In addition, the Delta Decision on Spatial Adaptation asks local authorities to pay attention to heat stress.[192] The updated Climate Impact Atlas disseminates knowledge and best practices.

Fig 6.10 Example of communicating what to do during heat waves

[191] Nationaal Hitteplan, versie 2015. W.I. Hagens, M. van Bruggen, RIVM 2014
[192] See: https://english.deltaprogramma.nl/three-topics/spatial-adaptation/delta-decision

Monitoring of vectors and vector-borne diseases is undertaken by the National Institute for Public Health and the Environment (RIVM) as well as the Netherlands Food and Consumer Product Safety Authority (NVWA). Government policy seeks to prevent the establishment of exotic (i.e. non-indigenous) mosquito populations in the Netherlands and the diseases that they carry (e.g. West Nile virus). If monitoring reveals the presence of exotic mosquitoes, they will be exterminated. Policy on indigenous mosquitoes (and other culcidae) is currently being prepared. In addition, environmentally related diseases – especially ones associated with exposure to water of poor quality – are under surveillance.

Adaptation measures

Municipal health departments provide various forms of support to prevent climate-related infectious diseases and exposure to allergens. They are responsible for monitoring risks in and around open water that is used for recreational purposes (in association with the water management authorities) as well as for public information about these risks. In addition, they are responsible for pest control and arrange for the extermination of rats or other vermin, among other things. For example, they also respond to outbreaks of the oak processionary (*Thaumetopoea processionea*), whose caterpillars provoke an extreme allergic skin reaction. The municipal health departments also provide advice on other allergens, including pollen, spores and mites, to members of the public as well as to the departments responsible for parks and recreation.

As part of the *Knowledge for Climate* Research Programme, a number of provincial and municipal authorities have studied the 'urban heat island' effect. Measures entail extensive modifications to physical structures. In addition, heat stress may be controlled with proper and timely information or extra care to vulnerable groups.

6.3.5 Recreation and tourism

Overall national policy outline

The general policy is to make the Netherlands more attractive for tourists, give more room to entrepreneurship and aim for sustainability. The Dutch weather might become more attractive – or less uncomfortable – than that elsewhere in Europe, which could have a positive effect on tourism. An attractive environment that invites outdoor recreational activity has a positive health effect. However, recreation also increases the change of exposure to pathogens and vectors (such as ticks and Lyme disease or cyanobacteria, also known as blue-green algae).

Adaptation measures

No specific adaptation measures for recreation and tourism are formulated.

6.3.6 Infrastructure (road, rail, water and aviation)

Overall national policy outline

The Delta Programme addresses the question of how to develop and maintain vital infrastructure in view of its resilience to climate change and extreme weather. The Delta Decision on Spatial Adaptation asks local authorities to pay attention to heat stress as part of the stress test to be performed by the municipalities. The Climate Impact Atlas[193] has been updated accordingly and a National Climate Portal has been built to disseminate both knowledge and best practices.

Adaptation measures

Adaptation measures include both spatial and non-spatial measures. Spatial measures address adaptations through urban planning, renewal and restructuring. Non-spatial measures include technical measures (such as more extensive surveillance), early identification and assessment of health risks, more targeted public information, cultural and behavioural adaptation, regulatory changes, and making climate resilience an integral part of national and local environmental and planning policies.

The climate-proofing of the urban area against flooding is improved by local measures (drainage, green roofs and water squares) or by spatial measures such as the construction of new open water (ditches, canals and ponds). An example of adaptation to changing weather patterns is the update of the design guidelines for infrastructure in order to account for the changing characteristics of rainfall. Rijkswaterstaat (the Directorate-General for Public Works and Water Management) examines whether it is necessary to update and amend the guidelines for road design and maintenance. The procedures for replacing essential water management structures such as locks and dams,

[193] Available from: http://www.klimaateffectatlas.nl/en/

as well as the plans for new infrastructure, take into account the risks imposed by climate change. Rijkswaterstaat has also produced its own Climate Impact Atlas,[194] showing the hotspots related to national road and water infrastructure. Rijkswaterstaat has also prepared an implementation programme for the next three years.[195] ProRail, which manages the national rail infrastructure, has implemented measures to deal with risks during calamities that are associated with flooding and extreme weather. For the design of new infrastructure, climate change is taken into account. ProRail has recently published an implementation agenda with respect to climate adaptation.

Water & inland shipping

Municipalities, water authorities, provinces and central government are working together on the ambitions from the Delta Plan on Spatial Adaptation (DPRA) to act climate-proof from 2020 and to be climate-proof by 2050. To this end, the Climate Resistant Networks programme maps out the risks of climate change for the main water system, main road network and the main waterway network. The first results of the stress tests have resulted in the Climate Resistant Networks Implementation Agenda, which was prepared this spring. This shows that drought in combination with soil erosion leads to bottlenecks for navigability in inland waterways. Climate change will also make very dry years become more prevalent, such as previously in 2018 and currently in 2022. The navigability of the main waterways therefore requires extra attention. Making inland waterways climate-proof necessitates an integrated approach to flood risk management, navigability, freshwater availability, water quality, nature and an (economically) attractive living environment in the Integrated River Management (IRM) programme. This programme will lay out, among other things, the choices regarding the intended riverbed position and sediment management, discharge and storage capacity on the Meuse and the Rhine tributaries before 2050. Formal decisions about this programme are expected in 2023.

6.3.7 Energy, IT and telecommunications

Overall national policy outline

The definition of 'vital' or 'critical' infrastructure has been expanded to include the supply systems for energy, IT, telecommunications and drinking water, in addition to the

[194] The Rijkswaterstaat Climate Impact Atlas is available here: [Rijkswaterstaat Klimaateffectatlas (rws.nl)]
[195] Uitvoeringsagenda Klimaatbestendige Netwerken, Ministry of Infrastructure and Water Management, March 2022

infrastructure mentioned in the previous section.[196,197] Risks of climate change, and possible approaches or measures to mitigate those risks, are one component of the 'all-hazard' safety and security approach which seeks to identify and manage all risks to the vital infrastructure in the Netherlands.

Adaptation measures

In a number of pilot projects, government authorities at all levels are working alongside private-sector companies and network managers to devise ways in which to climate-proof vital functions. Several grid managers have conducted research to determine the potential impact of climate change such as flooding on their section of the infrastructure, the objective being to identify measures intended to reduce risks. An important question being addressed is to what extent measures are necessary in order to ensure the required levels of performance. Research has also examined how a large-scale power outage would affect the chain of vital functions. The participation of the grid managers in the pilot projects has provided valuable experience and created a good basis for further cooperation.

6.4 Implementation of adaptation actions and plans

6.4.1 Progress and results achieved

As mentioned throughout the present chapter, the National Climate Adaptation Strategy is the core document outlining priorities within the Netherlands' climate adaptation policy. In order to review the progress made and the results achieved in the Dutch climate adaptation policy, the 2016 NAS was evaluated in 2022 (expected publication date: autumn 2022). Its findings will give insight into the speed and effectiveness of adaptation efforts at the national level. These findings include both the progress made as well as the barriers and challenges encountered; the findings are summarised in both section 6.4.1 and 6.4.2.

Since the NAS was formulated in 2016, the following progress has been made in the Dutch climate adaptation policy:

- All Dutch regions have assessed their climate risks.

[196] As described in the NAS: http://ruimtelijkeadaptatie.nl/english/nas/
[197] Kennis voor Klimaat (Knowledge for Climate) 2014. Infrastructuur en netwerken. Klimaat en vitale infrastructuur (Infrastructure and networks. Climate and vital infrastructure). Programmabureau Kennis voor Klimaat/Consortium Infrastructuur en netwerken. http://edepot.wur.nl/315803.

- Various local, regional and national authorities have started addressing knowledge gaps and implementing adaptation measures regarding agriculture, nature, critical infrastructure, built environment and health.
- Awareness and commitment to climate change adaptation has increased among a wide range of stakeholders (local and regional authorities, economic actors and the general public), for instance via stakeholder consultations, stress tests, dialogues and knowledge-sharing.

6.4.2. Barriers, challenges and gaps related to the implementation of adaptation

In its national climate adaptation policy, the Netherlands – like any country – faces barriers, challenges and gaps in the implementation of adaptation actions. In order to arrive at a better understanding of what those challenges are and, ultimately, overcome such challenges, the NAS evaluation has sought to identify the challenges experienced in Dutch adaptation policy. Concretely, this evaluation has found the following challenges, barriers and gaps:

- A lack of concrete targets for most of the sectors paired with a lack of an MER system hampers insight in progress made and to be made.
- Mainstreaming of adaptation in large programmes and transitions needs to be accelerated, e.g. energy transition, housing schemes and agricultural reform.
- The governance structure of the NAS should be strengthened in order to better integrate adaptation and responsibilities need to be defined more clearly, especially for themes that have no clear 'owner', such as heat.
- More attention should be paid to social, environmental and cultural aspects of climate change adaptation.

In addition, the Netherlands would like to get more insight into the effectiveness of tools and measures, hence we are taking steps from pilots to upscaling and involving the private sector, particularly the financial sector. More knowledge is necessary regarding possible measures regarding drought and heat as well the effects of shift of climate zones.

In order to tackle the abovementioned findings, the NAS Implementation Programme for 2023–2030 will be developed in 2023 and the NAS will be fully updated in 2026, based on the upcoming meteorological scenarios (2023) and consequent climate risk analysis (2025). This NAS will contain a vision for 2100; concrete interim milestones and targets; and a corresponding set of instruments and governance arrangements.

6.4.3. Good practices, lessons learned and information sharing

In its striving to adapt to climate change, the Netherlands is implementing a wide variety of climate change adaptation actions. These measures are undertaken at various levels of government, in all parts of the country, to combat various climate change-related challenges. In order to ensure transparency, as well as to learn from ongoing adaptation actions, a website has been created which comprises a large number of climate change adaptation measures.[198] The website currently presents 269 examples of different types of adaptation actions, and has been made publicly available. The website does not only list the various examples of adaptation measures, but also includes a description for all projects, in which significant background information about the project is included. For finalised projects a discussion on results and lessons learned is also included. This not only increases the transparency of our adaptation policy, but also helps identify important factors for success and good practices regarding adaption.

6.4.4. Monitoring and evaluation

The drafting of a national monitoring scheme for climate adaptation started in autumn 2021, based on the study of the Netherlands Environmental Assessment Agency (PBL) 'Navigating towards a climate-resilient country' (Navigeren naar een klimaatbestendig Nederland), describing options for short and long-term monitoring and evaluation of climate adaptation policies. It entails monitoring the progress of the implementation programme, monitoring the extent to which climate adaptation measures are effective in terms of risk reduction and monitoring the development of climate change risks to all sectors. The results will be added to the website klimaatatadaptatienederland.nl. This monitoring scheme will be fully operational in 2026 and will guarantee a structured monitoring of the progress on climate adaptation.

There are already several (sectoral or local/regional) monitoring schemes in place in the Netherlands. The monitoring programme of the Dutch Delta Programme ('Monitoring, Analysing, Acting') focuses on the questions whether the implementation (1) is on schedule and within budget (output), (2) is achieving the set goals (outcome), (3) is addressing the tasks in an integrated manner and (4) takes place with participation of other parties (authorities, companies, NGOs and citizens).

The national agency Rijkswaterstaat is responsible for measuring all kind of parameters with regard to the North Sea, coastal waters and the main rivers, including the water

[198] This website with examples of different types of adaptation actions is available from: https://klimaatadaptatienederland.nl/en/examples/

levels along the coast and in the main rivers. Rijkswaterstaat provides online information on water levels along the coast and in the main rivers and predicts these six hours before they occur.