TOWARDS WATER ROBUST CRITICAL INFRASTRUCTURE

AN INVENTORY OF STRATEGIES AND MEASURES

IN THE NETHERLANDS, AUSTRIA, DENMARK, GERMANY, THE UNITED KINGDOM & THE UNITED STATES OF AMERICA

Final Report

11/06/2015

Commissioner

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Executive Summary (Dutch)

Het doel van dit onderzoek ("Towards water robust critical infrastructure") is om vernieuwende en betekenisvolle maatregelen die de potentiele impact van overstromingen verkleinen, te verzamelen. Er wordt in dit onderzoek gekeken naar overstromingen die ontstaat vanuit de zee, rivieren en neerslag. Met het oog op klimaatverandering, kan het risico van deze overstromingen een toenemende uitdaging zijn voor de Nederlandse samenleving. Ondanks geografische verschillen tussen landen, zijn overstromingen een universele bedreiging voor het functioneren van nationale kritische infrastructuur. In dit rapport, is kritische infrastructuur gedefinieerd als "faciliteiten en sectoren die van substantieel belang zijn voor een land om haar publieke orde en economische functies te handhaven".

Dit onderzoek is uitgevoerd door vijf masterstudenten van de universiteit van Wageningen, in samenwerking met het Ministerie van Infrastructuur en Milieu. Er is een inventaris gemaakt van strategieën en maatregelen voor de volgende landen: Oostenrijk, Denemarken, Duitsland, Groot-Brittannië en de Verenigde Staten. Het ministerie verlangde een overzicht van deze mogelijk waardevolle maatregelen voor het vergroten van de water robuustheid van de kritieke infrastructuur in Nederland. Ondanks dat Nederland één van de best beschermde delta's ter wereld is, is de kans op een overstroming aanwezig. In het licht van toenemende klimaat verandering, is het belangrijk om voorzorgsmaatregelen te nemen. Dit onderzoek focust zich op vier sectoren, die door het ministerie zijn aangewezen als meest kritiek. Dit zijn de energiesector, de telecommunicatie & ICT sector, drinkwatervoorziening en de transportsector (hoofdwegennet). Er is een gestructureerd literatuuronderzoek uitgevoerd en een vragenlijst voor experts gemaakt. Deze complementeren en ondersteunen elkaar in het uiteindelijke rapport.

In dit rapport zijn meer dan 100 strategieën en maatregelen verzameld. Deze zijn verder onderverdeeld in vier analytische categorieën. De categorie voorkomen refereert naar strategieën en maatregelen die de oorzaak van het probleem aanpakken en zo het risico op overstromingen kunnen verkleinen. De categorie beschermen bevat fysieke maatregelen tegen overstromingen, zoals technische en bouwkundige versterkingen. De categorie voorbereiden betreft alle maatregelen die zich richten op het minimaliseren van de ontwrichtende gevolgen van overstromingen. De laatste categorie, bewustzijn, bevat maatregelen die autonome adaptatie en voorbereiding stimuleren. Ook zetten deze maatregelen aan tot het uitwisselen van kennis, informatie en expertise. De meeste strategieën en maatregelen vielen in twee categorieën, namelijk de categorieën voorbereiding en preventie.

De geanalyseerde landen beoordelen het belang van kritische infrastructuur per sector op verschillende manieren. Behalve in Denemarken, zijn de energie en telecommunicatie & IT sector in andere landen hoofdzakelijk geprioriteerd. Oostenrijk, Denemarken en de Verenigde Staten hebben een duidelijke visie en focus voor de transport sector. En de drinkwatervoorziening is vooral belangrijk in Denemarken en Groot-Brittannië.

Met betrekking tot beleidscoördinatie van beschermende maatregelen voor kritieke infrastructuur werden er verschillen gevonden in de spreiding van verantwoordelijkheden en competenties. Over het algemeen hebben de nationale overheden, een overkoepelende rol. Er zijn variaties in de lokale en regionale vormen van bestuur. In Nederland en Groot-Brittannië liggen de verantwoordelijkheden en competenties vooral op nationale niveau, bij de verantwoordelijke ministeries. In de Verenigde Staten heeft elke staat, zelf de leiding over het beveiligen van de kritieke infrastructuur. Alleen in Denemarken worden verantwoordelijkheden gedelegeerd naar lokale overheden. Oostenrijk en Duitsland hebben een gecombineerde aanpak waarin de nationale overheid hoofdzakelijk verantwoordelijk is voor het coördineren en sturen. De federale en lokale overheden leiden in deze landen de implementatie van strategieën en maatregelen.

Dit onderzoek adviseert een integrale aanpak voor het beschermen van kritieke infrastructuur. Een dergelijke aanpak bestaat uit preventie, bescherming, voorbereiding en bewustzijn. Tot nu toe focuste de Nederlandse overheid zich vooral op de categorieën preventie en bescherming. Het wordt aanbevolen om meer aandacht te besteden aan voorbereiding tezamen met het creëren van meer bewustzijn. Een selectie van de voor Nederland relevante strategieën en maatregelen is op de volgende pagina samengevat.

Executive Summary (English)

Within the research project Towards Water Robust Critical Infrastructure, the overall objective was to gather insightful and relevant strategies and measures for the Netherlands, which could address potential impacts of flooding, including coastal, river and pluvial floods. In view of future climate change, the risk of flooding can become an increasing challenge for societies. Despite geographical differences between countries, floods pose a universal threat to the functioning of critical infrastructures. In this study, 'critical infrastructure' is understood as functions and facilities, which are substantial to maintain a country's public life, economic well-being and national security.

This research project was carried out by five master students of Wageningen University in collaboration with the Dutch Ministry of Infrastructure and the Environment. An inventory of strategies and measures was established for the following countries: Austria, Denmark, Germany, the United Kingdom and the United States of America. By this, the ministry aims to receive an overview of those strategies and measures, which are potentially relevant for increasing the water robustness of critical infrastructures in the Netherlands. Although the Netherlands is one of the best protected deltas in the world, the chances of a flood are present. Especially with regard to future climate change precautionary actions are required. The study focused on four sectors, identified as most critical by the ministry. These are Energy, Telecommunication & IT, Drinking Water Supply and Transportation (road network). As a methodology, a structured literature research and an expert survey have been carried out, complementing each other.

During the research process, over one hundred strategies and measures were gathered and structured into four analytical categories. First, Prevention refers to strategies and measures, decreasing the chance of flooding by addressing the roots of the problem. Second, Protection embraces strategies and measures for physical actions against flooding in terms of technical and constructional changes. Third, Preparation covers all strategies and measures, which aims at minimising disruptive effects of floods. Finally, Awareness contains strategies and measures that encourage and enable autonomous adaptation and preparations of stakeholders through the exchange of knowledge, information and expertise. Most strategies and measures were found for the categories of preparation and prevention.

The analysed countries assess the criticality of the sectors differently. Except for Denmark, the energy and the telecommunication & IT sectors are prioritised. Austria, Denmark and the United

States of America have a clear focus on the transportation sector. Securing the drinking water supply is primarily addressed in Denmark and the United Kingdom.

In terms of policy coordination of strategies and measures for securing the functioning of critical infrastructures, differences were found regarding the division of responsibilities and competences. In general, the national level plays a superordinate role, while there are varieties regarding the involvement of the local and regional levels of government. In the Netherlands and the United Kingdom, responsibilities and competences are mainly located on national level within respective ministries. In the United States of America, each state is in charge of ensuring the functioning of its critical infrastructures. Only Denmark has a strong focus on delegating responsibilities towards local governments. Austria and Germany follow a combined approach in this regard, where the national government is mainly responsible for coordination and guidance, while the federal and local levels are in charge of implementing strategies and measures.

In general, this study recommends an integrated approach to secure the functioning of critical infrastructure, including prevention, protection, preparation and awareness. So far, the Netherlands primarily focused on flood protection. In this regard, it is advisable to put increased efforts on strategies and measures preventing and preparing for potential occurrence of a flood, as well as creating awareness. A selection of strategies and measures of relevance to the Netherlands is listed below.

Prevention	Protection	Preperation	Awareness
Overarching			
- Enhance water retention and reactivate natural flood plains (AT)	- Water- and load retaining structures (AT)	- Cooperation on flood risk management between neighbouring countries (AT)	- Raising Awareness and Preparedness within the broad public (AT)
- Green Infrastructure to enhance water capturing capacity and to unburden the local surface runoff in cities (USA)		- Minimum River Morphological Space Demand (AT)	- Knowledge exchange between stakeholders (DK)
		- Mobile flood protection systems (AT)	- New risk culture (GER)
		- Proactive organisation of recovery and rebuilding after a flood event (AT)	- Ministers receive national risk assessments of their respective sectors and are personally responsible to take action accordingly (UK)
- Increase the amount of renewable energy supply (UK) (DK) (AT) (GER)		- Forbid construction work in flood-prone areas by law (DK)	
		- Legally binding reporting mechanisms between the government and energy suppliers & telecommunication operators (GER)	- Local Resilience Forums with authorities and stakeholders (UK)
		- Visualize interrelations and complexities (GER)	
		- Adaptation Reporting Power: Companies responsible for critical infrastructure are obliged to report on impacts of climate change to the government (UK)	
		- Relocation essential equipment to higher levels (USA)	
		- Cut trees near communication lines and transportation facilities (USA) (DK)	
Energy			
	- Put subsystems of electricity supply grid underground (DK) (USA)	- Standardised method to make a cost-benefit assessment of investments into the resilience of infrastructure (UK)	- The economic regulator encourages electricity network companies to include the costs of making infrastructure resilient in their price (UK)
	- Replace distribution poles with stronger material (USA)	- Diversifying energy sources (AT)	
		- Decentralising energy generation (AT)	
	- Flood walls around refineries (USA)	- Replace distribution poles with stronger material (USA)	
		- Smart Grids that can cope and act on partial failure in energy system (AT)	
Telecommunication & IT			
	- Protective cover on switch points (AT)	- Hybrid base stations for an almost completely self-sufficient energy supply (AT)	- Implementation of information sharing mechanisms between governmental authorities

	- Transform cable system from copper wired systems to fibre-optic cables (AT) (USA)	- Mobile phone masts equipped with photovoltaic panels (AT)	and telecommunication service providers (GER)
		- Satellite flood maps as a backup information supply (AT)	
		- Legal obligations for telecommunication services providers (GER)	- Raise awareness amongst telecom-companies and promote information sharing (USA)
		- Decouple telecommunication infrastructure from the electric grid (USA)	
		- Crisis management teams and facilities (AT)	
Drinking Water Supply			
		- Networking of smaller supply units (AT)	- Support incentives for individuals to switch to low-usage of water (USA)
		- Create reserve capacity (AT)	
		- Simulation Program to find system weaknesses (AT)	
		- Price control and future investment assessment (UK)	
Transportation			
	- Elevate roads (USA)	- Adjustment of laws and regulations for construction and engineering by taking flood risks into account (AT)	- Provide evacuation routes (USA) (DK)
		- Plant robust vegetation along transportation routes (AT)	
		- Decrease sealed surfaces and its further expansion (AT)	
		- Emergency Response Plans (DK)	
		- Drainage system next to roads (DK)	
		- Pumping water off roads (DK)	
		- Monitoring of road network damages caused by ice and snow (GER)	
		- Enlarge drainage systems on roads to prepare for heavy precipitation (GER)	
		- Strengthen transportation facilities (AT) (DK)	
		- Lengthening the life time of transportation facilities by increasing planning for longer time scales and taking climate change impacts into account (DK) (USA)	

Acknowledgements

We would like to thank our commissioner Jasper Groos and his colleague Annemarieke Grinwis for their time and effort in providing us with valuable feedback. In addition we would like to thank our supervisor Bert van Hove, for his time and guidance towards our final product by giving useful feedback during the meetings.

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1. Introduction

1.1. Problem definition and background information

The disruptive consequences of flooding are a great challenge for societies, which may intensify with progressing climate change. In many countries, dikes may not withstand future sea-level rise or storm surge. At the same time the sealing of surfaces in connection with extreme precipitation may lead to floods in urban areas or river flooding. Besides international efforts for climate change mitigation, countries already establish individual adaptation strategies, preparing themselves for changes that already occur. In terms of flooding, one goal for securing the national well-being with regard to potential climate impacts is the protection of a country's critical infrastructure from water-related impacts. Despite geographical differences, flooding poses an almost universal challenge on countries, requiring them to take respective measures for securing the functioning of their national critical infrastructures. The need for international exchange of expertise on precautionary actions to ensure the functioning of national critical infrastructures is broadly recognised. Examples are projects such as INTACT[1], a research project funded by the European Commission on this topic with partners from 9 OECD countries, or the conference 'Critical Infrastructure Protection and Resilience Europe' taking place in The Hague in March 2016.[2]

In the Netherlands, integrated water management has been implemented successfully over the past centuries and the country has become one of the safest deltas in the world. However, residents and businesses are often unaware of existing risks of flooding and take safety for granted.[3] Even within the Dutch government flood risks are not always an integral part of planning and decision-making. As a consequence, critical infrastructures and facilities are susceptible to flood risk. Even if this risk seems rather small the consequences of flooding can be dramatic.

The Delta Programme is one of the most prominent examples of how the Dutch government started to address the challenge of making critical infrastructure more water robust in 2050. One goal is to anticipate the risk of flooding which occurs due to sea-level rise and increased discharges in rivers. Instead of reacting to a flood, the government strives to take proactive strategies or measures. According to the Ministry of Infrastructure and the Environment, a proactive approach also includes

[1] European Commission 2015c
[2] CIPRE 2015
[3] Ministry of Infrastructure and the Environment 2013:2

the gathering of knowledge and learning from other countries.[4] In other words: although the Netherlands is one of the best protected deltas in the world, it can still learn from other countries to make critical facilities more water robust. The Netherlands has carried out an evaluation of potential vulnerabilities to flooding and chain dependencies among different sectors.[5] Across governmental departments agreements have been made to protect respective facilities and infrastructure to the consequences of flooding. One central objective is to limit the likelihood of damages caused by floods. As a first step, different sectors are required to take into account flood risks in business decisions and investments. In this context, regional governments play an important role in the realisation of making facilities water robust. Moreover, they can play a central role in raising awareness at local scales, bringing together different stakeholders to share experiences. The Dutch National Water Plan defines water robustness in view of natural variability, e.g. extreme weather events, and future climate changes: Hence, a water robust system possesses over sufficient coping capacity to withstand extreme weather events and can meet the challenges of future developments such as climate change.[6]

Hence, water robustness also means to decrease vulnerability of critical infrastructures to impacts of climate change. Vulnerability is herein defined as the degree a system is susceptible to the effects of climate change in terms of its exposure, sensitivity and adaptive capacity.[7] Besides vulnerability to external effects, critical infrastructure can also be affected by internal disruptions due to chain dependencies. For instance, a power outage has vast effects on society and the economy of a country, as well as other infrastructures, e.g. telecommunication or IT, as occurred in the North of the Netherlands in March 2015. Interrelations between the critical sectors must therefore be considered when aiming at the protection of national critical infrastructures to prevent potential socio-economic damages.

In this study, five countries – Austria, Denmark, Germany, United Kingdom and United States of America – were analysed to receive an overview of strategies and measures that are taken nationally to protect critical infrastructures. On the basis of this compiled knowledge, the overall objective was to identify those strategies and measures, which are insightful, as well as of relevance to the Netherlands. Facilities and sectors, which are essential for the social and economic well-being of a country, are referred to as 'critical'. The term 'critical infrastructure' thus embraces facilities and sectors which are of substantial importance for a country to maintain its public order and economic

[4] J. Groos, personal communication, April 2, 2015
[5] Kennisportaal Ruimtelijke Adaptatie 2014
[6] Nationaal Waterplan 2009:27
[7] Adger 2006

functions.[8,9] As a focus, the sectors of energy supply, telecommunication and IT, drinking water supply and transportation (road network) were selected, considering them as the most vulnerable sectors in terms of flooding.[4] Energy supply is one of the main elements to ensure the functioning of a country's economy and public life. During the electricity outage in the Netherlands it became apparent how far-reaching consequences power outages can have, affecting public transport, airports, cities and companies. Telecommunication and IT are of similar importance for the national well-being of a country. Disruption within this sector could even constitute a threat to the national security of information societies. For instance, flooding may have a serious impact on governmental institutions or the economic sector in case an error hampers IT systems and telecommunication, affecting production, public life or disaster management. Drinking water supply can be highly affected by floods destroying water transport systems or contaminating groundwater and water wells by decreasing the water quality. Within the transport sector the road network is of particular importance for maintaining the functioning of the public life and is a crucial factor in terms of disaster management. River flooding or extreme precipitation causing landslides could make roads and bridges unusable, isolating entire regions from immediate disaster relief. This report summarises the results of the country specific research about strategies and measures to protect national critical infrastructures. As a result, recommendations have been formulated, which are considered as relevant for improving the water robustness in the Netherlands.

[8] OECD 2008:3

[9] In the Netherlands, critical infrastructures are referred to as 'vitaal en kwetsbaar', meaning vital and vulnerable. Due to the international scope of this study vital and vulnerable is seen as equivalent to critical.

1.2. Research Questions

The Dutch Ministry of Infrastructure and the Environment plays an important role in relation to the development of strategies and measures to make critical infrastructures water robust. To receive new insights for its policy and ministerial responsibility reports to the parliament, the Ministry of Infrastructure and the Environment would like to receive an overview about strategies and measures taken by other countries. To this end, the Ministry of Infrastructure and the Environment has commissioned students of Wageningen University to carry out this study. The objective of this research crystallises in the research question below.

What strategies and measures are being taken by countries or which strategies are being developed to make critical infrastructure water robust?

To structure the research the following sub-questions have been formulated:

- To what climate-related risks (i.e. flooding) are the selected countries being exposed?
- What is the political context and the impact of this context on the different actors involved in the selected countries for making critical infrastructure climate proof (in terms of water robustness)?
- What are the strategies or measures by the selected countries and which threats are dealt with?
- To what extent are taken measures or strategies different from the Netherlands?
- To what extent are taken measures or strategies applicable to the Netherlands?
- What main recommendations can be made for the Netherlands?

1.3. Objectives and Scope

The objectives of the present study are the following:

1. To make a quick-scan of the strategies and measures pursued in the Netherlands to protect critical infrastructure against flooding.
2. To provide an overview of strategies or measures taken by the selected countries to protect their critical infrastructure against flooding.
3. To list strategies or measures applicable and insightful to the Netherlands to protect critical infrastructure against flooding.

The scope of the research confined itself to strategies and measures related to the water robustness of four critical sectors in the five selected countries. Strategies and measures were related direct to

threats of water; that is flooding from precipitation, rivers and seas. The research focused on strategies and measures relating to the four most critical sectors, considered to be crucial for society:

- Energy
- Telecommunication and IT
- Drinking Water Supply
- Transportation (road network)

Initially, ten countries were selected to research: Austria, Belgium, Czech Republic, Denmark, France, Germany, Japan, Switzerland, United Kingdom, and the United States of America. However, in agreement with the commissioner, the research was confined to Austria, Denmark, Germany, United Kingdom and United States of America in a later stage of the research process.

1.4. Readers' guide

In the first part of this report the methodology and the general proceeding of this research project is outlined and further explained (chapter 2). This includes the developing of a matrix to carry out a structured literature research, as well as an expert survey established within this project. In the following, the country-specific chapters are included for the Netherlands, Austria, Denmark, Germany, UK and the USA (chapter 3). Within each country-specific chapter the following information is provided: a country's exposure, sensitivity and adaptive capacity to projected climate changes; information about the respective political context and coordination of responsibilities in terms of securing the functioning of national critical infrastructures; cross-sectoral strategies and measures taken by each country, as well as sector-specific strategies and measures, including Energy, Telecommunication & IT, Drinking Water Supply, and Transportation. On this basis, every country chapter gathers and highlights relevant measures for the Netherlands. In addition, the results of the expert survey are included in the end of each country-specific chapter, except for Germany and the UK. A separate section includes the more generalised findings of the expert survey (chapter 4). Finally, the recommendations for the Netherlands are listed and categorised within four analytical categories (chapter 5). This report closes with a discussion and conclusions, reflecting on the results and the main findings of this study (chapter 6).

2. Methodology

2.1. Proceeding

The research project was carried out in several phases. A list of the respective phases can be found in Table 1 below and are explained in the following.

Table 1: Overview of the proceeding

Phase	Activity
1.	General literature scan on available information
2.	Meeting with the commissioner
3.	Writing the project plan ▪ selection of countries ▪ developing the matrix
4.	Consultation with the commissioner
5.	Development of the expert survey
6.	Country research ▪ case study Netherlands (reference case) ▪ selection and research of country cases ▪ sending out the expert survey ▪ including the outcome of the expert survey into country research
7.	Writing the country chapters
8.	Developing recommendations ▪ gathering the strategies and measures ▪ selecting strategies and measures of relevance to the Netherlands ▪ developing analytical categories for structuring strategies and measures ▪ establishing recommendations for the Netherlands
9.	Writing the draft report
10.	Presentations at Wageningen University and at the Ministry of Infrastructure and the Environment
11.	Feedback by commissioner and supervisor
12.	Including feedback and finalising the report

2.2. Analysis Matrix

For this research, an analysis matrix was developed for two main purposes. First, the matrix supported a structured gathering and compiling of information. Second, it categorised and streamlined the information gathered by each researcher. The matrix was thus used as a framework to operationalise the research questions and enable a focus when scanning through the literature. This enabled a comprehensive and structured proceeding to examine and compare the strategies and measures of the selected countries. The matrix was flexible over time and several improvements were made during the process. The matrix can be found in Annex I. An example of the filled matrix for the Netherlands is included in Annex II.

2.3. Expert survey

Next to the extensive literature research using the matrix, an expert survey was carried out. The purpose of this survey was to gather background knowledge on critical infrastructures, as well as going beyond the descriptive scope of the structured literature review. This survey was established in consultation with contact persons of Wageningen University and the commissioners at the Ministry of Infrastructure and the Environment. In this study, as experts were defined public, private and non-state actors, being involved in the field of water management or critical infrastructure. Besides the experts recommended by the Ministry of Infrastructure and the Environment, surveys were also sent to contacts emerging from the literature research. This included, contact persons at universities, corresponding authors of (political) documents or the ministries themselves. The survey questions were structured in open and closed questions (see Annex III) and the interviewees were anonymised unless requested otherwise.

3. Country Analyses

3.1. General overview

In the following, the results of the country cases are briefly summarised. The analysed countries assess the criticality of the sectors differently. Except for Denmark, the energy and the telecommunication & IT sectors are prioritised. Austria, Denmark and the United States have a clear focus on the transportation sector. Securing drinking water supply is primarily addressed in Denmark and the United Kingdom. In terms of policy coordination of strategies and measures for securing the functioning of critical infrastructures, differences were found regarding the division of responsibilities and competences. In general, the national level plays a superordinate role, while there are varieties regarding the involvement of the local and regional levels of government. In the Netherlands and the United Kingdom, responsibilities and competences are mainly located within respective ministries at the national level. In the USA, each state is in charge of ensuring the functioning of its critical infrastructures. Merely Denmark has a strong focus on delegating responsibilities towards local governments. Austria and Germany follow a combined approach in this regard, where the national government is mainly responsible for coordination and guidance, while the federal and local levels are in charge of implementing strategies and measures.

Table 2: General overview of the selected country cases

	Main flood risk	Political context	Main Focus			
			Energy	Telecom.	Transport.	Drinking Water
	Coastal Riverine	National government No binding mechanisms	X	X		
	Riverine	National to local government	X	X	X	
	Pluvial	Local government			X	X
	Pluvial Riverine	National government Binding mechanisms	X	X		
	Pluvial	National government Binding mechanisms	X	X		X
	Coastal Pluvial Riverine	State government	X	X	X	

3.2. The Netherlands

3.2.1. Exposure, Sensitivity and Adaptive capacity[1]

- **Temperature:** Average temperature has risen by 1.7 degrees over the past 100 years, which is about twice as large as the global average. The average winter temperature is projected to be 0.9-2.3 degrees warmer in 2050 than in 1990.
- **Precipitation:** Total annual precipitation has increased by more than 20% over the past 100 years. Average precipitation is projected to increase further in winter by 3 to 17% and remain equal or decrease by 13% in summer by 2050 compared to 1981 to 2010.[2]
- **Flooding:** Climate Change is particularly exaggerating flooding/breaching of dikes. An increased chance of flooding and an increase in peak discharges from rivers in the winter, lead to a higher chance of flooding in rural areas and a more frequent flooding in urban areas, as heavier storms may exceed the capacity of sewage systems**.**

Without water defences, 60% of Dutch territory is vulnerable to flooding from the sea or rivers. This area is home to 60% of the population and 65% of the Gross National Product (GNP) is produced there. Therefore, the Dutch government gives high priority to the water defence systems. Besides this, the provision of freshwater is also threatened due to further warming and a deficit of precipitation (for which problems may already arise in 2050).[3]

3.2.2. Political Context

The Netherlands is a constitutional monarchy with a bicameral legislature. “Traditionally government in the Netherlands is spread across three hierarchical layers: national, regional (provinces) and local.”[4] Besides these governments, the Netherlands has a specific government layer responsible for aquatic matters, the Regional Water Boards.

- **Regional government:** Regionally the Netherlands are divided in 12 provinces. These are responsible for environment, planning, energy supply, social work, and sports and culture. The provinces are governed by a locally direct-elected representative provincial council. The size of the council depends on the number of inhabitants in the province. Members are elected for four-year terms. From among their members, the councils elect provincial

[1] OECD 2013:181
[2] Climate Adaptation 2015
[3] Ministry of Infrastructure and the Environment 2013:1
[4] UCLG 2008:2

executives […] with six to eight members. Each province has a commissioner appointed by and representing the Crown.

- **Local government:** Under the administrative level of provinces, the Netherlands has been divided into 393 municipalities.[5] These municipalities are responsible for services in traffic and water, housing, public education, social and health care, culture, sport and recreation. Municipalities "are administered by municipal councils, which are elected directly for four-year terms by the local inhabitants and make local bylaws. The executive powers of the municipality are entrusted to a corporate board consisting of a [mayor][….] and two to six aldermen; the latter are elected from and by the council, while the […] mayor is appointed by the Crown."[6] The number of municipalities is declining as Central Government is hoping to improve efficiency by creating larger municipalities through mergers." [7]
- **Regional Water Boards:** Besides the provinces and municipalities, the Netherlands has also been divided into 24 regional water boards, also referred to as waterships. "The Waterships are the public bodies responsible for dealing with all matters aquatic, including protecting the land from the water, distribution of water and maintaining the water table, and ensuring the quality of drinking water. They are the oldest public bodies in the Netherlands." Some dating back as far as the 13th century.

Until 2010 the policy of the Dutch government related to climate change adaptation and critical infrastructure was primarily focused on preventing a flood. However, in 2013 the Minister of Infrastructure and the Environment stressed that while the Netherlands is the best protected delta in the world, all citizens should also know how to react if a flood occurs.[8] The government has translated that into an effort to actualize policies on making critical infrastructure water robust. The first step of that effort has been to make an inventory of the applicable legislation in place and divide the responsibility of safeguarding critical functions to ministries.[9] This responsibility leads to policy of which the implementation is then assigned to other public and private institutions. Besides the (local) governments mentioned above, other important institutions dealing with the flood-resilience of critical infrastructure in the Netherlands are: the council for the Environment and Infrastructure[10],

[5] CBS 2015
[6] Worldmark Encyclopedia of the Nations 2015
[7] National Academy for Finance and Economics 2013:11
[8] Ministry of Infrastructure and the Environment 2013:2
[9] Ministry of Infrastructure and the Environment 2014:9
[10] Council for the Environment and Infrastructure 2015

the PBL Netherlands Environmental Assessment Agency[11], the National Coordinator for Security and Counterterrorism[12], the security regions[13], economic regulators and particular sector associations.

This policy follows two characteristics of traditional Dutch governance. The first of these is the tradition to mainstream issues among different governmental layers and institutions, instead of creating a new institution especially focused on this topic. The second characteristic it follows is that the Dutch government first tries to pursue a policy with voluntary measures for the private sector and civil society, and only if unavoidable binding rules.[14]

Below a basic overview will be given on the organisation and water robustness of the energy, telecommunication and IT, transportation and drinking water sector in the Netherlands. Concrete measures are not mentioned here, as those can be found in the detailed overview published by the responsible ministries in Dutch.[15] A more extensive summary of this document can be found in Annex III.

3.2.3. Sectoral Strategies and Measures[16]

Energy

The resilience of the energy sector falls under the responsibility of the Ministry of Economic Affairs, with different public and private parties managing the provision of electricity, gas and oil.
The impact of flooding on the electricity supply will mostly be local, as there is a high redundancy in electricity production nation-wide. When electricity installations are flooded, many of them will be irrevocably damaged. Electricity operators are bound by law to take flood risks explicitly into account into their risk analyses, but there is no oversight on whether these analyses are translated into actual measures. As with power plants, the gas network is locally vulnerable to flooding. The main transport network is also vulnerable to local black-outs. In areas of severe floods gas pipelines are likely to be depreciated. A proposed measure to decrease the impact of floods on the gas network, is simply to not connect flooding-prone areas to the gas network, but instead led them rely on gas-tanks or only electricity. Furthermore, it has been proposed to allow providers to transfer investment costs related to water robustness into the consumer price. In general the provision of oil is not considered to be

[11] PBL Netherlands Environmental Assessment Agency 2015
[12] National Coordinator for Security and Counterterrorism 2015a
[13] National Coordinator for Security and Counterterrorism 2015b
[14] R. Biesbroek, personal communication, May 19, 2015
[15] Kennisportaal Ruimtelijke Adaptatie 2014
[16] Kennisportaal Ruimtelijke Adaptatie 2014

very vulnerable to flooding. However, there is a clear lack of public information on the susceptibility of the oil provision network to floods.

Telecommunication & IT

The resilience of the telecommunication and IT sector falls under the responsibility of the Ministry of Security and Justice. In its approach to the water robustness of the sector the ministry makes a distinction between telecommunications used by emergency services to respond to crisis and public telecommunication.

For the telecommunication infrastructure used to respond to a crisis continuity plans and fall-back scenarios are in place. However, it is unclear what specific standards the infrastructure has to adhere to and to what extent floods are taken into account. Several governmental documents even suggest that the special emergency communication network C2000 would fall out if a flood occurs.[17, 18]

The public telecommunication sector is locally very vulnerable to flooding, as many installations are low lying and dependent on electricity supply. Current policies rely on the financial self-interest of telecom providers to safeguard continuity of service in the case of floods. The law only obliges telecom operators to a duty of care and the obligation to report on their all hazards analyses to the economic regulator (Agentschap Telecom). However, there seem to be no concrete standards to which the telecom providers have to adhere to safeguard provision in the case of a flood.

Drinking Water Supply

The Ministry for Infrastructure and the Environment is responsible for the policy on the resilience of the drinking water supply. Drinking water supply corporations, united in the branch association Vewin, are responsible for the execution of policy. In case of a crisis, municipalities are responsible for coordination and accessibility of distribution. Drinking water corporations and municipalities have covenants on how to cooperate regarding supply and distribution, no explicit national prescriptions are present. Supervision is done by Inspectie Leefomgeving en Transport ILT.

The supply of drinking water is relatively resilient to floods. The biggest problem can be found in its dependency on electricity supply. The Delta Programme has set out a clear plan to conduct

[17] Rijksoverheid 2015
[18] Provincie Utrecht 2009:12

disruption risk analyses for all the water provision companies. However the programme focuses on safeguarding the sources of sweet water for drinking water and not the supply network.

Transportation

The Ministry for Infrastructure and the Environment is responsible for setting the policy on the resilience of the road network in the Netherlands. A special agency of the ministry, Rijkswaterstaat, is responsible for the construction and the maintenance of the roads.

The Netherlands has a very extensive network of public roads in ownership, management and maintenance by the state, provinces, municipalities and regional water authorities. The highway network with A-roads (with four or more lanes) and some N-roads (with mostly two lanes) fall under the responsibility of the state. Characteristic is the interwovenness of the highway network with the underlying roads. The interwovenness of the highway network makes it difficult to indicate which parts of this are critical in case of a flood. For evacuation and supply of assistance a combination of local, regional and national roads will be necessary. Furthermore, as the main transport networks have been deepened in the construction (e.g. to diminish noise pollution), they tend to be particularly vulnerable to flooding.

A blue spot research was conducted to check which roads would be flooded in case primary and secondary dikes would break. The research concluded that a substantial part of the main transportation network within a dike ring would be flooded, which could have big consequences.[19] Which roads should be considered critical is not yet known however. In addition evacuation might not be the best choice in case of a flood since evacuees are 'trapped' during their evacuation. In this case citizens might better stay where they are. If this is the case, the accessibility of highways would be less critical.[20]

[19] Bles et al. 2012
[20] Ministry of the Interior and Kingdom Relations 2010:42

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PBL Netherlands Environmental Assessment Agency (2015): Home. Available at: http://www.pbl.nl/en [Accessed May 15, 2015].

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3.3. Austria

3.3.1. Exposure, Sensitivity & Adaptive Capacity

Austria is a democratic Republic landlocked in Central Europe; it has an area of 83.871,75 km² and 8.477.230 million inhabitants (2013).[1] Austria is located in the temperate climate zone and under Continental, Atlantic and Mediterranean influence. Temperatures can be described as moderate and the average precipitation is 1100 millimetres per year.[2] "Austria is expected to be very vulnerable to climate change given that ecosystems in mountainous regions are highly sensitive. 70% of Austria's surface area is higher than 500m above sea level and 40% higher than 1 000 meters."[3]

- **Temperature:** "In Austria, the temperature in the period since 1880 rose by nearly 2 °C, compared with a global increase of 0.85 °C."[4]
- **Precipitation:** "The development of precipitation in the last 150 years shows significant regional differences: In western Austria, an increase in annual precipitation of about 10-15% was recorded, in the southeast, however, there was a decrease in a similar order of magnitude."[5]
- **Run-off:** During winter there is enhanced water run-off due to the increase in the share of rain (compared to snowfall) in total precipitation.[6]
- Climate model output shows „[…] that heavy and extreme precipitation events are likely to increase from autumn to spring […]."[7]
- **Glaciers:** Glaciers are increasingly retreating. A shrinking in area and volume can be asserted.[8]
- **Droughts:** More drought periods in South-eastern Austria are predicted.[9]
- **Natural hazards:** The frequency of natural hazards, such as landslides and avalanches, are expected to increase because of more intense and frequent rain, higher temperatures and the retreat of glaciers.[10]

[1] UCLG 2008:1 & Statistik Austria 2015a
[2] BMLFUW 2006
[3] OECD 2013c:119
[4] APCC 2014a:15
[5] APCC 2014a:15
[6] OECD 2013c:119
[7] APCC 2014a:16
[8] OECD 2013c
[9] OECD 2013c
[10] OECD 2013c

- **Extreme events:** "The potential economic impacts of the expected climate change in Austria are mainly determined by extreme events and extreme weather periods"[11]
- In summary the primary concerns for Austria are extreme precipitation and long drought periods caused by more heat waves and a decrease in groundwater recharge and soil moisture.[12]

Flooding

"Without flood protection Austria's river valleys would be uninhabitable."[13] In total 391 'Areas of Potential Significant Flood Risk' can be identified in Austria. These areas are directly located to rivers. From 37.359 km considered river length, 2.654 km are potentially exposed to significant flood risk. This correspondents to 7,1% of the whole examined area.[14] Overall floods mainly originate due to long enduring rainfall in Austria. Other triggers like short and heavy precipitation, storms or snow melting are more important in specific regional contexts.[15] Floods count to the most destructive catastrophic events in Austria. From 1990 to 2013 just the five biggest floods created damages of approximatively 4,4 billion euro.[16]

- A "tendency to shift the risk of flooding into winter and spring in northern Austria […]" can be predicted.[17]
- "With respect to floods, no clear climate response could be identified, except for winter floods which are more likely to occur in the northern parts of Austria […]."[18]
- In the last 30 years flooding has increased in 20% of the catchment areas.[19] This increase is still within the limits of natural variability, but a direct influence of climate change cannot be ruled out.[20]
- An important factor with regard to flood risks in Austria is the Mediterranean Sea. Its warming could lead to more 'Vb cyclones' associated with more intense precipitation and considerable repercussions in the Alpine area.[21]
- In general an increase in flood related damages is likely.[22]

[11] APCC 2014a:16
[12] OECD 2013c:119
[13] BMLFUW 2006
[14] BMLFUW 2015a
[15] APCC 2014b
[16] APCC 2014b:674
[17] BMLFUW 2012b
[18] APCC 2014b:413
[19] BMLFUW 2012a
[20] APCC 2014b:92
[21] APCC 2014b:87
[22] APCC 2014b:645

- In the future it is likely that urban flooding – as a combination of strong precipitation run off, caused by a small seepage capacity, and an overload of the sewage system – will gain in importance. [23]

In the past, Austria has seen a steady growth in GDP per capita. Compared to other nations there is a low income inequality, high life expectancy, strong social system and high environmental standards.[24] It scores high on many aspects of well-being in comparison to other OECD countries. "Austria ranks above the OECD average in the dimensions of jobs and earnings, civic engagement, social connections, subjective well-being, personal security, income and wealth and environmental quality. It ranks close to the average in health status and housing, but below average in education and skills and work-life balance."[25]

The experts from Austria consider the overall approach Austria is taking in order to make critical infrastructure water robust as coordinated. Opinions range from 'neutral' to 'agreement'. However, when it comes to the actual preparedness of the critical infrastructure experts are in disagreement. Here opinions range from 'critical infrastructure is not well prepared' to positive perceptions. When asked about the effectiveness of the taken policies, experts perceive these as 'moderate' to 'effective'. Within the action plan towards flood security, Austria invests 1 billion euro from the years 2014 until 2019 into measures against natural hazards, such as flooding, landslides and avalanches.[26] Austria is member of many international organisations and has a stable political system. It invests a lot of resources into climate change adaptation. It can therefore be concluded that Austria has a high adaptive capacity to climate change and concerning its impacts, for example floods.

3.3.2. Political Context

Austria is a federal republic based on a parliamentary representative democracy. Austria is divided into nine provinces. These are further subdivided into 95 districts. And the districts furthermore are divided into 2,102 municipalities. The parliamentary system of Austria is constituted by a two chamber system compromising of: the National Council and the Federal Council. The former represents the citizens directly, the latter the member States (provinces) of the federation.[27]

[23] APCC 2014b:677
[24] OECD 2013a
[25] OECD 2013b:3
[26] BMLFUW 2014b:35
[27] UCLG 2008:2 & Statistik Austria 2015c & Statistik Austria 2015b

"Austria has a popularly elected federal president and a chancellor chosen from the ruling party in the legislature. Austria's president […] acts as the nation's head of state, a largely ceremonial role; […] In Austria the actual head of government is the federal chancellor. […] The most important government decisions are made by the cabinet."[28] The "[l]egislative and executive powers regarding major policy areas are the responsibility of the federal government."[29] And "[a]lthough Austria is a federal system and has a popularly elected president, it is fundamentally a parliamentary democracy, with the basic power residing in the legislative branch."[30] Within that the first chamber, the National Council, is responsible for the formation of legislation in Austria. The second chamber, the Federal Council, has only limited power and a restricted right of veto.[31] "Three types of courts are provided for in the Austrian constitution: judicial, administrative, and constitutional." Judicial courts are established by law. […] Complaints about procedural or substantive problems in administrative rulings are dealt with by […] [the Administrative Court]. The Constitutional Court […] determines the constitutionality of government statutes […]."[32]

Concerning the regional and local government in the Austrian political system can be asserted, that "[…] the established division of powers between the federal government and the individual provincial governments is rather complicated; however, most important political matters are delegated to the federal government." [33] For several issues and laws, such as electric utilities, which are passed at the federal level, the provinces are responsible for their implementation. However the individual provinces hold legislative and executive power over many matters; amongst others: building regulations, matters of regional planning, conservation of nature and landscape protection.[34]

"In a historic view the most important notions of local government is local democracy and in close contact to this basic pillar in some extent the thought of subsidiarity. […] [T]he own sphere of competence comprises all matters exclusively or preponderantly concerning the local community as personified by a municipality, and suited to performance by the community within its local boundaries."[35] All municipalities have the same rights, regardless their economic relevance or seize. The main emphasis in their actions lies on services of general interest, which include amongst others water supply and municipal streets.[36]

[28] Schlager & Weisblatt 2006:71f
[29] Schlager & Weisblatt 2006:71
[30] Schlager & Weisblatt 2006:72
[31] UCLG 2008:2 & Schlager & Weisblatt 2006:72
[32] Schlager & Weisblatt 2006:72f
[33] Schlager & Weisblatt 2006:71
[34] Parliamentary Administration 2015 & Schlager & Weisblatt 2006:71
[35] UCLG 2008:2
[36] UCLG 2008:2

Economy

The Austrian economy has seen a shift to liberalization since the 1980s; prior to that the state held a strong presence in Austria's national economy. During 1946–47 many industries (including amongst others rail and water transport, basic & heavy industry and mineral production) were nationalized. In the 1970s they were reorganized under the Austrian Industrial Administration (ÖIAG), a state-owned holding company. The process of restructuring and privatization takes place up to now.[37] In 2015 the Industrial Administration was reorganised and is now called ÖBIB. It is responsible for the management of the Austrian Republic's holdings in nationalised and part-nationalised companies. The ÖBIB's portfolio currently comprises, amongst several others companies, three on the stock market listed firms: OMV, Austrian Post and Telekom Austria.[38] The first enterprise is an oil & gas company and the latter the leading telecommunications provider. All three are relevant stakeholders when it comes to critical infrastructure.

3.3.3. Overarching Strategies and Measures

Climate change and with it extreme events like floods pose a threat to the entire country. The various kinds of impacts on water resources demand integrative adaptation measures. "Both high- and low-water events in Austrian rivers can negatively impact several sectors, from the shipping industry, the provision of industrial and cooling water, to the drinking water supply."[39] As well as "[…] pose potential risks for infrastructure related to settlement, transportation, energy and communications."[40] Especially transportation and energy infrastructure, with their exposed location and complex structure, are highly sensitive. An interruption in one place can have widespread service outages as a consequence."[41]

According to the questioned experts the most critical sectors in Austria are considered to be the energy and drinking water sector, which were named by all experts; closely followed by the telecommunication sector, with five mentions. Comparatively far behind, with two out of six experts mentions, the main road network. From all the other suggested sectors only one was once selected all in all. It can therefore be concluded that the selected sectors by the commissioner are in correspondence to the prioritisation of critical infrastructure in Austria. Not only sectors are interconnected, also the international connectivity with regard to flood risk management is a very

[37] Worldmark Encyclopedia of Nations 2015
[38] ÖBIB 2015a
[39] APCC 2014a:27
[40] APCC 2014a:26
[41] APCC 2014b:689

important issue. “Austria has three river basin districts (Danube, Elbe, Rhine), all of which are international sharing water courses with Czech Republic to the north, Germany to the north-east, Slovakia and Hungary to the east, Switzerland and Liechtenstein to the west and Slovenia to the south.”[42] When it comes to climate change adaptation this briefly touched interconnectedness of these issues could also explain why in Austria the structure of policy plans regarding critical infrastructure and or flooding can be described as overarching hazard policies rather than detailed specific policy plans for every sector. All interviewed experts agree that there is a need for an integrated coordination amongst countries, for example through the EU, for taking collaborative actions to make critical infrastructure water robust.

The fact that climate change adaptation measures can have positive effects on other issues should not be neglected. Flood protection can be combined with biodiversity conservation and moreover can contribute to carbon sequestration.[43]

Strategies

Key policy document concerning critical infrastructure:

- **Austrian Program for Critical Infrastructure Protection (APCIP):** The master plan was jointly developed by the Austrian Federal Chancellery and the Austrian Ministry for Transport, Innovation and Technology and published in November 2014. It is based upon the principles of cooperation, subsidiarity, complementarity, confidentiality, proportionality and follows an all-hazards approach. Critical infrastructure should be protected against a broad spectrum of risks, like criminal acts and terrorism but also against natural hazards, human error and technical failure. Austria has decided to take an ‚operator based approach‘, which means that the emphasis does not lie in identifying critical sectors per se; the strategy is more orientated towards strategic operators, because this approach would do more justice to today’s complex and interdependent economy. One key focus is therefore the support of strategic companies as part of a public private dialogue. The operators, based on the principle of subsidiarity, are primarily responsible for the continuity of their services and facilities. Due to national interests these operators are being encouraged to increase their resilience based on commonly-agreed voluntary self-commitments; whereas politics and administration define the guiding framework. All in all the focus of the Austrian Program for Critical Infrastructure Protection lies on security issues. There is no policy in place which

[42] European Commission 2015b
[43] APCC 2014a:27

addresses explicitly flood risks respectively how to make critical infrastructure water robust.[44]

Key policy document concerning climate change adaptation:

- **National Adaptation Strategy (NAS):** Austria started to work on its national climate change adaptation strategy in 2007; in the year 2012 the strategy was adopted by the Council of Ministers. Under the guidance of the Ministry of Agriculture, Forestry, Environment and Water Management a framework to assure a harmonisation, coordination and advancement of the numerous climate change adaptation actions in all sectors and areas was developed. The objective of the strategy is to decrease negative climate change impacts and increase the national resilience. The Austrian adaptation strategy consists of two parts; first a general adaptation framework illustrating the context and second an action plan. In the latter adaptation options based on a qualitative vulnerability assessment are suggested for 14 sectors, amongst others: water, energy, natural hazards, housing & construction, civil protection, transport infrastructure and spatial planning.[45] The evaluation and monitoring of the effectiveness of the strategy has not yet been developed and implemented.[46]

Key policy document concerning flooding

- **National Flood-risk Management Plan:** The European Union's Floods Directive prescribes every member state to develop flood risk management plans for areas with potential high flood risks. First, the member states have to make a preliminary flood risk assessment until the year 2011. Second, flood hazard maps and flood risk maps had to be developed by 2013. Third, the flood risk management plans have to be drawn up. This plan is currently in development. In December 2015 the final document and its strategies will be presented.[47] The recently published draft version can nonetheless give valuable insights and will therefore be utilized.

[44] BKA & BMI 2015:4-8 & Federal Chancellery 2015
[45] EEA 2015
[46] APCC 2014a:17
[47] BMLFUW 2015a:6f & European Commission 2015b

Measures

- **HORA**: Natural Hazard Overview & Risk Assessment Austria (HORA) is a digital risk map, including amongst many other hazards flood risk zones as well as current weather data on water levels and floods.[48]
- Consider **Flood plain buy-out and relocation** as part of an integrated Flood Management.[49]
- **Enhance water retention**: "Promotion of water retention in the catchment and the reactivation of natural flood plains, particularly as a contribution to precautionary land use."[50] This measure is being taken with the objective to reduce peak flows; with enabling the natural retention of water the threats of flooding can be reduced and dealt with most effectively.[51]
- **Minimum River Morphological Space Demand:** Aim respectively establish minimum safety strip next to the river.[52] It "[…] was defined, […] as three to sevenfold the existing river bed width […], where no buildings or other higher value usages are allowed."[53]
- **Spatially Variable Vegetation Management**: "The spatially variable vegetation management suggests a differentiation of the river into vegetation dynamic zones, transition zones and sensitive zones with different widths and densities of the vegetation, in order to improve the retention (hydrological) and minimize the water level (hydraulic)."[54]
- Build **linear protective measures**, like damms, dykes or walls.[55]
- **Water- and load-retaining structure:** In order to damp the flood wave a water-retaining structure should be constructed. For the detention of total sediment load with potential negative effects a load-retention system should be build.[56]
- **Mobile flood protection systems**[57]
- **Temporary flood protection systems**[58]
- **Raising awareness and Preparedness** within the broad public in order to reduce dependency on services from critical infrastructure.[59]

[48] BMLFUW 2014a
[49] BMLFUW 2015a:18 & BMLFUW 2015b:87-91
[50] BMLFUW 2012b:112
[51] BMLFUW 2012b:112 & BMLFUW 2006:31 & BMLFUW 2012a
[52] Habersack 2015
[53] Habersack et al. 2010:15
[54] Habersack et al. 2010:15
[55] BMLFUW 2015c:37-39 & BMLFUW 2015b:23;74
[56] BMLFUW 2015c:37
[57] Habersack 2015 & BMLFUW 2010:18
[58] BMLFUW 2015c:37-42
[59] BMLFUW 2015a:19

- **Emergency power generators and water** pumps preventively stored in the most important facilities.[60]
- **Emergency Event Response Planning**[61]
- **After Care:** Preventive organisation of rebuilding after a flood event.[62]
- **Flood protection cooperation across borders:** "Water does not recognise national borders. This is why Austria has entered into agreements and established bilateral and multilateral water management commissions with its neighbouring countries Germany, Slovakia, Czech Republic, Hungary, Switzerland, Liechtenstein and Slovenia. Water management issues, including flood protection issues, are tackled together in trans-border river basins."[63]

3.3.4. Sectoral Strategies and Measures

Energy

Austria currently does not fully take advantage of its renewable energy potential. Its share in the gross final energy consumption was 31% in 2011. Especially wind and photovoltaics have plenty room for expansion, but the 2020 target of 34% share in end energy use can be comfortably achieved.[64] "Austria covers approximately 60% of its electric energy demand by hydropower. Numerous high alpine storage schemes buffer seasonal runoff patterns and assist in balancing energy demand and generation."[65] The energy infrastructure consists essentially of power plants and the network infrastructure. With regard to climate change impacts attention should be given to transmission lines, which are highly vulnerable because of their exposed location. Many thermal power plants are situated in the immediate vicinity of rivers and are therefore exposed to a high flood risk. The sensitivity of hydroelectric power plants varies depending on their building type (storage power and or run-of-river power plant) as well as their flow regime (glacier, snow or rain feed). Grave fluctuations in the channel flow or in the reservoirs can represent a direct danger for hydropower plants.[66] Seasonal shifts in the precipitation patterns and increase water run-off in winter due to the growth in the share of rain compared to snowfall will "[…] lead to a more uniformly distributed annual cycle of water run-off. In general, this favours the production of hydropower, as supply will be

[60] BMLFUW 2010:14
[61] BMLFUW 2015a:20
[62] BMLFUW 2015a:21
[63] BMLFUW 2006:20
[64] APCC 2014a:23
[65] APCC 2014b:414
[66] APCC 2014b.692f

more in phase with electricity demand."[67] But it is also concluded that "[t]he hydrological changes will result in an overall decrease of annual hydropower production, with a decrease in summer and an increase in winter production. Depending on the selected forcing regional climate model, the annual changes in power generation range between +5% and -15% in 2100."[68]

The Austrian electricity market is administered by the regulatory authority E- Control Austria, which issues the decisions being made within the broad and complex framework lead by EU, national and provincial legislation.[69] "Since full liberalisation on 1 October 2001 the Austrian electricity market has no longer been controlled by monopolistic, vertically integrated companies."[70] Competitive activities, like power generation, wholesale and retail are separated from the grid operation.[71] The supply chain was broken up as well, but "[t]he Austrian electricity and gas industries are [still] hallmarked by high levels of public ownership, and vertical and horizontal integration. Most of the energy companies hold direct or indirect interests in other market participants. There have been no signs of a significant reduction in public ownership or in cross-ownership over the past decade."[72] Every of the nine provinces owns at least 51 percent of a regional electricity supplier. The Federal Ministry of Science, Research and Economy is responsible for the Austrian energy policy and supervises the energy sector.

Strategies and Measures

- Promotion of **decentralized energy generation** in order to be more flexible in the case of crisis.[73]
- "Increasing security of supply through more **diversified energy sources** structures […]."[74]
- **Smart Grids** can enable locally produced energy, as grid feed-in, to contribute to a more resilient and efficient energy system. Smart Grids can help to cope and act on partial failure of the energy system.[75]

[67] OECD 2013c:119
[68] APCC 2014b:415
[69] E-Control 2013:3
[70] E-Control 2015
[71] E-Control 2013:3
[72] E-Control 2011:6
[73] BMLFUW 2012a:125
[74] BMLFUW 2012b:110 & BMLFUW 2012a:133f; 356
[75] APCC 2014a:26 & BMLFUW 2012a:131

Telecommunication and IT

The Austrian telecommunications service was part of the Ministry for Transport, Innovation and Technology until the year 1996. That year it was converted into a joint-stock company and disconnected from the federal administration. Later in 1999, it was further divided into two enterprises, the Telekom Austria and the Austrian Postal Service.[76] "In accordance with the law of the European Union, the telecommunications market has been fully privatised since 1 January 1998."[77] Nonetheless the telecommunications sector still falls within the competence of the Ministry for Transport, Innovation and Technology. The Federal State owns, trough the Industrial Administration ÖBIB, 28,42% of the shares of the incumbent (Telekom Austria Group).[78] Presently they are "[…] the designated universal service provider for an undefined period through a tender procedure for the provision of the universal service at national level."[79] These universal services include: a functional internet connection, the general telephony services, directories and public pay telephones.[80] The telecommunication sector plays an increasingly important role in the economic and social development of Austria.[81] Today "[t]he Austrian telecommunication market is characterised by an intensive price-driven competition led by offers for less than half of the EU average […]. Both voice and broadband markets are dominated by mobile services […]"[82] The Austrian telecommunication system can be described as efficient and highly developed.[83] After a consolidation phase in the mobile market, there are currently three mobile operators competing on the Austrian market.[84]

Strategies and Measures

- **wasserstand.info**: A flood monitoring and early warning system, which informs relief units as well as the broad public about the current water level of rivers. When critical thresholds are being exceeded the system alarms automatically predefined stakeholders.[85]
- **Further expansion of fibre glass technique**: The functioning of this transmission technology is not interrupted when water leaks into the wire pipe. In contrast when copper cables are exposed to water they lead to short-circuits. [86]

[76] BMVIT 2015b
[77] BMVIT 2015b
[78] ÖBIB 2015b
[79] European Commission 2014
[80] European Commission 2014
[81] BMVIT 2015a
[82] European Commission 2014
[83] CIA 2015
[84] European Commission 2014
[85] Microtronics 2015

- **Hybrid base stations**: "Construction of […] hybrid base stations equipped with a hybrid energy supply system consisting of photovoltaics, wind turbines, energy-optimised container ventilation systems and hydrogen fuel cells, allowing for an almost completely self-sufficient energy supply."[87]
- "**Mobile phone masts equipped with photovoltaic panels** [are] in test mode."[88]
- **Protective cover on switch points**: After the devastating flood event in 2002 the Telecom Provider 'A1' equipped exposed switch points with protective covers.[89]
- Establish and train **crisis management teams** and supply necessary equipment: "They carry technical equipment such as emergency power generators and satellite phones."[90]
- **Crisis rooms**: „For emergencies, the Austrian subsidiary A1 has […] built a mobile, satellite-linked base station within a shipping container."[91]
- **Satellite flood maps** in order to diversify information supply: "Near-realtime satellite radar measurements are processed to create location-specific flood maps […]."[92] This measure can play an important role when other networks have already failed.

Drinking Water Supply

The water resources in Austria can be described as abundant as they far exceed the current levels of use. Only about 3% of the available water resources are being used; 0,7% fall within the domestic use.[93] Ground water is with 99% the constitutive source for drinking water supply.[94] „The average available water resources total about 76 billion m^3; this corresponds to a specific water resources availability of more than 9.000 m^3 per inhabitant."[95] There is no major change in water availability to be expected in the mid-term.[96] But a "[r]eduction of average precipitation and enhanced evapotranspiration due to higher than average temperatures can lead to deficiencies in drinking water supply, especially in communities depending on small and shallow springs in the southeast of

[86] A1 2013
[87] Telekom Austria Group 2013:22
[88] Telekom Austria Group 2013:13
[89] A1 2013
[90] Telekom Austria Group 2015
[91] Telekom Austria Group 2015
[92] ESA 2013
[93] OECD 2015:1, 4
[94] Environment Agency Austria 2015
[95] OECD 2015:3
[96] OECD 2015:4

Austria."[97] This is only expected on a small scale. Overall and especially "[w]ater supply from springs in alpine regions or from bank filtered groundwater will not face any water stress."[98]

Ground water can be privately owned by the owner of a land property; however these rights are restricted by a need for permits for any abstraction of water which can be considered more than insignificant. Surface water on the other hand is mainly publicly owned. Every other use, than watering, bathing and bailing, requires a permit.[99] The legal and institutional setting for water allocation in Austria is complex and spread across different scales. On a national level the Federal Ministry of Agriculture, Forestry, Environment and Water Management is primarily responsible for national policy, and therefore for the "[…] development and publication of river basin management plans; coordination of provincial planning; guidelines, and, monitoring strategies."[100] On a regional level the provincial governments take care of permits "[…] for 'major' water abstraction uses […]; monitoring and enforcement; provincial and local planning; and, resource protection for general water supplies […]."[101] The regional administration authority is responsible for the "[p]ermit for water abstraction uses and protection; permit surveillance; and, environmental inspections."[102] And on a local level Municipalities and Water Users Associations are in charge of "[w]ater supply and drinking water abstraction; protection and ongoing servicing; and, maintenance of water infrastructure."[103] Legal bodies, in this case the District authority, can declare exceptional circumstances and restrict existing water use entitlements due to shortages of water availability.[104]

Strategies and Measures

- **Networking of smaller supply units** and **creation of reserve capacity.** [105]
- **Project Achilles**: A simulation program and planning tool for identifying weak points during ongoing operation and in case of emergency in the water supply infrastructure. This tool is based on mathematic models and fed with data about the grid infrastructure (like water amount, velocity, pressure ratios, pump capacities, etc.). This information is combined with data about the risk potential of floods, avalanches and mudslides. In combining all those information the tool can assess the actual risks of the components which would have the

[97] OECD 2013c:119
[98] APCC 2014b:415
[99] OECD 2015:2
[100] OECD 2015:2
[101] OECD 2015:2
[102] OECD 2015:2
[103] OECD 2015:2
[104] OECD 2015:6
[105] APCC 2014a:27

biggest impact on the functioning of the system in the event of damage. It can therefore be used to recommend selective improvements of the systems Achilles heels.[106]

Transportation

The transportation infrastructure is of central importance to the society and economy of a country. Especially road and train infrastructure will probably be particularly affected by extreme precipitation events. More than three quarters of all damages arise because of indirect effects of extreme precipitation, such as mudslides, floods or avalanches.[107] Floods mainly cause damages to the pavement, drainage systems, bridges and dikes through erosion, undercutting and directly by flotsam. Long lasting floods lead especially to indirect damages by service disruptions.[108] The temporary outage of the transportation network can have huge impacts on the regional economy as well as on public health care. Especially alpine valleys and regions are expected to be highly vulnerable in Austria. Adapted construction can counteract many of the predominant vulnerabilities of the Austrian transportation infrastructure. [109] The direct damage on transportation infrastructure due to the weather events amounts extrapolated roughly to 50 million euro on average per year.[110] A forecast of the climate change related effects is only possible insofar as its causes – a higher frequency and amplitude of extreme precipitation events as well as a further increase in land surface sealing – fuel expectations of an increase in floods in the future. [111]

The responsibility for the planning, construction, operation, tolling and financing of the motorways and highways lies in the hands of the private stock company ASFINAG (Autobahnen- und Schnellstraßen-Finanzierungs AG), which is 100% owned by the Republic of Austria. It holds a monopoly position. The Austrian Ministry for Transport, Innovation and Technology sets targets and carries out an accompanying control of the measures.[112] The financing of regional and local reads lies within the responsibility of the respective regional or local public authorities. [113]

[106] University of Innsbruck 2011
[107] Environment Agency Austria 2014 & APCC 2014b: 646
[108] APCC 2014b:690
[109] Environment Agency Austria 2014
[110] APCC 2014b:646
[111] APCC 2014b:690
[112] BMVIT 2012:1
[113] BMVIT 2012:3

Strategies and Measures

- Taking climate change impacts and flood risks into account for adjustment of laws and regulations and **adapt the constructional rules** for critical infrastructure, like the power supply lines, the network configuration, road signs, foundations, etc. Develop distinct adaptation requirements for new construction and restauration.[114]
- **Decrease the amount of sealed surfaces** and its further expansion in order to increase water retention and prevent respectively reduce local flooding. There is a considerable potential in Austria to unseal surfaces because of over dimensioned road and parking areas (for example state roads next to highways). After these areas have lost their function these area stay often sealed, because of missing legal perquisites for dismantling. The goals of Austrian policy within this area are to first and foremost prevent further increase of sealed surfaces, then strive for an unsealing where possible. Only then the use of alternative permeable material should be considered and applied.[115]
- **Grow robust vegetation** along transportation routes: Certain tree species which are less prone for windfall, can withstand more water or with a favourable height should be selectively planted along transportation routes.[116]
- **Strengthen anchorage** of transportation facilities (like traffic lights, signposts, street lightning, etc.) and include the adaptation in dimensioning according to increased needs in the planning process of future facilities.[117]
- Initiate more "**[r]esearch** on adaptation to the consequences of climate change in the area of transportation infrastructure."[118]

[114] BMLFUW 2012b:117 & BMLFUW 2012a:289
[115] BMLFUW 2012b:117 & BMLFUW 2012a:291
[116] BMLFUW 2012a:289
[117] BMLFUW 2012a:289
[118] BMLFUW 2012b:117

Expert Survey

During the country case study of Austria 13 experts consisting of administrators, scientists and project managers in the field of climate change adaptation and flood risk management have been identified. A total of seven experts responded to the request. In the end, six experts participated by filling in the survey. One of the contacted experts did not feel capable of delivering useful insights, lacking sufficient background knowledge. Several efforts to receive responses from the remaining six experts were not successful.

Full agreement among all Austrian experts was established on the definition of critical infrastructures this research project is based on. Two third of the experts agree that past experiences with climate change impacts put climate proof critical infrastructures on the Austrian political agenda. Most experts agree that water robust critical infrastructures are important (one neutral, one disagrees). Half of the experts agree that critical infrastructures are already prioritised on the Austrian on political agenda. The remaining half has a neutral opinion about this statement. The awareness of businesses and the civil society about future climate changes and potential severe impacts on the critical infrastructures provides differing opinions without a clear trend.

Regarding the coordination of making critical infrastructure water robust, four experts perceive the Austrian approach as coordinated, while two express their neutral opinion. Hence, the overall trend in Austrian goes towards rather coordinated perception of the chosen approach in Austria. However, when it comes to the actual preparedness of the critical infrastructure to flooding, the experts remain sceptical. Opinions range from critical infrastructures are not well prepared (3), to neutral opinions (2) and one positive perception.

When asked about the effectiveness of the taken policies, experts perceive these as moderate to effective. On the one hand, half of the experts from Austria agree that the country possesses over effective policies to make its critical infrastructure water robust. On the other hand, most experts perceive the effectiveness of existing monitoring systems as neutral. Four out of six experts assert businesses to be unable to cope with uncertainties in decision making processes when carrying out adaptation measures.

There is a strong conformity when it comes to the need for coordinated action. In general, the Austrian survey has contributed to the research in terms of useful country-specific insights and the indication of further informative sources. All Austrian experts expressed the wish to receive the final report.

3.3.5. Recommendations

Below, a shortlist of the most relevant adaptation measures from the Austrian perspective:

Interconnected strategies and measures

- Enhance water retention
- Minimum River Morphological Space Demand
- Spatially Variable Vegetation Management
- Water- and load-retaining structures
- Mobile and temporary flood protection systems
- Raising awareness and Preparedness within the broad public
- Flood protection cooperation across borders

Energy

- Decentralising energy generation
- Diversifying energy sources
- Smart Grids

Telecommunication and IT

- Expansion of fibre glass technique
- Hybrid base stations for an almost completely self-sufficient energy supply
- Mobile phone masts equipped with photovoltaic panels
- Protective cover on switch points
- Crisis management teams and facilities
- Satellite flood maps as a backup information supply

Drinking Water Supply

- Networking of smaller supply units
- Creation of reserve capacity
- Make use of simulation programs to find system weaknesses

Transportation

- Taking flood risks into account for adjustment of laws and regulations
- Decrease sealed surfaces and its further expansion
- Strengthen anchorage of transportation facilities
- Grow robust vegetation along transportation routes

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3.4. Denmark

3.4.1. Exposure, Sensitivity and Adaptive Capacity

The expected climate-related changes for Denmark are summarized in the following:

- **Temperature:** The mean temperature already increased by 1.5°C since the 19th century. This is more than double the increase for the global mean temperature for the same period. The expected increase of the Danish annual mean temperature varies between 3°C to 5°C degrees depending on the chosen Restricted Concentration Pathway (RCP) scenario, leading to fewer days of frost and snow. Moreover, there will be 25% fewer days with snow cover compared to today.
- **Precipitation:** Since the beginning of records in 1874, the Danish annual precipitation increased by 15%, which differs in summer and winter. In winter, 10-40% increase in precipitation is projected, while a reduction of 10-25% of summer rainfall is expected. This indicates a tendency towards periods of heavy precipitation in winter and lengthy dry periods in summer.
- **Groundwater:** The lengthy dry periods in summer are expected to reduce groundwater formation. On the contrary, during the remaining seasons of the year formation of groundwater will increase. This will affect the use of groundwater for drinking water and irrigation purposes.
- **Runoff:** About 10% increase in runoff is expected between December and April. This increase in runoff could reduce the salinity of inner Danish waters.
- **Intrusion of salt water**: Salt water intrusion affects the quality of groundwater. Since Danish water supply entirely relies on groundwater, an increase of salt water intrusion may lead to limitations of water extraction.
- **Increased risk of flooding**. Due to sea level rise and higher precipitation extremes of about 20 to 30%, the risk of flooding increases[1].

Denmark is relatively well-off compared to other OECD countries and achieves high scores regarding indicators of national well-being. To determine Denmark's sensitivity the relatively high score on personal security, subjective well-being, environmental quality, housing and health status may be considered as indicators. Although the Danish economy was affected by the financial crisis in 2007, GDP has been steadily growing since 2012. Furthermore, Denmark has a stable political system,

[1] OECD 2013c

which stimulates proactive measures against climate change[2]. The expert survey indicated that the Danish critical infrastructure is well prepared to cope with the effects of climate change. Also, it is strongly agreed upon the statement that making critical infrastructure water robust is crucial in the face of climate change. Additionally, Denmark's dependency on groundwater resources and high precipitation rates lead to a relatively high exposure. Consequently, in terms of water-related impacts of climate change it seems that Denmark has a high adaptive capacity, but is also significantly exposed to potential effects. Hence, Denmark is relatively sensitive to climate change.

3.4.2. Political Context

Both, the expert survey we conducted within this research project and the expert survey by Biesbroek et al. (2014) affirm a high position of climate change on the Danish political agenda. As a result, the willingness to develop policies and undertake adaptation actions at the national level is rather high[3]. In this regard, the results of the expert survey from Denmark confirm the classification of Denmark's approach to make CI water robust as coordinated. Moreover, the expert strongly agrees with the statement that policies and monitoring applied by Denmark to achieve water robustness for its critical infrastructures are indeed effective. Regarding businesses and authorities, the expert perceives a rather high knowledge concerning the question of how to deal with uncertainties in decision-making processes.

3.4.3. Overarching Strategies and Measures

In general, in Denmark tasks are specifically delegated to municipalities supported by the national task force on climate change adaptation. Furthermore, there is a law providing municipalities with legal funding to prevent building in climate change prone areas.[4] In other words, climate change can be the sole reason for preventing any building in specific areas granting the municipalities authority in spatial planning. Municipalities containing areas at risk are obliged to establish risk control plans by 2050[5].

[2] OECD 2014:4-5
[3] Biesbroek, R., and R. J. Swart 2014
[4] OECD 2013
[5] COWI et al. 2011:75

The national adaptation strategy of Denmark was adopted in 2008[6]. In Denmark tasks are divided as locally as possible. Municipalities have the duty to supply climate change action plans and carry out risk assessments[7]. The national task force on climate change adaptation supports them by fulfilling an overarching, coordinating role.[8] The Danish Environmental Policy Agency prepares the decisions for the ministry and executes their political decisions[9]. The Ministry of Environment financially supports new climate adaptation solutions.[10] Aarhus University withholds the primary research centre on climate change with a special focus on adaptation. The forum on adaptation (KoK) ensures coordinated effort amongst public authorities[11]. In addition, the expert emphasizes the need for integrated coordination amongst countries for taking collaborative actions to make critical infrastructure water robust.

3.4.4. Sectoral Strategies and Measures

Energy

The energy sector generates 38.6 TWh electricity. This consists of: 44% coal, 20% gas, 20% wind and 13% biofuels. Inland energy production accounts for 23.2 million tons of oil equivalent. 14.7% Of the inland energy production is exported[12]. The Danish energy consumption varies with winter temperatures. During a mild winter energy needs for heating are up to 20% less than during a cold winter[13]. Denmark's electricity use has a relatively big share in wind power and it aims to increase this.[14] Denmark aims to be fully independent of fossil fuels by 2050.[15]

Responsibility for climate adaptation lies with the owners of installations, both private and public.[16] The Danish Ministry of Climate, Energy and Building is responsible for administering the energy supply legislation. The Danish Energy Agency is concerned with the day-to-day application of the

[6] European commission, European Environment Agency 2015
[7] Task Force for Climate Change Adaptation & The Danish Government 2012
[8] OECD 2014:4-5
[9] Danish Ministry of the Environment 2009:4
[10] OECD 2013c
[11] COWI et al. 2011:75
[12] International Energy Agency 2011:15
[13] The Danish Government 2008:26
[14] COWI et al. 2011
[15] The Danish Government 2015
[16] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:67

legislation. Together with Energinet.dk they are also responsible for the day-to-day running of the system and the administration of preparedness tasks[17].

The Danish documents emphasise the investment time horizon for electricity generating facilities of 10 to 30 years. The existing energy facilities are expected to be well-equipped to face the projected climate changes. Since no significant changes to the climate will occur within this timeframe, Denmark sees no need in specific adaptation measures. However, autonomous adaptation continues, meaning the establishment and shut-down of energy generating facilities required. [18]

Strategies and Measures

- **Wind power generation**. Currently the wind power generating facilities are already secured and stop working when high wind speeds occur.[19]
- **District cooling**. District cooling uses energy in heating water to produce air conditioning. The surplus of energy in district heating water from electricity production in CHP plants during summer is used to produce comfort cooling, as an alternative to air conditioning systems running on electricity.[20] An act of district cooling was adopted by the Danish Parliament, allowing municipal participation in district cooling projects. This used to be restricted to private companies.[21]
- **Electricity supply grid**. Vulnerable electricity supply grids like transformer substations will be constructed underground to prevent damages from flooding. By 2018, all air cables vulnerable to storms are replaced by underground cables.[22]
- **Moving electrical facilities**. In Copenhagen all electrical facilities such as light regulation and pumping stations on low lying levels are moved to higher levels.[23]

[17] Danish ministry of climate, energy and building 2012
[18] Task Force on Climate Change Adaptation and Danish Nature Agency 2012: 66-68
[19] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:67
[20] The Danish Government 2008:25
[21] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:67
[22] Danish Ministry of the Environment & Danish Nature Agency 2015
[23] COWI et al. 2011b:27

Drinking Water Supply

Danish water supply is exclusively based on extraction of groundwater. There is nation-wide access, good service and high quality of water. To a large extend drinking water supply concerning quality and monitoring lies within the responsibility of local governments.[24]

Drinking water is de-centrally supplied and can only be subtracted with a license. The Ministry of the Environment is responsible for the international obligations, research and development, the overall administration, establishment and adjustments of the legislative framework. The regional level is responsible for issuing permits, monitoring water quality, detailed mapping and planning. Municipalities are responsible for planning water supply and inspection of technical standards in water supply plants. Water supply plants are responsible for the quality of drinking water.[25] Environmental policy regarding drinking water is executed by the Danish Environmental Protection Agency. DANVA is the association for drinking water suppliers and looks after the common interests of Danish water and sewerage suppliers in promoting a steady and high-quality water and sewerage supply on an environmentally sustainable basis.[26]

In general the amount of groundwater will increase but shortages of groundwater in subsystems might occur during summer. Three particular effects of climate change on water supply can be distinguished. First, temperature rise will increase bacteria growth, which will make the water taste less fresh. Second, in the coastal areas water supply is subjected to salt water intrusion in case of sea level rise. Third, droughts in regional areas will cause lack of groundwater in other areas.[27]

Strategies and Measures:

- **Permits.** Permits for subtracting groundwater are reassessed and issued for a limited time frame. The groundwater extraction plants are to be replaced in case they endanger balanced groundwater levels.[28]
- **Subsidies to establish protection zones**. A task force aids municipalities in establishing protection zones to prevent groundwater depletion.[29]

[24] UNEP 2004
[25] Danish Ministry of the Environment & Danish Nature Agency 2015
[26] DANVA 2015
[27] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:47-59
[28] OECD 2013
[29] UNEP 2004

- **Modelling tools**. A nationwide water resource model has been developed by the Geological Survey of Greenland and Denmark. This model is called the DKmodel and calculates groundwater flow, increase and decrease.[30]

Transportation

The Danish main transport network consists of about 3800 km of roads and over 2300 structures. This includes 50 major bridges and four important tunnels. This is solely 5% of all public roads but carries almost half of Denmark's total traffic volume.[31]

The ministry of Transport for state roads is concerned with the climate change adaptation strategy. This contains the targets, milestone plan, declaration of services- availability infrastructure. The Danish road directorate designs the Danish road regulations. The regulations are implemented together with councils, service locations, suppliers and joint projects. The Road regulation council arranges the contact between the Danish road directorate and municipalities. SAMKOM is a cooperation forum for directorate and councils. The local communities are responsible for the individual road authority. This means dimensioning road and drainage systems to standards. The individual owners of the sewerage lines next to roads are responsible for these lines. Sewer line drainage must be sufficient.[32]

There are five main effects of climate change on the Danish infrastructure. The main effect is increased precipitation which leads to (amongst other things) increased groundwater levels which has several consequences. First of all, this reduces the carrying capacity of the roads, shortens their lifespan and the road banks become unstable (e.g. landslides). This could potentially endanger the traffic safety and flow. Second, more water on the roads means more pressure on bridges and tunnels. Third, on important transportation links, the excessive amounts of water need to be pumped away in order to avoid long periods of disruption and bridges to be closed down temporarily. Fourth, the road sign portals will be under pressure due to storms. Last, drainage systems will need full capacity to pump the water away.[33]

[30] National vandressourcemodel 2015
[31] Danish Road directorate 2013:4
[32] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:36-43
[33] Danish Road directorate 2013

Strategies and Measures:

- **Extension of road drainage system in new roads**. The road drainage systems can be extended. However this must be socio-economically feasible meaning the costs and risks are assessed to ability to cope with extreme events.[34]
- **Testing alternative drainage systems - Linear drainage.** Linear drainage if a channel shaped drainage systems which allows for rapid evacuation of water. However it is not sure yet whether this better fits situations with excessive amounts of precipitation. Linear drainage lines require water transportation across large distances.[35]
- **Trenches and trench basins** for capacity relief for surface water and rainwater. The number of places for discharging water needs to be increased in order to reduce inappropriate accumulation of water.[36]
- **Retention basins next to roads.** Maintenance needs to be improved so retention basins are cleared. This will restore them to full capacity so they can be optimally used. However, this seems rather expensive.[37]
- **Drainage design standards revised in 2009**. The critical water level for the design of pipes, culverts, and basins is 25 years. This is the maximum return period. Situations demanding full utilisation of the cross-sectional area of culverts should not occur more than once a year. Moreover, a factor measuring the uncertainty with regard to climate change is introduced in dimensioning precipitation.[38]
- Roads are increasingly situated under groundwater levels due to increasing groundwater levels. The carrying layers of the road are not designed to withstand this. This can be counteracted **by constructing roads on dams or by pumping water off roads**. Pumping water off roads can be extremely expensive but it is necessary on some existing roads. In particular, these include low-lying roads built for the prevention of noise pollution, making it difficult to drain them.[39]
- **Road trees** - these should be cut to prevent them from falling during storms.[40]
- **Road signs** - Construct a stronger foundation to prevent them from failing during storms. [41]

[34] Danish Road directorate 2013
[35] Danish Road directorate 2013
[36] Danish Road directorate 2013
[37] Danish Road directorate 2013
[38] CEDR 2011
[39] Danish Road directorate 2013
[40] Danish Road directorate 2013
[41] Danish Road directorate 2013

- **Comprehensive emergency response plans for relevant areas**. The declaration of services demanded the availability of transport infrastructure. Comprehensive emergency response plans have been established concerning major flooding events, and detailed subsequent analysis of these events. E.g. Lyngbyvejen, a major approach road to Copenhagen.
- **Blue spot method**. This is a tool to identify the most flood prone areas on national roads with the largest consequences.[42]
- **Intelligent transport systems (ITS) and intelligent speed adaptation (ISA).** These systems can automatically adjust road speed limits to the intensity of rainfall. Additionally, road radar can be implemented so targeted traffic reports can be established. Nevertheless, it is costly to develop such systems. [43]
- In case of a flooded road. The Danish Road directorate has call-out **services ready to close roads** if necessary. Road users will be informed about the flood via traffic information services, such as internet, mobile phone apps, radio and GPS. In the meantime the road will be cleared up quickly using pumps which work at optimal levels during extreme weather conditions. Emergency pumps are located across the country, while doubling the amount of pumps close to flood-prone areas is considered.[44]
- **Strategic road network**. This network ensures a focus on roads with the greatest economic significance. The most important measure is establishing regular diversion routes.[43]
- **Analyse the flooding event and decide on additional measures**. An event is supposed to be analysed using a cost-benefit analysis of possible solutions. Improvements are implemented if they are financially viable. The results will be saved in order to prepare guidelines. A database of events has been created to continually update the strategies. This database shows the distribution, type and consequences of events. The relevant authorities should optimally cooperate, which is enhanced through SANKOM.[45]
- **Legislation**. The Danish Road Directorate cooperates in legislative work concerning managing rainfall on roads. [46]
- **Prudence in planning and construction**. The Danish Road Directorate always prefers climate proofing during construction phase instead of adaptation during operational phase. New

[42] Danish Road directorate 2013
[43] Danish Road directorate 2013
[44] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:36-43
[45] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:36-43
[46] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:36-43

roads are not planned close to flood-prone areas and high barrier-structures are used if necessary.[47]

- **Carriageway widening**. While expanding the carriageway of a road, the opportunity is taken to adapt the roads to projected climate change impacts, if required. By this, climate adaptation is integrated into road construction projects already being executed. [48]
- **Research, development and knowledge exchange**. The Danish Road Directorate searches for short- and long-term solutions for the climate change problem. The focus is on optimal run-off to prevent flooding, resource use optimisation and supporting strategic planning. International information sharing and cooperation ensures access to most relevant and valuable information.[49]

Expert Survey

The most critical functions in Denmark are considered to be the following sectors electricity, natural gas, telecom to respond to a crisis, public telecom network, drinking water, waste water, surface pumping stations, main road transportation, chemical and hospitals. Overall the expert from Denmark reaffirms that there is a coordinated approach to tackle the challenges faced due to climate change. Still, he assumes Denmark could learn from the Netherlands to think very big. This could mean that Denmark could look at big infrastructural projects concerning water robustness in the Netherlands. On its turn, the Netherlands could learn from Denmark's combined actions, partnerships and public involvement. In Denmark, businesses are aware of the potential severe impacts. Still civil society is unaware of the potential impacts of climate change. However both authorities and business concerned with adaptation measures know how to deal with uncertainties in decision making. The expert agrees there is a need for an integrated coordination amongst countries for taking collaborative actions to make critical infrastructure water robust.

[47] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:36-43
[48] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:36-43
[49] Task Force on Climate Change Adaptation and Danish Nature Agency 2012:36-43

3.4.5. Recommendations

The following recommendations are selected for the specific sectors:

Interconnected strategies and measures

- A law which allows governmental bodies to forbid construction work in a certain area solely based on climate change reasons
- New building work only done on higher grounds
- Basements and foundations sealed against increased (ground) water levels
- Consider insurance/compensation for extreme events

Energy

- District cooling – Efficient use of heating water for air conditioning
- Electricity supply grid – Bury vulnerable subsystems underground and move them from low lying areas

Drinking Water Supply

- Flexibility – Limiting the period of validity of permits
- Subsidies to establish protection zones
- Modelling tool – The DK model calculates groundwater flow- and subtraction levels.

Transportation

- Drainage systems next to roads – Drainage the excessive amount of precipitation from the main transport networks. This can be done using trench basins, retention basins or linear drainage
- Pumping water off roads – To release pressure on carrying layers
- Road trees – Cut trees next to rods to prevent them from falling during a storm
- Road signs – Construct a stronger foundation
- Comprehensive emergency response plans – As can be read in the Dutch case, the Netherlands has huge problems when the main road network gets flooded. Therefore attention must be put on evacuation and call-out services in case of a flooding.
- Focus on diversion routes- make clear and extent the possibilities on where to go when a flood occurs.
- Climate adapt while constructing roads – Climate proof during construction instead of adaptation during operational phase
- Research, development and knowledge exchange in the area of transportation.

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3.5. Germany

3.5.1. Exposure, Sensitivity and Adaptive Capacity

Below the German exposure is given for several climate variables:

- **Temperature:** Germany expects its mean temperature to increase by 0.5°C to 1.5°C until 2050 and 1.5°C to 3.5°C until 2100.[1]
- **Precipitation:** The changes in rainfall patterns provide the most striking evidence of climate change in Germany. This includes mainly a shift of the rainfall cycle by a rather constant annual total of precipitation, leading up to 40% reduction in summer and to 40% increase of rainfall in winter.[2]
- **Groundwater:** Germany does not have problems with the supply of drinking water. Nevertheless, there is an increased danger from fertilisers and pesticides, which may contaminate the groundwater through erosion caused by extreme wind and rainfall events.[3]
- **Runoff:** Due to the milder winters and higher precipitation rate, storage of water in the form of snow will decrease. This leads to immediate runoff, increasing the likelihood of flooding during winter.[4]
- **Intrusion of salt water**: There may be changes in the penetration of salt water into the groundwater caused by sea-level rise and changes in storm climate until the end of the century.[5]
- **Increased risk of flooding:** Particularly in winter, the probability of flooding may increase due to heavier, more frequent and intensive rainfall in connection with immediate runoff. Risk of flooding particularly occurs in the river catchments of Rhine, Danube, Elbe and Oder.[6]

3.5.2. Political Context

Germany addresses the protection of its critical Infrastructure as a networking task, involving diverse governmental bodies at different levels. On its online portal informing about the protection of the German critical infrastructure, established by the Federal Office of Civil Protection and Disaster

[1] German Federal Government 2008:10
[2] German Federal Government 2008:11
[3] OECD 2013:155
[4] German Federal Government 2008:20
[5] German Federal Government 2008:45
[6] OECD 2013:155

Assistance (BBK) and the Federal Office for Information and Security (BSI), six stakeholders are identified being mainly responsible of making critical infrastructures robust.[7, 8, 9]

- **Federal Ministry of the Interior (BMI)** – Being mainly responsible for the internal security in Germany the Federal Ministry of the Interior is the coordinating governmental body in terms of critical infrastructure protection, supervising its subordinate agencies BBK and BSI.
- **Federal Office of Civil Protection and Disaster Assistance (BBK)** – The BBK is responsible for the protection of the German civil society and disaster relief. It thus develops measures and policies against the impact of catastrophes in order to prevent harm to the population and protect the national critical infrastructures.
- **Providers** – 'Providers' refers to those companies and organisations, which operate or own critical infrastructure, including the energy and transport sector. The involved German governmental departments see these companies and organisations as being responsible for securing and ensuring the functioning of critical infrastructures.
- **Federal Office for Information Security (BSI)** – The BSI is responsible for the IT security of the German Federal Government. As such, at the federal level the BSI protects critical information and telecommunication infrastructure and is also responsible for the finance and insurance industry sector.
- **Federal States (Bundesländer)** – Each of the 16 German federal states are individually responsible for the civil protection by ensuring the functioning of critical infrastructures within their own borders. Activities to protect critical infrastructures on the federal state level thus links to protection measures on the local level.
- **Communal level** – On this level, communities are taking concrete measures for civil protection, including respective land use planning and planning permission, as well as the development of emergency plans for the event of disasters. Particularly public facilities are decisive for the civil protection, including fire brigades, ambulance services or the Federal Technical Relief Agency (Bundesanstalt Technisches Hilfswerk – THW).

Activities in Germany to protect critical infrastructures can be distinguished into activities happening on the national level and on the international level.[10] On the national level Germany perceives the

[7] BBK; BSI 2015a
[8] BMI 2009:5
[9] For a more detailed description of coordination, cooperation and the exchange of information in Germany, including administrative districts, science and research or the media, see BMI 2009: National Strategy for Critical Infrastructure Protection (CIP Strategy), 14-15.
[10] BBK; BSI 2015b

protection and functioning of critical infrastructures as crucial for its international economic competitiveness and national security policy. This crucial role critical infrastructures play for the German state's well-being becomes also apparent in the way the German Federal Administration defined critical infrastructures in the German National Strategy for Critical Infrastructure Protection (CIP Strategy):

> Critical infrastructures (CI) are organisational and physical structures and facilities of such vital importance to a nation's society and economy that their failure or degradation would result in sustained supply shortages, significant disruption of public safety and security, or other dramatic consequences.[11]

To assess whether infrastructures can be referred to as critical, Germany has introduced the indicator of 'criticality', which describes

> […] a relative measure of the importance of a given infrastructure in terms of the impact of its disruption or functional failure on the security of supply, i.e. providing society with important goods and services.[12]

The German perception of criticality is further distinguished into 'systemic' and 'symbolic criticality'. Systemic criticality refers to the degree of integration of a specific infrastructure into the overarching context, which could create high interdependencies and thus a high level of criticality in case this particular infrastructure gets disrupted. Symbolic criticality describes more the psychological or emotional effect, disrupted infrastructures may have on the culture and identity of society.[13]

Moreover, Germany classifies its critical infrastructures into 'vital (absolutely essential) technical basic infrastructure' and 'vital (absolutely essential) socio-economic services infrastructure'.[14] The former includes the sectors of power supply, information and communications technology, transport(ation), (drinking-) water supply and sewage disposal. The latter embraces public health and food; emergency and rescue services, as well as disaster control and management; parliament, government, public administration and law enforcement agencies; finance and insurance business; media and cultural objects, e.g. cultural heritage items.

The German CIP Strategy identifies a spectrum of potential threats to national critical infrastructures, classified into the three categories of natural events; technical failure and human error; terrorism,

[11] BMI 2009:4
[12] BMI 2009:7
[13] BMI 2009:7
[14] BMI 2009:7

crime and war (see table 3). Water-related events such as heavy precipitation, floods and droughts are addressed first. Despite the expected increase in occurrence and severity of natural extremes with regard to future climate changes, natural hazards remain second priority to terrorist as potential cause of threat to the national infrastructure.[15]

Table 3: Spectrum of threats to German critical infrastructure

Natural events	Technical failure / human error	Terrorism, crime, war
Extreme weather events inter alia, storms, heavy precipitation, drops in temperature, floods, heat waves, droughts	**System failure** inter alia, insufficient or excessive complexity of planning, defective hardware and/or software bugs	**Terrorism**
Forest and heathland fires	**Negligence**	**Sabotage**
Seismic events	**Accidents and emergencies**	**Other forms of crime**
Epidemics and pandemics in man, animals and plants	**Failures in organisation** inter alia, shortcomings in risk and crisis management, inadequate coordination and co-operation	**Civil wars and wars**
Cosmic events inter alia, energy storms, meteorites and comets		

Germany is aware of the high vulnerability resulting from the dependency of its society on national infrastructures, in particular regarding external hazards but also disturbances occurring from within the system. In case disruptions trigger a 'domino effect', the CIP Strategy warns not only against tremendous economic damages, but also loss in society's confidence in the political leadership.

The main responsibility for taking respective protection measures for the secure functioning of critical infrastructures in Germany is lying within the joint responsibility of the national industry and government agencies. Especially since the majority of German critical infrastructure is privatised, the Federal Government seeks for a close cooperation with non-state, private actors, perceiving the protection of national critical infrastructures as a shared responsibility.[16] With the CIP Strategy the Federal Government of Germany has established a strategic guideline for the protection of national critical infrastructures. These guidelines are already practically implemented since the development

[15] BMI 2009:10
[16] BMI 2009:8;12

of the strategy in 2009.[17] With regard to the implementation of the CIP Strategy, Germany has identified several 'work packages' and 'instruments'. The implementation of these work packages is coordinated by the BMI and partly carried out by the public sector, as well as by private operators of critical infrastructures. Instruments for the implementation include

- "**programmes and plans** (e.g. the National Plan for Information Infrastructure Protection (NPSI) and the related implementation plans as a strategic concept for IT infrastructure protection);
- **specific recommendations for action** (e.g. the national Baseline Protection Concept as a basic guidance to physical critical infrastructure protection; the Risk and Crisis Management Guide for Critical Infrastructure Operators, or the national special protection concepts as detailed recommendations for action for the protection of individual CI sectors and sub-sectors);
- and **standards, norms and regulations** (e.g. the BSI Information Security Standards as a basic recommendation for action addressed to critical infrastructure operators; or the regulations of the German Gas and Water Supply Association (DVGW) on risk management in the field of drinking water supply)."[18]

[17] BMI 2009:3
[18] BMI 2009:16-17

3.5.3. Overarching Strategies and Measures

Strategies and Measures on multiple levels

- **The KRITIS-system:** To protect its critical infrastructures, Germany has established the KRITIS-System. This hierarchic system (Figure 1) supports the analysis of critical infrastructures and the identification of adequate protection measures.[19] The sector level describes the overarching category consisting of various infrastructures (e.g. transport including traffic, railway etc.). The components at the bottom of the pyramid refer to sub-categories of infrastructures. For instance railway includes train stations and traffic includes roads.

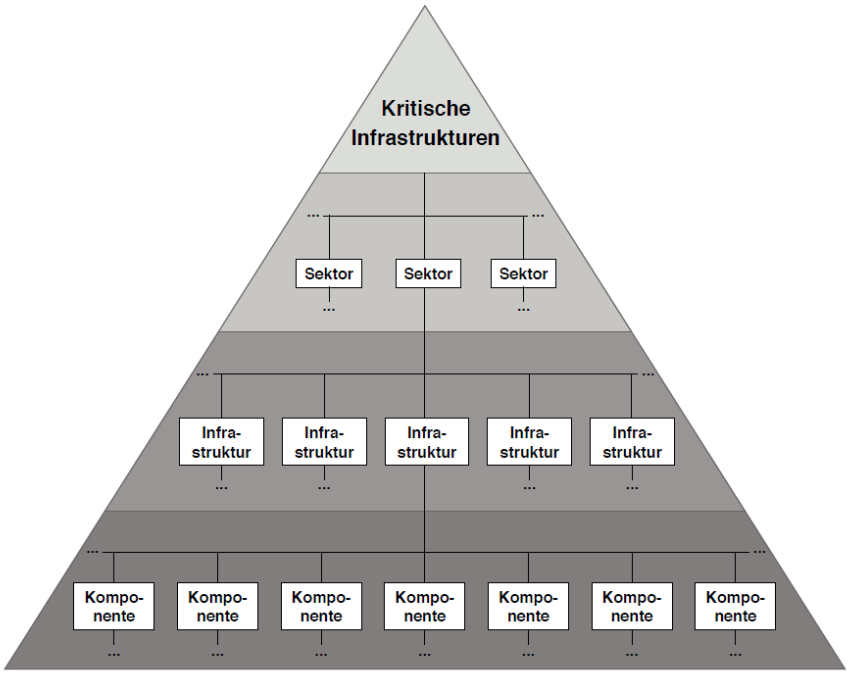

Figure 1: The KRITIS-System (Source: Lenz, 2009)

- **UP KRITIS:** UP (= implementation plan [dt. Umsetzungsplan]) KRITIS is a public-private cooperation between the providers owning critical infrastructure and the responsible state authorities. This implementation plan aims at maintaining the functioning of critical infrastructures in Germany in the following eight sectors: energy, health, IT and telecommunication, transportation, media and culture, water, finance and insurance commission, and food. Concrete measures include, among others, increasing the robustness of IT and telecommunication, to exchange knowledge about recent events concerning critical

[19] Lenz 2009:21-25

infrastructures, to develop and establish structures for crisis management and coordinated crisis responses. UP KRITIS mainly aims at ensuring the IT and telecommunication sector, since other critical infrastructures fundamentally rely on the functioning of this sector. The cooperation among the participating organisations in UP KRITIS is based on trust, the exchange of knowledge and mutual learning.[20]

UP KRITIS has been developed from 2007 onwards and renewed its organisational structures in 2013. These include several working groups, a plenary, a planning staff and a council as main bodies of UP KRITIS. The working groups are divided into sector- and issue-specific exchange of expertise.[21] Sector-specific working groups include, among others, electricity and gas, water and waste water, insurance industry, telecommunication and transportation.[22] Issue-specific working groups deal with the questions directly related to KRITIS across sectors, including operative exchange of information and experience, crisis communication system or scenario-based crisis precautions.[23] The UP KRITIS Plenary is the overarching organisational body of KRITIS, where the results of the working groups converge, information and knowledge exchange takes place and working groups are established or dissolved.[24] The Plenary mainly serves as a representation of the participating stakeholders being involved in critical infrastructures, as well as the exchange of expertise among them. The Planning Staff includes representatives of the plenary and the involved German ministries BMI, BSI and BBK. It mainly possesses a coordinating role and is responsible for strategic decision-making for UP KRITIS in-between the plenary meetings.[25] The UP KRITIS Council consists of high-level decision-makers within critical infrastructures, including representatives of the providers and administrators of critical infrastructure. The Council therefore works as a voice and connective link to the political level, advocating personnel, financial and organisational requirements of UP KRITIS, as well as providing strategic guidance to the different projects within UP KRITIS.[26] SKRIBT^{PLUS} is one of the national, cross-sectoral UP KRITIS projects[27] in Germany. As a follow-up project, SKRIBT^{PLUS} uses the knowledge and innovative ideas gained from SKRIBT to carry out risk analysis and assessments for improving the security of critical infrastructures, such as roads and tunnels, guiding the practitioners in terms of improving the

[20] BBK; BSI 2015c
[21] BBK; BSI 2015d
[22] BBK; BSI 2015e
[23] BBK; BSI 2015f
[24] BBK; BSI 2015g
[25] BBK; BSI 2015h
[26] BBK; BSI 2015i
[27] BBK; BSI 2015j

building and operating technology, as well as the security systems applied to these infrastructures.

- **Federal Government and State cooperation:** The cooperation between Federal Government and Federal States for the protection of the critical infrastructures in Germany is anchored in § 18 of the national law for 'Civil Protection and Disaster Assistance' (ZSKG; in German: Gesetz über den Zivilschutz und die Katastrophenhilfe des Bundes).[28] This law provides the framework for the cooperation between the Federal Government and the 16 German Federal States in terms of civil protection, risk analysis and catastrophe management. Federal Government and Federal States carry out a nationwide risk analysis for civil protection and the results are reported annually to the German parliament (Bundestag). Regarding the division of responsibilities and competences for protecting critical infrastructures, the Federal Government provides counsel for the Federal States. Together, Federal Government and States develop standardised approaches for civil protection and an effective catastrophe management.

- **Sectorial dialogue:** The working group 'Critical Infrastructure' within the BMI has been established in 2004 to identify critical infrastructures, as well as to develop respective protection measures, nationwide and across sectors. BMI and sectoral representatives are thus are constantly in touch and keep themselves updated about potential disturbing effects on critical infrastructures, perceiving this as a threat to public security requiring respective precautionary measures.[29]

- **Collaboration with the communal level:** For the protection of critical infrastructures, the communal level is crucial, as it is directly affected by malfunctions or breakdowns. The KRITIS strategy therefore provides concrete guidance for local communities, for instance in terms of a guideline for undertaking a risk analysis of the local water supply or in supporting measures for the implementation of local crisis management guidelines for cities and the providers of critical infrastructures.[30] This includes, among others, a communal vulnerability assessment towards flooding or guidelines for power failure.[31]

[28] ZSKG § 18, 1-3 last amended 29.07.2009
[29] BBK; BSI 2015k
[30] BBK; BSI 2015l
[31] BBK; BSI 2015m

- **New Risk Culture:** In terms of awareness, Germany is also recognising the fact that a full protection of its national infrastructures is not realistic and thus proposes a new 'risk culture', including
    - "open risk communication among the state, companies, citizens and the general public, taking account of the sensitivity of certain information;
    - co-operation among all stakeholders in preventing and managing incidents;
    - greater self-commitment by operators as regards incident prevention and management;
    - a greater and self-reliant self-protection and self-help capability of individuals or institutions affected by the disruption or compromise of critical infrastructure services."[32]

- **International Level:** Germany is striving for intensifying international cooperative initiatives and measures for the protection of critical infrastructures due to their increasing interconnectedness across borders, as for instance, electricity and gas networks across Europe or the communication sector distributed over the globe. Regarding enhanced international cooperation, Germany is referring to activities on EU-level, such as the European Programme for Critical Infrastructure Protection (EPCIP) from 2006, as well as information and cyber security.[33]

3.5.4. Sectoral Strategies and Measures

Energy

Germany perceives its energy sector to be most secure compared to other countries, despite potential effects climate change might have on the German energy sector.[34, 35] This can be attributed to the legal obligation that the private companies in the energy sector are obliged to guarantee a secure supply with electricity and operate the electricity network reliably and on a high performance. To monitor these high expectation to the private energy suppliers the German law prescribes in the

[32] BMI 2009:11
[33] BBK; BSI 2015n
[34] BMI 2009:4
[35] German Federal Government 2008:32-33.

Energy Industry Act (Energiewirtschaftsgesetz) regular control and reporting mechanisms carried out by the industry's associations and the Federal Network Agency (Bundesnetzagentur – BNetzA)[36]

However, with regard to climate change the German National Adaptation Strategy (German NAS) sees potential risks for power generation in thermal power stations (coal, gas, nuclear power plants) or power plants relying on cooling from the groundwater. Due to the dependency of these power stations on adequate availability of cooling water, the energy sector might be affected by low (ground) water levels and higher river water temperatures.[37] This could be particularly the case for the summer months, where higher temperatures and the projected lower precipitation may cause periods of drought. Energy suppliers may then have to limit the power production, to fulfil the requirements the German water legislation and safety regulations impose. As a safeguarding measure for the full operation of power plants in periods of drought, the German authorities have distributed permits under the German water law, which allowed them to raise the temperature of water discharges form 28°C-30°C during heat wave experienced in summer 2003.[38]

The most important task for the German energy sector remains in the transition from fossil and nuclear energy towards renewable energies. In the aftermath of the nuclear disaster in Fukushima, Japan, in March 2011, the German parliament (Bundestag) decided the phase out of nuclear energy and the extensive expansion of renewable energies. To ensure the security of supply during this transition process, reporting mechanisms were established and legally implemented within the Energy Industry Act in form of monitoring reports on the progress made. The last one has been published in 2014 by Federal Ministry for Economic Affairs and Energy (BMWi), emphasising the importance of these reports on the status quo for ensuring the security of supply in the future.[39]

Strategies and Measures:

- **GRASB:** This nationwide project within UP-KRITIS seeks enhance the awareness of potential risks concerning the secure supply with electricity by sensitising actors within the electricity sector, including public authorities and private companies, in order to decrease the default risks of electricity blackouts.
- The '**Energiewende'** is the most ambitious target of the German energy policy, aiming for energy efficiency and the transition towards renewable energies. In 2030 50% of the national energy supply should be covered by renewables, to be increased to 80% in 2050. By this,

[36] BMI 2009:4
[37] German Federal Government 2008:32
[38] German Federal Government 2008:32
[39] BMWi 2014:131

Germany wants to decrease its national GHG emissions up to 95% in 2050.[40,41] This transition in the German energy sector thus constitutes a fundamental measure to mitigate climate change.

- Extensive **legally binding reporting mechanisms**
    - to ensure the secure supply with electricity and a reliable electricity network
    - to monitor the transition towards renewable energies

Telecommunication and IT

To protect the telecommunication and IT sector, Germany attempts to connect and harmonise its CIP Strategy with the National Plan for Information Infrastructure Protection (Nationaler Plan zum Schutz der Informationsstrukturen – NPSI).[42] As an information society, Germany highly depends on information technology and perceives its protection as a matter of national security.[43] In terms of potential threats to the security of the information infrastructure, the German NPSI identifies terrorist attacks (even outside Germany), technical defects, human error or deliberate acts of destruction (e.g. hacking, computer viruses and worms). Potential disruptions by extreme weather events or water-related impacts (e.g. flooding) are not covered in the NPSI. Due to the interconnectedness of the sector, disruptions may have serious impact on the national economy and the German society in general.[44] Thus, the German Federal Government follows three strategic objectives for the information infrastructure protection.[45] First, Germany aims for the prevention of any potential harm by an adequate protection of the information infrastructure. Second, in order to be able to respond effectively to any IT disruptions, Germany wants to prepare for these incidents. Finally, Germany strives for sustainability in the protection of the information sector by enhancing its competences in IT security, as well as seeking for the implementation of international standards.

Strategies and Measures:

Regarding the protection of the telecommunication sector, Germany has set up legal measures, similar to the energy sector. These include legal obligations for telecommunication service providers to protect all relevant telecommunication and information processing systems. For this purpose, telecommunication providers are supposed to use technical safeguards, while the

[40] BMWi 2014:5
[41] BMWi 2015
[42] BMI 2009:3
[43] BMI 2005:2
[44] BMI 2005:3
[45] BMI 2005:5

telecommunication operators are being protected by security officers, who are in charge of establishing a security concept and providing the BNetzA with necessary information about taken technical precautions and protective measures.[46]

Drinking Water Supply

The supply with drinking water in Germany is to a large extent covered by local groundwater resources and is only marginally dependent on surface water from reservoirs. Hence, even with regard to future climate changes, drinking water supply in Germany is not really endangered, although there could be regional exceptions particularly suffering from droughts.[47] Moreover, it is possible that the projected more frequent wind and precipitation extreme events could contaminate the groundwater with pollutants, fertilisers and pesticides by causing erosion.[48] To protect its water resources, Germany has established a water protection policy. This policy aims at securing the drinking water supply in quality and quantity, as well as preserving existing water resources also for non-drinking purposes, such as leisure or recreation.

To achieve these goals the German water protection policy utilises the precautionary principle, the polluter pays principle and a cooperative approach including all relevant stakeholders for the protection of water resources.[49] The legal basis for the German water resource management is provided by the Federal Water Act[50], which was adopted in 1957 and regularly updated, for instance to integrate the EU Water Framework Directive (WFD) in 2002.[51] Typical for German federlism is also the coordination and distribution of competences. While the Federal Government merely issues the legal framework for the protection of water resources, each federal state is in charge of implement and enforce these legal provisions. In terms of horizontal policy coordination, the federal states established joint working groups on water issues (LAWA, Länderarbeitsgemeinschaft Wasser).[52]

[46] BMI 2009:4
[47] OECD 2013:155
[48] German Federal Government 2008:21
[49] BMUB 2007
[50] Wasserhaushaltsgesetzt (WHG), last amendment in 2009.
[51] BMUB 2007
[52] BMUB 2007

Transportation

The German CIP Strategy does not explicitly refer to the transportation sector. In view of a potential future increase in the occurrence of extreme weather events, the German adaptation strategy expects the road network to be affected by snow, ice, hail, heat-waves, storms, intense rainfall, floods, low river levels and heavy seas, landslides.[53] However, Germany sees no need for urgent action and generally perceives these possible effects on the federal trunk road infrastructure as manageable. In terms of rainfall, potential enlargements of road-specific drainage systems are seen as sufficient measure to cope with heavier rainfall. Regarding potential damages from snow and ice to roads and bridges, the German Federal Government stresses the need for continuous and careful monitoring. In general, the road network should be prepared for potential impacts by water and heat through the use of modified construction materials. In this regard, the German Federal Government delegates the responsibility of the implementing these measures to the Federal Ministry of Transport, Building and Urban Affairs.[54]

Strategies and Measures:

- Enlarging drainage systems on roads to prepare for heavy precipitation
- Continuous future monitoring of road network damages caused by ice and snow

[53] German Federal Government 2008:35.
[54] German Federal Government 2008:36.

3.5.5. Recommendations

Interconnected strategies and measures

- The KRITIS-system approach serves as an assessment tool of critical infrastructures, visualising interrelations and complexity
- The Implementation of reporting and information sharing mechanisms between Governmental authorities and private stakeholder; as for instance in Germany established with the sectorial dialogue
- Strategies and measures for improving the horizontal and vertical policy coordination across sectors of critical infrastructure
- A new risk culture may improve the awareness and the management of risks

Energy

- Legally binding reporting mechanisms between the government and energy suppliers
- To increase the amount of supply with renewable energies on the long run to prevent severe impacts of climate change

Telecommunication and IT

- To implement legal obligations for telecommunication services providers to ensure a high performance and reliable telecommunication and IT network
- Implement reporting-mechanisms
- The German CIP Strategy may serve as a reference in terms of IT security

Transportation

- Enlarge drainage systems on roads to prepare for heavy precipitation
- Monitoring of road network damages caused by ice and snow

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3.6. United Kingdom

3.6.1. Exposure, Sensitivity and Adaptive Capacity

Below the exposure of the United Kingdom is given for several climate variables:

- **Temperature:** The average annual temperature has increased in Central England about 1°C since the 1970s. The average annual temperature is projected to rise by 2°C to 3.5 °C by 2080, with an additional 0.5 °C rise in summer than in winter.
- **Precipitation:** The annual average precipitation has not changed significantly since records began in the United Kingdom. Precipitation is projected to decrease 0 to 15% by 2080, but the seasonal distribution will change significantly with wetter winters and drier summers.
- **Snowfall:** Mean snowfall in winter is projected to decrease by 65 to 95% throughout the UK.
- **Flooding:** The prevalence of extreme weather events is projected to increase. Especially in winters periods of heavy rainfall will increase, leading to increase flooding risk.

The United Kingdom (UK) is often plagued by floods. Annual precipitation is projected to decrease on an annual basis up to 15% by 2080, but the seasonal distribution of rain will change significantly, with winters becoming wetter and summers drier.[1] This will significantly increase the flood risk in the UK during the winter.

In 2007 the nation's vulnerability to floods was exposed, when prolonged floods cost the UK economy over £4 billion. Damage to critical infrastructures was estimated at £674 million and affected the supply of clean water to 350,000 people and the supply of power to 130,000 people. In addition about 10,000 people stranded on a motorway.[2]

If no climate change adaptation measures are taken and the population grows as projected, the damage to properties due to flooding from rivers or the sea is expected to rise from 2 to 12 billion in 2080.[3] Between 5% and 42% of the critical infrastructure assets related to waste and drinking water, energy, IT and transport are located in areas susceptible to flooding from rivers or the sea. This proportion of infrastructure exposed to flooding is projected to increase for all sectors by the 2050s.[4]

[1] OECD 2013:213
[2] Government Office for Science 2012:3
[3] OECD 2013:55
[4] Committee on Climate Change 2014a:69

3.6.2. Political Context

The United Kingdom government is a frontrunner on policies to make critical infrastructure water robust, which can be explained by the relatively high position of national security, climate change adaptation and flooding on the political agenda of the two previous governments.[5] Keywords used in the UK to refer to water robust critical infrastructure are: national critical infrastructure (NCI), resilient national infrastructure and climate resilient infrastructure.

In the United Kingdom adaptation to climate change is treated as a topic on its own, in contrast to the continental European strategy of mainstreaming adaptation policies throughout public administration layers. Nevertheless, public institutions at all levels of government have a policy on climate change adaptation. The long-term national policy is set by the Cabinet Office. The Centre for the Protection of National Infrastructure (CPNI) has been established to advise businesses and organisations dealing with critical infrastructures on protective security. The United Kingdom Regulators Network (UNRK) facilitates coordination between the nine economic regulators in the United Kingdom. The policy for the different sectors is developed by different departments. The Department of Environment, Food and Rural Affairs (Defra) has a special role, as it is able to demand climate change adaptation plans from businesses and organisations dealing with critical infrastructures. For an overview of the political organisation per sector, see Figure 2 on the next page.

[5] HM Government 2010:11

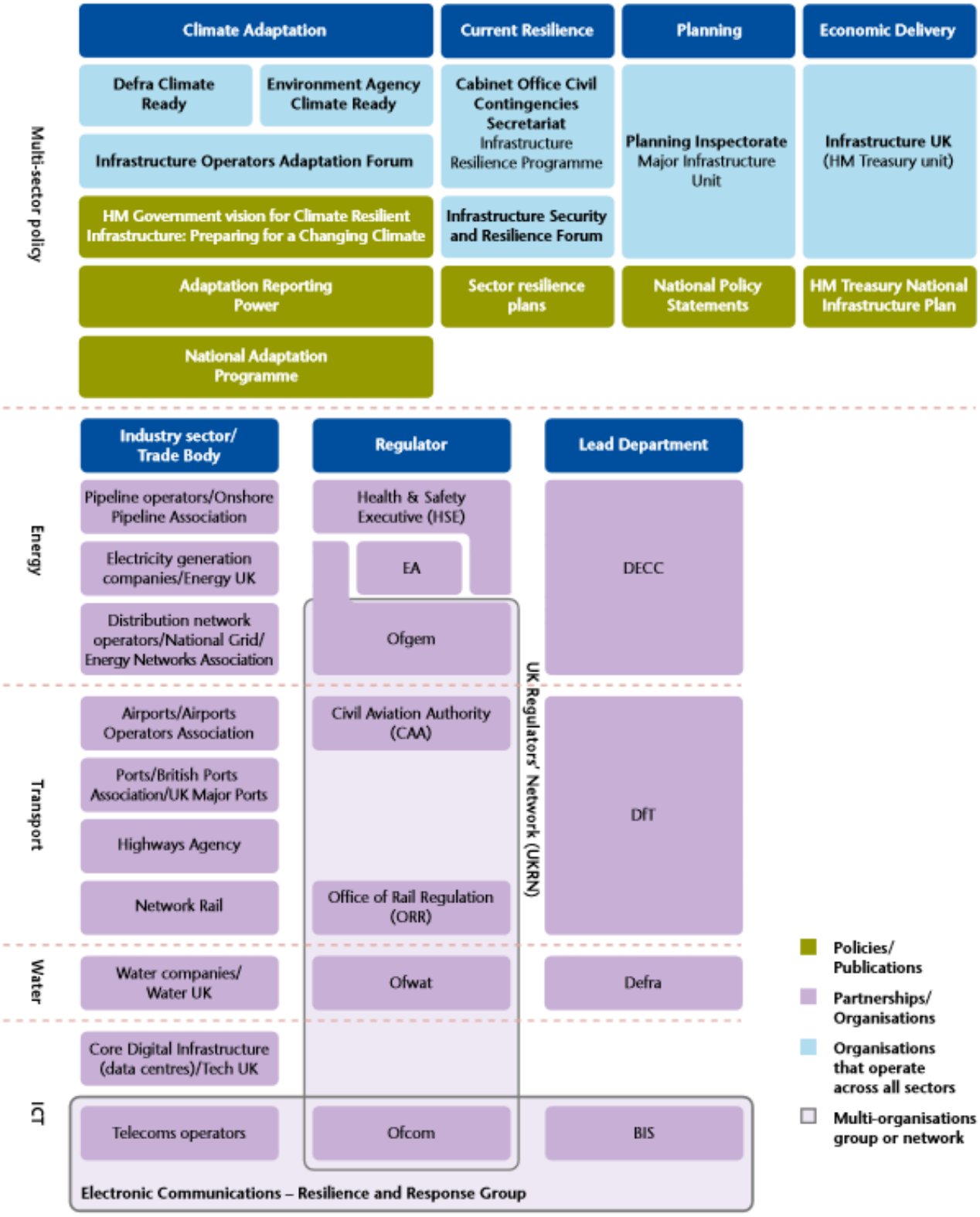

Figure 2: Governance structure of infrastructure resilience and adaptation in England

3.6.3. Overarching Strategies and Measures

- **Adaptation Reporting Power:** In 2008 the UK government introduced the Climate Change Act 2008, which gave the Department of Environment, Food and Rural Affairs (Defra) the so-called Adaptation Reporting Power. The Adaptation Reporting power is the authority to ask companies responsible for critical infrastructures to report on current and future impacts of climate change on their organisation. This Adaptation Reporting Power serves three goals. First, it provides a framework for greater consideration of climate change by several key infrastructure organisations. Second, it builds capacity to assess and monitor climate risks across a variety of sectors. This reporting process also provides valuable information on organisations that are already taking steps to climate-proof new infrastructure and to modify design standards to accommodate future climate change.[6]

- **National Risk Register:** The National Risk Register (NRR) is an assessment of the Cabinet Office on the likelihood and potential impact of different civil emergency risks caused by natural events, major accidents and malicious attacks, that may directly affect the United Kingdom in the next five years. The NRR has been published five times since 2008. The NRR is a resource aimed to assist local governments (through Local Resilience Forums), individuals and organisations to prepare themselves for emergencies. The NRR is the unclassified version of the National Risk Assessment (NRA).[7]

- **Sector Resilience Plans:**[8] In the Sector Resilience Plans the resilience of the critical infrastructure for each sector is set out. The Sector Resilience Plans are based on the risks identified in the National Risk Assessment. Ministers receive National Risk Assessments of their respective sectors and are personally responsible to take action accordingly. These Sector Resilience Plans are classified and a summary is publically available.[9]

- **Local Resilience Forums:** The Local Resilience Forums (LRFs)[10] were installed in the United Kingdom through the Civil Contingencies Act 2004 to facilitate local planning and response to emergencies by representatives of local public services (including emergency services), local

[6] International Institute for Sustainable Development 2013:25
[7] Government of United Kingdom 2013
[8] Cabinet Office 2015:27
[9] Government of United Kingdom 2014
[10] Local Resilience Forums are the name for the forums in England and Wales. In Scotland these forums are called Regional Resilience Partnerships.

authorities, the National Health Service and the Environment Agency. The Highways Agency and public utility companies have the obligation to share relevant information with a LRF. Furthermore, the government provides guidance to LRFs on how to interpret the risks of the NRA and NRR, as well as to help with the local assessment of risks. The LRFs are grouped according to the police districts.[11]

- **Joint Exercise Coordination** In 2015 the United Kingdom Regulators Network (UKRN) was working on a prescribed mechanism to share information about forthcoming emergency exercises of sectors under the Joint Exercise Coordination. At the moment, emergency exercises are carried out by sectors individually (such as Long shadow in 2007 and White noise in 2009 testing the country's response to widespread power and telecoms failure respectively), ignoring the essential role of interdependencies among sectors in the case of a flood.

- **Cross-regulatory emergency plan (CREP):** The United Kingdom Regulators Network (UKRN) proposed to establish a formal framework to facilitate communication and coordinate activities of the regulators in case of major incidents, such as a flood. At the moment, the online network ResilienceDirect, bilateral arrangements or meetings at the Cabinet Office's Briefing Room (COBR) are used in this regard.[12] The framework would consist of contact lists of important representatives, and diverse communication platforms, such as the Cabinet Office's Resilience Direct extranet web portal.

3.6.4. Sectoral Strategies and Measures

Energy

The provision of energy falls under the Department for Energy and Climate Change (DECC). The regulator bodies responsible for the electricity generation companies are the Office of Gas and Electricity Markets (Ofgem) and the Environmental Agency (EA), with Energy UK as trade body for the sector. The distribution network operators are solely regulated by Ofgem, and they are organised in the trade bodies: *National Grid* and the *Energy Networks Association*.[13]

[11] Government of United Kingdom 2013b
[12] Government of United Kingdom 2013c
[13] HM Government 2011:53

The UK Regulators Network spelled out that flooding and loss of key staff are two major risks to the energy sector.[14] While the energy sector also entails gas and petrol, the policy on infrastructure resilience focuses mostly on electricity provision in the United Kingdom. Natural hazards, including flooding, cause 10 to 35% of the interruptions of electricity supply in the United Kingdom. However, these black-outs are mostly caused by interruptions in the grid and not in the electricity generation. Similar to other countries, electricity generation is concentrated at a relatively small number of locations in the UK. These are to a certain extent protected against extreme weather events.

If individual power stations are disrupted consumers can continue to be supplied through the transmission grid.[15, 16]

Strategies and Measures:

- Including resilience into the Price Control Review: In 2010 the British energy regulator, the Office of Gas and Electricity Markets (Ofgem), installed a new price control review to encourage network companies to invest more into reliable services, reduced network costs for current and future consumers, and reduce greenhouse gases.[17] This performance-based regulation is called RIIO (Revenue = Incentives + Innovation + Outputs).[18] RIIO is hailed as a success and has been looked at by others. For instance, the US-state of New York plans to adopt such a regulation as well.[19]

- ETR 138 Process: In reaction to the floods in 2007, a task group including the government, Ofgem and the Met Office developed an approach to subject the assessment of flood risk and risk mitigation measures to a cost-benefit assessment. This process, labelled ETR 138, sets out six steps going from the identification of the substations in floodplains, undertaking a flood risk assessment of each substation, establish most appropriate protection measures and proposing an appropriate solution based on a cost-benefit assessment. In 2015 the flood risk assessments should be completed for all the substations.[20]

[14] UKRN 2015:12
[15] Committee on Climate Change 2014b:59
[16] For an in-depth and updated overview of the resilience of the electricity system, see: House of Lords Science and Technology Select Committee (2015): 1st Report of Session 2014-2015.
[17] Defra 2013:3
[18] Ofgem 2015
[19] Breaking Energy 2015
[20] Committee on Climate Change 2014:61

Telecommunication & IT

The Department of Business, Innovation and Skills (BIS) is responsible for policy on Telecommunication and IT. The sector is regulated by the Office of Communications (Ofcom) and organised in the trade body Tech UK. The main infrastructure-owning communications providers also take seat in the Electronic Communications Resilience and Response Group (EC-RRG), together with representatives from government, the CPNI and Ofcom. The EC-RRG publishes and updates the National Emergency Plan for Telecommunications.[21, 22]

Much of the digital infrastructure of the Telecommunication and IT sector has an overcapacity, so when a facility fails others can often take over without causing a disruption. However, it is unclear to what extend this overcapacity increases resilience in case of a big scale flood. Furthermore, the communication networks are not covered systematically by resilience policies, nor is it certain whether projected climate change is considered in the sector's risk assessments.[23]

Strategies and Measures:

- **Auditing power of a regulator** Companies operating in the telecommunication sector in the United Kingdom have high level obligations to take appropriate measures to maintain reliable networks and services. The Office of Communication (Ofcom) does not actively approve or monitor investments in resilience, but it has the power to gather information and to carry out an audit, requiring companies to take corrective actions. Ofcom can also issue fines when obligations are not being met. [24, 25]

[21] Electronic Communications Resilience & Communications Group 2007:27
[22] UKRN (2015):18
[23] Committee on Climate Change 2014:83
[24] UKRN 2015:13
[25] Committee on Climate Change 2014:85

Drinking Water Supply

The Department of Environment, Food and Rural Affairs (Defra) is responsible for the policy on drinking water. The sector is regulated by the Office of Water (Ofwat) and the water companies have organized themselves within Water UK.[26]

The assets of water companies are exposed to flood risk and particularly ground subsidence. There is no national-level data in the United Kingdom on current impacts of these hazards, nor are there any consistent assessments of risks across the sector.[27]

Strategies and Measures:

- **Price Control** The new Water Act 2014 gave the Office of Water (Ofwat) the obligation to secure the long term resilience of the supply with drinking water in the face of climate change and population growth, among others. Ofwat developed an analytical framework for water providers to review the risks of flooding to their critical assets and to identify whether further investment were necessary. On the basis of this review Ofwat encouraged companies to make a business case for flood protection works for the price control period 2010-2015.[28]

Transportation

The Department for Transport (Dft) is responsible for policy in the transportation sector. The motorways and trunk roads of the UK, referred to as the strategic road network, are managed by the state-owned enterprise Highways England (formerly the Highways Agency). Besides maintaining the strategic road network, Highways England is responsible for operating a variety of information services and liaises with other government agencies.

The strategic road network in the United Kingdom has been built relatively recently and is therefore designed to modern engineering standards. Disruptions caused by extreme weather events are recorded in detail, but the steps taken to improve the resilience to extreme weather are not reported consistently.[29]

[26] HM Government 2011:5
[27] Committee on Climate Change 2014:60
[28] UKRN 2015:15
[29] Committee on Climate Change 2014:60

Strategies and Measures:

- **Highway companies the under office for Rail Regulation.** The government plans to create more transparency on the resilience of the strategic road network by appointing the Office for Rail Regulation as regulator and the Passenger Focus as user watchdog organisations for a new strategic highways company. At the moment progress with implementing resilience measures in the strategic road network is not reported. As part of other reforms, the government plans to create a 'strategic highways company'. This highways company will have to account to the regulator and user watchdog organisation about the resilience of its plans.[30]

3.6.5. Recommendations

Below, a shortlist of the most relevant and applicable adaptation measures from the United Kingdom's perspective:

Interconnected strategies & measures

- Adaptation Reporting Power: Companies responsible for critical infrastructure are obliged to report on impacts of climate change to the government.
- Ministers receive national risk assessments of their respective sectors and are personally responsible to take action accordingly.
- Local Resilience Forums where local authorities and relevant private and public services coordinate emergency planning.

Energy

- The economic regulator Ofgem encourages electricity network companies to include the costs of making infrastructure resilient in their price.
- The government, Ofgem and the Met Office developed a standardised method to make a cost-benefit assessment of investments into the resilience of infrastructure.

Drinking Water Supply

- The economic regulator Ofwat encourages companies to make a business case for flood protection works within the price.

[30] Committee on Climate Change 2014:81

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3.7. United States of America

3.7.1. Exposure, Sensitivity and Adaptive Capacity

Below the potential future changes in climate in the USA are summarized for different climate variables:

- **Temperature:** Average temperature has risen by 1 °C over the past 50 years and is expected to rise even more by the end of the century: roughly 1.5°C to 2.5°C under lower emissions scenarios (RCP 4.5) involving substantial reductions in emissions, and 2.5°C to 5°C for higher emissions scenarios (RCP 8.5) assuming continuous increases in emissions.[1]
- **Droughts:** Extended dry periods with a higher frequency and intensity are likely to occur, especially in the Southwest and East of the USA. Tree ring data shows that the droughts over the last decade in Western U.S. represent the driest conditions in 800 years.[2] Northern parts of the country will become wetter, while southern parts will become drier. In general, the wet areas will become wetter and the dry areas will become drier.[3]
- **Precipitation:** The total precipitation increases with about 7% on average. Hence, more frequent and heavier rainfall events across the USA occur. The Northeast and Midwest will experience the highest increases in heavy precipitation during winter and spring.[4]
- **Sea Level Rise:** Since 1880, there has been an increase of the sea level of up to 20 cm.[5] The Gulf of Mexico and the Atlantic Coast experience the highest rates of relative sea level rise, which amounts up to 1.2 meter between 2050-2100.[6] The Northwest and Alaska experience dropping sea levels due to geological processes.
- **Storms:** The destructive energy of hurricanes and storms is likely to intensify within this century. Trends in intensity and frequency of tornadoes and thunderstorms remain uncertain.[7]
- **Runoff:** Increased stream flow in eastern USA which leads to higher runoff, especially during the winter. Floods will occur more often with a higher severity.[8]

The overall size of the US economy is very large and it has both the financial, as well as the operational resources to adapt to climate change impacts. In this context, the USA should be able to

[1] National Climate Assessment USA 2014a
[2] National Climate Assessment USA 2014b
[3] OECD 2013a
[4] OECD 2013b
[5] National Climate Assessment USA 2014c
[6] National Climate Assessment USA 2014d
[7] OECD 2013:24
[8] OECD 2013:24

protect its critical infrastructures by making it more water robust. The impacts are likely to be most apparent at regional scales and in the coastal regions where most people live.[9]

3.7.2. Political context

The USA is a federal union with a population of 305 million people in 2008.[10] The constitution consists of the House of Representatives and the Senate, an executive body headed by an elected President and a judiciary headed by the Supreme Court.[11] Current institutions reflect the traditional influences by the British practices during colonial times. Local democracy and decentralisation are important political features in the country. However, the states remain the main body to govern and control institutional forms at local scale.[12] The broad ranges of local governing bodies in the federal states create a rather high level of complexity and diversity. Each state operates by distinctive rules. The local government is the largest governmental component in the country, in terms of expenditures and personnel. See Figure 3 for an overview of the organisation of the US Government.

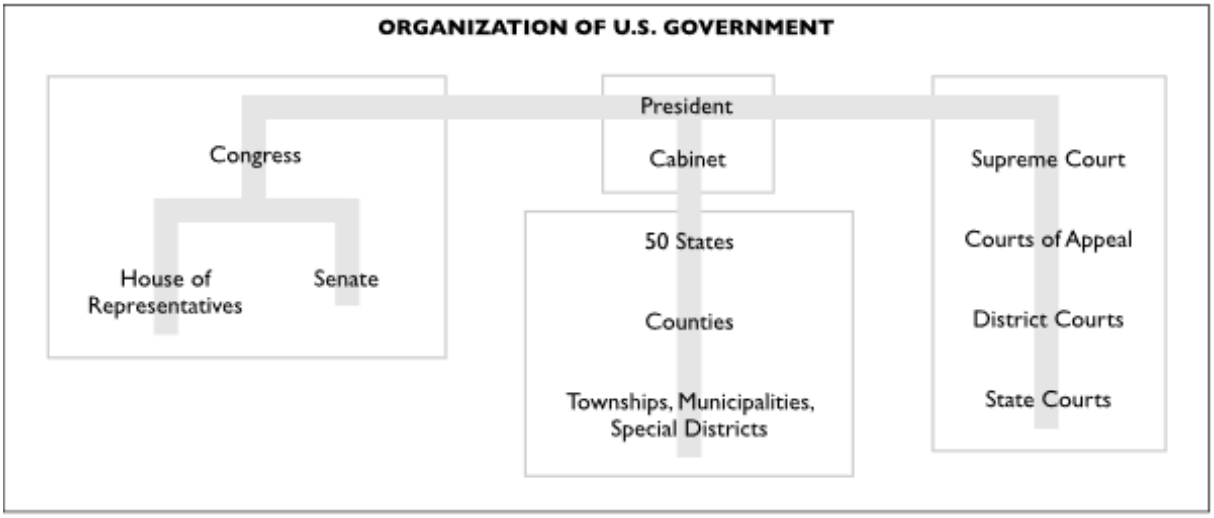

Figure 3: Organisation of the US Government (Source: Schlager & Weisblatt, 2006)

[9] OECD 2013:217
[10] United Cities and Local Governments 2015:1
[11] United Cities and Local Governments 2015:1
[12] United Cities and Local Governments 2015:1

3.7.3. Sectoral Strategies and Measures

Energy

Multiple departments are responsible for the energy sector on the national level. Next to the national departments, there are many agencies on the federal state-level steered by the respective government. Each state has its own departments. The Council on Environmental Quality coordinates the federal environmental efforts and plays an important role in developing policies and initiatives for the energy sector. The Department of Energy is located at the cabinet-level department which is primarily concerned with energy policies and safety in handling nuclear material. The department is controlled by the secretary of energy together with the deputy secretary, appointed by the president. The Environmental Protection Agency (EPA) is located within the US federal government which writes and enforces regulations based on laws, which have to be passed by Congress. The Federal Energy Regulatory Commission assists consumers in obtaining reliable, efficient and sustainable energy services at affordable costs through market means.

The USA is one of the largest energy consumers worldwide and the energy sector itself is the 3th largest industry within the USA[13]. The US electric grid is a large and complex system that consists of more than 9,000 electric generating units with more than 1,000 GW of generating capacity connected to more than 300,000 miles of transmission lines.[14] The largest part of the energy infrastructure is located near the coast and is therefore sensitive and vulnerable for sea level rise and storm events, which both could lead to flooding of important energy infrastructures. Equipment damages, power outages and destroyed electricity distribution networks are possible consequences of flooding. The East Coast and Gulf Coast are most vulnerable for sea level rise and, at the same time, account for 30% of the US oil production and 20% of the national natural gas production.

The energy sector consists of a complex system of interdependent facilities and components. Thus, damages to one part of the system can cause a chain reaction, affecting infrastructures in other sectors or within the supply chain. Recent events associated with Hurricane Sandy illustrate these interdependencies with over 7,000 transformers and 15,200 poles damaged, causing widespread power outages across 21 states.[15] For adaptation, measures taken after hurricane Sandy are outlined

[13] US Government of Commerce a
[14] USGAO 2014:8
[15] EPA 2015a

below. Interdependencies between the transportation, fuel distribution and the electricity sector were found to be major factors in Florida's recovery from past hurricanes.[16]

The energy demand is likely to be increased due to cooling by air-conditionings in the warmer summers. A possible decrease in demand for heating (gas, oil and wood) may occur during milder winters.[17] Higher air and water temperatures may contribute to both, an increase in electricity demand and a decrease in electricity supply.[18,19] This will have impacts on current infrastructures depending on the season. Moreover, the amount of available water to produce electricity may be affected by climate change.

According to the EPA[20], the demand for energy used for cooling will increase by 5-20% with a temperature rise of 1 °C , while there will be a 3-15% decrease in demand for heating. This demand is also affected by population movements, especially to the South and Southwest of the USA. A warmer climate may also affect power plants, since the water used for cooling has warmer temperatures and therefore less energy can be produced. A reduction of only 1% in electricity generated by thermal power plants would mean a loss of 25 billion kWh/year.[21] Water shortages will be the case for several American states by 2025, such as Texas, Arizona, Florida and California, which will affect the production of energy.

Strategies and Measures:

Adaptation measures for this sector falls generally into 2 broad categories: hardening and resiliency.[22] Hardening measures address physical changes to make infrastructures less susceptible to climate change impacts. Examples of hardening measures are the building of flood walls around refineries, elevating pumps used to transport fuels via pipelines, building power plants at higher elevations to minimize the risk of flooding and replacing transmission and distribution poles with poles made of stronger materials to make them less susceptible to damage from high winds and storms.[23] Resiliency measures focuses on the recovery of damages to quickly enable the system to operate.

[16] EPA 2015: Energy Adaptation
[17] US Government of Commerce b
[18] US Government of Commerce c
[19] Department of Energy (2015)a
[20] EPA, 2015b: Energy Impacts
[21] EPA, 2015c: Energy Impacts
[22] USGAO 2014:33
[23] USGAO 2014:34

Two measures will be treated in more depth in order to explain efforts to increase the water robustness for the energy sector in the US, including hardening (Entergy) and resiliency measures (PG&E).

- **Entergy Corporation – Relocation of facilities:** Entergy Corporation generates and transports electric power in the Southeast of the USA. After the hurricanes Katrina and Rita, Entergy experienced large damages to transmission and distribution systems, leading to power outages for 800 000 people in Louisiana. Since these events, Entergy aims to build larger resilience into their properties to achieve a higher protection level for floods and other climate related issues.[24] They relocated business centres to areas that are less vulnerable for flooding (e.g. inland). Moreover, they replaced the wooden distribution poles with steel or concrete, built levees and berms around oil refineries, elevated substations in flood prone areas and controlled vegetation along electricity lines. These measures have already paid off for the company, leading to less damages and power outages for electricity consumers.[25]

- **Pacific Gas and Electric Company (PG&E):**[26] The Pacific Gas and Electric Company (PG&E) is responsible for providing natural gas and electricity to 15 million people in North and Central California. The company incorporated climate-related risks as part of its business plan and hired a team to evaluate these risks, as well as to identify best adaptation practices for the assets of the company. PG&E has identified vulnerable distribution and transmission lines in the San Francisco Bay Area which are highly susceptible to sea level rise. In response, the company strengthened the structures of the transmission network and invested in habitat recovery to increase the resiliency for tidal action. As a result of water scarcity, PG&E implemented dry cooling technologies at two of its natural gas generating stations. These plants use 97% less water and produce 96% less discharge in comparison to conventional water cooling systems. Thus, the water used for cooling is significantly reduced via these resilient measures. In response to changing snowpack in parts of the Sierra Nevada Mountains, the company responded by developing new modelling tools to forecast runoff.

[24] USGAO 2014:37
[25] USGAO 2014:39
[26] USGAO 2014:39,40

Telecommunication & IT

The main department that is responsible for the telecommunication sector in the USA is the National Telecommunication and Information Administration (NTIA), which is part of the Department of Commerce.[27]

The US telecommunication & IT sector is almost entirely regulated by private actors, creating a high level of competition among the companies.[28] In this regard, it is important to note that the American wireless communication companies (part of the telecom infrastructure) is steered by four main companies that have a market share of 95%.[29] These companies include Verizon, AT&T, Sprint Nextel and T-Mobile USA. The competition among them, causes short-term thinking and a strong focus on making benefits, rather than adopting long-term strategies in the face of climate change. By this, the companies do not sufficiently improve their climate resiliency. At the moment, this implies a rather reactive than pro-active approach.

Telecommunication is one of the key utilities in the U.S. and has one of the largest markets on global scales, experiencing growth rates of 4% per year.[30] There are over 290 million wireless customers.[31] The sector is tightly coupled to the energy sector, with power outages affecting the reliability of communication services; many of the communication lines also are located on the same poles as power lines.[32]

Climate change has impacts on the telecommunication sector. Some major impacts are given below per climate variable:[33]

- **Temperature:** Higher temperatures will lead to more frequent failures of the equipment at base stations, since more water is required for cooling. Moreover, the life-time of the materials is stressed. Heat waves can lead to more power outages and thus affect telecom-services.
- **Precipitation:** Increased rainfall leads to higher risks of flooding of low-lying facilities together with increased chance of erosion to transport structures, such as cables. Decreased

[27] Adams and Steeves 2014:7
[28] Adams and Steeves 2014:7
[29] US Government of Commerce
[30] Adams and Steeves 2014:7
[31] Adams and Steeves 2014:7
[32] Adams and Steeves 2014:18
[33] Adams and Steeves 2014:13,14

precipitation can enhance the risk of fires in forests, which will threaten telecom infrastructure in remote rural areas.

- **Sea Level Rise:** Increases in the sea level enhance the risk of saline corrosion of coastal telecommunication infrastructures and inundation of underground connections.

From 2011 the US telecom industry lacks overarching databases that show the locations and elevations of installed facilities, lifelines and their operational capacity.[34]. Besides, there is a lack of quantitative studies that give insight about the scales and costs of future events on telecom infrastructure.[35] Hence, this could lead to weak business incentives to invest in climate resilience. Additionally, there is limited awareness amongst the decision and policy-makers about the climate risks that may threaten the telecommunication & IT sector.[36] Finally, there is a lack of regulation in the USA to enforce resilience towards climate change.[37]

Experiences with extreme events provide relevant insight for both, the data centres of telecom, as well as for the users of their services. Two examples of these experiences and impacts are given below:

Example 1: Hurricane Katrina[38] has damaged a data centre, which served many New Orleans public schools. It blew the air-conditioning of the roof causing flooding by rain. The data centre was located at the fourth floor. When the power was restored, the contacts of the switches were corroding due to the absence of air-conditioning. Other gear in the building became overheated and failed. 100 public schools were left with no connection to the data centre for several months. Estimated costs were over $3 Million.

Example 2: T-Mobile data centre.[39] An intensive rain-event has flooded a T-Mobile data centre in Seattle which resulted in an outage that took down many important service portals by the telecom company. Websites became inaccessible for users and the company was affected financially.
Key risks of the telecommunication and IT sector at the current stage consist of the attention given to slow-onset changes in the infrastructure and facilities due to climate change. These small changes can lead to reduced performance of used equipment and may affect the whole telecommunication

[34] Adams and Steeves 2014:29,30
[35] Adams and Steeves 2014:29,30
[36] Adams and Steeves 2014:25,32
[37] Adams and Steeves 2014:29,30
[38] Adams and Steeves 2014:16
[39] Adams and Steeves 2014:16

sector. A centralization of the assets may lead to a lower redundancy of the system in times of higher risks of extreme weather events.

Measures:

In the following some measures will be treated in more depth in order to explain efforts to increase the water robustness for the telecommunication sector. Most adaptation strategies within this sector are having a technical approach, rather than an institutional or strategic change. This means that current infrastructure is strengthened by equipment adjustments.

- **Verizon and hurricane Sandy:**[40] Hurricane Sandy caused large-scale power failures and inoperability of back-up power systems. Verizon has experienced costs of $1 Billion. Verizon Telecom took a rather reactive approach by implementing climate resilient measures after it has been hit by the hurricane. The company changed their entire copper wire system in lower Manhattan with fibre optic cables These cables are waterproof, while copper cables are very prone to erosion in case of the intrusion of water. Moreover, Verizon protected the back-up pump by putting it in a watertight room protected with submarine doors. Previously, this vital pump was flooded and entirely stopped working. The company moved their back-up pumping to higher parts in the building.

- **Building Resiliency Task Force:**[41] The first bottom floors are at risk of flooding and essential equipment is often placed at lower levels. This Building Resilience Task Force (law) demands that vulnerable elements of buildings must be located to above the design flood elevation in a flood zone. Examples of these vital facilities are power generators and fire protection systems.

- **Operations, Management and Infrastructure Strategies:**[42]

  This broad category can be split up into several measures, such as:

  - Trimming of trees near communication lines and put cables underground.
  - Designing of backup power at cell towers with generators that can replace disabled towers, in case of damages by climate impacts.
  - Expanding and developing alternative communication technologies to increase redundancy and reliability (e.g. universal phone chargers)

[40] Adams and Steeves 2014:27
[41] Urban Green Council 2013
[42] ClimAID Synthesis Report 2011:45

- Decouple telecommunication infrastructures from the electric grid.

- **Other Key Opportunities for the Telecom-sector:**[43]
  - Shared infrastructures will lead to shared resilience.
  - Companies should share best practices to increase the technology exchange contributing to the resilience of the sector.
  - Raising awareness by letting experts engages and collects more information.
  - Build on the work that is done in the energy sector, to make use of analogies in terms of network infrastructure.

Drinking Water Supply

Most Americans are provided with water via publicly owned water utilities. 11% of the inhabitants receive water from private utilities. Up to 15% of the people are using their own wells for drinking water (44 million people).[44] There are also a few large bulk water suppliers in the arid Southwest that sell water to utilities, either private or public. Water supply is controlled, maintained and regulated via the state governments and the overarching federal government.[45] At the state level, environmental regulation is ensured by state-departments. At the federal level, drinking water is regulated by the Environmental Protection Agency.[46]

Climate Change is likely to increase the water demand in the US, while the water supplies are shrinking.[47] In some areas, the risk of an increased runoff, floods or sea level rise will be more relevant than water shortages. These effects and impacts can all contribute towards a lower water security and continuity, since the infrastructures to provide and transport water might be damaged.[48]

The increase in temperature in the USA, leads to more evaporation of water and hence more dry areas. This can cause heavy rainfall events in neighbouring areas. Especially the Southeast and Northwest of the USA are experiencing increased change of droughts, while the Northeast is less affected by dry periods and droughts.[49] The rising temperatures will enhance the demand for water

[43] Adams and Steeves 2014:31,32
[44] US Government of Commerce
[45] Schlager & Weisblatt 2006
[46] EPA 2015
[47] EPA 2015: Water Resources Impacts
[48] EPA 2015: Water Resources Impacts a
[49] EPA 2015: Water Resources Impacts b

for all economic sectors.[50] The larger cooling requirements in summer will increase the electricity use, leading to an increase in demand for water to cool power plants. Additionally, warmer temperatures lead to more precipitation in the form of rain, rather than snow. Besides, snow will melt earlier in the year leading to a different run-off pattern in rivers.

In areas where precipitation levels are expected to rise strongly, the water quality will be impaired. This can lead to overwhelming sewers and water treatment plants. More nutrients, pollutants, animal waste and trash will enter the water system, which will increase the costs of treatment.[51] Moreover, the higher sea level at the East coast leads to salt water intrusion in the freshwater bodies.[52] This requires expensive desalination techniques to purify the drinking water. Droughts will enhance this process of salinization of coastal waters, since there is less water in the rivers.

There are many challenges for the USA for Water Planning:[53]

- Allocation of water in interstate rivers is governed by international treaties or national laws that are very hard to modify.
- Water is allocated according to the principle of 'first in time means first in right in the West', which prioritizes agriculture over cities regarding water supply. This puts more stress on the water availability in cities in Western USA.

Measures:

Most adaptation measures that are taken in the USA to protect the drinking water sector are not innovative or creative. They merely focus on extending current monitoring programmes and tools to analyse weaknesses in the drinking water sector.

However, below are some initiatives given that show great potential to deal with increased droughts on the one hand and increased risk of flooding on the other hand.[54]

- **Water Barrels:** Capture rainfall to minimize local flooding and allow for a constant supply of water.
- **Incentives** for individuals to switch to low-flow toilets, showers and faucets.
- **Green Infrastructure:** Green roofs and rain gardens to enhance the water capturing capacity to reduce the surface runoff in cities and to enhance groundwater recharges.

[50] EPA 2015: Water Resources Impacts c
[51] EPA 2015: Water Resources Impacts d
[52] EPA 2015: Water Resources Impacts e
[53] US Army COE 2010:33
[54] EPA 2015: Water Resources Adaptation a

- Design **Leak Detection programmes** to increase the water use efficiency
- **Maintenance** Upgrade existing pipes to promote water conservation

Federal Agencies have some projects to protect local water supplies and to include customers:[55]

- **WaterSense:** EPA partnership programme in which organisations and businesses cooperate in promoting water conservation by efficient appliances, using a water-efficiency label.
- **WaterSmart**: Initiative for the sharing of experiences to make sound decisions about water use

Transportation

The department of transportation and its divisions are in charge in regulating, supervising and funding all of the aspects of transport.[56,57] Each state has its own department of transportation which controls the main highways. Automobile traffic laws are enforced by state and local authorities.[58,59] By far, the majority of the roads in the USA are owned and managed by the state and the local governments.[60,61] Federally maintained roads are very scarce and generally limited to national parks and military bases. Next to the state led roads, there are a few private highways, where tolls are paid for maintenance. Finally, there are many local private roads.

In the USA most of the transport network is built to last for 50 years or longer. The planners have not incorporated future effects of climate change in their decisions about the construction and planning of roads. These future events may damage investments in transport due to higher temperatures, more severe storms and higher sea level, which may lead to severe consequences:[62,63]

- **Temperature:** Increasing temperatures may lead to higher chances of softening and expansion of the pavement. The life-expectancy of roads is probably going down. Overheating vehicles and loss of quality of tires is going to increase due to stronger heat events. This enhanced drought periods, will increase the risk of wildfires which could lead to road closures. The costs to maintain and build roads will increase due to all these impacts.

[55] EPA 2015: Water Resources Adaptation b
[56] Schlager & Weisblatt 2006
[57] Transportation Adaptation to Global Climate Change:12
[58] Schlager & Weisblatt 2006
[59] Transportation Adaptation to Global Climate Change:10
[60] Transportation Adaptation to Global Climate Change:10,11
[61] Schlager & Weisblatt 2006
[62] ClimAID Synthesis Report 2011:36,37
[63] EPA 2015: Transportation Impacts a

- **Heavier storms & Sea Level Rise.** The risk of flooding will increase which may lead to a disruption of the road network, where more frequent repairs are necessary. An estimated 60 000 miles of coastal roads are exposed to periodic flooding, either from sea or rainfall.[64] Moreover, the most important highways in the coastal areas serve as critical evacuation routes. In the Gulf Coast 2400 miles of roadways could become flooded permanently by sea level rise in the coming century. Moreover, across the US many coastal cities have tunnels, parking lots and airports belowground, which indicate serious threats to severe flooding. This also pinpoints the unknowing stage of the decision and policy-makers, leaving these infrastructures remain at rather low levels. Current once-in-100 year storms are projected to occur once in every 10 years at the end of the century.

Strategies & measures:

The USA takes (adaptation) measures to protect its transportation sector against impacts of climate change on several levels: federal, state and local. The measures are taken according to local impacts. Examples of measures are:[65,66]

- **Elevate critical infrastructure**
- **Change the construction and design standards** for bridges, levees and roads.
- Rebuild or abandon important infrastructure in less vulnerable areas
- **Building and strengthening levees or dikes**
- **Provide safe evacuation routes**

The range of adaptation strategies for the transportation sector can be divided into 4 categories of options:[67]

- **Manage and maintain:** Expecting an increasing cost of maintenance and repair due to increased severe events.
- **Protect and harden:** Enhancing the resilience of the infrastructures through techniques such as changing standards (higher bridge heights, elevated roads), building levees and develop natural buffers. This approach is most useful for critical infrastructure that is at highest risk.

[64] EPA 2015: Transportation Impacts b
[65] ClimAID Synthesis Report 2011:37
[66] EPA 2015: Transportation Adaptation a
[67] Transportation Adaptation to Global Climate Change:24

- **Develop Redundant Services:** Assuming loss of service by current infrastructures and attempts to invest in alternative roads.
- **Relocate or Abandon:** Reducing the exposure by moving infrastructure to lower-risk areas.

Several measures to increase the climate resilience of the transportation sector are illustrated below.

- **Relocation of a highway**[68] The California Transportation department (CALTRANS) is integrating the impacts of climate change into its strategic planning of building and maintaining roads. A good example is that they relocated parts of an important highway at the West-Coast further inland due to increased threat by sea level rise and coastal erosion. CALTRANS expects that the road will be fully protected for the coming century. The realignment took into account the existing land use and agreements with the involved partners and stakeholders.

- **Institutional and Planning Changes**[69] Possible changes are the lengthening of the planning horizon for the transportation system, by creating a larger protection level for the infrastructure on longer time scales. Moreover, vulnerability and risk assessments are included for roads to create higher protection levels of main hubs.

Expert Survey

The consulted expert from the United States of America, who is an expert in National Planning for Coastal Storm Risk Management, gave valuable input for the survey about the USA. She agrees with the provided definition of critical infrastructure for her country, although she states that the U.S. is "extremely diverse and there may not be uniform agreement on what is essential for social well-being". She states that there are too many private corporations responsible to list them all for the energy sector, IT & Telecom sector and the drinking water sector. The transportation sector is steered by states, counties and municipalities next to the Department of Transportation.

The expert affirms that the USA is been affected by flooding (either from sea or rivers), landslides, storms, extreme precipitation, heat waves, droughts, extreme cold, sea level change and tsunamis in the last twenty years. The expert strongly agrees with the fact that these impacts have put climate proof critical infrastructure on the political agenda. She disagrees with the statement that the critical infrastructure is well prepared towards potential future water-related climate change impacts. The

[68] EPA 2015: Transportation Adaptation b
[69] Transportation Adaptation to Global Climate Change:24

expert emphasizes the fact that the Netherlands can learn some things from the USA, since The Netherlands cooperates with other nations in the EU to achieve shared goals. The Netherlands can learn from “unique strategies to achieve long term goals, such as climate preparedness.

3.7.4. Recommendations

Below, a shortlist is given for each sector to stress the possibly relevant strategies and measures for the Netherlands:

Energy

- Hardening Flood walls around refineries, building power plants at higher elevation to minimize risk of flooding and replace distribution/transmission poles with stronger material that is less susceptible for storms.
- Resilience Recovery of damages to quickly enable the system to operate.
- Dry Cooling Technology Significant reduction of amount of cooling water

Telecommunication & IT

- Change in material: from copper wired systems to fibre-optic cables which are waterproof.
- Trim trees near communication lines and put cables underground.
- Decouple telecommunication infrastructure from the electric grid.
- Raise awareness amongst telecom-companies and let them share information.

Drinking Water Supply

- Green Infrastructure, such as green roofs and rain gardens to enhance water capturing capacity and groundwater recharges and to unburden surface runoff in cities.
- Support incentives for individuals to switch to low-use flow toilets, showers and faucets.
- Support some-sort of water-efficiency label, which should make individuals more aware of their water use.

Transportation

- Elevate roads and strengthen levees/dikes
- Provide evacuation routes in case of an emergency
- Support heat-resistant material for pavements or plant trees next to roads.
- Lengthen the planning horizon, by securing a larger protection level on longer time scales.

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4. Survey Analysis

The survey has been sent to 28 experts in the field of climate change adaptation and flood risk management in the selected five countries. Most of them work as researchers, project managers or administrators in areas directly connected to the research. A total of 14 experts responded to the request and, in the end, eight experts participated by filling in the survey. Three experts promised their participation, but until the end of the project no responses have been received. Two of the contacted experts did not feel capable of delivering useful insights. Several efforts to receive responses from the remaining 14 experts were not successful.

In the survey, full agreement was established on the definition of critical infrastructures this research project is based on. Indicating the most critical functions within their respective country, the experts also came to a consensus that electricity and drinking water supply count to the most critical functions. Seven out of eight respondents perceived the telecommunication and IT network as important critical infrastructure. Half of the experts perceive the road and transportation network as a critical function. Hence, from the four selected sectors within this research project, the latter is considered as less important.

All respondents indicated that flooding is an issue, while seven out of eight experts indicated extreme precipitation as a problem in their country. This is followed by landslides and storm events, being frequently indicated as potential future impacts of climate change. The experts from Denmark and the USA consider climate change to be prioritised on the political agenda of their country. The Austrian experts have partly differing opinions. Some agree that it is already prioritised on the political agenda, while one disagrees and another has a neutral opinion about this statement. Five out of eight experts agree that their countries follow a coordinated approach towards making critical infrastructure water robust. The remaining three share a neutral opinion. Three out of 8 respondents consider their country to be insufficiently prepared to cope with the effects of climate change. Especially some Austrian experts share a neutral position towards the preparedness or even disagree with the fact that their country is well-prepared to face climate change.

All experts indicate that, besides the ministries, many local governmental bodies such as municipalities and regional councils should be involved in making critical infrastructure water robust. Furthermore in every country numerous private stakeholders are seen as important stakeholders in to create and assure water robustness within their respective sector. There is a great consensus

among the interviewed specialists about the need for coordinated action to make critical infrastructures more water robust. All experts agree to this statement.

In general, the surveys have contributed the research in terms of useful country-specific insights and the indication of further informative sources. Moreover, every respondent was interested in the research project and desires to receive the final report.

5. Recommendations

After the thorough inventory of strategies and measures in the selected countries, recommendations are drawn for the Netherlands. A general impression of the current state of the Netherlands towards addressing water robustness for the critical sectors is known as a starting point. Here, making the critical sectors water robust is related to all types of flooding: coastal, riverine and pluvial floods. Strategies and measures that did entail other water-related issues go beyond the scope of this research project. Strategies and measures that are possibly already implemented in the Netherlands are not incorporated in this list of recommendations. For instance, making space for flood plains and renaturate river flows as the prominent Dutch 'room for the river programme' that is already successfully implemented in the Netherlands.

To structure the recommendations and as one step of our qualitative analysis, four analytical categories were established (see Figure 4). This allowed further examination of the found measures and strategies, based on the following objectives:

1. To allow a concise and easy overview of the found strategies and measures from the literature taken in the examined countries within the selected sectors.
2. To determine which sectors are given most attention by each country.
3. To conceptualise flood risk management by utilising the four established analytical categories as a notion based on and consisting of four different approaches towards the risk of flooding.

The four categories consist of Prevention, Protection, Awareness and Preparation and serve as an analytical framework in analysing the identified strategies and measures during the country-specific research. These categories represent different positions and coping strategies regarding flooding, including different foci. This study perceives the four categories as distinct, but closely interrelated.

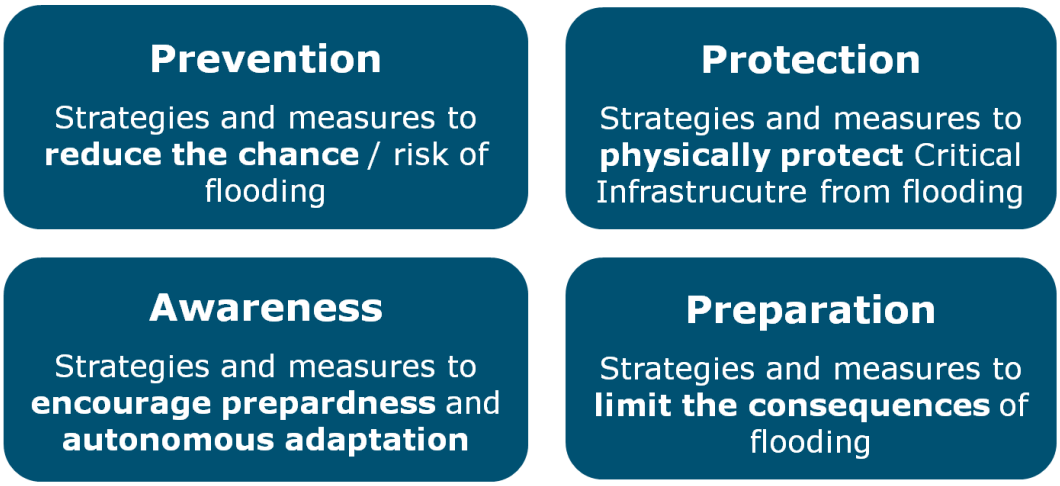

Figure 4: Overview of analytical categorisation

Prevention

Prevention mainly refers to strategies and measures which focus on pro-actively reducing the risk of flooding by addressing the roots of the problem. Preventive flood risk management entails concrete measures directly concerned with the existing environment surface precaution. Examples concerning this category would include spatial planning, afforestation, giving room to the rivers and enhancing water retention & biodiversity in the flood plains. Prevention also accounts to abstract, long-term strategies indirectly preventing flooding, as for instance by tackling climate change.

Protection

The term Protection refers to direct physical activities in terms of technical, structural and constructional measures, protecting the infrastructure against flooding. Therefore, this category includes strategies and measures to protect objects, as well as maintenance on already existing flood protection facilities.

Preparation

Preparation entails all strategies and measures focussing on directly preparing a country and its respective sectors for flood events. Examples for such measures would be hazard zone mapping, mandatory reporting mechanisms or the supply of needed emergency equipment. Furthermore, it includes adapting existing critical infrastructures in order to reduce potential damages to and keeping up the functioning of the critical infrastructures. Preparation also contains state and company strategies, such as crisis and catastrophe plans, as well as to be ready to act on them during

a flood event. Furthermore, to allocate roles for the reconstruction work in the recovery phase, in order to restore the services of the critical infrastructure as quick as possible, prior to a flood.
In summary, the strategies and measures being taken within the category of preparation are targeted to make a country and its respective sectors ready before, during and after flood events.

Awareness

The category Awareness includes all strategies and measures, which focus on stakeholders involved in critical infrastructures, such as the civil society and private companies. Through the sharing of information, knowledge and expertise on flood risks, preparedness and autonomous adaptation among the public and private stakeholders could be encouraged, minimising the severe consequences of flooding. In this sense, preparedness can decrease the criticality of infrastructures. The category awareness therefore serves as collection of indirect strategies and measures to decrease the risks of flooding by preparing involved stakeholders.

During the analysis all four categories were seen as analytically separated from each other. In reality, however, strategies and measures to cope with flooding possibly intersect with each other, as there is often no clear line of distinctions, resulting in overlap. Sometimes choices had to be made in order to assign the strategies and measures in a certain category. For example, a measure can have a protective and a preparative characteristic at the same time. In these cases, the measures are allocated to the category in which they fit most. After strategies and measures have been successfully implemented, they may even have supplementary effects. By this, the risk to flooding can be reduced and protected against, while the disruptive consequences of flood events can be decreased to a minimum.

Below, the strategies and measures are listed without any order in or priority. The list should therefore not be interpreted as a ranking. Within each recommended strategy or measure the country abbreviations are sorted in alphabetical order. The given abbreviations behind the strategies and measures are corresponding to the specific country:

AT	Austria	UK	United Kingdom
DK	Denmark	USA	United States of America
GER	Germany		

In order to use this report most efficiently, the abbreviations of each country after every strategy or measure are hyperlinked back to the respective detailed description in the country chapters.

Prevention

Overarching strategies and measures

- Enhance water retention and reactivate natural flood plains (AT)
- Green Infrastructure to enhance water capturing capacity and to unburden the local surface runoff in cities (USA)
- Increase the amount of renewable energy supply (AT) (DK) (GER)

Protection

Overarching strategies and measures

- Water- and load retaining structures (AT)

Energy

- Flood walls around refineries (USA)
- Put subsystems of electricity supply grid underground (DK) (USA)

Telecommunication & IT

- Protective cover on switch points (AT)
- Transform cable system from copper wired systems to fibre-optic cables (AT) (USA)

Transportation

- Elevate roads (USA)

Preparation

Overarching Strategies and Measures

- Cooperation on flood risk management between neighbouring countries (AT)
- Minimum River Morphological Space Demand (AT)
- Mobile flood protection systems (AT)
- Proactive organisation of recovery and rebuilding after a flood event (AT)
- Forbid construction work in flood-prone areas by law (DK)

- Visualise interrelations and complexities (GER)
- Legally binding reporting mechanisms between the government and energy suppliers & telecommunication operators (GER)
- Adaptation Reporting Power: Companies responsible for critical infrastructure are obliged to report on impacts of climate change to the government (UK)
- Relocation essential equipment to higher levels (USA)
- Cut trees near communication lines and transportation facilities (DK) (USA)

Energy

- Smart Grids that can cope and act on partial failure in energy system (AT)
- Diversifying energy sources (AT)
- Decentralising energy generation (AT)
- Standardised method to make a cost-benefit assessment of investments into the resilience of infrastructure (UK)
- Replace distribution poles with stronger material (USA)

Telecommunication & IT

- Hybrid base stations for an almost completely self-sufficient energy supply (AT)
- Mobile phone masts equipped with photovoltaic panels (AT)
- Satellite flood maps as a backup information supply (AT)
- Crisis management teams and facilities (AT)
- Legal obligations for telecommunication services providers (GER)
- Decouple telecommunication infrastructure from the electric grid (USA)

Drinking Water Supply

- Simulation Program to find system weaknesses (AT)
- Networking of smaller supply units (AT)
- Create reserve capacity (AT)
- Price control and future investment assessment(UK)

Transportation

- Adjustment of laws and regulations for construction and engineering by taking flood risks into account (AT)
- Plant robust vegetation along transportation routes (AT)
- Decrease sealed surfaces and its further expansion (AT)

- Emergency Response Plans (DK)
- Drainage system next to roads (DK)
- Pumping water off roads (DK)
- Monitoring of road network damages caused by ice and snow (GER)
- Enlarge drainage systems on roads to prepare for heavy precipitation (GER)
- Strengthen transportation facilities (AT) (DK)
- Lengthening the life time of transportation facilities by increasing planning for longer time scales and take climate change impacts into account during the construction phase (DK) (USA)

Awareness

Overarching Strategies and Measures

- Raising Awareness and Preparedness within the broad public (AT)
- Knowledge exchange between stakeholders (DK)
- New risk culture (GER)
- Local Resilience Forums with authorities and stakeholders (UK)
- Ministers receive national risk assessments of their respective sectors and are personally responsible to take action accordingly (UK)

Energy

- The economic regulator encourages electricity network companies to include the costs of making infrastructure resilient in their price (UK)

Telecommunication & IT

- Implementation of information sharing mechanisms between governmental authorities and telecommunication service providers (GER)
- Raise awareness amongst telecom-companies and promote information sharing (USA)

Drinking Water Supply

- Support incentives for individuals to switch to low-usage of water (USA)

Transportation

- Provide evacuation routes (DK) (USA)

6. Discussion & Conclusions

This research project gathered and structured different strategies and measures on how critical infrastructures are made water robust in Austria, Denmark, Germany, UK and the USA. The objective of this study was to establish recommendations to the Dutch Ministry of Infrastructure and the Environment on which of the taken strategies and measures by other countries might be of relevance to the Netherlands. The recommendations were developed on the basis of a thorough and structured literature research of the selected countries and supported by the outcome of the expert survey.

To structure this research, the matrix, which has been specifically developed for this project, served as a useful tool to capture the relevant aspects of each country case. The research process was particularly affected by the time constraint under which the study was carried out. Since this is a comprehensiveness subject, the focus of this research project was on the four essential sectors and the main water-related impacts on critical infrastructures in terms of all kinds of flooding, including pluvial, coastal and riverine floods. Future studies may extent the number of sectors, as well as consider further impacts, such as droughts or waste water treatment. This report makes no claim to completeness but instead intends to provide a first exploratory overview of taken measures and strategies in other countries. Hence, this report might not reflect the most recent background knowledge on water robust critical infrastructure, as the insights of practitioners or policy-makers may allow. However, it includes the major elements and the main strategies and measures taken by the selected countries and the Netherlands. One reason in this regard is that accessibility to country-specific political documents may generally be constraint by the delicate dimension critical infrastructures hold in the context national security. For instance, the UK does not make its sector resilience plans publicly available. Furthermore, limitations were identified regarding the nature of the examined country-specific (political) documents itself. Most of the governmental strategies or action plans for the protection of critical infrastructures do not provide in-depth information of the measures, nor establish thorough timescales on the implementation of sought strategies or measures. Regarding the survey, a great limitation of this study was to achieve sufficient responses under the given time constraints. With 32% the survey response rate is rather satisfactory. However, more time would have been necessary to await further responses as well as to identify, contact and remind experts to fill in the survey. Finally, another experience limiting the overall outcome of the survey made throughout the research process refers to the way the experts filled in their information. Open questions, which were expected to provide the most valuable background

information, were hardly filled in. In this regard, the survey can be improved for future use by transforming open questions into statements querying the same information.

The case study on the Netherlands has shown that it still remains an unprecedented example for water management, a frontrunner in climate adaptation and the best protected delta in the world. However, the country-specific research has revealed recommendations, which can be of relevance for enhancing the security of the national critical infrastructures in the Netherlands. In general, the Netherlands is well-protected from flooding, but possesses shortcomings in being prepared and adequately respond to the occurrence of a flood. Although the risk of flooding is rather small, the general possibility of flooding should be taken more into consideration in the Dutch policy on ensuring the functioning of the national critical infrastructures. This also accounts for transboundary floods occurring in Germany or Belgium. Especially in view of potential intensification of future climate change impacts, the current perception of being safe from flooding may proof as serious fallacy. The insights received from the examined country case studies and the expert survey might support the Dutch Ministry of Infrastructure and the Environment to formulate respective recommendations to the national government. As a result and a follow-up to this report, it is advisable to seek for further cooperation with respective governmental departments of the researched case studies for the exchange of knowledge and expertise.

Several observations can be noted which are characteristic for the approach in the Netherlands to make critical infrastructure water robust. First, the Netherlands rather tend to not implement binding reporting mechanisms or similar rules to companies or civilians. Instead, it merely provides a guidance to encourage companies and civilians to implement policies. Hence, especially with regard to the private sector the lack reporting mechanisms may affect the capacity of the Dutch Government to monitor, execute and enforce policies to make critical infrastructure water robust. Second, the Netherlands attempts to mainstream policies, similar to Germany. On the contrary, the UK chose an approach of fully integrating an issue into one specific governmental department. Regarding the protection of critical infrastructures, this study recommends to seek for both approaches. One specialised department being responsible for the coordination of making critical infrastructures less vulnerable to impacts of climate change, including water robustness, while outsourcing tasks to the appropriate departments being in charge of the various sectors (e.g. energy, telecommunication & IT, drinking water supply and transportation, but also others as agriculture, health, forestry, biodiversity, etc.).

Several observations apply to all the country case studies in their approach to make critical infrastructure water robust. i) Adaptation to climate change is on the political agenda of every

examined country. ii) Flood-risks emerge from different sources depending on country-specific contexts. For instance, Austria especially faces heavy and long precipitation events, while the Netherlands' top priority lies on the protection from future sea-level rise and river floods. iii) The protection of critical infrastructures is mainly framed as an issue of national security. In addition, to make critical infrastructures water robust is mainly addressed in the course of climate change adaptation. iv) The four sectors this study focused on were addressed in all the selected country cases. However, due to country specific differences the emphasis varies. There is a clear emphasis on ensuring a reliable supply with energy in all country cases. Remarkably, only Denmark considers its energy sector as well-prepared in view of potential climate change impacts. The security of telecommunication & IT is an issue in all the selected cases and particularly Germany puts specific emphasis on the protection of this sector. In terms of water robustness, drinking water supply is not seen as the most pressing issue. However, the supply with drinking water remains an essential issue on all national political agendas. Denmark particularly emphasises the importance of the transportation sector. v) In general, most of the encountered strategies and measures can be categorised within the dimension of preparation strategies and measures. vi) During the analysis, it became apparent that the right balance between prevention of risks and preparation for potential impacts form a central basis for a holistic safeguarding of critical infrastructures. vii) This study and the expert surveys show that international exchange of knowledge is needed to enhance mutual learning among different countries. In general, this study fortifies that countries can and do learn from each other. viii) Guiding principles require a legal basis to ensure implementation and a basis for enforcement and monitoring mechanisms. In this regard, particularly Germany and the UK do have established reporting mechanisms, accompanying respective legal obligations. ix) The private sector plays a pivotal role in the protection of critical infrastructures. However, the integration of the private sector in policies remains the crux of the matter, which the analysed countries still develop to some extent.

To conclude, in view of the analytical classification of the identified measures and strategies established within this study, an integrative approach should be prioritised to achieve water robust critical infrastructures through a holistic flood risk management. Preventive measures are required to enable a proactive approach to reduce flood risk, addressing the roots of the issue, for instance in terms of future climate change or riverbed management. Protection of the critical infrastructures constitutes the most physical dimension consisting of technical and constructional measures. This may include the building of dikes or flood walls and mainly depends on the availability of investments. Preparation is most essential for the Dutch critical infrastructures, as the general perception of being safe from flooding may cause serious consequences in case a flood eventually

occurs. Preparation thus includes the prior organisation of responsive actions during a flood event, as well as increasing the resilience against flooding for a quick recovery. Raising awareness is crucial to enable autonomous adaptation by relevant stakeholders, as well as to encourage them to take preoperational actions in order to minimise the criticality of the infrastructure and therefore the consequences of flooding. Thus, awareness increases the coping capacity of the Dutch critical infrastructures towards potential flood impacts. Generally speaking, it is advisable to tackle the potential threat of flooding according to the precautionary principle. The integrative approach, proposed in this study, can therefore constitute an essential element towards water robust critical infrastructures in the Netherlands, ensuring the security of the Dutch society and the country's general well-being.

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Annexes

Annex I – The Matrix

This plain Matrix which is guiding for structuring the information for the country-research. Note: not every box does necessary have to be filled in. The matrix is flexible, but should aim to structure information for the selected countries.

Country	
Vulnerability	Exposure (the magnitude and frequency of extreme events such as flooding. Two main elements to address are: 1) population, resources and properties and 2) sea level rise, Temperature change and Precipitation Changes) [IPCC 2001]

<table>
<tr><td></td><td colspan="2">Sensitivity (The degree to which a system will be affected by climate. It is the biophysical effect of climate change [damages, changes to current infrastructures etc.])</td></tr>
<tr><td rowspan="2">Political context</td><td colspan="2">A) Political system (How is the country organized; election systems; democracy, which departments are most prominent and dominant in decision making; [general tendency to privatized or state lead?]) (Clarification if governments obliges to take action on flood related risks)</td></tr>
<tr><td colspan="2">B) Responsibilities within the system (ministries and their tasks; execution of projects…) & structure of policy plans (Detailed policy plans for every sector or a rather ‘overarching hazard policy’) & laws:</td></tr>
<tr><td>Sectoral Strategies and Measures</td><td>A) Energy</td><td>General Information for the sector
- Scale, size, density

- To what extent is the status quo vulnerable to flooding?</td></tr>
</table>

		- Organisation (relevant actors, private/public?, ministries) - Overarching laws & projects
		Measures - Measure X - Description - Time frame - Part of a specific law or project - Actors involved and their responsibilities (policy, execution, supervision) - Strengths and applicability to the Netherlands

		strengths & applicability of all measures
	B) **Telecommunication & IT**	General Information for the sector - Scale, size, density - To what extent is the status quo vulnerable to flooding? - Organisation (relevant actors, private/public?, ministries) - Overarching laws & projects
		Measures - Measure X

		- Description - Time frame - Part of a specific law or project - Actors involved and their responsibilities (policy, execution, supervision) - Strengths and applicability to the Netherlands
		strengths & applicability of all measures
	C) Drinking Water Supply	General Information for the sector - Scale, size, density - To what extent is the status quo vulnerable to flooding?

		- Organisation (relevant actors, private/public?, ministries) - Overarching laws & projects
		Measures - Measure X - Description - Time frame - Part of a specific law or project - Actors involved and their responsibilities (policy, execution, supervision) - Strengths and applicability to the Netherlands

		strengths & applicability of all measures
	D) Transportation (road network)	General Information for the sector - Scale, size, density - To what extent is the status quo vulnerable to flooding? - Organisation (relevant actors, private/public, ministries) - Overarching laws & projects
		Measures - Measure X - Description - Time frame

		- Part of a specific law or project - Actors involved and their responsibilities (policy, execution, supervision) - Strengths and applicability to the Netherlands
		strengths & applicability of all measures
	E) Overarching measures / overlap of sectors (Do the countries have measures which will be beneficial for more sectors?	General Information (structure, importance, organisation, context)
		measures (implementation phase; goal, time frame)

		strengths & applicability (side-effects, …)
	F) Additional country specific strategies	(important for country itself; but not necessarily important for the Netherlands)
Recommendations / Lessons learned	(What is most valuable for the Netherlands? What strategies could be applicable [within the time frame 2050] for the Netherlands?)	

Annex II: The Matrix Filled-in for the Netherlands

This Matrix is filled in for the Netherlands; It should serve as an example of how the gathered information for every country case was structured, before it was transformed into the respective country chapter.

Country	The Netherlands
Vulnerability	**Primary concerns** Without water defences, 60% of Dutch territory is vulnerable to flooding from the sea or rivers. This area is home to 60% of the population and 65% of the Gross National Product (GNP) is produced there. Therefore, the Dutch government gives high priority to the water defence systems. [1] Besides this, the provision of freshwater is also threatened due to further warming and a deficit of precipitation (for which problems may already arise in 2050). **Observed Changes** • Average temperature has risen by 1.7 degrees over the past 100 years, which is about twice as large as the global average • Total annual precipitation has increased by more than 20% over the past 100 years • Climate Change is particularly exaggerating flooding/breaching of dikes **Projected Impacts**

[1] IPCC 2007

	• **Temperature**: Average winter temp. will be 0.9-2.3 degrees warmer in 2050 than in 1990 • **Sea Level Rise:** An expected rise of 15-35 cm compared with 1990 • **Flood Risk**: Increased changed of flooding and an increase in peak discharges from rivers in the winter. Increase in flooding of rural areas (very likely) and a more frequent flooding in urban areas (likely), as heavier storms may exceed the capacity of sewage systems • **Precipitation:** Increase in precipitation in winter will lead to higher discharges in the Rhine and Meuse • Larger penetration of saline water into surface water bodies • Decreased water levels of groundwater and surface water in the summer
Political Context	**Political system and government structure** The Netherlands, a small country in Western Europe, comprises of 41,526 km2 of which 17.9% is surface water. "With 16.4 million inhabitants it is one of the most densely populated countries in the world."[2] The Netherlands is a constitutional monarchy with a bicameral legislature. "Traditionally government in the Netherlands is spread across three hierarchical layers: national, regional (provinces) and local."[3] Besides these governments, the Netherlands has also water boards especially responsible for aquatic matters in their region. Regional government: • Regionally the Netherlands are divided in 12 provinces. These are responsible for environment, planning, **energy supply**, social work, and sports and culture. The provinces are governed by a locally direct-elected representative provincial council. The size of the council depends on the number of inhabitants in the province. Members are elected for four-year terms. From among their members, the councils elect

[2] UCLG 2008:1
[3] UCLG 2008:2

provincial executives […] with six to eight members. Each province has a commissioner appointed by and representing the Crown.

Local government:

Under the administrative level of provinces, the Netherlands has been divided into 393 municipalities.[4] These municipalities are responsible for services in traffic and water, housing, public education, social and health care, culture, sport and recreation. Municipalities "are administered by municipal councils, which are elected directly for four-year terms by the local inhabitants and make local bylaws. The executive powers of the municipality are entrusted to a corporate board consisting of a [mayor][….] and two to six aldermen; the latter are elected from and by the council, while the […] mayor is appointed by the Crown."[5] The number of municipalities is declining as Central Government is hoping to improve efficiency by creating larger municipalities through mergers."[6]

Regional water boards:

Besides the provinces and municipalities, the Netherlands has also been divided into 24 regional water boards, also referred to as waterships. "The Waterships are the public bodies responsible for dealing with all matters aquatic, including protecting the land from the water, distribution of water and maintaining the water table, and ensuring the quality of drinking water. They are the oldest public bodies in the Netherlands." Some dating back as far as the 13th century.[7]

Economy

"The Netherlands has an advanced economy, which combines high per capita income with a fairly even income distribution. An industrial

[4] CBS 2015
[5] Worldmark encyclopedia of the nations 2007
[6] National Academy for Finance and Economics 2013
[7] Worldmark encyclopedia of the nations 2007

nation with limited natural resources, the Netherlands bases its economy on the importation of raw materials for processing into finished products for export. Food processing, metallurgy, chemicals, manufacturing, and oil refining are the principal industries. Agriculture is particularly important to the economy, as about 60% of total agricultural production is exported."[8]

Responsibilities and Structure of Policy Plans

Until 2010 the policy of the Dutch government related to climate change adaptation and critical infrastructure was primarily focused on preventing a flood. However, in 2013 the Minister of Infrastructure and the Environment stressed that while the Netherlands is the best protected delta in the world, all citizens should also know how to react if a flood occurs.[9] The government has translated that into an effort to actualize policies on making critical infrastructure water robust. The first step of that effort has been to make an inventory of the applicable legislation in place and divide the responsibility of safeguarding critical functions to ministries.[10]

The Dutch government system consists of 11 ministries. The following ministries deal with critical infrastructure and or the sectors in questions (energy, telecommunication, drinking water and road network):

- *Ministry of Infrastructure and the Environment*

- Broadly speaking, the Ministry of Infrastructure and the Environment (I&M) is responsible for policy formulation, implementation and inspection.[11] In the context of this project the ministry deals, amongst others, with: Climate change, delta programme, drinking water,

[8] Worldmark encyclopedia of the nations 2007
[9] Ministry of Infrastructure and the Environment 2013:2
[10] STOWA 2014
[11] Ministry of Infrastructure and the Environment 2015

		mobility, public transport and road safety, spatial planning and infrastructure and water management.[12] "Rijkswaterstaat is the executive agency of the Ministry of Infrastructure and the Environment, responsible for the Dutch main road network, the main waterway network, the main water systems, and the environment in which they are embedded. Rijkswaterstaat facilitates smooth and safe flow of traffic, keeps the national water system safe, clean, user-friendly and protects the Netherlands against flooding."[13] - *Ministry of Economic Affairs* The ministry of Economic Affairs is responsible for the Dutch Energy policy[14] - *Ministry of Security and Justice* • "Important issues of the ministry of Security and Justice are: Alcohol; Crisis, national security and terrorism; Identification documents; Police."[15] This ministry is responsible for launching the National Security Strategy, to catalogue the various risks and prepare the Netherlands for any crisis."[16]
Sectors	**Energy (electricity)**	**General information** When the energy network shuts down, response time in the flooded area decreases and damage is direct (to the network) and indirect (in financial terms). Foundations of the energy network may be water resistant, but they may not be resistant to a high flow rate. Besides the critical function of the energy infrastructure for the Netherlands, the functioning of the infrastructure is also critical for neighbouring countries, as energy networks are internationally interconnected.

[12] Ministry of Infrastructure and the Environment 2015
[13] Ministry of Infrastructure and the Environment 2015
[14] Ministry of Infrastructure and the Environment 2015
[15] Ministry of Security and Justice 2015
[16] Ministry of Security and Justice 2015

		Responsibilities In the Netherlands the transport and maintenance of the electricity network have been uncoupled from the production of electricity. The main network is being maintained by TenneT, a state-owned enterprise. The maintenance and transport on regional level is the concern of the regional private net-operators (such as Alliander, Stedin). The network operators discuss regularly on the platform of integral security questions related to the continuity and security of the electricity.[17] The Ministry of Economic Affairs is main responsible for all energy related facilities. **Components:** Power plants: Execution is done by electricity providers. There is a high redundancy, meaning that if some power plants shut down others can compensate for it. However, if too many power plants shut down and the power supply goes below critical levels, the remaining power plants also shut down. Main network (for national energy distribution): Execution is done by TenneT, the sole responsible state-owned company responsible for maintaining the national electricity transmission system in the Netherlands. There are few vulnerable functions, only steering mechanisms are vulnerable since they are located below 2,5 m. Furthermore closed installations and secondary components like security and control are in flood risk zone. Regional network and electricity distribution: Execution is done by regional private operators. There is low redundancy in capacity and many vulnerable, low laying objects such as

[17] Ministry of Infrastructure and the Environment 2011

		transformer houses and electricity 'meterkast'. However there are requirements for the minimal building height. If these facilities get flooded, they are disrupted and fully depreciated. The IT and telecom facilities are dependent on this part of the electricity system. Installations: This means indoor infrastructure and facilities of individual customers. There is low or no redundancy and many vulnerable elements. Electronic installations are mainly constructed in basements. If indoor installations are disrupted, this is does not have any consequences for other houses. Backup generator facilities are only useful when located above flood height. They have a limited capacity and are still dependent on fossil fuel supplies.
		Strategies and Measures It has been suggested not to connect buildings in flood-prone areas to the gas network, but let them rely on the electricity network. Furthermore, it has been suggested that the government should give the companies in the sector the possibility to translate costs of making the infrastructure water robust into the consumer price. This requires an adjustment in the policy of the competition regulator (Mededingingsautoriteit).[18] Taken together there is supervision on risk management procedures and tariffs. However, there is no supervision on the content of the measures. This means, there is no oversight whether the content of the risk management procedures meets certain standards.
	Energy (gas)	**General information:** Just as with electricity the infrastructure of natural gas has been decoupled form the producers and the providers of natural gas. **Responsibilities**

[18] Ministry of Infrastructure and the Environment 2011

		Main responsible for policy is the ministry of Economic Affairs. The 'Gasunie' is responsible for the 'hoofdnet/hoge druknet'. The maintenance and transport on regional level is the concern of the regional net operators (such as Alliander and Stedin). **Components** Gas sources, treatment plants Execution is done by producers. Vulnerability is unclear. It is chain dependent on electricity. It is expected that floods in the area of the treatment plants do not affect the public network. Gas storage/LNG installations Execution done by corporations. Vulnerability is unclear. It is chain dependent on electricity. Main transport network Execution done by Gasunie, a state-owned enterprise that owns and operates the natural gas infrastructure and transportation. Compressor stations and control stations are sensitive to water and often build on ground level. Transportation pipelines are vulnerable, also because of their dependency on electronic control mechanisms. The amount of gas provided to households is safe during floods. The pressure needed by the system can be sustained, however it might be a little bit less due to failure of several compressor stations. In case of a crisis, the pipelines are secured/blocked so no additional gas escapes. However when electricity fails due to a flood, this should be done manually which is difficult if water levels are high. Regional distribution networks Responsible for execution: Regional private operators.

		The regional distribution gas networks are very vulnerable to floods. If an underground gas pipeline is flooded, water might enter if the gas pressure is too low. Once water enters the pipeline, it prevents the gas from flowing. If a gas pipeline is saturated with water it becomes dysfunctional. Hence, if an area is flooded the pipelines of every house have to be checked and potentially replaced. It was estimated that if a flood would occur in the northern provinces of the Netherlands, the damage to gas installations would be 20 to 30 billion euro.[19] Installations of the customers: Responsible for execution: business and individuals. When water enters the installations, all the pipelines involved have to be replaced. This leads to a long recovery time. However, this would probably not effect public facilities.
		Strategies and Measures It has been suggested not to connect buildings in flood-prone areas to the gas network, but let them rely on the electricity network. Furthermore, it has been suggested that the government should give the companies in the sector the possibility to translate costs of making the infrastructure water robust into the consumer price. This requires an adjustment in the policy of the competition regulator (Mededingingsautoriteit).[20] On top of this, flood risk analyses are enclosed in security measures of the Dutch Gas and electricity network operators (NL Technische Afspraak 8120).

[19] Alterra 2014
[20] Ministry of Infrastructure and the Environment 2011

	Energy (Oil)	**General information** The oil sector is almost completely in hands of private partners. These are organised in branchorganisations, of which the most important are the VNPI (oil companies), VOTOB (petrol reserves), NOVE (traders), BOVAG and Beta (petrol station enterprises).[21] **Responsibilities** The Ministry of Economic Affairs is responsible for the internal provision of oil in the Netherlands. For the Dutch role in the international provision of oil, the Ministry of Economic Affairs makes agreements of the OECD and IEA. Supervision is executed by Inspectie Leefomgeving en Transport (ILT). **Components** Oil supply for the Netherlands Oil is required for the society and economy to function. The sectors involved are obliged to secure a strategic backup amount of oil. If a refinery is flooded, it will fail. Specific information on whether refineries, depots, pipelines are located in potential flooding areas and to what degree they are resistant against water depth, is absent. International oil supply The Netherlands also plays a role in the international supply of oil. Rotterdam is used as a transition harbour for oil, while the port of Amsterdam is important for the transport of gasoline. From Rotterdam onwards the chain of oil consists of: Big tanks in Rijnmond (which are part of the strategic storage of 90 days)

[21]Ministry of Internal Affairs and Kingdom Relations 2010

		Refinery in Rijnmond (of which there is an overcapacity) Transit to the exterior through sea ships, inland ships, pipelines Transit to 8 big internal depots for petrol stations
		Strategies and Measures There is no specific policy for oil supply during a flood, however there is specific policy for mantaining a strategic reserve. It is unclear what kind of measures the private companies take themselves related to the security in case of a flood.
	B) Telecommunication & IT	**General information** Functioning telecommunication and IT infrastructure is essential for the government and emergency services to responds adequately to a flood. At the same time, telecommunication and IT infrastructure is particularly vulnerable to flooding in the direct area, as it relies on cables and electronic apparatuses stationed under or at ground level. This means that generally public telecommunication and IT infrastructures stop working in the area of a flood and have to be repaired afterwards. As telecommunication between the government, emergency services and towards the public is essential for an adequate response to a flood, these facilities are dealt with a different approach than public telecommunication facilities used for the communication between civilians. **Responsibilities** Telecommunication to be used for the response to a flood Responsible for policy: Ministry of Security and Justice, Ministry of Economic Affairs, and Ministry of Education, Culture and Science. Applicable laws: No specific information available. Execution: The execution is assigned in a complex manner to the State, Security Regions[22] and Municipalities.

[22] Security region Amsterdam-Amstelland 2015

		Supervision: No specific information available. Public telecommunication Responsible for policy of the public network: Ministry of Economic Affairs Applicable laws: Telecommunication Bill[23] (*Telecommunicatiewet*) Execution: Private telecom companies Supervision: 'Agentschap Telecom', part of the Ministry of Economic Affairs supervises the implementation of legal standards by telecom providers. Furthermore, it is being studied at the moment whether certain private IT facilities are also critical infrastructure, and whether the responsibility to safeguard them should be assigned to a body.
		Strategies & Measures Most measures related to the securing of Telecommunication and IT infrastructure are concerned with human-induced crises, such as cyber-crime and –terrorism. Telecommunication to respond to a flood The Ministry of Security and Justice strives to safeguard communication needed to respond to crises. However, it is unclear on what policy the Ministry basis its measures and whether measures are focussed on floods as well. These measures do not fall under the Telecom Bill (Telecomwet). For the communication used to respond to a crisis continuity plans and fall-back scenarios are in place. However, it is unclear to what extent these are focussed on flood risks. Occasionally special attention is given to floods, just as the recent placing of a transmitter in a flood-prone area near the Waal.

[23] Informatie Rijksoverheid 2015

		Public telecommunication The 'Telecomwet' binds all private operators to a duty of care and requires them to implement an all hazards approach, however it is unknown to what extent flood risks are included. Every year almost 500 telecom companies report to the Agentschap Telecom about their continuity. In the system of accountability and supervision special attention is given to the biggest telecom companies, responsible for 80% of the public market. However, it is unclear whether there are concrete standards to which the telecom providers have to adhere to safeguard provision in case of a flood. Two reports of the Dutch government state that the telecom providers are moved to protect their facilities out of A) their own financial interest to protect infrastructure and safeguard continuity of service for clients, and B) the sharing of knowledge within the Agentschap Telecom on dealing with threats. An example of this is that in Maastricht facilities of Vodafone were moved higher up in the building following a near flood in the area.
	C) Drinking Water Supply	**General information** Drinking water is needed during a crisis for citizen's to survive. Long term disruption of drinking water supply results in severe damage and disruption to and of society. Drinking water supply can be disrupted during a flood due to contamination and salinization, also because installations fail due to limited electricity supply and broken pipes. **Responsibilities** Ministry for Infrastructure and the Environment is the main responsible for policy. Drinking water supply corporations, united in the branch association Vewin, are responsible for the execution of policy. In case of a crisis, municipalities are responsible for coordination and accessibility of distribution. Drinking water corporations and municipalities have covenants on how to cooperate regarding supply and distribution, no explicit national prescriptions are present. Supervision is done by ILT (Inspectie leefomgeving en transport).

		Key policy documents The drinking water law is a relatively new law, implemented in 2009. It demands requirements regarding supply security, supply and readiness for crises. This entails a risk analysis about existing and expected threats and risks (floods). Certain maintenance measures could be taken on basis of this and the plans should be revised every 4 years. All corporations should be able to supply 3 litre emergency drinking water per person, per day, on another network besides their own network. **Strategies and Measures** Hospitals are connected directly to the main network which guarantees supply. The ILT must approve the supply plans of drinking water corporations. General supply will be maintained as long as possible, if deemed necessary by ILT (Inspectie leefomgeving en transport) to supply drinking water in times of crisis. The drinking water corporations need to practice crisis situations and the security region should be involved every four years. A risk analysis in these supply plans is based on 25 different flood scenarios. And a supply security analysis is executed in which a minimum of 75% of the maximum amount of drinking water supply should be supplied. If this is not possible, the network is adjusted. Policy, measures and oversight in general is focussed on securing drinking water supply, also during floods. Continuous improvement is explored by the ministry and sector, for example as part of the Delta programme. The goal of the Delta programme is to achieve only limited disruption of drinking water supply in case of a flood. To achieve this goal the programme has lined out four phases: Phase 1(2015): Which solutions are promising, who should take action? Phase 2: Disruption-risk analysis, second round of supply plans for drinking water corporations. Phase 3(2016): Measures are selected Phase 4(2020): Measures are executed

	D) Transportation (road network)	**General information** Transport is an essential precondition for economic activity. Disturbance could lead to great economic losses and disrupt society. In general the transport sector should not be characterized as vulnerable, as different modes of transport enable a functioning of the overall transport in case some parts are hindered. However, there are four elements from the transport sector that should be considered vital infrastructure: Mainports Schiphol and Rotterdam, specific parts of the railway system, and specific parts of the waterways and highway network.[24] This section will relate to the road network. The Netherlands has a very extensive network of public roads in ownership, management and maintenance by the state, provinces, municipalities and regional water authorities. The highway network with A-roads (with four or more lanes) and some N-roads (with mostly two lanes) fall under the responsibility of the state. Characteristic is the interwovenness of the highway network with the underlying roads. Different from countries, such as France, the Netherlands does not have secondary roads parallel to the highway network. The highways around cities are also part of the regional-urban network. The interwovenness of the highway network make it difficult to indicate which parts of this are critical in case of a flood. For evacuation and supply of assistance a combination of local, regional and national roads will be necessary. Furthermore, as the main transport networks have been deepened in the construction (e.g. to diminish noise pollution), they tend to be particularly vulnerable to flooding. **Responsibilities** The ministry for Infrastructure and the Environment is main responsible for policy. Rijkswaterstaat is responsible for construction & maintenance. There is no specific supervision on these governmental bodies.

[24] Ministry of the Interior and Kingdom Relations 2010

		Key policy documents The general policy is in the 'Structuurvisie, Infrastructuur en Ruimte' (vision structure, infrastructure and space). This document is guiding in the policy decisions of the Ministry of Infrastructure and the Environment. Whether a road is adjusted will be decided upon via a legal procedure. This policy for the main transport system does not oblige the ministry to consider natural disasters. Therefore there are no pre-described norms on how to deal with disasters. However, there are some guidelines included in the document 'kader klimaat voor planuitwerking' on how to deal with extreme weather (mainly precipitation). Rijkswaterstaat will also include this in her policy documents. After executing two pilots, additional inclusion of the theme 'klimaat' in policy documents will be decided upon. **Current developments** A blue spot research was conducted to check which roads would be flooded in case primary and secondary dikes would break. The research concluded that a substantial part of the main transportation network within a dike ring would be flooded, which could have big consequences. Which roads should be considered critical is not yet known however. In addition evacuation might not be the best choice in case of a flood since evacuees are 'trapped' during their evacuation. In this case citizens might better stay where they are. If this is the case, the accessibility of highways would be less critical. In the area around Nieuwegein a scenario analysis was made to access the consequences of an unexepcted flood in this area and which approach would be best to deal with it. It was found that in this scenario chaos would arise and the traffic would jam. Furthermore, the road- and railways between Utrecht and the Randstad would be unusable for months after the flood. The deaths would range between 326 to 625 and the economic damage would be around 13 billion euro. The scenario does not tell what would the results be if the roadnetwork had been made water robust. However, the study does indicate the importance of functioning transport in the case of a flood. To research best approach to deal with a flood, the ministries of Infrastructure and the Environment, and Security and Justice consider requiring all security regions to carry out a similar flood scenario analysis to access the effects of a flood in their region.

		Strategies and Measures Objects of the main transport network have been connected to the Alerteringssysteem Terrorismebestrijding (Alertsystem Counter-Terrorism). No specific measures for the accessibility of the main transport network in case of a flood have been enacted. Roads could be heightened, however costs would be tremendous and soot and noise disturbance would be a negative side effect. An illustrative example is the highway A20. If it would have to be made water secure, it would have to be heightened with 10 meters. An alternative strategy that has been suggested is vertical evacuation. This entails that people seek shelter in high buildings or compartmentalized areas in the flooded area itself. This would require a restructuring of spatial planning and an awareness raising among civilians. In April 2014 Rijkswaterstaat will explore more alternative measures. **Proposed measures** Rijkswaterstaat is involved in a European research cooperation to investigate the climate resilience of infrastructure. Within this project instruments are developed to determine climate risks. Also an inventory of measures to enhance the resilience against extreme weather and floods. If applicable to the Netherlands, the results will be used.

Annex III – Expert Survey

Ministry of Infrastructure and the Environment

Towards Water Robust CRITICAL INFRASTRUCTURE

Expert Survey

The research project "Towards Water Robust Critical Infrastructure – An Inventory of Strategies and Measures" has been collaboratively developed by the Dutch Ministry of Infrastructure and the Environment and Wageningen University, the Netherlands. The research objective is to provide an overview of strategies and measures taken by a selection of countries to make critical infrastructure water robust in the face of climate change. Water robust means that infrastructure remains functioning in case of flooding or a drought. This project focuses on four critical functions: energy supply (electricity, gas and oil), road transportation, telecommunication & IT (for both crisis response and the public network) and drinking water supply. This expert survey is meant as a vital support on which our research is based. Your profession and experience is seen as a valuable contribution to understand how to make critical infrastructure water robust. We particularly hope to gain in-depth insights into country-specific activities.

By this, not only the Netherlands but also the countries we are doing research on can learn from each other. This could improve national decision-making processes by being aware of already available strategies and measures to make critical infrastructure water robust.

The results of the survey are integrated into the final project report, which can be provided by the Dutch Ministry of Infrastructure and the Environment. We will use your contribution to this report in a confidential manner. That means the input will be solely connected to your country. No names will be mentioned in the report unless desired.

General information

Country: click here to insert text.

What is your profession? click here to insert text.

Do you wish to receive the final report of this research?
☐Yes ☐No

Critical infrastructure

Facilities and infrastructure, which are essential for the social and economic well-being of a country, are referred to as 'critical'. The term 'critical infrastructure' thus embraces facilities and sectors which are of substantial importance for a country to maintain its public order and economic functions. 'Criticality' is understood as a relative measure indicating the significance or importance of certain infrastructure for the supply security of society.

1) This research focuses on 'critical infrastructure'. We have provided a definition of how we understand critical infrastructure and criticality above. To what extent do you agree with this definition? Please select

   In case you disagree please elaborate briefly on your understanding of 'critical infrastructure'? click here to insert text.

2) What are the most critical functions in your country?

☐ electricity	☐ surface water pumping stations
☐ natural gas	☐ main road transportation
☐ oil	☐ chemical
☐ telecom to respond to a crisis	☐ nuclear
☐ public telecom network	☐ other: click here to insert text.
☐ drinking water	☐ other: click here to insert text.
☐ waste water	☐ other: click here to insert text.

Responsibilities and Competences

3) How are responsibilities and competences divided among different ministries? Please fill in the names of the ministries responsible for making the functions below water robust in the face of climate change:

   - Which ministries are responsible for the energy supply?
     click here to insert text.
   - Which ministries are responsible for road transportation?
     click here to insert text.
   - Which ministries are responsible for IT and telecommunication?
     click here to insert text.
   - Which ministries are responsible for drinking water supply?
     click here to insert text.

4) Which public and private parties besides the ministry are involved in making these sectors water robust? Please fill in the names of the parties involved in the sectors below:

- Which parties besides the ministries are responsible for the energy sector?
  click here to insert text.
- Which parties besides the ministries are responsible for the road transportation?
  click here to insert text.
- Which parties besides the ministries are responsible for the IT and telecommunication sector?
  click here to insert text.
- Which parties besides the ministries are responsible for drinking water supply?
  click here to insert text.

Past Experiences

5) Has the critical infrastructure in your country in the last twenty years been affected by one of the following impacts? Please tick the applicable boxes below:

☐ flooding (sea)
☐ flooding (rivers)
☐ land slides
☐ storm events
☐ extreme precipitation
☐ heat wave
☐ drought
☐ other: click here to insert text.
☐ other: click here to insert text.
☐ other: click here to insert text.

Strategies and measures for making critical infrastructure water robust

6) To what extent do you agree with the following statement:
Past experiences with climate changes impacts (mentioned in question 4) have put climate proof critical infrastructure on the political agenda: Please select

If applicable, please give examples: click here to insert text.

7) To what extent do you agree with the following statements:
   a) I perceive the approach that my country is taking in order to make critical infrastructure water robust as coordinated: Please select

   b) I perceive the critical infrastructure in my country to be well prepared towards potential future water-related climate impacts: Please select

8) Are there measures or strategies you want to highlight, which are implemented in the short or long term? click here to insert text.

Effectiveness

9) To what extent do you agree with the following statements:
   a) I perceive the policies taken by my country to make critical infrastructure water robust in the face of climate change as effective: Please select

   b) I perceive the monitoring of making critical infrastructure water robust in my country as effective: Please select

   c) The authorities concerned with adaptation measures know how to deal with uncertainties in the decision making: Please select

   d) The businesses concerned with adaptation measures know how to deal with uncertainties in the decision making: Please select

Importance of water robust critical infrastructure

10) To what extent do you agree with the following statement:
   a) In my country, making critical infrastructure water robust is important in the face of climate change: Please select

   b) In my country, making critical infrastructure water robust is prioritised on the political agenda: Please select

   c) In my country, businesses are aware of future climate changes and potential severe impacts on the critical infrastructure: Please select

   d) In my country, civil society is aware of future climate changes and potential severe impacts on the critical infrastructure: Please select

International Cooperation

11) To what extent do you agree to the following statement:
   There is a need for an integrated coordination amongst countries (for example in the EU) for taking collaborative actions to make critical infrastructure water robust. Please select

   If applicable, please state your suggestions.

Additional remarks

12) What do you think the Netherlands can learn from your country?
   click here to insert text.

13) What do you think your country can learn from the Netherlands?
   click here to insert text.

14) Do you recommend documents related to your country that we should consider in our research project?
click here to insert text.

15) Do you have any additional remarks, which are of added value for the research?
click here to insert text.

Thank you very much for you participation.