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Appendix 9: Assessment of the Water Sector

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Abbreviations and Acronyms

AR5	Assessment Report 5
BAS	Bulgarian Academy of Sciences
BAT	Best Available Techniques
BCR	Benefit-Cost Ratio
BFSA	Bulgarian Food Safety Agency
BSRBD	Black Sea River Basin Directorate
BWA	Bulgarian Water Association
CAP	Common Agricultural Policy
CBA	Cost-Benefit Analysis
CC	Climate Change
CCA	Climate Change Adaptation
CFP	Common Fisheries Policy
CIS	Common Implementation Strategy
CO2	Carbon Dioxide
CoM	Council of Ministers
CP	Cohesion Policy
DAS	German Strategy for Adaptation to Climate Change
DG CAA	Directorate General "Civil Aviation Administration"
DRBD	Danube River Basin Directorate
DWD	German National Meteorological Service (Deutscher Wetterdienst)
EARBD	East Aegean Sea River Basin Directorate
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EEA	European Environment Agency
EMEPA	Enterprise for Management of Environment Protection Activities
ENPI	European Neighbourhood and Partnership Instrument
ERDF	European Regional Development Fund
EU ETS	European Union Emissions Trading System
EU	European Union
EUSF	European Union Solidarity Fund
EWRC	Energy and Water Regulatory Commission
ExAAA	Executive Agency Automobile Administration
ExAEMDR	Executive Agency for Exploration and Maintenance of the Danube River
ExAMA	Executive Agency Maritime Administration

ExARA	Executive Agency Railway Administration
ExEA	Executive Environment Agency
ExFA	Executive Forest Agency
FAO	Food and Agriculture Organization of the United Nations
FLAG	Fund for Local Authorities and Governments
FRMP	Flood Risk Management Plan
FYR of Macedonia	Former Yugoslav Republic of Macedonia
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GVA	Gross Value Added
HPP	Hydropower Plant
ICPDR	International Commission for the Protection of the Danube River
INTERREG	Interregional Cooperation Program
IPA	Instrument for Pre-Accession Assistance
IPCC	Intergovernmental Panel on Climate Change
MAFF	Ministry of Agriculture, Food and Forestry
MC	Ministry of Culture
MCA	Multicriteria Analysis
MEc	Ministry of Economy
MEn	Ministry of Energy
MEx	Ministry of Exterior
MF	Ministry of Finance
MH	Ministry of Health
MI	Ministry of Interior
MoEW	Ministry of Environment and Water
MRDPW	Ministry of Regional Development and Public Works
MTITC	Ministry of Transport, Information Technology and Communications
NAS	National Adaptation Strategy
NECCC	National Expert Council on Climate Change
NEK	National Electricity Company (Natsionalna Elektricheska Kompania)
NGO	Non-Governmental Organization
NIMH-BAS	National Institute for Meteorology and Hydrology at the Bulgarian academy of Sciences

NPP	Nuclear Power Plant
NPV	Net Present Value
NSI	National Statistical Institute
NTEF	National Trust EcoFund
OPE	Operational Program Environment
PE	Population Equivalent
PWTP	Potable Water Treatment Plan
R&D	Research and Development
RBD	River Basin Directorate
RBMP	River Basin Management Plan
RCP	Representative Concentration Pathway
RDP	Rural Development Program
RIEW	Regional Inspectorates of Environment and Water
SAMTS	State Agency for Metrological and Technical Surveillance
TPP	Thermal Power Plant
U.K.	United Kingdom
WA	Water Act
WARBD	West Aegean Sea River Basin Directorate
Water sector strategy	National Strategy for Management and Development of the Water Sector in Bulgaria
WFD	Water Framework Directive
WGII	Working Group II
WSS	Water Supply and Sanitation
WWTP	Wastewater Treatment Plant

Glossary[1]

Climate change refers to a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to the natural climate variability observed over comparable time periods.
Global warming refers to the gradual increase, observed or projected, in the global surface temperature, as one of the consequences of radiative forcing caused by anthropogenic emissions.
Adaptation is the process of adjustment to actual or expected adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.
Mitigation (of climate change) is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs).
Vulnerability to climate change is the degree to which any system is susceptible to, and unable to cope with, the negative impacts that climate change imposes upon it. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.
Resilience is the opposite of vulnerability and is defined as the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, capacity for self-organization, and capacity to adapt to stress and change.
Risk is the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as the probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.

[1] Definitions are based on WGII AR5 (IPCC 2014).

Executive summary

1. **The report aims at** the identification of climate change adaptation (CCA) options for the water sector in Bulgaria based on a risk management approach. Unlike other sectors, the water sector is fully reliant on the availability of a resource, which by nature, is most susceptible to variation and uncertainty. This requires both **managed water systems** – water supply and sanitation, hydro-melioration, hydropower, and industrial use – and **natural water systems** to be considered.

2. **Water resources** in Bulgaria are unevenly distributed by region and season. Climate change is expected to have a significant effect on the hydrology of rivers. For some river basins, total annual discharge rates are projected to drop by approximately 10 percent over a period of 30 years in comparison to the reference period 1976–2005. Significant shifts are expected in the seasonal distribution of rivers' runoff. While in winter and spring there will be an increase, summer and autumn river discharge rates are expected to decline. Groundwater availability is not expected to change significantly.

3. Besides the availability of water, the **vulnerability of the sector** depends on the combined impact of many factors: preparedness of the infrastructure to cope with climate change, preparedness of people to manage and operate water systems under climate change conditions, preparedness of users, exposure to hazards, demographic and economic development, legislative and political framework, and so on.

4. The report discusses each of these factors and concludes that the water sector is not prepared to cope with climate change. **Water supply and sanitation** has the highest improvement dynamics in the sector, but still the biggest part of the infrastructure is outdated as well as designed and operated without climate change considerations. The **hydro-melioration infrastructure** is either destroyed or in a poor condition. Insufficient maintenance and lack of safety monitoring pose significant risks to the population, settlements, agricultural land, and infrastructure. **The major hydropower plants (HPPs)** are maintained and operated properly, but the condition of the small HPPs has a potential safety threat. Comprehensive assessment of the **industrial water use** is not possible due to lack of data.

5. The report discusses how prepared managers, operators, and users are to cope with climate change. It concludes that **lessons from past events have not been used**. The response actions taken are more visible at the national (development of Flood Risk Management Plans [FRMPs]), than at the local level. It appears that once a flood is gone and the most significant damage has been recovered, the efforts of the responsible authorities are redirected to other duties. After the drought in 2000, the government adopted a '*Program for the Necessary Measures under the Conditions of Droughts'*, but it was not implemented, because wetter years followed.

6. At the **national level,** roles and responsibilities for climate change adaptation (CCA) have not yet been clarified. A positive fact is that some legislation and strategic documents already consider climate change. River Basin Management Plans (RBMPs) and FRMPs also include measures to cope with climate change.

7. **The Intergovernmental Panel on Climate Change (IPCC 2014) notes that risks arise from interaction of climate hazards with exposure and vulnerability to impacts.** Two climate **hazards** are identified as most relevant to the water sector – **floods and droughts**. Floods cannot be predicted based on location, time and intensity; therefore, this hazard concerns flood-prone areas in the entire country. Droughts create higher risk in regions with water scarcity. The report suggests a simplistic approach to identify the regions with water scacity risk. Projections show that climate change will not affect groundwater availability. This fact, together with the projected decline of Bulgaria's population and slow growth of industrial and agricultural activities, results in high likelihood for low scarcity risk in regions which use groundwater. However, if for example, water supply systems continue wasting more than 50 percent of the water produced, the risk might increase. The risk will also increase if water thirsty industries and crops are situated in this region. High scarcity risk is likely to appear in regions supplied with surface water and having high touristic activities, which are projected to increase. The **Black Sea region** appears to be the most vulnerable to scarcity risk because it uses surface water and is the most visited by tourists. Poor condition of the infrastructure in this region adds another dimension toward increasing the risk.

8. Based on the analyzes, the report identifies and discusses three major types of risks: **risk to infrastructure, risk to services, and risk to natural water systems.**

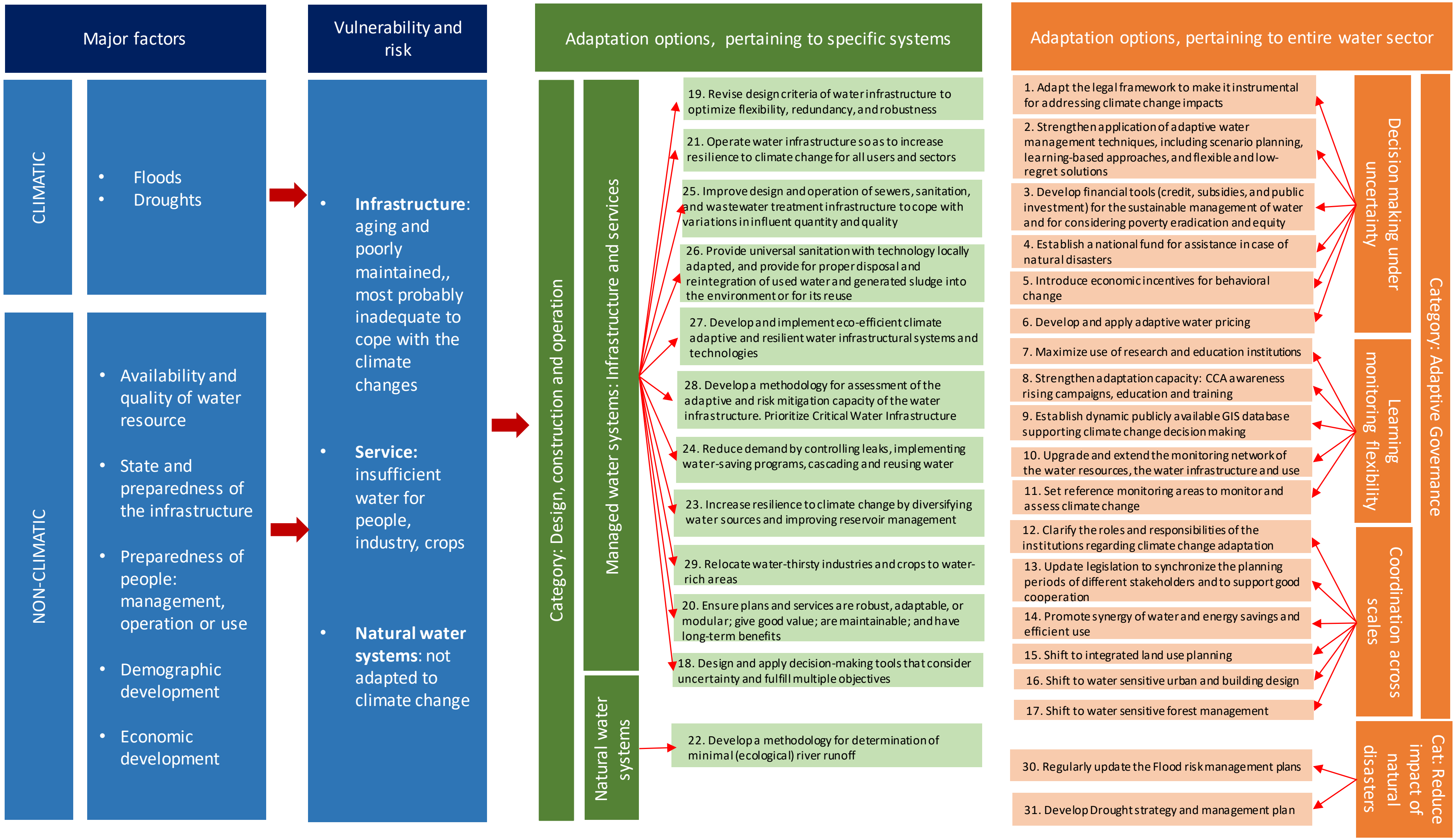
9. The risks could be managed if appropriate options are implemented on time. The report presents possible adaptation options. They are grouped into three main categories.

Categories of adaptation options

• Adaptive governance
    ○ Decision making under uncertainty
    ○ Learning, monitoring, and flexibility
    ○ Coordination across scales
• Design, construction, and operation
• Reduce impact of natural disasters

10. The options under the category 'Design, construction, and operation' are specific to managed natural water systems. The other two categories are appliacable to the entire sector. The options are presented in ***Figure 1***. It illustrates the risk-based approach, applied to identify these options.

Figure 1. Simplified illustration of impact of climate change and identified adaptation options



Source: World Bank design.

Introduction

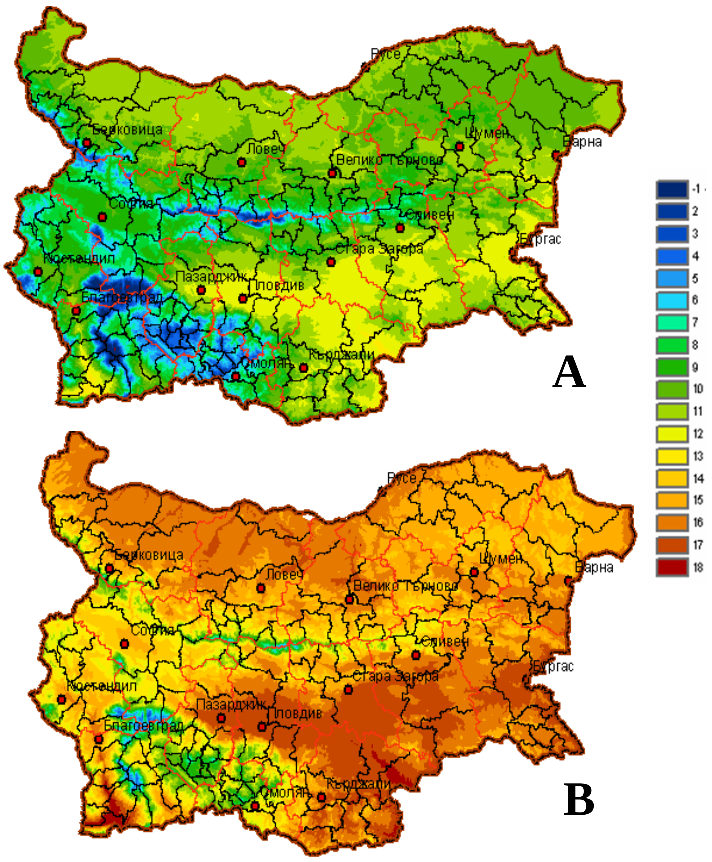
11. Bulgaria is situated in one of the regions that is particularly vulnerable to climate change (mainly through temperature increase and extreme precipitation) and to the increased frequency of climate change-related extreme events, such as droughts and floods. The risks inflicted by climate change-related events may lead to loss of human life or cause considerable damage, affecting economic growth and prosperity, both nationally and transboundary.

12. Consensus exists in the scientific community that climate change is likely to increase the frequency and magnitude of extreme weather events. Over the past decades, in Bulgaria, this frequency has increased significantly. The most common hydrometeorological and natural hazards are extreme precipitation and temperatures, storms, floods, wildfires, landslides, and droughts. The number of deaths and victims due to natural hazards is considerable, indicating weather and climate vulnerability. The vulnerability of Bulgaria's population and businesses to the impacts of climate change is accelerated by a relatively high degree of poverty in the most affected areas, the continuing concentration of the country's population in several industrial and urban regions, and various consequences of the transition from a state-controlled economy to a free-market economy. A growing body of evidence suggests that economic losses from climate- and weather-related disasters have also been rising.

13. Scientific projections indicate that global temperature will rise between 1.8°C and 4°C by 2100, with the temperature increase in Europe expected to be even higher than the estimated global average.

14. Research conducted by the Department of Meteorology, National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences (NIMH-BAS), projects an increase in annual air temperature in Bulgaria of between 0.7°C and 1.8°C by 2020. Even warmer temperatures are expected by 2050 and 2080, with projected increases of between 1.6°C and 3.1°C and between 2.9°C and 4.1°C, respectively. Generally, the temperature increase is expected to be more significant during the summer season (from July to September).

Figure 2. Average year temperature for 1961–1990 (A); Pessimistic climate scenario for average year temperature for 2080 (B)

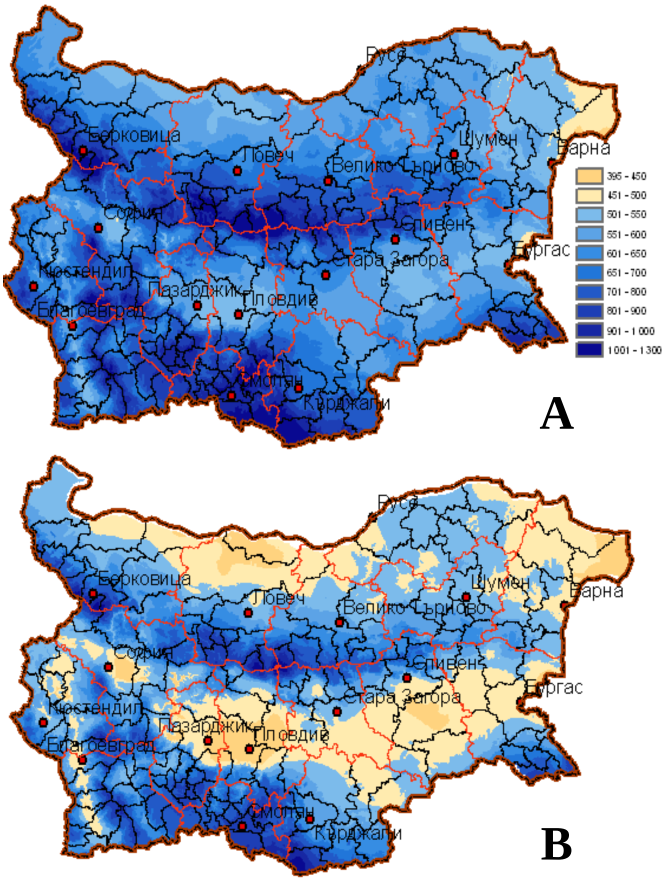


Source: NIMH-BAS.

15. In terms of the expected changes in rainfall patterns, a reduction in precipitation is likely, leading to a significant reduction of the total water reserves in the country. In this regard, projections suggest a decrease in precipitation by approximately 10 percent by 2020, 15 percent by 2050, and up to 30–40 percent by 2080. In most climate change scenarios, rainfall during the winter months is likely to increase by the end of the century, but significant decrease in rainfall during the summer months is expected to offset this increase.

16. According to the available climate change scenarios for Bulgaria, there is a trend toward increased frequency of extreme events and disasters, as demonstrated in frequent occurrences of heavy rainfalls, heat and cold waves, floods and droughts, hurricane winds, forest fires, and landslides.

Figure 3. Precipitation per year for 1961–1990 (A); Precipitation per year for 2080, according to the pessimistic scenario (B)



Source: NIMH-BAS.

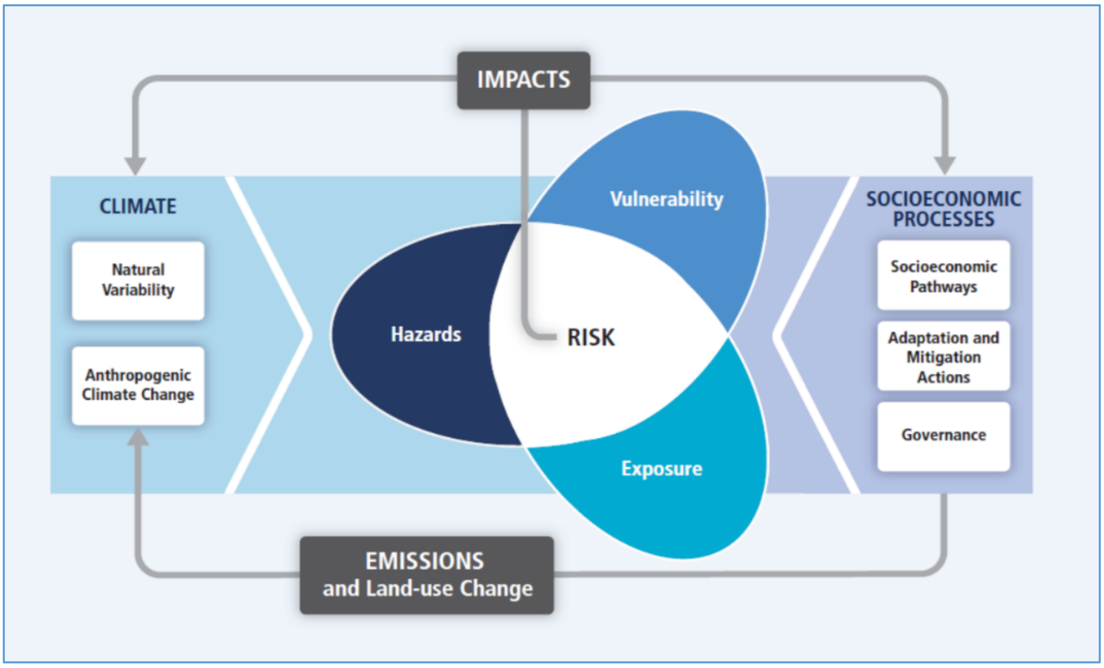
17. Biodiversity, land and aquatic ecosystems, as well as water resources, agriculture, and forestry sectors are expected to be affected by the anticipated changes. These changes would further affect society and its citizens as well as the economy as a whole.

18. Climate change impacts do not affect all people and territories equally due to different levels of exposure, existing vulnerabilities, and adaptive capacities. The risk is greater for the segments of the society and businesses that are less prepared and more vulnerable.

19. **This report aims to inform on vulnerabilities to the Bulgarian water sector and identification of adequate climate change adaptation options.** The report is part of a set of nine sectoral assessment reports considered under the climate adaptation support program for Bulgaria, which will form the baseline for the National Climate Change Adaptation Strategy and Action Plan (NCCAS). The report follows the general logic and structure as proposed for all sectors and is divided into three parts: a) part one of the report (Chapter 1) focuses on the climate change risks and vulnerabilities' assessment; b) part two comprises a gap analysis of the policy, legal and institutional context (Chapter 2); and c) part three focuses on the identification and prioritization of adaptation options (Chapter 3). This sector assessment was carried out during March – November 2017, as a combination of quantitative and above all, qualitative analysis. Several workshops have been organized as part of an ongoing consultation process, bringing in the wealth of expertise of various stakeholders.

20. **The report uses the terms and definitions of risk, vulnerability and adaptation options as introduced by Working Group II** (WGII), **Assessment Report 5** (AR5) (IPCC 2014). Risk of climate-related impacts results from the interaction of climate-related hazards with vulnerability and exposure. Changes in both the climate system (left side in ***Figure 4***) and socio-economic processes, including adaptation and mitigation (right side in ***Figure 4***) are drivers of hazards, exposure, and vulnerability. This understanding reveals the importance of the adaptation options. When they are properly identified and implemented on time, vulnerability, hazards and/or exposures will be reduced, thus mitigating risk.

Figure 4. General concept of WGII AR5



Source: IPCC 2014.

21. As a European Union (EU) Member State, Bulgaria's water resources are managed according to the EU Water Framework Directive (WFD),[2] the EU Floods Directive,[3] and other EU environmental policies. The WFD does not refer to the notion of 'water sector'. It defines water bodies including surface water and groundwater, and it identifies water services, which provide for households, public institutions, or any other economic activity. Accordingly, the Water Act[4] in Bulgaria defines water services as "*all services which provide water for households, public institutions or any economic activity, through water abstraction, impoundment, storage, treatment and distribution of surface waters or groundwaters, as well as waste-water collection, removal and treatment through treatment facilities which subsequently discharge into surface water bodies*". Bulgaria's water service sector provides water to four major areas of economic activity:[5]

[2] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, 23 October 2000, http://ec.europa.eu/environment/water/water-framework/index_en.html

[3] Directive 2007/60/EC on the assessment and management of flood risks, 26 November 2007, http://ec.europa.eu/environment/water/flood_risk/.

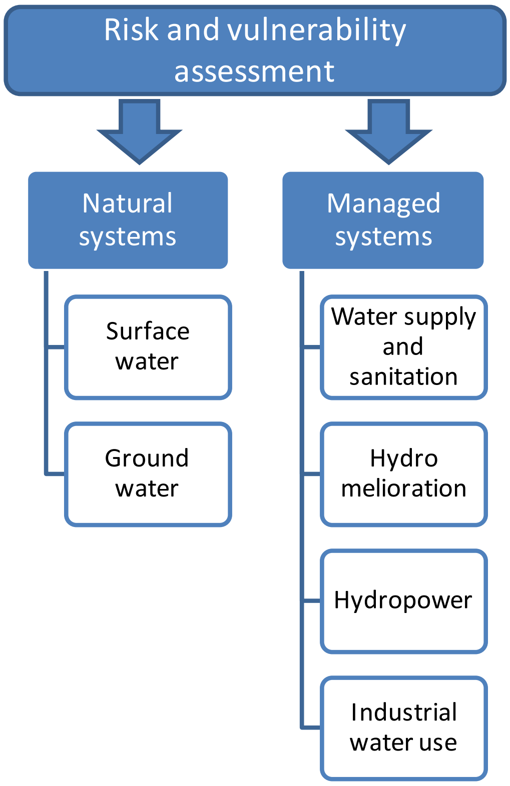
[4] Water Act of the Republic of Bulgaria (last amended on July 18, 2017).

[5] National strategy for management and development of the water sector in Bulgaria, 2012.

- Water supply and sanitation (urban water supply and sewerage systems);
- Hydro-melioration (irrigation, drainage and protection from harmful effects of water);
- Hydropower systems and facilities (technical operation and maintenance of dams and hydropower facilities); and
- Fisheries and aquaculture.

22. The first three subsectors have been established historically. The fisheries ad aquaculture subsector emerged more recently addressing the requirement of the EU-harmonized legislation. It is not a subject of this report, but of the sector report for agriculture. There is no distinct subsector for industrial water use. Depending on the industrial sector, needs are met by one or another operator of the first three subsectors in the list mentioned earlier. There are no distinct subsectors for water use for sport, recreation, and medical treatment as well.

Figure 5. Water-related systems, subject of the assessment



Source: World Bank design.

23. The WFD is grounded on the basic principle that "*Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.*" Therefore, development of a climate change adaptation (CCA) strategy requires not only managed systems of the water sector to be analyzed (***Figure 5***). The report also addresses natural water systems (***Figure 5***). A risk and vulnerability assessment of these two types of systems is presented in Chapter 1. Integrated water management, as an aspect of key importance, is discussed in Chapter 2 together with other water-related policies. Based on the analyzes in the first two chapters, Chapter 3 suggests adaptation options.

24. The National Strategy for Management and Development of the Water Sector 2012 (Water Sector Strategy) provides the most comprehensive recent analysis of the entire water sector. However, the document clarifies that the necessary information for carrying out thorough and credible analysis is not always available due to various reasons such as lack of regular and detailed monitoring, non-systematic database, ownership of the information by several institutions, and so on. The characterization of the water sector, done in the current report, faced the same problem. Although a variety of sources has been reviewed and used, in a number of cases, insufficient or contradicting information was detected. The authors of this report believe that despite this information barrier, the conclusions are based on a sufficiently solid background.

Chapter 1. Risk and Vulnerability Assessment and Analysis

1.1 Sector Characteristics and Trends

1.1.1. Natural systems: availability, quality, and use

25. Unlike other sectors, the water sector is fully reliant on the availability of a resource, which by nature is most susceptible to variation and uncertainty. Bulgaria's total long-term annual renewable water resources amount to 21.3 km^3, of which 20.4 km^3 is accounted for as surface water and 0.9 km^3 as net groundwater resources.[6] The area covered by surface freshwater bodies accounts proximately 2,000 km^2, which is less than 2 percent of the country's territory.

26. The monitoring of the water resources in Bulgaria is performed by the NIMH-BAS.[7]

27. Bulgaria has four river basin directorates (RBD): Danube River Basin Directorate (DRBD), Black Sea River Basin Directoratte (BSRBD), East Agean River Basin Directorate (EARBD) and West Agean River Basin Directorate (WARBD) (***Figure 6***).

Figure 6. Geographical map of Bulgaria with boundaries of the river basins

Source: https://www.bsbd.org/bg/zanas_2538712.html.

28. The overall Freshwater Exploitation Index shows that since 1990 there has been no stress on the Bulgarian aquatic ecosystem. Compared to other European countries, Bulgaria has relatively significant **freshwater resources**, both in absolute terms as well as on per capita basis (MoEW and EEA 2016). However, the water resources are unevenly distributed throughout the country and by season. If broken down by river basin district, it becomes apparent that the

[6] Food and Agriculture Organization of the United Nations (FAO) Aquastat 2017.
[7] http://www.meteo.bg

renewable water resources are unevenly distributed (***Table 1***). Two-thirds of surface water resources are generated in the East Aegean and Danube River Basin District, with 36 percent being generated in the East Aegean and some 33 percent in the Danube River Basin District. With nearly 19 percent, a significant portion of total runoff is generated in the West Aegean River Basin District, while the Black Sea rivers contribute just slightly over 10 percent.

Table 1. Renewable fresh water resources of Bulgaria by river basin, average multiyear runoff 1981–2015 (million m^3/year)

	Bulgaria	River Basin			
		Danube	Black Sea	East Aegean	West Aegean
Internal runoff	16,175	5,473	1,710	5,943	3,049
Actual external inflow	85,148	84,785	-	-	363
Total renewable fresh resources	101,323	90,258	1,710	5,943	3,412
Groundwater available for annual abstraction	4,793	2,399	423	1,731	240

Source: National Statistical Insttitute – Environment 2015.

29. Regarding the **quality of the water resources,** only nearly a third of surface water bodies meets the objective of a 'good ecological' water status (River Basin Management Plans [RBMPs] 2016–2021). Again, the Black Sea River Basin has the lowest rate – 5 percent.

Table 2. 'Good status' objectives met for surface water bodies

Surface Water Bodies/ River Basin	West Aegean	East Aegean	Danube	Black Sea	At the national level
Overall	183	311	256	205	955
With achieved objectives (number)	60	123	104	10	297
With achieved objectives (perentage)	33	40	41	5	31

Source: RBMPs 2016-2021.

30. In all river basins the most common causes for failure to achieve a good ecological status are increased nitrogen and phosphorus concentrations, and high eutrophication of water. Discharge of untreated or insufficiently treated municipal wastewater, discharge of insufficiently treated industrial wastewater, and farming activities are the common reasons of surface water body pollution. There are some specific pollutants for each river basin, which is the reason for not achieving a good chemical status (***Table 3***).

Table 3. Specific pollutants with concentrations above the limits

Surface Water Bodies/ River Basin	West Aegean	East Aegean	Danube	Black Sea
Pollutants	Cadmium, nickel and lead	Cadmium, lead, nickel and mercury	Nickel, cadmium trichloromethane	Mercury

Source: RBMPs 2016–2021.

31. Groundwater bodies perform better than surface water bodies. At the national level 63 percent (106 of total 169) meet the objective of 'good status' (described in Article 4 of the WFD and in Section 5 of the RBMPs).

Table 4. 'Good status' objectives met for groundwater bodies

Groundwater Bodies/River Basin	West Aegean	East Aegean	Danube	Black Sea	At the national level
Overall	38	41	50	40	169
With achieved objectives (number)	32	23	28	23	106
With achieved objectives (percentage)	84	56	56	58	63

Source: RBMPs 2016–2021.

32. In the Black Sea River Basin, 17 water bodies were classified as having 'poor status' due to excessive levels of the following parameters: nitrates, orthophosphate, ammonium ions, sodium, chlorides, calcium, magnesium, manganese, iron, and conductivity. In the East Aegean River Basin, 18 groundwater bodies were classified as having poor chemical status due to higher concentrations of the following indicators: nitrates, ammonium ions, chlorides, sulphates, manganese, iron, calcium, sodium, magnesium, solidity (general), permanganate oxidation, and phosphates. In the Danube River Basins 22 water bodies do not achieve 'good status'. Best performing is the West Aegean River Basin, where only 6 water bodies were classified as having a 'poor status'.

33. About 90 percent of **abstracted water** comes from surface water bodies (***Table 5***). In the period 2007–2015 there was a steady reduction in the volumes of abstracted water. The volumes abstracted from surface water bodies declined more rapidly compared to those from groundwater. This trend is, however, mainly due to the decline of the population, set back in the industry, and destruction of irrigation systems, and not so much due to an increase in water-use efficiency. The observed minimum in 2014 is due to smaller volumes used for irrigation because of higher precipitation.

Table 5. Abstracted water by water sources (million m^3)

Abstracted water	2007	2008	2009	2010	2011	2012	2013	2014	2015
Surface water	5,560.02	5,809.64	5,536.46	5,403.39	5,840.35	5,149.44	4,910.18	4,828.72	5,070.75
Surface water including dams	2,434.73	2,370.30	2,356.80	2,253.24	2,544.49	2,289.54	2,349.21	2,164.48	2,423.17
Groundwater	641.77	615.75	584.27	556.70	544.74	565.61	558.04	546.84	558.35
Return water	1.86	29.58	5.57	9.10	30.36	20.49	9.11	16.40	1.25
Total abstracted fresh water	6,201.78	6,425.39	6,120.73	5,960.09	6,385.10	5,715.05	5,468.22	5,375.56	5,629.11

Source: NSI 2016.

34. Distribution of water use by sectors for the period 2010–2015 is presented in ***Table 6.*** The biggest share of water use is assigned to industry – 87 percent, followed by agriculture and

irrigation – 7 percent and for domestic water supply – 6 percent. There is a huge volume used for energy, but the net consumption (the difference between abstracted water and water not returned to the source) is low. For irrigation, this is the opposite. This is the net consumption that counts to evaluate water scarcity. If water for cooling in energy generation is excluded, industry will have 51 percent, followed by irrigation (27 percent) and domestic water supply (22 percent).

Table 6. Water use by economic activities 2010–2015 (million m³)

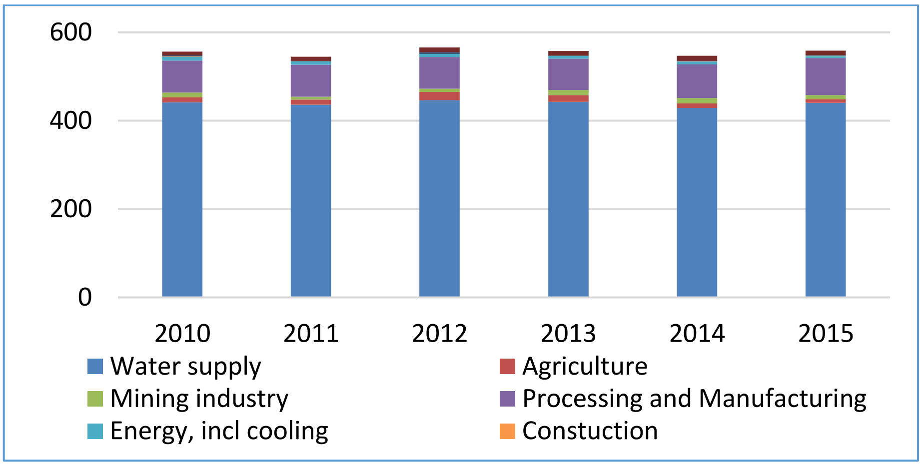
Economic activities	2010	2011	2012	2013	2014	2015
Water use total	4821.28	5177.77	4559.42	4477.32	4505.68	4735.50
Agriculture, forestry and fishing	308.90	348.43	295.83	296.15	289.25	359.59
• **including for irrigation**	283.28	322.46	261.57	269.27	258.32	316.38
Industry	4180.40	4496.80	3926.93	3840.80	3887.18	4036.66
• **including for cooling in energy generation**	3507.43	3795.32	3283.96	3181.92	3236.75	3686.38
Households	264.35	266.33	271.01	260.73	250.71	258.64

Source: NSI 2016.

35. At the river basin level, water use by economic activities is presented in ***Annex 4***.

36. **Groundwater** is abstracted mainly for water supply (79 percent), followed by water for the processing industry (15 percent). The other economic sectors have a share of 6 percent (***Figure 7***).

Figure 7. Abstracted groundwater by sectors in 2010–2015



Source: NSI 2016.

37. Bulgaria has a significant stock of hydraulic storage capacity, including 216 large dams. The total storage capacity of 53 multi-purpose and significant dams amounts to 6,697.8 million m^3. Twenty-three dams are in the East Aegean region, representing a total storage volume of 3,105.5 million m^3. The main purpose of reservoirs is to store water for irrigation, electricity generation, drinking and industrial water supply including cooling, transport, fish farming, and recreation. The dams have an important function in river flow regulation. There are also many smaller dams, not listed in Annex No. 1 to Article 13, of the Water Act (***Table 7***).

Table 7. Smaller dams, not listed in Annex No. 1 to Article 13, of the Water Act

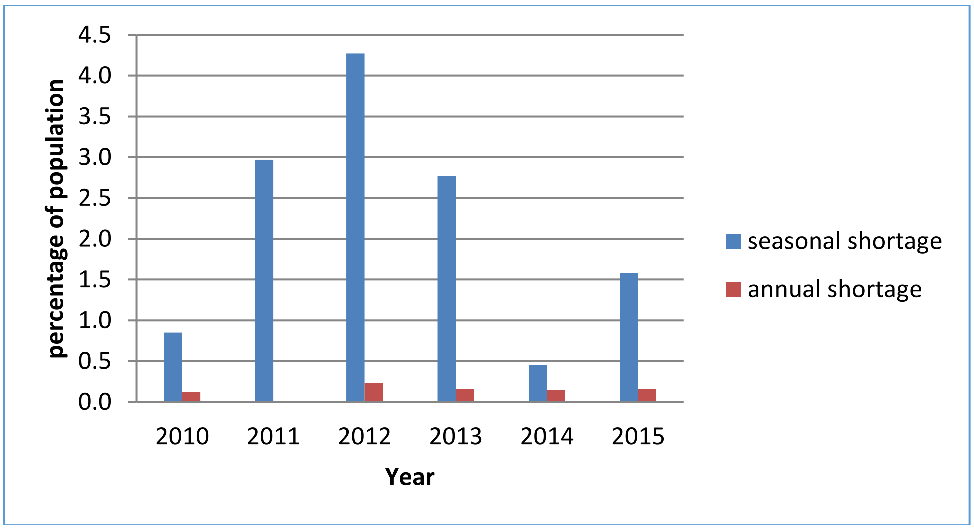
RBD	Number	Storage Volume (million m^3)
Danube RBD	724	444
Black Sea RBD	513	424
East Aegean RBD	1,068	523
West Aegean RBD	431	46

Source: The National Strategy for Management and Development of the Water Sector in Bulgaria 2012.

38. The ratio of storage volumes to the average multi-annual flow discharge in each river basin measures the magnitude of storage. This ratio is the highest for the Black Sea rivers. This indicates that there is no room to build new storage facilities on these rivers as there will not be sufficient runoff to impound them.

39. The positive balance between sufficient available water resources and hydraulic storage capacity, described earlier, could be misleading. They are made at a too large territorial scale (country) and time (year). Considering the uneven distribution of the water resources throughout the country and seasons, a more precise analysis (for example, at catchment territorial scale) is needed to support reliable conclusions. The **seasonal shortage** is illustrated in ***Figure 8***. It shows that the percentage of the population, facing water shortage is rather seasonal than annual.

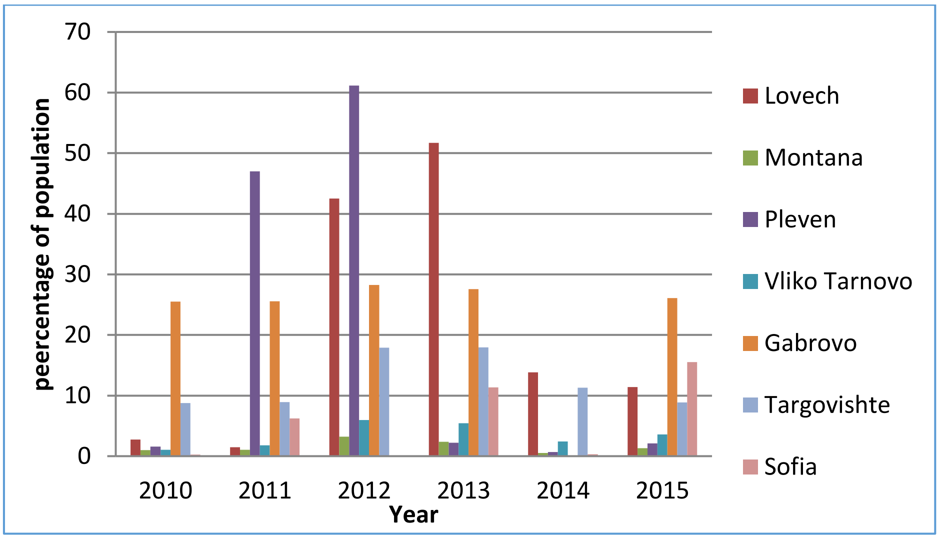
Figure 8. Percentage of the population with water shortage



Source: NSI 2016.

40. Regarding **geographical distribution**, there are several districts, which suffer from water shortage (regular interruption of water supply) in the last years (***Figure 9***).

Figure 9. The top seven districts with regular water shortage



Source: NSI 2016.

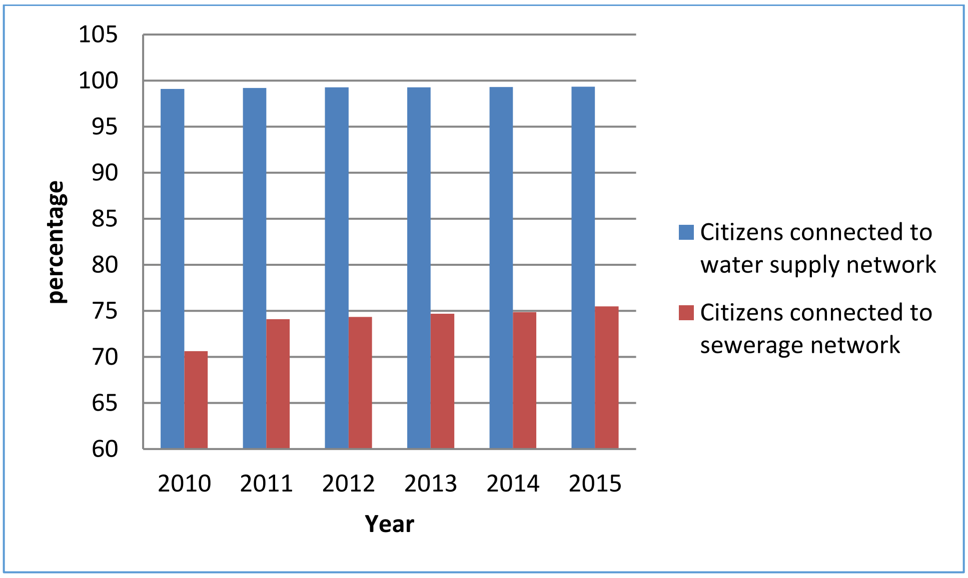
41. ***Figures 8 and 9*** illustrate the importance of seasonal and territorial considerations, when conclusions are to be made.

1.1.2. Managed systems

Water supply and sanitation

42. The subsector 'water supply and sanitation' is the most dynamically developing subsector in the last years, mainly due to the funds of the Operational Programme Environment (OPE). Nearly 100 percent of the population has centralized water supply and the connection to sewerage systems constantly grows (***Figure 10***).

Figure 10. Connection rates to water supply and sewerage systems



Source: NSI 2016.

43. The networks have been rehabilitated or extended mainly with OPE funds as shown in the ***Tables 8*** and ***9***.

Table 8. Total, new and reconstructed water supply network in Bulgaria

		2010	2011	2012	2013	2014	2015
Total	km	73,529	73,604	73,690	73,670	73,515	74,226
New network	km	99	51	78	51	111	187
Reconstructed or replaced network	km	284	365	425	348	445	590

Source: NSI 2016.

Table 9. Total, new, and reconstructed sewerage network in Bulgaria

		2010	2011	2012	2013	2014	2015
Total	km	10,115	10,278	10,312	10,463	10,518	10,835
New network	km	130	96	46	20	31	179
Reconstructed or replaced network	km	4	4	36	19	6	70

Source: NSI 2016.

44. However, the percentage of the new/rehabilitated networks in the period 2010–2015 is very low – 3.6 percent for the water supply network and 5 percent for the sewerage network. Significant progress is observed with the construction of wastewater treatment plants (WWTPs). The latter have doubled (mainly due to the funds of the OPE) – from 79 in 2010 to 163 in 2015 (NSI 2016).

45. The Water Sector Strategy concludes that the major part of the existing water supply and sewerage network was constructed before 1980. Overall, both the networks have not been adequately maintained, regularly rehabilitated, or renovated. As a result, they are overage and outside their technical period of operation.

46. A recent analysis of the water supply and sanitation (WSS) infrastructure and services was performed by the World Bank, aimed at benchmarking the performance of the participating water operators, using 2015 data. The main issues identified in the study, which are relevant to the subject of the current report, are shown in ***Table 10***.

Table 10. Quantified malfunctions of the water supply and sanitation systems with relevance to climate change mitigation and adaptation based on the benchmarking study of 21 water operators in Bulgaria with data for 2015

Quantified Malfunctions 'Water Supply Systems'
• The number of the water pipe failures per 100 km pipe is more than five times higher than in Western European countries. • The percentage of the rehabilitated network is extremely low (below 2 percent). • Non-revenue water is 57.5 percent (mainly due to water losses) which is three times higher than in Western European countries (19 percent).

Quantified Malfunctions 'Sewerage Systems'
• The percentage of the rehabilitated network is extremely low (below 2 percent). • The number of registered clogging of the sewerage pipes is much higher (293 per 100 km pipe) compared to Western European countries (49.2 per 100 km pipe). • The registered floods due to the sewerage system are 5 per 100 km pipe, which is much higher than Western European countries (1.7 per 100 km pipe). • 29 percent of the required sewerage networks (measured as connected population) is to be constructed – opportunity for appropriate modern storm sewerage systems.

Source: World Bank 2017.

47. Due to the lack of measurements and reliable data – a problem, described in the Introduction to this report, it is not possible to quantify several malfunctions of the water supply and sewerage systems. However, there is sufficient evidence for their existence and magnitude (***Table 11***).

Table 11. Non-quantified malfunctions of the water supply and sanitation systems with relevance to climate change mitigation and adaptation

Non-Quantified Malfunctions 'Water Supply Systems'	
Item	**Evidence**
Energy-inefficient pumps	Comparison with the performance of modern pumps
Higher diameters then necessary (that is, low velocities) in the distribution network	Hydraulic modeling of the systems (Regional Feasibility Studies, 2017)
Outdated water purification plants using old technologies	The year of construction, technological scheme and best modern practices
Lack of modern pressure management	High number of failures due to high pressure

Non-Quantified Malfunctions 'Sewerage Systems'	
Item	**Evidence**
Energy-inefficient equipment (pumps and WWTPs)	Comparison with the performance of modern equipment
High infiltration rate (in many cases above 100 percent of dry weather domestic wastewater flow)	Wastewater flowrate and concentration at the WWTP inlet
Lack of modern flood mitigation storm water systems	Most of the sewerage systems are combined; no equipment for flood mitigation (for example retention reservoirs, wetlands, and so on)
Clogged pipes due to lack of maintenance	Basement stores are flooded during intensive precipitation due to incorrect sewer design.

Source: World Bank 2017.

48. In summary, despite the recent improvements, the infrastructure in the WSS subsector is outdated, as well as designed and operated without climate change considerations.

49. Additional to inadequate infrastructure, the water supply and sewerage subsector faces challenges related to non-implementation of the legally binding integrated approach toward water management. Particularly the failure to take account of the interconnection of water and forests leads to a reduction in available water resources. Cases of deforestation are not rare, even in sanitary protection zones of water sources.

Hydro-melioration

50. The hydro-melioration subsector provides three types of water services.

- Irrigation of agricultural crops;
- Drainage of agricultural land subject to water-logging; and
- Flood protection of agricultural land.

51. This subsector had a stable growth until 1989 when about 50 percent of the agricultural production in the country was from irrigated land. After the transition in 1989, mainly due to the change of land ownership, the equipped area has been reduced to one-third. However, most worrying is that the use of the existing equipment is less than 10 percent during the last decade (Water Sector Strategy). The decline of the hydro-melioration services has resulted in infrastructure, which is overage and outside its technical period of operation.

52. A presentation of the subsector in numbers is as follows (Water Sector Strategy, Hydro-melioration Sector Strategy[8], Irrigation Systems Company):

- Dams: The following state dams are part of the irrigation systems:
  - 22 multi-purpose dams under Article 13, p. 1 of the Water Act
  - 146 irrigation dams
  - Total storage capacity of 3.1 km^3 of water
- 168 irrigation pumping stations
- 6,435 km of open canals and 9,269 pipe networks for irrigation
- The total length of drainage canals is 2,334 km; the total length of field drains amounts to 11,192 km
- Dykes with a total length of 487 km, 253 km of which are along the Danube river
- River corrections of 3,157 km

53. A SWOT analysis, presented in the Hydro-melioration Sector Strategy shows some infrastructure-related weaknesses, which are relevant to the subject of the current report (***Table 12***).

[8] Strategy for the management and development of hydro-meliorations and protection from the harmful impact of waters, 2016

Table 12. Major climate change-relevant weaknesses of the infrastructure in the hydro-melioration subsector

Category of Weakness	Weakness
Overage and outdated infrastructure	Construction of the systems dates back to years
	Insufficient maintainance due to low budget, ownership of tenants, etc.
	Broken or non-functioning pipes, channels and equipment
Low efficiency	High water losses
	Irrigation is used accidently at critical moments, only when rainfall is insufficient
	40–50 percent of the small dams is filled with deposits
Lack of monitoring and management	Delivered water is not measured, but calculated
Lack of information and understanding	Lack of a national inventory with technical parameters of the infrastructure
	Lack of information about municipality-owned infrastructure

54. In summary, the hydro-melioration infrastructure and facilities are either destroyed or in an extremely poor condition. Insufficient maintenance and monitoring related to the engineering safety has created a situation, which poses significant risks to the population, settlements, agricultural land, and the infrastructure. In view of climate change, the probability of these risks increases.

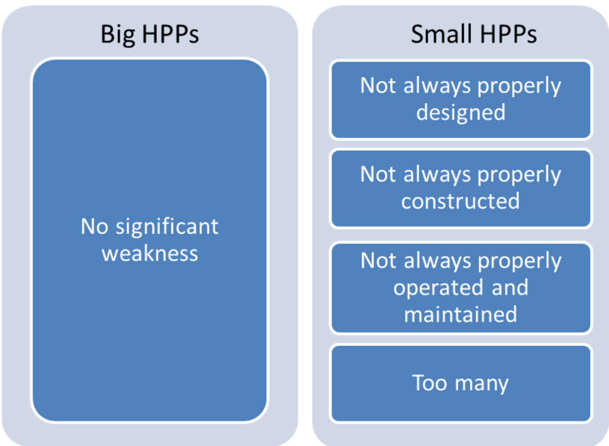
Hydropower systems and facilities

55. Nearly all hydropower systems in the country have been designed, built, and operated as part of multi-purpose hydro systems, meeting the demands of all water users beyond the energy sector (irrigation, drinking and industrial water supply, recreation, fish-farming).

56. In Bulgaria there are 242 major hydropower plants (HPPs) in operation. Their average age is about 30 years. On average, HPPs process between 11 billion m^3 and 22 billion m^3 of water, depending on the year. As of 2010, the number of small HPPs built and in operation in the country is about 110.

57. The Water Sector Strategy identifies several infrastructural problems related to small HPPs (***Figure 11***).

Figure 11. Infrastructure-related problems of HPPs (Water Sector Strategy)



Source: World Bank design.

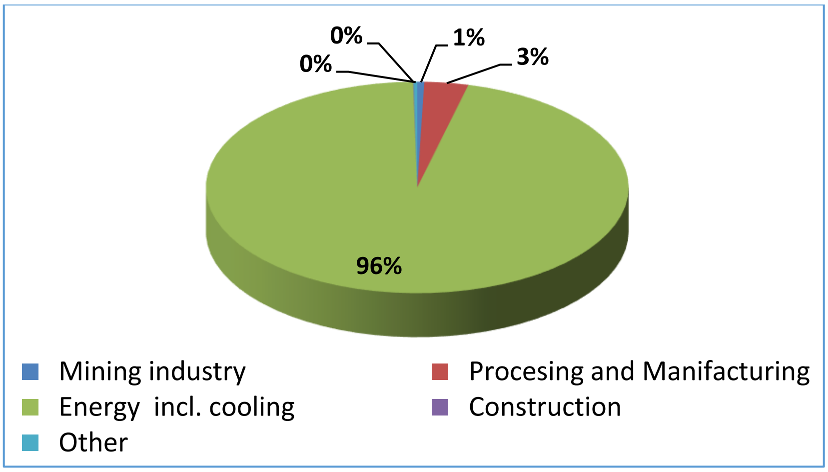
58. ***Figure 11*** shows that, while the major HPPs are maintained and operated adequately, the state of the small HPPs represents a potential safety threat.

59. Hydropower water reservoirs reduce the frequency and scale of damage caused by disastrous flooding along rivers. Proper management of hydropower water reservoirs provides a possibility to reduce damage on water users and water consumers in dry years and on physical assets and population in wet years.

Industrial water use

60. Water is used by industry for a variety of technological purposes – cooling, transport, washing, rinsing, as a reactant, solvent, and so on. ***Table 6*** shows that the industry has the major share among different types of water use in Bulgaria over the last years. However, 96 percent of this industrial water is used for energy generation, including cooling (***Figure 12***).

Figure 12. Average share of water use, by type of industry, for the period 2010–2015

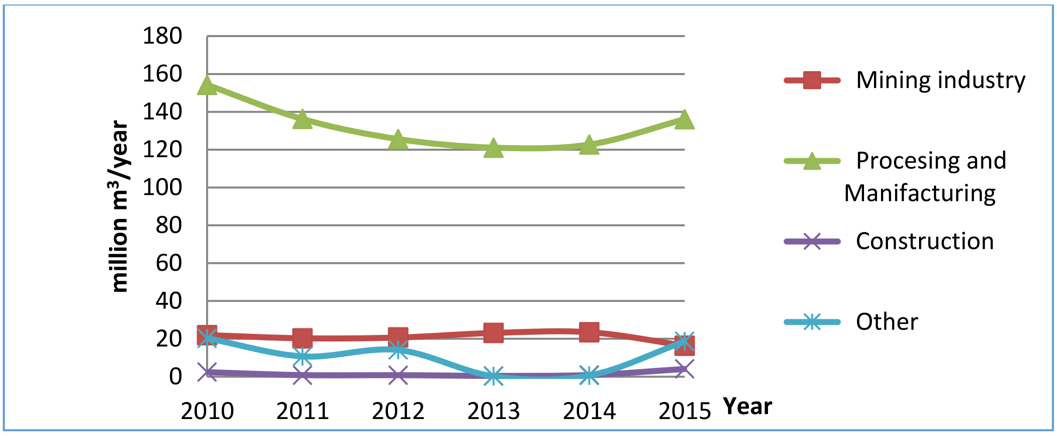


Source: NSI 2016.

61. This subchapter discusses industrial water use excluding energy generation, which was subject of the previous subchapter and does not have a significant impact on water bodies. Cooling does not have a significant impact on water bodies. However, it is very vulnerable to the availability of water and in case of droughts, these industries are at high risk of improper functioning.

62. Industrial water use has two major negative impacts: 1) competing for water (in case of shortage); and 2) deterioration of water quality. The industrial subsector in Bulgaria (except energy and cooling), which during the last decade used the highest quantities of water is 'Processing and manufacturing' (***Figure 13***).

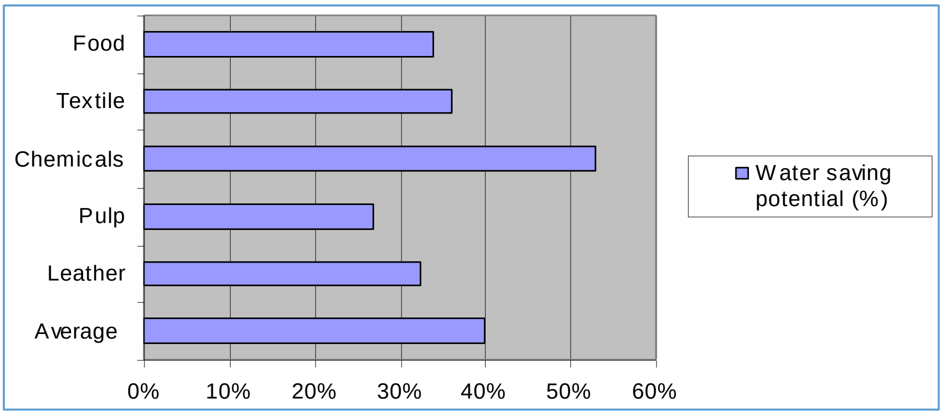
Figure 13. Water use by industry (without energy production and cooling)



Source: NSI 2016.

63. According to the assessment of the European Environment Agency (EEA) at the EU level, this type of industrial use has high potential for saving water (***Figure 14***).

Figure 14. Potential water savings in different industrial sectors



Source: EEA 2001.

64. The assessment, shown in ***Figure 14*** uses the determined Best Available Techniques (BATs) in the framework of the IPPC Directive[9] and the corresponding BAT Reference documents – BREFs[10]. They popularize the best examples of industrial processes with good complex environmental performance and serve also as a benchmark for efficient industrial water utilization and reuse.

65. There are insufficient data to assess the potential for improvement of water efficiency of the Bulgarian industries. The lack of data for profound assessment is a significant problem for the water sector. The main issues regarding industrial water use are the following:

- Water for potable purposes in most cases is not measured separately;
- Water used from groundwater sources located at their site in most cases is not properly measured and controlled;

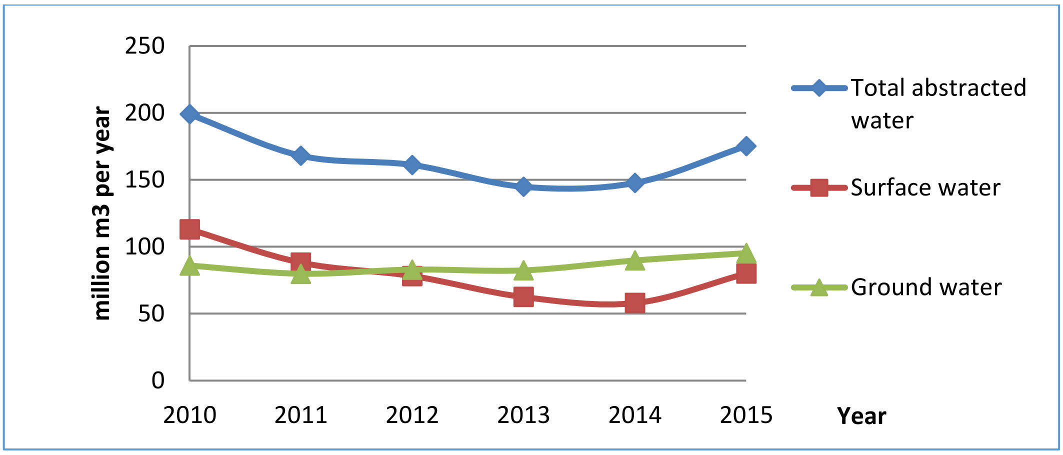
[9] This Directive has in the meantime been replaced by the Industrial Emissions Directive

[10] EC (2008) European Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (Codified version); OJ L 24, 29.1.2008, p. 8–29

- Water discharged to the sewerage system in most cases is not measured; and
- Water quality before discharge into sewerage systems is rarely monitored and only a few parameters are measured.

66. Another important aspect is the type of water source, especially in view of the threat of scarcity. The NSI data shows that in the last decade the abstracted groundwater for industrial purposes has increased (***Figure 15***).

Figure 15. Abstracted groundwater and surface water for industrial use



Source: NSI 2016.

67. The lack of proper measurement and oversight does not allow to conclude if this is due to increased use of groundwater or due to stricter oversight for recording water used from industrial site sources.

68. Considering that groundwater is the main source for domestic water supply, this issue needs to be studied further to understand the reasons for its increase as well as to find appropriate mitigation.

1.1.3. Investment plans and trends

69. The assessment of the capital expenditure carried out under the Water Sector Strategy shows that over BGN 12 billion are necessary to cover the minimum needs of the sector and over BGN 43 billion is necessary to upgrade the sector to achieve more effective use of energy and water.

70. The total investment needed in the water supply and sanitation subsector till 2037 is estimated at BGN 9.65 billion for water supply systems and BGN 4.4 billion for sewerage systems.[11] The sewerage network has not been completed to meet the requirements of the Directive 91/271 of all agglomerations above 2,000 population equivalent (PE). In 2012, the estimation was that about 7,800 km of pipelines need to be constructed, as well as about 200 WWTPs. There are 49 potable water treatment plants (PWTPs) in operation, 7 under construction, 19 in design stage, six pending design and another 10 in need of redesigning. PWTPs constructed during the period 1960–1990 need rehabilitation and modernization. Thirty-five new PWTPs need to be built to provide safe supplies for domestic and industrial

[11] National Water Sector Management and Development Strategy 2012.

needs.

71. In the subsector hydro-melioration, proposed interventions for canal rehabilitation and modernization represent the highest investment need of nearly €605 million. Total investment needed for recovery and modernization of the irrigation infrastructure is more than €979 mln.[12]

72. The national document '*Guidelines on Mainstreaming of Environmental Policy and Climate Change Policy in CP, CAP, and CFP Funds 2014–2020*' identifies thematic objectives required for better water management to achieve and maintain a good ecological status, higher efficiency of the resources and to address climate change effects supported by funding through the Operational Program in the 2014–2020 programming period. They are as follows:

- Construction of water supply and sanitation (WSS) infrastructure, in compliance with the Resource Efficiency Road Map and the Blueprint to Safeguard Europe's Water Resources – wastewater treatment, drinking water treatment, WSS network, and incoming water mains and pumping stations – in agglomerations **above** 2,000 PE;
- Construction of WSS infrastructure – network, incoming water mains pumping stations, drinking water treatment and wastewater treatment – in case of constructed sewerage networks in agglomerations **below** 2,000 PE;
- Reduction of water consumption and losses, solving existing or future water scarcity problems:
  - Measures to reduce water losses from hydro-melioration systems
  - Measures to improve and restore the irrigation infrastructure, and
  - Measures to drain irrigable areas
- Construction/ rehabilitation/ reconstruction of sludge treatment facilities from WWTPs and provision of the necessary equipment, including already constructed WWTPs, with priority on improving their quality indices, in view of their subsequent use for energy purposes (as fuel from biomass);
- Planning, design, and construction of a water monitoring system, including investment in equipment;
- Flood prevention/protection:
  - Implementation of Flood Risk Management Plan (FRMP) investment measures on a basin principle (for example, green infrastructure, drainage systems, protective equipment along the rivers, river corrections).
  - Planning, design, and construction of early warning systems and information systems, including improving flood risk projection;
- More efficient water use, including eco-innovations, new water technologies, and methods for status assessment, monitoring and management, water treatment; and
- Creation of information systems and systems introducing modeling in water management, including models for projection and assessment of water amounts and projection of floods and drought.

[12] Common strategy in the sector of Hydro-melioration and protection against the adverse impact of water.

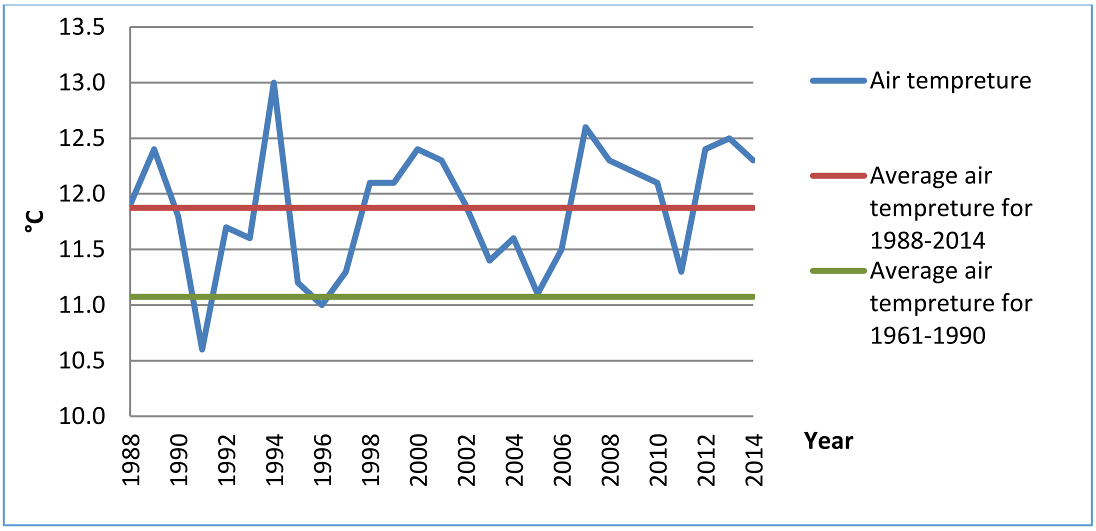
1.2 Past and Present Weather Events and their Consequences and Response Actions in the Sector in Bulgaria

1.2.1. Past and present weather events and trends

73. Several official documents and publications have been reviewed to find well-grounded information about past weather events, as well as the weather trends in Bulgaria (NIMH-BAS, Bulgarian Executive Environmental Agency, and so on). It was found that the availability of data related to climate-change is like the situation with water-sector related data (Raichev & Dimitrova 2016). In general, information is scarce, some conclusions are not supported by data, or data analyzes are not supported by a description of the way they were processed. Because of the latter, the information presented in this subsection will be discussed considering its uncertainty.

74. **Temperature anomalies and trends** are indicators often used when the manifestation of climate change is analyzed. Despite different approaches and values, most of the reviewed documents report an **increase of air temperatures during the past 20–30 years compared to the reference period 1961–1990**. For example, the Bulgarian Executive Environmental Agency published information that in the period 1988–2014 the diurnal annual air temperature for the altitude below 800 m had increased by 0.8°C in comparison with the reference period 1961–1990 (***Figure 16***).

Figure 16. Temperature move in the period 1988–2014 [13]



Source: Bulgarian Executive Environment Agency.

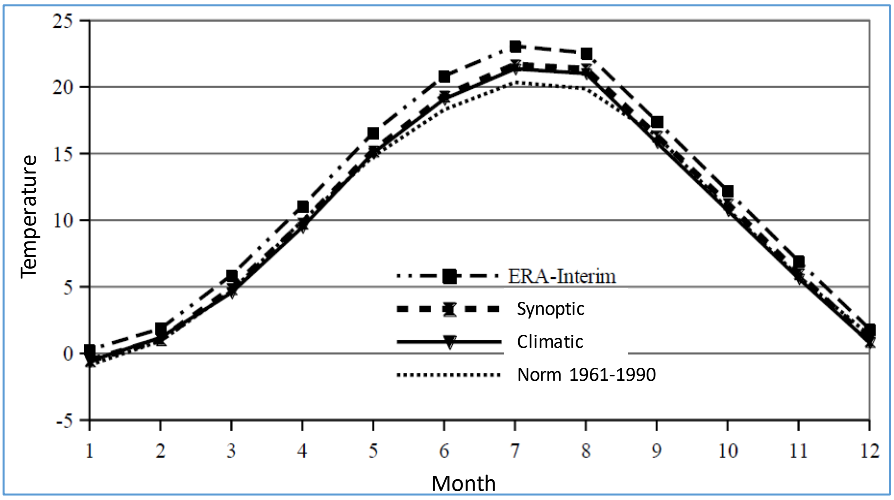
75. A research publication reports that the increase in air temperature was most significant in the summer months (***Figure 17***).

76. **Precipitation anomalies and trends** are other indicators for climate change manifestation. Raichev and Dimitrova (2016) state that due to the uneven distribution of rainfall events, not all data are public, and because some data were found to be incorrectly measured, it was not possible to do a credible analysis at the country level. Thus, they based their analysis on single meteorological stations. The main conclusion in their study is that there is a trend of

[13] Bulgarian Executive Environment Agency, http://eea.government.bg/bg/soer/2014/climate/climate0

decreasing of rainfalls in summer and autumn, while in spring and winter, there is rather an increase than a decrease. But as an average, on an annual basis, the trend is close to zero.

Figure 17. Monthly data for the air temperature in the period 1995–2011 (synoptic and climatic), compared with ERA-Interim data and climatic norms for 1961–1990

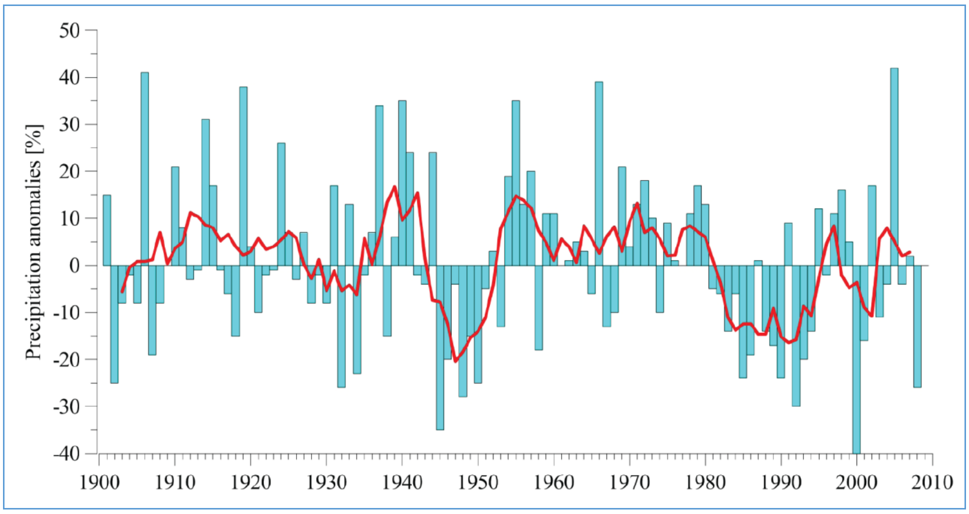


Source: Raichev and Dimitrova 2016.

Note: ERA-Interim is a global atmospheric reanalysis from 1979, continuously updated in real time

77. The anomalies of the historic mean annual precipitation in Bulgaria are recorded by the NIMH-BAS (***Figure 18***). Drier and wetter months appear throughout the entire period.

Figure 18. Anomalies of historic mean annual precipitation in Bulgaria.



Source: NIMH-BAS 2014. Note: Bars: measure: precipitation anomalies compared with period 1961–1990; and red line measures the moving average.

78. ***Figure 18*** shows that, in this long period, dry and wet years alternated. More recently, there were two years with clear and extreme anomalies – the driest year 2000 and the wettest year 2005 (with the most severe recorded floods as well). Thus, Bulgaria has experienced droughts and floods, which occur in some time intervals.

79. During the 20th century Bulgaria witnessed three distinct periods of drought, which hit the country severely: 1902–1903; 1942–1953 and 1982–1994. With regard to the latter, low rainfall started in 1982 in eastern and southern Bulgaria. While average precipitation declined to 90 percent of what normally was observed, runoff dropped to 75 percent of the mean annual discharge. The drought continued throughout the 1990s. River discharge rates declined and water levels in multi-annual reservoirs dropped drastically. The years 1993, 1994 and 2000 have been recorded as the driest years in the history of Bulgaria. River discharge rates dropped down to 43 percent in 1994 and 41 percent in 2000 respectively. During 2011, southern Bulgaria also experienced a sustained dry period, with water levels of large rivers reduced by more than 75 percent.

80. Over the last 20 years Bulgaria was hit by several major floods, of which the floods in the summer of 2005 were the most devastating. Some of the worst floods in recent years are listed in ***Annex 5***.

1.2.2. Consequences and response actions in the sector in Bulgaria

81. The NSI provides data on the impaired water sector infrastructure, because of the floods that hit the country in the corresponding years (***Table 13***).

Table 13. Impaired infrastructure

Infrastructure	Unit	2004	2005	2006	2007	2008
Reservoirs (dams)	m^2	102.0	124.2	0.8	0	0.2
Dykes	km	5.3	726.,1	166.7	8	19.5
Barrages	m	27.0	3,608	300.4	500	61
Buttress walls	m^2	8,997.3	13,608	12,304	3,387	4,680
Pumps, catchment, pumping and purification stations	number	7	41	0	0	0
Pipelines of local water supply networks	km	4.4	47.6	351.2	96	1.8
Pipelines of local sewage networks	km	15.5	826.1	0.3	7	0.5
Embankment dam walls (length)	m	-	1,005.7	204	300	-

Source: NSI 2018.

82. The statistics in ***Table 13*** cover the period 2004–2008. More recent statistics are not availabe on the NSI website. The numbers in ***Table 13*** show that the most significant damage was recorded in 2005, which corresponds with the analysis of the anomalies showing the most severe floods in the same year (***Figure 18***).

83. Although there is available data of the past flood events, essential data needed to conduct a thorough analysis of the causes and consequences of floods, is lacking, such as the following:

- Reasons for the floods – intensive rains or lack of appropriate flood mitigation measures, poor condition of existing structures, insufficient capacity of the sewerage system or a combination of all these, and so on;
- Damage, expressed in monetary terms;

- Maximum water quantities per flood;
- State of the dykes and the corrections of the rivers;
- State of the dams and the pertaining facilities; and
- Flood protection measures already taken.

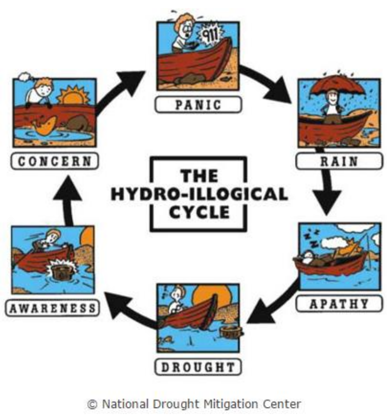
84. The response actions taken regarding floods are more visible at the national (development of FRMPs), than at the local level. It appears that once a flood has gone away and the most serious damage has been recovered, the efforts of the responsible authorities are redirected to other duties. Cleaning of the river-beds is one of the examples. In 2005, stratified riverbeds and overgrown river banks were one of the main reasons for magnifying the impact of the intensive rainfalls.

85. Flooding due to insufficient capacity of the sewerage system is another reason for damage in urbanized areas. In some cases, flooding is a reason for subsequent landslides. Appropriate drainage/storm collection systems can mitigate both the impact of floods and landslides. So far, no other response measures than cleaning after the flood have been taken. The capacities of the sewerage systems to mitigate flood effects have not been assessed. Landslides-prone areas have not been prioritised for construction of appropriate storm/drainage systems. There are no up-to-date design values for rain intensities. Long-lasting mitigation measures (like wetlands, green roofs, pervious parking lots, and so on) are not in use in the country.

86. A good example for appropriate response measures is the adequate operation of large dams to prevent flooding due to huge overflows. A new Ordinance was adopted in 2016 for safe operation of dams.[14]

87. Regarding the response to drought events, after the crisis in 2000, the government adopted a '*Program for the necessary measures under the conditions of droughts'*. It was not implemented, because soon after the dry year of 2000, climatic conditions changed, and wetter years came. It seems that the country follows the hydro-illogical behavior mode (***Figure 19***), which was identified in 1990 by the national drought mitigation center of Nebraska, United States of America.

Figure 19. The hydro-illogical cycle[15]



[14] Regulation on the Terms and Conditions for the Technical and Safe Operation of the Dams and the Pertianing Facilities, and the Control of their Technical Condition

[15] http://drought.unl.edu/Planning/HydroillogicalCycle.aspx

1.3 Sector Related Climate Change Risks and Vulnerabilities

88. This chapter assesses the risks and vulnerabilities of the water sector based on the current state, described in the previous chapters, as well as projections of climatic and non-climatic factors. The time horizon for this risk assessment is 2050. It should be noted that projections always carry some uncertainties.

1.3.1. Major driving factors and their projections

Climatic factors

89. The main climatic drivers, which determine the availability of freshwater resources, and thus affecting the water sector, are precipitation and potential evapotranspiration (IPCC 2014). These factors, however, depend on a combination of other factors, such as temperature, atmospheric water vapor content, atmospheric carbon dioxide (CO_2), and so on. This climatic complexity with several interrelations and interdependences is one of the main reasons for the uncertainty in climate modelling. Nevertheless, scientists are developing, using and improving climate models.

90. The latest national climatic modeling for the territory of Bulgaria simulates two climatic parameters: mean temperatures and precipitation over future time horizon. The period 1976–2005 is used as a reference period. Two IPCC AR5 Representative Concentration Pathway (RCP) scenarios – 'moderate' RCP4.5 and 'pessimistic' RCP8.5 – are run with the ALADIN 5.2 model. The results are summarized in ***Table 14***.

Table 14. Projected values for temperature and mean diurnal amounts of precipitation for Bulgaria

Parameter	Period	RCP4.5	RCP8.5
Temperature	2021–2050	Increase by approx. 1°C	Increase by 1.3°C to 1.5°C
Mean precipitation	2021–2050	Increase by 2.71 percent	no data

Source: Final Report under the implementation of a contract on: 'Assessment of Pressures and Impacts oc Climate Change on Surface and Groundwater and Evaluation of Water Availability for the Economic Sectors' 2016.

Note: The changes are compared to the reference period 1976–2005; The ranges are because of the different values at river basin level.

91. Regarding temperature, despite the two scenarios providing different values, they firmly envisage a slight **increase** until 2050. However, more worrying is the projection of the seasonal values. The expected increase is most pronounced in the summer months.

92. ***Table 14*** shows that an increase is projected for the mean precipitation. Overall, this is not a threat by itself. More worrying is the projected change of the distribution and intensity of precipitation with a decrease in the summer and an increase in autumn, as shown in ***Table 15***.

Table 15. Seasonal projections for the precipitation

Parameter	Period	RCP4.5	RCP8.5
Summer precipitation	2021–2050	12 percent decrease	2 to 11 percent decrease
Autumn precipitation	2021–2050	12 percent increase	21 to 27 percent increase

Source: Final Report under the implementation of a contract on: 'Assessment of Pressures and Impacts of Climate Change on Surface and Groundwater and Evaluation of Water Availability for the Economic Sectors' 2016.

Note: The changes are as compared to the reference period 1976–2005; The ranges are because of the different values at the river basin level.

Water availability

93. The most recent report about projected water availability is the '*Assessment of Pressures and Impacts of Climate Change on Surface and Groundwater and Evaluation of Water Availability for the Economic Sectors'* (2016). However, it provides more data for the period 2070–2100 than 2021–2050. That is why, both projections will be presented in the following paragraphs.

94. The scarce data for the period 2021–2050 indicate rather an increase than a decrease of the runoff in spring, autumn and winter, mostly around 15 percent as compared to the current resources. No data is provided for summer or on an annual basis.

95. The following might be concluded for the river runoff for 2070–2100 (***Table 16)***:

- Runoff of investigated rivers decreases on an annual basis
- Summer and autumn runoff of investigated rivers decreases significantly

Table 16. Summary of modeled river runoff changes in comparison with the reference period 1976–2005 period (RCP4.5 scenarios, period 2070–2100)

River Basin	Mean Annual Runoff		Spring		Summer		Autumn		Winter	
	From	To	From	To	From	To	From	To	From	To
Black Sea	-16.28	-3.52	no data	no data	-35.13	-14.23	no data	-16.37	no data	no data
Danube River	-23.50	-4.86	33.12	42.33	-44.27	-14.93	-31.10	-17.20	14.78	37.93
East Aegean Sea	-11.68	-3.52	no data	no data	-30.33	-14.23	-31.10	-16.37	no data	no data
West Aegean Sea	-14.60	-1.38	no data	no data	no data	no data	-19.85	-14.02	no data	no data

Source: Final report under the implementation of a contract on 'Assessment of Pressures and Impacts of Climate Change on Surface and Groundwater and Evaluation of Water Availability for the Economic Sectors' 2016.

*Note: The ranges are due to different projections of the runoff by rivers in the corresponding RBD; details are provided in **Annex 6**.*

96. The report provides the following projections of **groundwater**:

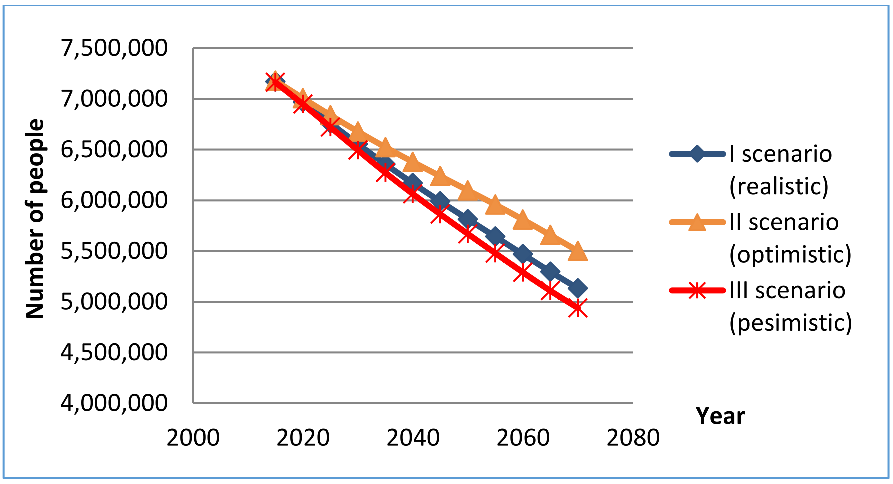
- Changes in quality and quantity of groundwater in Bulgaria will be moderate. Radical (catastrophic) changes should not be expected provided that their use level remains the same.

- No critical depletion of resource of the groundwater bodies is expected. The projection period 2021–2050 signifies a certain increase in groundwater natural resources, primarily due to an upsurge in precipitation. For the next period 2071–2100, a decrease of 10–15 percent at the most, as compared with the current resources, is projected.
- The quality (composition) of groundwater will not undergo substantial change.
- It should be borne in mind that all projections (both regarding climate change and the impacts on water resulting thereof) are modelled for decades ahead and are bound to be inaccurate and uncertain to some extent. Therefore, it is of utmost importance to have adequate regular monitoring in place. Particularly for groundwater, it is crucial to improve and maintain an adequate and well-functioning monitoring network to keep track of water debit, level, temperature and composition. Such a network would help identify potential adverse trends and take duly and on-time water protection measures.

Demographic development

97. Outmigration and low fertility rates in the past have led to a rapidly aging population. Not only the past, but also future demographic development is of great national concern. The three forecasting scenarios – realistic, optimistic, or pessimistic lead to the worrying results of a steep decline in Bulgaria's population (***Figure 20***).

Figure 20. Demographic forecast



Source: NSI 2017.

98. Overall, according to the NSI, the population is expected to shrink from 7.2 million people in 2015 to about 6 million people in 2050.

Economic development

99. The 'Tourism Sector Report' provides an assessment of the major macro-economic indicators (***Table 17*** and ***Table 18***).

Table 17. Major macro-economic indicators

Main parameters	2010	2011	2012	2015	2020	2025	2030
GDP (billion euro)	26.5	27.2	28	31.1	38.5	45.6	52.2
GVA (billion euro)	23	23.2	23.9	26.4	32.9	40.1	47.2
Population (millions)	7.5	7.36	7.35	7.14	6.91	6.68	6.45
Employment (15+, millions)	3.05	3.06	3.07	3.08	3.14	3.01	2.93
Employment coefficient (15+, percentage)	47.2	47.8	48.5	50.2	52.8	51.8	51.6
GDP per person (€)	3,532	3,700	3,815	4,361	5,565	6,823	8,089
GVA per employee (€)	7,539	7,605	7,782	8,546	10,468	13,304	16,124

Source: NSI, forecast by the Ministry of Finance.
Note: GDP = Gross Domestic Product; GVA = Gross Value Added.

Table 18. Growth rates by sectors as a percentage of the GDP

	2011	2012	2010-2015	2015-2020	2020-2025	2025-2030	2010-2030
GVA	0.96	2.82	2.75	4.54	4.02	3.32	3.66
Agriculture	-1.82	2.26	-0.01	1.76	1.17	0.49	0.85
Industry	4.07	2.35	3.03	4.35	4.03	3.33	3.68
Mining industry	9.74	3.7	3.64	3.45	3.44	3.10	3.41
Processing and Manufacturing	6.83	2.69	3.84	4.49	4.04	3.35	3.93
Production and distribution of electricity and heat energy and gaseous fuels	9.63	2.61	4.02	3.95	3.93	3.34	3.81
Water supply and Sanitation services, waste management and recovery	9.82	9.33	7.54	6.15	6.53	5.01	6.30
Construction	-10.38	-0.50	-1.18	3.99	3.44	2.75	2.23
Services	-0.35	3.11	2.83	4.77	4.11	3.42	3.78
Trade; vehicle and motorcycle repair	1.31	2.55	3.03	4.51	3.68	3.55	3.69
Transport, storage and mail	1.66	3.12	3.27	5.06	5.16	3.81	4.32

Source: Ministry of Finance

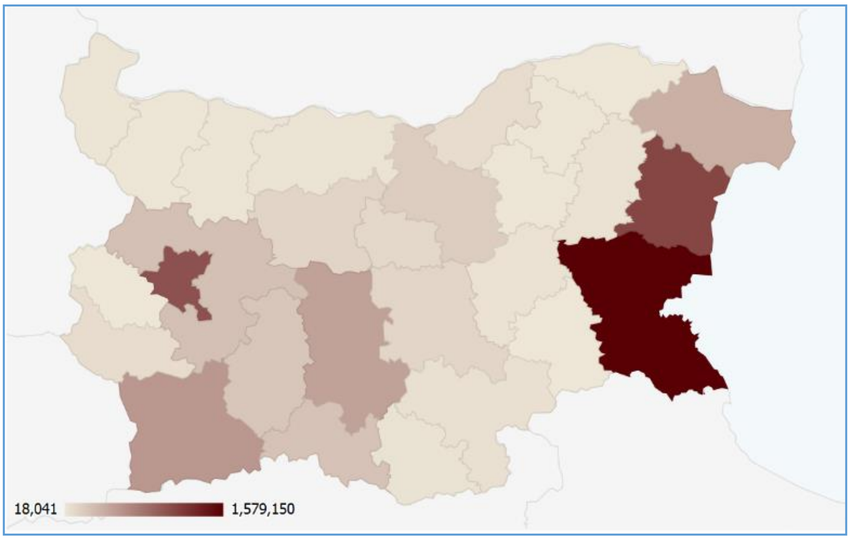
100. The important conclusions arising from these projections in relation to this report are:

- Despite the slightly growing trend, agriculture will continue to be underdeveloped;
- Industry will maintain its current position;
- Services will grow more significantly;
- Water supply, sewerage and solid waste services will decrease as percentage of the GDP.

101. Tourism is part of the 'services sector' and the figures above show that most probably that sector will continue to grow. In 2016, international visitors reached 10.6 million of whom 5.1 million were on holiday.

102. Domestic tourists are estimated at 3.4 million with a trend to increase in the future due to more frequent trips. More than 90 percent of international tourists stay in commercial accommodation on the coast or in mountain resorts for the winter season. ***Figure 21*** illustrates the districts with the highest numbers of tourists.

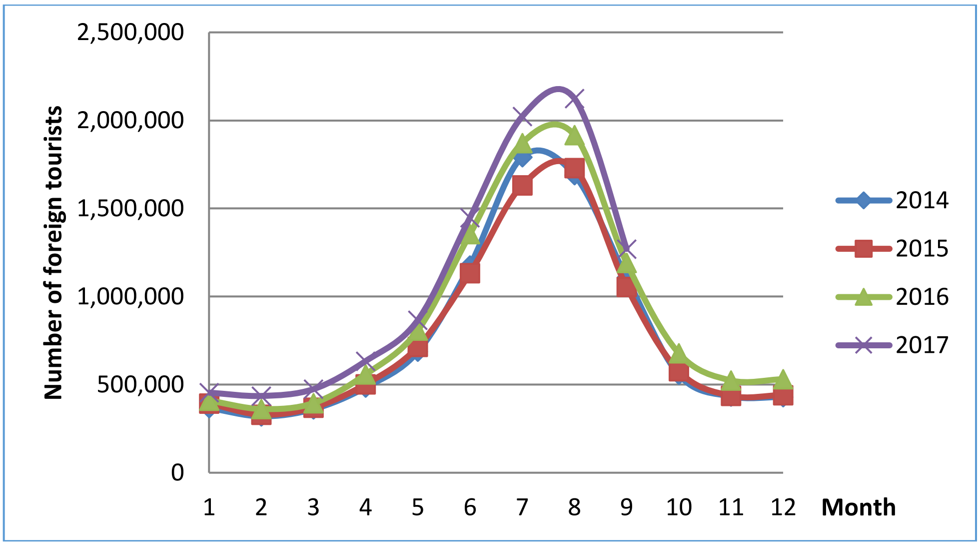
Figure 21. Total number of overnight visitors in 2016



Source: NSI 2017.

103. The tourists increase is in the summer months (***Figure 22***).

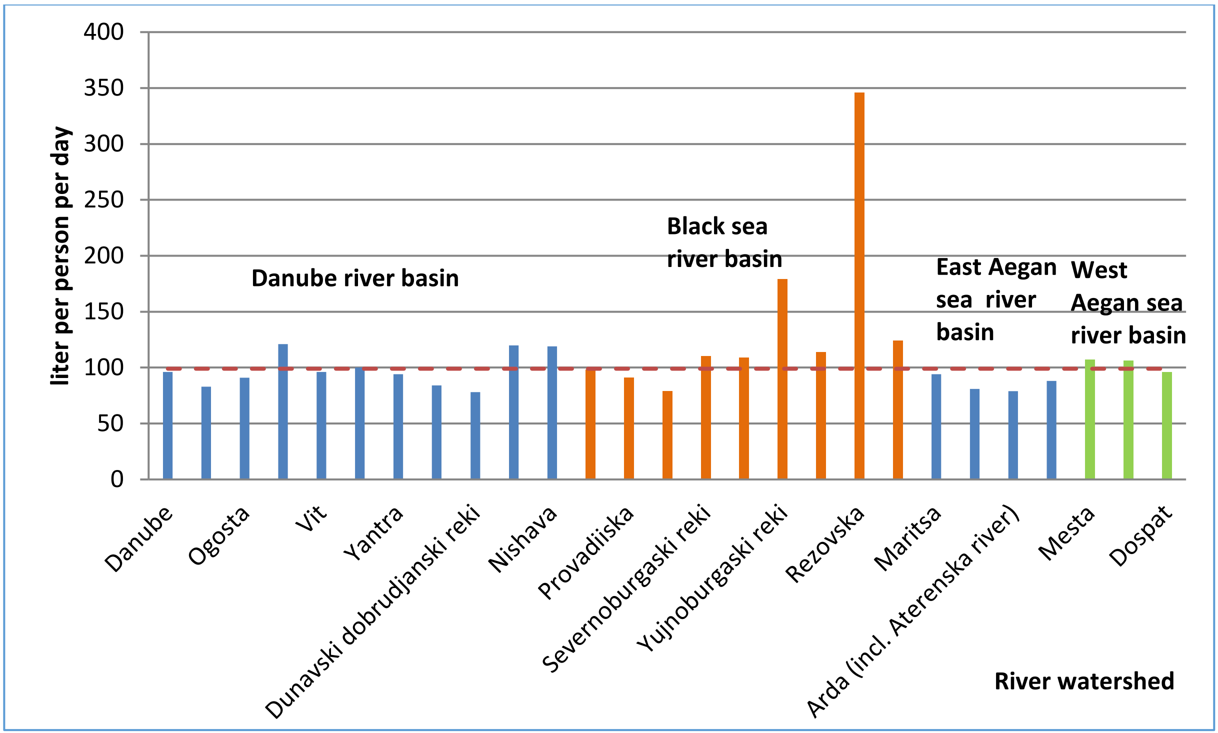
Figure 22. Seasonal dynamics of foreign tourists



Source: NSI 2017.

104. While Bulgaria's population is in decline, the number of foreign visitors is steadily on the rise. ***Figure 21*** shows that the **Black Sea River Basin is the region with the highest number of tourists.** The sheer number of holiday-makers generates a major challenge for the water supply and sanitation sector (***Figure 23***).

Figure 23. Water use per capita per day in 2015



Source: NSI 2017.

105. ***Figure 23*** shows that for some of the rivers in the Black Sea River Basin the water use per person per day has the highest values.

1.3.2. Climate change risks for managed systems

106. The IPCC's definition of risk notes that risk arises from the interaction of climate hazards with exposure and vulnerability to impacts (***Figure 4***).

Identification of the hazards

107. Based on the analyzes, presented in the previous chapters, two **water related hazards** for Bulgaria have high likelihood of occurrence:

- **Floods** – due to projections of higher amounts of precipitation and a change in its distribution and intensity; and
- **Summer droughts** – due to projections of higher temperatures and a decrease in summer precipitation.

Identification of the exposure

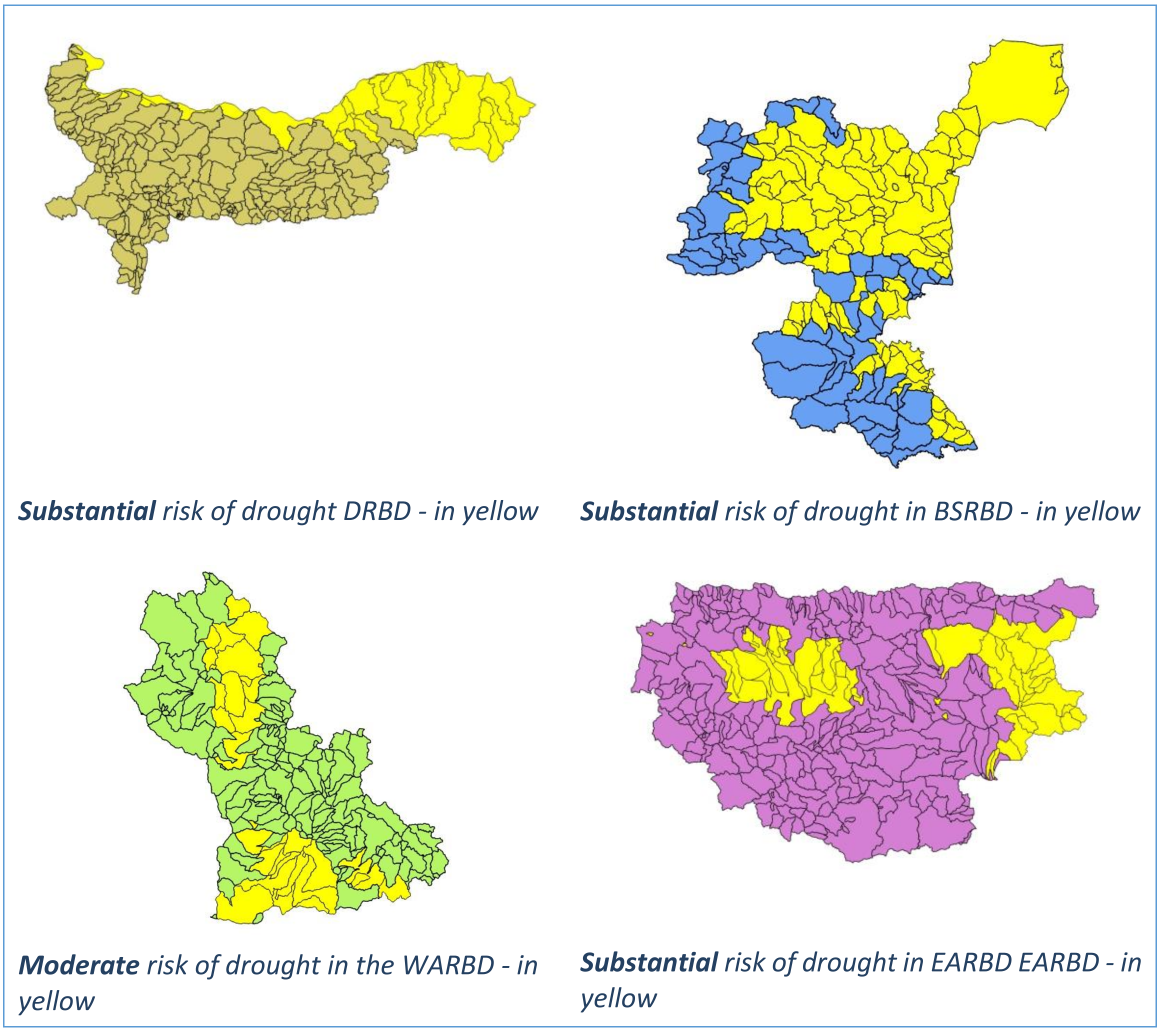
108. Higher mean diurnal precipitation and shift in precipitations from the summer season to autumn or spring will have a negative effect on floods. However, modeling extreme weather events comes with high uncertainty, especially at a local scale. For that reason, floods are considered as a hazard for the entire country. As required by the EU Floods Directive,[16] a preliminary flood risk assessment should be regularly performed to identify areas where potential and significant flood risks exist. Further, flood-hazard maps and flood-risk maps for

[16] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks

such areas must be developed. These maps serve to identify areas with a medium likelihood of flooding (at least a 1-in-100-year event) and extreme events or low-likelihood events, in which expected water depths should be indicated. The Bulgarian RBDs have already fulfilled this task in the FRMPs.

109. Droughts are site-specific, that is, the magnitude of drought differs depending on the combination of local conditions. The 'Assessment of Pressures and Impacts of Climate Change on Surface and Groundwater and Evaluation of Water Availability for the Economic Sectors' (2016) report identifies the river basins with a substantial risk of drought, summing up the scores of three indicators: risk of atmospheric and soil drought, annual runoff module, and percentage of runoff change for the projected period. No maps are available for the period to 2050. Maps are provided for the worst-case scenario – 'pessimistic' climatic scenario RCP 8.5 and the worst period 2070–2100.

Figure 24. Substantial and moderate risk of drought under scenario RCP 8.5 in 2070–2100



***Substantial** risk of drought DRBD - in yellow*

***Substantial** risk of drought in BSRBD - in yellow*

***Moderate** risk of drought in the WARBD - in yellow*

***Substantial** risk of drought in EARBD EARBD - in yellow*

Source: Assessment of Pressures and Impacts of Climate Change on Surface and Groundwater and Evaluation of Water Availability for the Economic Sectors, 2016.

110. The river basins in risk of drought are listed in ***Table 19***.

Table 19. River basins in drought risk under 'pessimistic' climatic scenario RCP 8.5 for 2070–2100

River Basin Directorate	River basins	Level of risk
DRBD	Danube River	Substantial
	Dobrudzha Rivers	
EASRBD	Lower reaches of Tundzha river	
	Upper and middle reaches of Maritsa River	
BSRBD	Kamchia River	
	Provadiyska River	
	Dobrudzha Rivers	
	Lower reaches of some rivers in the Southern part	
WASRBD	Upstream and downstream of Struma River	Moderate
	Upstream of Mesta River	

Source: Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007, on the assessment and management of flood risks.

111. Most affected appears to be the Black Sea River Basin, having the highest percentage of yellow marked river watersheds. Least affected is the West Aegean river basin, where only moderate risk is projected (***Table 19*** and ***Figure 24***)

Identification of the vulnerability

112. If infrastructure is situated ('exposure') in a region where flood/drought ('hazard') will potentially occur, its vulnerability will depend on:

- State and preparedness of the infrastructure;
- Preparedness of the human factor, the operator or user; and
- Availability of the resource (water) so that this infrastructure is operable.

Table 20. Vulnerability of the water sector

Factor	Vulnerability
State and preparedness of the infrastructure	The analysis, performed in Section 1.1.2., shows that the infrastructure of all subsectors (except big dams) is in general overwhelmed, aging and poorly maintained; and therefore, are highly vulnerable and most probably inadequate to cope with climate change.
Preparedness of the human factor, who operates or use the infrastructure	The analysis, performed in Section 1.2.2., shows that droughts have not often hit the country in the near past, so there is no awareness and preparedness. About floods, every next event shows that the lessons from the previous years have not been well learned. Therefore, it may be concluded that the human factor is highly vulnerable, not adequately prepared to cope with climate change.
Availability of the resource so that this infrastructure is operable	The availability of water resources reduces hydraulic head due to reduced storage of the hydropower generation equipment. For water supply and sanitation, and Hydro-melioration subsectors, the lack of the water affects service (insufficient water for people, industry, and crops).

113. The industry sector's vulnerability depends on its preparedness (level of implementation of water-efficiency measures) as well as on the availability of the water and on competition with the other users in the region.

Identification of the risks

114. Risk arises from the interaction of climate hazards with exposure and vulnerability to impacts. It should be underlined that all risks imply some measure of likelihood and impact, which cannot always be defined.

Table 21. Identification of the risks for managed systems

Hazards	Exposure	Vulnerability	Risk
Floods	Flood cannot be predicted with regard to location, time and intensity, and therefore, this hazard concerns flood-prone areas in the entire country	Overwhelmed, aging, poorly maintained, and inadequate infrastructure and limited ability to cope and adapt	Risks to infrastructure and services (see ***Table 22***)
		Populations and infrastructure exposed and lacking historical experience with floods	
		Dependence on water resources in energy production systems	Risks to hydroelectric generation from high river flows
Droughts	Only regions with identified threat of water scarcity (see ***Table 19***)	Overwhelmed, aging, poorly maintained, and inadequate infrastructure and limited ability to cope and adapt	Risks to services (see ***Table 22***)
		Population and infrastructure exposed and lacking historical experience with droughts	
		Dependence on water resources in energy production systems	Risks to hydroelectric generation from low river flows

115. Risks to infrastructure and infrastructure services are presented in more detail in ***Table 22***.

Table 22. Risks to infrastructure and services in detail

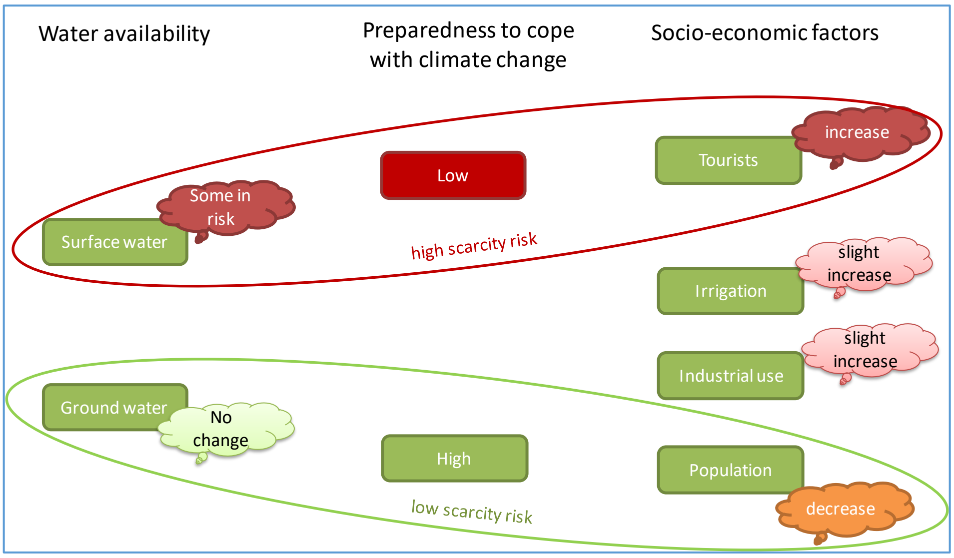
Subsectors	Risks to Infrastructure and Services
Dams	• *Risk of uncontrolled overflow*. Combination of intensive rainfall with a lack of early warning systems • *Siltation risk*. Silting of reservoirs resulting from increased turbidity leading to decreasing live storage • *Ecological risk*. Under-capture in low rainfall season, over-capture in high rainfall seasons putting the ecological minimum at risk
Water supply and sewerage	• Flooding directly damages infrastructure assets (pipes, pumps, WWTPs) • Changing the quality of the water sources in case of flooding, which makes it difficult to purify the water for drinking and household needs

Subsectors	Risks to Infrastructure and Services
	• Flooding can lead to sewer overspills and overloading of the WWTPs • High levels of inefficiency will lead to quicker usage of water resources and thus reduce resilience in case of prolonged dry periods • Increased water needs for domestic and industrial consumption due to hot summers, reduced supply from reservoirs and river flows, while increases in temperature leading to increased consumers' demand
Hydro-melioration facilities	• Increase in periods of heavy rainfall putting drainage systems under stress, leading to more frequent and more severe flooding • Heavy rains and muddy streams interrupting the functioning of pumping stations that are part of the irrigation systems • Continuous dry periods and soil shrinkage causing the formation of expansion gaps in the earth and deformation of the hydro-melioration canals • Hotter, drier summers leading to increased irrigation needs that, in combination with less water stored in dams, can lead to water shortage
HPPs	• *Operational performance risk*. Reduced hydraulic head due to reduced live storage • *Seasonal disruption*. HPPs that are highly dependent on seasonal precipitation will face increasing difficulties to project river flows. This may result in reduced power generation in case of decreasing precipitation and dry summer season
Cooling at NPPs and TPPs	• *Disruption risk* increased due to insufficient supplies from reduced storage • *Operation performance risk*. Sub-optimal performance due to a rise in temperature or a decrease in the availability of cooling water (low flows because of droughts) • *Flood risk*. Power stations constructed in flood-risk zones, with insufficient flood protection

Note: NPP = Nuclear Power Plant; TPP = Thermal Power Plant.

116. A simplistic approach to identify the regions with **risk of water scarcity** is presented below (***Figure 25***). It is based on the analyzes in the previous chapters.

Figure 25. Simplistic determination of the scarcity risk



117. Two extreme cases are presented in ***Figure 25***. Projections indicate a decline in population. If the region uses groundwater resources, most likely there will be a low scarcity risk because projections show that climate change will not reduce their availability. However, the likelihood depends on the preparedness to cope with climate change. In this ideal case (population decrease, no change in the availability of the groundwater), the risk could easily increase, if for example, water supply systems continue wasting more than 50 percent of the water produced. The risk will increase as well, if water thirsty industries and crops are situated in the region.

118. The other extreme, high scarcity risk, is likely to appear in case projections show a decrease in available water resources combined with increased water demand for tourism. Here also, the likelihood depends on the preparedness to cope with climate change.

119. ***Figure 25*** illustrates where appropriate climate adaptation options should be directed. If the condition and management of the infrastructure improves, the risk could be reduced from high to moderate or even low. Another option is to select appropriate territories for water thirsty industries and crops. This could significantly mitigate the water scarcity risk.

120. The **Black Sea region** uses surface water resources and is the most visited by tourists. The condition of the infrastructure is poor. Thus, this region appears as the most vulnerable to scarcity risk.

1.3.3. Climate change risk for natural systems

121. The risks for the natural systems are identified through superposition of the hazard, exposure and vulnerability. It should be underlined that all risks imply some measure of likelihood and impact, which cannot always be defined.

Table 23. Identification of the risks for natural systems

Hazards	Exposure	Vulnerability	Risk
Floods	Flood cannot be predicted with regard to location, time and intensity, and therefore, this hazard concerns flood prone areas in the entire country	River morphology: change of the riverbeds; silting with sediments	Risk of impaired biodiversity
		River morphology: due to human adaptations to flood risk, such as the construction of dykes and dams	
		Water quality: higher turbidity during intensive rains	
Droughts	Only regions with identified threat of water scarcity (see ***Table 19***)	Ecosystems: when there is less water, the entire net of interdependent relationships will change	Risk of impaired biodiversity
		River morphology: more narrow riverbeds	
		Water quality: when there is less water, there will be a higher concentration of pollutants	

122. ***Annex 1*** presents further information about assessed impacts of some weather phenomena on the water sector.

123. The risks can be managed, and impacts can be reduced when appropriate and on time adaptation measures are taken (***Table 24***).

Table 24. Opportunities to manage risks for water sector

Weather Phenomena	Risks	Opportunities
Higher temperature (including heat spells and heat waves), droughts	• Risk to irrigation services	• Policies taking account of rural decision-making contexts • Adoption of more water-efficient technologies and of water-saving strategies • Awareness rising to change behaviour
	• Risk to water supply and sanitation services	• Adaptive management of water supply and sanitation systems • Adoption of more water-efficient technologies, re-use and water-saving strategies (industries, domestic use) • Awareness rising to change behavior
	• Risk of impaired biodiversity	• Maintenance of genetic diversity, assisted species migration and dispersal, manipulation of disturbance regimes (for example, fires, floods), and reduction of other stressors
Lower temperatures (including cold spells and cold waves)	• Risk to irrigation services	• Policies taking account of rural decision-making contexts • Awareness rising to change behavior
	• Risk to water supply and sanitation services	• Adaptive management of water supply and sanitation systems, particularly water purification and wastewater treatment plants
	• Risk to above ground infrastructure	• Appropraite design • Adaptive management of water systems
	• Risk of impaired biodiversity	• Maintenance of genetic diversity, assisted species migration and dispersal, manipulation of disturbance regimes (for example, fires, floods), and reduction of other stressors
More precipitation and humidity	• Risk to irrigation services	• Policies taking account of rural decision-making contexts • Awareness rising to change behavior
	• Risk to water supply services	• Adaptive management of water systems, particularly water purification and wastewater treatment plants

Source: IPCC 2014.

1.4 Conclusions

124. Regarding '*Sector characteristics and trends*' the following conclusions can be drawn:

A. Water resources: availability.

- At country level, there is no annual water resource deficit. The seasonal flow variations of surface water bodies are regulated by sufficient numbers of reservoirs. However, there are regions, suffering from water shortage for water supply needs in the summer months. The weakest river basin is the Black Sea Riber Basin with both the smallest amount of available water resources and the smallest available volumes per capita.

B. Water resources: quality.

- Two-third of the groundwaters and one-third of the surface water bodies are in a good ecological status.
- The Black Sea River Basin has the smallest percentage of achieved objectives (5 percent) for surface water bodies and the highest number of groundwater bodies in 'poor condition'.

C. Water resources: use.

- In the period 2007–2015 there was a steady reduction in the volumes of abstracted water (decline of population, irrigation, and industrial use).
- Surface water resources are used mainly for industrial needs (cooling and energy production), while groundwater resources are used mainly for domestic water supply.

D. Water supply and sanitation.

- Despite the highest improvement dynamics in this subsector, in general till now the biggest part of the infrastructure is outdated as well as designed and operated without climate change considerations.

E. Hydro-melioration.

- The hydro-melioration infrastructure is either destroyed or in an extremely poor condition. Insufficient maintenance and monitoring related to engineering safety has created a situation, which poses significant risks to the population, settlements, agricultural land, and the infrastructure. In view of climate change, the probability of these risks increases.

F. Hydropower.

- While the major HPPs are maintained and operated properly, the state of the small HPPs represents a potential safety threat.

G. Industrial water use.

- Lack of data for comprehensive assessment.
- Increased registered use of groundwater resources, which in case of water shortage may cause a problem of competing with water use for domestic needs.

125. Regarding '*Past and present weathe events and trends'* the conclusions are as follows:

A. Researchers claim that over the past 20–30 years compared to the reference period 1961–1990 in Bulgaria:
   - an increase of air temperatures has taken place; and
   - there is a trend of decreasing rainfall in summer and autumn, while in spring and winter there is rather an increase in rainfall than a decrease. But in average, on an annual basis, the trend is close to zero.

B. Since 2000, the country has faced serious droughts and floods.

C. Lessons from past events have not been adequately addressed.

126. Regarding '*Sector related climate change risk and vulnerabilities'* the conclusions are as follows:

A. Major driving factors (projections):
   - Increase in temperature (from 1^{o}C to 1.5^{o}C depending on scenario)
   - Higher mean diurnal amounts of precipitation (to 2.71 percent depending on scenario)
   - Change in the distribution and intensity of precipitation: decrease in summer (from 2 percent to 12 percent depending on scenario) and increase in autumn (from 12 percent to 27 percent depending on scenario and period)
   - Significant decline of population
   - Regarding economic development, agriculture and industry are not expected to change significantly, while tourism is expected to grow
   - Projected summer and autumn decrease of the river runoff and no change in undergroundwater

B. Regions most vulnerable regions to drought risks:
   - Black Sea River Basin

C. Vulnerability
   - Overwhelmed, aging, poorly maintained infrastructure, and therefore highly vulnerable and most probably inadequate to cope with climate change
   - Population and operators of infrastructure lack historical experience and good practices with floods and droughts, and therefore, are highly vulnerable
   - Hydropower production systems – vulnerable to operation during droughts
   - Water services (water supply, sanitation, melioration) – vulnerable during droughts

D. Major risks to managed systems
   - Risks to infrastructure and services – damage, improper operation, and low-level or insufficient services
   - Risks to hydroelectric - generation from low or high river flows

E. Major risks to natural systems
   - Impaired biodiversity

Chapter 2. Baseline – Policy Context

2.1. State of Awareness and Understanding

127. Following the EU policy framework, the water management functions in Bulgaria are aligned with the EU *acquis*, namely with the requirements of the EU WFD[17] and to the EU Floods Directive.[18] Accordingly, RBMPs are developed and implemented through associated programs of measures. Actions for flood risks management are embedded in the formulation of FRMPs, which are implemented through measures for preparedness, prevention, and protection.

128. In line with the requirements of the WFD and the Floods Directive, public participation procedures were carried out in the preparation of the Bulgarian RBMPs and FRMPs. All assessments, maps, and plans prepared are publicly available. These two strategic planning documents are targeted to a wide range of stakeholders – society, business (industries and other water users), and municipalities. Regarding public consultations and involvement of stakeholders, the main actions taken by the RBDs can be divided into passive (informing) and active (consultation and active participation). Different tools are used: Internet publications, questionnaires, surveys, round tables, and so on.

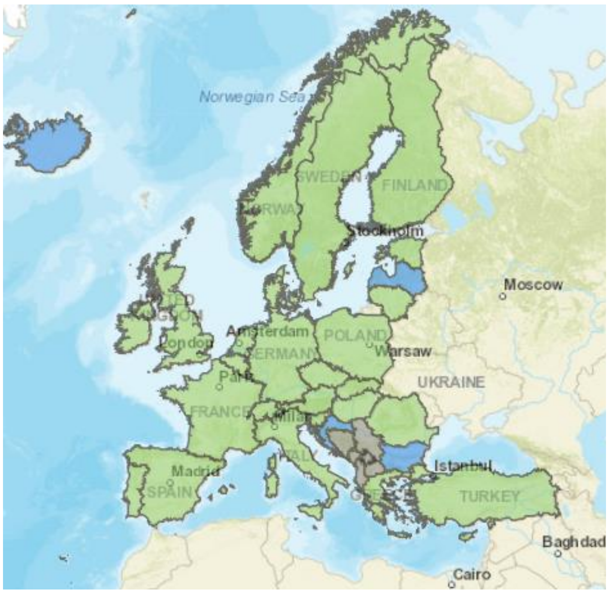
129. Despite the achievements of the RBDs in involving the public and stakeholders in the discussions of the RBMPs and FRMPs, public awareness on climate change is limited to local experience as a result of flood events or to information through the media (newspapers, television, and the Internet). Floods are the most devastating disasters that have hit Bulgaria in the recent years. Human victims and high costs of damage lead to a broad social consensus regarding the pressing necessity of defining and implementing disaster risk management measures, mainly relating to the water sector.

2.2. Experience with CCA in the Sector in Other EU Countries

130. The EU Member States are at different stages of preparing, developing and implementing national adaptation strategies (NASs) and plans. In line with the European mechanism for monitoring and reporting information relevant to climate change (Regulation (EU) No 525/2013) Member States have provided the corresponding information to be uploaded to the European Climate Adaptation Platform (***Figure 26***). Bulgaria is among the few countries without a strategy and action plan.

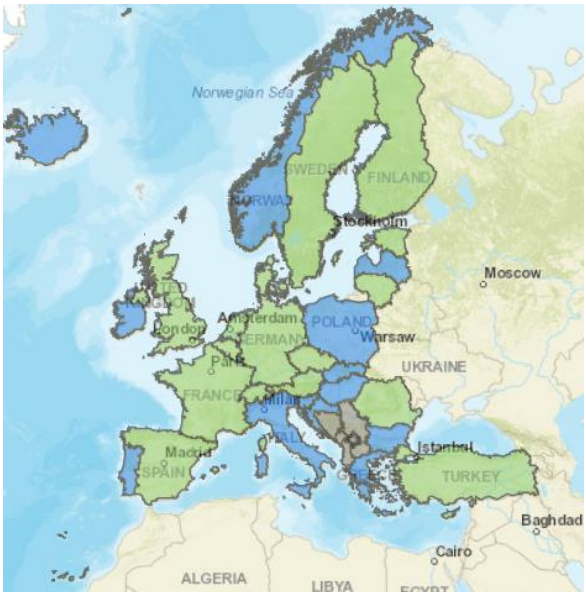
[17] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, 23 October 2000
[18] Directive 2007/60/EC on the assessment and management of flood risks, 26 November 2007

Figure 26. Countries with (in green) and without adaptation strategies (in blue)



Source: http://climate-adapt.eea.europa eu/countries-regions/countries.

Figure 27. Countries with (in green) and without action plans (in blue)



Source: http://climate-adapt.eea.europa eu/countries-regions/countries.

131. The maps above show that France, Germany, the United Kingdom and Austria are among the countries, that provided both the documents. Therefore, their experience has been used for the development of this report.

132. The adaptation strategies of these countries indicate a good understanding of the future consequences of climate change in the water sector as well as of the increased importance of reliable data accumulation and fundraising for the implementation of adaptation measures. Regarding the water sector, different approaches are considered (***Table 25***).

Table 25. Water sector in CCA strategies of some EU Member States

Country	How the Water Sector is Considered
France, 2007[a]	Chapter 'Cross-disciplinary approaches' • Section 'Water' - discusses **water as a resource for multiple use** as well as **flood hazard**. Chapter 'Sector issues' – water is considered under sectors 'agriculture' and 'tourism'.
United Kingdom, 2013[b]	Chapter 2. 'Built environment' • Focus area 1 is 'Flood and coastal erosion risk management' • Focus area 2 is 'Spatial planning' – **sustainable new development, including infrastructure** • Focus area 4 is 'Making homes and communities more resilient' – **water efficiency**, community and property level **flood protection** and sustainable drainage Chapter 3. 'Infrastructure' • Focus area 1 is '**Infrastructure asset management'** – analyzes water companies Chapter 5. 'Agriculture and foresty' • Focus area 1 is 'Building resilience in agriculture through effective water management' Chapter 6. 'Natural environment' – **water ecosystems**

<table>
<tr><th>Country</th><th>How the Water Sector is Considered</th></tr>
<tr><td>Germany, 2008[c]</td><td>Chapter 3.2. ‘Impacts on nature and society – identifying action options’
• Section 3.2.3 ‘Water regime, water management, coastal and marine protection’
o Inclusion of climate change effects in integrated river basin management;
o Adapting the infrastructure;
o Efficient use of water; and
o Support of individual precautions in the flood control sector.</td></tr>
<tr><td>Austria, 2013[d]</td><td>The first fourteen chapters of the strategy are general for all sectors, discussing trends, challenges, principles, research needs, good practices, and so on. The adaptation options are structured in 14 action areas: Agriculture, Forestry, Water resources and water management, Tourism, Energy – Focus on the Electrical Industry, Construction and Housing, Protection from Natural Hazards, Disaster Risk Management, Health, Ecosystems and Biodiversity, Transportation Infrastructure, Spatial Planning, Business/Industry, Cities – Urban Green and Open Spaces.</td></tr>
<tr><td>IPCC, 2014[e]</td><td>Introduces terms ‘natural systems’ and ‘managed systems’
Chapter 3. Freshwater resources (including their use)
Chapter 10. Key economic sectors and services
• Section 10.3. Water Services
o 10.3.1. Water Infrastructure and Economy-Wide Impacts
o 10.3.2. Municipal and Industrial Water Supply
o 10.3.3. Wastewater and Urban Storm Water
o 10.3.4. Inland Navigation
o 10.3.5. Irrigation
o 10.3.6. Nature Conservation
o 10.3.7. Recreation and Tourism
o 10.3.8. Water Management and Allocation</td></tr>
</table>

Notes:
a. National Strategy for Adaptation to Climate Change, 2007;
b. The National Adaptation Program: Making the Country Resilient to a Changing Climate, 2013;
c. German Strategy for Adaptation to Climate Change (DAS) 2008;
d. The Austrian Strategy for Adaptation to Climate Change, 2013; and
e. IPCC 2014.

133. In addition to the national strategies, a document of the IPCC was included in the review because it is a very recent assessment of adaptation and vulnerability, considering up-to-date knowledge.

134. The United Kingdom and Germany have the closest approach, considering natural water systems (resource with multiple users, water ecosystems, integrated water management) and managed water systems (part of built environment, infrastructure). Therefore, their adaptation options will be considered and discussed further in sub-chapter 3.2.

2.3. EU CCA Legal Framework and Policies in the Sector

135. Key water sector policy documents implemented in the EU are outlined in this section.

- EU Water Framework Directive[19]

136. The WFD was the first EU document, tracing a substantially new attitude toward water resources. It requires the Member States to take an integrated and cyclic approach in managing water resources to protect them for future generations. The cyclic approach includes a regular review of progress and adaptation of measures, as well as adequate updates. This ensures climate change effects to be appropriately and timely considered.

137. Although the focus of the WFD is on preserving the quality of aquatic ecosystems, it also requires the RBMPs to have effective measures in their ‘programs of measures’ for water use. In 2012, the European Commission (EC) published its assessment of the first RBMPs. The conclusion was that information about water quantities is incomplete and water scarcity is often not different from droughts and vice versa. Only 35 percent of the plans have developed scenarios about water use and less than 25 percent about water availability. 80 percent of the plans do not consider the quality of data and more than 90 percent do not report on the financial sources (EC 2012).

- Common Implementation Strategy for the Water Framework Directive[20]

138. Published in 2009, this guidance document focuses on how climate change could be integrated into the second and third river basin management cycles of the WFD, also broadening the scope with floods and droughts. The document outlines that climate change should be integrated into river basin management. The pillars of the approach to adaptation through river basin management under the WFD are:

1) Effective long-term monitoring (to enable climate change signals to be identified and reacted to in due course);
2) Assessment of the likely additional impact of climate change on existing anthropogenic pressures; and
3) Incorporation of this information into the design of measures (particularly for proposed measures with a long-term design life).

139. Thus, the document specifies that as a minimum, the Member States should clearly demonstrate how climate change projections have been considered in the pressures and impacts assessment, monitoring programs, and selection of measures.

- EU Floods Directive[21]

140. The Floods Directive aims at increasing resilience and reducing and managing risks that floods pose to human health, the environment, cultural heritage and economic activities.

141. The development of the FRMPs is based on three steps: (a) preliminary flood-risk assessment; (b) flood-hazard and risk maps; and (c) FRMPs.

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[19] Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, 23 October 2000
[20] Common Implementation Strategy (CIS) for the Water Framework Directive (2000/60/EC)
[21] Directive 2007/60/EC on the assessment and management of flood risks, 26 November 2007

142. The Floods Directive requires a cyclical approach like the WFD. Such approach is beneficial because of the periodic reassessment of selected measures and their implementation.

143. The WFD and the Floods Directive should be implemented synchronously to maximize the benefits.

- EC Communication 'Addressing the Challenge of Water Scarcity and Droughts'[22]

144. Alongside the increased risk of flooding, climate change will make water scarcity and droughts an increasingly frequent phenomenon. In July 2007, the EC adopted a Communication on 'Addressing the challenge of water scarcity and droughts' in the EU setting out several policy options for addressing the challenge of water scarcity. The measures identified in the Communication represent an important tool box for responding to the increased likelihood of such events due to climate change. In particular, the Communication identified the importance of moving toward a water-efficient and water-saving economy and the important roles played by water pricing and land-use planning in incentivizing efficient water use.

145. The Communication calls for a paradigm change from crisis-oriented to a planned drought-risk management approach and expresses the need to explore all possibilities to improve water efficiency before exploring increase in supply. The Communication also highlights the untapped potential for water efficiency measures in sectors like agriculture, industry, distribution networks, buildings, and energy production. It also states that a clear water-use hierarchy established through participative approaches should inform policy making. More specifically, the Communication offers voluntary measures to cope with water scarcity and droughts, recommends development of Drought Management Plans and a comprehensive European drought strategy, and discusses the establishment of a European drought observatory.

- EC Communication "A Blueprint to Safeguard Europe's Water Resources"[23]

146. The Impact Assessment of the Blueprint to Safeguard European Water Resources gives an assessment of the vulnerability of water and environmental resources to both climate change and human-conducted environmental impact. The blueprint document embodies guarantees that climate change is taken into consideration when implementing the EU Floods Directive. The document addresses several aspects like improving efficiency, preventio illegal abstractions, and importance of pricing policy as instrument to raise awareness and stimulating increase of efficiency, water metering, and so on. Measures like natural water retention and restoring flood plains and wetlands are presented to mitigate the impact of both floods and droughts.

147. The Communication underscores the increasing interplay between the water and agricultural sectors to address issues of water scarcity and drought. First, the blueprint calls for better implementation and increased integration of water policy objectives in policy areas such as the Common Agricultural Policy (CAP), the Cohesion and Structural Funds, as well as energy, transport, and integrated disaster management. As essential in facilitating an integrated approach, the blueprint views the development of CIS guidance on natural water retention measures.

[22] COM (2007) 414 final EC Communication Addressing the challenge of water scarcity and droughts in the European Union
[23] COM(2012) 673 final EC Communication A Blueprint to Safeguard Europe's Water Resources

➢ EU White paper on Adapting to Climate Change: Towards a European Framework for Action[24]

148. Published in 2009, the document sets out a framework to reduce the EU's vulnerability to the impact of climate change. It discusses the following categories: health and social policies, agriculture and forest, biodiversity, ecosystems and water, coastal and marine areas and production systems and physical infrastructure. Water-related needed actions are identified as follows:

- Develop guidelines and a set of tools (guidance and exchange of best practices) by the end of 2009 to ensure that the RBMP are climate-proofed;
- Ensure that climate change is considered in the implementation of the Floods Directive; and
- Assess the need for further measures to enhance water efficiency in agriculture, households, and buildings.

➢ EU Strategy on Adaptation to Climate Change[25]

149. The overall aim of the EU's 2013 Strategy on Adaptation to Climate Change is to contribute to a more climate-resilient Europe. The document points out that the integration of adaptation measures is at an early stage. Some countries prepared plans to tackle droughts and heat waves. However, only a few Member states developed vulnerability studies to support the selection of measures. The strategy stresses the difficulty of evaluation because of the early stage of development of indicators and monitoring methodologies. Some of the main actions set in the strategy are filling the gaps in knowledge, ensuring more resilient infrastructure, and facilitating climate-proofing of the CAP, the Cohesion Policy (CP) and the Common Fisheries Policy (CFP).

150. The strategy recognizes that evaluation of the effect of mitigation measures, risk assessment at the regional and local levels, and lack of information on damage, adaptation risk and benefits are key issues, needing further elaboration. Decision support tools like models are recognized in the process of selecting measures. The modeling allows development of scenarios and different combinations of measures to be tested and evaluated. Past adaptation efforts also need to be evaluated.

151. The strategy stresses the importance of good coordination and coherence at all levels of planning and management in the process of selecting cost-effective adaptation measures. For that reason, the exchange of good practice between stakeholders is encouraged.

2.4. Bulgarian CCA Legal Framework and Policies in the Sector

2.4.1. Legal framework

152. Bulgaria's legislation is synchronized with EU policies and follows the framework for climate change mitigation and emission reduction.

153. The Climate Change Mitigation Act introduces mechanisms for reducing the generation of GHG emissions and sets the basis for long-term planning of CCA measures. It stipulates that

[24] COM(2009) 147/4 White Paper Adapting to Climate Change: Towards a European Framework for Action
[25] COM(2013) 216 final An EU Strategy on Adaptation to Climate Change

the first CCA strategy should consider the period until 2030. It requires climate change policies to be integrated into corresponding sectoral policies. The water sector is not separately listed.

154. A number of laws and ordinances provide the legal framework for waters on the Bulgarian territory. Only the Water Sector Strategy provides a definition of ‘water sector’ and its subsectors, which include only managed water systems.

155. The Water Act (WA) is the major water-related legal document. It was promulgated in the State Gazette in July 1999. Since then it went through a significant number of amendments, of which the latest was on July 18, 2017. The WA transposes the requirements of the WFD and the Floods Directive into national legislation. It also specifies other aspects, such as ownership of waters and water infrastructure, water use, and management of water supply and sanitation systems. Despite the law’s benefits for nature and society, there are several weaknesses, which make its use cumbersome:

- It is too long with more than 200 articles, often one article making reference to a number of other articles.
- It is too detailed – some provisions would better be published as ordinances to be more flexible and easy to change.
- It has a specific chapter for the WSS subsector, but not for other subsectors (hydro-melioration and hydropower generation) – thus it appears as imbalanced regarding the subsectors. The WSS subsector is the subject of other laws as well, which furthermore complicates the use.
- It does not include climate change related provisins, other than flood-specific ones.

156. Another intersectoral act, the Spatial Development Act, also includes provisions related to the water supply and sanitation subsector. There is a specific Water Supply and Sewerage Services Regulation Act as well, adopted in 2005 and with its latest amendment in 2015. It aims to create a legal framework to ensure better services to the clients, as well as better operation and maintenance of the infrastructure.

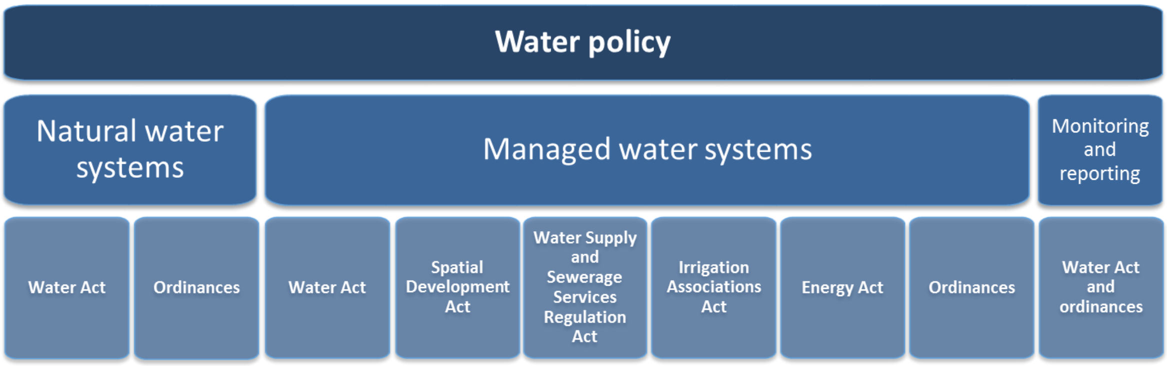
157. The main legal act in the field of hydro-melioration is the Irrigation Associations Act, which regulates the structure and activity of irrigation associations. The associations carry out the operation and maintenance of hydro-meliorative infrastructure, construction of new irrigation and drainage systems and facilities, supply and distribution of water for irrigation, and so on.

158. The legal framework in the field of hydropower generation includes several acts. The Energy Act regulates the public relations for implementation of the production activities, import and export, transmission, and distribution of electricity and heat. It does not include further specific provisions for energy produced by hydropower or hydropower facilities, but this is well-stipulated in the corresponding ordinances. The energy services are regulated by the same authority which regulates water supply and sanitation services – the Energy and Water Regulatory Commission (EWRC). The Water Act has specific provisions aimed at the protection of water, achieved through partial limitation of the use of surface water for hydropower production. The most important legislation related to the hydropower systems and facilities regarding climate change consists of (a) Ordinance №9 of 2004 on the technical

operation of power plants and networks, and (b) Ordinance on the terms and conditions for the technical and safe operation of dams and pertaining facilities and monitoring of their technical condition of 2016. They include provisions on the regime of the hydrotechnical facilities, technical operation of power plants and hydrotechnical facilities, as well as on the monitoring of their technical condition.

159. ***Figure 28*** synthesises the current legal and regulatory framework.

Figure 28. Structure and main actors in implementing the Bulgarian Water sector policy



Source: World Bank design.

2.4.2. Strategies

160. The National Environmental Strategy 2009–2018 sets out six key strategic objectives. Strategic Objective II relates to the water sector and it is "*To provide sufficient water and good quality water*". The specific goals of Strategic Objective II are:

- Ensuring good condition of surface water and groundwater, good ecological potential of artificial and heavily modified water bodies;
- Providing water with the necessary quantity and quality for the population, water ecosystems, and the country's economy, and reduce the consequences of floods and droughts in the conditions of global climate change; and
- Perceiving water as an element of national security, with the aim of sustainable development of the country.

161. The Guidelines on Mainstreaming of Environmental Policy and Climate Change Policy in CP, CAP, and CFP Funds 2014–2020[26] provides a coherent set of measures concerning the environment and climate change and aims at the implementation of these measures at the national level by the institutions responsible for the operational programs.

162. CCA measures are also foreseen in the Sixth National Communication on Climate Change for the most vulnerable areas: agriculture and forestry, soils. Water adaptation measures in Bulgaria are divided into the following groups:

- Measures to increase the areas for irrigation;
- Measures to improve the management, use, and conservation of water resources in irrigated agriculture;

[26] Guidelines on Mainstreaming of Environmental Policy and Climate Change Policy in CP, CAP and CFP Funds 2014–2020: http://www.ope.moew.government.bg/files/useruploads/files/Programirane/2013_02__22_guidelines_mainstreaming_en_t_ms.pdf

- Measures to improve the efficiency of management and use of existing irrigation systems and the development of new technological and technical means of irrigation; and
- Determination of the vulnerability of agricultural crops to climate change, long-term droughts, and water deficit in the main agroclimatic areas of the country, respectively the impact on the quantity and quality of the yield from them.

163. The long-term strategic objective for the water sector is formulated in the Water Sector Strategy as "*Sustainable use of water resources, providing to the optimal extent the present and future needs of the country's population and economy as well as of the water ecosystems*". There are four specific objectives and two of them relate to climate change:

- Objective 1: Guaranteed provision of water to the population and businesses in times of climate change leading to drought.
- Objective 4: Reduce the risk of flood damage.

164. For two of the subsectors, specific strategies have been prepared. The Strategy for Development and Management of the Water Supply and Sanitation Sector in the Republic of Bulgaria 2014–2023 was approved in 2014. It sets out the main objectives and priorities for the WSS subsector in Bulgaria, as well as proposals for the implementation and financing of policies to achieve these objectives within a ten-year horizon. The vision for the WSS sector is a financially, technically and environmentally sustainable WSS sector, providing value for money and affordable services to customers. The key sector issues identified in the strategy include the following:

- Water supply services largely meet standards, but water losses are high and investments in water supply are far below the level needed to sustain good quality and uninterrupted service in the long run.
- Wastewater services fall short of standards.

165. The strategy recognizes that the climate is changing in southeastern Europe. In response, the strategy emphasizes the need for design and construction of flexible and adaptive systems.

166. The Hydro-melioration Strategy[27] was approved in 2016. It identifies restoration of irrigation and land drainage infrastructure as a priority and analyzes the sector in the context of climate change in the medium and long term. The strategy concludes that, if rehabilitated and modernized, the existing irrigation infrastructure will be a critical element in reducing the risks of climate change in terms of productivity, sustainable agriculture, and land management. Expected long-term droughts, combined with more frequent and more severe floods, will lead to growing insecurity in the agriculture sector in Bulgaria. Under these conditions, the irrigation infrastructure will be used to meet the growing needs of crop for water, while drainage and flood protection infrastructure as well as river corrections would provide protection for arable land against harmful impacts related to climate hazards. In this way, the irrigation sector will generate significant benefits for both the farming community and the wider society.

[27] Strategy for Management and Development of the Hydro-melioration Sector and Protection from the Harmful Effects of Water, 2016

2.4.3. Plans

167. In compliance with the requirements of the WFD and the Floods Directive, as well as of the Water Act, Bulgaria develops and implements RBMPs and FRMPs for each of the four river basins. Two cycles of RBMPs (2010–2015 and 2016–2021) and one cycle of FRMPs (2016–2021) have run in the country. A round table discussion of the plans, organized by the Bulgarian Water Association, and attended by representatives of RBDs, water operators, and academia, identified the following weaknesees regarding the preparation of the plans[28]:

- There is no national methodology for development of these documents and thus the quality depends on the approach and experience of the team contracted to develop them:
  - RBDs do not always have the capacity to prepare good Terms of Reference which affects the quality of the plans; and
  - Public procurement procedures used for selection of consultants to prepare the plans are subject to appeals, which results in insufficient time for elaboration of the plans, thus lowering their quality.
- Data needed for analyzes belong to different institutions and sometimes is difficult to obtain. In some cases, they refer to different periods, or the measuring method is unclear.
- In the national catalogues of measures for the RBMPs and FRMPs there is duplication of measures, too generally formulated measures, poor assessment of the costs, etc.
- A modeling approach is not applied. The experience in other EU countries shows that this is a very helpful decision-making tool for water management at the basin level.
- Flood risk and hazards maps should be revised to include the existing flood protection measures (such as dykes or river bed corrections). These are not considered in all maps and unrealistic risks are mapped.
- Lack of assessment of the capacity of the storm water system to retain intensive rains. This results in suggesting expensive mitigation measures, which might not be needed.
- Maps with drought projections until 2050 are not available.
- Analysis of the implementation of the first RBMPs has not been carried out and it is not clear if a learning-based approach is applied for the second plans.

168. In addition to the RBMPs and FRMPs other plans listed in ***Table 26*** are legally required.

[28] Round table discussion 21 March 2016, organized by the Bulgarian Water Association with participation of RBDs, water operators, and researchers

Table 26. Planning periods of the major water sector plans in Bulgaria

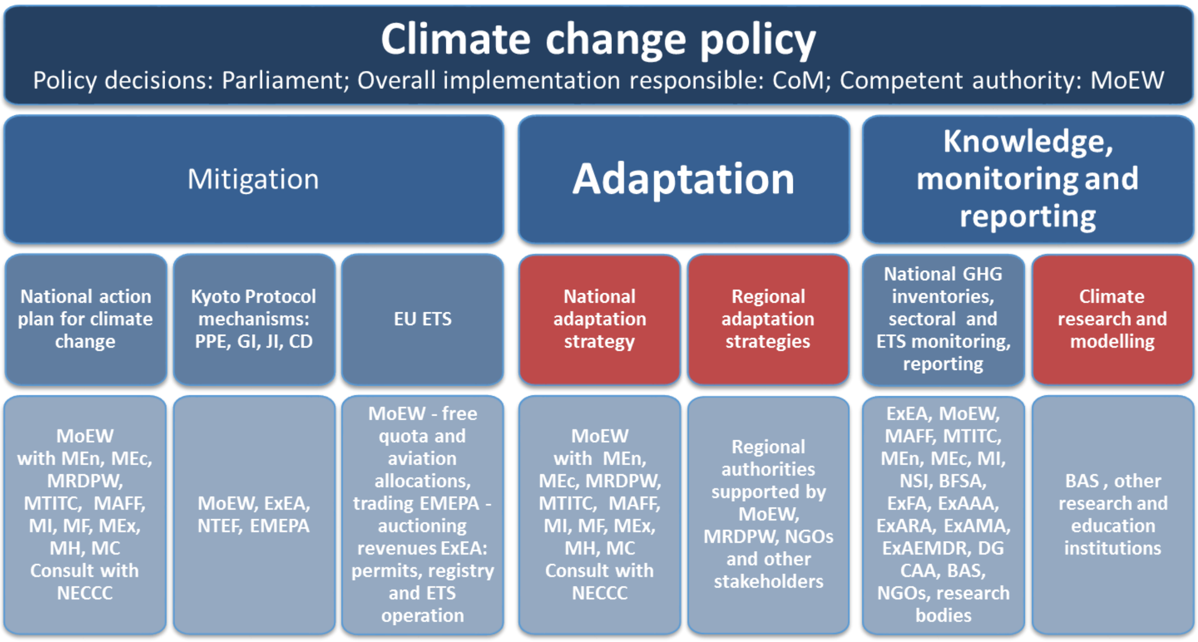
Document	Planning Period	Current Period	Reference
RBMP	6 years	2016–2021	Water Act/ Directive 2000/60/EC of the European Parliament and of the Council
FRMP	6 years	2016–2021	Directive 2007/60/ EU
Ten-year network development plan of hydropower operators	10 years (presented every year)	-	Energy Act/ Directive 2009/72/EC of the European Parliament and of the Council
Business plan of water WSS operators	5 years	2017–2021	Regulation of Water Supply and Sewerage Services Act
Regional master plans for water supply and sanitation	25 years	2014–2039	Water Act and http://midp.bg/bg/regionalni-generalni-planove.html

169. Consistency between these planning documents should be ensured so that all efforts are adequately directed to meet the strategic objectives. The planning periods of the RBMPs and FRMPs are set by EU directives; therefore, relevant national legislation may be amended to achieve consistent planning periods.

2.5. Institutional Framework and Stakeholder Community in Bulgaria

170. Water sector functions are split between several institutions (***Figures 29 and 30***).

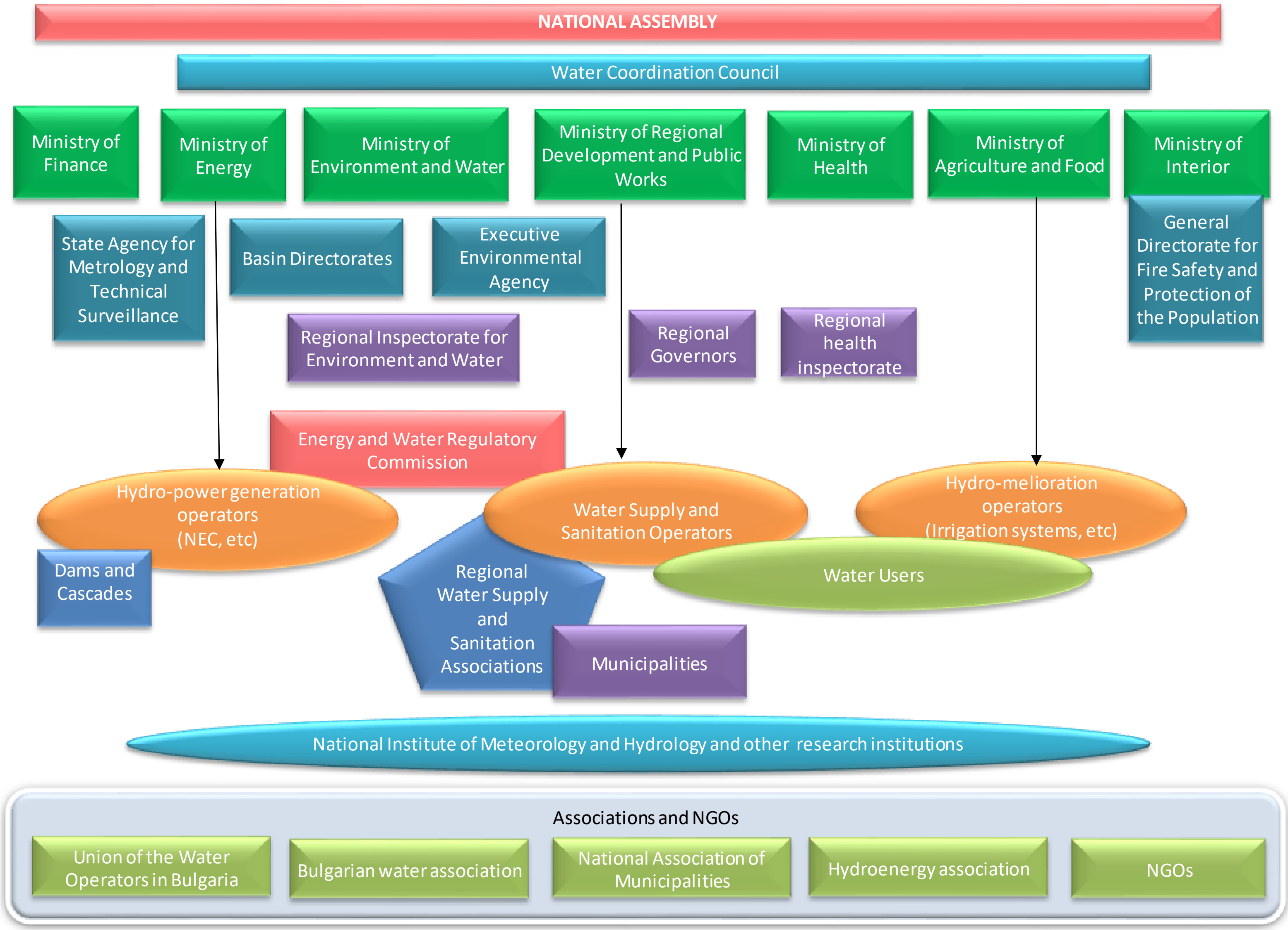
Figure 29. Structure and main actors in implementing the Bulgarian climate change policy



Note: All abbreviations used in this figure could be found within the Abbreviations and Acronyms section.

Source: World Bank design.

Figure 30. Overview of the major institutions and stakeholders



Source: World Bank design.

More details of the institutional framework are provided in ***Annex 7***.

Table 27. Conclusion on institutional framework

Conclusion on institutional framework
Several institutions have responsibilities for management and development of the water sector, which requires very good coordination. A major problem of the work of the state and municipal administration is a lack of coordinated and unified collection and aggregation of necessary information on climate change and related phenomena, especially natural disasters, such as floods and droughts.

2.6. Financial and Human Resources in Bulgaria

2.6.1. Financial resources

171. The elaboration and implementation of CCA measures in the water sector is closely intertwined with the proper maintenance and management of the water infrastructure and resources. The sources of funding could be divided into the following main categories:

- Financial resources of the business sector
- Public financing
- Loans
- Grants

A. Financial resources of the business sector

172. Financial resources of the business sector include the funds allocated for investment and maintenance carried out by the water operators, National Electricity Company *(Natsionalna Elektricheska Kompania* [NEK]), Irrigation Systems Company, Zeminvest and private associations for irrigation, other companies (including operators of industrial wastewater treatment plants (WWTPs) as well as those using circulating water supply and integrated water technologies), private operators of water bodies and small HPPs. Revenues in the sector accumulate from the provision of services such as water supply and wastewater treatment, irrigation, and energy sale.

B. Public financing

173. Public funding of the water sector is formed by subsidies from the state budget for municipal water projects and municipal contributions, transfers for national public co-financing of EU projects, the state budget for public hydro-melioration services, government subsidies for flood protection activities and state budget for administrative staff (Ministry of Environment and Waters [MoEW], Ministry of Regional Development and Public Works [MRDPW], and other institutions).

➢ State subsidies from the state budget for municipal water projects

174. Each year, with the State Budget of the Republic of Bulgaria Act, the state allocates targeted subsidies for investments in the municipalities. The municipal councils approve the municipal budget, a part of which concerns investments, to be covered by these subsidies.

➢ National public co-financing of EU projects

175. The amount of funds that the state allocates to co-finance EU projects is determined by the co-financing rate of the relevant EU fund (Structural Funds and Cohesion Fund). The relevant operational programs for the period 2014–2020 are analyzed in this report.

➢ State budget for public hydro-melioration services

176. Protection from harmful effects of water will continue to be provided in the form of public services of general economic interest. Providers of such services are compensated based on general conditions established by an order of the Council of Ministers. Accordingly, the amount of the compensation for the relevant year shall cover the net costs of the service provider for the provision of the public service, the amount of the investments made, and a profit margin of up to five percent of the net costs. The maximum annual amount of compensation to be transferred to the Irrigation Systems Company is fixed at €15 mln. The funds are provided and reported through the budget of the Ministry of Agriculture, Food and Forestry (MAFF).[29]

➢ Target government subsidies for flood protection activities

177. The financial and logistical provision of disaster protection (including floods) is provided by the budgets of ministries and agencies, municipal budgets, commercial companies and sole traders – for their sites, the Structural Funds of the EU and others. Funding (with the Council of Ministers' decision) from the contingency reserve and/or emergency expenditures for preventing, mitigating and overcoming the consequences of disasters are also provided for financing of disaster protection activities. These funds are administered by the Interministerial Recovery and Assistance Commission, which is an authority under the Council of Ministers. The subsidy and the reserve are generally allocated for disasters and emergencies (including fires, landslides, floods, and other disasters) and not solely targeted at flood protection. In the planning and reporting of funds, no distinction is made between means intended for permanent protection and means intended for operational protection, that is, these are common financial resources for preventing, mitigating, and overcoming the consequences of disasters.

➢ Municipalities

178. Municipal funding includes the revenues from local taxes, sale of assets and those related to the management of municipal property (rents, dividends, and so on) in which municipalities invest in infrastructure. The share of municipal funding in the total amount of municipal investments is in the range of about 70 percent.[30]

179. Within their budgets, municipalities finance several activities falling within the scope of the FRMPs. These are activities related to public works and communal activities – river-bank cleaning and reinforcing including river bed corrections, anti-erosion activities, and so on. For a large part of these measures, municipalities can apply for funding under the new cross-border cooperation programs.[31]

[29] Strategy for the Management and Development of Hydro-melioration and Protection from Harmful Effects of Water, 2016
[30] Appendix 7 to the National Strategy for Management and Development of the Water Sector, 2012.
[31] West Aegean Flood Risk Management Plan

C. Loans and other national funds

➢ Enterprise for Management of Environmental Protection Activities

180. The Enterprise for Management of Environmental Protection Activities (EMEPA) is a state-owned enterprise which provides funding for the implementation of environmental projects and activities identified in the national and municipal strategies and programs. The EMEPA provides the following types of funding:

- Grants for environmental projects of municipalities;
- Interest-free or low interest loans for financing of environmental projects of municipalities, individuals and legal entities; and
- Subsidies to cover a part or the total amount of interest due on bank loans for the implementation of environmental projects.

181. Projects in the water sector have the largest relative share (varying between 80 and 90 percent) in the total amount of grants for investment projects.[32]

182. Fees, fines and proprietary sanctions are paid to the EMEPA by transfer from the budget accounts of the Basin Directorates or the Ministry of Environment and Waters, in accordance with the provisions of the Water Act.

➢ Fund for Local Authorities and Governments

183. The Fund for Local Authorities and Governments (FLAG) was established in March 2007 by the Council of Ministers with funding from the Bulgarian national budget. It is structured as a revolving mechanism for financing the development and implementation of economically and financially viable municipal infrastructure projects and for supporting the administrative capacity of municipalities to absorb the structural and cohesion funds proceeds. The fund is designed as a financial mechanism to overcome the problem of ensuring cash funds to municipalities to develop project proposals or finance approved projects under the operational programs, cofinanced by the EU funds. FLAG provides loans only to beneficiaries eligible for funding from the EU funds and which are either 'municipalities or a group of municipalities in Bulgaria' (for the development of project proposals or for implementation of investment projects, approved by the managing authority of the operational programme), or 'public entities operating in Bulgaria, owned or controlled by municipalities, local governments or local government agencies in the Republic of Bulgaria' (only for implementation of investment projects, approved by the managing authority of the OP).[33]

➢ Financial Instruments

184. A Financing Agreement is to be signed between the Managing Authority of the OPE 2014–2020 and the Fund Manager of Financial Instruments in Bulgaria (FMFIB) on providing support through financial instruments in the field of water, with a budget of BGN 234 million.[34] The fund will provide loans for the implementation of investment projects for construction, rehabilitation, and modernization of water supply and sewerage infrastructure, identified in the

[32] Appendix 7 to the National Strategy for Management and Development of the Water Sector, 2012.
[33] http://www.flag-bg.com/?l=2.
[34] http://www.fmfib.bg/en/fi/26-environment-20142020.

Regional Water Supply and Sewerage Master Plans and RBMPs guarantees for loans provided by commercial banks.[35]

- Banks

185. Financing can be provided by Bulgarian and international financial institutions. The share of these funds in the total amount of funding is insignificant.[36]

D. Grants

- Operational Programme Environment 2014–2020

186. OPE 2014–2020 contains six priority axes. Priority Axis 4 'Prevention and management of flood and landslide risk' is directly focused on the prevention of flood risk. Two groups of measures will be financed:

- Measures to enhance protection and preparedness for adequate response of the population to floods; and
- Measures to increase the protection of the population from landslides.

187. The first group of measures falls within the scope of the RBMPs and is aimed at meeting the commitments stemming from the Floods Directive. The second group of measures does not fall directly within the scope of the RBMPs, but usually measures aimed at landslide prevention also reduce the negative impacts of floods. The investment strategy of Priority Axis 4 shows that the funds that can be allocated for financing activities within the scope of the RBMPs' objectives amount to BGN 153.6 million.[37]

- Rural Development Program 2014–2020 (RDP 2014–2020)

188. Because of the demarcation approach of the activities supported under the operational programs for the period 2014–2020, the RDP 2014–2020 will not finance measures enhancing the protection and preparedness for an adequate response of the population to floods which will be within the scope of OPE 2014–2020. The RDP 2014–2020 provides indirect funding for projects related to the RBMPs.

189. Under Measure 4 'Investments in tangible assets', alongside investments in farms, investment in processing/marketing of agricultural products, and so on, the following measures identified in the RBMP will be supported:

- Measures supporting the reconstruction and modernization of existing or construction of new infrastructure for irrigation and drainage of agricultural lands improving the competitiveness of agricultural farms for the successful adaptation of agriculture to climate change in the country through the introduction of modern hydro-melioration practices. Irrigation associations are an eligible beneficiary under the measure.
- Wetlands restoration measures (including restoration of vegetation, slope stabilization of riverbeds, maintenance and construction of small ponds in grasslands, and so on). Such small ponds and wetlands correspond to the measures in the FRMPs which address the creation of manageable polders and buffer pools as well as the creation and

[35] Ex-ante assessment of financial instruments for OPE 2014–2020.
[36] Appendix 7 to the National Strategy for Management and Development of the Water Sector, 2012.
[37] East Aegean FRMP.

restoration of wetlands. Eligible beneficiaries are registered farmers.[38]

190. Under the RDP 2014–2020, the measure for investment in agricultural farms (M4.1) does not provide for specific funding in irrigation infrastructure 'in farms', while the measure supporting irrigation 'outside the farms' (M4.3) amounts to € 99.96 mln.

- Financial mechanism of European Economic Area and Norwegian financial mechanism

191. In December 2016 Bulgaria signed a Memorandum of Understanding for the implementation of the agreements on the European Economic Area and Norway Grants for the period 2014–2021. In the new funding period, a total of € 210.1 million will be made available to Bulgaria for the reduction of social and economic disparities and for strengthening bilateral relations with the three donor countries (Iceland, Liechtenstein and Norway).[39] One of the priority areas for the 2014–2021 funding period is 'Environment, Energy, Climate Change and Low Carbon Economy' whose suggested measures include the following:

- Development and implementation of national, regional, and local strategies and action plans on adaptation and mitigation measures;
- Integration of ecosystem-based solutions in action plans for adaptation and mitigation;
- Climate-proofing of infrastructure;
- Flood and drought prevention;
- Mapping and assessment of specific climate change risks and integration into relevant policies, strategies and plans;
- Development of climate change-related extreme event contingency plans;
- Integration of climate change-related issues into general disaster/contingency plans; and
- Awareness-raising activities.[40]

- Cross-border cooperation Programs

192. The European territorial cooperation financed by the European Regional Development Fund (ERDF) is intended to support the balanced integration on the territory of the EU by fostering cooperation at cross-border, transnational, and interregional levels. Programs for territorial cooperation include the following:

- Programs for cross-border cooperation at the internal borders of the EU: Bulgaria-Greece and Bulgaria-Romania with ERDF funding;
- Programs for cross-border cooperation at the external borders of the EU: Bulgaria-Turkey, Bulgaria-Former Yugoslav Republic of Macedonia (FYR of Macedonia), and Bulgaria-Serbia. These three programs are funded by both the ERDF and the EU Instrument for Pre-Accession Assistance (IPA);
- The Black Sea Basin Cross-Border Cooperation Program, funded by both the ERDF and the European Neighbourhood and Partnership Instrument (ENPI);

[38] East Aegean FRMP.

[39] https://www.eufunds.bg/novini/item/16200-s-210-mln-evro-islandiya-lihtenshtain-i-norvegiya-podkrepyat-prioritetni-proekti-v-balgariya

[40] Priority sectors and programme areas of the EEA and Norway grants 2014 – 2021 (http://www.eeagrants.bg/bg/assets/files/2014-2021/FMOBlueBook.pdf)

- The South-East European Space Transnational Cooperation Program;
- INTERREG (Interregional Cooperation program);
- ‘Balkan-Mediterranean 2014–2020’ Transnational Cooperation Program; and
- Danube Transnational Program 2014–2020.[41]

➢ European Union Solidarity Fund

193. The European Union Solidatiry Fund (EUSF) was set up to respond to major natural disasters and express European solidarity to disaster-stricken regions within Europe. The fund was created as a reaction to the severe floods in Central Europe in the summer of 2002.[42] In Bulgaria, the fund covered damage from snowfall, floods and landslides.

2.6.2. Human resources

Ministry of Environment and Water

194. According to the MoEW, the water related staff in the ministry structures is about 18 percent of the total staff. However, due to the close interrelationship and intertwining of activities, it is difficult to determine the exact number of staff with responsibilities only in water. In quantitative terms, the available staff can be assessed as sufficient, provided the staff has the necessary qualification and experience to exercise the functions. The main difficulty in recruiting qualified staff is the unattractive remuneration, which does not stimulate specialists with appropriate qualifications and experience to apply.

195. A major problem is the lack of specialized training (on water monitoring, implementation of specialized software/ater management models, implementation of the latest EC directives in the field of water, including the Floods Directive, the Marine Strategy Framework Directive, and so on). Similar, but even more serious problems are also observed in the secondary budget spending units, subordinated to the MoEW’s Executive Environment Agency, Regional Inspectorates of Environment and Water (RIEW), and RBDs.

196. The Executive Environment Agency does not feature sufficient staff. There is a need to increase the number of experts in the regional laboratories. For the water sector, the necessary increase in executive staff is estimated at around 15 percent of the current staff.[43]

197. In all four RBDs, the available staff is not sufficient to carry out the functions assigned to the departments. Preparing tender documentation requires knowledge and expertise almost at the same level as for the experts preparing the plans. The needs for additional staff are estimated between 30 percent and 50 percent of the approved positions.[44] The responsibilities related to the implementation of the RBMPs are not secured by the necessary specialists – according to their numbers and qualifications. An additional workload for the staff also arises from the implementation of the Floods Directive.

198. In all RIEWs, the ‘Water Protection’ departments have 2–3 experts, and this is considered sufficient.

[41] East Aegean Flood Risk Management Plan.
[42] http://ec.europa.eu/regional_policy/en/funding/solidarity-fund/.
[43] National Strategy for Management and Development of the Water Sector – Annex 6. Analysis of the Capacity of Institutions with Responsibilities in Water Management.
[44] Ibid.

Ministry of Regional Development and Public Works (MRDPW)

199. The Water Supply and Sewerage Directorate assists the Minister in conducting the state policy in the sector of water supply and sewerage at the national level. Some functions in the water supply and sewerage subsector are also performed by employees of the Concessions and Trade Companies Directorate and the Directorate for Territorial Cooperation Management (maintaining contacts with the regional water and sewerage companies on issues related to participation in the preparation, implementation, monitoring, and control of projects financed by the EU and international financial institutions).

200. Because of the interconnection of activities between different structural units, it is difficult to determine the exact number of employees performing functions only in the water supply and sewerage sector. In general, it can be concluded that the MRDPW staff dealing with water is sufficient in numbers and has the appropriate qualification.

Ministry of Agriculture, Food, and Forestry (MAFF)

201. Within the framework of the MAFF with direct functions in water management is the Hydro-meliorations Department. It employs 3 percent of the total number of specialized administrations in the ministry. This staff is considered insufficient.[45] The qualification of the employees in the Directorate is appropriate and corresponds to the functions they fulfil.

202. In most of the 28 Regional Directorates for Agriculture, there are also specialists in the management of hydro-melioration facilities. Their qualification and experience are very good.

Dams and Cascades Company under the Ministry of Energy

203. The available staff is sufficient and well-qualified to carry out the functions and additional staff if not required in the short term. At the same time the lack of hydrotechnical engineers in the labor market is considered a risk for the future.[46]

Irrigation Systems Company

204. The Irrigation Systems Company manages almost all hydro-melioration facilities in the country. There is a steady downward trend in the number of employees of the company – after 1991, it has decreased by more than two and a half times. The company has a strong need for qualified staff, both in the head office and in the regional branches. There are full-time vacancies due to a lack of qualified candidates and low remuneration.

National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences

205. Approximately one third of the staff work in the field of water resources. In addition, 500 volunteer observers work across the country. There is a need for additional staff (hydrologists, hydrogeologists, and information technology specialists) to exercise the new obligations introduced by the amendments to the Water Act in 2010. The qualification of the existing employees is appropriate and sufficient.

General Directorate for Fire Safety and Protection of the Population at the Ministry of Interior

206. Some functions under the Water Act are exercised by the Risk Monitoring and Management Department in the General Directorate and by the district authorities. The

[45] ibid
[46] ibid

available staff is sufficient in numbers and qualification.

Municipalities

207. Not all municipalities have specialized water units or experts and they use external consultants, exclusively involved in the management of water and sewerage infrastructure.

2.7. Sector Participation in CCA Specific International Cooperation or Information Exchange

2.7.1. Transboundary river basins

208. Several rivers in Bulgaria are part of transboundary river basins - catchments of the Danube, Struma, Mesta, Dospat, Byala, Arda, Maritsa, Tundja, Veleka and Rezovska. In compliance with the requirements of the WFD and the Floods Directive, RBMPs and FRMPs are developed based on international cooperation and information exchange.[47]

209. The territory of the Danube River Basin in Bulgaria is part of the international Danube River Basin. The major contractual tool for cooperation within this basin is the Convention on Cooperation for the Protection and Sustainable Use of the Danube River.[48]

210. The implementation of the WFD and the Floods Directive is coordinated by the International Commission for the Protection of the Danube River (ICPDR).[49] The corresponding management plans are the the following:

- Danube FRMP
- Danube RBMP

211. One of the main objectives of the Danube RBMP is to help overcome the gaps in measures at the national level and harmonize the coordination at the basin level. By implementing that objective, it will contribute to the realization of the common objectives set by the WFD. Both plans – the National Danube RBMP and Danube FRMP – are based on the same information regarding the territory of Bulgaria.

212. The Danube FRMP and Danube RBMP have sections focusing on climate change, developed in accordance with the Danube River Basin Climate Adaptation Strategy.[50] Priority is given to measures that are cost-effective and minimize climate risks or increase adaptive capacity, and which also have other social, environmental, or economic benefits – win-win or no-regret measures.

213. The measure ‘collaboration with competent basin management and flood risk management of other countries’ is provided in the national Danube FRMP. The measure is directly targeted toward ensuring coordination with the Danube RBMP. The exchange of information at all stages of the development of the Danube FRMP has been done through the Danube geographic information system (GIS) joint database, whereby a technical opportunity for access and use of general information by the countries was created.

[47] Based on information from RBMPs and FRMP
[48] https://www.icpdr.org/main/icpdr/danube-river-protection-convention
[49] http://icpdr.org/main/icpdr
[50] ICPDR Strategy on Adaptation to Climate Change, 2012

2.7.2. International cooperation for the Black Sea

214. As a country that signed the Convention on the Protection of the Black Sea against Pollution, Bulgaria exchanges information with Georgia, Romania, Russia, Turkey, and Ukraine. The Convention is a basic framework agreement that aims to preserve the Black Sea as a valuable natural ecosystem. There are three specific protocols:

- The control of land-based sources of pollution;
- Dumping of waste; and
- Joint action in the case of accidents (such as oil spills).

215. The implementation of the Convention is managed by the Commission for the Protection of the Black Sea against Pollution.

2.7.3. Bilateral cooperation

216. Bulgaria is working on the exchange of information and cooperation with its neighboring countries.

217. The transboundary coordination with Romania regarding the Danube River is done through the Joint Commission on Water Management Bulgaria – Romania. The creation of this commission is based on a bilateral agreement on co-operation in water management signed in 2004. Within the commission, working groups were set up and procedures were established for their work.

218. Bulgaria shares the river basins of Struma, Mesta, Dospat, Maritsa, Arda, and Byala Reka with Greece. A joint declaration was signed for successful cooperation. The declaration is considered by the Bulgarian side as a bilateral agreement. Both countries are coordinating their actions by:

- Coordination and exchange of information in expert working groups and subgroups;
- Further exchange of information according to agreements reached; and
- Participation in joint projects related to water management.

219. Part of the Struma River Basin also covers some of the territories of the FYR of Macedonia and Serbia. In the FYR of Macedonia these are the watersheds of the rivers Strumeshnitsa and Lebnitsa and in Serbia this is the watershed of the Dragovishtitsa River, and all tributaries of the Struma River.

220. In recent years, the cooperation with the FYR of Macedonia is limited. Bulgaria is looking for a way to intensify the relationship between both countries in the water sector and the exchange of experience about the implementation of the goals set by the WFD.

221. Workshops were held with Serbia regarding the Danube River, the Dragovishtitsa River, and common groundwater bodies. In these workshops, information was provided by both countries about the implementation of the WFD and the Floods Directive. Consultations and negotiations on the scope and the parameters of a bilateral agreement are in progress.

222. Transboundary river basins with Turkey are the basins of the Rivers Maritsa (also with Greece), Tundza, Veleka, and Rezovska. A joint declaration has been signed between the Minister of Environment and Water in Bulgaria and the Minister of Forestry and Water Affairs

in Turkey which contains an article about the cooperation regarding the water sector and water resources. Up to now, there is an exchange of information regarding water legislation, authorities, implementation of the WFD, and prospects for cross-border coordination in this process. Bulgaria has proposed a road map for the implementation of the WFD and the Floods Directive for 2016–2021 which will be at the core of the coordination of the WFD enforcement activities in Bulgaria and Turkey.

2.7.4. Cooperation at stakeholder level

223. The Danube Water Program provides the opportunity for water utilities from the Danube region to participate in benchmarking initiatives. Being part of the project activities provides water companies with the opportunity to compare their performance with other utilities within and across countries. In Bulgaria, the benchmarking activities started as a cooperation between the BWA and the International Association of Water Supply Companies in the Danube River Catchment Area with the support from the World Bank. The Danube Water Programme is also using a variety of mechanisms, including conferences, workshops, study tours, and online communication tools to strengthen utilities in their efforts to provide efficient and sustainable services.

2.8. Bulgarian Sector Specific Ongoing and Foreseen Climate Change Adaptation Related Actions

224. The MoEW has launched activities specifically aiming at CCA, during the current project and the preparation of the national CCA Strategy. In addition, all activities described in the previous sections already present some action with respect to CCA. The major actions, that are under implementation are done in the framework of the programs of measures under the RBMPs and FRMPs.

225. The Black Sea Integrated Monitoring and Assessment Program is about to be upgraded as part of the activities under the Convention on the Protection of the Black Sea against Pollution. There is an update on the mandatory and optional monitoring parameters, a new reporting format, and proposals for an acceptable way of comparing data.

226. Water utilities are participating in various projects and initiatives, including benchmarking projects. Although they are not directly targeting CCA, they provide an opportunity for the water utilities to increase their efficiency. This is the way to also increase their resilience, especially in terms of increasing the efficiency of water supply systems, reducing leakages, and unbilled consumption.

227. Regional feasibility studies are currently carried out for the designated areas of 14 water and sewerage systems that will assess the risks associated with climate change and will set up measures to adapt to future climate change and mitigate their impact as well for disaster resilience. As a result of the assessment, measures will be proposed to comply with existing national and European legislation related to climate change.[51]

[51] Climate Change and Major Projects, EC.

2.9. Gaps and Barriers Hindering Adequate Response to Climate Change

228. Based on the analysis, presented in the previous sections, it could be summarized that in Bulgaria, the barriers hindering an adequate response to climate change are as shown in ***Table 28***.

Table 28. Barriers hindering adequate response to climate change

Category	Barriers
Institutions' responsibilities	• Lack of good coordination between the institutions at different levels of governance on the water management aspects. The MoEW needs to cooperate with all other ministries, but they have different priorities; • Different authorities are responsible for the monitoring and storage of relevant data. The information is collected and stored differently which is a prerequisite for errors leading to wrong conclusions; and • The operation, maintenance and monitoring of dams are under responsibility of different authorities.
Institutional capacity	• Lack of sufficient staff, both in numbers and qualification because of unattractive remuneration.
Regulation and legislation	• The 'dynamic' regulatory framework and the lack of synchronization between the different legal acts, existence of contradictory regulations, delay in adoption of secondary legislation; • Lack of a national methodology for determination of minimal (ecological) runoff; • Water operators' business plans are for a period of five years while the RBMPs and FRMPs have a planning cycle of six years. This causes problems with the coordination and implementation of selected measures; • The water bodies' permitting regime for water abstraction and use, introduced by the Water Act does not specifically focus on climate change; • The design codes for flood protection facilities are outdated; • There is no legislation regarding rainwater harvesting and reclaimed water use, indicated as a 'top priority area' in the Strategic Implementation Plan of the European Innovation Partnership on Water, and as a 'specific objective' in the blueprint; • The Emergency Action Plans, developed under the responsibility of the Ministry of Interior are not updated on a regular basis at every level of governance – local, regional, and national; • There are no criteria laid down in the Bulgarian legislation for the distinction between dams and ponds. Liquidation of small dams, posing risk is carried out under a cumbersome procedure; • Lack of adequate legislation about rainwater. It is considered as wastewater, and thus, it is not allowed to be discharged into soil; and • The RBMPs and FRMPs are developed by different teams selected by public procurement procedures. The process showed several weaknesses as described earlier.

Category	Barriers
Monitoring network, models, and forecasting models	• RBDs do not monitor all water abstractions and rely on data from other authorities' (often water operators); • There are a lot of nonautomated hydrometric stations; • Past events have shown that small dams are not monitored and maintained properly by private operators and/or municipalities and there is a gap in the system for monitoring and control. The situation is similar with the irrigation systems, which were built several decades ago and whose financing scheme needs optimization; • Lack of historical statistical data and scientifically based investigations about natural hazards; • The accuracy of regional impact models; • RBDs do not use models, which are a powerful tool to bridge the gap of the insufficient monitoring stations; • There are no water balance models in the RBDs that can be used to develop different scenarios considering changes in climate, water use by different subsector, and so on; and • There are no flood risk projections.
Financial and technical	• In the first three years, there is an overwhelming accumulation of costs for the execution of the measures in the FRMPs. Experience shows that the allocation of a big amount of financial resources for a short period impedes the implementation of the measures by the central and local authorities and requires a reasonable burden-sharing approach throughout the six-year period 2016–2021 (West Aegean FRMP); • Even though the RBMPs and FRMPs provide evaluation of the measures, not all financial sources are guaranteed. Moreover, a financial deficit has been identified after analysis of the West Aegean FRMP; • There is no comprehensive database containing costs and financing in the water sector in Bulgaria and the lack of systematic and consistent information is a problem for the preparation of accurate analyzes of the financial flows in this sector; and • The condition of the infrastructure is poor, including flood protection ones.
Knowledge and awareness	• Lack of targeted information and awareness rising policy; • Knowledge available in research institutions is not sufficiently used; and • Knowledge gaps exist, both in the sector and in the subsectors.

229. It should be noted that some of these barriers are in a process of being overcome. The RBMPs have already identified weaknesses like insufficient network stations, lack of use of models, lack of methodology for determination of the minimal runoff, and so on. Corresponding measures are also suggested in the RBMPs.

2.10. Conclusions

230. Regarding the '*State of awareness and understanding'* the conclusions are the following:

A. Despite the achievements of the RBDs to involve the public and stakeholders in the discussions of the RBMPs and FRMPs, Bulgaria lacks targeted information and awareness-raising policies. Knowledge available in research institutions is not sufficiently well-exploited. Knowledge gaps such as the following exist:
   - Projected surface water and groundwater quantity for each river basin is not well-identified and is not publicly available;
   - Adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions have not been exploited in Bulgaria;
   - Methodology for assessment of the adaptive and risk mitigation capacity of the water infrastructure has not been elaborated, which does not allow stakeholders to assess their assets; and

B. Critical water infrastructure needs to be prioritized regarding adaptation and risk mitigation capacity, so that investments can be properly targeted.

231. Regarding the '*Bulgarian Climate Change Adaptation legal framework'* the conclusions are the following:

A. The EU legislation has been adequately transposed into the Bulgarian legal framework.

B. The legal framework at the subsector level:
   - Does not have specific climate change related provisions. However, indirectly there are some provisions aiming at better performance (less energy and resources used or flood preventive operation of large dams) in addressing climate change mitigation; and
   - Is covered by several acts, which is a complication for the country.

C. The legal framework is supplemented by several strategies, which are coherent and profound, considering climate change as well. Although the responsibilities are described in the strategies, the implementation is not always monitored.

D. Different teams, selected following public procurement procedures, develop methodologies and/or the RBMPs and FRMPs themselves. The process showed several weaknesses. A possible way to overcome them is long-term cooperation between RBDs and research institutions. Legal arrangements are needed to ensure that preparation of these strategic planning documents is done by organizations with appropriate knowledge.

E. A reliable database should be established for credible analyzes before the development of the next RBMPs and FRMPs.

F. It is not clear whether a knowledge-based approach was applied in the development of the second batch of the RBMPs.

G. Consistency between planning periods of the strategic planning documents in the water sector (RBMPs, FRMPs, subsectoral business plans) needs to be ensured for their more efficient implementation.

232. Regarding the '*Financial resources in Bulgaria*' the conclusions are the follwing:

A. NEK, the Irrigation Systems Company, and private operators maintain and rehabilitate water infrastructure mainly with their own funds.
B. Water operators carry out a large part of the investments with their own funds, while in sewage and wastewater treatment, the main sources of financing are currently the EU funds, target subsidies from the state through the municipal budgets, and funds from the EMEPA.
C. OPE 2014–2020, the municipal budgets, and the Irrigation Systems Company are the biggest potential sources of funding of measures falling within the scope of the FRMPs. They will provide 24.1 percent, 23.5 percent and 18.8 percent of the estimated total financial resources during the period 2016–2021.
D. Additional financial resources may be secured because of an increase in the fees for water abstraction, water use and water bodies pollution as well as an increase in the prices for water supply and sewerage services and irrigation. However, the effect of such an increase is difficult to forecast.

233. Regarding "*Human resources*": adequate employment policy as well as training should be ensured at all levels: state administration, municipal administration, etc.

Chapter 3. Adaptation Options

3.1. Identified Adaptation Options

234. The approach taken here is to identify a long list of adaptation options, based on the analyzes of the previous chapters of the report. A provisional list of CCA options was presented to water sector stakeholders and discussed at the Sector Consultation Session on June 15, 2017. The purpose of the discussion was to receive feedback regarding the relevance and priority of the various adaptation options identified. The list was revised based on the stakeholders' feedback. The revised list was presented at the Sector Prioritisation Session on October 16, 2017, where the options were prioritized.

235. What could be considered 'good adaptation' has received substantial attention in the literature. To achieve good adaptation, adaptation options must comply with a number of principles, and be the following:

- *Sustainable* – adaptation options must not only mitigate threats but also consider the opportunities available;
- *Proportionate and integrated* – the ability to respond to climate change must be permanently integrated in the decision-making system of the stakeholders;
- *Collaborative and open* – often joint action between multiple stakeholders is required. It is important to recognize that stakeholders must be informed and motivated to deliver collaborative efforts and involve external parties;
- *Effective* – the actions must be concrete, implementable and specific to the given context;
- *Efficient* – a major factor to consider is to attempt to weight the costs and benefits of the options; and
- *Equitable* – the costs and residual risks of adaptation options must be distributed across society in a fair and proportionate manner, especially considering the effects on vulnerable groups.

236. The suggested options are grouped in three main categories, which are discussed below.

3.1.1. Category 'Adaptive Governance'

237. The complexity and uncertainty associated with climate change require a new form of governance, namely adaptive governance - flexible, intersectoral, based on learning-based approaches. This category of options is considered, because of their preventive role. Their implementation could save money, time, efforts, and even human lives when it comes to floods. Options are further divided into three sub-categories as shown in ***Table 29***.

Table 29. Long list of adaptation options - category 'Adaptive Governance'

CLIMATE CHANGE ADAPTATION OPTIONS
I. Adaptive Governance
Decision making under uncertainty
1. Adapt the legal framework to make it instrumental for addressing climate change impacts
2. Strengthen application of adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions
3. Develop financial tools (credit, subsidies, and public investment) for sustainable management of water considering poverty eradication and equity
4. Establish a national fund for assistance in case of natural disasters
5. Introduce economic incentives for behavioural change
6. Develop and apply adaptive water pricing
Learning, monitoring, and flexibility
7. Maximize the use of research and education institutions
8. Strengthen adaptation capacity: CCA awareness rising campaigns, education, and training
9. Establish dynamic, publicly available GIS database supporting climate change decision making
10. Upgrade and extend the monitoring network of water resources, water infrastructure, and water use
11. Set reference monitoring areas to monitor and assess climate change
Coordination across scales
12. Clarify the roles and responsibilities of institutions regarding CCA
13. Amend relevant legislation to synchronize the planning periods of different stakeholders and to support good cooperation
14. Promote synergy of water and energy savings and efficient use
15. Shift to integrated land use planning
16. Shift to water sensitive urban and building design
17. Shift to water sensitive forest management

3.1.2. Category 'Design, construction, and operation'

238. Managed water systems normally pass three stages: design, construction and operation. Each stage plays an important role in the overall picture and is not to be neglected. The projected climate change calls for infrastructure that is resilient, flexible, cost-effective and environmentally friendly. Engineers should be provided with design standards reflecting state-of-the-art knowledge. Construction should be done using modern techniques, materials, and equipment. Operations should ensure reduced environmental impact. The list of options in this category is presented in the ***Table 30***.

Table 30. Long list of adaptation options - category 'Design, construction, and operation'

CLIMATE CHANGE ADAPTATION OPTIONS
II. Design, construction and operation
18. Design and apply decision-making tools that consider uncertainty and fulfill multiple objectives
19. Revise design criteria of water infrastructure to optimize flexibility, redundancy, and robustness

20.	Ensure plans and services are robust, adaptable, or modular; give good value; are maintainable; and have long-term benefits
21.	Operate water infrastructure to increase resilience to climate change for all users and sectors
22.	Develop a methodology for determination of minimal (ecological) river runoff
23.	Increase resilience to climate change by diversifying water sources and improving reservoir management
24.	Reduce demand by controlling leaks, implementing water-saving Programs, cascading and reusing water
25.	Improve design and operation of sewers, sanitation, and wastewater treatment infrastructure to cope with variations in influent quantity and quality
26.	Provide universal sanitation with technology locally adapted and provide for proper disposal and reintegration of used water and generated sludge into the environment or for its reuse
27.	Develop and implement eco-efficient climate adaptive and resilient water infrastructural systems and technologies
28.	Develop a methodology for assessment of the adaptive and risk mitigation capacity of the water infrastructure. Prioritize critical water infrastructure with regard to its adaptation and risk mitigation capacity
29.	Relocate water-thirsty industries and crops to water-rich areas

3.1.3. Category ‘Reduce impact of natural disasters’

239. Water related natural disasters, which have been considered in this report as major for the water sector, are floods and droughts. Floods have already been paid attention to, as required by the Flood Direcive. Droughts were somehow neglected in Bulgaria in recent years – as explained in Chapter 1. This category considers two options, one addressing floods and the other addressing droughts. The options are listed in ***Table 31***.

Table 31. Long list of adaptation options - category ‘Reduce impact of natural disasters’

CLIMATE CHANGE ADAPTATION OPTIONS	
III.	**Reduce impact of natural disasters**
30.	Regularly update the FRMPs
31.	Develop a Drought Strategy and Management Plan

3.2. Experience with Selecting Adaptation Options in the Sector in Other (EU) Countries

240. At the EU level, both Germany and the United Kingdom are countries with a comparatively long history of CCA policy elaboration and their experience might be valuable for a variety of matters. Both countries had their adaptation strategies developed before the EC started implementing its White Paper ‘Adapting to Climate Change’ in 2009.

3.2.1. Germany

241. The Federal Government adopted the German DAS in 2008. The DAS constitutes the foundation for a progressive, medium-term process in which the effects of global climate change are to be identified, risks assessed, required actions specified, and adaptation measures developed and implemented together with the Länder and other social groups. Because of the

large number of fields affected by climate change impacts, the DAS assumes an integrated approach. This intends to ensure that the consequences of climate change across various fields of action and sectors, and possible interactions between adaptation measures are considered, shared advantages fostered, and conflicts and tradeoffs between resource uses and objectives identified and averted at an early stage.

Box 1. Learning from international best practice: German adaptation measures for water regime, coastal, and marine protection

- **Adapting infrastructure:** rainwater must soak away locally, be used for irrigation, or be discharged into a body of water by means of drains kept separate from wastewater sewers; reservoirs and retention basins can be used to regulate downstream water levels, reservoirs must be operated in keeping with the necessary time and space requirements.
- **Supporting precautions against floods:** clarify in advance the best course of action for people to take in the case of sudden flooding, install non-return valves for building connections, modify sewage systems to prevent flooding.

Source: DAS 2008.

242. With the adoption of an Adaptation Action Plan in 2011, the Federal Government fleshes out the DAS with concrete activities as a means of developing the strategy further. The Adaptation Action Plan mainly sets out activities at the national level and activities undertaken by the Federal Government that are jointly initiated with the Länder. All activities under the action plan will be funded – given that budget resources are available – from the budgets of the respective governments' departments within the current financial planning. Thereby, all activities reside in the responsibility of the ministries. The preparation of the action plan was accompanied by a cross-sectoral, multi stakeholder discussion and various formats for participation as part of the ongoing dialogue and participation process concerned with the DAS.

Box 2. Learning from international best practice: Water and climate data in Germany

- The Federal Institute of Hydrology, the Federal Maritime and Hydrographic Agency, and the Federal Institute for Hydraulic Engineering work in close cooperation with the German Meteorological Service (Deutscher Wetterdienst [DWD]), a federal authority subordinated to the Federal Ministry of Transport, Building, and Urban Development. Together, they possess fundamental information about water, operate as a consortium within the jurisdiction of the Federal Ministry of Transport, Building, and Urban Development and work on the possible consequences of climate change for inland waters and coastal areas.
- The DWD provides the climate data required for all fields of action as a foundation for climate impact assessment. As part of its policy and climate advice activities, the DWD operates several observation networks and collates user-friendly monitoring, climate and climate projection data for diverse climate services. These services are drawn on by many federal and Länder-level authorities to support disaster management and civil protection and used for the development of measures to promote adaptation to the impacts of climate change.

Source: Adaptation Action Plan of the DAS 2011.

243. In 2015 the first Progress Report on the Implementation of the DAS Strategy was published containing a Monitoring Report which describes, based on indicators, climate impacts and adaptation in the individual sectors, regarding both past developments and current situation.

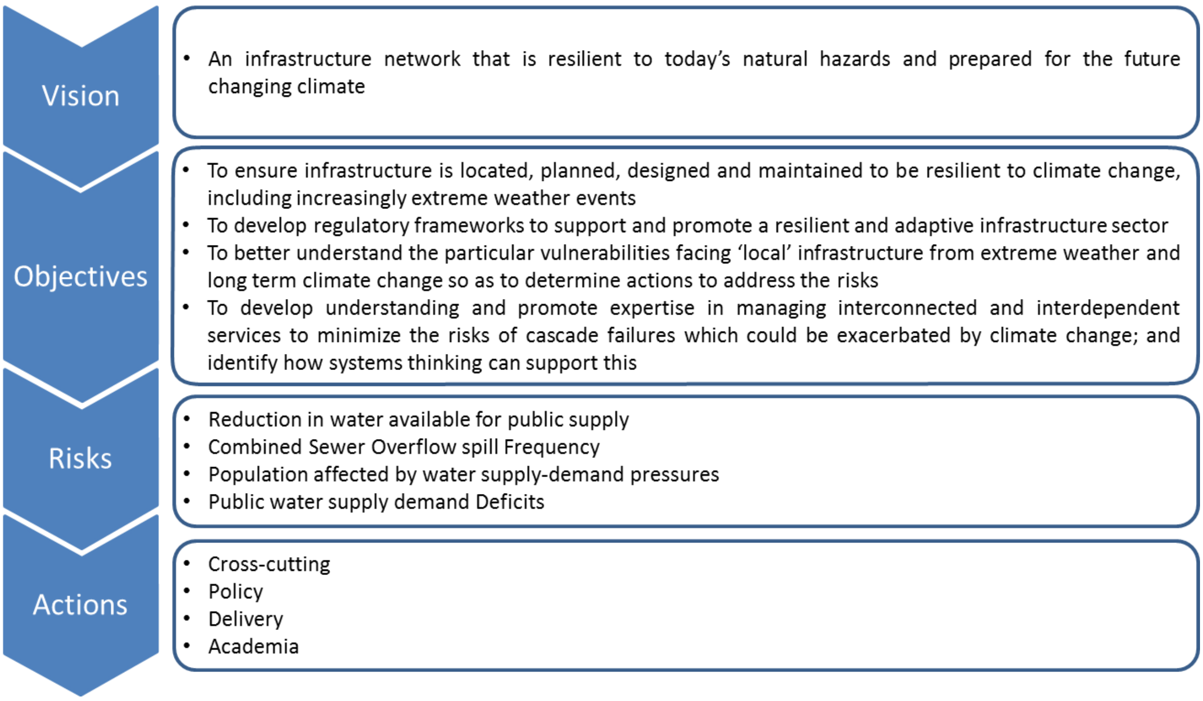
244. Lessons learned in Germany (Federal Environment Agency 2014):

- Future is uncertain ➔ iterative policy process
- Adaptation requires multilevel governance ➔ local and regional levels are most important for implementation of measures
- Mainstreaming is a key issue ➔ integration into different sectoral policies
- Adaptation needs broad commitment/participation ➔ involvement of different governmental and nongovernmental actors is essential for success of the strategy and its implementation

3.2.2. United Kingdom

245. The 2012 National Adaptation Programme "Making the country resilient to a changing climate" has a special chapter devoted to 'Infrastructure'. It includes infrastructure in the energy, transport and water sectors. The presentation is structured in four main headings: vision, objectives, risks analysis, actions to address priority list (***Figure 31***).

Figure 31. U.K. infrastructure adaptation Program in four steps



246. Although the United Kingdom (U.K.) and Bulgaria have significant differences regarding their condition of infrastructure, the U.K. approach appears very appropriate for Bulgaria. It has a special chapter on infrastructure, and as discussed in Chapter 1, this is one of the most vulnerable aspects under local conditions.

3.3. Adaptation Options Assessed

3.3.1. Qualitative analysis

247. The suggested adaptation options are assessed by: costs, benefit-cost ratio (BCR), time, efforts and institutional arrangments. A general assessment by sub-category is presented in ***Table 32***. The assessment in view of BCR is based on experience in other countries and studies. Its results are not included in ***Table 32*** but presented in detail in ***Annex 8***.

Table 32. Rough assessment of options, done by their sub-category

Sub-category	Costs	Time to make it workable	Efforts	Institutional arrangements (efforts)
Decision making under uncertainty	moderate	moderate	moderate	moderate
Learning, monitoring and flexibility	high	contant duration	moderate	low
Coordination across scales	high	long	high	high
Design	low	short	moderate	low
Construction	high	moderate	moderate	low
Operation	low	contant duration	low	low
Reduce impact of natural disasters	low	contant duration	moderate	low

248. Although general in its approach, this assessment shows that options in the sub-category 'Design' are associated with less costs, efforts and time for implementation. The options in sub-category 'Operation' also appear favorable, achieving 'more' with 'less'. Another favorable sub-category is 'Decision making under uncertainty'.

249. The sub-category 'Coordination across scales' appears most difficult to implement, because it requires more costs, efforts, and time.

250. Numeric assessment of the benefits of the options is not always possible, especially for options regarding awareness raising, education, research, monitoring, and so on. Literature shows some indicative values, that might be useful when prioritizing options (see ***Annex 8***). However, both options 'costs' and 'benefits' very much depend on local conditions. For example, the reported values for the benefit-cost ratio for the option 'Strengthen adaptation capacity: CCA awareness rising campaigns, education, and training' vary from 1.2 to 14.8 (***Annex 8***).

251. Higher than 1 (higher benefits than costs) are the reported BCR for the following options (***Annex 8***):

- 'Upgrade and extend the monitoring network of the water resources, the water infrastructure and use' – 9.7
- 'Shift to water sensitive forest management' – 1.92
- 'Operate water infrastructure to increase resilience to climate change for all users and sectors' – 1.3 for one study and 23.9 for another study
- 'Reduce demand by controlling leaks, implementing water-saving programs, cascading and reusing water' – 9.7

3.3.2. Cost-benefit analysis

252. The cost-benefit analysis (CBA) for the sector (further explanation in ***Annex 3***) focuses on the assessment of soft adaptation measures. It should also be noted that only adaptation options included in the National Climate Change Adaptation Action Plan are taken into account in the estimates presented below. Considering that water is a natural resource, benefits gained as a result of the implementation of adaptation options are best exemplified through the quantification of saved costs in main performance indicators (Total abstracted water; Total water used by sectors; and others). Having in mind the complex impact of the proposed adaptation measures on the water sector, these were not separately quantified in the current CBA. The net present value (NPV) in ***Table 33*** illustrates the monetary value of avoided losses as a result of implemented adaptation measures, while the cost effectiveness quantifies the benefits achieved in relation to the required investments/costs.[52]

Table 33. Benefits of adaptation measures in the Water sector under different climate scenarios until 2050 (in € million)

Climate scenarios	NPV (€ million)	Cost-effectiveness (Benefit/Cost ratio)
Realistic scenario +2°C	73.81	29.19
Optimistic scenario +2°C	85.99	33.85
Pessimistic scenario +2°C	61.63	24.54
Realistic scenario +4°C	98.73	38.71
Optimistic scenario +4°C	114.89	44.89
Pessimistic scenario +4°C	82.58	32.54

253. The projection shows that on average, under the +2°C realistic scenario, the total cash flow in NPV is €73.8 million, and €98.7 million under the realistic scenario at +4°C. Under the optimistic scenario, the projected cash flow in NPV is €86.0 million under the +2°C scenario and €114.8 million under the +4°C scenario. Even under the pessimistic scenario, the future cash flow in NPV is projected at €61.6 million at +2°C and €82.5 million at +4°C.

254. Within the current analysis, the cost-effectiveness of the adaptation measures is used to quantify the effect of investments under each scenario.[53] Under the +2°C realistic scenario, the benefit/cost ratio is €29.2 (that is, the benefits achieved per Euro spent), and €38.71 under the +4°C realistic scenario. The benefit is higher at +4°C temperature rise. In that case, the benefit is €44.89 per one Euro of investment under the optimistic scenario and €32.54 per one Euro of investment under the pessimistic scenario. A higher effect of investments is observed under the +4°C scenario because the average air temperature during 1991–2015 has already increased by +1.6°C. Thus, to date, the level of the +2°C scenario has already almost been reached.

[52] The NPV of an adaptation option is given by the present value of the estimated benefits and costs. If NPV is more than zero, this indicates that the investment is efficient and incremental benefits of adaptation exceed the incremental resource costs. If NPV is <0 or B/C is <1, then the adaptation measures add no net benefit to the Water sector. If NPV is >0 or B/C is >1, then it adds positive benefits. The positive value of NPV confirms that investments for adaptation are efficient.
The benefit-cost ratio (B/C) is the ratio of the present value of benefits to the present value of costs. When the B/C ratio is more than one, the present value of the option's benefits is larger than the present value of its costs.
[53] The cost-effectiveness refers to all measures.

255. Effects of taking adaptation measures will be cost savings as a result of decreased potential damage on water resources caused by climate change. The NPV for all climate scenarios is positive and high, indicating that the implemented adaptation measures are beneficial in the short- and long-term, independently of changes in temperature and fluctuations in precipitation. The assessment shows that adaptation measures contribute to reducing costs due to avoidance of losses deriving from decreased total used water and total abstracted water.

3.4. Cross-cutting Issues, Trade-offs, and Synergies of Adaptation Options

256. The interdependencies between the different sectors, as well as within each sector, must be recognized and adequately managed.[54] They may sometimes result in 'cascade failure' when the failure of one type of infrastructure leads to the failure of the next. In recognition of this, some studies analyze transport, energy and water infrastructure as a whole and attempt to best address the interdependencies (Dawson et al. 2016).[55]

257. Several climate change impacts in other sectors can also affect the water sector. A summary of how climate change effects in other sectors affect the water sector positively or negatively is presented in ***Table 34***.

Table 34. Matrix of interdependencies

Affecting ➔	WATER SECTOR	
CC effect in … 🡅 *(see below)*	**Positively**	**Negatively**
Agriculture	Water-efficient agriculture saves water in the catchment for water supply.	Improper agricultural practices (for example water-thirsty crops) in conjunction with increased temperatures would require more water than the design capacity of the irrigation system (for example pipes diameters, reservoir storage capacities).
Biodiversity and ecosystems	Water provision and water purification ecosystem services can lead to more affordable water supply for the vulnerable population. The retention of water and its filtration to underground water bodies provided by forest ecosystems and urban green infrastructure can help mitigate water shortages.	An increase in air and water temperature, combined with changes in precipitation may lead to an increase in invasive species resulting in improper functioning of the systems, for example water purification plants do not reach the required treatment level or hydropower generation disturbed.
Energy	Clean energy means clean water.	Higher price of electricity due to more expensive technologies, preventing CO_2 generation. Energy inefficient water-sector infrastructure might appear too expensive for the customers.

[54] Royal Academy of Engineering (2011).
[55] The approach employed in the UK Climate Change Risk Assessment 2017.

Affecting →	WATER SECTOR	
CC effect in … ↑ *(see below)*	**Positively**	**Negatively**
Forestry	The retention of water and its filtration to underground water bodies provided by forest ecosystems can help mitigate water shortages.	Deteriorated condition of forests due to storms and severe droughts will negatively affect water catchment and surface water quality.
Human health	Healthy people – less medicines, less contaminants in the wastewater.	Less water, more concentrated pollutants – this might require implementation of new treatment methods both for water purification and wastewater treatment.
Tourism	Sustainable tourisim – less pressure on water.	Prolonged summer season and higher summer temperatures will lead to an increase in the number of tourists at the seaside, and therefore two consequences for the water sector: (i) increasing the water demand and (ii) putting stress on wastewater collection and treatment.
Transport	Well constructed roads – prevented water underground infrastructure.	Damage to transport infrastructure due to extreme weather events (erosion, landslides, and so on) may hinder access to water infrastructure, especially in case of emergencies.
Urban environment	The retention of water and its filtration to underground water bodies provided by forest ecosystems and urban green infrastructure can help mitigate water shortages.	Higher temperatures/dry spells will lead to increased water consumption in urban areas.

Note: The above matrix of sectoral interdependencies reflects how climate change effects in one sector positively or negatively affect the water sector.

258. The description of the options in ***Annex 2*** indicates how a particular option addresses cross-cutting issues.

3.5. Priority Setting Approach

259. Identification of CCA options is an important step in the process of establishing resilience to climate change. However, it is not realistic to expect that all identified adaptation options can be implemented simultaneously. Therefore, adaptation options are normally scored to establish a priority order for their implementation. The framework of this report follows EU guidance[56], prioritizing the adaptation options specifically identified for the water sector.

260. A basic version of the multi-criteria analysis (MCA) is used. MCA is an approach as well as a set of techniques, that aims at providing an overall ordering of options, ranging from

[56] http://climate-adapt.eea.europa.eu/knowledge/tools/adaptation-support-tool/step-4/prioritise-and-select

the most preferred to the least preferred. It represents a way of looking at complex problems that are characterized by a mix of monetary and non-monetary objectives. MCA breaks down options into more manageable pieces by using a set of criteria. The two groups of criteria used for the analysis were those of 'Net Benefits' further broken down into economic, social, and environmental benefits, and 'Implementation Risks' further broken down into financial, social, institutional, technical, and technological risks (***Table 35***). This approach allows data and judgements to focus on the separate pieces that are then reassembled to present a coherent overall picture.

Table 35. Criteria applied in the MCA

NET BENEFITS				IMPLEMENTATION RISKS						Score
Net economic benefits	Net environmental benefits	Net social benefits	Weighted sum score	Financial	Social	Institutional	Technical	Technological	Weighted sum score	
0 to 5	0 to 5	0 to 5	0 to 5	0 to 5	0 to 5	0 to 5	0 to 5	0 to 5	0 to 5	

261. The prioritization of the options was done in a workshop with stakeholders' representatives, held on October 16, 2017. Ten stakeholders from different institutions participated: the NIMH-BAS, marine administration, BSRBD, State Agency for Metrological and Technical Surveillance (SAMTS), DRBD, National Electricity Company (NEK), MRDPW, WARBD, and MAFF.

262. In carrying out the MCA (that is, 'scoring the different adaptation options'), the meeting benefited from the presence of stakeholders with professional knowledge and experience in the sector. Nevertheless, this priority setting effort must be considered as indicative and tentative, for three main reasons. First, the effort was carried out at an early stage in the process of developing a strategic view and planning of sector-specific CCA options. Second, not all who were invited to the prioritization meeting attended. And third, a broader understanding of underlying information and notions on the side of the stakeholders would be beneficial to allow them to make more founded scores. Therefore, the current priority list only serves as a 'first feel' about the main direction of actions to be taken first.

263. At a later stage, further attention should be paid to the priority-setting process, both for this sector and across all economic sectors that play a role in the planning of Bulgaria's CCA actions.

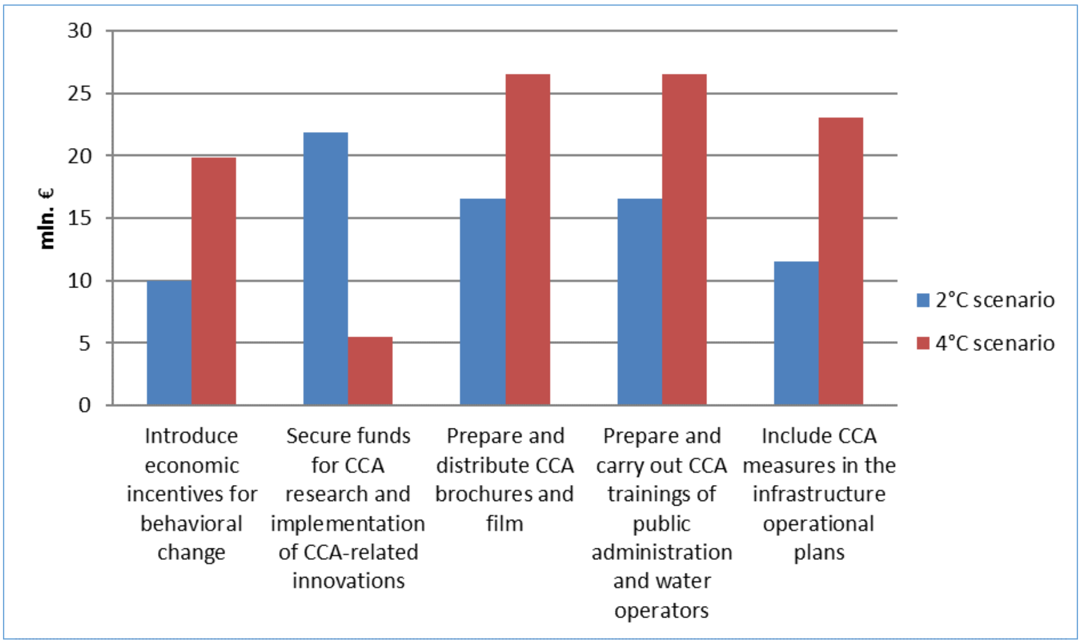
264. The ten main priority adaptation options (in descending order of total scores gained) that were tentatively and indicatively identified for the water sector are listed in ***Table 36***.

Table 36. Top ten ranked options by stakeholders' prioritization

Top ten ranked options by stakeholders' prioritization
1. Reduce demand by controlling leaks, implementing water-saving programs, cascading and reusing water
2. Improve design and operation of sewers, sanitation, and wastewater treatment infrastructure to cope with variations in influent quantity and quality
3. Maximize the use of research and education institutions
4. Strengthen adaptation capacity: CCA awareness rising campaigns, education, and training
5. Develop Drought Strategy and Management Plan
6. Develop and implement eco-efficient climate adaptive, and resilient water infrastructural systems and technologies
7. Increase resilience to climate change by diversifying water sources and improving reservoir management
8. Adapt the legal framework to make it instrumental for addressing climate change impacts
9. Develop a methodology for assessment of the adaptive and risk mitigation capacity of the water infrastructure. Prioritize critical water infrastructure with regard to its adaptation and risk mitigation capacity
10. Regularly update the FRMPs

265. The results of the CBA identify the most economically efficient adaptation actions and allow for their ranking. The adaptation measures for which the benefit exceeds the cost can be ranked as follows: secure funds for CCA research and implementation of CCA-related innovations, introduce economic incentives for behavioural change, and include CCA measures in the infrastructure operational plans, and others. The figure below shows the estimated contribution of selected adaptation measures in reaching the overall positive effects of climate change adaptation.

Figure 32. Prioritization of the adaptation measures (total present value effect in € million)



3.6. Conclusions

266. The long process with the number of iterations regarding the identification and prioritization of the suggested options, revealed, that some options are components of other options (***Table 37***). The suggested top five options were selected based on: (1) prioritization session with stakeholders; (2) additional feedback from stakeholders; (3) expert judgement.

Table 37. Suggested top five options

Main option	Component options
1. Adapt the legal framework to make it instrumental for addressing climate change impacts	Relocate water-thirsty industries and crops to water-rich areas
	Introduce economic incentives for behavioral change
	Develop and apply adaptive water pricing
	Synchronize the planning periods of different stakeholders and to support good cooperation
	Shift to integrated land use planning
	Shift to water sensitive urban and building design
	Shift to water sensitive forest management
2. Establish dynamic publicly available GIS database supporting climate change decision making	
3. Maximize the use of research and education institutions	Design and apply decision-making tools that consider uncertainty and fulfill multiple objectives
	Develop a methodology for assessment of the adaptive and risk mitigation capacity of the water infrastructure. Prioritize Critical Water Infrastructure in regard to its adaptation and risk mitigation capacity
	Develop and implement eco-efficient climate adaptive and resilient water infrastructural systems and technologies
	Promote synergy of water and energy savings and efficient use
	Revise design criteria of water infrastructure to optimize flexibility, redundancy, and robustness
	Develop a methodology for determination of minimal (ecological) river runoff
	Develop a Drought Strategy and Management Plan
	Improve design and operation of sewers, sanitation, and wastewater treatment infrastructure to cope with variations in influent quantity and quality
4. Operate water infrastructure to increase resilience to climate change for all users and sectors	Reduce demand by controlling leaks, implementing water-saving programs, cascading, and reusing water
5. Strengthen adaptation capacity: CCA awareness raising campaigns, education, and training	

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Annex 1. Potential Climate Change Impacts on the Water Sector in Bulgaria

Table 38. Potential climate change impacts on the water sector in Bulgaria

Affected water sector aspects	High temp.		Low temp.		Prolonged rainfall		Drought		Water table rise		Sea level rise		Specific effects of CC relevant for the water sector						Extreme Weather Events											
													Low water availability		Changed runoff regime		Changed water quality		Electric storms		Fogs		Floods		Avalanches		Landslides		Storms	
	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P
Infrastructure																														
Dams			L	L	L	L			L	L			H	H	L	H	M	M					H	L			H	L		
Underground - pipes					L	L			M	L	M	L											M	M			H	L		
Above ground - WWTPs, etc.	M	H	M	H	L	M	M	M			H	L					M	M					H	M			H	L	L	L
Services																														
Energy generation	M	M	M	L									H	H	M	H	L	L					L	L			H	L		
Irrigation	M	H	L	L	L	H	H	H	L	L	M	M	H	H	M	M	M	L					L	L			L	L		
Drainage	H	M			H	H	H	H	H	H	H	H			L	L							H	H						
Water supply	M	H	M	M	L	H	H	H					H	H	M	L	M	L					L	L					L	L
Sanitation	L	M	L	M	H	H	L	H															H	H						
Natural systems																														
Surface	H	H	H	H	M	H	H	H			L	M											L	H			H	H	L	M
Ground					M	M	M	M			M	L															L	L		

Legend: D = damage; P = probability of occurrence by 2050 at latest; U = unknown; H = high; M = medium; L = low

red = negative impact; green = positive impact; blank = neutral impact

Annex 2. Climate Change Adaptation Options in Detail

Table 39. Adaptation options presented in detail

<table>
<tr><th colspan="5">CLIMATE CHANGE ADAPTATION OPTIONS</th></tr>
<tr><td colspan="5">I. Adaptive Governance</td></tr>
<tr><td colspan="5">Decision making under uncertainty</td></tr>
<tr><td colspan="5">1. Adapt the legal framework to make it instrumental for addressing climate change impacts</td></tr>
<tr><td rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Description

Option’s relevance
Economic: ++
Ecologic: +++
Social: +</td><td colspan="4">The review of the legislative framework (Chapter 2.4) shows that it needs revision to become instrumental for addressing climate change impact. Although at national level some legislative and strategic documents as well as RBMPs and FRMPs consider climate change, the main document in water sector, the Water Act, is too long and too detailed to be flexible in addressing the dynamic of understanding of climate change and its impact. Furthermore, roles and responsibilities for CCA have not yet been clarified. Subsector regulations do not have specific climate change related provisions as well.
The legal framework could consider the following:
• Precautious land use (limited development, restrictions) and construction planning (flood-adapted) in risk areas.
• Rainwater harvesting, and reclaimed water use for scarcity risk regions.
• Maximum retention and utilization of the wastewater and rainwater from private properties to reduce the sewerage systems overload in settlements as well as at discharge point of receiving water bodies
• Update of design, technologies, and materials of water infrastructure to withstand ongoing or expected climate change.
• Regulation for use of fertilizer and pesticides on agricultural land to reduce impact on water bodies.
• Development of a legal framework that is in line with each region's specific characteristics (to deal with its expousure/lack of exposure to climate change risks).</td></tr>
<tr><td>Opportunities that arise</td><td colspan="4">When the legislation is oriented toward preventive climate change risk management, this saves financial resources for post-event recovery.</td></tr>
<tr><td>Cross-cutting relevance</td><td>YES</td><td colspan="3">Some legislative documents are intersectoral.</td></tr>
<tr><td>Risks addressed</td><td colspan="4">All risks</td></tr>
</table>

<table>
<tr><th colspan="7">2. STRENGTHEN APPLICATION OF ADAPTIVE WATER MANAGEMENT TECHNIQUES, INCLUDING SCENARIO PLANNING, LEARNING-BASED APPROACH, AND FLEXIBLE AND LOW-REGRET SOLUTIONS</th></tr>
<tr><td colspan="3" rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="3">Description</td><td colspan="4" rowspan="4">Managers of water utilities have experience in adapting their policies and practices to the weather. But in the face of climate change, long-term planning (over several decades) is needed for a future that is highly uncertain. Water management should consider the best available practices and the latest research development. The planning must be based on profound analysis of the past and current situation, with conclusions of good and bad practices (learning-based approach). The climate change scenarios, which are more likely to occur should be used. The measures should be flexible and, if possible, low-regret.</td></tr>
<tr><td colspan="3">Option’s relevance</td></tr>
<tr><td>Economic</td><td>Ecologic</td><td>Social</td></tr>
<tr><td>++</td><td>++</td><td>++</td></tr>
<tr><td colspan="3">Opportunities that arise</td><td colspan="4">Water management is a basic factor enabling smooth adaptation of the water sector to climate change. Thus, application of adaptive water management techniques creates several opportunities, among which are financial ones. If there is sufficient water, the water sector will run normally; when there are appropriate flood mitigation measures, damage will be less, and so on.</td></tr>
<tr><td colspan="3">Cross-cutting relevance</td><td>YES</td><td colspan="3">Water management affects various human activities and the environment.</td></tr>
<tr><td colspan="3">Risks addressed</td><td colspan="4">All risks</td></tr>
</table>

<table>
<tr><th colspan="7">3. DEVELOP FINANCIAL TOOLS (CREDIT, SUBSIDIES, AND PUBLIC INVESTMENT) FOR SUSTAINABLE MANAGEMENT OF WATER CONSIDERING POVERTY ERADICATION AND EQUITY</th></tr>
<tr><td colspan="3" rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="3">Description</td><td colspan="4" rowspan="4">The lack of sufficient funding is one of the main reasons for the weaknesses of the sector, such as a lack of appropriate and sufficient database, deferred rehabilitation, and so on. Poverty is one of the reasons for low water tariffs. Its increase will enable water operators to invest in adequate rehabilitation Programs. However, such increase, would require subsidies for vulnerable people and groups.</td></tr>
<tr><td colspan="3">Option’s relevance</td></tr>
<tr><td>Economic</td><td>Ecologic</td><td>Social</td></tr>
<tr><td>+++</td><td>++</td><td>+++</td></tr>
<tr><td colspan="3">Opportunities that arise</td><td colspan="4">When financing is ensured, it creates opportunities for improvement of the infrastructure and new jobs as well.</td></tr>
<tr><td colspan="3">Cross-cutting relevance</td><td>YES</td><td colspan="3">All water-related activities and social impact as well.</td></tr>
<tr><td colspan="3">Risks addressed</td><td colspan="4">Risk to infrastructure: better operation and maintenance.</td></tr>
</table>

<table>
<tr><th colspan="7">4. ESTABLISH A NATIONAL FUND FOR ASSISTANCE IN CASE OF NATURAL DISASTERS</th></tr>
<tr><td colspan="3" rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower generation</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="3">Description</td><td colspan="4" rowspan="4">Establishment of a national fund for assistance in case of natural disasters will allow better management of the consequences.</td></tr>
<tr><td colspan="3">Option’s relevance</td></tr>
<tr><td>Economic</td><td>Ecologic</td><td>Social</td></tr>
<tr><td>+++</td><td>+</td><td>+++</td></tr>
<tr><td colspan="3">Opportunities that arise</td><td colspan="4">If a fund is available, the damage will be recovered faster, and normal life will start sooner.</td></tr>
<tr><td colspan="3">Cross-cutting relevance</td><td>YES</td><td colspan="3">Human well-being and life, buildings, roads, and so on.</td></tr>
<tr><td colspan="3">Risks addressed</td><td colspan="4">Risk to infrastructure and services</td></tr>
</table>

<table>
<tr><td colspan="7">5. INTRODUCE ECONOMIC INCENTIVES FOR BEHAVIORAL CHANGE</td></tr>
<tr><td colspan="3" rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td></td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="3">Description</td><td colspan="4" rowspan="4">Includes options like introduction of environmental taxes and charges (for example if drinking water is used for irrigation of private land) or providing higher subsidies on products and practices (for example farmers using drip irrigation).</td></tr>
<tr><td colspan="3">Option’s relevance</td></tr>
<tr><td>Economic</td><td>Ecologic</td><td>Social</td></tr>
<tr><td>+++</td><td>+++</td><td>+++</td></tr>
<tr><td colspan="3">Opportunities that arise</td><td colspan="4">Behavioural change is a powerful factor. Even the best regulations may fail, if behaviour does n’ot change. When people are motivated to change their behaviour, with the time, it will become their normal behaviour and eventually contributeinh to preventing or at least mitigating climate change.</td></tr>
<tr><td colspan="3">Cross-cutting relevance</td><td>YES</td><td colspan="3">Efficient water use means also efficient energy use.</td></tr>
<tr><td colspan="3">Risks addressed</td><td colspan="4">Risk to services (less water will be used, higher availability in nature)</td></tr>
</table>

<table>
<tr><td colspan="7">6. DEVELOP AND APPLY ADAPTIVE WATER PRICING</td></tr>
<tr><td colspan="3" rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td></td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="3">Description</td><td colspan="4" rowspan="4">Water tariff levels and water tariff structure can both contribute to environmental sustainability if “it is used to manage demand (to encourage a more rational and efficient use of the resource) and to recoup the costs of the damages born by the environment (that is, negative impacts on ecosystems, including pollution).”[57]
Some countries have already applied tariffs, which are believed to contribute to more efficient water use. Examples are two-component tariff structures with a fixed part (uniform flat rate) and a variable part (increasing block rate), applied in Belgium, Portugal, Spain, and Italy.</td></tr>
<tr><td colspan="3">Option’s relevance</td></tr>
<tr><td>Economic</td><td>Ecologic</td><td>Social</td></tr>
<tr><td>+++</td><td>+++</td><td>-</td></tr>
<tr><td colspan="3">Opportunities that arise</td><td colspan="4">More revenues collected by water operators, would allow infrastructure improvement investments</td></tr>
<tr><td colspan="3">Cross-cutting relevance</td><td>YES</td><td colspan="3">Efficient water use means also efficient energy use.</td></tr>
<tr><td colspan="3">Risks addressed</td><td colspan="4">Risk to services (less water will be used, higher availability in nature)</td></tr>
</table>

[57] OECD (2010), Pricing Water Resources and Water and Sanitation Services, ISBN 978-92-64-08360-8 (PDF)

<table>
<tr><td colspan="5">Learning, monitoring, and flexibility</td></tr>
<tr><td colspan="5">7. Maximise the use of research and education institutions</td></tr>
<tr><td rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Description

Option's relevance
Economic: +++ / Ecologic: +++ / Social: +++</td><td colspan="4">The analyzes in this report show that Bulgaria does not fully use its research capacity. Important plans like the RBMPs and FRMPs are developed by 'random' teams, which change every time. Among other weaknesses of such approach, it does not allow a learning-based approach to be applied. If one research team is responsible for the development of one RBMP, it is expected that this team will gradually enhance its knowledge in the field of integrated water management. Researchers will bring up-to-date knowledge in the process, especially in the dynamic field of understanding climate change. The following research contribution would enhance the overall quality of the actions of the national institutions (the MoEW, RBDs, and so on):
• Improved understanding of droughts and floods, leading to different levels of response
• Policies and regulation elaboration
• Developing models to support monitoring networks and decision making
• Development of eco-efficient technologies in line with the principles of a circular economy
To realize this option, Bulgaria needs to change the approach for development of the RBMPs and FRMPs. Funds should be allocated to well-targeted research activities.</td></tr>
<tr><td>Opportunities that arise</td><td colspan="4">Research achievements bring novelty. When implemented, several side benefits will arise, including social and environmental. In many cases this has also a preventive or mitigating role in climate change</td></tr>
<tr><td>Cross-cutting relevance</td><td>YES</td><td colspan="3">Social – better lifestyle (for example new appliances); financial – less costs (for example more efficient technologies); and environmental – less resources used, less pollution.</td></tr>
<tr><td>Risks addressed</td><td colspan="4">All risks</td></tr>
</table>

<table>
<tr><td colspan="5">8. Strengthen adaptation capacity: CCA awareness raising campaigns, education, and training</td></tr>
<tr><td rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Description

Option's relevance
Economic: ++ / Ecologic: +++ / Social: ++</td><td colspan="4">Citizens and stakeholders should be informed about the vulnerabilities and risks, associated with climate change. They should be further informed about the measures they can take to proactively adapt to climate change. This option requires stimulation of public self-mobilization and action and mobilization of local knowledge and resources. Awareness campaigns can address groups of people in a region affected by a particular climate threat. This option requires development and implementation of public education and training Programrs.</td></tr>
<tr><td>Opportunities that arise</td><td colspan="4">This option creates great opportunities. Behavioral change is a powerful factor. It can contribute to prevent or at least mitigate climate change.</td></tr>
<tr><td>Cross-cutting relevance</td><td>YES</td><td colspan="3">Social – behavior change; environmental – protection and mitigation; and financial – less damages due to natural hazards, which means less finances for recovery.</td></tr>
<tr><td>Risks addressed</td><td colspan="4">Risk to infrastructure and service</td></tr>
</table>

<table>
<tr><td colspan="7">9. ESTABLISH DYNAMIC PUBLICLY AVAILABLE GIS DATABASE SUPPORTING CLIMATE CHANGE DECISION MAKING</td></tr>
<tr><td colspan="3" rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="3">Description</td><td colspan="4" rowspan="4">Currently, data monitoring is carried out by different institutions like the NIMH-BAS, RBD, water operators, and so on. Its collection is difficult, and in some cases, the information must be paid for. Not all parameters are measured and monitored. The way the indicators are monitored, and data are processed, is not unified which creates uncertainty. There is no coordinated and unified collection of extreme events data from different institutions.
This option is about development of a publicly-available GIS database with information about the following:
• Historical data on climate and extreme weather events
• Register of infrastructure
• Real-time monitoring of water resources, weather data, and infrastructure indicators, and so on</td></tr>
<tr><td colspan="3">Option's relevance</td></tr>
<tr><td>Economic</td><td>Ecologic</td><td>Social</td></tr>
<tr><td>+++</td><td>+++</td><td>++</td></tr>
<tr><td colspan="3">Opportunities that arise</td><td colspan="4">Storing data in one place in a unified format will reduce the risk of mistakes and wrong interpretations. Making data publicly available will allow different stakeholders to use it (like climate data for RBDs to evaluate water availability) and researchers to prepare more comprehensive studies.</td></tr>
<tr><td colspan="3">Cross-cutting relevance</td><td>YES</td><td colspan="3">Database could be used by different stakeholders for analysis and decision making</td></tr>
<tr><td colspan="3">Risks addressed</td><td colspan="4">All risks</td></tr>
</table>

<table>
<tr><td colspan="7">10. UPGRADE AND EXTEND THE MONITORING NETWORK OF WATER RESOURCES, WATER INFRASTRUCTURE AND USE</td></tr>
<tr><td colspan="3" rowspan="2">Relevant to:</td><td>Natural systems</td><td>Water supply and sanitation</td><td>Hydro-melioration</td><td>Hydropower</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td></tr>
<tr><td colspan="3">Description</td><td colspan="4" rowspan="4">The weaknesses of the exisiting monitoring practice are summarized in the description of the previous option. To overcome them, it is necessary (but not limited) to
• Improve the density of the monitoring networks;
• Monitor the natural water cycle in more detail, including precipitation, runoff, groundwater table, water abstractions, and water use;
• Synchronize monitoring to allow an accurate water balance estimation. Clarify the roles and responsibilities of institutions to avoid metering errors; and
• Continue developing early warning systems.</td></tr>
<tr><td colspan="3">Option's relevance</td></tr>
<tr><td>Economic</td><td>Ecologic</td><td>Social</td></tr>
<tr><td>++</td><td>+++</td><td>+</td></tr>
<tr><td colspan="3">Opportunities that arise</td><td colspan="4">Better monitoring will allow better understanding of interconnections between climate parameters, water resource availability, water infrastructure, and water use. This will allow more accurate measures to be selected and no-regret solutions to be applied.</td></tr>
<tr><td colspan="3">Cross-cutting relevance</td><td>YES</td><td colspan="3">Database could be used by different stakeholders for analysis and decision making</td></tr>
<tr><td colspan="3">Risks addressed</td><td colspan="4">All risks</td></tr>
</table>

11. Set reference monitoring areas to monitor and assess climate change					
Relevant to:		Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X			
Description		The report discusses the importance of flexible and adaptive behavior. However, it requires profound knowledge on 'is there climate change' and 'what its magnitude is'. Therefore, wherever possible, monitoring areas with no human activities should be set up to allow accurate recording and assessment of the changes.			
Option's relevance					
Economic	Ecologic	Social			
+	++	+			
Opportunities that arise		Adaptation options will be based on a solid ground. This will save human efforts and finance avoiding investments in non-necessary or highly uncertain options.			
Cross-cutting relevance		YES	Not only water-related studies, but all sectors will benefit		
Risks addressed		All risks			

Coordination across scales

12. Clarify the roles and responsibilities of the institutions regarding CCA					
Relevant to:		Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X	X	X	X
Description		Unlike other institutional responsibilities, CCA is relatively recent. The option requires the establishment of a management concept for CCA, for example a clear hierarchical structure and established institutional roles.			
Option's relevance					
Economic	Ecologic	Social			
+	+	+			
Opportunities that arise		This option will allow an appropriate response, not only in case of extreme weather events, but whenever climate change-related measures are implemented (like measures from the RBMPs and FRMPs).			
Cross-cutting relevance		YES	Roles and responsibilities regarding CCA cannot and should not be considered separately from the other activities of the institutions.		
Risks addressed		All risks			

13. Amend the relevant legislation to synchronize the planning periods of different stakeholders and to support good cooperation					
Relevant to:		Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X	X		
Description		The RBMPs and FRMPs are prepared for six-year periods. However, the business plans of water operators are for five-year periods. This makes their synchronization difficult, and thus devalues their effect. For example, if a measure is included in a RBMP, its implementation might fail because this measure is not included in the respective business plan of the water operator. This will call for a change in Article 10 of the Law on Regulation of Water Supply and Sewerage Services, which requires water operators to prepare five-year business plans.			
Option's relevance					
Economic	Ecologic	Social			
+	+	+			
Opportunities that arise		The better the planning, the higher the likelihood of implementation. Once a measure is implemented, it creates several opportunities.			
Cross-cutting relevance		NO			
Risks addressed		Risk to infrastructure and to services			

14. Promote synergy of water and energy savings and efficient use					
Relevant to:		Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X	X	X	
Description		Several EU documents prompt the interrelation of water and energy. In pumping water supply or irrigation systems, the more water is delivered, the more energy is used. At the household level, some appliances like dishwashing machines or washing machines use both water and energy. This option requires all systems to be analyzed regarding their eco-efficiency. The life cycle assessment approach has proven to be the most comprehensive one. Once such analyzes are done, particular options for each system should be further suggested and financially assessed.			
Option's relevance					
Economic	Ecologic	Social			
+++	+++	+++			
Opportunities that arise		The synergy between water and energy efficiency will lead to environmental benefits (less CO2 emissions, less water wasted), financial benefits (less water or energy used, less finances spent), and social benefits (enhanced living comfort)			
Cross-cutting relevance		YES	This option will affect mostly the urban sector.		
Risks addressed		Mostly the risk is to infrastructure, but it is also to service (when water efficient infrastructure and appliances are available, there is higher probability for sufficient water in drought periods).			

15. Shift to integrated land use planning					
Relevant to:		Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X	X	X	X
Description		This option requires identification and mapping of potential risk areas (lacking water resources, floods hazard) and groundwater bodies recharge areas to be performed. In these localities specific legislation should be adopted, like avoiding construction in flood areas, urban development in low hazard areas, setting up agricultural areas that can mitigate floods, and so on. Further specific measures could be restoring or creation of new wetlands or riverbeds, managing aquifer recharge areas like artificial increase of the river-water level next to groundwater sources, or shifting water-thirsty industries and crops to water-rich basins.			
Option's relevance					
Economic	Ecologic	Social			
+	++	+			
Opportunities that arise		Climate change impacts can be mitigated when land is use in a wiser way. Global and strategic thinking in land-use planning brings benefits like improved regional water balance.			
Cross-cutting relevance		YES	Restrict or encourage different economic activities.		
Risks addressed		All – this option has preventive effect.			

16. Shift to water sensitive urban and building design					
Relevant to:		Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X	X		
Description		In recent years, knowledge about water sensitive urban and building design has deepened and enhanced. The practice proved the concepts that water can be significantly saved, and floods can be mitigated when appropriate design and planning is applied. Measures, which contribute to water-sensitive urban design are, but not limited to, implementing green roofs, green and permeable parking lots, rain water harvesting, smart water metering, separated sewerage systems, urban water systems of new generation considering the concept of the circular economy, and so on.			
Option's relevance					
Economic	Ecologic	Social			
+	++	+			

Opportunities that arise	This option contributes to reduced water demand (protecting the environment from over abstraction) and reduced load to the WWTPs. Both aspects lead to greater benefits such as financial and energy savings.	
Cross-cutting relevance	YES	Human wellbeing and life, buildings, open areas, and so on.
Risks addressed	Risk to water supply and sanitation infrastructure and services.	

17. Shift to water sensitive forest management						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
			X	X		
Description			This option requires an integrated approach for water and forest management. Having in mind that these two activities are interrelated and having knowledge of their cause-effect chains, the option will mean planting hardwood species, regeneration from seedlings rather than sprouts, afforestation especially next to river beds, minimizing wastewater generation, and treating wastewater to a standard suitable for effluent re-use, use of stabilized sludge as a forest fertilizer, and so on.			
Option's relevance						
Economic	Ecologic	Social				
+	++	+				
Opportunities that arise			Afforestation, particularly near watercourses, brings benefits for the regulation of water flows and maintenance of water quality, reducing the intensity of floods and severity of droughts.			
Cross-cutting relevance			YES	Forest management		
Risks addressed			Risks to water services			

II. Design, construction, and operation

18. Design and apply decision-making tools that consider uncertainty and fulfill multiple objectives						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
			X	X	X	X
Description			Modeling can fill gaps from monitoring even for historic events to allow better understanding of the interconnection between human activities and climate. It can be used to support decision making by applying scientific knowledge. The option requires development and application of decision-making tools, based on modeling to fill gaps in metering, evaluate threatened water bodies, and evaluate the effect of selected measures. Developing and applying water balance models will allow investigation of different scenarios considering change in climate, water use, and so on, as well as tackling uncertainty like climate change, land management, and population growth.			
Option's relevance						
Economic	Ecologic	Social				
++	+	+				
Opportunities that arise			When a well-informed decision is made, the consequences will be positive and vice-versa. For example, if the water balance is properly done and respective water saving measures are implemented on time, the effect of droughts will be mitigated.			
Cross-cutting relevance			YES	Agriculture is sensitive to water availability, and thus appropriate water distribution among users plays a crucial role. In severe cases, it might be relevant to human health (when the threat is underestimated), and so on.		
Risks addressed			Risk to biodiversity, risk to services.			

19. REVISE DESIGN CRITERIA OF WATER INFRASTRUCTURE TO OPTIMIZE FLEXIBILITY, REDUNDANCY, AND ROBUSTNESS					
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
				X	X	X
Description			Most of the design criteria were established a long time ago, when climate change was not identified as an issue. In view of the projected changes and their dynamics, the infrastructure should be designed and constructed to allow flexibility and adaptivity. It is necessary to revise the design parameters “rain flow intensities” and “returned periods”. New technologies and practices should be encouraged, and corresponding design methods should be developed, such as measures for flood mitigation, water-energy saving, and so on. Special attention should be paid to developing the guidance for operation of managed systems, for example in high or low flow condition.			
Option’s relevance						
Economic	Ecologic	Social				
+	+	+				
Opportunities that arise			The better a system is designed; the lower its operational and maintenance costs are. If a system is designed, considering projected climate change, less damage should be expected during hazard events.			
Cross-cutting relevance			NO			
Risks addressed			Risk to infrastructure and services.			

20. ENSURE PLANS AND SERVICES ARE ROBUST, ADAPTABLE, OR MODULAR; GIVE GOOD VALUE; ARE MAINTAINABLE; AND HAVE LONG-TERM BENEFITS						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
			X	X	X	X
Description			This option requires every planning to start with setting up of appropriate and well-thought long-term goals. Afterward it requires plans to be developed in a way, which allows modifications during implementation without negative cascade effect. When planning is performed, side-effects should be considered (both positive and negative). Planning should be consistent among water subsectors and among different planning documents.			
Option’s relevance						
Economic	Ecologic	Social				
++	++	+				
Opportunities that arise			A Bulgarian proverb says, ‘Measure twice, cut once’. Wise planning saves money, efforts, resources, and time.			
Cross-cutting relevance			NO			
Risks addressed			Risk to infrastructure and services			

21. OPERATE WATER INFRASTRUCTURE TO INCREASE RESILIENCE TO CLIMATE CHANGE FOR ALL USERS AND SECTORS						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
				X	X	X
Description			Once the infrastructure is constructed, its performance depends on the way it is operated. To increase resilience to climate change, water operators should analyze in detail their preparedness, assess their adaptation capacity in view of the projected climate change and develop an operational strategy. A good example is improving efficiency by leakage reduction, applying proactive leakage control of the water supply systems, undertaking energy-saving measures to reduce CO_2 generation, and so on.			
Option’s relevance						
Economic	Ecologic	Social				
++	++	++				
Opportunities that arise			The more efficient the operation is, the longer the lifetime of the system and the lower the costs.			
Cross-cutting relevance			YES	There are complex systems.		
Risks addressed			Risk to infrastructure and services			

22. DEVELOP A METHODOLOGY FOR DETERMINATION OF MINIMAL (ECOLOGICAL) RIVER RUNOFF						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
			X			
Description			The Water Act requires such methodology to be developed (Article 135.1.1), however, so far it has not been done.			
Option's relevance						
Economic	Ecologic	Social				
+	+++	+				
Opportunities that arise			This will ensure protection of river ecosystems and provision of more accurate water balance planning			
Cross-cutting relevance			YES	Biodiversity		
Risks addressed			Risk to impair biodiversity			

23. INCREASE RESILIENCE TO CLIMATE CHANGE BY DIVERSIFYING WATER SOURCES AND IMPROVING RESERVOIR MANAGEMENT						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
			X	X	X	
Description			This option is relevant to areas, which are exposed to droughts. Therefore, it requires these areas to be delineated and a comprehensive analysis of the water balance to be performed. An integrated approach for different types of water use and different water sources should be applied. Potential backup water sources need to be studied. Groundwater bodies should be preserved for potable water supply whenever possible.			
Option's relevance						
Economic	Ecologic	Social				
+	+	+++				
Opportunities that arise			Mitigates water scarcity risk, ensures water for human needs.			
Cross-cutting relevance			YES	Agriculture, in case of droughts this option would reduce the vulnerability of the agricultural systems.		
Risks addressed			Drought, risk to services.			

24. REDUCE DEMAND BY CONTROLLING LEAKS, IMPLEMENTING WATER-SAVING PROGRAMS, CASCADING AND REUSING WATER						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
				X	X	
Description			This option requires water balance to be performed and water demand to be analyzed. When systems' deficiencies are clarified, measures such as setting up district metering areas and active leakage control for water supply systems, relining of irrigation channels, rain water harvesting, reusing water for irrigation, and so on, should be taken.			
Option's relevance						
Economic	Ecologic	Social				
++	++	++				
Opportunities that arise			Reduced water demand will protect aquatic ecosystems.			
Cross-cutting relevance			YES	Water saving means energy saving in most of the cases.		
Risks addressed			Drought, risk to services, and risk to biodiversity.			

25. IMPROVE DESIGN AND OPERATION OF SEWERAGE AND WASTEWATER TREATMENT INFRASTRUCTURE TO COPE WITH VARIATIONS IN INFLUENT QUANTITY AND QUALITY

Relevant to:	Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X		
Description	Drought and water scarcity will probably result in use of less water and a lower flowrate at the WWTPs inlets. The flowrate and the pollutants' concentrations are interdependent, thus variation in influent quality and quantity might be expected because of climate change. However, the analysis in this report showed that a decline of the population or the increase of tourists may have a higher impact on the generated wastewater than climate change. Therefore, this option requires the design and operation of the sanitation systems to be based on a sound analysis, which in the Bulgarian context, means emphasis on feasibility studies. The interconnection between the sewerage network and the WWTPs should be considered. Up-to-date sewerage systems including appropriate flood mitigation measures should be applied. The WWTPs should allow flexible operation.			
Option's relevance: Economic + / Ecologic + / Social +				
Opportunities that arise	Sound design means better performance and, in most cases, less operational costs.			
Cross-cutting relevance	NO			
Risks addressed	Infrastructure and service			

26. PROVIDE UNIVERSAL SANITATION WITH TECHNOLOGY LOCALLY ADAPTED, AND PROVIDE FOR PROPER DISPOSAL AND REINTEGRATION OF USED WATER AND GENERATED SLUDGE INTO THE ENVIRONMENT OR FOR ITS REUSE

Relevant to:	Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
		X		
Description	This option requires local conditions to be considered in the design and operation of the WWTPs and sewerage networks. For example, borehole sewerage systems are applicable for a hot climate, but are inappropriate for Bulgaria due to the cold winters. The option requires the design of sanitation systems to consider the life cycle of the generated wastewater, including side products like wastes from screens, grid chambers, and sludge. Appropriate management programs should be developed in the design phase and if necessary, wastewater treatment technology should be changed to ensure sustainable utilization of sludge and/or treated wastewater.			
Option's relevance: Economic ++ / Ecologic ++ / Social ++				
Opportunities that arise	Sustainable sludge utilization, including energy generation.			
Cross-cutting relevance	YES	Agriculture, forest – re-use of wastewater or sludge utilization.		
Risks addressed	Drought, risk to service			

27. Develop and implement eco-efficient climate adaptive and resilient water infrastructural systems and technologies					
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
				X	X	X
Description			Water services are based on a product value chain, in which water is taken from nature and is returned with a changed quality. Knowledge shows that the principles of a circular economy improve the system's performance and bring several side benefits (environmental, social, and financial). To implement the circular economy concept, baseline performance of the systems should be assessed, one of the tools being eco-efficiency assessment. Afterward, different CCA scenarios should be assessed and the one with the highest cost-benefit ratio should be selected.			
Option's relevance						
Economic	Ecologic	Social				
+++	+++	+++				
Opportunities that arise			Environmental, social, and financial benefits. For example, if the water supply system runs by gravity and is in a water-rich area, studies show that reducing the system leakages do not have higher benefit than changing sanitary appliances at households with water and energy saving ones.			
Cross-cutting relevance			YES	Urban sector, agricultural sector, energy sector.		
Risks addressed			All			

28. Develop a methodology for assessment of the adaptive and risk mitigation capacity of the water infrastructure. Prioritize critical water infrastructure with regard to its adaptation and risk mitigation capacity						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
				X	X	X
Description			The analysis in this report revealed that most of the infrastructure is overage. Its full reconstruction would require huge investments, which are not available. Therefore, infrastructure rehabilitation/reconstruction should be carefully planned following appropriate assessment and ranking. This requires a methodology to be developed including guidance on how adaptive and risk mitigation capacity of sector-specific infrastructure will be assessed. It should also provide a prioritization approach.			
Option's relevance						
Economic	Ecologic	Social				
+	+	++				
Opportunities that arise			Targeting of funding to the 'hot' spots will increase efficiency of the efforts and contribute to smarter use of financial resources.			
Cross-cutting relevance			YES	Assessing adaptive capacity in case of floods will affect all infrastructure and human lives.		
Risks addressed			All			

29. Relocate water-thirsty industries and crops to water-rich areas						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
				X	X	
Description			The analysis in this report showed that industry and agriculture are mediators if there is a scarcity risk (***Figure 25***). If the area has moderate scarcity risk, locating water-thirsty industries or crops there might shift the risk to high. This option requires smart planning following profound analysis of the current state and projections.			
Option's relevance						
Economic	Ecologic	Social				
+	+++	++				
Opportunities that arise			This option will enable normal functioning of industrial and/or agricultural activities as well as will ensure water for domestic needs.			
Cross-cutting relevance			YES	It affects industry and farmers.		
Risks addressed			Droughts, water service risk			

III. Reduce impact of natural disasters

30. Regularly update the FRMPs						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
			X	X	X	X
Description			This is a requirement of the Floods Directive. However, the option requires updating of the FRMPs to be based on a comprehensive review of the previous plan, updated projections, and flood risk and hazard identification. Measures, which prove to be useful, should continue being implemented. Up-to-date knowledge on flood mitigation measures should be considered. Country- and area-specific measures should be selected. Currently, a catalogue of measures is available, but it has shortcomings, such as repeating measures, too generally formulated measures, lack of appropriate cost estimates, and so on. RBDs should update this catalogue.			
Option's relevance						
Economic	Ecologic	Social				
+	+	+++				
Opportunities that arise			Flood mitigation means less damage, less financial means to recover, andsaved human life.			
Cross-cutting relevance			YES	Protect all infrastructure and human lives.		
Risks addressed			Floods, risk to infrastructure and service.			

31. Develop Drought strategy and management plan						
Relevant to:			Natural systems	Water supply and sanitation	Hydro-melioration	Hydropower
			X	X	X	X
Description			The FRMPs were developed for all river basins, but droughts have not been well-considered. Projections show that in some areas in the summer droughts are likely to occur. Experience in other countries shows that when mitigation measures are taken on time, damage is less. This requires development of a plan for drought management. It should be based on analysis of the location and magnitude of projected droughts to be as realistic as possible despite the uncertainty of the projections.			
Option's relevance						
Economic	Ecologic	Social				
+	+	+++				
Opportunities that arise			Drought mitigation means less damage, less financial means to recover.			
Cross-cutting relevance			YES	Human health, ecosystems.		
Risks addressed			Drought, risk to infrastructure and service, risk to biodiversity.			

Annex 3. Cost-benefit Analysis

1. General Description

The water sector is among the most important sectors where climate change effects become explicit, sometimes into extremes. A disturbed water balance can have far-fetching impacts, on for example agriculture, urban life, energy production, public health, industrial production, transport, biodiversity and others. The conceptual framework of the cost-benefit-analysis (CBA) was developed based on climate change affecting the water sector.

The purpose of this section is to:

- Estimate the parameters of a relationship between performance indicators and climate change indicators for the water sector (temperature + 2° C and +4°C, and precipitation changes). It is considered that climatic drivers associated with the impact assessment are average temperature and average precipitation.
- Develop a CBA model – appraising the costs and benefits of adaptation actions, thus measuring the efficiency of investments. It quantifies the anticipated costs and benefits of adaptation options with the aim of comparing them and determining whether the benefits outweigh the costs. Benefits are the advantages or positive effects of adaptation measures. Costs are the resources required to deliver adaptation measures. The effects are expressed as a decrease in costs because of measurers taken.
- Evaluate and rank the adaptation options in terms of economic efficiency.

1.1. Description of the methodology

Climate effects were evaluated in an integrated assessment model, which combines a regression (or sensitivity) analysis with CBA, that is, assesses the value of the costs and benefits of each adaptation action - giving a net present value (NPV) - and compares the costs (investment expenditure) and benefits (costs avoided). Costs and benefits are expressed in monetary terms and a discount rate is used to determine the NPV of the adaptation measures.

The regression analysis - as a technique to assess adaptation measures under uncertainty - identifies those factors that have most influence on main sectoral indicators.[58] The effect can be positive or negative.

Regression analysis was used to determine the effect of climatic variables on the performance of the water sector indicators. This function is normally used when both the dependent and the explanatory variables are linear. The dependent variables are the main sectoral indicators where the independent variables are climatic (temperature and precipitation). Linear extrapolation of the key indicators was accounted aiming at identifying how the sector would develop under each scenario. Extrapolation quantified each individual indicator.

The estimation of the negative and positive effects of climatic change was developed according to distinct scenarios at +2°C and +4°C temperature rise by 2050. These main scenarios are divided into sub–scenarios: optimistic, realistic, and pessimistic. The sub-scenarios are

[58] The regression is linear; the dependent and the explanatory variables are linear.

considered in the context of efficient and effective implementation of the proposed climate change adaptation measures.

The projected effects of adaptation measures are expressed as a logarithmic function, which is a tool to measure the effects of investments that would be gradually made until 2050.

An assessment was carried out of the NPV and the benefits until 2050, holding all other aspects constant. The monetary value of the effects was discounted by 4.5 percent for public funding and by 8 percent for private funding.

The benefits are defined as the positive effect of the implementation of climate change adaptation measures in the water sector.

1.2. Data collection procedures

The primary data used for the CBA was obtained from the Action Plan that is part of the draft proposal for a National Climate Change Adaptation Strategy and Action Plan for Bulgaria, and from official statistical data.

The correlation determined whether there is a relationship between the performance indicators and climate factors. The relationship indicates which indicators are significantly dependent on climate change. Estimation of the correlation coefficient (dependence between each sectoral indicator and climate change factors [temperature and precipitation]) is used to stand out and select the critical variables (variables, which are highly sensitive to climate factors).

1.3. Model specifications - assumptions and limitations

A number of assumptions were made when preparing and carrying out the CBA.

- The projected trend value of each sector indicator based on historical data (2008–2016). The main performance indicators are: total abstracted fresh water and total water used.
- Climate projection (temperature and precipitation) was applied to historical variances experienced in Bulgaria (1991–2015). The input data for climate factors consist of annual temperature (maximum, minimum, and average) and precipitation (maximum, minimum, and average).
- A baseline scenario is used to evaluate the development trend of the performance indicators under the +2°C and +4°C temperature rise scenarios. The baseline scenario reflects a continuation of current policies and plans, that is, a future in which no new measures are taken to address climate change.
- The benefits are defined as the positive effect of the implementation of climate change adaptation measures in the water sector.

2. Results of the Regression Analysis

A differential assessment was carried out by comparing the climate change effects on key performance indicators in all climate scenarios against the baseline scenario. The results display negative or positive effects to the indicators per scenario.

Results show that there is a substantial negative correlation between climate change factors and performance indicators, that is, total abstracted fresh water and total used water. Precipitation influences on freshwater resources, thus affecting the water sector. The expected relationship between total used water in the agriculture sector and temperature and precipitation is negative, the correlation is significant. The correlation between total used water in industry and temperature and precipitation is substantial.

The water sector is significantly sensitive to minimum fluctuations in precipitation. It means that, under equal conditions, in case of drought, precipitation will have a stronger effect on the total use of water and total abstracted water than temperature. The costs for water used in industry and households increase because of temperature rises.

The statistic dependency shows that the variation in total abstracted water and total used water caused by climate variables is not significant. It means that there is no explicit statistic dependency. It is important to note that other factors (economic, social, human, and management) caused a variation in performance indicators. Additionally, water utilization, increasing water demands, efficiency of irrigation systems, the level of evapotranspiration, and other parameters identified the demand of water used. The influence of these factors is difficult to be filtered and calculated. Therefore, statistic dependency between climate change factors and performance indicators cannot be explicitly expressed.

The baseline scenario reveals the costs derived from the direct impact of climate change on water resources. The cumulative sector effects presented in Table 40 illustrate the difference between the baseline scenario (that is, without implementing selected adaptation options), and the +2°C and +4°C temperature rise scenarios until 2050.

Table 40. Expected cumulative sector effects from climate change in the Water sector until 2050 without adaptation measures (baseline scenario)

Effects of climate change (€ million)	2°C scenario	4°C scenario	Precipitation
Total water used	-8,782.6	-17,565.3	159,093.6
Of which:			
Agriculture, forestry, and fishing	*-20,958.0*	*-41,916.1*	*-21,951.2*
Industry (excl. cooling)	*11,762.3*	*23,524.7*	*180,246.8*
Households	*413.1*	*826.2*	*798.0*

The costs for covering the losses from a decrease in total water used will add up to no less than €8.7 billion under the +2°C and even more than €17.5 billion under the +4°C scenario until 2050.

The expected cumulative sector effects presented in the table above show that higher temperatures decrease the total water used. Expenditure in the agriculture, forestry, and fishing sectors are expected to increase. The monetary value of 'total water used' losses is €20.9 billion at the +2°C scenario and €41.9 billion at the +4°C scenario. The agriculture sector will be seriously affected by temperature rise. Irrigation facilities can contribute to mitigate the losses of water used. Increased precipitation will decrease the costs for securing the sector's water needs. The agriculture sector is highly sensitive to abstracted fresh water.

The monetary value of the water losses in industry until 2050 is projected to be €11.7 billion under the +2°C, and €23.5 billion under the +4°C scenario.

3. Cost-benefit Analysis

The cost-benefit analysis for the sector focuses on the assessment of soft adaptation measures. It should also be noted that only adaptation options included in the National Climate Change Adaptation Action Plan are taken into account in the estimates presented below. Considering that water is a natural resource, benefits gained as a result of the implementation of adaptation options are best exemplified through the quantification of saved costs in main performance indicators (Total abstracted water; Total water used by sectors; and others). Having in mind the complex impact of the proposed adaptation measures on the water sector, these were not separately quantified in the current CBA. The net present value (NPV) in Table 41 illustrates the monetary value of avoided losses as a result of implemented adaptation measures, while the cost effectiveness quantifies the benefits achieved in relation to the required investments/costs.[59]

The monetary value of the effects is discounted, using a discount rate of 4.5 percent for public funding and 8 percent – for private funding[60].

Table 41. Benefits of adaptation measures in the Water sector until 2050 under different climate scenarios (in € million)

Climate scenarios	NPV (€ million)	Cost-effectiveness (Benefit/Cost ratio)
Realistic scenario +2°C	73.81	29.19
Optimistic scenario +2°C	85.99	33.85
Pessimistic scenario +2°C	61.63	24.54
Realistic scenario +4°C	98.73	38.71
Optimistic scenario +4°C	114.89	44.89
Pessimistic scenario +4°C	82.58	32.54

The projection shows that on average, under the +2°C realistic scenario, the total cash flow in NPV is €73.8 million, and €98.7 million under the realistic scenario at +4°C. Under the optimistic scenario, the projected cash flow in NPV is €86.0 million under the +2°C scenario and €114.8 million under the +4°C scenario. Even under the pessimistic scenario, the future cash flow in NPV is projected at €61.6 million at +2°C and €82.5 million at +4°C.

Within the current analysis, the cost-effectiveness of the adaptation measures is used to quantify the effect of investments under each scenario.[61] Under the +2°C realistic scenario, the benefit/cost ratio is €29.2 (that is, the benefits achieved per Euro spent), and €38.71 under the +4°C realistic scenario. The benefit is higher at +4°C temperature rise. In that case, the benefit is €44.89 per one Euro of investment under the optimistic scenario and €32.54 per one Euro of

[59] The NPV of an adaptation option is given by the present value of the estimated benefits and costs. If NPV is more than zero, this indicates that the investment is efficient and incremental benefits of adaptation exceed the incremental resource costs. If NPV is <0 or B/C is <1, then the adaptation measures add no net benefit to the Water sector. If NPV is >0 or B/C is >1, then it adds positive benefits. The positive value of NPV confirms that investments for adaptation are efficient.
The benefit-cost ratio (B/C) is the ratio of the present value of benefits to the present value of costs. When the B/C ratio is more than one, the present value of the option's benefits is larger than the present value of its costs.

[60] Discount rate: the rate at which future benefits and costs are discounted to make them comparable with benefits and costs at the present time.

[61] The cost-effectiveness refers to all measures.

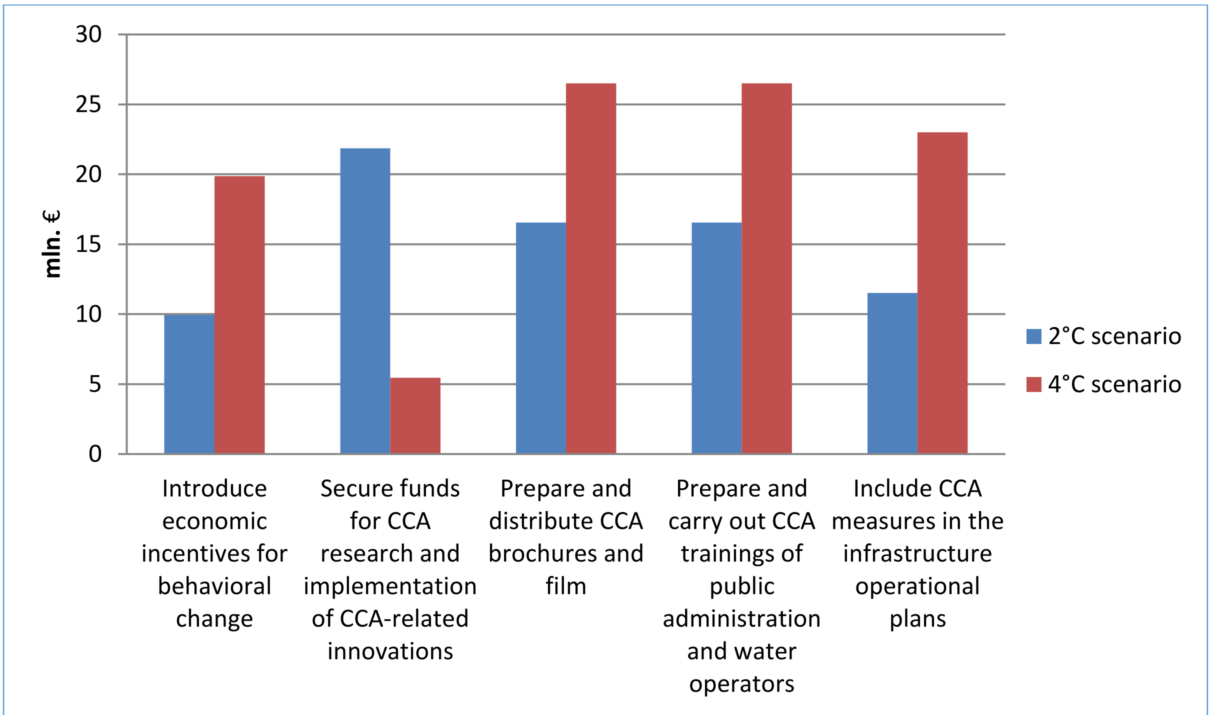
investment under the pessimistic scenario. A higher effect of investments is observed under the +4°C scenario because the average air temperature during 1991–2015 has already increased by +1.6°C. Thus, to date, the level of the +2ºC scenario has already almost been reached.

Over the years, the applied adaptation options will contribute to maintaining the value of the performance indicators (total abstracted fresh water and total used water) and avoided damages from climate change. Adaptation measures will have positive effects and will increase water management efficiency.

3.1. Prioritization of Adaptation Measures according to CBA

CBA can be used for decision making as a tool to identify measures that efficiently use financial resources. CBA identifies the most economic adaptation actions and allows for their ranking based on economic efficiency. The adaptation measures for which the benefit exceeds the cost can be ranked as follows (see ***Figure 33***): secure funds for CCA research and implementation of CCA-related innovations; introduce economic incentives for behavioural change; and include CCA measures in the infrastructure operational plans, and others.

Figure 33. Prioritization of the adaptation measures (total present value effect in € million)



4. Conclusions

Effects of taking adaptation measures will be cost savings as a result of decreased potential damage on water resources caused by climate change. The NPV for all climate scenarios is positive and high, indicating that the implemented adaptation measures are beneficial on the short and long-term, independently of changes in temperature and fluctuations in precipitation. The assessment shows that adaptation measures contribute to less costs due to avoidance of losses deriving from decreased total used water and total abstracted water.

The estimated financial efficiency of the application of adaptation measures is positive. NPV calculations show that these investments are economically efficient. Moreover, combining multiple adaptation measures will generate synergetic effects.

Annex 4. Annual Water Use by Economic Activities per River Basin

Table 42. Annual water use by economic activity per river basin (million m3/year)

Economic activities (million m^3 per year)	2008	2009	2010	2011	2012	2013
Danube River Basin						
Total water use	**2,994**	**2,913**	**2,862**	**2,941**	**2,678**	**2,513**
Agriculture	16	14,314	9,374	11	18	12
Industry	2,813	2,739	2,697	2,772	2,503	2,345
Including electricity generation	2,742	2,688	2,644	2,735	2,462	2,294
*Including cooling**	2,723	2,671	2,625	2,717	2,448	2,277
Services *(including cooling)*	28	24	23	24	21	26
Households	137	136	133	133	136	130
Black Sea River Basin						
Total water use	**655**	**435**	**470**	**507**	**368**	**250**
Agriculture	8	8	6	6	6	6
Industry	587	367	409	444	304	185
Including electricity generation	543	331	361	394	256	141
*Including cooling**	517	309	337	369	233	124
Services *(including cooling)*	19	18	15	16	17	19
Households	40	42	40	40	41	40
West Aegean River Basin						
Total water use	**75**	**72**	**71**	**70**	**78**	**78**
Agriculture	9	12	7	6	8	7
Industry	36	31	31	33	40	41
Including electricity generation	20	16	15	22	24	24
*Including cooling**	14	9	9	14	18	18
Services *(including cooling)*	8	8	11	9	8	8
Households	22	22	22	22	23	22
East Aegean River Basin						
Total water use	**1,444**	**1,491**	**1,417**	**1,661**	**1,435**	**1,637**
Agriculture	259	292	286	325	264	272
Industry	1,093	1,109	1,043	1,248	1,081	1,270
Including electricity generation	1,006	1,040	976	1,185	1,022	1,210
*Including cooling**	671	690	635	787	682	853
Services *(including cooling)*	20	19	18	18	19	26
Households	72	71	69	71	72	69

**Note: This figure includes water used for cooling both in the processing industry, and in the generation of electricity. Source: RBMPs (2016–2021)*

Annex 5. Some of the Worst Floods in Recent Years

Table 43. Some of the worst floods in recent years

Year	Event
2015	According to NSI data, there were 266 flood events with recorded damages of BGN 171 million. The most affected areas were Varna, Pleven, Sliven and Smolyan.
June 2014	Flood rains in northeastern Bulgaria where there was more than 100 liters per square meter fall two to three times the monthly rate, caused flooding in the Asparuhovo District of Varna and in Dobrich and took 13 lives. The Dobrich River correction was damaged, and there were torn bridges and claddings. As a result of torrential rain, the dam of Novo Panicharevo near Primorsko overflowed and destroyed bridges and swept over the Burgas-Tsarevo road. There were casualties too. In the same year, there were floods in Veliko Tarnovo, Burgas, Mizia, Montana, Kyustendil, Plovdiv, Haskovo, and Sofia. The damage from the floods this year was estimated at €400 million according to the Ministry of Interior, and the total number of deaths was 26. Floods caused the rupture of dam walls in Byala Slatina and Mizia (Vidin).
May 2012	After heavy rain, the Ivanovo Reservoir overflowed and its wall broke. A few meters-wide wave swept over the Harmanli Village of Bisser. Besides material damage, there were 10 casualties. There were also broken dykes along the Maritsa River near Svilengrad and Kapitan Andreevo.
July 2010	Heavy rains in many areas of the country. Large areas of agricultural lands flooded, and huge harvest damage occurred. The districts of Dobrich, Silistra, Targovishte, Shumen, Varna, Ruse, Plovdiv, Pazardzhik, Smolyan, and Blagoevgrad were the most affected.
June 2010	Heavy rainfall in central and southern Bulgaria. Water levels of dams and rivers increased dramatically. In just one day, the amount of rainfall in certain regions of the country reached 116 to 270 liters per square meter.
July 2009	Heavy rain in Varna. Basements and ground floors of houses and public buildings were flooded, In the same year, a flood in southwestern Bulgaria caused a rupture of dykes on the Bistritsa River near Kyustendil.
September 2008	Torrential rains across the country triggered floods, disasters, and damage, but there were no injuries to people.
June 2008	Hail caused damage in some parts of Bulgaria. After the torrential rains in Pleven, 15 houses and yards were flooded in the lower part of the Komarevo Village, Dolna Mitropolia municipality. On June 6, 2008, heavy rain, mixed with hail, blocked traffic on the streets and boulevards of Sofia.
May 2008	Heavy rain in Shumen, Pleven, Razgrad, and Ruse. Vegetables were cropped and some of the streets in the villages were destroyed.
March 2008	The level of the Danube River rose to Lom and exceeded 6 m. All the beaches were flooded, and the water was on the fringe in the dykes
August 2007	The town of Tsar Kaloyan, Razgrad District, was flooded by a two-meter wave, caused by record precipitation—291 liters per square meter in less than 1 day. Six people died, four were reported missing. Dozens of streets in the city were completely wiped out, hundreds of houses were destroyed. Two died in the Nisovo Village in Rousse and Montana. The floods that swept over the country after record heat and devastating drought caused severe damage in Pazardzhik, Montana, Pleven, Plovdiv, Bourgas, and Sofia.
June 2007	Botevgrad Village, Trudovets experienced devastating flooding. An hour and a half of heavy rain with hail resulted in a wave of 1.5 m which overflowed into streets and yards. The state of emergency was declared in the entire municipality of Pazardzhik, Saedinenie, Asenovgrad, and Botevgrad. The northern lane of the Trakia Highway was flooded. Tochilartsi, Pravishte, and Lenovo Dams started to overflow.

Year	Event
May 2007	After prolonged drought and abnormally high seasonal temperatures in the regions of Vratsa and Montana falls, torrential rain accompanied by hail destroyed farmland. Torrents flooded almost all of Bulgaria. On May 20, the Vladayska River overflowed into the Vladaya quarter of Sofia.
March 2007	A hurricane wind left 46 powerless settlements in Smolyan and 40 houses in Taran Village without roofs. Electricity was interrupted, with the whole Chepelare Municipality without electricity. In the Kardzhali region, pavements were swept away, and there were damaged bridges, retaining walls and culverts. Kirkovo measured rainfall of 84 liters per square meters, and the wind speed reached 120 km/h.
July 2006	Heavy rains and strong winds flooded the southern Black Sea coast. For about 20 hours, the region experienced 200–250 liters of rain per square meter, while Malko Tarnovo set a record of 300 liters per square meter of rain. Three municipalities announced a state of emergency.
April – May 2006	The swollen Danube River overflowed the Bulgarian region. The government announced the emergency situation in 21 Danube municipalities. River level marks reached historic levels.
March 2006	Over the whole of Bulgaria, there were torrential rains. 15 cities were flooded. In some places, a state of emergency was declared.
September 2005	Throughout the country torrential rains and swollen rivers flooded industrial and residential buildings, infrastructure, and agricultural lands. Dozens of families were evacuated. There were casualties. There was destruction of facilities on the Luda Yana River (Pazardjik); one of the inverted siphons of the main irrigation canal 'Aleko-Potoka' was broken.
August 2005	Western Bulgaria was under water. Again, there were casualties. A state of emergency was declared in 23 municipalities. The Lesnovska River dyke near the Dolni Bogrov Village, Sofia, was destroyed.
July 2005	A third wave of large floods affected almost the entire country. The floods took the lives of 11 people. Diverse infrastructure was damaged, including the destruction of the corrective dyke of the Kalnitza River in Sliven District. The dykes of the Mativir River near Ihtiman were cracked; the Topolnitza Dam overflowed. The damages on the water supply and sewerage infrastructure were estimated at about BGN 3.5 million from the third wave alone, and the recovery of the irrigation systems facilities was estimated at BGN 25 million.
June 2005	Western Bulgaria was flooded. According to the Permanent Commission for the Protection of the Population from Disasters, Accidents, and Catastrophes, this was the strongest rainfall in 50 years. The correction dykes of the Rivers Bebresh, Bogovina, and Rudarka in Botevgrad municipality was destroyed.
May 2005	The heavy rains in northern Bulgaria caused the first serious floods. The swollen Rivers Skat, Iskar took the first casualties.

Annex 6. Projected River Runoff in 2071–2100, Scenario RCP 4.5

Table 44. Projected river runoff in 2071–2100, Scenario RCP 4.5

RBD	River System	Mean Annual (percentage)	Climate Change Regions	Spring	Summer	Autumn	Winter
				(percentage)			
West Aegean Sea	Struma River	-14.60	Upper	-	-	-	-
		-	Middle	-	-	-19.85	-
		-	LowerLower Struma River, Mesta River and Dospat River	-	-	-14.02	-
	Mesta River	-1.38		-	-	-14.02	-
	Dospat River	-1.38		-	-	-14.02	-
Danube	Iskar River	-	Upper	-	-	-17.20	-
		-	Middle	-	-14.93		37.93
		-	Lower	-	-	-19.20	-
	Erma River	-8.61	Erma River	-	-	-17.20	-
	Nishava River	-	Nishava River	-	-	-17.20	-
	Ogosta River	-5.31	Upper and W of Ogosta	-	-21.58	-	23.22
		-	Middle and Lower	-	-	-21.90	22.73
	Vit River	-4.86	Upper	42.33	-28.33	-	-
		-	Middle	-	-24.63	-	14.78
	Osam River	-14.13	Upper	33.12	-22.87	-	-
		-	Middle and Lower	-	-17.68	-	24.93
	Yantra River	-5.44	Upper	-	-44.27	-	-
		-	Middle	-	-28.45	-	-
		-	Lower	-	-25.90	-	-
	Rusenski Lom	-21.22	Cherni Lom and Beli Lom	-	-36.85	-	-
		-	Lower Rusenski Lom	-	-43.90	-	-
	Danube Dobrudzha	-23.50	Upper river sections	-	-	-31.10	-
		-	Middle and Lower river section	-	-43.90	-	-
East Aegean Sea	Maritsa River	-	up to Pazardzhik	-	-25.63	-	-
		-	from Pazardzhik to Parvomay	-	-	-31.10	-
		-	from Parvomay to Harmanli	-	-20.61	-	-
		-	from Harmanli to the border	-	-23.80	-	-
	Tundzha River	-4.57	Upper	-	-25.63	-	-
		-11.68	Middle	-	-27.98	-	-
		-11.68	Lower	-	-30.33	-	-
	Arda River	-3.52	Upper	-	-	-16.37	-
		-	Lower and Middle	-	-14.23	-	-
Black Sea	Byala	-3.52	Upper	-		-16.37	
		-	Lower	-	-14.23	-	-
	Black Sea Dobrudzha	-16.28	North Black Sea Rivers	-	-35.13	-	-
	Provadiyska River	-16.28		-	-35.13	-	-

RBD	River System	Mean Annual (percentage)	Climate Change Regions	Spring	Summer	Autumn	Winter
				(percentage)			
	Kamchia River	-16.28		-	-35.13	-	-
	North Burgas	-16.01		-	-35.13	-	-
	Mandrenski Rivers	-16.01	South Black Sea Rivers	-	-32.87	-	-
	South Burgas Rivers	-16.01		-	-32.87	-	-
	Veleka River	-16.01		-	-32.87	-	-
	Rezovska River	-16.01		-	-32.87	-	-

Source: Final report under the implementation of a contract on 'Assessment of Pressures and Impacts of Climate Change on Surface and Groundwater and Evaluation of Water Availability for the Economic Sectors'

Annex 7. Institutional Framework in More Detail

Ministry of Environment and Water

The Ministry of Environment and Water (MoEW) is responsible for the formulation and implementation of the policies and measures to climate change mitigation and adaptation and implementation of the national water management policy. To support the activity, a Higher Advisory Council on Waters has been set up with the Minister of Environment and Water. This council includes representatives of ministries with functions and responsibilities in water management and conservation, the BAS, municipalities, non-profit legal entities with a direct relation to water, and others.

The specific functions of the MoEW in the water sector are detailed in the Water Act.

The specialized administration of the MoEW consists of nine directorates. The Water Management Directorate has direct water functions and has a leading role in the implementation of the program 'Assessment, Management and Protection of the Water Resources of the Republic of Bulgaria' from the program budget of the MoEW. Some of the responsibilities of the directorate are related, but not limited to:

- Water management implementation at the national level;
- Coordination, methodological management, analysis, and control of the activities of the basin directorates in the operational water management; and
- Interaction with other central agencies and their regional structures in water management.

The directorate also participates in the development of the state policy for bilateral and multilateral cooperation in the field of water use and protection, in the development of a National Strategy for Management and Development of the Water Sector and of national programs in the field of the protection and sustainable development of the water sector.

Other directorates in the ministry also perform functions and tasks in the management and protection of water. The Directorate General of OPE participates in the implementation of the budget program 'Assessment, Management and Protection of Water Resources of the Republic of Bulgaria' and performs the functions of managing authority of 'OPE 2014–2020'. The Directorate Coordination on EU Affairs and International Cooperation executes the preparation, implementation, monitoring, and control of international and European projects outside the OPE.

Regarding the implementation of the water management policy, the MoEW interacts mainly with the following institutions:

- The MRDPW – as a body executing the state policy in the field of exploitation, construction, repair, and reconstruction of the water supply and sewerage systems of the settlements, of the systems and facilities for protection against the harmful impact of the waters in the boundaries of the settlements, and as principal of WSS companies with more than 50 percent state ownership, as well as the structure and development of the territories and the provision of organized and efficient water supply for urbanized territories;

- The MAFF – regarding the protection of waters against pollution by nitrates from agricultural sources, harmful, and dangerous substances used for plant protection; and rational and efficient water use in the development of irrigated agriculture;
- Ministry of Interior, General Directorate Civil Defense – the pursuit of concerted action under protection from the harmful effects of water, providing assessments, development plans, and implementation measures to prevent or mitigate the effects of the harmful effects of water in flooding and drought;
- The District Governors – for keeping the conductivity of river beds and protection from the harmful effects of water;
- The mayors of municipalities – for the use and protection of waters public municipal property, including water of dams and micro-dams, public municipal property, and mineral waters, exclusive state property available for management, and use of the respective municipalities and management of water systems and facilities municipal property, including WSS companies (municipal property), and coordination of activities to protect against harmful effects of waters, including maintaining conductivity of river beds within the settlements; and dams, municipal property, including those under construction, as well as their reservoirs to the high water level, and the adjacent equipment and collecting derivations, protective dikes and equipment and systems for the strengthening of river beds within the settlements;
- The NIMH-BAS – concerning the meteorological and hydrological forecasts and the monitoring of the amount of precipitation, surface and groundwater, incl. silt runoff.

➢ Executive Environmental Agency

The Executive Environmental Agency is a key institution that implements the requirements of environmental legislation and regulations. It is responsible for the preparation and reporting of the annual inventories of GHG emissions. The main functions of the agency in the field of water include the following:

- Conducting laboratory and field studies to determine the status of water;
- Carrying out the monitoring at the national level of (a) the chemical and biological status of surface water bodies and related measurements of quantity, and (b) chemical status and quantitative status of groundwater bodies as provided for in the points of the monitoring network of the chemical status of groundwater;
- Maintaining a geographic information system (GIS) for water at the national level;
- Preparation of yearbook on water status;
- Issuing a periodical bulletin on the state of water resources of the Republic of Bulgaria based on data from the monitoring of the ecological and chemical status of waters and data on the amount of water provided by the NIMH-BAS;
- Creation and maintenance of specialized databases, maps, registers, and information system for water.

➢ River Basin Directorates

Water management in the Republic of Bulgaria is carried out at the national and basin levels. According to Article 152, paragraph 1 of the Water Act and in compliance with the WFD, the territory of Bulgaria is divided into four river basin management areas and accordingly, to four basin directorates:

- Danube River Basin Directorate (DRBD)
- Black Sea Basin Directorate (BSBD)
- East Aegean River Basin Directorate (EARBD)
- West Aegean River Basin Directorate (WARBD)

The RBDs are legal entities, almost like a secondary authorizing officer with the MoEW. Their activity is coordinated and controlled by the Water Management Directorate at the MoEW. In their work, RBDs are supported by basin councils. The functions of the RBD can be structured into four main groups:

- The management functions consist mainly of the elaboration of RBMPs and FRMPs, the management of waters exclusive state property that are not granted on concession, the management of groundwater facilities and public state property.
- The regulatory functions are related to the permitting regime for water abstraction and use of water bodies, which is introduced by the Water Act as a means of regulating the needs of the society and the persons of water resources with a certain quantity and quality.
- The information functions consist of providing information to the public on the state of the water.
- The control functions are related to the implementation of activities related to non-admission and prevention of the consequences of harmful effects on water, preservation, and protection of aquatic ecosystems and related ecosystems.

The RBDs are responsible for the implementation of the state water management and protection policy at the basin level in the respective region as well as for the achievement of European standards in water management.

➢ Regional Inspectorates for Environment and Water

The Regional Inspectorates of Environment and Water (RIEWs) are administrative structures at the MoEW, which ensure the implementation of the state policy on environmental protection at the regional level. Their total number for the country is 16, and the activity of one RIEW covers the territory of one or several districts. The activity of the RIEWs is coordinated by the Environmental Policy Directorate at the MoEW. The work of the RIEWs is supported by Expert Environmental Councils.

In the field of water protection against pollution, the RIEWs exercise preventive, ongoing, and ex post control. The preventive control includes the following:

- Participation in permit-issuance procedures for discharging wastewater into surface water bodies; and
- Annual updating of lists of wastewater sites subject to mandatory emission control.

The ongoing and ex post control over water protection is carried out with respect to

- The quality and quantity of discharged wastewater from sources of pollution;
- Pollution of water bodies in emergencies and bursts;
- Status and proper operation of the networks for own wastewater monitoring;
- Status and proper operation of sewer networks of sites generating wastewater and sewage treatment plants and related facilities;
- Status and proper operation of tailing ponds, sludge pits, and embankments and their security monitoring systems; and
- The fulfilment of the conditions and requirements of the permits for discharging wastewater issued under the Water Act and the implementation of the plans for reduction of the wastewater discharge and the complex permits.

Ministry of Regional Development and Public Works

One of the main areas of activity of MRDPW is the construction and maintenance of the technical infrastructure related to the integrated management of the water resources.

The main functions and competences of the MRDPW regarding water include the following:

- Elaboration of strategy for development and management of water supply and sewerage and coordination and control over its implementation;
- Drafting of normative acts related to the management and development of the water supply and sewerage system and issuance of secondary legislation in the cases where this is provided by law;
- Coordinating the management of water supply systems at the national level;
- Acting as principal of commercial companies – WSS operators, in which the state is the sole shareholder, and of the commercial companies – WSS operators with state participation in the capital;
- Creation and maintenance of a unified information system and register of associations of water supply and sewerage and WSS operators;
- Approval of short- and medium-term programs for research, design and construction of public water supply and sewerage systems in compliance with the RBMPs.

Ministry of Agriculture, Food and Forestry

Pursuant to the Water Act, the MAFF implements the state policy related to the exploitation, construction, reconstruction and modernization of irrigation systems and facilities and protection from the harmful effects of water outside the boundaries of the settlements. The minister endorses rules for the proper and safe operation and maintenance of the irrigation infrastructure facilities, which describes the specific requirements for the operation of the small dams.

The Irrigation Associations Act entrusts the minister with additional functions in relation to the management of irrigation systems and facilities. Pursuant to this law, the minister exercises legal, financial and technical supervision over the activities of the irrigation associations, approves annually with an order on the prices of the water supply service for the following year; approves general terms and conditions of contracts for water supply for irrigation of associations and water users who are not members of the association.

In the framework of the MAFF with direct functions in water management is the directorate Hydro-meliorations. The main responsibilities of the directorate are to assist the minister in exercising his functions under the Water Act and the Irrigation Associations Act. The directorate organizes, directs and supervises the implementation of the following activities:

- Irrigation of agricultural lands;
- Development of hydro-meliorations, including design, construction, repair, reconstruction, and maintenance of the irrigation fund, development of investment projects, and investor control over the objects of the irrigation structure for the effective use of irrigation water projects;
- Elaboration of the national water economic plan and compilation of the water and water economic balances of the country in their part related to irrigation and drainage; and
- Maintaining a registry of the Hydro-melioration Fund.

Ministry of Energy

The Water Act defines the functions of the Ministry of Energy in relation to the management of water resources. The Minister of Energy:

- Implements the state policy related to the exploitation, construction, reconstruction, and modernization of the hydropower systems and sites;
- Controls the state of water bodies and water economic systems and facilities within his competence;
- Participates in co-operation with the other competent ministers in the adoption of an ordinance on exploration, use and protection of groundwater; ordinance on emission standards for the permissible content of harmful and dangerous substances in wastewaters discharged into water bodies; ordinance on the conditions and order for the technical exploitation of the dam walls and the facilities for them; and
- Provides information to the Minister of Environment and Waters for all hydropower sites for compilation of the water economic cadaster.

The functions related to the implementation of the powers of the Minister of Energy are assigned to the Dams and Cascades Enterprise, which is in the organizational structure of NEK,[62] which in turn is a subsidiary of the state Bulgarian Energy Holding EAD. The Minister of Energy is the principal head and exercises the rights of the state in these companies.

Energy and Water Regulatory Commission

The function of the Energy and Water Regulatory Commission is to regulate activities in the energy and the water sector. Some of the powers of the Commission are:

- Issues, amends, supplements, suspends, terminates, and withdraws licenses for certain needs;
- Regulates the quality of water services (water supply and sanitation, energy

[62] Natsionalna Elektricheska Kompania (NEK): http://www.nek.bg/index.php/en/

generation);
- Carries out price regulation of the services; and
- Approves business plans.

National Institute of Meteorology and Hydrology at the Bulgarian Academy of Sciences

The functions of NIMH–BAS are described clearly and in detail in Article 171 of the Water Act and concern the monitoring of the quantity of water resources. The NIMH-BAS is entrusted with:

- Monitoring the amount of rainfall, groundwater and surface water, including alluvial runoff and infiltration;
- Conducting scientific and applied research, operational activities, and development of methodologies for water quantity and alluvial-runoff analysis and monitoring;
- Publishing the monitoring data on its website; and
- Providing the MoEW with data and information on the quantity of water.

Water-related functions are carried out by the Department of Hydrology, the Department of Water Management and Use, and the four subsidiaries of the NIMH–BAS in Plovdiv, Pleven, Varna, and Kyustendil. The institute performs operational, scientific investigations, and applied research tasks in the field of production of hydrological information and data products.

State Agency for Metrological and Technical Surveillance

The Directorate General Supervision of dam walls and related facilities at the SAMTS has the following functions:

- Controlling the measures for keeping the dam walls and related facilities in good technical condition and ensuring their safe exploitation;
- Controlling the implementation of activities for immediate decommissioning of dam walls and/or related facilities, which are in poor condition, until they recover their technological and constructive safety or liquidation of such dam walls and/or facilities in case their recovery and reconstruction are inexpedient;
- Controlling the implementation of the directions of the Commissions under Article 138a, paragraph 3 and Article 190a, paragraph 1, point 3 of the Water Act;
- Controlling the implementation of measures for good technical condition of the dam walls and related facilities and their safe exploitation;
- Controlling the implementation of activities for decommissioning and/or liquidation of dam walls and related facilities;
- Giving mandatory prescriptions to the owners of dam walls and/or related facilities in accordance with its powers, given by the Water Act, including for the implementation of measures and activities for the clarification of the technical condition and the conditions for exploitation of the controlled objects, and also fixing time period for their implementation;
- Applying enforcement administrative measures ordering: prohibition of using and access to a dam, which is being exploited not according to the requirements of the

Ordinance pursuant to Article 141, paragraph 2 of the Water Act; decommissions dam walls and related facilities; provisional decommissions of dam walls and related facilities to prevent accident hazard of the facilities until they are brought to a condition, where they comply with the technical rules;

- Controlling the implementation of the activities under Article 145, paragraph 2 of the Water Act; and
- Cooperating for timely recovering of the Agency's claims.

General Directorate for Fire Safety and Protection of the Population at the Ministry of Interior

The functions of the Ministry of Interior concern the operational protection against the harmful effect of water under the Water Act. Operational protection consists in carrying out the activities under Article 19, paragraph 1 of the Disaster Protection Act and is implemented by the Unified Rescue System. Operational protection is implemented in accordance with the emergency plans under Articlle 138a of the Water Act and the plans for protection in case of disasters under Article 9 of the Disaster Protection Act.

Annex 8. Cost and Cost-benefit Assessment of the Options[63]

Table 45. Cost and cost-benefit assessment of the options

Option	Cost	Cost effectiveness/cost-benefit	Source
Strengthen application of adaptive water management techniques, including scenario planning, learning-based approaches, and flexible and low-regret solutions	**The LIFE AgroClimaWater Project (Research and Knowledge Project, duration 2015–2020):** promote water efficiency and support the shift toward climate resilient agriculture in three farmers' organizations located in Crete, Greece (Platanias and Mirabello), and in Basilicata, Italy (Metapontino). Water Management Adaptation Strategies will be developed and implemented at farmers' organizations' level to increase water efficiency in the cultivation of perennial crops and establish pilot farms adapted to water scarcity. **(Total budget €2.4 million)**		(CLIMATE-ADAPT, Accessed in October 2017b)
Develop financial tools (credit, subsidies and public investment) for the sustainable management of water and for considering poverty eradication and equity	**The City of Copenhagen Cloudburst Management Plan 2012:** Get CCA measures implemented through water charges Capital Costs: Private financing - €160 million, Financing by charge revenues - €300 million, and Financing by taxes - €5 million		(The City of Copenhagen 2012)
Introduce economic incentives for behavioral change	**Economic incentives to reduce vulnerability to drought in Segura and Tagus Basins, Spain (2014) - develop drought insurance and water-use right trading**	1. The analysis on drought insurance shows that between the fair risk premium and risk-averse farmers' willingness to pay, there is space for insurance systems that would stabilize income and reduce incentives for groundwater over exploitation during dry periods. 2. Water-use right trading has been designed based on an analysis of actual opportunities for water transfers among different users. The analysis shows that opportunities for water trading decay with distance as transport costs increase.	(CLIMATE-ADAPT, Accessed in October 2017d)

[63] Prepared by Qiong Lu, October 2017

Option	Cost	Cost effectiveness/cost-benefit	Source
Develop and apply adaptive water pricing	**Economic incentives to reduce vulnerability to drought in Segura and Tagus basins, Spain (2014) - water security pricing scheme** It works as a cost-sharing mechanism among those interested in having a secure water supply		(CLIMATE-ADAPT, Accessed in October 2017d)
Maximizing the use of research and education institutions	**Integrated management and adaptation strategies for Cork Harbor, Ireland (2014):** A strategic partnership was established between the local authority and multidisciplinary academic experts (Harbour Management Focus Group) to help implement the integrated management strategy for Cork Harbor.	It has been developed through a voluntary process, co-ordinated through funding provided through the COREPOINT and IMCORE projects. The stakeholder partnership remains in place and climate change adaptation will be embedded in future planning policy in the near future.	(CLIMATE-ADAPT, Accessed in October 2017e)
Strengthen adaptation capacity: CCA awareness rising campaigns, education, and training	**SWITCH Learning Alliance in Lodz (a stakeholder forum for exchanging ideas, plans, and interests):** €130,000 was invested in the activities	1. The learning alliance built and trained a facilitation team, developed a website and communication strategy and hosted several meetings, trainings and workshops on different urban water management issues. Participation in the project helped to marry the technical expertise with the planning in the city and raise awareness of the need to consider green and blue spaces in the city. 2. The alliance undertook a wide range of awareness raising and advocacy activities. These included engaging young people to raise their awareness of environmental issues and to create interest in the city's hidden rivers. The mass media were also engaged.	(CLIMATE-ADAPT, Accessed in October 2017i)
	Lee Catchment Flood Risk Assessment and Management Study: Fluvial flood forecasting and warning system, combined with targeted public awareness campaign and individual property protection Costs: (1) Upper Lee and Lower Lee (2167 properties located within the flood extent of the estimated 1 percent AEP fluvial event) - €11.5 million (2) Owennacurra and	Upper Lee and Lower Lee – Benefits of option €133 million, **Benefit Cost Ratio (BCR): 11.6** Owennacurra and Midleton - Benefits of option €25.9 million, **BCR: 14.8** Owenboy and Carrigaline - Benefits of option €1.6 million, **BCR: 1.6** Glashaboy and Glanmire/ Sallybrook - Benefits of option €0.8 million, **BCR: 1.2**	(OPW 2010)

Option	Cost	Cost effectiveness/cost-benefit	Source
	Midleton (213 buildings located within the flood extent of the estimated 1 percent AEP fluvial event) - €1.75 million (3) Owenboy and Carrigaline (54 bulidings located within the flood extent of the estimated 1 percent AEP fluvial event) - €1.0 million (4) Glashaboy and Glanmire/Sallybrook (34 properties located within the fluvial flood extent of the estimated 1 percent AEP event) - €0.7 million.		
	Lee Catchment Flood Risk Assessment and Management Study: Tidal flood forecasting and warning system, combined with targeted public awareness campaign and individual property protection/flood-proofing Costs: Cork Harbor, Cork City, Glanmire, Little Island, Glounthaune, Midleton, Rostellan, Aghada, Crosshaven, Carrigaline, Monkstown, Passage West, Cobh and Whitegate (2,462 buildings located within the flood extent of the estimated 0.5 percent AEP fluvial event) - €9.7 million	Cork Harbor, Cork City, Glanmire, Little Island, Glounthaune, Midleton, Rostellan, Aghada, Crosshaven, Carrigaline, Monkstown, Passage West, Cobh and Whitegate - **Benefits of option €48.5 million, BCR: 5.0**	(OPW 2010)
	Financial Institutions: preparing the market for adapting to climate change – Climabiz: 1. Develop the Climate Risk Management Model to provide integrated solutions, suggesting interventions that enhance businesses' adaptability to new climatic conditions and reduce their carbon footprint. 2. Within the framework of the Climabiz project, three e-learning Programs were completed. 3. A total of 68 small business officers, located at 68 different branches all around Greece, were trained on how to use the CRMM and how to communicate the results to clients. **Total cost at the end of the project was € 1.683.141**	1. Climate risk estimation allows an assessment of climate risks in relation to the other financial risks, to enable climate risk to be integrated in a general risk management strategy for the financial sector. 2. A total of 677 clients from several economic sectors responded to the Piraeus Bank campaign on climate adaptation solutions. A pilot exercise on the adoption of most of the climate mitigation measures by hotels taking part in the pilot indicated that a risk reduction of 22 percent per year and a carbon reduction of 70 percent per year are possible in a cost-benefit manner. 3. The Climabiz project enhanced Piraeus Bank's effort in low carbon investments. During 2012 Piraeus Bank increased its green credit limits and balances by 26	(CLIMATE-ADAPT, Accessed on October 2017c)

Option	Cost	Cost effectiveness/cost-benefit	Source
		percent from the year before €1.3 billion and €861 million, respectively.	
Establish dynamic publicly available GIS database supporting climate change decision making			
Upgrade and extend the monitoring network of the water resources, the water infrastructure and use	**Private investment in a leakage monitoring program to cope with water scarcity in Lisbon:** The leakage monitoring system helps identify and locate any water leakages in the distribution network. After the location of the leak is identified, specialized technicians, known as leak detection mechanics, are sent out to carry out field-based leak detection and repair the problem. (Costs: Software development: **€1 million;** Network monitoring systems: about **€1 million**; The operational costs of the program account to about **€0.5 million per year**)	The return on investment for leakage repairs has been highly profitable for the company. It has resulted in a reduction of non-revenue water from 23.5 percent in 2005 to around 8.5 percent in 2015, which equals to around **€68 million** in accumulated savings in the last 10 years. **BCR: 68/(1+1+0.5*10)=9.7**	(CLIMATE-ADAPT, Accessed in October 2017h)
Set reference monitoring areas to monitor and assess climate change	**The SAFE warning system for extreme weather events:** The SAFE-system is a ‘sensor-actor-based early warning system’ for extreme weather events developed for the case of the municipality of Mering (13,000 citizens) in Bavaria, Germany. Onetime costs: **€0.14 – 0.36 million** Annual operations costs: **€3.500 – 6.500**		(Altvater *et al.* 2012)
Promote synergy of water and energy savings and efficient use	**Ukraine Urban infrastructure project: improve the energy efficiency in water and wastewater utilities** Total cost: about US$80 million (€68.7 million) World Bank loan to raise energy efficiency (EE) in water and wastewater utilities; and estimated US$2.2 million (€1.9 million) Swedish International Development Cooperation Agency grant to support for detailed design, supervision, and energy audits.	Energy efficiency was also achieved in full. Annual savings estimated to amount to the wholesale market price of electricity as of Q4 2014 (US$0.047 per kWh) to **US$188.47 million** (€161.8 million) **in savings** or to **US$60.15 million** (€51.6 million) using current electricity retail price as of quarter 4 2014 (US$1.5 cent per kWh) The benefit-to-cost ratio of the whole project is 1.51. At 12 percent assumed opportunity cost of capital, the project	(The World Bank 2015)

Option	Cost	Cost effectiveness/cost-benefit	Source
		resulted in positive NPV of about US$70.8 million.	
Shift to integrated land use planning	**United Kingdom:** Provide a flood compensation area which provides 1 in 100 annual probability of river flooding protection (delivered in a partnership between Rotherham MBC, the Environment Agency and Yorkshire Forward Renaissance, costing €16.73 million).	Protected an area of 30 hectares from future flooding	(UKCIP, Accessed in October 2017)
	Netherlands, room for river project: Typical cost rate for reducing high water levels varies between river branches ranges from € 8,000 per m^2 in the Maas River to €26,000 per m^2 in the Waal River.		(CPB 2017)
	Defra Multi-objective Flood Management Demonstration Projects: Land use and management can make a significant contribution to reducing flood risk Source to Sea Project (Holnicote, Somerset)	Land management changes in the River Aller catchment reduced the flood peak by 12 percent. The capital cost of the associated land management changes amounted to some £0.1 million (€0.11 million); the 90 properties protected have an insurance value of £30 million (€34 million). Around 1.2 million visitors come to Holnicote each year. If just 10 percent of the visitors can be engaged in spending £1, this would generate revenue of £0.1 million (€0.11 million) per year to invest in on-going land management initiatives.	(Frontier Economics 2013)
Shift to water sensitive urban and building design	**The Sokołówka River (Poland) demonstration project and the development the Blue-Green Network concept for city planning (within the EU SWITCH project,** the total SWITCH project budget for activities in Lodz is about €1.15 million for five years. The Sokołówka River demonstration project had a budget of approximately €0.7 million**)**	The Blue-Green Network is to frame the development in the city by a network of (restored) river systems and green spaces (agricultural areas, parks and brownfield land). Benefits have not been quantified so far. But, connecting 'blue' and 'green' spaces provides an integrated approach to storm-water retention and to purification and amelioration of the city microclimate, thus allowing flexible adaptation to climate change and improvements in quality of life and environment in the urban area.	(CLIMATE-ADAPT, Accessed in October 2017i)

Option	Cost	Cost effectiveness/cost-benefit	Source
Shift to water sensitive forest management	**Defra Multi-objective Flood Management Demonstration Projects: Land use and management can make a significant contribution to reducing flood risk -** **Slowing the Flow Project in Pickering:** 1.Construction of low level bunds 2.Planting Riparian and floodplain woodland 3.Large woody debris dams 4.Planting farm woodland 5.Blocking moorland drains 6.Establishing no-burn buffer zones along moorland streams 7.Blocking forest drains, restoring streamside buffer zones, and amending the Forest Design Plan. Total costs: £3.6 million (€ 4.08 million)	Total benefits: £6.9 million (€7.83 million) **BCR: 7.83/4.08=1.92**	(Frontier Economics 2013)
Revise design criteria of water infrastructure to optimize flexibility, redundancy, and robustness	**The Flood Management Plan of the Basque Autonomous Community (Spain):** norms for improved urban drainage systems (€0.03 million)		(ECONADAPT 2013)
Ensure plans and services are robust, adaptable, or modular; give good value; are maintainable; and have long-term benefits	**The updated Sigma Plan (Scheldt Estuary, Belgium):** The original Sigma Plan (1977) was designed to protect the Scheldt storm surge floods. But, it was insufficient to provide adequate protection both under current conditions and the likely conditions predicted by climate change models. The 2005 update referred to a projected rise in sea-level of 9 cm to 88 cm by 2100, taking into account varying estimates of seawater expansion, melting of the icecaps and glaciers and climate sensitivity. The total costs for realizing the updated Sigma Plan were estimated at €994 million for the constructions and €62 million for the accompanying measures (2010).	1. The updated Sigma Plan also calls for raising an additional 24 km of dykes and increasing the land set aside solely for flood protection to 1523 hectares (390 ha more than in the original plan); 2. The benefits of the updated plan were estimate to range between €143 million and €984 million, with the highest level of benefits realized by the maximization of the use of controlled tidal areas.	(CLIMATE-ADAPT, Accessed in October 2017f)

Option	Cost	Cost effectiveness/cost-benefit	Source
Operate water infrastructure to increase resilience to climate change for all users and sectors	**Vltava river basin, Czech Republic:** Damming of the stream, mobile barriers in municipality Stechovice (€2.84 million, €0.38 million per ha)	Planned efficiency: from Q10 to Q50 at Vltava River, from Qmin to Q20 Kocába River, decrease of area under flood risk by 7.5 ha;	(Vltavy 2007; ECONADAPT 2013)
	Vltava river basin, Czech Republic: adjustment of the stream, solid constructions, and mobile barriers in Kralupy nad Vltavou (€7.36 million, €0.13 million per ha)	Planned efficiency: from Q_{min} to Q_{20} river Vltava; decrease of area under flood risk by 57.3 ha;	(Vltavy 2007; ECONADAPT 2013)
	Vltava river basin, Czech Republic: increasing the capacity of the riverbed in the area of Rohanský island (relief river branches) (€40.4 million)		(Vltavy 2007; ECONADAPT 2013)
	Macedonia: 1. Improve the efficiency of M&I water systems (total NPV €29.5; NPV calculations assumed a 5 percent discount rate); 2. Improve the efficiency of irrigation systems (total NPV €27.1; NPV calculations assumed a 5 percent discount rate); 3. Expand irrigation systems (total NPV €130.2; NPV calculations assumed a 5 percent discount rate)		(IEC 2013)
	Lee Catchment Flood Risk Assessment and Management Study: Further optimization of the operation of Carrigadrohid and Inniscarra Dams informed by integrated flood forecasting Costs: Lower Lee, Ballincollig and Cork City (2056 properties located within the flood extent of the estimated 1 percent AEP fluvial event) - €0.8 million	Benefits of option €18.7 million **BCR: 23.9**	(OPW 2010)
	Lee Catchment Flood Risk Assessment and Management Study: Provision of permanent flood walls and embankments combined with flood storage reservoirs. Costs: Midleton - €26.6 million	Benefits of option €33.6 million **BCR: 1.3**	(OPW 2010)
Reduce demand by controlling leaks, implementing water-saving programs, cascading and reusing water	**Water Metering in the United Kingdom** (costs: € 0.97 per m^3)		(Sutherland and Fenn 2000)
	Private investment in a leakage monitoring program to cope with water scarcity in Lisbon: The leakage monitoring system helps identify and locate any water leakages in the distribution network. After the location of the leak is identified,	The return on investment for leakage repairs has been highly profitable for the company. It has resulted in a reduction of non-revenue water from 23.5 percent in 2005 to around 8.5 percent in 2015, which equals to	(CLIMATE-ADAPT, Accessed in October 2017h)

Option	Cost	Cost effectiveness/cost-benefit	Source
	specialized technicians, known as leak detection mechanics, are sent out to carry out field-based leak detection and repair the problem. (Costs: Software development: **€1 million;** Network monitoring systems: about **€1 million**; The operational costs of the program account to about **€0.5 million per year**)	around **€68 miillion** in accumulated savings in the last 10 years. **BCR: 68/(1+1+0.5*10)=9.7**	
Improve design and operation of sewers, sanitation, and wastewater treatment infrastructure to cope with variations in influent quantity and quality	**Accommodate the existing drainage system to the projected sea level rise in the Fondi plane, Italy:** estimated costs: € 50 - 100 million	Due to an already developed and well working drainage system, the incremental costs linked to the expected sea level rise are much lower compared to the potential damage implied by a 'do nothing' strategy (€130 - 270 million at 3 percent discount rate)	(Goria and Gambarelli 2004)
Provide universal sanitation with technology locally adapted, and provide for proper disposal and reintegration of used water and generated sludge into the environment or for its reuse	**The Empuriabrava WWTP Wastewater Reclamation and Reuse Systems, Spain - a lagooning system and a constructed wetland that allows the reuse of water:** Estimated Initial investment (Year 0): €1.38 million, and estimated annual expenditure: €0.23 million;	The Empuriabrava reclamation water reuse measure is highly profitable in all climate change scenarios, especially from an environmental point of view. Benefits are evident as it is a very complete measure: an extensive volume of water is saved for environmental restoration while pollutants are removed, it requires very low energy consumption to achieve its targets and sludge produced is destined to agriculture. The most positive aspect of the analysis is that environmental benefits are **4.78** times higher than total costs (without discounting depreciation).	(Máñez and Cerdà 2014)
Develop and implement eco-efficient climate adaptive and resilient water infrastructural systems and technologies	**The flood management plan of the Basque Autonomous Community (Spain):** develop the Hydrological conservation (small structural defences, clearing stream debris, improvement of river bank vegetation and intervention in the river bed) plan (€3.5 million)	Within the program for maintenance and conservation of river basins, relatively low cost interventions are undertaken to punctually prevent flood occurrences	(ECONADAPT 2013)
	The flood management plan of the Basque Autonomous Community (Spain): New hydrological control stations and modern forecast system (€1 million)		(ECONADAPT 2013)

Option	Cost	Cost effectiveness/cost-benefit	Source
	Macedonia: constructing new HPPs (Total NPV €63.1 million; €3.94 per hydropower facility; NPV calculations assumed a 5 percent discount rate)		(IEC 2013)
Regularly update the FRMPs	**Multi-Hazard approach to early warning system in Sogn og Fjordane, Norway:** The county of Sogn og Fjordane frequently experiences avalanches and landslides, storm surges and flooding. This project was to set, test and demonstrate a modern emergency population warning system by disseminating phone-based warning messages in a specified geographic area. (Total cost €0.1 million)	Early warning systems are usually cost-effective non-structural measures. Their cost, non-negligible in absolute terms, is extremely low in comparison with the potential amount of losses that these systems allow to reduce.	(CLIMATE-ADAPT, Accessed in October 2017g)
Develop Drought Strategy and Management Plan	The costs associated with the development of a state-level drought management plan have been estimated between €50,000 and €100,000.		(CLIMATE-ADAPT, Accessed in October 2017a)

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