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How do water companies adapt to climate change impacts?

A literature review

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Prof. Dr. Edeltraud Günther
Dipl.-Kffr. Kristin Stechemesser
Marie-Christin Weber

Technische Universität Dresden
Fakultät Wirtschaftswissenschaften
Lehrstuhl für Betriebswirtschaftslehre,
insbes. Betriebliche Umweltökonomie
01062 Dresden

Telefon: (0351) 463-3 4313
Telefax: (0351) 463-3 7764

E-Mail: bu@mailbox.tu-dresden.de
Homepage: www.tu-dresden.de/wwbwlbu

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Foreword

Due to the emergence of shortages concerning natural resources and the globalization of production, sustainability has become vital in business decisions. Meanwhile, sustainability management has become an independent field of research in business science and in the decision processes of companies. The research and teaching of the Chair of Environmental Management and Accounting of the Technische Universität Dresden focus on the economic and environmental efficiency (e^3) in organizations. Strategies for practical use are developed based on scientific concepts. In recent years the importance of the natural environment in the economic sciences has been increasing continuously.

The research program of the Chair of Environmental Management and Accounting at the Technische Universität Dresden is reflected in the composition of the teachings. In this way the knowledge gained from the theoretical and practical research flows directly into each of the lectures. The current scientific series "Dresdner Beiträge zur Lehre der Betrieblichen Umweltökonomie" aims to support this integration process. Contents of the scientific series are predominantly theses selected from the Chair of Environmental Management and Accounting through which the reader may gain an insight into the key activities of the chair as well as a clear understanding of the work content.

The scientific series was composed by Dr. Susann Silbermann and the coordination of the present series was carried out by Dipl.-Kffr. Kristin Stechemesser.

The primary objective of this work was to analyse how water companies are affected by climate change and how they try to adapt to it. Therefore, a systematic literature review was being accomplished.

The work is being divided into a theoretical and a methodological part. First of all an overview of the climatic changes that are projected to occur during the next years is being given. Then, resulting impacts on the water cycle are being pointed out. Furthermore, raw water sources, water companies obtain water from are being defined as well as the treatment process. Within the methodological part the approach of a systematic literature review is being applied, which includes the selection of references as well as their evaluation.

The results of the literature review are that concerning the effects of climate change on water companies, the risks water providers might face, clearly predominate possible opportunities. Especially the deterioration of the raw water quality caused by increasing temperatures, floods as well as heavy rainfalls can be seen as a serious problem. Moreover, the most often mentioned adaptation strategies are dealing with quantitative water problems such as measures to increase storage as well as treatment capacity or leakage reductions. All in all it can be stated that there is still uncertainty about how climate change is going to effect water companies, especially concerning water quality changes and the treatment process.

Edeltraud Günther

The scientific foundation of the work is based upon the results of the bachelor thesis by Marie-Christin Weber which was written at the TU Dresden, Chair of Environmental Management and Accounting.
Professor/Lecturer: Prof. Dr. Edeltraud Günther / Supervisor: Dipl.-Kffr. Kristin Stechemesser. The author is solely responsible for the content of this scientific work.

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Abbreviations

DOC	Dissolved Organic Carbon
EEA	European Environment Agency
IPCC	Intergovernmental Panel on Climate Change
SLUB	Sächsische Landesbibliothek – Staats- und Universitätsbibliothek Dresden
U.K.	United Kingdom
UV	Ultraviolet Light

1 Introduction

"It's not the strongest of the species that survives, nor the most intelligent that survives.
It is the one that is the most adaptable to change."

Charles Darwin

Climate change resulting from human activity is already starting having negative impacts on our way of life. The increasing frequency of natural hazards as well as rising temperatures can be seen as a result of it. Because changes in climate also affect the hydrological cycle, climate change represents new challenges for water companies as well. Particularly affected are water supply, water demand and changes in raw water quality. To maintain an universal human right, which is the access to clean water, water companies need to deal with the subject of climate change and start to develop suitable adaptation strategies. Adaptation to climate change implies in particular to reduce negative impacts of climate change for humans and the environment as well as taking precautions to secure prosperity, the quality of life and future possibilities.

On this account, the primary objective of this work is to analyse how water companies are affected by climate change impacts and how they try to adapt to it. Therefore, two research questions were derived:

Research Question 1:

"What effects does climate change have on water companies?"

Research Question 2:

"How do water companies adapt to climate change impacts?"

To answer these questions a systematic literature review of 40 references is being performed, which helps to identify already existing papers and articles.

As seen in Figure 1 the paper is divided into a theoretical and methodological part, followed by a conclusion. The theoretical part gives an overview of the climatic changes that are projected to occur during the next years and points out resulting impacts on the water cycle, both in a qualitative and quantitative way. Furthermore, possible raw water sources, water companies obtain water from are being defined and the treatment process of raw water is being explained.

Then, the approach of a systematic literature review is being applied. The literature is being searched for relevant references and a coding sheet is being implemented to structure relevant information found within the examined references. The references, that are going to be analysed will be selected by using screening criteria.

Finally, the implemented coding sheet is being examined and evaluated with regard to the main research questions.

The work closes with an overall conlusion and points out possible future research needs.

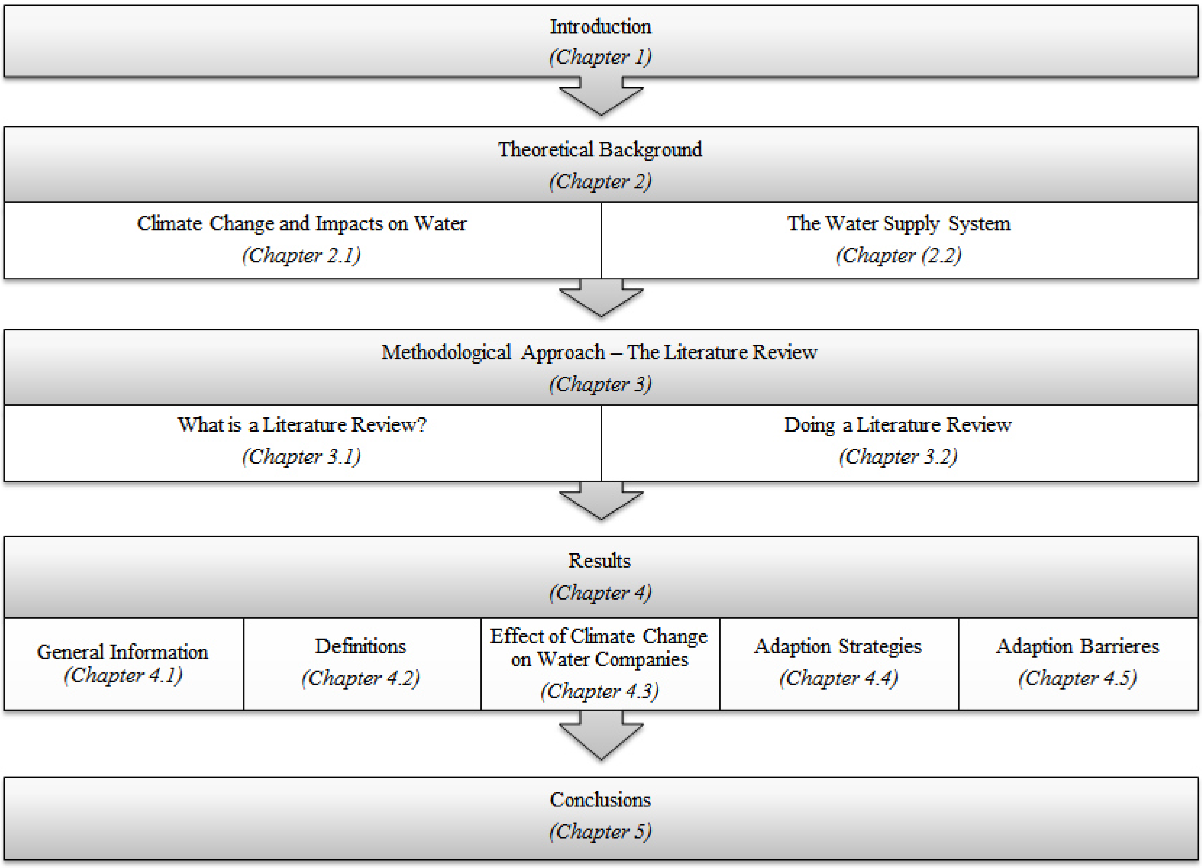

Figure 1: Structure of this work

(Own illustration.)

2 Theoretical Background

This chapter gives an overview of the climatic changes that might occur during the next years and points out resulting impacts on water resources. Furthermore, raw water sources, water companies obtain water from, are being defined and the water treatment process of water suppliers is being explained with the help of the multi-barrier concept.

2.1 Climate change and impacts on water

The worldwide effects of climate change are clearly noticeable. Main projected impacts are increased average global temperatures, changes in precipitation, sea leve rise, extreme events such as droughts, floods, hurricanes, and other effects.[1] With regard to the research topic the following chapter discusses changes in climate as they relate to water resources.

According to the *Intergovernmental Panel on Climate Change* (IPCC) global warming has been linked to worldwide changes in the large-scale hydrological cycle such as variations in precipitation patterns, reduced snow cover and ice melting as well as changes in soil moisture and runoff. Dry areas have more than doubled since the 1970s which leads to higher water temperatures. Heavy rainfall is projected to increase the risks of floods in many areas.[2] Regarding to the IPCC all regions that are discussed in the *Working Group II Fourth Assessment Report* show a negative impact of climate change on water resources and freshwater ecosystems.[3]

However, impacts of climate change vary regionally. Southern Europe for example will be more severely affected by climate change than the north. Southern Europe is expected to become warmer and dryer in contrast to the northern part where precipitation and anual run-off is projected to increase. Besides, flood risk is prognosticated to increase throughout the continent. The combined effects of higher temperatures and reduced summer precipitation will lead to heatwaves and droughts especially in central Europe, where the highest increase in water demand is projected.[4]

These climatic changes can affect the quantitative and qualitative status of water resources, for example, the water availability and demand. With rising temperature, the sensitivity of ground water levels to temperature increases which leads to decreasing ground water levels.[5] Besides, higher air temperatures lead to increasing water temperatures. According to the *European Environment Agency* (EEA) the water temperature of European rivers and lakes increased during the last century by 1-3 °C which affects the quality of water, especially the bacteriological conditions.[6] In regions with intense rainfall pollutants such as pesticides, organic matter or heavy metals will be washed increasingly from soils to water bodies. Besides, increasing precipitation may lead to increasing turbidity of surface water sources.[7] Further-

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1 See SUSSMANN, F.; FREED, J. (2008), p. 5.
2 See IPCC (2008), p. 3.
3 See IPCC (2007), p. 175.
4 See IPCC (2008), p. 93 ff.
5 See IPCC (2007), p. 185.
6 See EEA (2007), p. 16.
7 See IPCC (2007), p. 188.

more, low water flows lead to less dilution of pollutants and especially in coastal areas sea level rise influences the salination of aquifers.[8]

It is an important prerequisite to know and understand these changes because it ensures an effective adaptation process for water companies.

2.2 The water supply system

The primary task of a water company is to provide enough water, that is free from unpleasant taste or odour, of good physical quality and contains nothing which might be harmful to health.[9] This task requires several steps that a water company has to fulfill.

First of all the water companies have to obtain raw water from several sources. These are: *ground water*, *surface water* and *spring water*.[10]

Ground water

The term "ground water" refers to water, which is stored underground in the water-bearing formation of the earth's crust. The main source of ground water is precipitation but it also originates as infiltration from lakes, streamflows and reservoirs. Because of filtration through soil and geological materials, ground water is considered to be a more protected resource than surface water. It is characterized by high water quality and its constant water yield.[11] The worldwide amount of ground water used for the drinking water supply is 55 %. In Germany it is 70 %. The ground water can be tapped from wells, bore holes and from infiltration galleries.[12] To increase water supplies aquifer storage and recovery is a key strategy for water companies. Aquifer storage is the direct percolation of drinking water into an aquifer through wells during times when water is available and recovery of the water during dry months when water demand is the highest and surface water supplies are limited.[13]

Suface water

Surface water refers to water occuring in rivers, reservoir storages or natural lakes. The risk of a sudden contamination especially in river water is higher as in spring and ground water. Main factors are for example the discharge of inadequately treated waste water or the rain-wash of land areas.

Because they provide a convenient source of water, rivers are often used for water supply. To capture the river water, intakes are located to the upstream of a city so that pollution can be minimized. An intake is a connecting structure that provides raw water. They are either located inside the river or near the river bank. A possibility for a water company to withdraw water from a river is the performance of bank filtration. Wells are dug in sediments next to the water body. The water from the river which percolates through the river bed is being filtered through the sediments removing contaminants and is being extracted by the well. The bank

8 See EEA (2007), p. 18.
9 See PUNMIA, B. C. et al. (1995), p. 8.
10 See LECHER, K.; LÜHR, H.-P.; ZANKE, U. (2001), p. 818.
11 See HAMMER, M.; HAMMER JR., M. (2011), p. 101 ff.
12 See KARGER, R.; CORD-LANDWEHR, K.; HOFFMANN, F. (2008), p. 25.
13 See HAMMER, M.; HAMMER JR., M. (2011), p. 104 f.

filtrate contains besides river water ground water as well.[14] The water obtained through bank filtration is often of higher quality than the water directly withdrawn from the river.

Dams are constructed across rivers to create an artificial lake or reservoir behind it. They store water on a rivers upstream side. Dams may be classified into different categories depending on its purpose such as use, hydraulic design or material. They are not only built for water supply but also for other purposes such as flood control, recreation, irrigation or hydroelectrics.[15]

The withdrawal of lake water happens mostly in stagnant water bodies with sufficient water depth and suitable water quality.[16]

The raw water intakes at dams and lakes are usually located at different depths to obtain varying water temperatures and suspended sediments.[17] This is important because the thermal stratification in reservoirs and lakes changes during the seasons and has a direct influence on the quality of the water supply. In summer for example the region near the thermocline, which lies between the hypolimnion (bottom layer of a lake or a reservoir) and the epilimnion (top layer) provides the most satisfactory water quality. During winter, water closer to the surface is more desirable. In spring and autumn the water circulates, spreading undesirable matter throughout the water body. This vertical variation that may occur in a lake or a reservoir shows the importance of having a water intake tower, that has ports at various depths. It helps water companies to draw water from the most advantageous level of the water body.[18]

Spring water

A spring is a place on the earth’s surface where ground water emerges naturally. Springs used for water supply need to be analysed carefully because they may be contaminated by surface water.[19]

After obtaining water from the just mentioned sources, drinking water needs to be treated and distributed. That happens with the help of the so called multi-barrier concept. The multi-barrier concept consists of several barriers which help to prevent pathogens and other contaminants from reaching water consumers.

The *first barrier* stands for selecting the best available water supply source and protecting it from contamination through reducing adverse impacts on water sources.

The *second barrier* is a robust water treatment that often consists of serveral processes.[20] The following water treatment steps are being performed after the raw water is delivered to the drinking water treatment plant: First of all, the water is allowed to stand in tanks to promote sedimentation to separate particles by their density. The next step includes adding chemicals to the raw water to cause very fine suspended matter to settle out. This procedure is called flocculation and coagulation. Chemicals such as aluminium potassium sulfate, soda or clay

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[14] See PUNMIA, B. C. et al. (1995), p. 57 ff.
[15] See CECH, T. (2005), p. 181 f.
[16] See LECHER, K.; LÜHR, H.-P.; ZANKE, U. (2001), p. 824.
[17] See CECH, T. (2005), p. 330.
[18] See HAMMER, M.; HAMMER JR., M. (2011), p. 100 f.
[19] See KARGER, R.; CORD-LANDWEHR, K.; HOFFMANN, F. (2008), p. 78 ff.
[20] See HAMMER, M.; HAMMER JR., M. (2011), p. 112.

are used in this process. To eliminate turbidity, odour and colour the water is being passed through layers of sand and gravel. This is called filtration and follows flocculation and coagulation. After the raw water is being slowly sprinkled onto the filtering media, it is being forced by gravity through the sand particles. Occasionally the filters need to be backwashed to remove unwanted materials. After the process of filtration the raw water is being disinfected using chlorine gas, which kills remaining bacteria. At this stage pH control also occur by adding chemicals like lime and soda ash. Furthermore, having treatment trains with more than one step reduces treatment failure.[21]

The *third barrier* includes disinfection of treated water by chlorination in the distribution system because the drinking water needs to be delivered to the consumers. Disinfection helps against water quality degradation and microbial intrusion.

The *final barrier* is to operate storage reservoirs at a high enough water pressure. An adequate water pressure is important to properly move treated water through elaborate systems of delivery pipes.[22]

[21] See CECH, T. (2005), p. 332 ff.
[22] See HAMMER, M.; HAMMER JR., M. (2011), p. 112 f.

3 Methodological Approach – The Literature Review

The following chapter is about the method applied within this work. First of all, the term literature review is being defined and discussed (Chapter 3.1) and the process of a literature review is being explained. Therefore, research questions are being developed, the literature is being searched, the results filtered by screening criteria and a raster for analysing the articles is being developed (Chapter 3.2).

3.1 What is a literature review?

Literature reviews have many uses. They are a method of collecting information to answer research questions. The reasons for doing a review are diverse, for example finding out what is currently known about a topic.[23] They try to integrate what other scientists have done and said, they identify the main issues in a field and they criticise previous scholarly works.[24] Literature reviews are used to write proposals for funding, for academic degrees, research articles or reports. They are very comprehensive and easy to reproduce. Besides, a literature review bases its conclusions on the work of reasearchers.[25] Fink defines a literature review as follows: “A research literature review is a systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners.”[26]

3.2 Doing a literature review

The process of a literature review can be divided into several tasks. Table 1 gives an overview of the steps by different authors.

Table 1: Stages in a literature review

Fink (2005)	Cooper (1998)
1. Selecting research questions	1. Problem formulation
2. Selecting bibliographic or article databases, Web sites, and other sources	2. Data collection or the literature search
3. Choosing search terms	3. Data evaluation (assessing the quality of studies)
4. Applying practical screening criteria	4. Analysis and interpretation
5. Applying methodological screening criteria	5. Presentation of results
6. Doing the review	
7. Synthesizing the results	

(Own illustration.)

As we can see in Table 1 Fink’s approach is more detailed than Cooper’s. The number of steps vary only slightly. Both authors formulate questions that guide the review. They search the literature for relevant studies and they develop criterias to separate valid from invalid studies. Besides, both Fink and Cooper interpret the relevant studies. The steps for the literature review within this work base on the approach by Fink because it is more detailed. Figure 2 shows the steps involved in a literature review according to Fink.

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23 See FINK, A. (2005), p. 5.
24 See COOPER, H. (1998), p. 3.
25 See FINK, A. (2005), p. 2 f.
26 FINK, A. (2005), p. 2.

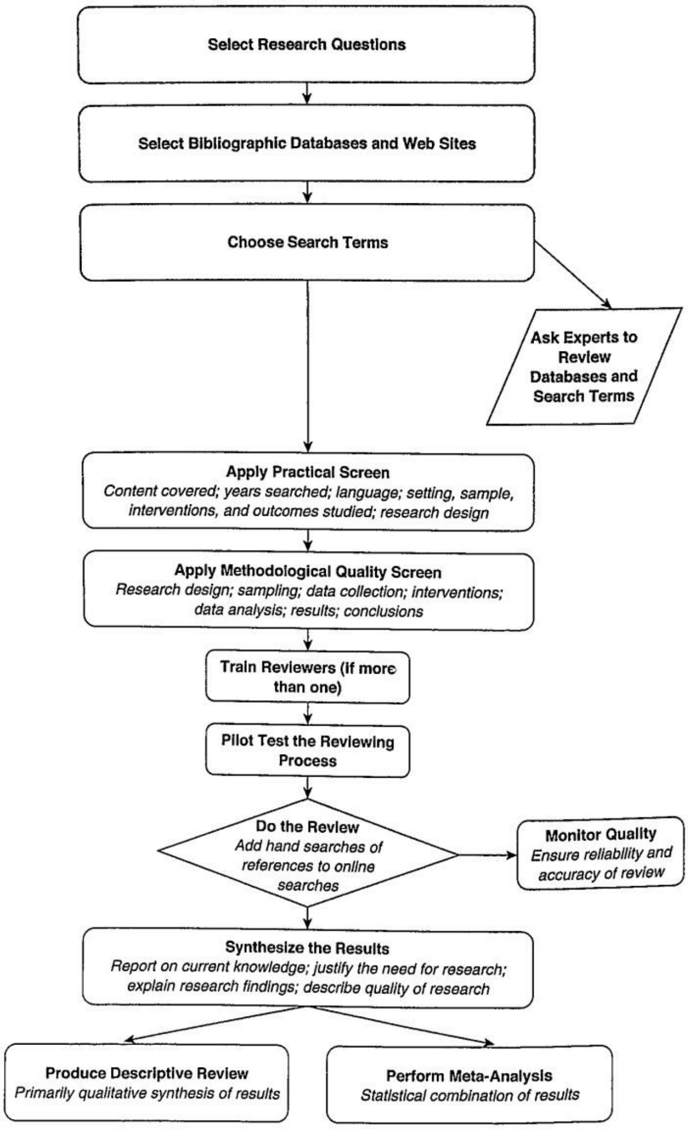

Figure 2: Steps involved in conducting a research literature review
(Source: FINK, A. (2005), p. 4.)

The **first step** includes the selection of research questions. They help to guide the review.[27]

Within the **second step** it is important to select sources such as bibliographic or article databases that can provide data to answer the research questions created in the first step. Other sources of literature reviews are often the reference lists contained in articles.

In the **third step** it is necessary to choose search terms. They help to find appropriate articles, books or reports and are based on the words of the research questions.

Within the **fourth** and **fifth step** it is essential to apply practical and methodological screening criteria. The search for literature always yields many articles, but only some are relevant. By setting criteria it is possible to get all the relevant articles. Screening criteria include factors such as the language in which the article is printed, the topic of a study, the country of origin or the scientific quality.

27 See FINK, A. (2005), p. 3.

Step six is the actual review. It is necessary to use a standardised form, the coding sheet, for abstracting data from articles.

In **step seven** literature review results may be synthesized descriptively. This process involves the application of statistical procedures. Statistical methods are used to combine the results of the studies.[28]

The following pages show the approach by Fink which is applied to this work.

Selection of research questions

As seen in step 1 of the previous section literature reviews start with research questions. There are two main research questions to answer within this work:

Research Question 1:

> *"What effects does climate change have on water companies?"*

Research Question 2:

> *"How do water companies adapt to climate change impacts?".*

Searching the literature

For searching the literature the second and third step of the previous section are being combined. The review of the literature within this work depends on data from two main sources: (1) online bibliographic databases; and (2) manual search of the references in articles. The relevant databases were being selected with the help of the Sächsische Landesbibliothek - Staats- und Universitätsbibliothek Dresden, that has a list of databases by subject areas. Refering to the subjects of the research questions which include economical and environmental subjects as well as water management topics, the following four databases were chosen: Web of Science; WISO; EBSCO*host* which includes the databases Academic Search Complete, Business Source Complete, EconLit with Full Text, E-Journals, Risk Management Reference Center as well as TOC Premiere; and TEMA - Technik und Management. The databases EBSCO*host* and WISO cover the economic aspects and Web of Science and TEMA – Technik und Management the water management issues. Additionally, the SLUB catalogue was checked as well as Google Scholar. Furthermore, the search was accomplished by searching within the reference lists contained in articles and books. The entries in the reference lists were juged for their relevance to the problem.

Based on the words of the research questions English and German search terms were chosen. The key search terms are "climate change adaptation" (Klimawandelanpassung) and synonyms of the term "water supply" (Wasserversorgung). Often the search term "climate change adaptation" did not deliver any or enough results, therefore it was splitted up into "climate change" and "adaptation". Sometimes the term "adaptation" was entirely left out. Besides "climate change" is being replaced with "global warming". To extend the search truncations like "", "?" or "*"were used. The truncation "" searches for an exact phrase or a combination of words, "?" replaces a consonant and the truncation "*" allows to search for various endings. The search terms with adequate synonyms are shown in Table 2 and Table 3.

[28] See FINK, A. (2005), p. 4.

Table 2: Combination of English search terms

<table>
<tr><td colspan="3">„climate change adaptation“</td><td rowspan="2">AND</td><td rowspan="2">"community water suppl*"
"private water suppl*"
"public water suppl*"
"supply of water"
water
"water compan*"
"water economy"
"water industry"
"water management"
"water preparation"
"water provider"
"water resources management"
"water service"
"water supplying"
"water supply compan*"
"water supply organi?ation"
"water treatment"
"water utilities"</td></tr>
<tr><td>“global warming”</td><td>AND</td><td>adaptation</td></tr>
</table>

(Own illustration.)

Table 3: Combination of German search terms

<table>
<tr><td colspan="3">Klimawandelanpassung</td><td rowspan="2">UND</td><td rowspan="2">"kommunale Wasserversorger"
"öffentliche Wasserversorger"
"private Wasserversorger"
Rohwasserqualität
Talsperren
Trinkwasser
Trinkwasseraufbereitung
Trinkwasserversorgung
Wasser
Wasseraufbereitung
Wasserbereitstellung
Wassergewinnung
Wasserindustrie
Wassermanagement
Wasserqualität
Wasserressourcenmanagement
Wasserunternehmen
Wasserversorger
Wasserversorgung
Wasserverteilung
Wasserwerk
Wasserwirtschaft</td></tr>
<tr><td>“globaler Wandel”</td><td>UND</td><td>Anpassung</td></tr>
</table>

(Own illustration.)

A comprehensive overview of the search results with the help of online bibliographic databases, the SLUB catalogue and Google Scholar is provided in Appendix A.

Altogether 590 searchings were accomplished and 17081 results were found. 10800 results come from Google Scholar, 3698 from the database EBSCO*host*, WISO delivered 2128 results, Web of Science 271, TEMA – Technik und Management found 165 articles and the SLUB catalogue 19.

Filtering the results

The next important step is to decide whether the results are relevant or not. A literature search that has no restrictions may yield thousands of articles. As seen in the previous section 17081 results were found, 63 % of them from Google Scholar. It is essential to create screening criteria as told in step four and five of chapter 3.1 of Fink's approach in conducting a research literature review. Figure 3 shows the screening criteria used within this work.

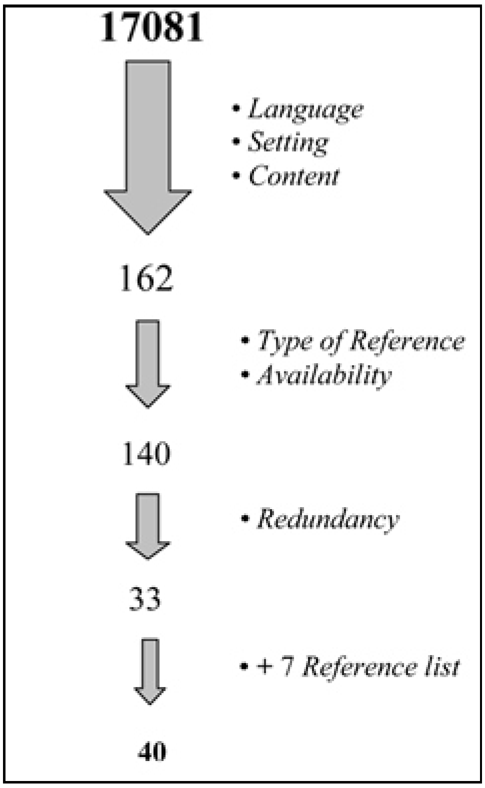

Figure 3: Selection process for limiting results
(Own illustration.)

First of all, the 17081 results found in online bibliographic databases, the SLUB catalogue and Google Scholar, were screened by the *publication language*, the *country* they take place in and the study's *content*. First of all, only articles published in German and English were included as well as studies from countries with similar climatic conditions and technical standards as Germany. That means that studies which are bounded to Asia, South America and Africa were exluded. The most important criteria is the study's content. With regard to the research topic studies were only integrated in further analysis if they focus on the effects of climate change on water supply and if they deal with adaptation measures of water companies.

Furthermore, the quality of the studies were examined. Especially the *type of reference*. Newspaper articles, flyer, brochures or dissertations were exluded. Additionally, the results were limited by the articles which were not *available*.[29] After this screening process 140 studies were left.

However, some of the 140 articles were listed more than once because in some cases different search terms delivered the same or *redundant* results. Those articles were deducted. At the end of that screening process 33 references found in online bibliographic databases, the SLUB catalogue and Google Scholar were left.

Additionally, 7 references found within the *reference lists* contained in articles and books were added.

Altogether, **40** articles were found, in the following described by the terms "references" or "relevant results".

The following bar chart gives an overview of the absolute number of relevant studies found in online bibliographic databases (EBSCO*host*, TEMA, Web of Science, WISO), the SLUB catalogue, Google Scholar and in the reference lists contained in articles and books.

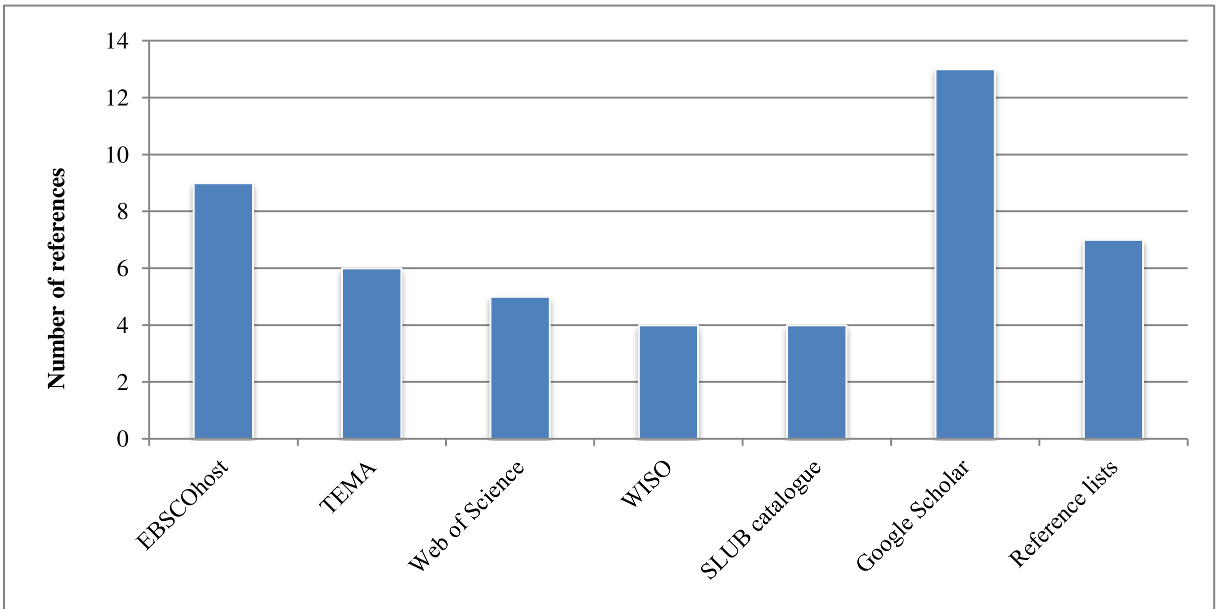

Figure 4: Number of references by databases
(Own illustration.)

Google Schlolar was only been searched extra. This becomes apparent in the fact that four of the 13 references were also found in the databases EBSCO*host*[30], WISO[31], TEMA[32] and Web of Science[33]. Still, most of the relevant results were found in the database EBSCO*host* as well as Google Scholar. The following search terms provided the most results: *Klimawandel UND Wasserversorgung* (twelve references) and *Klimawandel UND Wasserwirtschaft* (ten refer-

29 Four references were not available. Two of them might be of interest: (1) HAMSTEAD, M. (2011): Climate change adaptation in the water sector. In: Australasien Journal of Environmental Management, Vol. 18, 2011, No. 1, pp. 62-64. (2) HEINBUCH, R. (2008): Energieerzeugung in Trinkwassertransportnetzen. In: Energie, Wasser, Praxis, Vol. 59, 2008, No. 12, pp. 6-9.

30 The reference BLÖSCH, G. et al. (2011) was found both in EBSCO*host* and Google Scholar.

31 The reference AUERSWALD, H.; LEHMANN, R. (2010) was found in WISO as well as in Google Scholar.

32 The reference NILLERT, P.; SCHÄFER, D.; ZÜHLKE, K. (2008) was found in TEMA and Google Scholar.

33 The reference SUBAK, S. (2000) was found both in Web of Science and Google Scholar.

ences), *Klimawandel UND Anpassung UND Wasserversorgung* (nine references) as well as *"climate change adaptation" AND "water resources management"* (eight references). A complete overview of the search terms and the number of references they led to gives Appendix B.

Developing a raster for analysing the articles

The previous steps explained the approach for searching the literature and filtered relevant articles with the help of screening criteria. The next step according to Fink's approach in conducting a research literature review (chapter 3.1) is to abstract data from the 40 relevant articles with the help of a standardized form - the coding sheet. The coding sheet is used to collect information from the research reports, helps to structure relevant information by categories and prepares for the synthesis of the references in chapter 4. Any information that might have the remotest possibility of being considered relevant was retrieved from the studies.[34] Table 4 shows the coding sheet applied within this work and Appendix C includes the coding sheets of all 40 references.

Table 4: Coding sheet

Title	***Title of reference***	Page
Author	First name, Name	
Year	Year of publication	
Type of Reference	Book, Grey literature, Journal, Report, Working Paper	
Type of Article	Empirical Paper, Theoretical Paper	
Source	Full name of journal, Internet address	
Volume		
Issue		
Pages		
Country of origin	Origin of the study by author	
Setting	Is the study bound to a special country or geographical location?	
Database	EBSCO*host*, Google Scholar, SLUB catalogue, Search within reference list, TEMA, Web of Science, WISO	
Search terms	Which search terms lead to the paper?	
Scientific theories	Does the author use any scientific theories within the paper?	
Definitions	Are there any definitions used within the paper?	
Global change / Climate change	Is the term *global change* or *climate change* defined in the paper?	
Vulnerability	Does the paper define *vulnerability* to climate change?	
Adaption to climate impacts	Is *adaptation to climate impacts* defined within the paper?	
Climatic parameters	Which climatic parameters are discussed in the paper that may affect water companies and the water cycle?	
Time horizon	What timescale is used in the paper to explain climate change projections?	
Risks	What are the risks that water companies face because of climate change?	
Opportunities	What opportunities do water companies have because of climate change?	
Adaptation strategies	What does the paper say about adaptation strategies of water companies?	
Adaptation barriers	Are there any adaptation barriers mentioned?	

(Own illustration.)

[34] See COOPER, H. (1998), p. 26 f.

First of all, as seen in the previous coding sheet general information was collected from the references such as the *title* of the paper, the *authors* name and the *year* of publication. Furthermore the *type of reference* such as books, grey literature, journals, reports or working papers were mentioned as well as the *type of article*. Within this work the references were categorised into theoretical paper and empirical paper. In some cases the author did not state which method was applied, therefore, references were assessed as empirical papers if they contained a case study, an interview, a survey or an accomplished scenario analysis. If the focus of a paper was strongly theoretical it was assessed as a theoretical paper. Furthermore, the *source* of the reference such as the full name of the journal or the internet address was mentioned. Another information ingrained in the coding sheet is the *origin of the study*, which depends on the first authors origin. To find out if the study is bound to a specific country, the *setting* of a study is mentioned within the data extraction sheet as well. This information most often includes the geographical location of the study. Furthermore, the *databases* and the *search terms* that conducted the paper are alluded. Other information integrated into the coding sheet are possible *scientific theories* the author used within the paper.

Secondly, definitions used within the studies were extracted. This step clarifies if the author defined the terms “Global change” or “Climate change”, “Vulnerability to climate change” and “Adaptation to climate impacts”.

The next category is about the first research question that needs to be answered within this work: “What effects does climate change have on water companies?”. Included into the coding sheet are *climatic parameters* that affect the drinking water supply as well as the *timescale*, which is used to explain the changes of the climatic parameters. The literature differentiates between 1st and 2nd order *climatic parameters*. 1st order climatic change effects relate to average values and 2nd order effects to extreme weather events. According to SCHÖNWIESE, C.-D. (2007) extreme weather events are specific events such as storms or floods, that occur relatively rare, cause very high damage and are far away from the arithmetic average.[35] Another category listed in the coding sheet is the effect of climate change on water companies. These effects are classified into *risks* and *opportunities* that water companies face because of climate change.

Furthermore, the category of *adaptation strategies* is being included into the coding sheet. This category helps to answer the second research question “How do water companies adapt to climate change impacts?”. Any information that might be relevant was retrieved from the studies. Besides, the adaptation strategies discussed in the papers are being divided into (1) strategies that are conceivable and (2) strategies that are already fully implemented. The already implemented strategies are marked green and strategies that are only conceivable red. This division is used for an easier and better distinction.

The **last part** of the coding sheet includes information about *adaptation barriers* that water companies might face while adapting to climate change impacts.

Within this chapter the methodological approach of a literature review was being explored and applied to this work. At first the reasons for doing a literature review were presented and

[35] See SCHÖNWIESE, C.-D. (2007), p. 61 f.

a definition was given. Then, the process of a literature review was explained with the help of Fink's approach in conducting a research literature review. Finally Fink's approach was applied to this work by developing research questions and searching the literature in online bibliographic databases, the SLUB catalogue, Google Scholar and within the reference lists contained in articles and books. The references were filtered by using screening criteria and a coding sheet was implemented to structure relevant information by categories.

4 Results

The final step of a literature review is a synthesis of the contents of the literature and an evaluation of its quality. In the previous chapter 40 references were found by using screening criteria and relevant information was implemented into a coding sheet. Now, the information from the 40 references will be analysed and evaluated within this chapter. This procedure is based on the order of the catgeories within the coding sheet. First of all, general information about the literature (chapter 4.1) will be examined. Then, an overview of the definitions used within the references will be given (chapter 4.2). Furthermore, the effects of climate change on water companies (chapter 4.3) and possibe adaptation stategies (chapter 4.4) will be analysed. Finally, adaptation barriers that might conctrict the adaptation process will be pointed out (chapter 4.5).

4.1 General information about the literature

To get an overview of the reference pool general information such as *year of publication*, *type of reference* as well as *type of article* will be analysed within this section. Furthermore, the *geographical origin* and the *setting* of the study will be examined. Therefore the references are being analysed by using absolute and relative frequencies. Besides, the question is being answered if the references are bound to specific *scientific theories*.

Year of publication

The majority of the references were published after 2004 as shown in Figure 5. About one-fourth of all relevant studies were published in 2008. During the last three years the number of publications is steadily increasing. This emphasises the actuality and the importance of the issue. The interests of scientific researchers on climate change and the resulting impacts on the water supply are more and more growing. One reason might be the particularly vulnerability of the water sector towards climate change.[36]

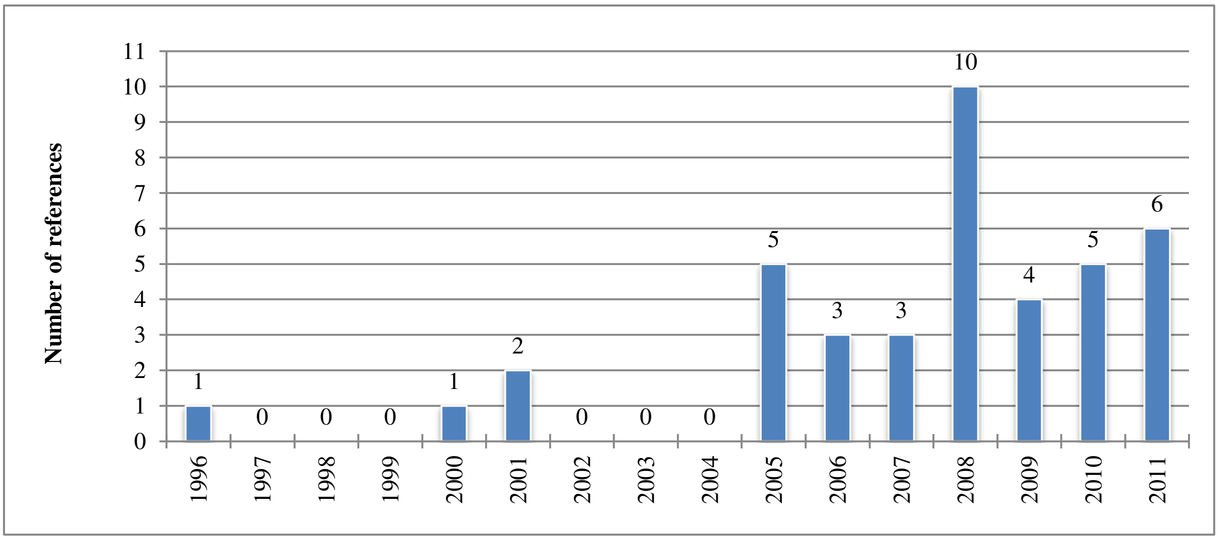

Figure 5: Number of references by year of publication

(Own illustration.)

[36] See THORNE, O.; FENNER, R. A. (2011), p. 74.

Type of reference

Another classification of the references was by their type of article. Therefore, the relevant studies were categorised into *Book*, *Grey literature*, *Journal*, *Report* and *Working Paper*. Figure 6 shows the number of references assigned to their type.

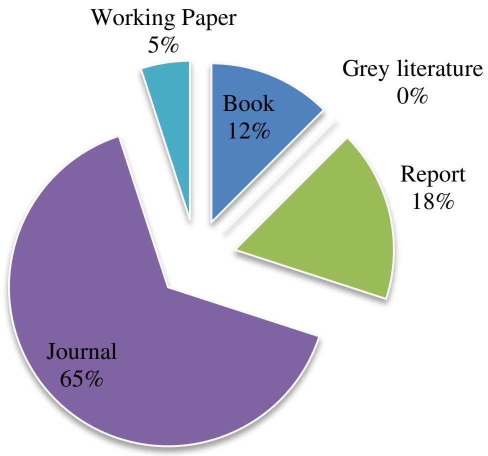

Figure 6: Number of relevant articles by type of reference
(Own illustration.)

The distribution of the references shows that 64 % of the relevant studies are journal articles. Seven references are reports and five are books or book chapters. Two references can be categorised into working papers, because they are not published in a journal yet. Grey literature was not found.

Type of article

To find out if the references are more conceptual or empirical, journals, reports and working papers were subdivided into *Empirical Paper* and *Theoretical Paper*. As seen in Figure 7 the distribution of theoretical and empirical papers within this work is almost equal.

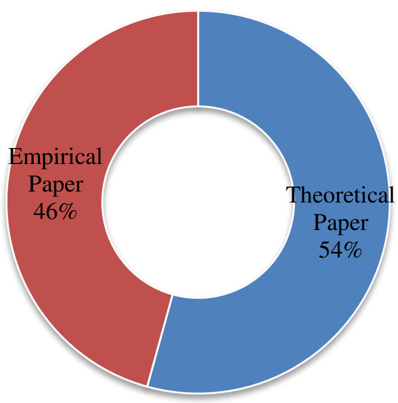

Figure 7: Number of references by type of article
(Own illustration.)

References which included a literature review or referred to a specific scenario analysis were assessed as theoretical papers. Papers which included surveys, interviews, case studies or accomplished scenario analyses or trend analyses were assessed as empirical papers. Figure 8 shows different methodologies several authors used in theoretical and empirical papers. It is possible that an author used more than one methodology within a reference.

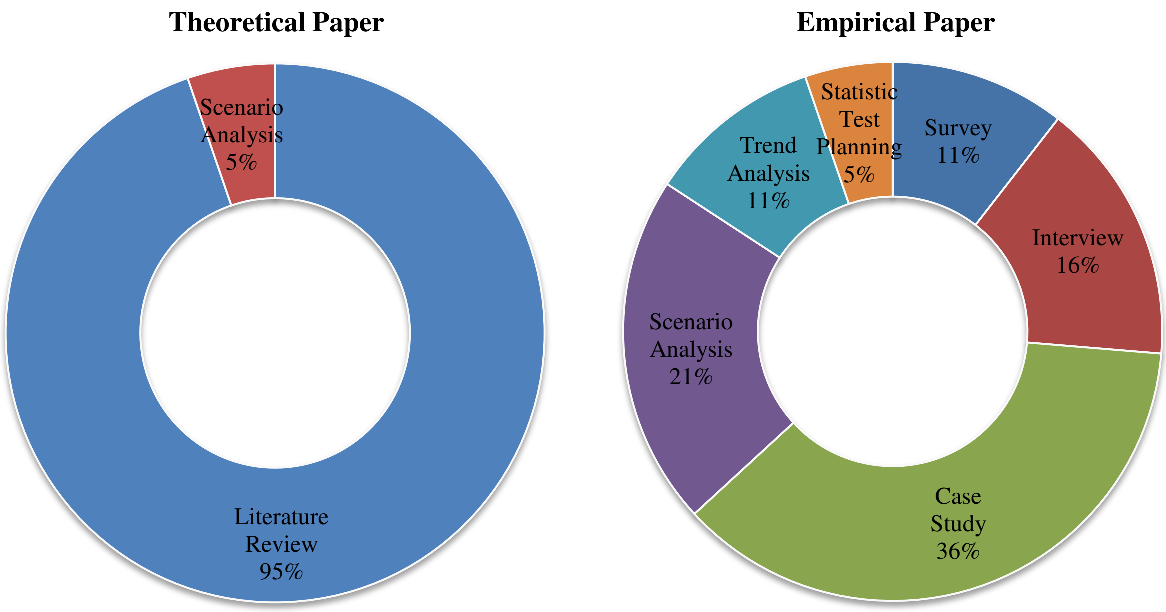

Figure 8: Methodology categorised by type of article
(Own illustration.)

The most common methodology within theoretical papers is the literature review. Only one theoretical paper, examined within this work, referred to a scenario anlysis. On the other hand, the mostly used methodologies in empirical papers are case studies and scenario analyses. Furthermore, two references are based on surveys. One of them is by ZEBISCH, M. et al. (2005) and is a survey of regional experts from the sector-specific functional departments of each German federal state. Aims of the survey are to estimate the sector-specific significance of potential impacts of climate change and to appraise the present degree of adaptation and suitable adaptation measures to these impacts.[37] Three references are based on interviews and two on trend analyses. Besides one reference deals with the methodology of statistic test planning. It is used by UHL, W.; SLAVIK, I. (2009) and helps to arrange experimental design and evaluation plans in such a manner that the predetermined objectives of the study can be optimally achieved.[38]

Geographical origin and setting

The classification of the geographical origin is based on the first authors origin or his background. As shown in Figure 9 most of the references originate from Europe, 16 of them come from Germany. This can be explained by the fact that the literature was not only searched in

[37] See ZEBISCH, M. et al. (2005), p. 29.
[38] See UHL, W.; SLAVIK, I. (2009), p. 101.

English, but also in German. Seven references originate from North America and one from Australia. Only one study can not be assigned to its georgraphical origin because it is not clearly emphasised who the author is.[39] The reason why there can not be found any references from other continents in this bar chart is because studies from South America, Asia and Africa were excluded (chapter 3.2).

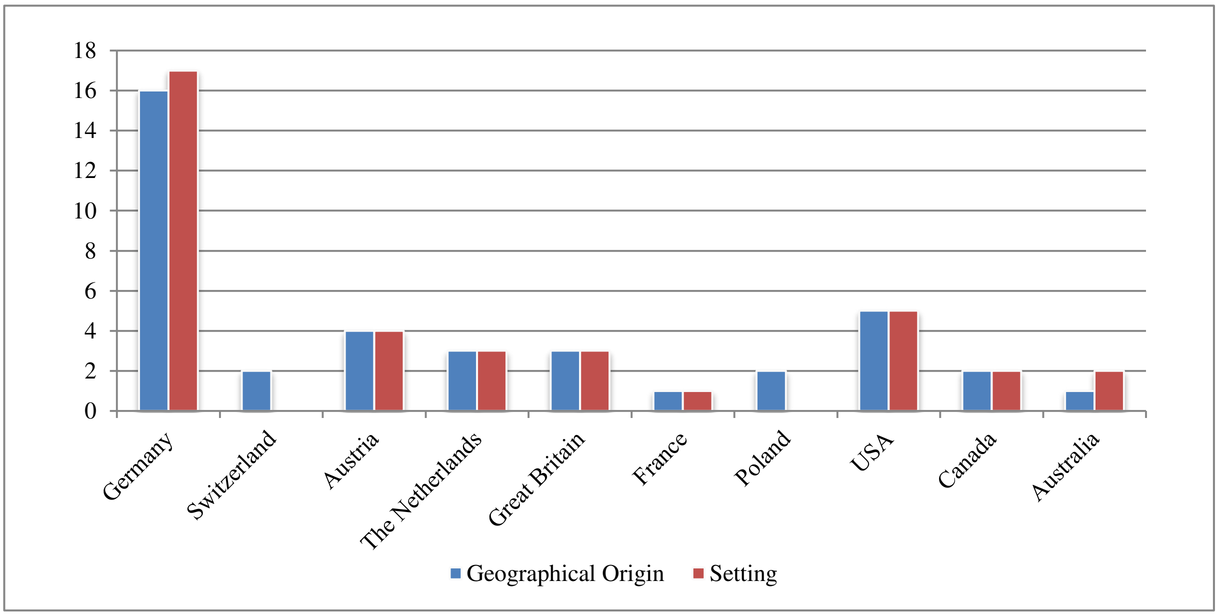

Figure 9: Absolute distribution of references by geographical origin and setting (Own illustration.)

Another classification is the setting of the relevant study. It is noticeable that most of the studies are bound to the country the first author originates from (Figure 8). Some articles are bound to two or more countries, unlike seven references, which are not linked to a specific country. Those references deal with worldwide climate change effects on water and water supply.

Scientific theories

This classification is used to find out if the author used any theoretical concepts or scientific theories within his or her paper. None of the 40 references included a specific scientific theory. The reason for that is because most of the references, especially the journal articles, have an engineering oriented background.

4.2 Definitions

This chapter clarifies how many references provided definitions for the terms (1) "Global change" or "Climate change", (2) "Vulnerability", and (3) "Adaptation to climate impacts". Figure 10 gives an overview of the definitions used within the references divided by sources. All in all 13 of 40 references included definitions to at least one of the just mentioned terms.

[39] See ECONOMIC COMMISSION FOR EUROPE (ed.) (2009).

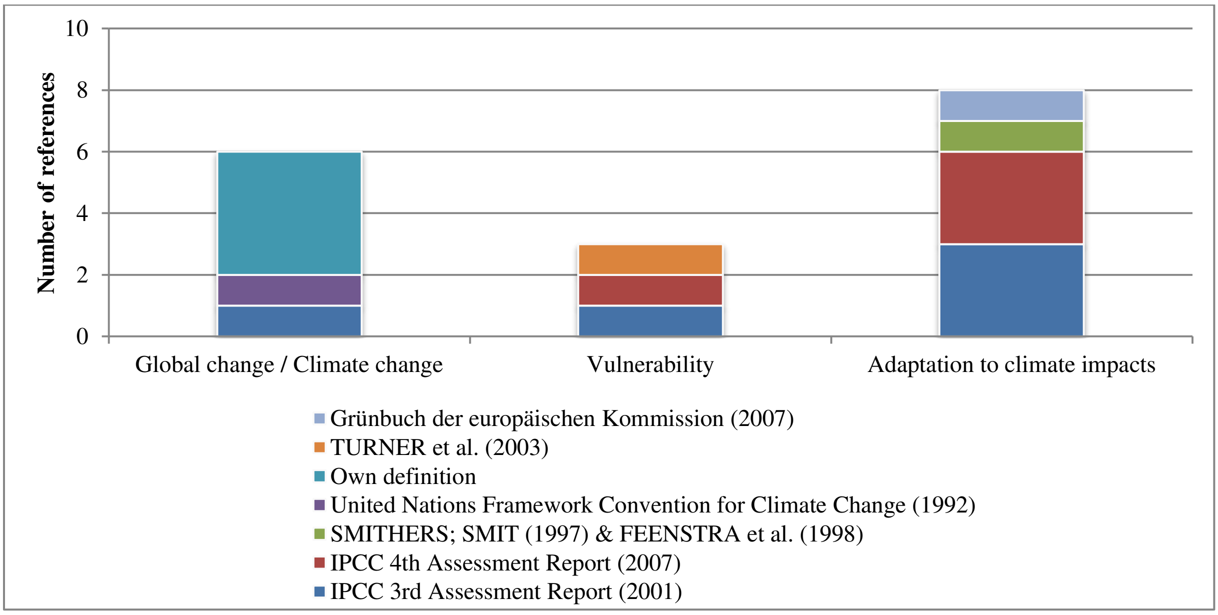

Figure 10: Definitions divided by source
(Own illustration.)

It is noticeable that more than half of the definitions used within the references refer either to the *3rd* or *4th IPCC Assessment Report*, mostly defining the term "Adaptation to climate impacts". This shows the importance and relevancy of the IPCC in the field of climate change research. JARRAUD, M. (2008) defines "Adaptation to climate impacts" as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" [40]. JARRAUD, M. (2008) cites the *4th IPCC Assessment Report* from 2007.

Furthermore, six of 13 references define the terms "Global change" or "Climate change". However, most of the authors made up new or own definitions, unlike The ECONOMIC COMMISSION FOR EUROPE (ed.) (2009), who defines the term "Climate change" as follows: "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"[41]. They refer to the definition from the *United Nations Framework Convention for Climate Change (article 1)* from 1992.

The minority of the references define "Vulnerability". HERSH, R.; WERNSTEDT, K. (2001) and the ECONOMIC COMMISSION FOR EUROPE (ed.) (2009) refer to the *IPCC Assessment Reports* from 2001 and 2007. ZEBISCH, M. et al. (2005) refers to the definition by TURNER et al. (2003), who defines the term "Vulnerability" as "the likelihood of a specific human-environment system to experience harm due to changes in society or the environment, accounting for its adaptive capacity"42.

A detailed overview of all 17 definitions divided by authors and who they refer to gives Appendix D. It should be noted that the German definitions were not translated into English.

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40 JARRAUD, M. (2008), p. 531.
41 ECONOMIC COMMISSION FOR EUROPE (ed.) (2009), p. 111.
42 ZEBISCH, M. et al. (2005), p. 19.

To sum up, the relative number of references, which gave a defintion to one of the mentioned terms amounts to 33 %, which is one third of all references. This majority can be explained by the fact that regarding to the issue "climate change" clarification is still necessary. Furthermore, most of the references refered to the definitions of the *IPCC Assessment Reports* from 2001 and 2007.

4.3 Effects of climate change on water companies

The key question that will be answered within this chapter is: *"What effects does climate change have on water companies?"*. Climate change entails risks as well as opportunities for water companies, which are caused by climatic parameters. Within this chapter climatic parameters, which affect water companies, are being examined and the risks and opportunities that are caused by those parameters are being analysed.

Climatic parameters

The impacts of climate change on water resources is a critical issue for water companies. The following section examines which climatic parameters affect water companies, both in a direct or indirect way. The absolute numbers of references categorised by climatic parameters are listed in Figure 10.

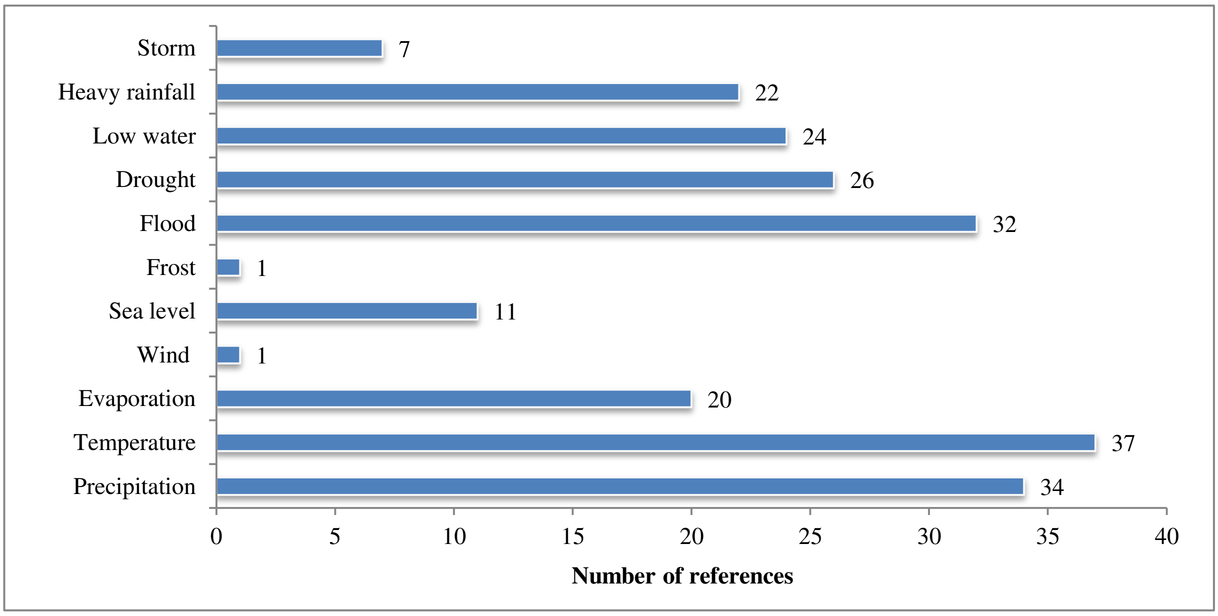

Figure 11: Absolute number of references by climatic parameter
(Own illustration.)

The most frequently mentioned climatic parameter is temperature. In 37 of 40 possible references temperature is seen as a parameter that affects water companies, whereby some studies distinguish between water and air temperature. Temperature is followed by precipitation (34 references) and flood (32 references). Besides, floods are the most often mentioned extreme weather events as well. Figure 12 separates the climatic parameters into 1st and 2nd order climate change effects. Events that relate to average values are classified into 1st climate change order effects and events that occur very rare and cause very high damage are categorised into extreme weather events (2nd climate change order effect).

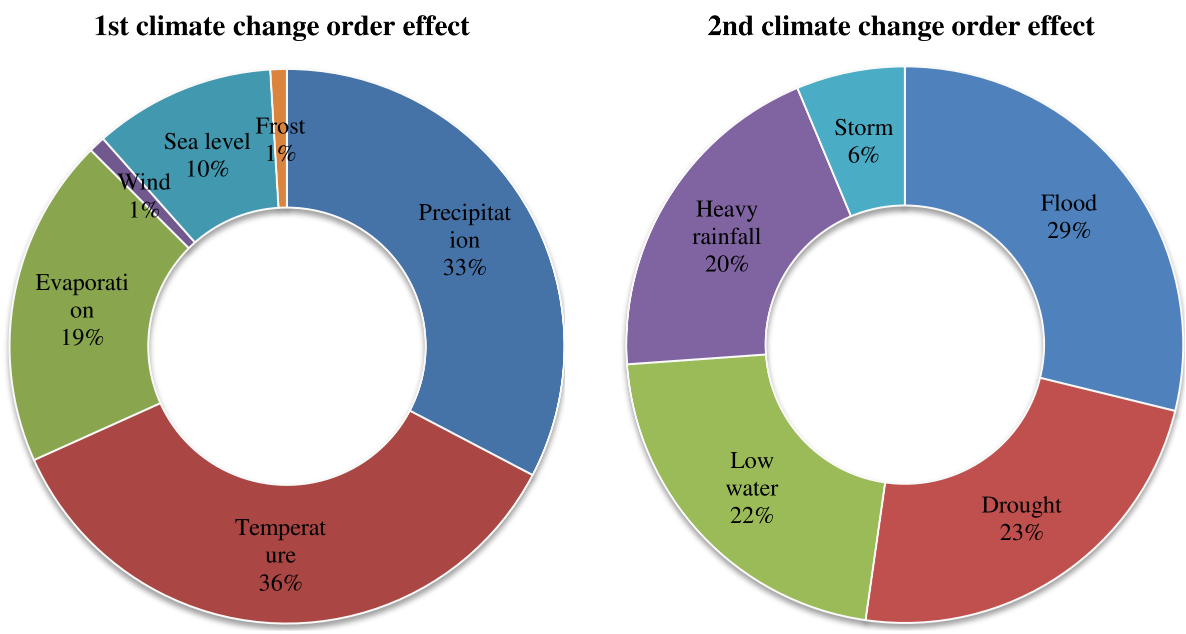

Figure 12: 1st and 2nd climate change order effect
(Own illustration.)

It is noticeable that except for storms the percentage distribution of extreme weather events (2nd climate change order effect) is relatively constant. In more than half of the references heavy rainfalls, floods, droughts and low waters are mentioned as influences on water companies. This concentration on extreme weather events shows a high vulnerability of water providers towards climate change. Not least because the water industry is directly reliant on the hydrological cycle.

Within the 1st climate change order effects the parameters temperature and precipitation were mentioned in almost every reference. In all studies temperature is projected to increase during the next years.

Furthermore, especially references that deal with coastal countries mentioned sea level rise as a climate change impact on water companies.

Besides, two references deal with either frost or wind, but did not analyse their effects on water companies.

Additionally, the timescale used within the papers, which is stated to explain climate change projections, is being examined. Altogether 15 references mentioned time horizons. Most of them referred to the period of 2020 until 2050.

All in all, climatic parameters lead to risks and possible opportunities for water companies, which will be analysed within the next section.

Risks

The following pages give an overview of the risks and opportunities that 1st and 2nd climate change order effects might cause to water companies. As shown in Appendix C the risks as well as the opportunities are assigned to specific climatic parameters. This classification was accomplished because in most of the references climatic parameters were assigned to particular risks or opportunities as well. This assignment is shown by three bar charts during the next pages. However, eight references did not assign climatic parameters to specific risks or opportunities. Those references are not included in the bar charts, but are still mentioned within the qualitative analysis. Furthermore, it can be noticed that within the references that are being examined in this work, the risks clearly predominate the opportunities. Only four references assessed possible opportunities for water companies because of climate change.

First of all the risks that water suppliers may have becaue of the previously analysed climatic parameters are being discussed. It should be noted that the climatic parameters frost and wind are not part of the following observation because they were only mentioned once and did not lead to any risks or opportunities for water providers.

Within this work the risks are classified into *water quality* problems, impacts on the *water quantity* and *damage* to infrastructure.

<u>*Water quality*</u>

Figure 13 shows the number of references which discuss water quality problems caused by 1st and 2nd climate change order effects. Almost 50 % of the references mention water quality problems caused by an increase in air **temperature**, which leads to an increase in water temperature as well. Warmer temperatures combined with higher phosphorus concentrations in lakes and reservoirs promote algal blooms in the raw water. This impairs water quality through undesirable odour, colour and taste. This causes problems in the water treatment process including difficulties in achieving effective coagulation and decreased filter run times.[43] According to THORNE, O.; FENNER, R. A. (2011) the increasing algal formation

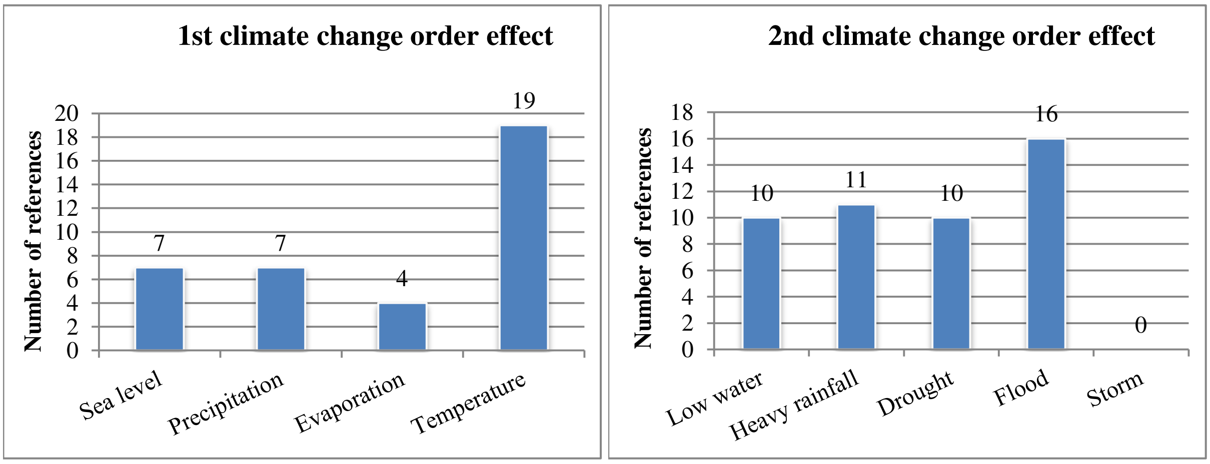

Figure 13: Absolute number of references which mention water quality problems caused by 1st and 2nd climate change order effects

(Own illustration.)

43 See BATES, B. et al. (2008), p. 71.

leads to increased DOC levels in the raw water, which will be reflected in rising DOC levels in the filtered water. The consequences are increasing coagulant dosing and disinfection requirements by the water companies. THORNE, O.; FENNER, R. A. (2011) argue that the combined chemical costs of coagulation and chlorination are projected to increase by up to 6% at Grafham Water in the east of England.[44] In addition, higher temperatures lead to changes in the thermal structure of reservoirs. An increase in temperature of the surface water would complicate the circulation with deeper stratifies. Therefore, no freshwater would reach the ground of the reservoir, which leads to an decrease in oxygen and nutrients. The result is an increasing putrefaction on the ground which makes the water for the dinking water production unusable.[45] Furthermore, drinking water companies have to maintain a 25°C limit for safe drinking water production, which turns out to be difficult keeping temperatures below that limit.[46] Another risk that water companies are being confronted with are increasing drinking water temperatures during transport in distribution networks from treatment facilities to the taps of the customers, which leads to increasing microbiological risks. According to MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007) during the summer of 2005, an increase of water temperature from 15°C to 20°C was measured in several networks in The Netherlands as a result of the warming during transport in urban areas.[47]

16 of 40 references analysed affects on the water quality caused by **floods**. During floods the velocity of river streams increases, which leads to an increasing transport of sediments in rivers. Those sediments are often contaminated with heavy metals and organic pollutants such as pesticides or discharge of chemical industries. Besides, elevated suspended sediment levels lead to higher turbidity, which in turn leads to more frequent backwashing of filters and adjusting chemical mixtures. The results for water companies are increasing costs associated with additional chemical use and operator over-time. According to HERSH, R.; WERNSTEDT, K. (2001) high turbidity levels impaired the slow sand filters of a large municipal water treatment system in the northwestern United States, forcing the system to shut down for a week. The water utility had to implement conservation measures and bought water from an utility to which they were connected by an inter-tie.[48] Futhermore, high run-off causes mud waves containing accumulated contaminants, which forces drinking water companies to close river water intake stations more often.[49] Additionally, floods increase the risk of water source contamination from sewage overflows, which decreases water quality as well.[50]

Heavy rainfall leads almost to the same risks and quality problems for water companies than floods. Water quality decreases because sediments and a variety of pollutants are being washed into the water body during times of heavy rainfall. Furthermore, combined and separated sewerage systems might overflow, which leads to a microbial contamination of the wa-

[44] See THORNE, O.; FENNER, R. A. (2011), p. 85.
[45] See ROHN, A.; MÄLZER, H.-J. (2010), p. 6.
[46] See RAMAKER, T. A. B. et al. (2005), p. 40.
[47] See MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007), p. 141.
[48] See HERSH, R.; WERNSTEDT, K. (2001), p. 12.
[49] See RAMAKER, T. A. B. et al. (2005), p. 38.
[50] See MILLER, K.; YATES, D. (2005), p. 48.

ter supply. Moreover, fertilisers may be washed into the ground water. The results are increasing nitrate concentrations.[51]

Ten references mentioned **droughts** and their negative influences on the water quality as a risk for water suppliers. After long dry periods for example the filtering effect of the soil starts to deteriorate. That is why during extreme rainfalls pollutants and pathogens can be easily washed into the ground water.[52] The worst case could be the loss of the aquifer as drinking water source. Furthermore, during long periods of drought reservoir levels start to decrease, which leads to increasing contact area of the warm surface water and the sediment. Those sediments influence the raw water quality as well.[53] In some references it is stated that droughts lead to the same risks than increasing temperatures. For example the increasing microbiological activities in the distribution networks or the increased growth of algae.

Low water deteriorates the water quality as well. This might happen because according to ARNELL, N. W.; DELANEY, K. (2005) lower flows during summer lead to greater concentrations of pollutants, especially nitrates and phosphates. Those pollutants need to be removed from the raw water. The consequences are increasing treatment costs for water companies.[54]

The same risk occurs because of decreasing **precipitation** events, which might limit the capacity to dilute waste and lead to increased pathogen and chemical load in the raw water. As a result water companies have to face increasing treatment as well as monitoring costs.[55]

Flooding as a result of **sea level** rise mostly influences water companies in coastal areas. As a result salt water intrusions in fresh aquifers and deltas of rivers might occur. According to MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007) more than 25 % of The Netherlands' 200 drinking water facilities are estimated to be threatened by salt water intrusion from coastal areas. Fifteen of 200 freshwater production sites had to shut down because of saltwater contamination. That is why The Netherlands will become much more dependent on surface water.[56]

Possible qualitative risks of **evaporation** were only mentioned in four references. Evaporative water losses could increase the salinity of surface waters such as lakes or reservoirs[57], especially in areas where evaporation is greater than precipitation[58].

Water quality problems caused by **storms** are not mentioned in any references.

All in all changes in the water quality lead to increasing treatment costs, more often backwashing of filters and decreasing filter run times as well as increasing amounts of sludge produced at water companies.

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51 See DEUTSCHE VEREINIGUNG FÜR WASSERWIRTSCHAFT, ABWASSER UND ABFALL e.V. (ed.) (2010), p. 14.
52 See ROHN, A.; MÄLZER, H.-J. (2010), p. 5 f.
53 See WILLMITZER, H. (2007), p. 61.
54 See ARNELL, N. W.; DELANEY, K. (2005), p. 234.
55 See JARRAUD, M. (2008), p. 533.
56 See MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007), p. 139.
57 See BATES, B. et al. (2008), p. 70.
58 See KACZMAREK, Z. et al. (1996), p. 52.

Water quantity

Water companies can also be confronted with water quantity problems caused by climate change. Figure 14 gives an overview of the number of references which discuss water quantity problems caused by 1st and 2nd climate change order effects. It can be noticed that water quantity problems caused by the climatic parameters sea level, heavy rainfall as well as storm are not mentioned in any references.

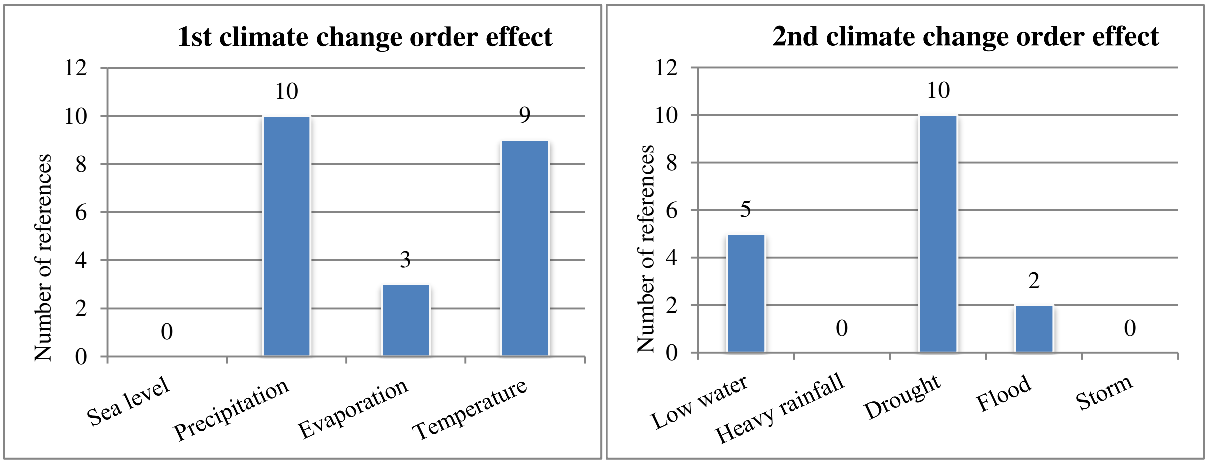

Figure 14: Absolute number of references which mention water quantity problems caused by 1st and 2nd climate change order effects

(Own illustration.)

Ten references mention drought as well as precipitation as a reason for water quantity problems.

During **droughts** the run-off into storage reservoirs decreases[59], which reduces the reliability of dams and the availability of raw water. By the way, the more the reservoir level declines the more the number of raw water extraction depths decreases. This could be a problem for water companies because only clean and cool deep water is suitable for drinking water production.[60] But droughts also lead to decreasing river flows and thereby decreasing raw water supply. According to HERSH, R.; WERNSTEDT, K. (2001) a major impact occured at an utility in the northwestern United States where the level of the source river dropped below the sill of the utilities intake structure, requiring operators to use a portable pump to draw water from the river channel into the intake.[61] But the ground water availability is also affected by droughts because long dry periods lead to a reduction of the ground water recharge. As a result the ground water level declines and water suppliers may experience problems delivering enough water.[62] This tendency is intensified by the increasing competition between the drinking water supply and agricultural producers, who use wells for irrigation and thereby decline the ground water table additionally. Another challenge for water companies during droughts is the increasing drinking water demand. According to SUBAK, S. (2000) peaks in demand

[59] See WARNER, R. (2009), p. 227.
[60] See WILLMITZER, H. (2007), p. 61.
[61] See HERSH, R.; WERNSTEDT, K. (2001), p. 11.
[62] See KÖSTER, S. (2008), p. 202.

because of climate change tend to be the main reason for many British water providers' supply problems.[63]

According to BATES, B. et al. (2008) does decreasing summer **precipitation** lead to reduced water availability and a reduction of stored water in reservoirs fed with seasonal rivers. Besides, decreasing precipitation events lead to a reduction in inland ground water levels, just like droughts.[64]

Nine references analyse risks towards water companies because of an increase in **temperature**. Increasing temperatures lead to changes in supply and demand just like droughts. Because of higher temperatures the water table might decline, which can affect the water supply or delivery[65] and can increase competing claims between agriculture and drinking water supply[66].

Low water leads to decreasing water availabilities and limitations in water withdrawals. Five references mention water quantity problems for water companies because of low water. Especially drinking water intakes are adversely affected by reduced low flows.[67] Furthermore, according to BATES, B. et al. (2008) low water availability can lead to ground water overexploitation and increasing costs of supplying water for any use as a result of the need to pump water from deeper and further away.[68]

Evaporation can lead to water losses and decreasing water availability, which can reduce the reliability of reservoirs.[69]

According to HERSH, R.; WERNSTEDT, K. (2001) a small water utility in the northwestern United States did not have the treatment capacity to handle the volume of sediments in the stream during the 1996 **floods**. The utility was forced to use stored water and had to request that customers reduce their water use by 50 % for a few weeks to ensure supplies.[70]

Summing up, climate change affects water companies through quantitative changes in supply as well as in demand. The availability of raw water is supposed to decrease and in contrast peaks in demand will increase.

Damage to infrastructure

Climate change does not only influence water companies in a qualitative and quantitative way, but also causes damage to a water companies infrastructure. Figure 15 shows the number of references that analyse possible damages to infrastructures caused by 1st and 2nd climate change order effects. It can be noticed that most of the references discuss damages caused by extreme weather events, especially floods. Damage caused by the climatic parameters heavy rainfall, sea level or evaporation are not mentioned in any references.

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[63] See SUBAK, S. (2000), p. 138.
[64] See BATES, B. et al. (2008), p. 70.
[65] See AUERSWALD, H.; LEHMANN, R. (2010), p. 16.
[66] See BLASCHKE, A. P. et al. (2011), p. 41.
[67] See JARRAUD, M. (2008), p. 533.
[68] See BATES, B. et al. (2008), p. 70.
[69] See FRANKE, J. et al. (2006), p. 103.
[70] See HERSH, R.; WERNSTEDT, K. (2001), p. 13.

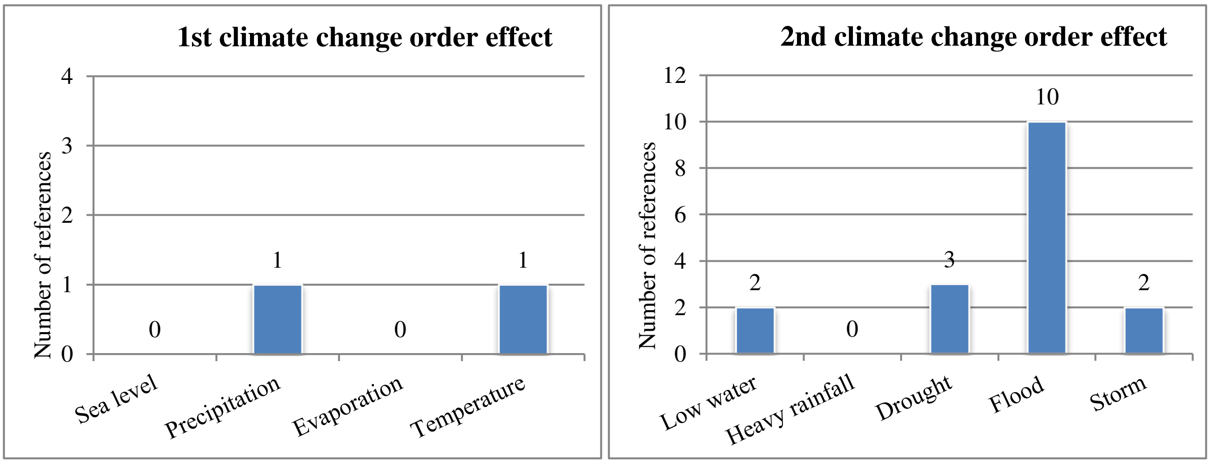

Figure 15: Absolute number of references which mention damage to infrastructures caused by 1st and 2nd climate change order effects

(Own illustration.)

Floods lead to physical damage to water storage and components of the water system such as treatment facilities or pump houses. According to HERSH, R.; WERNSTEDT, K. (2001) even intake structures and slow sand filters designed to handle fixed volumes failed.[71] Furthermore, during floods water treatment facilities are often out of order or completely breakdown, leaving the population with no sanitary protection.[72]

Moreover, extreme **droughts** can lead to pipe burst and technical problems because of increasing raw water temperatures. According to HAAKH, F. (2008) an increase of the raw water temperature from 10°C to 20°C leads to a decrease of the kinematic viscosity by 24 %.[73] Kinematic viscosity is a measure of the resistive flow of a fluid under the influence of gravity. According to STEININGER, K. W.; STEINREIBER, C.; RITZ, C. (ed.) (2005) winter droughts lead to freezing water pipes because of the missing snow cover.[74]

Storms can cause pipe burst just like droughts, but for another reason. As stated in ROHN, A.; MÄLZER, H.-J. (2010) pipe bursts are primarily observed in wooded areas because the movement of trees caused by storms transfers to the pipes or damages the pipes completely while the tree uproots.[75]

During times of **low water** which can be caused by increasing **temperatures** and decreasing **precipitation,** the cavitation limit of pumps can be reached or the lifting pipe system can draw in air and get broken.[76] According to DEUTSCHE VEREINIGUNG FÜR WASSERWIRTSCHAFT, ABWASSER UND ABFALL E.V. (ed.) (2010) increasing temperatures and

71 See HERSH, R.; WERNSTEDT, K. (2001), p. 12.
72 See BATES, B. et al. (2008), p. 71.
73 See HAAKH, F. (2008), p. 22.
74 See STEININGER, K. W.; STEINREIBER, C.; RITZ, C. (ed.) (2005), p. 183.
75 See ROHN, A.; MÄLZER, H.-J. (2010), p. 17.
76 See HAAKH, F. (2008), p. 24.

reducing precipitation events can cause cavitation problems on well pumps because of decreasing ground water levels and lead in extreme cases to the drying-up of some wells.[77]

Altogether it can be stated that the water quality problems water companies have to face outweigh the quantitative problems as well as the damage issues caused by extreme weather events. It can be noticed that the question how far climate change affects the water treatment process is only being mentioned briefly within the examined references. This leads to the coclusion that there is still need for research.

Opportunities

Despite all stated risks, four references mentioned opportunities that water providers might have because of climate change.

According to KREUZINGER, N.; KROIß, H. (2011) one opportunity that comes with increasing temperatures and droughts is the domestic and industrial increase in demand, which causes shorter residence times of drinking water in the water supply pipes. Increasing water demand counteracts biofilm formation that might occcur in drinking water pipes during long dry periods.[78] THORNE, O.; FENNER, R. A. (2011) mention an increased dilution of pollutants and pathogens with higher flows. Furthermore, they stated the opportunity of flushing away algal blooms by storms.[79] According to ROHN, A.; MÄLZER, H.-J. (2010) agricultural uses in The Netherlands is projected to decrease during the next years, which leads to better water qualities because of reduced immissions of pesticides and fertilizers into the water bodies. Moreover, the competition between the drinking water supply and agricultural producers will be ended.[80]

Considering the fact that the risks for water companies caused by climate change outweigh the possible opportunities many times, adaptive stategies are necessary. Furthermore, it became apparent that qualitative water problems have more negative effects on water companies than quantitative problems. Especially the papers by MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007) as well as BATES, B. et al. (2008) and ROHN, A.; MÄLZER, H-J. (2010) provided a very detailed overview of the impacts of climate change on water companies.

4.4 Adaptation strategies

The following chapter discusses adaptation strategies for water providers with the objective to reduce their vulnerability towards climate change and answers the research question: *"How do water companies adapt to climate change impacts?"*. As mentioned in chapter 3.2 the adaptation strategies found within the 40 references were divided into (1) strategies that are conceivable and (2) strategies that are already fully implemented. As performed in chapter 4.3 the adaptation measures are once more classified into measures that involve *water quality* as well as *water quantity* problems and adaptation measures that have to do with *damage to infrastructure*.

[77] See DEUTSCHE VEREINIGUNG FÜR WASSERWIRTSCHAFT, ABWASSER UND ABFALL e.V. (ed.) (2010), p. 13.
[78] See KREUZINGER, N.; KROIß, H. (2011), p. 48.
[79] See THORNE, O.; FENNER, R. A. (2011), p. 81.
[80] See ROHN, A.; MÄLZER, H.-J. (2010), p. 16.

Water quality

First of all, conceivable and already implemented adaptation strategies that deal with deteriorations in raw water quality are being analysed. Figure 16 shows the number of references, that try to adjust to water quality changes with the help of adaptation strategies. In most of the cases the conceivable strategies outweigh the already implemented ones.

Improve treatment process / treatment techniques

In view of the deterioration of water quality in rivers and lakes, treatment techniques must be improved.[81] It becomes apparent while analysing the references that five articles only give a brief overview of possible adaptation strategies such as implementing innovative and flexible treatment technologies or optimizing already existing treatment processes. These references do not expand on how treating raw water efficiently or how optimising the treatment process at all. However, the paper by UHL, W.; SLAVIK, I. (2009) gives a more detailed statement about how to improve the treatment process. Because of floods and more frequent intense rainfall events the concentrations of organic compounds is projected to increase. The conventional treatment processes of coagulation and filtration, which are the chosen technologies to treat raw water with low organic loads, are no longer sufficient. Therefore, process combinations of oxidation/biofiltration and nanofiltration have to be applied by water companies additionally to the conventional processes.[82] According to DEUTSCHE VEREINIGUNG FÜR WASSERWIRTSCHAFT, ABWASSER UND ABFALL E.V. (ed.) (2010) the disinfection in distribution and storage systems need to be considered.[83] As reported by ROHN, A.; MÄLZER, H.-J. (2010) the water company Essen GmbH added in 2009 additional treatment trains to their water preparation such as carbon filtration, physical deacidification and disinfection by UV light. This modification icreased the microbiological safety and improved the taste of the drinking water.[84]

81 See JARRAUD, M. (2008), p. 533.
82 See UHL, W.; SLAVIK, I. (2009), p. 101 f.
83 See DEUTSCHE VEREINIGUNG FÜR WASSERWIRTSCHAFT, ABWASSER UND ABFALL E.V. (ed.) (2010), p. 15.
84 See ROHN, A.; MÄLZER, H.-J. (2010), p. 10.

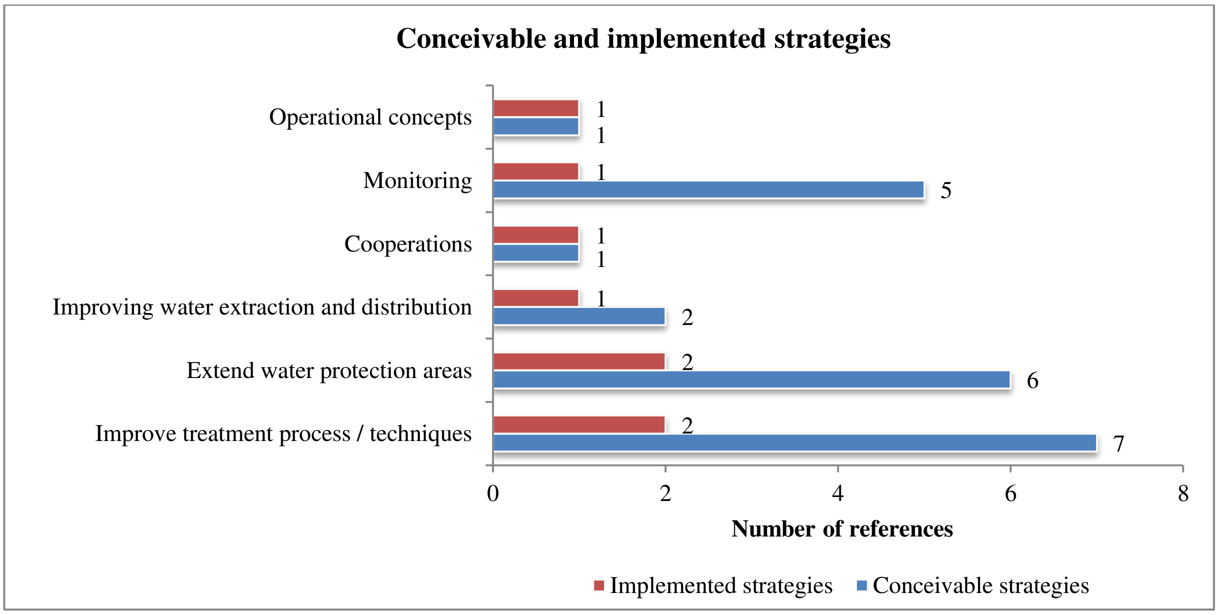

Figure 16: Conceivable and implemented adaptation strategies that have to do with water quality problems (Own illustration.)

Extend water protection areas

Another adaptation strategy that deals with water quality problems is the extension of water protection areas. This measure improves raw water quality by reducing the load through increasing extensive protection areas.

Monitoring

Furthermore, monitoring systems should be implemented for identifying water quality changes indicated by the parameters turbidity, water temperature or electrical conductivity.[85] Especially after floods and drought periods, which may lead to microbiological or chemical contaminations, additional monitoring systems are needed.

Improving water extraction and distribution

In order to reduce chemical treatment needs caused by extreme weather events, New Yorks water providers implemented so called Turbidity Reduction Programs such as turbidity curtains or modifying the design of intakes. Additionally, a Stream Management Program to reduce streambed and streambank erosion during stream baseflow was being implemented.[86] Another mentioned adaptation strategy deals with recontamination of drinking water during the transport in distribution networks. Increasing temperatures and more frequent heatwaves lead to increasing microbiological risks. To avoid a microbiological contamination of the drinking water it can be heplful to bury pipelines deeper into the ground.[87]

Cooperations

Two references mentioned cooperations between laboratories, authorities, disaster control, drinking water customers and water companies as an adequate adaptation strategy. Especially

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85 See WILLMITZER, H. (2007), p. 62.
86 See MILLER, K.; YATES, D. (2005), p. 50.
87 See ROHN, A.; MÄLZER, H.-J. (2010), p. 11.

small scale water suppliers should work with laboratories that are specialised in emergency health risks. The aim is to assist and strengthen the current health risk assessment of the water utility.[88]

Operational concepts

ROHN, A.; MÄLZER, H.-J. (2010) recommend an operational concept in case of increasing water temperatures. Especially the frequency of backwashing the filters and the dosages of disinfectants should be examined by water companies.[89] To determine the optimal reaction to changing raw water conditions UHL, W.; SLAVIK, I. (2009) developed a decision support tool for water providers. It is used to guarantee a secure and sustainable water supply because it makes separate predictions of treatment capacity and costs of different treatment technologies for changing raw water qualities.[90]

Water quantity

The following section analyses both conceivable and already implemented adaptation measures that have to do with water quantity problems. Figure 17 shows the number of references that deal with conceivable and implemented adaptation strategies of water companies. Once more it can be noticed that most of the relevant articles deal with strategies that are only imaginable, but not implemented yet.

New or alternative sources

Most of the references suggest to increase the water production from alternative sources such as sea water, precipitation or brackish ground water.[91] Four references suggested desalination as a possibility to increase water supply. Especially in countries where the availabilty of raw water sources is already decreasing. Australia for example faces the problem of a more and more increasing salinisation of rivers and aquifers. That is why according to ROHN, A.; MÄLZER, H.-J. (2010) the desalination of water is already being performed in Australia.[92] Other references examine the possibility to build new dams or reservoirs.

Increasing storage and treatment capacity

Twelve references examine the adaptation strategy to increase storage as well as treatment capacity and three references analyse already implemented strategies. Most references deal with the issue of increasing water storage capacity in reservoirs and dams for providing enough raw water or expanding existing water storage facilities such as elevated tanks. Those measures can be particularly helpful during long periods of drought. Furthermore, the maximum treatment capacity of production facilities should be increased to meet peak and seasonal demands[93] as well as the capacity of the distribution network[94].

88 See DELPLA, I. et al. (2011), p. 231.
89 See ROHN, A.; MÄLZER, H.-J. (2010), p. 10.
90 See UHL, W.; SLAVIK, I. (2009), p. 104 f.
91 See MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007), p. 142.
92 See ROHN, A.; MÄLZER, H.-J. (2010), p. 11 f.
93 See MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007), p. 141.
94 See ARNELL, N. W.; DELANEY, K. (2005), p. 244.

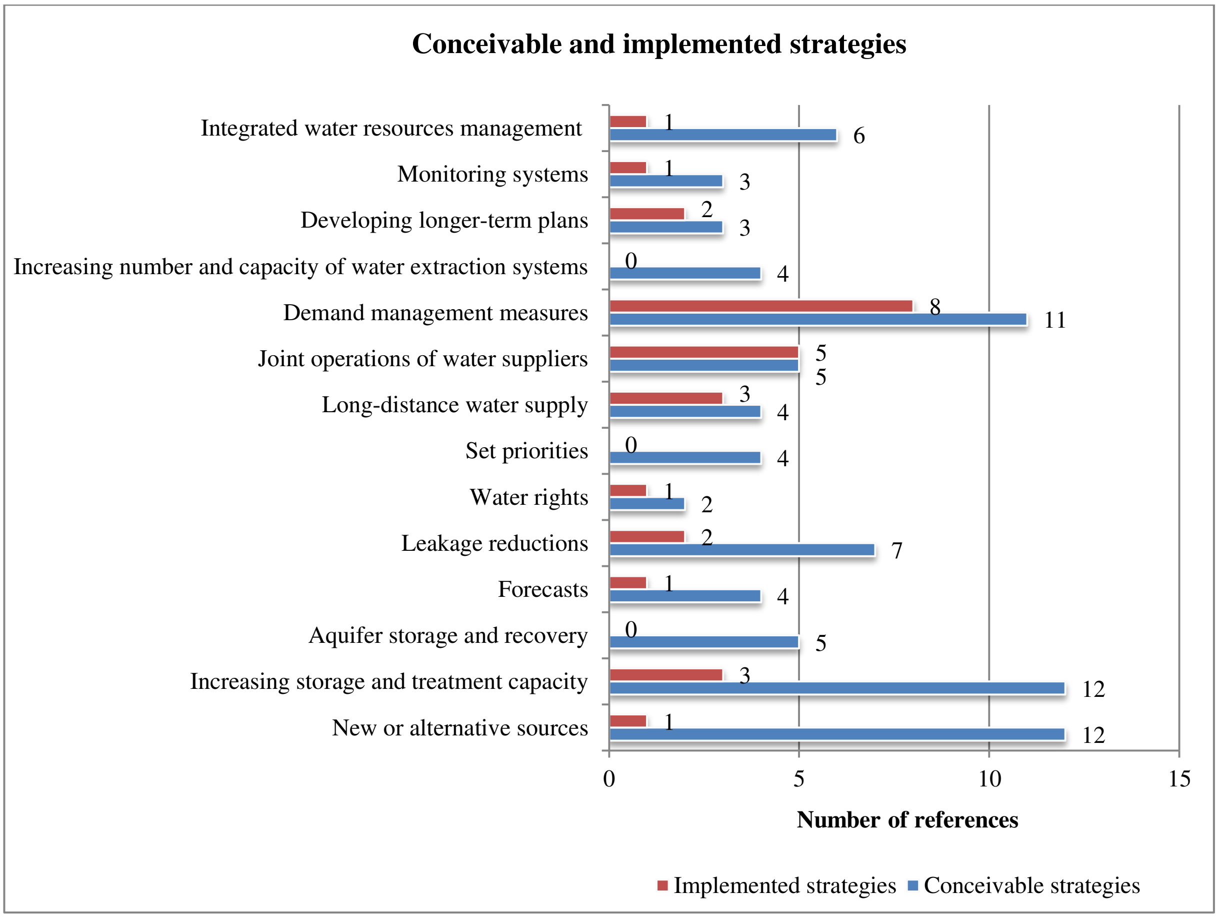

Figure 17: Conceivable and implemented strategies that deal with water quantity problems (Own illustration.)

Demand management measures

Demand management and water saving measures should be implemented in industry, agriculture and private households, to avoid restrictions of usage.[95] Because of increasing periods of droughts water companies need to raise the awareness of their customers to decrease water consumption as well as demand.[96] According to HERSH, R.; WERNSTEDT, K. (2001) water utilities in the norhwestern United States were able to manage low flow conditions by implementing several demand reduction measures such as prohibitions on selected institutional uses like public park watering restrictions, or restrictions on nonessential uses.[97] Demand management measures can be performed with the help of economic instruments as well such as pricing or metering.[98] According to SUBAK, S. (2000) water companies in England and Wales agreed to remove some of the costs for installing water meters in households because water consumption is not metered in most of the British households. This measure has the effect of reducing water consumption by up to 12 % per household and, therefore, reducing peak demands.[99]

[95] See ZEBISCH, M. et al. (2005), p. 61.
[96] See KUNDZEWICZ, Z. W. (2006), p. 109.
[97] See HERSH, R.; WERNSTEDT, K. (2001), p. 11.
[98] See ECONOMIC COMMISSION FOR EUROPE (ed.) (2009), p. 92.
[99] See SUBAK, S. (2000), p. 141.

Leakage reductions

Additionally water production can be optimised by leak reduction programs to curb system loss. According to HERSH, R.; WERNSTEDT, K. (2001) most utilitis in the northwestern United States, were able to increase their ability to cope with low flow events through an aggressive leak reduction program.[100] As reported by SCHERZER, J. et al. (2010) it can be useful to monitor and continuously maintenance the water supply network to reduce and detect water loss.[101]

Integrated water resources management

As stated in the report by ROHN, A.; MÄLZER, H.-J. (2010) the water company Hessenwasser, which is located in southern Hesse in Germany is part of the project „Anpassungsstrategien an Klimatrends und Extremwetter sowie Maßnahmen für ein nachhaltiges Grundwassermanagement". The water provider faces decreasing water availability by enriching ground water with treated surface water and can therefore ensure water supply during extreme drought.[102]

Aquifer storage and recovery

As explained in chapter 2.2 aquifer storage and recovery is a good way for temporarily storage water below ground. As seen in the previous point even integrated water resources management includes aquifer storage and recovery. This adaptation strategy involves the re-injection of treated water back into an aquifer during times when water is plentiful and withdraw the water when it is needed. It helps increasing water supply during seasonal droughts.

Joint operations of water suppliers

According to five references linkages of water companies are already known and implemented as adaptation strategies. As stated in the article of SUBAK, S. (2000) many British water providers distribute water between companies that have a surplus and companies that have a deficit of water.[103] This helps to guarantee water supply during times of shortage.

Long distance water supply

Another adaptation strategy for water companies is the transport of water trough long-distance pipelines, which improves the availability of drinking water.[104]

Increasing number an capacity of water extraction systems

According to DE LOE, R.; KREUTZWISER, R.; MORARU, L. (2001) the intake capacity from surface sources should be increased to meet peak demands and the intake pumping capacity should be increased, too.[105] Furthermore, developing new well fields or deepen existing wells[106] and new direct river abstractions[107] help to increase water supply as well.

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100 See HERSH, R.; WERNSTEDT, K. (2001), p. 16.
101 See SCHERZER, J. et al. (2010), p. 116.
102 See ROHN, A.; MÄLZER, H.-J. (2010), p. 9.
103 See SUBAK, S. (2000), p. 143.
104 See MAHAMMADZADEH, M. (2010), p. 325.
105 See DE LOE, R.; KREUTZWISER, R.; MORARU, L. (2001), p. 233 ff.
106 See HERSH, R.; WERNSTEDT, K. (2001), p. 20.
107 See ARNELL, N. W.; DELANEY, K. (2005), p. 244.

Set Priorities

Another adaptation measure for ensuring water supply during times of water shortage is the fact that drinking water supply should have priority over other kinds of use such as irrigation.[108] As stated in the report of ROHN, A.; MÄLZER, H.-J. (2010) the utilisation conflict can be avoided by developing water balances, which include the additional demand of agricultural irrigation.[109]

Monitoring systems

Moreover, monitoring systems should not only be implemented because of changes in water quality, but also because of recognizing changes in the quantity of surface and ground water.

Developing longer-term plans

According to the ECONOMIC COMMISSION FOR EUROPE (ed.) (2009) drought management plans have been implemented by water companies in Spain. This measure can be grouped into structural measures such as new pumping wells, new pipes or the use of desalination plants and non-structural measures like saving water by applying restrictions to users.[110] Another reference suggests drought contingency planning as an adaptation strategy because of increasing heatwaves.[111] To help guide operations during floods HERSH, R.; WERNSTEDT, K. (2001) found out that the majority of larger utilities in the northwestern United States have developed longer-term plans. One water company, for example, documented in detail the record of the 1996 flood events to create a usable reference document that operators could consult if they encounter such peak flow conditions and turbidity again. The document reveals who did what, when, and what chemical dosages were used at what point during the flood.[112] This plan helped to keep drinking water flowing to the water companies customers.

Forecasts

According to SUBAK, S. (2000) climate change scenarios were devolped by the Hadley Centre and updated by the U.K. Climate Impacts Program to estimate water supply and water demand over the next 25 years in England and Wales. After developing four sceanrios for each water services region, water companies were supposed to average the sceanrios and consider impacts on future water demand and supply. Furthermore water providers were asked how they would keep supply and demand in adeqaute balance until 2025.[113] As stated in four more references water companies should consider using climate change projections more often and integrate them into their supply and demand management.

Water rights

Purchasing water rights for covering peak demands and protecting drinking water supply should be considered as an adaptation strategy for water utilities as well.

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108 See HAAKH, F. (2008), p. 19.
109 See HERSH, R.; WERNSTEDT, K. (2001), p. 13.
110 See ECONOMIC COMMISSION FOR EUROPE (ed.), p. 82.
111 See DE LOE, R.; KREUTZWISER, R.; MORARU, L. (2001), p. 233.
112 See HERSH, R.; WERNSTEDT, K. (2001), p. 17.
113 See SUBAK, S. (2000), p. 140.

Damage to infrastructure

As seen in Figure 18 seven references examine adaptation measures that deal with damages to infrastructures caused by extreme weather events.

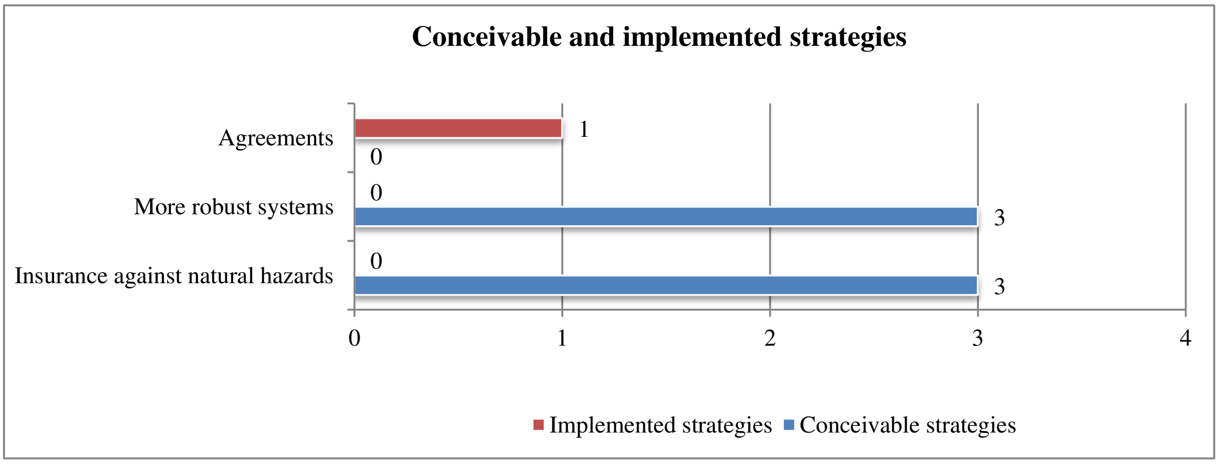

Figure 18: Conceivable and implemented strategies that deal with damages to infrastructures (Own illustration.)

Insurance against natural hazards

Three references mention insurances against damages through climate change as an adaptation strategy for water companies. Especially insurance against floods is reported.

More robust systems

Another adaptation strategy noted by BLÖSCHL, G. et al. (2011) is a robust treatment system which has a little chance of functional failure.[114] Furthermore, in case of more frequent black-outs caused by extreme weather events, back-up generators should be installed.[115]

Agreements

According to HERSH, R.; WERNSTEDT, K. (2001) many large water utilities in the north-western United States have formalised agreements with outside agencies to provide water in case of system failure.[116] Therefore, drinking water keeps flowing to the customers.

In summary, it can be noticed that the adaptation strategies that deal with water quantity problems clearly outweigh the measures that have to do with qualitative and infrastructural problems. However, this conclusion contrasts with the fact determinded in chapter 4.3, that water quality problems, water companies have to face predominate the quantitative problems. In general it can be stated that even though water companies more and more frequently face qualitative raw water problems, the number of possible adaptation strategies is still small. This applies above all the number of adaptation strategies that have to do with water treatment processes. The reason for that is because there is still a lack of reliable information about how raw water quality is going to change during the next years.

[114] See BLÖSCHL, G. et al. (2011), p. 8.
[115] See HERSH, R.; WERNSTEDT, K. (2001), p. 20.
[116] See HERSH, R.; WERNSTEDT, K. (2001), p. 18.

Moreover, the accomplished classification of the adaptation strategies shows that the number of conceivable strategies clearly predominate the number of already implemented strategies. This reveals that ideas for possible adaptation strategies are already existing, but there is still a lack in informing and involving water providers.

The report by HERSH, R.; WERNSTEDT, K. (2001) as well as the paper by ROHN, A.; MÄLZER, H.-J. (2010) delivered the most interesting adaptation strategies that water companies can implement to reduce their vulnerability towards climate change. Furthermore, the article by ROHN, A.; MÄLZER, H.-J. (2010) draws on comprehensive interviews of water utility operators in the northwestern United States.

4.5 Adaptation barriers

The following section examines possible adaptation barriers for water companies. Altogether 13 of 40 references mention barriers that water providers might face while adaptation to climate change impacts. Figure 19 gives an overview of the barriers found within the references. It becomes obvious that most of the relevant studies mention financial restrictions as an adaptation barrier for water utilities.

Financial restrictions

Ten of thirteen references analyse adaptation barriers caused by financial restrictions. According to MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007) most water companies are afraid of the high investment costs when increasing the capacity of production facilities or building new reservoir constructions to meet peak demands.[117] As reported by HERSH, R.; WERNSTEDT, K. (2001) especially smaller water utilities in the northwestern United States are disadvantaged because of their limited fiscal independence. They need to convince city councils, who are the rate making authorities for publicly-owned water utilities, to increase rates to cover the costs of replacing aging infrastructure or adding flexibility to the system through the purchase of back-up generators or increasing storage capacity.[118] According to ARNELL, N.; DELANEY, K. (2005) an adaptation barrier for water companies in England and Wales is the requirement that all investments, that have to to with adaptation to climate change are supposed to be funded by efficiency savings, borrowing or through charges to customers. The government does not directly contribute anything.[119]

[117] See MEULEMAN, A. F. M.; CIRKEL, G.; ZWOLSMAN, G. J. J. (2007), p. 141.
[118] See HERSH, R.; WERNSTEDT, K. (2001), p. 19 f.
[119] See ARNELL, N.; DELANEY, K. (2005), p. 251.

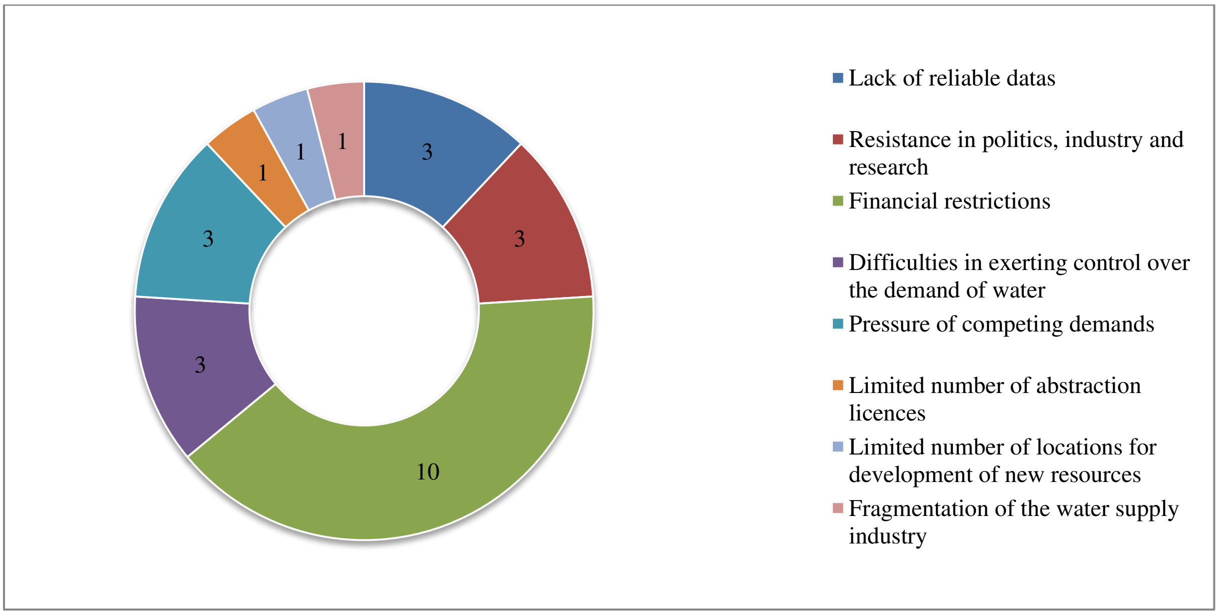

Figure 19: Absolute number of references that mention adaptation barriers
(Own illustration.)

Difficulties in exerting control over the demand of water

Sometimes water companies must face difficulties in exerting control over the demand of water. As hurdles for saving water the current ample water supply and low water prices are named. Furthermore, citizens are often low motivated to implement water saving measures.[120]

Pressure of competing demands

The conflict between drinking water supply and flood control through dams is considered as another adaptation barrier. The water level in dams need to be low in cases of flood events, on the other hand, water storage in reservoirs is needed for drinking water supply and for raising low water levels in rivers during droughts.[121] Moreover, competing demands between agricultural uses such as irrigations and water supply, pressures water companies as well.[122]

Resistance in politics, industry and research

According to ZEBISCH, M. et al. (2005) the improvement of water quality is said to be hindered by resistance in politics and industry.[123] The resistance in politics and research was also mentioned by MAHAMMADZADEH, M. (2010). He also refered to the low motivation of decision makers, which also hinders water providers in adapting to climate change impacts.

Lack of reliable data

The lack of reliable data and information about climate change as well as climate change impacts represents antother adaptation barrier. There is still uncertainty about how climate change is going to affect water companies.[124]

[120] See ZEBISCH, M. et al. (2005), p. 61.
[121] See SCHERZER, J. et al. (2010), p. 117.
[122] See ARNELL, N. W.; DELANEY, K. (2005), p. 251.
[123] See ZEBISCH, M. et al. (2005), p. 61.
[124] See MAHAMMADZADEH, M. (2010), p. 332.

According to ARNELL, N. W.; DELANEY, K. (2005) *time-limited abstraction licences*, which deter water company investments, as well as the *limited number of locations* for uncontroversial development of new resources, represent adaptation barriers for water providers in Great Britain. Furthermore, the water supply industry particularly in southeast England is being *fragmented* with diverse and changing patterns of ownership.[125]

All in all, a good overview of several adaptation barriers water companies must face while adapting to climate change, provides ARNELL, N. W.; DELANEY, K. (2005).

Within this chapter 40 references were being examined to answer the research questions *"What effects does climate change have on water companies?"* and *"How do water companies adapt to climate change impacts?"*. It is noticeable that climate change more often leads to qualitative raw water problems than quantitative or infrastructural problems. Despite of that conclusion, most of the references are focusing on adaptation strategies for water utilities that deal with quantitative raw water problems.

[125] See ARNELL, N. W.; DELANEY, K. (2005), p. 251.

5 Conclusions

The primary objective of this work was to analyse how water companies are affected by climate change and how they try to adapt to it. This aim has been achieved with the help of a systematic literature review, which included the selection and evaluation of 40 references. Therefore, a coding sheet was developed and implemented, which helped to structure relevant information.

The literature review showed that the risks of water companies towards climate change are not unknown. The number of scientific researchers that deal with the issue of climate change and the resulting impacts on the water supply is more and more growing.

It can be concluded that concerning the effects of climate change on water companies, the risks water providers might face, clearly predominate possible opportunities. Especially the deterioration of the raw water quality caused by increasing temperatures, floods as well as heavy rainfalls, is mentioned as a serious problem for water companies. Further effects of climate change on water companies are changes in the water availability as well as damages to infrastructures.

On the other hand, the most often mentioned adaptation strategies are dealing with quantitative water problems such as measures to increase storage as well as treatment capacity, or leakage reductions. Fewer measures deal with the adjustment to qualitative and infrastructural changes such as the improvement of treatment techniques or the extension of water protection areas. Even though water companies will be more often confronted with qualitative raw water problems than changes in water quantity, the number of possible adaptation strategies is still small. Especially changes within the raw water treatment processes caused by climate change as well as the implementation of sufficient adaptation measures are mostly unexplored. One reason might be the uncertainty about how water quality is going to change during the next years.

Furthermore, the classification of the examined adaptation strategies into "conceivable" and "already implemented" strategies shows that the conceivable strategies clearly outweigh the implemented ones. This indicates that most of the water companies, which were being mentioned within the references, did not adapt to the impacts of climate change yet or did not even discuss possible adaptation measures.

This fact leads to the conclusion that scientists and researchers should involve water providers stronger into their work, for example by accomplishing surveys or interviews with water utilities. Researchers should try to encourage water companies to think about the impacts of climate change on the water sector, so that suitable adaptation strategies can be developed.

Additionally, to implement effective adaptation measures, adaptation barriers need to be eliminated. The financial hurdle could be faced through financial contributions by governments or subsidies. Moreover, the lack of reliable data about climate change needs to be reduced, for example by implementing scenario analyses that deal with impacts on the water cycle.

All in all, it can be stated that there is still uncertainty about how climate change will affect water companies. There is still need for research to ensure an effective adaptation process.

Appendix A: Search Results

Table 5: Search results by databases

Web of Science				
topic AND topic	date	hits	relevant	used
"climate change adaptation" AND "community water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "private water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "public water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "supply of water"	13.07.2011	1	0	0
"climate change adaptation" AND water	13.07.2011	80	1	0
"climate change adaptation" AND "water compan*"	18.07.2011	1	1	1
"climate change adaptation" AND "water economy"	18.07.2011	0	0	0
"climate change adaptation" AND "water industry"	13.07.2011	1	1	1
"climate change adaptation" AND "water management"	13.07.2011	18	0	0
"climate change adaptation" AND "water preparation"	13.07.2011	0	0	0
"climate change adaptation" AND "water provider"	18.07.2011	0	0	0
"climate change adaptation" AND "water resources management"	18.07.2011	5	0	0
"climate change adaptation" AND "water service"	18.07.2011	0	0	0
"climate change adaptation" AND "water supplying"	13.07.2011	0	0	0
"climate change adaptation" AND "water supply compan*"	13.07.2011	0	0	0
"climate change adaptation" AND "water supply organi?ation"	13.07.2011	0	0	0
"climate change adaptation" AND "water treatment"	13.07.2011	0	0	0
"climate change adaptation" AND "water utilities"	13.07.2011	0	0	0
total		**106**	**3**	**2**

Web of Science				
topic AND topic AND topic	date	hits	relevant	used
"climate change" AND adaptation AND "community water suupl*"	18.07.2011	1	0	0
"climate change" AND adaptation AND "private water suppl*"	18.07.2011	0	0	0
"climate change" AND adaptation AND "public water suppl*"	18.07.2011	3	1	1
"climate change" AND adaptation AND "supply of water"	13.07.2011	4	0	0
"climate change" AND adaptation AND "water compan*"	18.07.2011	2	1	1
"climate change" AND adaptation AND "water economy"	18.07.2011	1	0	0
"climate change" AND adaptation AND "water industry"	13.07.2011	5	1	1
"climate change" AND adaptation AND "water management"	13.07.2011	98	0	0
"climate change" AND adaptation AND "water preparation"	13.07.2011	0	0	0
"climate change" AND adaptation AND "water provider"	18.07.2011	1	0	0
"climate change" AND adaptation AND "water resources management"	18.07.2011	37	0	0
"climate change" AND adaptation AND "water service"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water supplying"	13.07.2011	0	0	0
"climate change" AND adaptation AND "water supply compan*"	13.07.2011	4	1	1
"climate change" AND adaptation AND "water supply organi?ation"	13.07.2011	0	0	0
"climate change" AND adaptation AND "water treatment"	13.07.2011	7	3	3
"climate change" AND adaptation AND "water utilities"	13.07.2011	0	0	0
total		**163**	**7**	**7**

Web of Science				
topic AND topic AND topic	date	hits	relevant	used
"global warming" AND adaptation AND "community water suupl*"	21.07.2011	0	0	0
"global warming" AND adaptation AND "private water suppl*"	21.07.2011	0	0	0
"global warming" AND adaptation AND "public water suppl*"	21.07.2011	0	0	0
"global warming" AND adaptation AND "supply of water"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water compan*"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water economy"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water industry"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water management"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water preparation"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water provider"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water resources management"	21.07.2011	2	0	0
"global warming" AND adaptation AND "water service"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water supplying"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water supply compan*"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water supply organi?ation"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water treatment"	21.07.2011	0	0	0
"global warming" AND adaptation AND "water utilities"	21.07.2011	0	0	0
total		**2**	**0**	**0**

EBSCO (Academic Search Complete, Business Source Complete, EconLit with Full Text, E-Journals, Risk Manegement Reference Center, TOC Premier)				
abstract AND abstract	date	hits	relevant	used
"climate change adaptation" AND "community water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "private water suppl*"	18.07.2011	0	0	0
"climate change adapttaion" AND "public water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "supply of water"	14.07.2011	0	0	0
"climate change adaptation" AND water	14.07.2011	64	1	1
"climate change adaptation" AND "water compan*"	18.07.2011	0	0	0
"climate change adaptation" AND "water economy"	18.07.2011	0	0	0
"climate change adaptation" AND "water industry"	14.07.2011	1	0	0
"climate change adaptation" AND "water management"	14.07.2011	7	0	0
"climate change adaptation" AND "water preparation"	14.07.2011	0	0	0
"climate change adaptation" AND "water provider"	18.07.2011	0	0	0
"climate change adaptation" AND "water resources management"	18.07.2011	4	1	1
"climate change adaptation" AND "water service"	18.07.2011	0	0	0
"climate change adaptation" AND "water supplying"	14.07.2011	0	0	0
"climate change adaptation" AND "water supply compan*"	14.07.2011	0	0	0
"climate change adaptation" AND "water supply organi?ation"	14.07.2011	0	0	0
"climate change adaptation" AND "water treatment"	14.07.2011	0	0	0
"climate change adaptation" AND "water utilities"	14.07.2011	1	0	0
total		**77**	**2**	**2**

EBSCO (Academic Search Complete, Business Source Complete, EconLit with Full Text, E-Journals, Risk Manegement Reference Center, TOC Premier)				
all text AND all text	date	hits	relevant	used
"climate change adaptation" AND "community water suppl*"	18.07.2011	1	0	0
"climate change adaptation" AND "private water suppl*"	18.07.2011	3	0	0
"climate change adaptation" AND "public water suppl*"	18.07.2011	14	0	0
"climate change adaptation" AND "supply of water"	18.07.2011	24	0	0
"climate change adaptation" AND "water compan*"	18.07.2011	34	3	2
"climate change adaptation" AND "water economy"	18.07.2011	2	0	0
"climate change adaptation" AND "water industry"	14.07.2011	32	2	2
"climate change adaptation" AND "water management"	14.07.2011	211	0	0
"climate change adaptation" AND "water preparation"	18.07.2011	0	0	0
"climate change adaptation" AND "water provider"	18.07.2011	4	1	1
"climate change adaptation" AND "water resources management"	18.07.2011	47	3	3
"climate change adaptation" AND "water service"	18.07.2011	5	0	0
"climate change adaptation" AND "water supplying"	14.07.2011	0	0	0
"climate change adaptation" AND "water supply compan*"	14.07.2011	1	0	0
"climate change adaptation" AND "water supply organi?ation"	14.07.2011	0	0	0
"climate change adaptation" AND "water treatment"	18.07.2011	44	1	1
"climate change adaptation" AND "water utilities"	18.07.2011	39	3	2
total		**461**	**13**	**11**

EBSCO (Academic Search Complete, Business Source Complete, EconLit with Full Text, E-Journals, Risk Manegement Reference Center, TOC Premier)				
all text AND all text AND all text	date	hits	relevant	used
"global warming" AND adaptation AND "community water suppl*"	24.07.2011	3	0	0
"global warming" AND adaptation AND "private water suppl*"	24.07.2011	2	0	0
"global warming" AND adaptation AND "public water suppl*"	24.07.2011	35	0	0
"global warming" AND adaptation AND "supply of water"	24.07.2011	90	1	1
"global warming" AND adaptation AND "water compan*"	24.07.2011	23	2	2
"global warming" AND adaptation AND "water economy"	24.07.2011	22	0	0
"global warming" AND adaptation AND "water industry"	24.07.2011	30	1	1
"global warming" AND adaptation AND "water management"	24.07.2011	609	2	2
"global warming" AND adaptation AND "water preparation"	24.07.2011	2	1	1
"global warming" AND adaptation AND "water provider"	24.07.2011	2	1	1
"global warming" AND adaptation AND "water resources management"	24.07.2011	105	2	2
"global warming" AND adaptation AND "water service"	24.07.2011	16	0	0
"global warming" AND adaptation AND "water supplying"	24.07.2011	2	0	0
"global warming" AND adaptation AND "water supply compan*"	24.07.2011	2	0	0
"global warming" AND adaptation AND "water supply organi?ation"	24.07.2011	1	0	0
"global warming" AND adaptation AND "water treatment"	24.07.2011	2173	1	1
"global warming" AND adaptation AND "water utilities"	24.07.2011	43	2	1
total		**3160**	**13**	**12**

TEMA Technik und Management				
Globalsuche AND Globalsuche	date	hits	relevant	used
"climate change adaptation" AND "community water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "private water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "public water suppl*"	18.07.2011	0	0	0
"climate change adaptation" AND "supply of water"	18.07.2011	0	0	0
"climate change adaptation" AND water	18.07.2011	1	1	1
"climate change adaptation" AND "water compan*"	18.07.2011	0	0	0
"climate change adaptation" AND "water economy"	18.07.2011	0	0	0
"climate change adaptation" AND "water industry"	18.07.2011	0	0	0
"climate change adaptation" AND "water management"	18.07.2011	0	0	0
"climate change adaptation" AND "water preparation"	18.07.2011	0	0	0
"climate change adaptation" AND "water provider"	18.07.2011	0	0	0
"climate change adaptation" AND "water resources management"	18.07.2011	0	0	0
"climate change adaptation" AND "water service"	18.07.2011	0	0	0
"climate change adaptation" AND "water supplying"	18.07.2011	0	0	0
"climate change adaptation" AND "water supply compan*"	18.07.2011	0	0	0
"climate change adaptation" AND "water supply organi?ation"	18.07.2011	0	0	0
"climate change adaptation" AND "water treatment"	18.07.2011	0	0	0
"climate change adaptation" AND "water utilities"	18.07.2011	0	0	0
total		**1**	**1**	**1**

TEMA Technik und Management				
Globalsuche AND Globalsuche AND Globalsuche	date	hits	relevant	used
"climate change" AND adaptation AND "community water suppl*"	18.07.2011	0	0	0
"climate change" AND adaptation AND "private water suppl*"	18.07.2011	0	0	0
"climate change" AND adaptation AND "public water suppl*"	18.07.2011	0	0	0
"climate change" AND adaptation AND "supply of water"	18.07.2011	1	0	0
"climate change" AND adaptation AND water	18.07.2011	8	1	1
"climate change" AND adaptation AND "water compan*"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water economy"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water industry"	18.07.2011	1	0	0
"climate change" AND adaptation AND "water management"	18.07.2011	1	0	0
"climate change" AND adaptation AND "water preparation"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water provider"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water resources management"	18.07.2011	1	0	0
"climate change" AND adaptation AND "water service"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water supplying"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water supply compan*"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water supply organi?ation"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water treatment"	18.07.2011	0	0	0
"climate change" AND adaptation AND "water utilities"	18.07.2011	0	0	0
total		**12**	**1**	**1**

TEMA Technik und Management				
Globalsuche AND Globalsuche AND Globalsuche	date	hits	relevant	used
"global warming" AND adaptation AND "community water suppl*"	20.07.2011	0	0	0
"global warming" AND adaptation AND "private water suppl*"	20.07.2011	0	0	0
"global warming" AND adaptation AND "public water suppl*"	20.07.2011	0	0	0
"global warming" AND adaptation AND "supply of water"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water compan*"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water economy"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water industry"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water management"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water preparation"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water provider"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water resources management"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water service"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water supplying"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water supply compan*"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water supply organi?ation"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water treatment"	20.07.2011	0	0	0
"global warming" AND adaptation AND "water utilities"	20.07.2011	0	0	0
total		**0**	**0**	**0**

TEMA Technik und Management				
Globalsuche UND Globalsuche	date	hits	relevant	used
Klimawandelanpassung UND "kommunale Wasserversorger"	18.07.2011	0	0	0
Klimawandelanpassung UND "öffentliche Wasserversorger"	18.07.2011	0	0	0

Klimawandelanpassung UND "private Wasserversorger"	18.07.2011	0	0	0
Klimawandelanpassung UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandelanpassung UND Talsperren	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasser	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasseraufbereitung	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasserversorgung	18.07.2011	0	0	0
Klimawandelanpassung UND Wasser	18.07.2011	0	0	0
Klimawandelanpassung UND Wasseraufbereitung	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserbereitstellung	18.07.2011	0	0	0
Klimawandelanpassung UND Wassergewinnung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserindustrie	18.07.2011	0	0	0
Klimawandelanpassung UND Wassermanagement	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserqualität	23.08.2011	0	0	0
Klimawandelanpassung UND Wasserresourcenmanagement	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserunternehmen	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserversorger	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserversorgung	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserverteilung	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserwerk	18.07.2011	0	0	0
Klimawandelanpassung UND Wasserwirtschaft	19.07.2011			
total		**0**	**0**	**0**

TEMA Technik und Management				
Globalsuche UND Globalsuche UND Globalsuche	date	hits	relevant	used
Klimawandel UND Anpassung UND "kommunale Wasserversorger"	18.07.2011	0	0	0
Klimawandel UND Anpassung UND "öffentliche Wasserversorger"	18.07.2011	0	0	0
Klimawandel UND Anpassung UND "private Wasserversorger"	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Talsperren	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Trinkwasser	19.07.2011	1	1	1
Klimawandel UND Anpassung UND Trinkwasseraufbereitung	19.07.2011	1	1	1
Klimawandel UND Anpassung UND Trinkwasserversorgung	18.07.2011	1	1	1
Klimawandel UND Anpassung UND Wasser	18.07.2011	4	1	1
Klimawandel UND Anpassung UND Wasseraufbereitung	18.07.2011	1	1	1
Klimawandel UND Anpassung UND Wasserbereitstellung	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wassergewinnung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserindustrie	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wassermanagement	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserqualität	23.08.2011	0	0	0
Klimawandel UND Anpassung UND Wasserresourcenmanagement	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserunternehmen	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserversorger	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserversorgung	18.07.2011	2	1	1
Klimawandel UND Anpassung UND Wasserverteilung	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserwerk	18.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserwirtschaft	19.07.2011			
total		**10**	**6**	**6**

TEMA Technik und Management				
Globalsuche UND Globalsuche	date	hits	relevant	used
Klimawandel UND "kommunale Wasserversorger"	18.07.2011	0	0	0
Klimawandel UND "öffentliche Wasserversorger"	18.07.2011	0	0	0
Klimawandel UND "private Wasserversorger"	18.07.2011	0	0	0
Klimawandel UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandel UND Talsperren	19.07.2011	1	1	1
Klimawandel UND Trinkwasser	19.07.2011	12	2	1
Klimawandel UND Trinkwasseraufbereitung	19.07.2011	4	1	1
Klimawandel UND Trinkwasserversorgung	18.07.2011	8	1	1
Klimawandel UND Wasser	19.07.2011	57	5	4
Klimawandel UND Wasseraufbereitung	18.07.2011	12	1	1
Klimawandel UND Wasserbereitstellung	18.07.2011	0	0	0
Klimawandel UND Wassergewinnung	19.07.2011	2	1	1
Klimawandel UND Wasserindustrie	18.07.2011	0	0	0
Klimawandel UND Wassermanagement	18.07.2011	1	0	0
Klimawandel UND Wasserqualität	23.08.2011	1	1	1
Klimawandel UND Wasserresourcenmanagement	18.07.2011	0	0	0
Klimawandel UND Wasserunternehmen	18.07.2011	0	0	0
Klimawandel UND Wasserversorger	18.07.2011	0	0	0
Klimawandel UND Wasserversorgung	18.07.2011	16	3	3
Klimawandel UND Wasserverteilung	18.07.2011	0	0	0

Klimawandel UND Wasserwerk	19.07.2011	3	1	1
Klimawandel UND Wasserwirtschaft	19.07.2011	23	5	5
total		**140**	**22**	**20**

TEMA Technik und Management				
Globalsuche UND Globalsuche UND Globalsuche	date	hits	relevant	used
"globaler Wandel" UND Anpassung UND "kommunale Wasserversorger"	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND "öffentliche Wasserversorger"	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND "private Wasserversorger"	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Rohwasserqualität	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Talsperren	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasser	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasseraufbereitung	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasserversorgung	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasser	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasseraufbereitung	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserbereitstellung	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wassergewinnung	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserindustrie	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wassermanagement	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserqualität	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserresourcenmanagement	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserunternehmen	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserversorger	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserversorgung	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserverteilung	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserwerk	01.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserwirtschaft	01.08.2011	0	0	0
total		**0**	**0**	**0**

TEMA Technik und Management				
Globalsuche UND Globalsuche	date	hits	relevant	used
"globaler Wandel" UND "kommunale Wasserversorger"	01.08.2011	0	0	0
"globaler Wandel" UND "öffentliche Wasserversorger"	01.08.2011	0	0	0
"globaler Wandel" UND "private Wasserversorger"	01.08.2011	0	0	0
"globaler Wandel" UND Rohwasserqualität	01.08.2011	0	0	0
"globaler Wandel" UND Talsperren	01.08.2011	0	0	0
"globaler Wandel" UND Trinkwasser	01.08.2011	0	0	0
"globaler Wandel" UND Trinkwasseraufbereitung	01.08.2011	0	0	0
"globaler Wandel" UND Trinkwasserversorgung	01.08.2011	0	0	0
"globaler Wandel" UND Wasser	01.08.2011	1	0	0
"globaler Wandel" UND Wasseraufbereitung	01.08.2011	0	0	0
"globaler Wandel" UND Wasserbereitstellung	01.08.2011	0	0	0
"globaler Wandel" UND Wassergewinnung	01.08.2011	0	0	0
"globaler Wandel" UND Wasserindustrie	01.08.2011	0	0	0
"globaler Wandel" UND Wassermanagement	01.08.2011	0	0	0
"globaler Wandel" UND Wasserqualität	23.08.2011	0	0	0
"globaler Wandel" UND Wasserresourcenmanagement	01.08.2011	0	0	0
"globaler Wandel" UND Wasserunternehmen	01.08.2011	0	0	0
"globaler Wandel" UND Wasserversorger	01.08.2011	0	0	0
"globaler Wandel" UND Wasserversorgung	01.08.2011	0	0	0
"globaler Wandel" UND Wasserverteilung	01.08.2011	0	0	0
"globaler Wandel" UND Wasserwerk	01.08.2011	0	0	0
"globaler Wandel" UND Wasserwirtschaft	01.08.2011	1	0	0
total		**2**	**0**	**0**

WISO Fachzeitschriften (eBooks, Fachzeitschriften, Literaturnachweise, Presse, Firmeninformationen, Marktdaten)				
alle Medien UND alle Medien	date	hits	relevant	used
Klimawandelanpassung UND "kommunale Wasserversorger"	19.07.2011	0	0	0
Klimawandelanpassung UND "öffentliche Wasserversorger"	19.07.2011	0	0	0
Klimawandelanpassung UND "private Wasserversorger"	19.07.2011	0	0	0
Klimawandelanpassung UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandelanpassung UND Talsperren	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasser	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasseraufbereitung	19.07.2011	1	0	0
Klimawandelanpassung UND Trinkwasserversorgung	19.07.2011	0	0	0

Klimawandelanpassung UND Wasser	19.07.2011	5	0	0
Klimawandelanpassung UND Wasseraufbereitung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserbereitstellung	19.07.2011	0	0	0
Klimawandelanpassung UND Wassergewinnung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserindustrie	19.07.2011	0	0	0
Klimawandelanpassung UND Wassermanagement	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserqualität	23.08.2011	0	0	0
Klimawandelanpassung UND Wasserressourcenmanagement	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserunternehmen	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserversorger	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserversorgung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserverteilung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserwerk	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserwirtschaft	19.07.2011	0	0	0
total		**6**	**0**	**0**

WISO Fachzeitschriften (eBooks, Fachzeitschriften, Literaturnachweise, Firmeninformationen, Marktdaten)				
alle Medien UND alle Medien UND alle Medien	date	hits	relevant	used
Klimawandel UND Anpassung UND "kommunale Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND Anpassung UND "öffentliche Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND Anpassung UND "private Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Rohwasserqualität	19.07.2011	1	0	0
Klimawandel UND Anpassung UND Talsperren	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Trinkwasser	19.07.2011	82	1	1
Klimawandel UND Anpassung UND Trinkwasseraufbereitung	19.07.2011	11	0	0
Klimawandel UND Anpassung UND Trinkwasserversorgung	19.07.2011	43	0	0
Klimawandel UND Anpassung UND Wasser	19.07.2011	443	1	1
Klimawandel UND Anpassung UND Wasseraufbereitung	19.07.2011	41	1	1
Klimawandel UND Anpassung UND Wasserbereitstellung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wassergewinnung	19.07.2011	10	0	0
Klimawandel UND Anpassung UND Wasserindustrie	19.07.2011	2	0	0
Klimawandel UND Anpassung UND Wassermanagement	19.07.2011	32	1	1
Klimawandel UND Anpassung UND Wasserqualität	23.08.2011	33	0	0
Klimawandel UND Anpassung UND Wasserresourcenmanagement	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserunternehmen	19.07.2011	3	0	0
Klimawandel UND Anpassung UND Wasserversorger	19.07.2011	18	0	0
Klimawandel UND Anpassung UND Wasserversorgung	19.07.2011	147	2	2
Klimawandel UND Anpassung UND Wasserverteilung	19.07.2011	10	0	0
Klimawandel UND Anpassung UND Wasserwerk	19.07.2011	31	0	0
Klimawandel UND Anpassung UND Wasserwirtschaft	19.07.2011	79	0	0
total		**986**	**6**	**6**

WISO Fachzeitschriften (eBooks, Fachzeitschriften, Literaturnachweise)				
alle Medien UND alle Medien	date	hits	relevant	used
Klimawandel UND "kommunale Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND "öffentliche Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND "private Wasserversorger"	19.07.2011	1	0	0
Klimawandel UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandel UND Talsperren	19.07.2011	8	0	0
Klimawandel UND Trinkwasser	19.07.2011	177	1	1
Klimawandel UND Trinkwasseraufbereitung	19.07.2011	4	0	0
Klimawandel UND Trinkwasserversorgung	19.07.2011	34	0	0
Klimawandel UND Wasseraufbereitung	19.07.2011	85	0	0
Klimawandel UND Wasserbereitstellung	19.07.2011	0	0	0
Klimawandel UND Wassergewinnung	19.07.2011	26	0	0
Klimawandel UND Wasserindustrie	19.07.2011	1	0	0
Klimawandel UND Wassermanagement	19.07.2011	154	3	3
Klimawandel UND Wasserqualität	23.08.2011	80	0	0
Klimawandel UND Wasserresourcenmanagement	19.07.2011	0	0	0
Klimawandel UND Wasserunternehmen	19.07.2011	2	0	0
Klimawandel UND Wasserversorger	19.07.2011	26	0	0
Klimawandel UND Wasserversorgung	19.07.2011	323	5	5
Klimawandel UND Wasserverteilung	19.07.2011	9	0	0
Klimawandel UND Wasserwerk	19.07.2011	5	0	0
Klimawandel UND Wasserwirtschaft	19.07.2011	128	2	2
total		**1063**	**11**	**11**

WISO Fachzeitschriften (eBooks, Fachzeitschriften, Literaturnachweise)				
alle Medien UND alle Medien UND alle Medien	date	hits	relevant	used
"globaler Wandel" UND Anpassung UND "kommunale Wasserversorger"	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND "öffentliche Wasserversorger"	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND "private Wasserversorger"	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Rohwasserqualität	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Talsperren	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasser	23.08.2011	2	0	0
"globaler Wandel" UND Anpassung UND Trinkwasseraufbereitung	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasserversorgung	23.08.2011	2	0	0
"globaler Wandel" UND Anpassung UND Wasser	23.08.2011	5	0	0
"globaler Wandel" UND Anpassung UND Wasseraufbereitung	23.08.2011	1	0	0
"globaler Wandel" UND Anpassung UND Wasserbereitstellung	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wassergewinnung	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserindustrie	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wassermanagement	23.08.2011	3	0	0
"globaler Wandel" UND Anpassung UND Wasserqualität	23.08.2011	3	0	0
"globaler Wandel" UND Anpassung UND Wasserresourcenmanagement	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserunternehmen	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserversorger	23.08.2011	1	0	0
"globaler Wandel" UND Anpassung UND Wasserversorgung	23.08.2011	3	0	0
"globaler Wandel" UND Anpassung UND Wasserverteilung	23.08.2011	1	0	0
"globaler Wandel" UND Anpassung UND Wasserwerk	23.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserwirtschaft	23.08.2011	2	0	0
total		**23**	**0**	**0**

WISO Fachzeitschriften (eBooks, Fachzeitschriften, Literaturnachweise)				
alle Medien UND alle Medien	date	hits	relevant	used
"globaler Wandel" UND "kommunale Wasserversorger"	23.08.2011	0	0	0
"globaler Wandel" UND "öffentliche Wasserversorger"	23.08.2011	0	0	0
"globaler Wandel" UND "private Wasserversorger"	23.08.2011	0	0	0
"globaler Wandel" UND Rohwasserqualität	23.08.2011	0	0	0
"globaler Wandel" UND Talsperren	23.08.2011	0	0	0
"globaler Wandel" UND Trinkwasser	23.08.2011	3	0	0
"globaler Wandel" UND Trinkwasseraufbereitung	23.08.2011	0	0	0
"globaler Wandel" UND Trinkwasserversorgung	23.08.2011	2	0	0
"globaler Wandel" UND Wasser	23.08.2011	22	0	0
"globaler Wandel" UND Wasseraufbereitung	23.08.2011	1	0	0
"globaler Wandel" UND Wasserbereitstellung	23.08.2011	0	0	0
"globaler Wandel" UND Wassergewinnung	23.08.2011	0	0	0
"globaler Wandel" UND Wasserindustrie	23.08.2011	0	0	0
"globaler Wandel" UND Wassermanagement	23.08.2011	4	0	0
"globaler Wandel" UND Wasserqualität	23.08.2011	3	0	0
"globaler Wandel" UND Wasserresourcenmanagement	23.08.2011	0	0	0
"globaler Wandel" UND Wasserunternehmen	23.08.2011	0	0	0
"globaler Wandel" UND Wasserversorger	23.08.2011	1	0	0
"globaler Wandel" UND Wasserversorgung	23.08.2011	7	0	0
"globaler Wandel" UND Wasserverteilung	23.08.2011	1	0	0
"globaler Wandel" UND Wasserwerk	23.08.2011	0	0	0
"globaler Wandel" UND Wasserwirtschaft	23.08.2011	6	0	0
total		**50**	**0**	**0**

Google Scholar (published between 1997-2011, subject areas: Biology, Life Sciences, and Environmental Science, Business, Administration, Finance, and Economics)				
exacte phrase AND all words	date	hits	relevant	used
"climate change adaptation" AND "community water supply"	25.08.2011	8	0	0
"climate change adaptation" AND "private water supply"	25.08.2011	1	0	0
"climate change adaptation" AND "public water supply"	25.08.2011	40	3	3
"climate change adaptation" AND "supply of water"	25.08.2011	103	1	1
"climate change adaptation" AND "water company"	25.08.2011	23	1	1
"climate change adaptation" AND "water economy"	25.08.2011	10	0	0
"climate change adaptation" AND "water industry"	25.08.2011	45	3	2
"climate change adaptation" AND "water management"	25.08.2011	824	5	4
"climate change adaptation" AND "water preparation"	25.08.2011	1	0	0
"climate change adaptation" AND "water provider"	25.08.2011	3	0	0
"climate change adaptation" AND "water resources management"	25.08.2011	302	5	4
"climate change adaptation" AND "water service"	25.08.2011	36	2	1

"climate change adaptation" AND "water supplying"	25.08.2011	1	0	0
"climate change adaptation" AND "water supply company"	25.08.2011	6	0	0
"climate change adaptation" AND "water supply organisation"	25.08.2011	0	0	0
"climate change adaptation" AND "water supply organization"	25.08.2011	0	0	0
"climate change adaptation" AND "water treatment"	25.08.2011	162	0	0
"climate change adaptation" AND "water utilities"	25.08.2011	54	0	0
total		**1619**	**20**	**16**

Google Scholar (veröffentlicht zwischen 1997-2011, Zitate einschließen)				
genaue Wortgruppe UND alle Wörter	date	hits	relevant	used
Klimawandelanpassung UND "kommunale Wasserversorger"	25.08.2011	0	0	0
Klimawandelanpassung UND "öffentliche Wasserversorger"	25.08.2011	0	0	0
Klimawandelanpassung UND "private Wasserversorger"	25.08.2011	0	0	0
Klimawandelanpassung UND Rohwasserqualität	25.08.2011	0	0	0
Klimawandelanpassung UND Talsperren	25.08.2011	0	0	0
Klimawandelanpassung UND Trinkwasser	25.08.2011	7	0	0
Klimawandelanpassung UND Trinkwasseraufbereitung	25.08.2011	7	0	0
Klimawandelanpassung UND Trinkwasserversorgung	25.08.2011	7	0	0
Klimawandelanpassung UND Wasser	25.08.2011	7	0	0
Klimawandelanpassung UND Wasseraufbereitung	25.08.2011	7	0	0
Klimawandelanpassung UND Wasserbereitstellung	25.08.2011	0	0	0
Klimawandelanpassung UND Wassergewinnung	25.08.2011	0	0	0
Klimawandelanpassung UND Wasserindustrie	25.08.2011	0	0	0
Klimawandelanpassung UND Wassermanagement	25.08.2011	0	0	0
Klimawandelanpassung UND Wasserqualität	25.08.2011	7	0	0
Klimawandelanpassung UND Wasserressourcenmanagement	25.08.2011	0	0	0
Klimawandelanpassung UND Wasserunternehmen	25.08.2011	0	0	0
Klimawandelanpassung UND Wasserversorger	25.08.2011	2	0	0
Klimawandelanpassung UND Wasserversorgung	25.08.2011	7	0	0
Klimawandelanpassung UND Wasserverteilung	25.08.2011	0	0	0
Klimawandelanpassung UND Wasserwerk	25.08.2011	7	0	0
Klimawandelanpassung UND Wasserwirtschaft	25.08.2011	9	0	0
total		**67**	**0**	**0**

Google Scholar (veröffentlicht zwischen 1997-2011, Zitate einschließen)				
alle Wörter UND alle Wörter UND genaue Wortgruppe	date	hits	relevant	used
Klimawandel UND Anpassung UND "kommunale Wasserversorger"	30.09.2011	0	0	0
Klimawandel UND Anpassung UND "öffentliche Wasserversorger"	30.09.2011	2	0	0
Klimawandel UND Anpassung UND "private Wasserversorger"	30.09.2011	2	0	0
Klimawandel UND Anpassung UND Rohwasserqualität	30.09.2011	14	3	1
Klimawandel UND Anpassung UND Talsperren	30.09.2011	219	3	2
Klimawandel UND Anpassung UND Trinkwasser	01.10.2011	1350	3	2
Klimawandel UND Anpassung UND Trinkwasseraufbereitung	30.09.2011	61	1	1
Klimawandel UND Anpassung UND Trinkwasserversorgung	30.09.2011	400	6	5
Klimawandel UND Anpassung UND Wasseraufbereitung	30.09.2011	147	3	2
Klimawandel UND Anpassung UND Wasserbereitstellung	30.09.2011	25	0	0
Klimawandel UND Anpassung UND Wassergewinnung	30.09.2011	82	2	1
Klimawandel UND Anpassung UND Wasserindustrie	30.09.2011	10	0	0
Klimawandel UND Anpassung UND Wassermanagement	30.09.2011	172	2	2
Klimawandel UND Anpassung UND Wasserqualität	30.09.2011	607	3	2
Klimawandel UND Anpassung UND Wasserressourcenmanagement	30.09.2011	20	1	1
Klimawandel UND Anpassung UND Wasserunternehmen	30.09.2011	20	1	1
Klimawandel UND Anpassung UND Wasserversorger	30.09.2011	76	2	1
Klimawandel UND Anpassung UND Wasserversorgung	01.10.2011	1590	7	6
Klimawandel UND Anpassung UND Wasserverteilung	30.09.2011	82	1	1
Klimawandel UND Anpassung UND Wasserwerk	30.09.2011	96	3	2
Klimawandel UND Anpassung UND Wasserwirtschaft	30.09.2011	1100	7	6
total		**6075**	**48**	**36**

Google Scholar (veröffentlicht zwischen 1997-2011, Zitate einschließen)				
genaue Wortgruppe UND alle Wörter UND alle Wörter	date	hits	relevant	used
"globaler Wandel" UND Anpassung UND "kommunale Wasserversorger"	17.09.2011	11	0	0
"globaler Wandel" UND Anpassung UND "öffentliche Wasserversorger"	17.09.2011	21	0	0
"globaler Wandel" UND Anpassung UND "private Wasserversorger"	17.09.2011	19	0	0
"globaler Wandel" UND Anpassung UND Rohwasserqualität	17.09.2011	0	0	0
"globaler Wandel" UND Anpassung UND Talsperren	17.09.2011	4	0	0

"globaler Wandel" UND Anpassung UND Trinkwasser	17.09.2011	106	0	0
"globaler Wandel" UND Anpassung UND Trinkwasseraufbereitung	17.09.2011	105	0	0
"globaler Wandel" UND Anpassung UND Trinkwasserversorgung	17.09.2011	109	0	0
"globaler Wandel" UND Anpassung UND Wasser	17.09.2011	106	0	0
"globaler Wandel" UND Anpassung UND Wasseraufbereitung	17.09.2011	102	0	0
"globaler Wandel" UND Anpassung UND Wasserbereitstellung	17.09.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wassergewinnung	17.09.2011	2	0	0
"globaler Wandel" UND Anpassung UND Wasserindustrie	17.09.2011	1	0	0
"globaler Wandel" UND Anpassung UND Wassermanagement	17.09.2011	13	0	0
"globaler Wandel" UND Anpassung UND Wasserqualität	17.09.2011	103	0	0
"globaler Wandel" UND Anpassung UND Wasserressourcenmanagement	17.09.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserunternehmen	17.09.2011	2	0	0
"globaler Wandel" UND Anpassung UND Wasserversorger	17.09.2011	29	0	0
"globaler Wandel" UND Anpassung UND Wasserversorgung	17.09.2011	109	0	0
"globaler Wandel" UND Anpassung UND Wasserverteilung	17.09.2011	5	0	0
"globaler Wandel" UND Anpassung UND Wasserwerk	17.09.2011	106	0	0
"globaler Wandel" UND Anpassung UND Wasserwirtschaft	17.09.2011	106	0	0
total		**1059**	**0**	**0**

Google Scholar **(veröffentlicht zwischen 1997-2011, Zitate einschließen)**				
genaue Wortgruppe UND alle Wörter	date	hits	relevant	used
"globaler Wandel" UND "kommunale Wasserversorger"	17.09.2011	22	0	0
"globaler Wandel" UND "öffentliche Wasserversorger"	17.09.2011	33	0	0
"globaler Wandel" UND "private Wasserversorger"	17.09.2011	33	0	0
"globaler Wandel" UND Rohwasserqualität	17.09.2011	0	0	0
"globaler Wandel" UND Talsperren	17.09.2011	8	0	0
"globaler Wandel" UND Trinkwasser	17.09.2011	199	0	0
"globaler Wandel" UND Trinkwasseraufbereitung	17.09.2011	198	0	0
"globaler Wandel" UND Trinkwasserversorgung	17.09.2011	205	0	0
"globaler Wandel" UND Wasser	17.09.2011	193	0	0
"globaler Wandel" UND Wasseraufbereitung	17.09.2011	193	0	0
"globaler Wandel" UND Wasserbereitstellung	17.09.2011	1	0	0
"globaler Wandel" UND Wassergewinnung	17.09.2011	4	0	0
"globaler Wandel" UND Wasserindustrie	17.09.2011	2	0	0
"globaler Wandel" UND Wassermanagement	17.09.2011	24	0	0
"globaler Wandel" UND Wasserqualität	17.09.2011	194	0	0
"globaler Wandel" UND Wasserressourcenmanagement	17.09.2011	2	0	0
"globaler Wandel" UND Wasserunternehmen	17.09.2011	3	0	0
"globaler Wandel" UND Wasserversorger	17.09.2011	52	0	0
"globaler Wandel" UND Wasserversorgung	17.09.2011	205	0	0
"globaler Wandel" UND Wasserverteilung	17.09.2011	8	0	0
"globaler Wandel" UND Wasserwerk	17.09.2011	200	0	0
"globaler Wandel" UND Wasserwirtschaft	17.09.2011	201	0	0
total		**1980**	**0**	**0**

SLUB Dresden **(alle Zweigstellen, alle Medientypen, alle Literaturabteilungen, alle Jahre)**				
Schlagwort UND Schlagwort	date	hits	relevant	used
Klimawandelanpassung UND "kommunale Wasserversorger"	19.07.2011	0	0	0
Klimawandelanpassung UND "öffentliche Wasserversorger"	19.07.2011	0	0	0
Klimawandelanpassung UND "private Wasserversorger"	19.07.2011	0	0	0
Klimawandelanpassung UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandelanpassung UND Talsperren	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasser	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasseraufbereitung	19.07.2011	0	0	0
Klimawandelanpassung UND Trinkwasserversorgung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasser	19.07.2011	0	0	0
Klimawandelanpassung UND Wasseraufbereitung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserbereitstellung	19.07.2011	0	0	0
Klimawandelanpassung UND Wassergewinnung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserindustrie	19.07.2011	0	0	0
Klimawandelanpassung UND Wassermanagement	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserqualität	24.08.2011	0	0	0
Klimawandelanpassung UND Wasserresourcenmanagement	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserunternehmen	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserversorger	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserversorgung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserverteilung	19.07.2011	0	0	0
Klimawandelanpassung UND Wasserwerk	19.07.2011	0	0	0

Klimawandelanpassung UND Wasserwirtschaft	19.07.2011	0	0	0
total		**0**	**0**	**0**

SLUB Dresden (alle Zweigstellen, alle Medientypen, alle Literaturabteilungen, alle Jahre)				
Schlagwort UND Schlagwort UND Schlagwort	date	hits	relevant	used
Klimawandel UND Anpassung UND "kommunale Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND Anpassung UND "öffentliche Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND Anpassung UND "private Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Talsperren	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Trinkwasser	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Trinkwasseraufbereitung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Trinkwasserversorgung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasser	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasseraufbereitung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserbereitstellung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wassergewinnung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserindustrie	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wassermanagement	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserqualität	24.08.2011	0	0	0
Klimawandel UND Anpassung UND Wasserresourcenmanagement	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserunternehmen	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserversorger	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserversorgung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserverteilung	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserwerk	19.07.2011	0	0	0
Klimawandel UND Anpassung UND Wasserwirtschaft	19.07.2011	0	0	0
total		**0**	**0**	**0**

SLUB Dresden (alle Zweigstellen, alle Medientypen, alle Literaturabteilungen, alle Jahre)				
Schlagwort UND Schlagwort	date	hits	relevant	used
Klimawandel UND "kommunale Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND "öffentliche Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND "private Wasserversorger"	19.07.2011	0	0	0
Klimawandel UND Rohwasserqualität	19.07.2011	0	0	0
Klimawandel UND Talsperren	19.07.2011	0	0	0
Klimawandel UND Trinkwasser	19.07.2011	1	1	1
Klimawandel UND Trinkwasseraufbereitung	19.07.2011	0	0	0
Klimawandel UND Trinkwasserversorgung	19.07.2011	1	1	1
Klimawandel UND Wasseraufbereitung	19.07.2011	0	0	0
Klimawandel UND Wasserbereitstellung	19.07.2011	0	0	0
Klimawandel UND Wassergewinnung	19.07.2011	0	0	0
Klimawandel UND Wasserindustrie	19.07.2011	0	0	0
Klimawandel UND Wassermanagement	19.07.2011	0	0	0
Klimawandel UND Wasserqualität	24.08.2011	1	0	0
Klimawandel UND Wasserresourcenmanagement	19.07.2011	0	0	0
Klimawandel UND Wasserunternehmen	19.07.2011	0	0	0
Klimawandel UND Wasserversorger	19.07.2011	0	0	0
Klimawandel UND Wasserversorgung	19.07.2011	10	4	4
Klimawandel UND Wasserverteilung	19.07.2011	0	0	0
Klimawandel UND Wasserwerk	19.07.2011	0	0	0
Klimawandel UND Wasserwirtschaft	19.07.2011	6	3	3
total		**19**	**9**	**9**

WISO Fachzeitschriften (eBooks, Fachzeitschriften, Literaturnachweise)				
Schlagwort UND Schlagwort UND Schlagwort	date	hits	relevant	used
"globaler Wandel" UND Anpassung UND "kommunale Wasserversorger"	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND "öffentliche Wasserversorger"	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND "private Wasserversorger"	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Rohwasserqualität	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Talsperren	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasser	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasseraufbereitung	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Trinkwasserversorgung	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasser	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasseraufbereitung	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserbereitstellung	24.08.2011	0	0	0

"globaler Wandel" UND Anpassung UND Wassergewinnung	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserindustrie	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wassermanagement	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserqualität	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserresourcenmanagement	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserunternehmen	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserversorger	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserversorgung	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserverteilung	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserwerk	24.08.2011	0	0	0
"globaler Wandel" UND Anpassung UND Wasserwirtschaft	24.08.2011	0	0	0
total		**0**	**0**	**0**

SLUB Dresden (alle Zweigstellen, alle Medientypen, alle Literaturabteilungen, alle Jahre)				
Schlagwort UND Schlagwort	date	hits	relevant	used
"globaler Wandel" UND "kommunale Wasserversorger"	24.08.2011	0	0	0
"globaler Wandel" UND "öffentliche Wasserversorger"	24.08.2011	0	0	0
"globaler Wandel" UND "private Wasserversorger"	24.08.2011	0	0	0
"globaler Wandel" UND Rohwasserqualität	24.08.2011	0	0	0
"globaler Wandel" UND Talsperren	24.08.2011	0	0	0
"globaler Wandel" UND Trinkwasser	24.08.2011	0	0	0
"globaler Wandel" UND Trinkwasseraufbereitung	24.08.2011	0	0	0
"globaler Wandel" UND Trinkwasserversorgung	24.08.2011	0	0	0
"globaler Wandel" UND Wasser	24.08.2011	0	0	0
"globaler Wandel" UND Wasseraufbereitung	24.08.2011	0	0	0
"globaler Wandel" UND Wasserbereitstellung	24.08.2011	0	0	0
"globaler Wandel" UND Wassergewinnung	24.08.2011	0	0	0
"globaler Wandel" UND Wasserindustrie	24.08.2011	0	0	0
"globaler Wandel" UND Wassermanagement	24.08.2011	0	0	0
"globaler Wandel" UND Wasserqualität	24.08.2011	0	0	0
"globaler Wandel" UND Wasserresourcenmanagement	24.08.2011	0	0	0
"globaler Wandel" UND Wasserunternehmen	24.08.2011	0	0	0
"globaler Wandel" UND Wasserversorger	24.08.2011	0	0	0
"globaler Wandel" UND Wasserversorgung	24.08.2011	0	0	0
"globaler Wandel" UND Wasserverteilung	24.08.2011	0	0	0
"globaler Wandel" UND Wasserwerk	24.08.2011	0	0	0
"globaler Wandel" UND Wasserwirtschaft	24.08.2011	0	0	0
total		**0**	**0**	**0**

(Own illustration.)

Appendix B: Number of References

Table 6: Number of references categorised by search term

Search terms	*EBSCO*	*TEMA*	*Web of Science*	*WISO*	*SLUB catalogue*	*Google Scholar*	*Σ*
"climate change adaptation" AND "public water suppl*"						3	**3**
"climate change adaptation" AND "supply of water"						1	**1**
"climate change adaptation" AND water	1	1					**2**
"climate change adaptation" AND "water compan*"	2		1			1	**4**
"climate change adaptation" AND "water industry"	2		1			2	**5**
"climate change adaptation" AND "water management"						4	**4**
"climate change adaptation" AND "water provider"	1						**1**
"climate change adaptation" AND "water resources management"	4					4	**8**
"climate change adaptation" AND "water service"						1	**1**
"climate change adaptation" AND "water treatment"	1						**1**
"climate change adaptation" AND "water utilities"	2						**2**
"climate change" AND adaptation AND "public water suppl*"			1				**1**
"climate change" AND adaptation AND water		1					**1**
"climate change" AND adaptation AND "water compan*"			1				**1**
"climate change" AND adaptation AND "water industry"			1				**1**
"climate change" AND adaptation AND "water supply compan*"			1				**1**
"climate change" AND adaptation AND "water treatment"			3				**3**
"global warming" AND adaptation AND "supply of water"	1						**1**
"global warming" AND adaptation AND "water compan*"	2						**2**
"global warming" AND adaptation AND "water industry"	1						**1**
"global warming" AND adaptation AND "water management"	2						**2**
"global warming" AND adaptation AND "water preparation"	1						**1**
"global warming" AND adaptation AND "water provider"	1						**1**
"global warming" AND adaptation AND "water resources management"	2						**2**
"global warming" AND adaptation AND "water treatment"	1						**1**
"global warming" AND adaptation AND "water utilities"	1						**1**
Klimawandel UND Anpassung UND Rohwasserqualität						1	**1**
Klimawandel UND Anpassung UND Talsperren						2	**2**
Klimawandel UND Anpassung UND Trinkwasser		1		1		2	**4**
Klimawandel UND Anpassung UND Trinkwasseraufbereitung		1				1	**2**
Klimawandel UND Anpassung UND Trinkwasserversorgung		1				5	**6**
Klimawandel UND Anpassung UND Wasser		1		1			**2**
Klimawandel UND Anpassung UND Wasseraufbereitung		1		1		2	**4**
Klimawandel UND Anpassung UND Wassergewinnung						1	**1**
Klimawandel UND Anpassung UND Wassermanagement				1		2	**3**
Klimawandel UND Anpassung UND Wasserqualität						2	**2**
Klimawandel UND Anpassung UND Wasserressourcen-management						1	**1**
Klimawandel UND Anpassung UND Wasserunternehmen						1	**1**
Klimawandel UND Anpassung UND Wasserversorger						1	**1**
Klimawandel UND Anpassung UND Wasserversorgung		1		2		6	**9**
Klimawandel UND Anpassung UND Wasserverteilung						1	**1**
Klimawandel UND Anpassung UND Wasserwerk						2	**2**
Klimawandel UND Anpassung UND Wasserwirtschaft						6	**6**
Klimawandel UND Talsperren		1					**1**
Klimawandel UND Trinkwasser		1		1	1		**3**
Klimawandel UND Trinkwasseraufbereitung		1					**1**
Klimawandel UND Trinkwasserversorgung		1			1		**2**
Klimawandel UND Wasser		4					**4**
Klimawandel UND Wasseraufbereitung		1					**1**
Klimawandel UND Wassergewinnung		1					**1**
Klimawandel UND Wassermanagement				3			**3**
Klimawandel UND Wasserqualität		1					**1**
Klimawandel UND Wasserversorgung		3		5	4		**12**
Klimawandel UND Wasserwerk		1					**1**
Klimawandel UND Wasserwirtschaft		5		2	3		**10**
Σ							**140**

(Own illustration.)

Appendix C: Coding Sheets

Title	***Die deutsche Trinkwasserversorgung im (Klima-)Wandel***	
Author	Stephan Köster	
Year	2008	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	GFW Wasser, Abwasser	
Volume	149	
Issue	12	
Pages	200-206	
Country of origin	Germany	
Setting	Germany	
Database	TEMA – Technik und Management	
Search terms	Klimawandel UND Anpassung UND Trinkwasser Klimawandel UND Anpassung UND Trinkwasseraufbereitung Klimawandel UND Anpassung UND Trinkwasserversorgung Klimawandel UND Anpassung UND Wasser Klimawandel UND Anpassung UND Wasseraufbereitung Klimawandel UND Anpassung UND Wasserversorgung Klimawandel UND Trinkwasser Klimawandel UND Trinkwasseraufbereitung Klimawandel UND Trinkwasserversorgung Klimawandel UND Wasser Klimawandel UND Wasseraufbereitung Klimawandel UND Wasserversorgung Klimawandel UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1) Precipitation	200
	2) Temperature	200
	3) Floods	200
	4) Drought	200
Time horizon	-	
Risks	2.) • Attenuation of the protective function of the basin by climatic changes → Increasing evaporation rate → Desiccation of the soil → Increasing run off during heavy rainfall → Degradation of the retention processes → Pest infestation in the basin because of drought and warm winters	202

Risks	4.) • Deterioration of the filtering effect of the soil after long dry periods → Increasing bacterial load in raw water after heavy rainfall → water treatment costs ↑ • Increasing water consumption, especially during dry periods and hot summers • Reduction of groundwater recharge • Deterioration of groundwater quality because of declined material retention in the soil • Decreasing raw water supply because of low flows in rivers • Enhanced water temperatures of the bank filtrate • Low reservoir levels • Increased eutrophication in reservoirs because of higher radiant energy • Extended summer stagnation in reservoirs • Intensified bacterial load in the raw water	202
Risks	1.) & 3.) • Enhanced run-off with high rates of erosion and massive input of germs, pollutants and nutrients in surface water / ground water • Overlapping of flood areas and raw water catchment areas • Rising groundwater levels • Damage to drinking water pipes	202
Opportunities	-	
Adaptation strategies	• Measures to improve flood protection → Nature based reconstruction of rivers → Natural flood retention in or at the body of water → Regulation that limits construction on the flood plains → Technical flood protection	203
	• Measures to improve the water quality	203
	• Water saving measures	203
	• Having two independent water recovery facilities in major supply areas available	203
	• Option of a long-distance water supply	203
	• Sufficient provision of water in dams	203
	• Upgrading the mechanical technologies (membrane systems)	204
	• Ensuring energy supply	204
	• Preparation of emergency plans	204
	• Adapted / usage-oriented pricing to reduce delivery of water	204
	• Documentation of qualitative / quantitative raw water trends	204
	• Strengthening of the multi-barrier system	204
Adaptation barriers	-	

Title	***Anpassung an den Klimawandel in der deutschen Wirtschaft – Ergebnisse aus Expertenbefragungen***	
Author	Mahammad Mahammadzadeh	
Year	2010	
Type of Reference	Journal	
Type of Article	Empirical Paper (Survey)	
Source	Zeitschrift für Umweltpolitik und Umweltrecht	
Volume	33	
Issue	3	
Pages	309-340	
Country of origin	Germany	

Setting	Germany	
Database	TEMA – Technik und Management	
Search terms	Klimawandel UND Wasserwirtschaft "climate change adaptation" AND water "climate change" AND adaptation AND water	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	*„Anpassung ökologischer, sozialer oder ökonomischer Systeme als Reaktion auf aktuelle oder erwartete klimatische Stimuli und deren Auswirkungen und Einfluss verstanden. Der Begriff* *Anpassung bezieht sich dabei auf Veränderungen in Prozessen, Handlungsroutinen oder Strukturen, um potenzielle Schäden abzumildern oder aufzuheben, oder mögliche Vorteile aus dem Klimawandel zu ziehen. Dies beinhaltet Maßnahmen zur Verminderung der Verwundbarkeit von Kommunen, Regionen oder Aktivitäten gegenüber Klimawandel und –variabilität.“* (IPCC,2001)	315
	„Anpassung zielt darauf ab, die Risiken und Schäden gegenwärtiger und künftiger negativer Auswirkungen kostenwirksamnzu verringern oder potenzielle Vorteile zu nutzen.“ (European Commission, 2007)	316
Climatic parameters	1) Precipitation	321
	2) Temperature	321
	3) Floods	325
	4) Low water	325
	5) Extreme rainfall	321
	6) Drought	325
Time horizon	-	
Risks	• Overloading sewerage systems	323
	• Risks of floods	323
	• Problems with the availability of water	325
	• Damage to the infrastructure because of flooding	325
	• Changes in the quality of water	325
	• Increase in demand	321
Opportunities	-	321
Adaptation strategies	• Securing the availability and quality of water → Efficient water resource management → Adequate water storage in dams → Improvement of the availability of drinking water via long distance water supply pipes	325
	• New water sources (reservoirs, ...)	325
	• Reducing water consumption	326
	→ Flood protection → Building of dykes → Heightening of existing dams → Measures of risk prevention → Disaster control	326
	• Insurance for natural hazards	326

Adaptation barriers	• Short-term corporate planning (armortisation of long-term adaptational investments is outside the short-term planning horizon)	332
	• Lack of reliable datas / information about climate change	332
	• Lack of reliable datas / information about climate impacts	332
	• Resistance in politics and research	332
	• Low motivation of decision makers	332
	• Financial restrictions	334

Title	***Auswirkungen der regionalen Klimaentwicklung auf die Wasserversorgung am Beispiel Wasserwerk Potsdam Leipziger Straße***	
Author	Peter Nillert, Dietmar Schäfer, Karsten Zühlke	
Year	2008	
Type of Reference	Journal	
Type of Article	Empirical Paper (Scenario Analysis)	
Source	GFW Wasser, Abwasser	
Volume	149	
Issue	12	
Pages	948-955	
Country of origin	Germany	
Setting	Germany	
Database	TEMA – Technik und Management	
	Google Scholar	
Search terms	*TEMA Technik und Management:* Klimawandel UND Trinkwasserversorgung Klimawandel UND Wasserversorgung Klimawandel UND Wasser Klimawandel UND Wasserwerk Klimawandel UND Trinkwasser Klimawandel UND Wasserwirtschaft	
	Google Scholar: Klimawandel UND Anpassung UND Trinkwasserversorgung Klimawandel UND Anpassung UND Wasserwerk Klimawandel UND Anpassung UND Wasserversorgung	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1.) Temperature	
Time horizon	2055	948
Risks	• During times of high demand overutilisation of natural ground water • Because of ground water compression ratios, rise of salt water into areas that are used for water supply → Salinization of the raw water → Increasing chloride concentration in the raw water → Decommissioning of the waterworks	950
Opportunities	-	

Adaptation strategies	• Implementation of monitoring systems (chloride threshold value) → Data collection of ground water levels and delivery volume → Acquisition of meteorologic and climatic data → Monitoring systems for evaluation of the water availability	955
Adaptation barriers	-	

Title	***Herausforderungen des globalen Klimawandels für die Wasserwirtschaft in Deutschland: Praxisberichte, Handlungsfelder und Forschungsbedarf***	
Author	Wolf Merkel, Wolfgang Leuchs, Gerhard Odenkirchen	
Year	2008	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	GFW Wasser, Abwasser	
Volume	149	
Issue	4	
Pages	332-337	
Country of origin	Germany	
Setting	Germany	
Database	TEMA – Technik und Management	
Search terms	Klimawandel UND Wasserversorgung Klimawandel UND Wasser Klimawandel UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1) Precipitation	332
	2) Temperature	332
	3) Low water	334
	4) Flood	334
	5) Heavy rainfall	334
Time horizon	-	
Risks	• Changes in the quantity of surface and ground water and usage conflicts between irigation and drinking water supply may lead to shortage situations	149
Opportunities	-	
Adaptation strategies	• Optimisation of water production by reduction of leaks	335
	• Water supply shoul have priority over other kinds of uses	336
	• Expansion of the distributed systems for supporting the supply	336
	• Regular evaluation of monitoring systems to recognize changes in quantity and quality of surface and ground water	336
Adaptation barriers	-	

Title	***Wasserqualität und Klimawandel. Temperaturerhöhungen, Extremniederschäge, Trockenheit***	
Author	Hartmut Willmitzer	
Year	2007	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	wwt Wasserwirtschaft Wassertechnik	
Volume	-	
Issue	9	
Pages	59-62	
Country of origin	Germany	
Setting	Germany	
Database	TEMA – Technik und Management	
Search terms	Klimawandel UND Wasserversorgung Klimawandel UND Wasseraufbereitung Klimawandel UND Wasser Klimawandel UND Talsperren Klimawandel UND Trinkwasseraufbereitung Klimawandel UND Wassergewinnung Klimawandel UND Wasserwirtschaft Klimawandel UND Wasserqualität	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1) Temperature	59
	2) Drought	60
	3) Flood	60
Time horizon	-	
Risks	1) • Increases in water temperature leads to acceleration of chemical processes and increasing biological activities → Algae growth ↑ • Increasing water temperatures lead to increasing micobiological activities in the drinking water network	59 / 60
	2) • Decreasing reservoir levels lead to increasing contact area of the warm surface water with the sediment → Sediments influence raw water quality ↑ • Number of raw water extraction depth ↓ (Only clean and cool deep water is suitable for drinking water production)	61
	3) • Floods have negative impacts on the raw water quality: → Turbidity ↑ → Pollutants from agricultural used areas ↑ → Treatment costs ↑	60
Opportunities	-	
Adaptation strategies	• Monitoring systems for observing quality parameters such as turbidity, water temperature and electrical conductivity	62

	• Regulations for information exchange between laboratory, operators, authorities, disaster control and drinking water customers	62
Adaptation barriers	-	

Title	***Sich ändernde Planungsgrundlagen für Wasserinfrastruktur -systeme - Teil 1: Klimawandel, demographischer Wandel, neue ökologische Anforderungen***	Page
Author	Thomas Hillenbrand, Harald Hiessl	
Year	2006	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	KA – Abwasser, Abfall	
Volume	53	
Issue	12	
Pages	1265-1271	
Country of origin	Germany	
Setting	Germany	
Database	TEMA – Technik und Management	
Search terms	Klimawandel UND Wasser Klimawandel UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1) Temperature	1266
	2) Evaporation	1266
	3) Precipitation	1266
	4) Heavy rainfall	1266
	5) Drought	1266
	6) Low water	1268
	7) Floods	1268
Time horizon	-	
Risks	2) & 3) • Decreasing ground water recharge and therefore, ground water levels caused by reducing precipitation events and increasing evaporation → Water shortages	1268
	3) & 6) • Decreasing water levels in surface waters because of low water decreasing precipitation → Water shortages	1268
Opportunities	-	
Adaptation strategies	-	
Adaptation barriers	-	

Title	***Keynote speech – Responding to the challenges posed by climate change in the water sector***	Page
Author	Michel Jarraud	
Year	2008	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Water International	
Volume	33	
Issue	4	
Pages	529-537	
Country of origin	Switzerland	
Setting	-	
Database	EBSCO	
Search terms	"climate change adaptation" AND "water treatment" "climate change adaptation" AND "water compan*" "global warming" AND adaptation AND "water compan*" "global warming" AND adaptation AND "water management"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	*"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."* (IPCC, 2007)	531
Climatic parameters	1) Precipitation	530
	2) Temperature	530
	3) Floods	533
	4) Extreme Rainfall	533
	5) Drought	530
	6) Storms	530
Time horizon	-	
Risks	• Dwindling water reserves	532
	• Deterioration of water quality	532
	• Increased run-off	532
	• Increased ground water salinity due to rising sea levels	532
	• Infrastructure problems	533
	• Drinking water intakes in many cities may be adversely affected by lower low flows	533
	• Flooding will add to the problems that water companies will have to deal with if they are to meet the needs of consumers	533
	• Decreased rainfall will limit the capacity to dilute waste and could lead to an increased pathogen and chemical load	533
Opportunities	• Increased demand of water (domestic and industrial)	533
Adaptation strategies	• In view of the deteriorating water quality of rivers and lakes, treatment techniques must be improved	533
	• Improving decision-making for integrated risk and disaster management by using climate information	534
	• Integrated flood management based on solid risk management principles	535
	• Watershed management	535

Adaptation barriers	-	

Title	***Anpassungsstrategien an den Klimawandel für Österreichs Wasserwirtschaft – Ziele und Schlussfolgerungen der Studie für Bund und Länder***	Page
Author	G. Blöschl, W. Schöner, H. Kroiß, A. P. Blaschke, R. Böhm, K. Haslinger, N. Kreuzinger, R. Merz, J. Parajka, J. L. Salinas, A. Viglione	
Year	2011	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Scenario Analysis)	
Source	Österreichische Wasser- und Abfallwirtschaft	
Volume	63	
Issue	1-2	
Pages	1-10	
Country of origin	Austria	
Setting	Austria	
Database	EBSCO	
	Google Scholar	
Search terms	*EBSCO:* “climate change adaptation" AND water "climate change adaptation" AND "water resources management"	
	Google Scholar: Klimawandel UND Anpassung UND Trinkwasserversorgung Klimawandel UND Anpassung UND Wasserqualität Klimawandel UND Anpassung UND Wasserwirtschaft Klimawandel UND Anpassung UND Wasserversorgung	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1) Precipitation	1
	2) Temperature	1
	3) Evapotranspiration	3
	4) Floods	1
	5) Low water	1
	6) Heavy rainfall	3
	7) Frost	
Time horizon	2021–2050	4
Risks	1) & 2) • Deterioration of the water quality	7
Opportunities	-	
Adaptation strategies	• Water supply facilities should try for cross linking	8
	• In cases of water use conflicts you may think about prioritization of the use of water	8
	• Robust systems which have a litte chance of functional failure	8
Adaptation barriers	-	

Title	***Climate change and water resources: The challenges ahead***	Page
Author	Kathleen A. Miller	
Year	2008	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Journal of International Affairs	
Volume	61	
Issue	2	
Pages	35-50	
Country of origin	United States of America	
Setting	United States of America (Western United States)	
Database	EBSCO	
Search terms	"climate change adaptation" AND "water industry" "climate change adaptation" AND "water utilities" "climate change adaptation" AND "water provider" "global warming" AND adaptation AND "water industry" "global warming" AND adaptation AND "water management" "global warming" AND adaptation AND "water provider" "global warming" AND adaptation AND "water utilities"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1) Precipitation	36
	2) Temperature	37
	3) Floods	35
	4) Storms	35
	5) Evaporation	36
	6) Heavy rainfall	38
	7) Sea level	41
	8) Low water	41
Time horizon	-	
Risks	1) & 5) • Changes in run-off and ground water recharge	38
	2) • Surface water quality is likely to be directly impaired by warmer temperatures because reduced dissolved oxygen levels under warmer conditions will cause natural self-purification processes in lakes and streams to slow down, while warming will tend to favor the growth of algae and bacteria	41
	6) • Intense rainfall events will also lead to episodes of poor water quality by washing sediment and a variety of pollutants—including pesticides, organic matter and heavy metals—into water bodies	41
	7) • Rising sea levels would lead to impaired water quality for coastal cities that rely on groundwater to serve their populations because saline water is likely to intrude into these aquifers	41

	8) • Water quality will suffer further if streamflows decline because pollutants will become more concentrated in reduced water volumes	41
Opportunities	-	
Adaptation strategies	• Purchase water rights	44
	• Purchases of agricultural water	45
	• Demand management, including conservation incentives, metering and increasing block-rate pricing to keep up with population growth	45
	• Water resource planning	48
Adaptation barriers	-	

Title	***Coping with global warming and climate change***	Page
Author	Peter Rogers	
Year	2008	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Journal of Water Resources Planning & Management	
Volume	134	
Issue	3	
Pages	203-204	
Country of origin	United States of America	
Setting	-	
Database	EBSCO	
Search terms	"climate change adaptation" AND "water resources management" "global warming" AND adaptation AND "water resources management"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	*"Two kinds of adaptation have been characterized by the IPCC: autonomous adaptations, which arise over time in response to altered demands, and planned adaptations, which are planned in advance of the climate change."* (IPPC, 2007)	204
Climatic parameters	1) Precipitation	203
	2) Temperature	203
	3) Drought	204
Time horizon	-	
Risks	-	
Opportunities	-	
Adaptation strategies	• Storage reservoirs	204
	• Treatment plants	204
Adaptation barriers	-	

Title	***Secular regime shifts, global warming and Sydney's water supply***	Page
Author	Robin Warner	
Year	2009	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Geographical Research	
Volume	47	
Issue	3	
Pages	227-241	
Country of origin	Australia	
Setting	Australia	
Database	EBSCO	
Search terms	"global warming" AND adaptation AND "supply of water" "global warming" AND adaptation AND "water management"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaptation to climate impacts	-	
Climatic parameters	1) Precipitation	228
	2) Temperature	231
	3) Drought	227
	4) Floods	228
	5) Evaporation	233
	6) Sea levels	234
Time horizon	2030 / 2070	233
Risks	1) & 3) • Reduced run-off into the city's storage reservoirs	227
Opportunities	-	
Adaptation strategies	• Water restricions to reduce demand → Community education	235
	• Alternative sources of water such as harvesting rainfall, recycling used water, desalination, harvesting groundwater	235
Adaptation barriers	• Desalination is expensive	237

Title	***Gauging the vulnerabilty of local water utilities to extreme weather events***	Page
Author	Robert Hersh, Kris Wernstedt	
Year	2001	
Type of Reference	Working Paper	
Type of Article	Empirical Paper (Interview)	
Source	http://www.rff.org/documents/RFF-DP-01-33.pdf	
Volume		
Issue		
Pages	1-33	
Country of origin	United States of America	
Setting	United States of America (Northwestern U.S.)	

Database	EBSCO	
Search terms	"climate change adaptation" AND "water utilities"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	*Vulnerability underlines the point that vulnerability to climate change impacts is related not simply to changing average conditions but to increased climate variability and extreme events.*(IPPC, 2001)	1
Adaptation to climate impacts	-	
Climatic parameters	1) Precipitation	5
	2) Temperature	6
	3) Flood	1
	4) Drought	1
	5) Evapotranspiration	6
	6) Low flow	11
Time horizon	-	
Risks	3) • Intake structures and slow sand filters designed to handle fixed volumes were subject to physical failure • Extensive structural damage to components of the water system, for example pump houses and water treatment plants were damaged by floodwater • Elevated suspended sediment levels or turbidity leads to morefrequent backwashing of filters and adjusting chemical mixes → Increased costs associated with additional chemical use and operator overtime • Unability to keep drinking water flowing to customers • High turbidity levels impaired the slow sand filters of a large municipal water treatment system, forcing the system to shut down for a week; the utility had to implement conservation measures and bought water from a utility to which they were connected by an inter-tie • Water utility did not have the treatment capacity to handle the volume of sediment in the stream and was forced to use stored water. It had to request that customers reduce water use voluntarily by 50% for a few weeks to ensure supplies while turbidity levels remained high	12 / 13
	4) • Level of the source river dropped below the sill of the utility's intake structure, requiring operators to use a portable pump to draw water from the river channel into the intake	11
Opportunities	-	
Adaptation strategies	• Water utilities were able to manage low flow conditions with a variety of demand reduction measures, ranging from requests for voluntary compliance, prohibitions on selected institutional uses (for example, public park watering restrictions), restrictions on nonessential uses, and staged curtailment plans	11
	• In case of high turbidity turning to storage and alternative water sources, using ample supplies of chemical coagulants, and drawing on the expertise of experienced operators	13
	• Build a new, larger intake structure and add new pipelines	14
	• Increases in system efficiency such as through an aggressive leak reduction program to curb system loss	16
	• Having legal authority to undertake short-term demand side management activities including imposing penalties on customers who do not comply with the restrictions	16

	• Developing longer-term plans to help guide operations during flood conditions (Who did what, when, and what chemical dosages were used at what point during the flood)	17
	• Formalising agreements with outside agencies to provide water in case of system failure	19
	• Adding flexibility to the system (Buying back-up generators, increasing storage capacity, developing new well-fields)	20
Adaptation barriers	• Uncertainty about developing existing water rights and obtaining new ones is the most problematic area for many of the basin's water utility managers	3
	High cost to finance system impovements	14
	• A number of water utilities have been unable to convince city councils, usually the rate making authority for publicly- owned utilities, or local citizens to increase rates sufficiently to cover the costs of replacing aging infrastructure, complying with new environmental requirements, and adding flexibility to the system to help utilities cope with disruptions	19

Title	***Impact of summer droughts on water quality of the Rhine river – A preview of climate change?***	Page
Author	J.J.G. Zwolsman, A.J. van Bokhoven	
Year	2007	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Water Science & Technology	
Volume	56	
Issue	4	
Pages	45-55	
Country of origin	The Netherlands	
Setting	The Netherlands, Germany	
Database	EBSCO	
Search terms	"global warming" AND adaptation AND "water compan*" "global warming" AND adaptation AND "water preparation" "global warming" AND adaptation AND "water resources management"	
Scientific theories	-	
Definitions		
Global change / Climate change	*"Climate change will lead to an intensification of the hydrological cycle, on a global, regional, and local scale."* (IPPC, 2001)	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Temperature	45
	2) Precipitation	45
	3) Evapotranspiration	45
	4) Sea level	45
	5) Flood	45
	6) Drought	45
	7) Low water	46

	8) Heavy rainfall	46
Time horizon	2050	46
Risks	1) & 6) & 7) • Deterioration of water quality because of: → Water temperature ↑ → Development of algae blooms in the raw water ↑ (have to be removed by flocculation or filtration) → Chloride concentration would easily exceed the 200 mg/l threshold, forcing the drinking water companies to stop the intake of river water for drinking water production → Concentration of chloride and bromide ↑ (The increasing concentration of bromide during low river flows is relevant if ozone is used in the water treatment process, because this will increase the formation of (potentially carcinogenic) bromate → during ozonation) → Low river discharges which is related to limited dilution of the chemical load derived from point sources • Increase in water temperature, which may enhance the microbiological activity in the distribution network	46 / 50 / 52 / 54
	8) • Chemical loading of surface waters from non-point sources (e.g. soil leaching)	46
Opportunities	-	
Adaptation strategies	-	
Adaptation barriers	-	

Title	***When climate change is a fact! Adaptive strategies for drinking water production in a changing natural environment***	Page
Author	A.F.M. Meuleman, G. Cirkel, G.J.J. Zwolsman	
Year	2007	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Water Science & Technology	
Volume	56	
Issue	4	
Pages	137-144	
Country of origin	The Netherlands	
Setting	The Netherlands	
Database	Searched within reference list	
Search terms	-	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	

Climatic parameters	1) Temperature	137
	2) Precipitation	137
	3) Evaporation	137
	4) Heavy rainfall	137
	5) Sea level	138
	6) Low water	140
	7) Drought	139
	8) Floods	139
	9) Storm	139
Time horizon	-	
Risks	1) & 7) • Increase of water temperature during transport in networks from treatment facility to taps of customers, resulting in increasing microbiological risks. For instance, during the summer of 2005, an increase of water temperature from 15 to 20 degrees Celsius was measured in several networks in The Netherlands as a result of the warming during transport in urban areas	141
	6) • Climate change induced decreased river run-off (because of reduction of storage in snow pack) causes increasing concentrations of pollutants → This increase in concentrations may lead to a significant increase of treatment costs	140
	4) & 8) • Increase of sediment transport in rivers due to increasing dynamics of river stream velocity → Sediments are often contaminated with heavy metals and organic pollutants (e.g. pesticides, discharge of chemical industries) → Influences water quality at intake points of production facilities using surface water as a source for drinking water production	141
	5) • The risk of flooding of coastal areas as a result of sea level rise is well known whilst salt water intrusion in fresh aquifers (e.g. Florida and The Netherlands) and deltas of rivers → More than 25% of The Netherlands' 200 drinking water facilities are estimated to be threatened by salt water intrusion from coastal areas → Fifteen of 200 freshwater production sites have been abandoned because of saltwater contamination • Higher sea water levels in combination with lower discharge rates of rivers during dry periods may cause increasing salt concentrations in surface water in deltas of river systems	139
	6) & 7) • Decreased river run-off in combination with the increased occurrence of heat waves caused increasing surface water temperatures in The Netherlands → As a result, algae blooms were observed in major Dutch water systems	140
	7) • Increase of drinking water demand during droughts	141
	8) & 9) • Physical damage to assets due to extreme events	141
Opportunities	-	
Adaptation strategies	• Increasing the maximum capacity of production facilities to meet peak demands	141
	• Production from alternative resources such as sea water, precipitation, brackish ground water and domestic wastewater	142
	• Using innovative treatment techniques such as membrane technology	142

	• The combination of large scale production capacity used for a relatively constant production (low peak factors), and small scale flexible production facilities that are used during peak demands	142
	• Temporary storage of run off water (aboveground and below ground storage using aquifer storage and recovery) (ASR)	142
	• Multi source production strategies for small and large water supplies, using various resources and treatment techniques depending on water availability and treatment costs	142
Adaptation barriers	• High investment costs by increasing the capacity of production facilities	141

Title	***Climate change in Germany – Vulnerability and adaptation of climate sensitive sectors***	Page
Author	Marc Zebisch, Torsten Grothmann, Dagmar Schröter, Clemens Hasse, Uta Fritsch, Wolfgang Cramer	
Year	2005	
Type of Reference	Report	
Type of Article	Empirical Paper (Survey)	
Source	Umweltbundesamt	
Volume	-	
Issue	-	
Pages	1-202	
Country of origin	Germany	
Setting	Germany	
Database	Searched within reference list	
Search terms	-	
Scientific theories	-	
Definitions		
Global change / Climate change	*"Global change is a far-reaching and widely used collective term. We understand this term not only to refer to climate change, but also to trends in other factors that reflect human influence on the Earth system, i.e. the era of the so-called Anthropocene."*	16
Vulnerability	*"The likelihood of a specific human-environment system to experience harm due to changes in society or the environment, accounting for its adaptive capacity."* (Turner et al., 2003)	19
Adaption to climate impacts	*"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm* *or capitalizes on beneficial opportunities."* (IPCC,2001)	19
Climatic parameters	1) Precipitation	48
	2) Temperature	48
	3) Evaporation	48
	4) Floods	48
	5) Low water	48
	6) Extreme rainfall	48
	7) Drought	48
Time horizon	2080	14
Risks	1) • Ground water qualitiy is beeing altered by agriculture through the use of fertilisiers and pesticides → These are transported to the groundwater or to the surface waters through erosion, leading to eutrophication of surface waters and oceans → Loss in the usability of the aquifer as drinking water resource	52

Title	***Climate change in Germany – Vulnerability and adaptation of climate sensitive sectors***	Page
	1) & 2) • In shallow and warm water bodies the growth of zoo- and phytoplankton and therefore the risk of eutrophication can increase • Reduction of ground water recharge • Changes in quality and quantity of drinking water	55
	2) • Changes in temperatures of flowing and standing water bodies	58
Opportunities	-	
Adaptation strategies	• Flood protection → Sufficient flood retention on flood plains → Regulation that limits construction on the flood plains; Precautionary land use → Hazard protection → Technical flood protection → Nature-oriented reconstruction of rivers	59
	• Sustainable land use management, which secures the retention of water in the landscape	58
	• Open the possibility of transporting water through long-distance pipelines	58
	• Infrastructure should be built to store sufficient amounts of water in dams	58
	• Water saving measures should be implemented in industry, agriculture, forest-ry and private households, to avoid restrictions of usage	61
	• Improving water quaility	58
	• Financial safeguarding through insurances against flood damage	59
	• Insurance against damages through climate change	59
	• Creation of integrated water supply systems	62
	• Expansion of water conservation areas to secure drinking water supplies	62
	• Minimisation of nutrient deposition	62
	• Collaboration of flood warning stations across borders	62
	• Projects and practical programmes for the adaptation to climate change are subjects in a water companies administrations → "Control TS" in Saxony (LTV Saxony) → "INKLIM 2012" in Hesse → "KLIWA" in Baden-Württemberg	62

Title	***Climate change in Germany – Vulnerability and adaptation of climate sensitive sectors***	Page
Adaptation barriers	• Flood protection → Financial restrictions → Conflicts of use and lacking readiness to turnover land area (natural flood retention)	60
	• Improving water quality → Financial restrictions → Resistance in industry and politics	61
	• Saving water → Current ample water supply → Low water prices → Low motivation of citizens	61
	• Nature-oriented reconstruction of rivers → Financial restrictions → Vast demand of area → The existing dense development → High maintenance costs	62

Title	***WASKlim Entwicklung eines übertragbaren Konzeptes zur Bestimmung der Anpassungsfähigkeit sensibler Sektoren an den Klimawandel am Beispiel der Wasserwirtschaft***	Page
Author	Jörg Scherzer, et al.	
Year	2010	
Type of Reference	Report	
Type of Article	Empirical Paper (Scenario Analysis)	
Source	http://www.uba.de/uba-info-medien/4019.html	
Volume	-	
Issue	-	
Pages	1-234	
Country of origin	Germany	
Setting	Germany	
Database	Searched within reference list	
Search terms	-	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	29
	2) Temperature	28
	3) Evaporation	82
	4) Floods	89
	5) Low water	90
	6) Drought	97
	7) Heavy rainfall	97
Time horizon	2021-2050 / 2071-2100	163

Risks	1) & 2) & 3) • Because of decreasing precipitation events and increasing temperatures as well as evaporation, reservoir levels are projected to decrease	113
	4) & 5) • Changes in the concentrations of pollutants in tha raw water caused by changes in water quantity will lead to changes in water quality	140
Opportunities	-	
Adaptation strategies	• Monitoring of the supply network as well as continuous maintenance to avoid water loss	116
	• Long-distance water supply	116
	• Optimisation of the supply structure by cross-linking of water companies	116
	• Cross-linking of water catchment facilities	116
	• Protection of ground and surface water	116
	• Expansion of water protection areas	117
	• Ground water monitoring	117
	• Sufficient water storage in reservoirs	143
	• WASKlim desicion support system	144
Adaptation barriers	Flood protection vs. drinking water supply and low water elevation	117

Title	***Klimawandel, qualitative Aspekte der Wasserwirtschaft und Nutzungsaspekte***	Page
Author	N. Kreuzinger, H. Kroiß	
Year	2011	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Österreichische Wasser- und Abfallwirtschaft	
Volume	63	
Issue	1-2	
Pages	42-51	
Country of origin	Austria	
Setting	Austria	
Database	Google Scholar	
Search terms	Klimawandel UND Anpassung UND Trinkwasserversorgung Klimawandel UND Anpassung UND Wasserwirtschaft Klimawandel UND Anpassung UND Wasserversorgung	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	47
	2) Temperature	44
	3) Low water	45
	4) Heavy rainfall	48
Time horizon	2020-2050	42

Risks	1) • Decreasing precipitation and decreasing gound water recharge lead to water shortages	48
	2) • Increasing air temperatures lead to increasing water temperatures → Oxygen and carbon dioxide ↓ • Increasing summer temperatures as well as increasing winter temperatures lead to decreasing ground water qualities • Increasing ground water temperatures accelerate hydrolysis processes as well as chemical and biological processes in the aquifer • Increasing drinking water temperatures during the transport in distribution networks from treatment facilities to the taps of the customers leads to increasing microbiological risks → Changes in drinking water quality → More intensive treatment is necessary	44 / 47 / 48
	3) • Low water leads to decreasing dilution of inputs from diffuse sources	45
	4) • Extreme weather events have a negative effect on raw water sources (flooding of wells, ...)	48
Opportunities	• Increase in domestic and industrial demand, which causes shorter residence times of drinking water in the water supply pipes	48
Adaptation strategies	• Cross-linking of small water utilities with larger water utilities	48
	• Integrated water resource management plans	51
Adaptation barriers	-	

Title	***Auswirkungen des Klimawandels auf das Wasserdargebot von Grund- und Oberflächenwasser***	Page
Author	A. P. Blaschke, R. Merz, J. Parajka, J. Salinas, G. Blöschl	
Year	2011	
Type of Reference	Journal	
Type of Article	Empirical Paper (Trend Analysis, Scenario Analysis, Elasticity Method, „Trading space for time“ Method)	
Source	Österreichische Wasser- und Abfallwirtschaft	
Volume	63	
Issue	1-2	
Pages	31-41	
Country of origin	Austria	
Setting	Austria	
Database	Searched within reference list	
Search terms	-	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	31
	2) Temperature	31

	3) Evaporation	31
Time horizon	2021-2050	34
Risks	1) & 2) • Decreasing ground water levels in the east of Austria, because of low precipitation and high temperatures • Water supply is going to challenge increasing competing claims (public drinking water supply versus irrigation) • Increasing ground water temperatures because of higher temperatures	40 / 41
Opportunities	-	
Adaptation strategies	• Water resources management	40
Adaptation barriers	-	

Title	***Adapting to climate change: Public water supply in England and Wales***	Page
Author	Nigel W. Arnell, Kate Delaney	
Year	2005	
Type of Reference	Journal	
Type of Article	Empirical Paper (Case Study)	
Source	Climatic Change	
Volume	78	
Issue	2-4	
Pages	227-255	
Country of origin	Great Britain	
Setting	Great Britain (England, Wales)	
Database	Web of Science	
Search terms	"climate change" AND adaptation AND "water industry" "climate change" AND adaptation AND "public water suppl*" "climate change" AND adaptation AND "water supply comp*"	
Scientific theories	-	
Definitions		
Global change / Climate change	*"Climate change is one of many drivers which may lead to changes in the external conditions for an organisation, but is distinctive in two main ways. It affects the natural resources used by the organisation – conventionally these are assumed to be constant – and second it is both uncertain and, in many senses, contested and controversial."*	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Floods	233
	2) Low water	233
Time horizon	2025	234
Risks	• Climate change may alter the demand for water (particularly the peak demands), which affects demand-side shortages → average irrigation demands may increase by up to 20%	233
	• It may alter the reliability of the supply infrastructure by altering reservoir safety	233
	• It may alter the reliability of raw water sources by changing the frequency of low flows and recharge, increasing the frequency of floods which can inundate bankside facilities	233
	• Floods increase the frequency of highly turbid flows and threatening abstraction points with saline intrusion	233

	• It may alter the ability to treat raw water to potable standards by changing the frequency of inundation of treatment works and by changing the quality of the abstracted water	233
	• Changes in quality and quantity of river flows and ground water recharge affects the frequency of supply-side shortages	234
	• Lower flows during summer lead to greater concentrations of pollutants which need to be removed from raw water (especially nitrates and phosphates) → supply costs ↑	234
	• High peak flows lead to increased sediment concentrations or flushes of pollutants	234
Opportunities	-	
Adaptation strategies	• New or enhanced reservoirs	244
	• New direct river abstractions	244
	• Ground water development	244
	• Bulk water transfers	244
	• Artificial aquifer recharge	244
	• Aquifer storage recovery (treated water)	244
	• Desalinisation	244
	• Import of icebergs	244
	• Conjunctive use of sources	244
	• Improvements to supply network linkages	244
	• Resource sharing	244
	• Seasonal forecasting	244
	• Improvements to raw water treatment capacity and capacity of distribution network	244
	• Leakage reduction	244
	• Water efficient equipment and fittings	244
	• Promotion of more efficient use through education (influences water use)	244
	• Promotion of more efficient use through tariff structures	244
	• Water reuse and recycling	244
Adaptation barriers	• The related problem of the long lead times (typically around 20 years) necessary for implementation of new resource schemes, due largely to the planning process	251
	• The connected problem of the short time horizon imposed by the five-year periodic review of investment requirements (encourage companies to take a longer perspective)	251
	• Difficulties in exerting control over the demand for water. Few domestic customers are metered, and tariff structures do not currently discourage high use; there is also limited understanding within the water industry of how to influence customer behaviour to reduce usage	251
	• The pressures of competing demands on water resources, including environmental obligations	251
	• Fragmentation of the water supply industry, particularly in south east England, with diverse and changing patterns of ownership	251
	• The current requirement that all investment in adapting to climate change by the water supply companies should be funded by efficiency savings, borrowing or through increased charges to customers, with no direct government contribution	251
	• Time-limited abstraction licences, which give flexibility to the Environment Agency but can potentially deter water company investment	251
	• The limited number of locations for uncontroversial development of new resources: all the proposed sites for new water resources options are contested, and any application would be challenged	251

Title	***Issues of drinking water quality of small scale water services towards climate change***	Page
Author	I. Delpla, E. Baures, A. V. Jung, M. Clement and O. Thomas	
Year	2011	
Type of Reference	Journal	
Type of Article	Empirical Paper (Case Study)	
Source	Water Science and Technology	
Volume	63	
Issue	2	
Pages	227-232	
Country of origin	France	
Setting	France (Brittany)	
Database	Web of Science	
	EBSCO	
Search terms	*Web of Science:* "climate chanage" AND adaptation AND "water treatment"	
	EBSCO: "global warming" AND adaptation AND "water treatment"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Temperature	227
	2) Heavy rainfall	227
	3) Floods	227
	4) Drought	227
	5) Low water	228
Time horizon	2030	227
Risks	3) • For floods, an increase of TOC concentration and a decrease of nitrates levels	232
	4) • For droughts periods, a decrease in nitrates concentration	232
Opportunities	-	
Adaptation strategies	• Water quality monitoring: New monitoring tools and procedures for on site use and more appropriate laboratory monitoring methods must be proposed	230
	• New sampling strategies must also be designed to cover the water quality variability around extreme weather events	231
	• Laboratories that specialize in emerging health risks, including cyanobacterial blooms, should be encouraged to work with small-scale water suppliers to assist and strengthen current health risk assessment	231
Adaptation barriers	-	

Title	***Implications of land disturbance on drinking water treatability in a changing climate: Demonstrating the need for "source water supply and protection" strategies***	Page
Author	Monica B. Emelko, Uldis Silins, Kevin D. Bladon, Micheal Stone	
Year	2011	
Type of Reference	Journal	
Type of Article	Empirical Paper (Case Study)	
Source	Water Research	
Volume	45	
Issue	2	
Pages	461-472	
Country of origin	Canada	
Setting	Canada (Alberta)	
Database	Web of Science	
Search terms	"climate change" AND adaptation AND "water treatment"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	464
	2) Temperature	463
Time horizon	-	
Risks	• Changes in water quality	462
	• Changes in water quantity	462
	• Changes in timing of availability	462
	• Climate-associated changes in source quality may present incremental cost increases for water treatment operations (e.g., increased chemical consumption), while others may necessitate new infrastructure to remove new target compounds (e.g., heavy metals, algae) or treat the associated challenges that they create (e.g., taste and odor compounds, toxic algal by-products)	462
	2) • High Temperatures may lead to *wildfires* which can significantly impact both water quality and quantity in headwater streams, increases in soil moisture and runoff → Source water turbidity ↑ → DOC ↑ → Challenges for water treatability	463 / 466 / 470
Opportunities	-	
Adaptation strategies	• Source water protection: They state or imply that "watershed protection approaches safeguard drinking water supplies from potential contamination as a way to ensure the highest quality water and to reduce treatment costs"	462
	• Designing new or optimizing existing treatment processes	462
	• Adequately respond to changing water quality conditions by either utilizing robust treatment processes that are resilient to changing water quality conditions	471
Adaptation barriers	-	

Title	***Climate change adaptation in the U.K. water industry: Managers' perceptions of past variability and future scenarios***	Page
Author	Susan Subak	
Year	2000	
Type of Reference	Journal	
Type of Article	Empirical Paper (Interview)	
Source	Water Resources Management	
Volume	14	
Issue	2	
Pages	137-156	
Country of origin	Great Britain	
Setting	Great Britain (England, Wales)	
Database	Web of Science	
	EBSCO	
	Google Scholar	
Search terms	*Web of Science:* "climate change adaptation" AND "water industry" "climate change adaptation" AND "water compan*" "climate change" AND adaptation AND "water compan*"	
	EBSCO: "climate change adaptation" AND "water industry" "climate change adaptation" AND "water compan*" "climate change adaptation" AND "water resources management"	
	Google Scholar: "climate change adaptation" AND "public water supply" "climate change adaptation" AND "water company" "climate change adaptation" AND "water industry" "climate change adaptation" AND "water service" "climate change adaptation" AND "water management" "climate change adaptation" AND "water resources management"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	138
	2) Temperature	139
	3) Drought	140
	4) Evaporation	145
Time horizon	2020	145
Risks	2) & 3) • Rising 'peaks' of water usage after climate-adjustment → Peaks in demand, because of climate change, tend to be the main reasons for many water companies' supply problems → Increasing "competition" from domestic consumers and from agricultural producers • Water authorities experienced problems delivering enough water → Shortages in supply	138 / 139 / 143
Opportunities	-	

Adaptation strategies	• Developing climate change scenarios and water companies should consider the implications of the results for future water demand and water supply → Producing a plan showing how water companies would keep supply and demand in adequate balance	140
	• Demand-side-management measures to promote the efficient use of water by water company customers. These pledges marked the first time that many water companies made serious efforts to reduce water consumption	141
	• Companies also agreed to offer free pipe leakage detection and repair service to all customers → drop in leakage	141
	• Companies initially agreed to remove some of the costs for installing water meters in households because water consumption is not metered in most households in the U.K. (although they are known to be effective in reducing consumption) → Reducing peak demands	141
	• Increase supply through increase water storage capacity (reservoirs)	143
	• Extra treatment capacity	143
	• Co-operative water transfer schemes that distribute water between companies from areas of surplus	143
	• Investing in infrastructure to help with water distribution	145
Adaptation barriers	• Low motivation of citizens to save water	153
	• Companies do not believe that the Environment Agency's climate change scenarios should elicit a change in water resource planning	153

Title	***The impact of climate change on reservoir water quality and water treatment plant operations: A U.K. case study***	Page
Author	O. Thorne, R. A. Fenner	
Year	2011	
Type of Reference	Journal	
Type of Article	Empirical Paper (Case Study)	
Source	Water and Environment Journal	
Volume	25	
Issue	1	
Pages	74-87	
Country of origin	Great Britain	
Setting	Great Britain (England, Wales)	
Database	Web of Science	
Search terms	"climate change" AND adaptation AND "water treatment"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	75
	2) Temperature	75
	3) Floods	75
	4) Heavy rainfall	75
	5) Evaporation	75
	6) Storms	81

Time horizon	-	
Risks	1) & 2) • The resultant higher water temperatures and greater variations in runoff associated with climate change are likely to produce changes in the water quality that will adversely affect human water use → Chemical reaction rates and aquatic flora and fauna growth rates and mortality will be affected → The oxygen-carrying capacity of the water will also be decreased, increasing anoxia in eutrophic waters → Climate change will also alter the thermal structure of surface water storages which leads to an increase in the frequency and/or the severity of *algal bloom* occurrences → Formation of taste and odour compounds such as methylisoborneol and geosmin that can be detected by humans at very low concentrations → Lead to problems in the water treatment process including difficulties in achieving effective coagulation and decreased filter run times → Changes in the thermal structure of the reservoir may also lead to the invasion of temperature-sensitive exotic species → Increased DOC levels (because of microbial degradation of organic particle such as plants) in the raw water will be reflected in increased DOC levels in the filtered water. It is considered possible that the projected increased raw DOC concentrations could increase the chlorine demand of the water, resulting in increased dosing requirements → Increases in chemical costs by up to 6% (coagulant and chlorine only) → Increased water treatment costs due to decreased filter run times and increased chemical dosing	75 / 85 / 86
	3) • Strong positive correlations between river nutrient loads and high flow events • An increase in the frequency of high-flow events may negatively impact on the operations of water utilities through increased potential for flood-related infrastructure damage and decreased water quality because of sewer overflows and increased diffuse source pollutant concentrations (such as nitrates)	75 / 81
	4) • More intense rainfall events will also lead to increased levels of suspended solids because of fluvial soil erosion	75
	5) • Decreased reservoir water levels because of increases in evaporation will further concentrate pollutants within the reservoirs	75
Opportunities	• There may be an increased dilution with higher flows	81
	• Storms will also flush away algal blooms	81
Adaptation strategies	-	
Adaptation barriers	-	

Title	***Zur Klimasensibilität der Wirtschaft in der Region Dresden***	Page
Author	Heike Auerswald, Robert Lehmann	
Year	2010	
Type of Reference	Journal	
Type of Article	Empirical Paper (Case Study)	
Source	ifo Dresden berichtet	
Volume	-	
Issue	3	
Pages	15-23	
Country of origin	Germany	

Setting	Germany	
Database	WISO	
	Google Scholar	
Search terms	*WISO:* Klimawandel UND Anpassung UND Trinkwasser Klimawandel UND Anpassung UND Wasser Klimawandel UND Anpassung UND Wasseraufbereitung Klimawandel UND Anpassung UND Wasserversorgung Klimawandel UND Trinkwasser Klimawandel UND Wasserversorgung	
	Google Scholar: Klimawandel UND Anpassung UND Wasseraufbereitung Klimawandel UND Anpassung UND Trinkwasser Klimawandel UND Anpassung UND Wasserversorgung	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation 2) Temperature 3) Floods 4) Extreme rainfall 5) Drought 6) Storms	15
Time horizon	-	
Risks	1) & 2) • Price increases as a result of competitive uses (in the field of industrial and drinking water) • Decline of the water table which can affect the water supply / delivery • Changes in quality of water → water treatment costs ↑, but only moderate change / shortage in quantity	16
Opportunities	-	
Adaptation strategies	-	
Adaptation barriers	-	

Title	***Climate change and water***	Page
Author	Bryson Bates, Zbigniew W. Kundzewicz, Shaohong Wu, Jean Palutikof	
Year	2008	
Type of Reference	Working Paper	
Type of Article	Theoretical Paper (Literature Review)	
Source	http://www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf	
Volume	-	
Issue	-	
Pages	200	
Country of origin	Switzerland	
Setting	-	

Database	WISO	
Search terms	Klimawandel UND Wasserversorgung	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	70
	2) Temperature	70
	3) Evapotranspiration	70
	4) Sea level	70
	5) Floods	70
	6) Droughts	70
	7) Low water	70
Time horizon	-	
Risks	1) • Changes in water availability due to changes in precipitation and other related phenomena (e.g., groundwater recharge, evapotranspiration) • Reduced water availability because of decreased summer precipitation leading to a reduction of stored water in reservoirs fed with seasonal rivers • Reduced water availability because of reductions in inland ground water levels • Increased precipitation may also result in higher turbidity and nutrient loadings in water, requiring substantial additional treatment and monitoring costs	70
	2) • Reductions in dissolved oxygen content, mixing patterns, and self purification capacity because of increasing surface water temperatures • Warmer temperatures, combined with higher phosphorus concentrations in lakes and reservoirs, promote algal blooms that impair water quality through undesirable colour, odour and taste, and possible toxicity to humans, livestock and wildlife → Water has a high cost with the available technology	70 / 71
	3) • Water availability reduction because of increasing evapotranspiration as a result of higher air temperatures • Salinisation of water resources because of evapotranspiration • Lower ground water levels	70
	4) • Salinisation of coastal aquifers → Reduced water availability • Salinisation can also affect inland aquifers due to a reduction in groundwater recharge	70 / 71
	5) • Increases the difficulty of flood control and reservoir utilisation during the flooding season • Floods affect water quality and water infrastructure integrity, and increase fluvial erosion, which introduces different kinds of pollutants to water resources • During floods, water treatment facilities are often out of service, leaving the population with no sanitary protection	70 / 71
	6.) • Droughts affect water availability and water quality	70

	7) • Low water availability will lead to ground water over-exploitation and increasing costs of supplying water for any use as a result of the need to pump water from deeper and further away • Ground water over-exploitation may lead in some cases to water quality deterioration (arsenic poisoning and fluorosis)	70
Opportunities	-	
Adaptation strategies	• The use of climate projections should also be considered, especially in cases involving systems that deal with floods and droughts	71
	• To ensure adequate supplies, you may build new storage reservoirs or use alternative water sources	71
	• One of the quickest ways to increase water availability is through minimising water losses in urban networks and in irrigation systems	71
	• The protection of water resources is an important, cost-effective strategy for facing future problems concerning water quality	71
	• Public participation in water planning will be necessary, particularly in regard to changing views on the value of water, the importance and role that water reuse will play in the future, and the contribution that society is willing to make to the mitigation of water-related impacts	72
	• Flood protection → Expanded floodplain areas → Emergency flood reservoirs → Flood forecasting and warning systems	95
Adaptation barriers	• New reservoir construction is being increasingly constrained in Europe by environmental regulations and high investment costs	95

Title	***Guidance on water and adaptation to climate change***	Page
Author	Economic Commission for Europe (ed.)	
Year	2009	
Type of Reference	Report	
Type of Article	Theoetical Paper (Literature Review)	
Source	http://www.unece.org/env/documents/2009/Wat/mp_wat/ECE_MP.WAT_30_E.pdf	
Volume	-	
Issue	-	
Pages	1-127	
Country of origin	-	
Setting	-	
Database	WISO	
Search terms	Klimawandel UND Anpassung UND Wassermanagement Klimawandel UND Anpassung UND Wasserversorgung Klimawandel UND Wassermanagement Klimawandel UND Wasserversorgung	
Scientific theories	-	
Definitions		
Global change / Climate change	*"A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."* (UNFCCC 1992. United Nations Framework Convention for Climate Change, article 1)	111

Vulnerability	*"Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes."* (IPCC, 2007. Climate Change 2007: Synthesis Report. Annex II – Glossary)	112
Adaption to climate impacts	*"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."* (IPCC, 2007. Climate Change 2007: Synthesis Report. Annex II – Glossary)	111
Climatic parameters	1) Precipitation	8
	2) Temperature	8
	3) Evaporation	9
	4) Floods	8
	5) Drought	8
	6) Heavy rainfall	8
	7) Low water	8
	8) Sea level	8
Time horizon	-	
Risks	2) & 4) & 5) • Higher water temperatures and changes in extreme events, including more and more intense floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt – and also cause thermal pollution → Damage to water system reliability and operating costs	8
	2) • Increased water temperatures • Prolonged lake stratification with decreases in surface layer nutrient concentration and prolonged depletion of oxygen in deeper layers • Increased algae growth reducing dissolved oxygen levels in the water body which may lead to eutrophication	9
	5) • Increased water pollution due to lower dissolution of sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution • Changes in run-off • Salinization of coastal aquifers	8
	6) • Adverse effects on quality of surface and ground water due to sewer overflows • Contamination of water supply	9
	8) • Sea-level rise is projected to extend areas of salinization of ground water and estuaries resulting in a decrease of water availability	8
Opportunities	-	
Adaptation strategies	• Desalinization of saline water for water supply	23
	• Improving energy efficiency in drinking water treatment facilities	43
	• Water supply systems may need additional monitoring for microbiological or chemical contamination following floods or drought periods (pipe infiltration, increased chlorination, increased concentration of contaminants)	52
	• Continuous monitoring of the loss of water from pipes is necessary	52

	• Drainage management plans, which are tools to manage water resources during droughts → They describe appropriate measures to apply to protect water ecosystems facing water stress: *structural measures* (new pumping wells, new pipes, use of new desalination plants) and *non-structural measures* (water savings by applying restrictions to the users, increase in the use of ground water) → They minimize effects on public water supply	82
	• Increase of storage capacity (for surface and ground waters) both natural and artificial	92
	• Economic instruments like metering, pricing to reduce demand	92
	• Enlarging the availability of water (e.g. increase of reservoir capacity)	91
	• Joint operation of water supply and water management networks or building of new networks	91
	• Identification and evaluation of alternative strategic water resources (surface and ground water)	91
	• Improving drinking water intakes because of impaired water quality	91
	• Catchment protection (e.g. increasing protected areas)	91
	• Reducing leakages in distribution network	92
	• Awareness raising in case of drought situations	92
Adaptation barriers	• High energy needs for desalinization of saline water	23

Title	***Klimawandel und Wasserversorgung. Auswirkungen auf das Wasserdargebot, die Wasserqualität und die Versorgungs-sicherheit***	Page
Author	F. Haakh	
Year	2008	
Type of Reference	Book chapter	
Type of Article	-	
Source	-	
Volume	-	
Issue	-	
Pages	11-26	
Country of origin	Germany	
Setting	Germany (Baden-Württemberg)	
Database	SLUB catalogue	
	Google Scholar	
Search terms	*Slub catalogue:* Klimawandel UND Trinkwasser Klimawandel UND Trinkwasserversorgung Klimawandel UND Wasserversorgung	

	Google Scholar: Klimawandel UND Anpassung UND Rohwasserqualität Klimawandel UND Anpassung UND Talsperren Klimawandel UND Anpassung UND Trinkwasser Klimawandel UND Anpassung UND Trinkwasseraufbereitung Klimawandel UND Anpassung UND Trinkwasserversorgung Klimawandel UND Anpassung UND Wasseraufbereitung Klimawandel UND Anpassung UND Wassergewinnung Klimawandel UND Anpassung UND Wassermanagement Klimawandel UND Anpassung UND Wasserqualität Klimawandel UND Anpassung UND Wasserressourcenmanagement Klimawandel UND Anpassung UND Wasserunternehmen Klimawandel UND Anpassung UND Wasserverteilung Klimawandel UND Anpassung UND Wasserwirtschaft Klimawandel UND Anpassung UND Wasserversorger Klimawandel UND Anpassung UND Wasserwerk Klimawandel UND Anpassung UND Wassversorgung	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	12
	2) Temperature	12
	3) Low water	13
	4) Floods	13
	5) Drought	15
Time horizon	-	
Risks	2) & 5) • Tightening of the peak drinking water supply during droughts → Local water resources were exhausted → Change to distant water • Changes in the raw water quality → Higher nitrate concentrations after droughts or intensive ground water discharge → high water temperatures deteriorate the microbial raw water characteristics in surface waters • Increase of technical problems becuase of increasing raw water temperatures: Increase of raw water temperature from 10 to 20°C lead to a decrease of the kinematic viscosity by 24% → You have to increase the velocity of the rinsing process by 30% • Extreme droughts lead to pipe burst	19 / 21 / 22 / 25
	3) • During times of low water the cavitation limit of pumps can be reached or the lifting pipe system can draw in air • Deterioration of raw water quality of surface waters, because of extreme flow rates and their high concentration of pollutants	22 /24
	4) • Endangerment of the water supply systems	23
Opportunities	-	
Adaptation strategies	• Long-distance water supply → Distributed system	16

	• Protection of the drinking water supply with adequate water rights (Priority of the public drinking water supply over irrigation)	19
	• Energy efficient water supply has priority	22
	• Forecast of supply assessment	25
	• Forecast for changes in raw water quality	25
	• Water resources management	25
	• Water price that cover costs	25
Adaptation barriers	-	

Title	***Climate change and drinking water production in The Netherlands: a flexible approach***	Page
Author	T.A.B. Ramaker, A.F.M. Meuleman, L. Bernhardi, G. Cirkel	
Year	2005	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Water Science & Technology	
Volume	51	
Issue	5	
Pages	37-44	
Country of origin	The Netherlands	
Setting	The Netherlands	
Database	SLUB catalogue	
Search terms	Klimawandel UND Wasserversorgung Klimawandel UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	*"Climate change is a consequence of human-induced rapid accumulation of carbon dioxid and other greenhouse gases in the atmosphere, though the sensitivity of the climate system is not fully understood."*	37
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	37
	2) Temperature	37
	3) Evaporation	37
	4) Heavy rainfall	38
	5) Floods	38
	6) Low water	38
	7) Sea level	39
Time horizon	-	

Risks	1) • Increasing temperatures accelerate microbiological growth • Drinking water treatment processes could be affected • Natural filtration processes (river bank filtration, artificial recharge) might be less effective due to increaseing biomass growth and fouling • Drinking water companies have to maintain a 25°C limit for safe drinking water production → Difficult keeping temperatures below this limit • Water consumption peaks increased by 40-50% on hot days, forcing drinking water companies to seek the limits of ground water extraction licences	40
	5) • High run-off causes mud waves containing accumulated contaminants → Drinking water companies are forced to close river water intake stations more often	38
	6) • Low run-off causes high concentrations of pollutants → Drinking water companies are forced to close river water intake stations more often	38
Opportunities	-	
Adaptation strategies	• New sources for drinking water production (rain water, brackish ground water)	40
	• Storage concepts → Reservoirs to meet daily peak demands → Large surface water reservoirs to meet seasonal demands → Aquifer Storage and Recovery (ASR) to meet peak demands in dry periods → In-house drinking water storage	41
	• Flexible treatment techniques	42
Adaptation barriers	• High investments in flexible water supply systems	42

Title	***Klimawandel – Herausforderungen und Lösungsansätze für die deutsche Wasserwirtschaft***	Page
Author	Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (ed.)	
Year	2010	
Type of Reference	Book	
Type of Article	-	
Source	-	
Volume	-	
Issue		
Pages	1-32	
Country of origin	Germany	
Setting	Germany	
Database	SLUB catalogue	
	WISO	
Search terms	*SLUB catalogue:* Klimawandel UND Wasserversorgung Klimawandel UND Wasserwirtschaft	

	WISO: Klimawandel UND Wassermanagement, alle Medien Klimawandel UND Wasserversorgung, alle Medien Klimawandel UND Wasserwirtschaft, alle Medien	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	6
	2) Temperature	6
	3) Floods	6
	4) Drought	6
	5) Low water	6
	6) Heavy rainfall	6
	7) Sea level	13
Time horizon	-	
Risks	1) & 2) & 5) • Reduced ground water recharge leads to decreasing ground water levels (Especially in regions with less groundwater bodies) • Decreasing ground water levels lead to cavitation problems on well pumps and lead in extreme cases to the drying-up of some wells • Changes in the ground water quality because of missing dilution of contaminated ground water → Increase of concentration in the raw water • Decreasing sea and reservoir levels reduce the raw water availability • Utilisation conflicts	13 / 14 / 15
	2) • Because of higher air temperatures in reservoirs and lakes, the vertical temperature gradient will increase → The circulations become rarer and shorter → Decreasing oxygen supply into the hypolimnion → Hypolimnion = important for drinking water supply • Acceleration of biological and chemical processes in the water body as a reseult of higher temperatures → Deterioration of the water quality (because of algal bloom) • Increasing drinking water temperatures in the distribution network → bacterial growth ↑	14
	3) • Floods can affect the groundwater quality and intrusions from contaminated sites may increase • Breakdown of the water supply system • Using reservoirs for flood protection → Storage space for drinking water abstraction ↓	14
	7) Sea water level rise leads to increased ground water salinity in coastal areas	13
	5) • Low water in rivers can lead to limited water withdrawal • Decreasing channel flow leads to increasing concentration of substances → water quality ↓	14

	6) • Heavy rainfall may lead to changes in the raw water quality because of erosive surface runoff and increasing overflows of combined and separated sewerage systems → Microbial contamination ↑ • Fertilisers may be washed into the groundwater → Nitrate concentration ↑	14
Opportunities	-	
Adaptation strategies	• Trend analyses and forecast about availability of water	15
	• Monitoring programme to identify changes in water quality	15
	• Distributed system	15
	• Distant water supply	15
	• New raw water sources	15
	• Possibility to disinfect in distribution and storage	15
	• Increasing storage capacity for peak water demand	15
	• Decreasing leakage	16
	• Water rights for covering peak demands	16
	• Priority of drinking water supply over e.g. irrigation	16
Adaptation barriers	-	

Title	***Water resources management in the face of climatic / hydrologic uncertainties***	Page
Author	Zdzislaw Kaczmarek et al.	
Year	1996	
Type of Reference	Book	
Type of Article	-	
Source	-	
Volume	-	
Issue	-	
Pages	1-395	
Country of origin	Poland	
Setting	-	
Database	SLUB catalogue	
Search terms	Klimawandel UND Wasserversorgung Klimawandel UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	51
	2) Evapotranspiration	51
	3) Temperature	51
Time horizon	-	

Risks	1) • Increasing precipitation increases erosion and nutrient leaching from the catchment, and thus contribute to the non-point pollution entering lakes → Nutrient leaching enhances water quality problems as well as enhancing the turbidity and hygiene problems	52
	2) & 3) • In areas where the climate becomes more arid, lake retention times increases and erosion and nutrient leaching are decreasing → Increaed retention and decreased throughflow lead to the concentration of pollutants and salts → Risk of salinisation in areas where evaporation is greater than precipitation	52
Opportunities	-	
Adaptation strategies	-	
Adaptation barriers	-	

Title	***Risiken des regionalen Klimawandels in Sachsen, Sachsen-Anhalt und Thüringen***	Page
Author	Johannes Franke, Valeri Goldberg, Udo Mellentin, Christian Bernhofer	
Year	2006	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Wissenschaftliche Zeitschrift der Technischen Universität Dresden	
Volume	55	
Issue	3-4	
Pages	97-104	
Country of origin	Germany	
Setting	Germany	
Database	Google Scholar	
Search terms	Klimawandel UND Anpassung UND Talsperren Klimawandel UND Anpassung UND Trinkwasserversorgung Klimawandel UND Anpassung UND Wassermanagement Klimawandel UND Anpassung UND Wasserversorgung Klimawandel UND Anpassung UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	99
	2) Temperature	99
	3) Evapotranspiration	
	4) Drought	101
	5) Low water	101
	6) Floods	103
Time horizon	2100	99

Risks	3) • Increasing evaporation rates caused by increasing temperature → Reduction of the reliability of the reservoir system	103
	4) • Salination of the ground water caused by decreasing ground water recharge and over utilization of the ground water supply	101
Opportunities	-	
Adaptation strategies	• Cross-linking of reservoirs	103
	• Extend measures for flood protection	104
Adaptation barriers	• Flood protection vs. drinking water supply	

Title	***Herausforderungen der Klimawandel-Auswirkungen für die Trinkwasserver-sorgung***	Page
Author	Anja Rohn, Hans-Joachim Mälzer	
Year	2010	
Type of Reference	Report	
Type of Article	Empirical Paper (Interview, Trend Analysis)	
Source	*dynaklim*-Publikation	
Volume	3	
Issue	-	
Pages	1-45	
Country of origin	Germany	
Setting	Germany, United States of America (California), Australia	
Database	Searched within reference list	
Search terms	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate im-pacts	-	
Scientific theories	-	
Climatic parameters	1) Precipitation	2
	2) Temperature	2
	3) Drought	2
	4) Heavy rainfall	2
	5) Low water	3
	6) Floods	3
	7) Storms	17
Time horizon	2031-2060	2

Risks	2) • An increase in air temperatures leads to changes in the stratification of reservoirs because an increase in water temperatures would complicate the circulation with deeper layers → No freshwater would reach the ground of the reservoir and there would be no exchange with oxygen and other nutrients → Putrefaction on the ground → Raw water becomes unusable • Increasing microbiological risks in water distribution networks caused by increasing temperatures	6 / 7
	2) & 3) • Increasing number of days with peak demands caused by droughts and higher temperatures → However, there is no long-term prognosis if droughts really lead to increasing water demand in Germany • Utilisation conflicts (Decreasing ground water levels caused by agricultural usage of wells for irrigation)	3 / 13
	2) & 4) • An increase in temperature as well as run-off could mobilise organic pollutants again (POP)	4
	3) • Hot summers as well as long periods of drought can deteriorate the filtering effect of the soil → During extreme rainfalls pollutants and pathogens can be easily washed into the ground water → Increase of filter run times • Increasing number of pipe bursts caused by drought	5 / 6 / 7
	3) & 1) • Dry summers and increasing precipitation events during winter lead to an intensification of nitrate in the ground water	5
	3) & 5) • Decreasing reliability of reservoirs • Increasing concentration of pollutants in surface waters caused by decreasing dilution of industrial pollutants • Times of low water can be noticed through increasing concentration of pollutants and higher water temperatures in the bank filtrate • Cavitation problems of the raw water pumps caused by low water and decreasing ground water levels → Deficit in water extraction	3 / 4 / 6
	4) • Changes in the quality of surface and ground waters caused by heavy rainfalls • Sewerage overflows → Increasing input of sediments, pathogens, pesticides and phosphorus, which promotes algae growth → Increasing filter run times • Input of humic substances into the raw water caused by run-off or erosion may influence the flocculation process negatively and, therefore, decrease the efficiency of the raw water treatment process	4 / 6 / 7
	5) & 6) • Changes in the inflow of reservoirs	3
	6) • Increasing turbidity in reservoris → Increasing addition of chemicals as well as flushing → Increasing amount of sludge → Decreasing filter run times	5 / 7

	7) • Pipe bursts especially in wooden areas caused by uprooting of trees	17
Opportunities	• Agricultural uses in The Netherlands is projected to decrease during the next years, which leads to better water qualities because of reduced immissions of pesticides and fertilizers into surface and ground water • No more utilisation conflicts between agriculture and drinking water supply	16
Adaptation strategies	• Flood protection because heavy rainfall leads to flooding of streams in the catchment area	4
	• Water companies should deal more often with prognoses about the availability of water within the next years	8
	• Cross-linking of water companies	8
	• „Water resources management" through ground water recharge	9
	• Management plan of the usage of ground water, which defines the delivery volume	9
	• Increasing the capacity of drinking water storages	9
	• Optimisation of the crisis management, which includes adjusting to changes in raw water quality	9
	• Developing a management plan in case of increasing water temperatures	10
	• Adding additional treatment trains to water preparation such as carbon filtration, physical deacidificaion and disinfection by UV light	10
	• Measures for protecting resources in cooperation with agriculture	10
	• Hydraulical encapsulation of the water catchment area through a retaining wall → Minimisation of the microbiological contamination of the bank filtrate	10
	• To reduce microbiological contamination in the water distribution network, pipes need to be buried deeper into the ground	11
	• Water saving measures in residential houses (subsidization)	11
	• Water management plan for bulk consumers	11
	• Reduction of leakages in pipes	11
	• Usage of deeper ground water, desalination plants	12
	• Regulation of water demand through pricing	12
	• Water recycling	12
	• Check water facilities for their flood safety	13
	• Increase of storage capacity	13
	• Implementation of water balances to calculate the additional demand for agricultural irrigation	13
	• Monitoring programs for water	14
	• Water protection areas	15
	• Online-monitoring of the water quality in the dirstribution network	17
	• Removing of trees, which grow over pipes to avoid pipe bursts	17
	• Strengthening of the multi-barrier-concept	24
Adaptation barriers	-	

Title	***Analysing water quality changes due to reservoir management and climate change for optimization of drinking water treatment***	Page
Author	Wolfgang Uhl, Irene Slavik	
Year	2009	
Type of Reference	Journal	
Type of Article	Empirical Paper (Statistic Test Planning)	
Source	Water Science & Technology: Water Supply	
Volume	-	
Issue	-	
Pages	99-105	
Country of origin	Germany	
Setting	Germany (Saxony)	
Database	Searched within reference list	
Search terms	-	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Floods	100
	2) Heavy rainfall	100
Time horizon	-	
Risks	• Increasing inputs of organic matter into raw waters requires a higher degree of treatment plant efficiency, mostly requiring changes to the whole treatment technology and supply system operation	99
	• Increasing concentrations of e. g. humic substances deteriorate the coagulation of water contaminants	99
	• The disinfection by-product formation potential and the microbial contamination within the supplying system will increase with decreasing treatment efficiencies	99
	• Consequences of increasing concentrations of particles, algae and organic matter and temporary changes in iron and aluminum concentration within the raw water are: → More chemicals and flushing water are needed → Higher amounts of sludge are produced → There will be a faster breakthrough of filtration plants	100
	• Water suppliers are increasingly confronted with rising costs of operation and waste disposal as well as with sudden and long-term declines in raw water quality	100
	1) • Extreme events (e. g. floods) can even culminate in temporary system breakdowns	100
	• Declines of reservoir water levels to improve flood protection all over Germany can negatively influence raw water quality	100

	2) • Heavy rainfall causes an abrupt rise of inflow to the drinking water reservoirs followed by high increases in turbidity, organic load and iron concentration → The consequences for drinking water treatment were: → Increase in coagulant dosage → Increase in flushing water → Increased amounts of sludge produced → Decreases in filter run time	100
Opportunities	-	
Adaptation strategies	• Conventional treatment processes, especially efficient processes to remove dissolved organics and particles are to be applied and optimised using varying raw water qualities	100
	• A novel tech-nique in water treatment (direct nano-filtration of reservoir water) is considered	100
	• Coagulation and filtration are the chosen technologies to treat raw water with low organic loads and variable particle concentrations. To treat raw water with high concentrations of organic compounds, increased requirements exist. Therefore, process combinations of oxidation/biofiltration and nanofiltration (with and without pre-t treatment) have to be applied in addition to the conventional processes of coagulation and filtration	102
	• Using decision-making tool that the author developed to optimize reservoir management and consequently drinking water treatment	104
Adaptation barriers	-	

Title	***Bayerische Klima-Anpassungsstrategie (BayKLAS)***	Page
Author	Bayerisches Staatsministerium für Umwelt und Gesundheit (ed.)	
Year	2009	
Type of Reference	Report	
Type of Article	Empirical Paper (Case Study)	
Source	http://www.regensburg.de/sixcms/media.php/121/broschuere_bayerisc he_klimaanpassungsstrategie.pdf	
Volume	-	
Issue	-	
Pages	1-67	
Country of origin	Germany	
Setting	Germany	
Database	Searched within reference list	
Search terms	-	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	

Climatic parameters	1) Temperature	17
	2) Storms	17
	3) Low water	17
	4) Floods	17
	5) Heavy rainfall	17
	6) Drought	17
Time horizon	-	
Risks	• Changes in the availability of ground water during the seasons	17
	• Infrastructural damage caused by extreme weather events	17
	• Changes in temperature as well as changes in the quality of raw water and the ground water	17
Opportunities	-	
Adaptation strategies	• Ensure the availability and quality of raw water sources	17
	• Early detection of adverse changes in water quality and quantity	17
	• Optimisation of monitoring systems for low flow management	18
	• Increase number of reservoir storages	18
	• Extension of water portection areas	18
	• Increase number of water intakes	18
	• Increase number of storages	18
Adaptation barriers	-	

Title	***Quantifying the urban water supply impacts of climate change***	Page
Author	Jeffrey K. O'Hara, Konstantine P. Georgakakos	
Year	2008	
Type of Reference	Journal	
Type of Article	Empirical Paper (Case Study with a Scenario Analysis)	
Source	Water Resources Management	
Volume	22	
Issue	10	
Pages	1477-1497	
Country of origin	United States of America	
Setting	United States of America (California)	
Database	Google Scholar	
Search terms	"climate change adaptation" AND "supply of water" "climate change adaptation" AND "water management" "climate change adaptation" AND "water resources management"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate im-pacts	-	
Climatic parameters	1) Precipitation	1478
	2) Temperature	1478
	3) Evaporation	1478
	4) Floods	1478

Time horizon	2030	
Risks	-	
Opportunities	-	
Adaptation strategies	• Expanding storage reservoirs	1478
	• Expanding existing water storage facilities	1478
	• Urban water reservoir storage allows agents to transfer water both within and between years from periods when supply is high to periods when demands are high	1478
Adaptation barriers	-	

Title	***Climate change and water resources: A primer for municipal water providers***	Page
Author	Kathleen A. Miller, David Yates	
Year	2005	
Type of Reference	Book	
Type of Article	-	
Source	-	
Volume	-	
Issue		
Pages	1-41	
Country of origin	United States of America	
Setting	United States of America (New York)	
Database	Google Scholar	
Search terms	"climate change adaptation" AND "water industry"	
Scientific theories	-	
Definitions		
Global change / Climate change	*"Any trend or persistent change in the statistical distribution of climate variables (temperature, humidity, wind speed, ...)"*	71
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1) Precipitation	37
	2) Temperature	37
	3) Wind speed	41
	4) Evaporation	37
	5) Floods	40
	6) Drought	40
	7) Low water	48
	8) Sea level	45
	9) Heavy rainfall	40
Time horizon	-	
	2) Warmer water temperatures have directs impacts on water quality (for example by reducing dissolved oxygen concentrations)	48
	4) • Evaporative water losses could increase the salinity of surface waters (lakes, reservoirs)	48

	5) • Physical damage to water storage and treatment facilities • Floods increase the risk of water source contamination from sewage overflows, and runoff from agricultural land and urban areas • The flooding caused by Hurricane Floyd (1999), Hurricane Ivan (2004), and heavy spring rain in 2005 resulted in turbidity values in the Ashokan Reservoir (New York) between 300 and 500 NTU	48 / 49
	7) • Declining stream flows and lake levels lead to water quality deterioration because nutrients and contaminants become more concentrated in reduced volumes of carrying water	48
	8) • Sea level rise leads to saltwater intrusions into estuaries and freshwater aquifers → Ground water is still contaminated several miles inland of the coast → This intrusion has driven the location of well fields and treatment facilities inland • Damage to freshwater infrastructure caused by flooding	45 / 46
	9) • Heavy precipitation events may result in increased leaching and sediment transport, causing greater sediment and non-point source pollutant loadings to watercourses → Makes water treatment more difficult	48
Opportunities	-	
	• Stream Management Program to reduce streambed and streambank erosion during stream basefl ow using a geomorphic approach (Catskill Mountains – New York)	50
	• Turbidity reduction programs: NYCDEP conducted a study of structural (intake design, turbidity curtains) and non-structural (operational) alternatives to control turbidity	50
Adaptation barriers	-	

Title	***Adaptation options for the near term: climate change and the Canadian water sector***	Page
Author	Rob de Loe, Reid Kreutzwiser, Liana Moraru	
Year	2001	
Type of Reference	Journal	
Type of Article	Theoretical Paper (Literature Review)	
Source	Global Environmental Change Part B: Environmental Hazards	
Volume	11	
Issue	3	
Pages	231-245	
Country of origin	Canada	
Setting	Canada	
Database	Google Scholar	
Search terms	"climate change adaptation" AND "public water supply" "climate change adaptation" AND "water management" “climate change adaptation" AND "water resources management"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	

Vulnerability	-	
Adaption to climate impacts	*"In essence, adaptations are adjustments in response to climate stimuli. These adjustments may be planned or unplanned. They may take the form of institutional, technological, or behavioural changes.* *Decisions to adapt can be made by individuals, communities, corporations, governments, and international and transnational bodies."* (Smithers and Smit, 1997; Feenstra et al., 1998)	232
Climatic parameters	1) Precipitation	231
	2) Temperature	234
	3) Evaporation	231
	4) Drought	234
	5) Low water	234
Time horizon	-	
Risks	• Reduced supply and demand	233
	• Drop in ground water levels, at existing municipal wells, in the range of 5-20 m	234
	• A 10% reduction in peak discharge of the spring food will occur which will decrease the fushing action required to remove accumulated sediment and sludge from the Grand River, thus affecting water quality	234
	• Water and wastewater treatment systems become more sensitive which leads to higher frequency of system problems or failures	234
Opportunities	-	
Adaptation strategies	• Drought contingency planning	233
	• Increase water intake pumping capacity	233
	• Promote water conservation	233
	• Seek alternative water sources (e.g., Great Lakes pipeline)	235
	• Technological adjustments such as leak detection and system optimization	235
	• Increase intake capacity (for municipalities taking from surface sources)	235
	• Construct new wells or deepen existing wells	235
	• Demand management measures such as water rationing, public education, water pricing, and installation of water-saving equipment	236
Adaptation barriers	-	

Title	***Climate change impacts on water management and adaptation needs in Europe***	Page
Author	Zbigniew W. Kundzewicz	
Year	2006	
Type of Reference	Report	
Type of Article	Theoretical Paper (Literature Review)	
Source	http://ec.europa.eu/research/environment/pdf/kina22422ens_web_water_and_cc.pdf	
Volume	-	
Issue	-	
Pages	106-110	
Country of origin	Poland	
Setting	-	
Database	Google Scholar	

Search terms	"climate change adaptation" AND "water management" "climate change adaptation" AND "water resources management" "climate change adaptation" AND "public water supply"	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	*"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." (IPPC)*	107
Climatic parameters	1) Temperature	106
	2) Precipitation	106
	3) Sea level	106
	4) Floods	107
Time horizon	-	
Risks	1) & 2) • Climate changes cause changes in both water supply and water demand • Increasing temperature and variability in run-off are likely to lead to adverse changes in water quality → Turbidity increase → Algal bloom → Mobilizing and washing away pollutants, pathogens, and thermal pollution	107 / 108
	3) • Sea level rise will extend areas of salinization of ground water and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems	107
Opportunities	-	
Adaptation strategies	*Supply side – enhance water supply:*	
	• Desalination of sea water	109
	• Conjunctive use of surface water and groundwater	109
	• Increased storage capacity for surface water, ground water & rain water	109
	• Water transfer	109
	Demand side – reduce water demand:	
	• Water demand management through metering, promoting water saving technologies	109
	• Leak reduction	109
	• Soil moisture conservation e.g. through mulching	109
	• Market-based instruments, e.g. water pricing	109
	• Re-allocation of water to high-value uses	109
	• Awareness raising	109
	Too much water (flooding, heavy rainfall):	
	• Reduce load through enhancing implementation of structural (technical) protection measures (dikes, relief channels, enhanced water storage)	109
	• Watershed management "to keep water where it falls" and reduce surface runoff and erosion	109
	• Flood forecasting and warning	109
	• Flood insurance	109
Adaptation barriers	• Significant costs	110

Title	***Deutschland im Klimawandel – Anpassung ist notwendig***	Page
Author	Bastian Schuchardt, et al.	
Year	2008	
Type of Reference	Report	
Type of Article	Theoretical Paper (Literature Review)	
Source	Umweltbundesamt	
Volume	-	
Issue	-	
Pages	1-14	
Country of origin	Germany	
Setting	Germany	
Database	Google Scholar	
Search terms	Klimawandel UND Anpassung UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	*„Klimaanpassungsmaßnahmen dienen der Bewältigung der Folgen eines sich wandelnden Klimas und der Vermeidung künftiger Gefährdungen. Anpassung zielt darauf, die Risiken und Schäden gegenwärtiger und künftiger negativer Wirkungen zu verringern oder damit potenzielle Vorteile zu erzielen.“* (Grünbuch der Europäischen Kommission „Anpassung an den Klimawandel in Europa – Optionen für Maßnahmen der EU“ vom Juni 2007)	8
Climatic parameters	1) Temperature	5
	2) Precipitation	5
	3) Heavy rainfall	7
	4) Drought	5
	5) Floods	7
	6) Low water	7
	7) Sea level	5
Time horizon	2100	5
Risks	• Changes in gound water levels → Water shortages	7
Opportunities	-	
Adaptation strategies	• More efficient usage of water resources	9
	• Storage of water in reservoirs and aquifers	9
	• Cross-linking of water companies	9
	• Water saving measures in industry, agriculture and households	9
Adaptation barriers	-	

Title	***Extreme Wetterereignisse und ihre wirtschaftlichen Folgen: Anpassung, Auswege und politische Forderungen betroffener Wirtschaftsbranchen***	Page
Author	Karl W. Steininger, Christian Steinreiber, Christoph Ritz (ed.)	
Year	2005	
Type of Reference	Book chapter	
Type of Article	-	
Source	-	
Volume	-	
Issue	-	
Pages	177-187	
Country of origin	Austria	
Setting	Austria, Germany	
Database	Google Scholar	
Search terms	Klimawandel UND Anpassung UND Wasserwirtschaft	
Scientific theories	-	
Definitions		
Global change / Climate change	-	
Vulnerability	-	
Adaption to climate impacts	-	
Climatic parameters	1.) Drought	182
	2.) Floods	178
Time horizon	-	
Risks	1) • Shortages in water availability because drinking water supply does not have enough reserves • Freezing of pipes in winter caused by missing snow cover	183
	2) • Intrusion of polluted water into drinking water pipes → Impairment of the water quality	179
Opportunities	-	
Adaptation strategies	• Emergency water supply in case of disasters such as floods	185
	• Cross-linking of water companies	183
Adaptation barriers	-	

Appendix D: Definitions

Table 7: Definitions categorised by author

	DEFINITIONS		
Author	***Global change / Climate change***	***Adaptation to climate impacts***	***Vulnerability***
MAHAMMADZADEH, M. (2010)		MAHAMMADZADEH, M. (2010) refers to the definition of the „3rd Assessment Report“ of the IPCC from 2001: „Anpassung ökologischer, sozialer oder ökonomischer Systeme als Reaktion auf aktuelle oder erwartete klimatische Stimuli und deren Auswirkungen und Einfluss verstanden. Der Begriff Anpassung bezieht sich dabei auf Veränderungen in Prozessen, Handlungsroutinen oder Strukturen, um potenzielle Schäden abzumildern oder aufzuheben, oder mögliche Vorteile aus dem Klima-wandel zu ziehen. Dies beinhaltet Maßnahmen zur Verminderung der Verwundbarkeit von Kommunen, Regionen oder Aktivitäten gegenüber Klimawandel und –variabilität.“	
JARRAUD, M. (2008)		JARRAUD, M. (2008) refers to the definition of the “4th Assessment Report” of the IPCC from 2007: “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.”	
ROGERS, P. (2008)		ROGERS, P. (2008) refers to “The Synthesis Report” of the “4th Assessment Report” of the IPCC from 2007: “Two kinds of adaptation have been characterized by the IPCC: autonomous adaptations, which arise over time in response to altered demands, and planned adaptations, which are planned in advance of the climate change.”	
HERSH, R.; WERNSTEDT, K. (2001)			HERSH, R.; WERNSTEDT, K. (2001) refer to the “3rd Assessment Report” of the IPCC from 2001: “Vulnerability underlines the point that vulnerability to climate change impacts is related not simply to changing average conditions but to increased climate variability and extreme events.”

	DEFINITIONS		
Author	***Global change / Climate change***	***Adaptation to climate impacts***	***Vulnerability***
ZWOLSMAN, J.J.G.; VAN BOKHOVEN, A. J. (2007)	ZWOLSMAN, J.J.G.; VAN BOKHOVEN, A.J. (2007) refer to the “3rd Assessment Report” of the IPCC from 2001: “Climate change will lead to an intensification of the hydrological cycle, on a global, regional, and local scale.”		
ZEBISCH, M. et al. (2005)	“Global change is a far-reaching and widely used collective term. We understand this term not only to refer to climate change, but also to trends in other factors that reflect human influence on the Earth system, i.e. the era of the so-called Anthropocene.”	ZEBISCH, M. et al. (2005) refer to the “3rd Assessment Report” of the IPCC from 2001: “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or capitalizes on beneficial opportunities.”	ZEBISCH, M. et al. (2005) refer to TURNER et al. (2003): “The likelihood of a specific human-environment system to experience harm due to changes in society or the environment, accounting for its adaptive capacity.”
ARNELL, N. W.; DELANEY, E. K. (2005)	“Climate change is one of many drivers which may lead to changes in the external conditions for an organisation, but is distinctive in two main ways. It affects the natural resources used by the organisation – conventionally these are assumed to be constant – and second it is both uncertain and, in many senses, contested and controversial.”		
ECONOMIC COMMISSION FOR EUROPE (ed.) (2009)	The ECONOMIC COMMISSION FOR EUROPE (ed.) (2009) referes to the “United Nations Framework Convention for Climate Change” (article 1) from 1992: “A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”	The ECONOMIC COMMISSION FOR EUROPE (ed.) (2009) referes to the definition of the “Synthesis Report” of the “4th Assessment Report” of the IPCC from 2007: “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.”	The ECONOMIC COMMISSION FOR EUROPE (ed.) (2009) referes to the IPCC “Synthesis Report” from 2007: “Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes.”

	DEFINITIONS		
Author	***Global change / Climate change***	***Adaptation to climate impacts***	***Vulnerability***
DE LOE, R.; KREUTZWISER, R.; MORARU, L. (2001)		DE LOE, R.; KREUTZWISER, R.; MORARU, L. (2001) refer to the definition by SMITHERS, SMIT (1997) & FEENSTRA et al. (1998): "In essence, adaptations are adjustments in response to climate stimuli. These adjustments may be planned or unplanned. They may take the form of institutional, technological, or behavioural changes. Decisions to adapt can be made by individuals, communities, corporations, governments, and international and transnational bodies."	
RAMAKER, T.A.B. et al. (2005)	"Climate change is a consequence of human-induced rapid accumulation of carbon dioxid and other greenhouse gases in the atmosphere, though the sensitivity of the climate system is not fully understood."		
MILLER, K.; YATES, D. (2005)	"Any trend or persistent change in the statistical distribution of climate variables (temperature, humidity, wind speed, ...)"		
KUNDZEWICZ, Z. W. (2006)		KUNDZEWICZ, Z. W. (2006) refers to the "3rd Assessment Report – The Scientific Basis" of the IPCC from 2001: "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."	
SCHUCHARDT, B. et al. (2008)		SCHUCHARDT, B. et al. (2008) refer to the „Grünbuch der Europäischen Kommission" from 2007: „Klimaanpassungsmaßnahmen dienen der Bewältigung der Folgen eines sich wandelnden Klimas und der Vermeidung künftiger Gefährdungen. Anpassung zielt darauf, die Risiken und Schäden gegenwärtiger und künftiger negativer Wirkungen zu verringern oder damit potenzielle Vorteile zu erzielen."	

(Own illustration.)

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Abstract

The primary objective of this work was to analyse how water companies are affected by climate change and how they try to adapt to it. Therefore, a systematic literature review was being accomplished.

The work is being divided into a theoretical and a methodological part. First of all an overview of the climatic changes that are projected to occur during the next years is being given. Then, resulting impacts on the water cycle are being pointed out. Furthermore, raw water sources, water companies obtain water from are being defined as well as the treatment process. Within the methodological part the approach of a systematic literature review is being applied, which includes the selection of references as well as their evaluation.

The results of the literature review are that concerning the effects of climate change on water companies, the risks water providers might face, clearly predominate possible opportunities. Especially the deterioration of the raw water quality caused by increasing temperatures, floods as well as heavy rainfalls can be seen as a serious problem. Moreover, the most often mentioned adaptation strategies are dealing with quantitative water problems such as measures to increase storage as well as treatment capacity or leakage reductions.

All in all it can be stated that there is still uncertainty about how climate change is going to effect water companies, especially concerning water quality changes and the treatment process.

Keywords: Climate change adaptation, Global warming, Literature review, Water providers, Water supply, Water utilities

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