KU LEUVEN
HOGESCHOOL-UNIVERSITEIT BRUSSEL
HUB

FACULTY OF ECONOMICS & BUSINESS

Internally Organised Master's Thesis

The Future of Water

What actions can be undertaken to guarantee a future with sufficient freshwater for the three sectors in the world?

Laura VANDERNOOT

Master's Thesis Submitted for the Degree of
Master of Science in Business Administration
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FACULTY OF ECONOMICS & BUSINESS - CAMPUS BRUSSELS (HUBRUSSEL)
WARMOESBERG 26 – B 1000 BRUSSELS BELGIUM

KU LEUVEN | HOGESCHOOL-UNIVERSITEIT BRUSSEL (HUB)

FACULTY ECONOMICS AND MANAGEMENT

Summary Master's Thesis

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Summary

1. Problem Definition and Research Question

What is water exactly? In chemistry and physics water is defined as "a molecule consisting of two hydrogen and one oxygen atom, symbolized in the chemical formula H_2O."(Stikker, 1998, p.43) Without freshwater we cannot live. Therefore it is important to realise that we are using this resource at an unsustainable speed. Demand already exceeds supply and freshwater availability is and will become a very important issue for future generations. Today, 20% of the world's population is experiencing a water shortage. (WEF, 2009) With a growing population and economic development in mind, we can conclude this problem is not going to diminish.

The earth's surface consists for 70% of water, out of which only 3% is freshwater. (Lazlad, 2007, p.7) Water consumption can be divided into three big sectors: irrigation and livestock in the agricultural sector uses 70% of the world's freshwater resources, 22% is used in the industry and only 8% corresponds to residential use. The well-known solutions of dry toilets or showering instead of bathing are thus not the ones that will have a major impact on the reduction of the global water use. (Water Futures Partnership, 2009, p.4)

Our Central Research Question (CRQ) is the following: "What actions can be undertaken to guarantee a future with sufficient freshwater for the three sectors (households, industry and agriculture) in the world?" Our research was aimed at actions that can be undertaken from an environmental economics point of view. The environment is of crucial importance, but the costs and benefits of each option have to be balanced against one another. The specific problem statement further guides us towards global action and better water management techniques that can avoid a war for water in the future.

Our research objectives helped us creating building blocks towards an answer on the CRQ. Our first research objective consists of describing water as a global, economic good. We discuss demand, supply and equilibrium of freshwater around the world. This report shows that in future decennia freshwater demand will continue to exceed supply and water scarcity issues will increase.

The second research objective is to discover the main world water challenges of the future decades. A lot of money is needed to develop techniques to waste less, to purify, to desalinate or to recycle water. Most countries do not have enough funds to invest in any of those techniques. Therefore, water scarcity leads us to the depletion of natural resources, which in the long run could lead to competition between countries to obtain water. We also deepen on other aspects such as the quality and the price of water around the world. Can water be seen as an economic good? Can privatization of freshwater resources ensure access for everyone? Do we pay enough for water? We mainly used data from the OECD, the IWMI (International Water Management Institute) and the UNEP (United Nations Environment Program) (2008) to find an answer to those questions.

Our last research objective consists of revealing solutions to tackle the water scarcity problem in the future for the three sectors, keeping our main focus on the agricultural sector, which has the biggest reduction potential. New, inventive approaches to tackle the water scarcity problem are discussed. For example: we analyse how a change in people's diet can influence a nation's water footprint.

A lot of research by, *inter alia*, Hoekstra, Mekonnen and Vanham (2013) has been conducted about the water consumption of different diets. Meat eaters consume a lot more water than vegetarians and therefore the average water footprint of an American is much higher than that of an Asian person. (Institution of Mechanical Engineers, 2013) Are consumers ready to change their nutritional habits? Are they ready to buy substitutes for meat such as in-vitro hamburgers or insects? Can water labels change the consumers' behaviour? Can new regulations be implemented to make sure water is used more wisely? We answered those questions using the existing literature and interviews with Mr Marc Buysse, director-coordinator of AquaFlanders, and Jean-Marie Kindermans, ex-production director of Vivaqua, as our main sources of information.

Proposing original and realistic solutions to tackle the water stress problem in the long run and on a global scale created added value. We also contributed to the literature by combining several sources in an original way and by contacting people with specific knowledge and information on the topic. Furthermore, we created a "water wise label" for food products in order to make this theoretical solution more understandable and visible to readers.

2. Research method

a) Justification of the research method

Our research was mainly based on secondary data, which we collected from a literature review. We decided not to gather data ourselves, as it would be impossible to make an analysis on a global scale within the time limit.

For the first two research objectives we conducted a literature study. We analysed qualitative data and looked at the differences in regulations for water across regions. We studied the pros and contras of privatization going through the works of Gleick, Wolff, Chalecki and Reyes (2002, pp.1-37), among others. We also used quantitative, statistical data from the OECD, Aquastat and Eurostat in order to compare water use and prices among different countries.

For our last two research objectives, we collected data interviewing Mr Marc Buysse, director-coordinator of AquaFlanders and Mr Jean-Marie Kindermans, ex production-director of Vivaqua, as their expertise provided us new insights into the subject. Our interview results were then transcribed from tape. In this report, a radical-humanist approach is taken to try to get people out of their existing thinking patterns. People will have to get used to new diets (which are less water consuming) and new regulations.

b) Collection and processing of the data

Our approach towards the research was deductive. From the literature we explained the major problems concerning freshwater. We mainly retrieved scientific articles from e-sources such as Elsevier ScienceDirect, EBSCO and Google Scholar. We used several search terms including “water scarcity”, “water privatization”, “water future”, “water pricing” and “freshwater challenges”. To build on our first part, we visited the PASS (parc d’aventures scientifiques) in Mons (Belgium), which by October 2013 had a special exhibition about water, as well as Hidrodoe in Herentals (Belgium), where water facts are taught to children in an interactive way. A contact person from the European Commission also provided us with some brochures concerning water projects organized in the European Union. The interviews we conducted gave us new insights into the subject and helped us complete the work.

As might be clear from previous information, we used an exploratory research strategy. We found out what is happening nowadays, and analysed this data in order to come up with a new perception for the future. We undertook an archival research to collect information, as we did not have enough time to gather data about water in the world ourselves. Moreover, a lot of data on this subject were already available throughout the literature.

The research is a longitudinal study in which we look at water scarcity in the world today and how it will evolve in the future. We also examine the causal relationships between present actions and their impact on future generations. Although we are expected to analyse the literature in an objective way, personal opinions or a lack of data for certain regions possibly harmed the reliability of the research. Moreover, this thesis was written by European citizens, which might orient the results towards feasible solutions on European level. During the interviews we might have been threatened by an observer bias, which hindered us from interpreting the answers in an objective way.

3. Findings and conclusion

Freshwater is already a challenge in many regions and it will spread further throughout the world in the years to come. Everyone is concerned and action should be taken to provide people, industry and agriculture all over the world with sufficient freshwater. A lot of supply side measures already exist to guarantee a continuous water supply, such as the desalination of seawater, recycling of wastewater and the pumping of groundwater. Yet, recently an additional focus on demand side measures is needed to avoid the depletion of natural water resources.

Reduction in demand should be achieved through raising awareness about water related issues in all sectors. Children are the future water consumers, and they should be sensitized to this problem. Among all, the agricultural sector has the biggest reduction potential. Water labels for food could be used to raise consumer awareness. To apply for such a label, farmers will make an effort to reduce their water consumption by using new techniques like drip irrigation (explained later). The Government, consumers and businesses all have an important role to play to ensure no international water wars will take place.

Further research could focus on the carrying out of the solutions. For instance: how should the Government proceed to impose stricter regulations concerning the water consumption? How can higher water prices be imposed and how can a new water label be implemented practically? How can the Government control whether the information given by companies is right? How can insects and the in-vitro hamburger be promoted in our alimentation, and how can bigger, worldwide campaigns be organized to raise awareness in the field? Transparency in statistical data is also lacking. No uniformity exists concerning the price and the consumption of water, as it is not always clear what is included. As a consequence, future research could focus on the harmonization of water statistics, so that comparison of data becomes possible. This report provides interesting solutions and ideas, but the practical, stepwise implementation of each solution is lacking.

Preface

I would like to thank my supervisor, Mr Edward Omey, for his continuous improvement advice and Mr Marc Buysse, Director-Coordinator for AquaFlanders, and his secretary, Mrs Riet Lismont, for allowing me an interview and providing me with useful information. Also, I would like to thank Mr Luc Mouton, Senior project manager at the water company TMVW, for giving me interesting documentation and connecting me to the right people. Lastly, I would like to thank Mr Jean-Marie Kindermans, ex production-director of Vivaqua, for accepting a meeting and guiding me in my work.

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Overview of Graphs

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List of Abbreviations

AUS: Australia

BAU: Business-as-usual

BC: Before Christ

CAP: Common Agricultural Policy

CHE: Switzerland

Cm: centimetre

CRQ: Central Research Question

CWA: Clean Water Act

DEU: Germany

EIP: European Innovation Partnership

EWP: European Water Partnership

FAO: Food and Agriculture organization

FASFC: Federal Agency for the Safety of the Food Chain

FOD: Federale Overheidsdienst= Federal Public Service

GDP: Gross Domestic Product

GWP: Global Water Partnership

IEA: International Energy Agency

ILEC: International Lake Environment Committee

ISL: Iceland

IMF: International Monetary Fund

IWA: International Water Association

IWMI: International Water Management Institute

IWRM: Integrated Water Resources Management

Kg: Kilogram

Km: Kilometre

Lcd: Litre per capita per day

NGO: Non-Governmental Organization

OECD: Organization for Economic Cooperation and Development

OTA: Office of Technology Assessment

PASS: Parc d'Aventures Scientifiques

PPP: Polluter Pays Principle

PRT: Portugal

RO: Reversed Osmosis

RWSI: Relative Water Stress Index

SVN: Slovenia

TMVW: Tussengemeentelijke Maatschappij der Vlaanderen voor Watervoorzieningen

UN: United Nations

UNEP: United Nations Environment Program

VWC: Virtual Water Content

VWF: Virtual Water Footprint

WBCSD: World Business Council for Sustainable Development

WEF: World Economic Forum

WELL: Water Efficiency Labels and Standards

WF: Water Footprint

WFD: Water Framework Directive

WHO: World Health Organization

WPC: Water Production Cost

WRM: Water Resources Management

WSI: Water Scarcity Indicator

1 Introduction

From 20th of August 2013 on, the world was living on credit. The "World Overshoot Day" means that the world has consumed all natural resources that it is able to renew in one-year time. Each year, this day is coming closer to the beginning of the year. (WWF, 2013)

One of the most important resources on earth is WATER, also known as the molecule of life, because it made life possible when it appeared on earth four billion years ago. Our planet, the "blue planet", is filled with water, yet one person out of three is deprived of it. "Life hazard or civilization choice? Water is our common inheritance, access to water is a right, and saving it is a duty." (PASS, 2013)

From the second half of the 20th century, freshwater stress and scarcity have been growing throughout the world. Populations started consuming water at a scale that surpasses the rate at which water can be renewed through rain. Climate change is worsening this problem. To achieve sustainable development in the 21st century, it is important that the present generation takes action. However, as water is available for most of us so easily, consciousness of the importance and scarcity of this "blue gold" is lost. (WEF, 2009) "Water is a unique commodity with no substitute or alternative, a high future demand and a low price volatility". (WEF, 2009, p. 41)

With this awareness in mind, our report was written. It is divided into three parts. The first one deepens on the freshwater demand and supply in the world for the three sectors (households, industry and agriculture). Water is a natural resource that is unevenly distributed across areas and sectors. Can supply meet demand? The second part focuses on world water challenges. Several issues are discussed such as water conflicts, water quality and the virtual water footprint of products. Also more recent topics about water as an economic good, the price and the privatization of water are looked into. The last part offers original solutions to deal with the water scarcity problem in the three sectors in the future.

2 Water Demand and Supply for the Three Sectors in the World

2.1 Introduction

By 2050, there will be 9 billion people to feed on the planet and climate change will increase the number of floods and droughts, which will put extra pressure on our freshwater resources. (United Nations, 2013b) In this chapter, the total water supply is compared with the total water demand. The purpose is to find an answer to the question whether water supply can satisfy demand for the three sectors in the future.

2.2 Freshwater Supply

2.2.1 The Earth's Water Cycle

Availability of freshwater depends on the earth's water cycle. Water evaporates from the earth's surface into the atmosphere. When water in gaseous state gets into contact with suspended dust, molecules cluster around the dust particle. Depending on the temperature, the water then condensates and falls back to the surface in the form of rain or snow. Part of this water flows into rivers and lakes and returns to the sea. The other part is absorbed by the ground and becomes soil moisture or groundwater. (PASS, 2013)

The sun governs the earth's water cycle. The amount of water available on the planet is thus always constant. Water is reused thanks to an ever-repeating cycle where water is consumed, discharged, recycled and reused. The water we are using today is therefore still the same as the one that made life possible four billion years ago. The problem is that more people are using it in bigger quantities. This results in a shortage but also in a mismatch between places where water is available and where it is needed. (PASS, 2013)

Lazlad (2007, p. 10) states that according to Niemczynowicz (2000) the yearly amount of rain that falls on the planet is about 42.700 billion m^3. Most of this water flows back to the sea before humans are able to use it. Only 9.000 to 14.000 billion m^3 of rainfall remain annually available as freshwater resource. Unfortunately, this rain is unequally divided between regions but also in time. In some regions 90% of the yearly rain falls in a period of three to four months, which makes the water scarcity problem very challenging. (Lazlad, 2007)

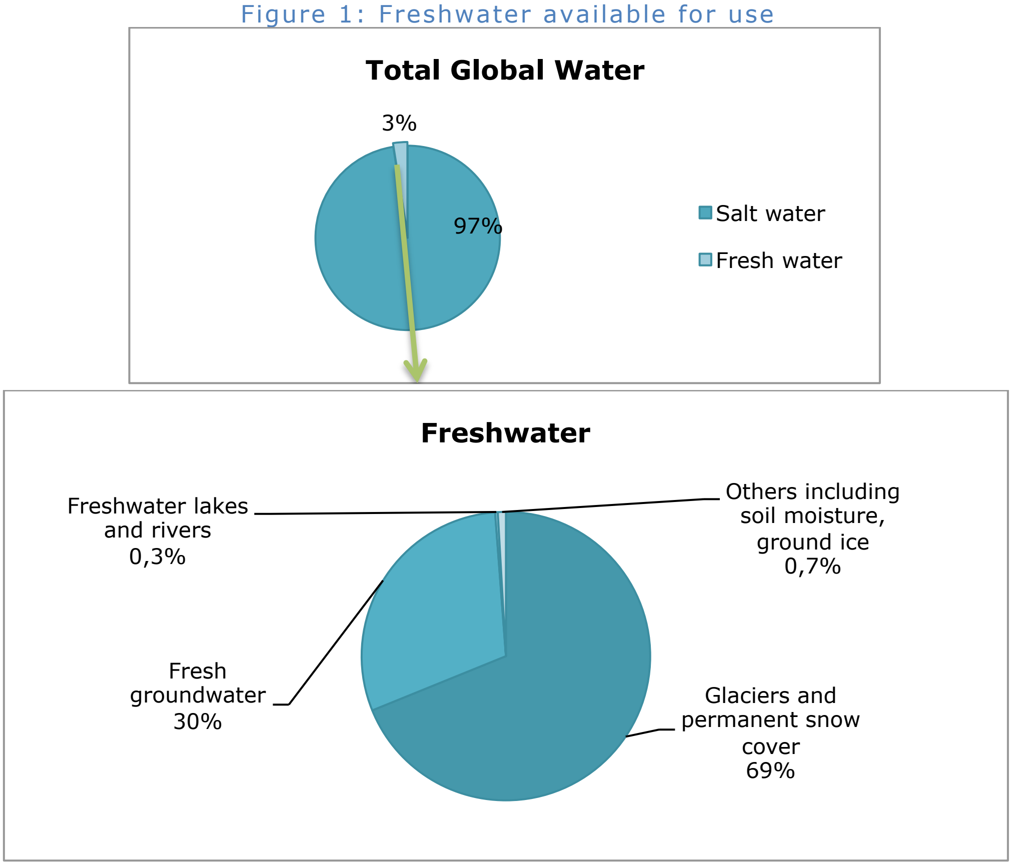
2.2.2 Freshwater as a Part of Total Water

About 70% of the earth's surface consists of water. Our planet thus well deserves her surname "the blue planet". About 97% of the total water on earth is salt water and only 3% is freshwater. In figure 1 we see that about 69% of this freshwater can be found in the form of ice or snow in the Poles. Another 30% is located underground and 0,7% is soil moisture or ground ice, which leaves only 0,3% or 93 billion m^3 of freshwater concentrated in lakes and rivers, where it is easily accessible to humans. (PASS, 2013)

If freshwater reserves are being depleted without being renewed, it will decrease the 0,3% of accessible freshwater and irreversibly diminish the world's water capital. (Stikker, 1998, p. 49)

From the 3% of total freshwater available on the planet, 70% or 9,800 billion m^3 of water is needed to sustain the natural ecosystem, which leaves only 30% or 4.200 billion m^3 available for all human uses. When we divide this number by the total world population of 7 billion it gives an average of 600 m^3 of freshwater available per person per year. (Lazlad, 2007)

Figure 1: Freshwater available for use



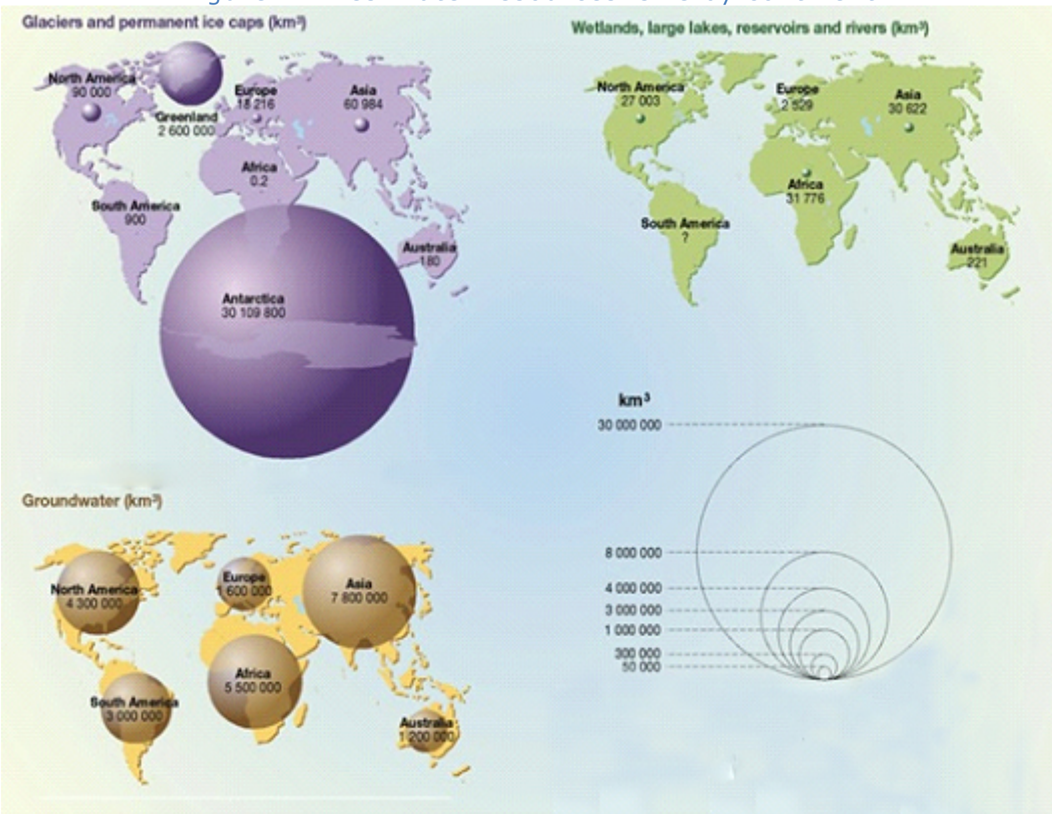
Source: (Stikker, 1998)

2.2.3 Freshwater Resources by Continent

Figure 2 gives an overview of the freshwater resources around the world. We can see that from the total amount of freshwater, only very little is available in wetlands, lakes, reservoirs, and rivers for economic use. As resources are limited, fragile and unequally distributed, good water management is crucial. (PASS, 2013)

Different types of water can be distinguished. Groundwater can be found beneath the earth's surface in an aquifer, which is a Latin word for water transporting layer in the subsurface. This is due to infiltration of rainwater, rivers or snow. Groundwater is a relatively pure source of water as it went through a process of natural cleaning. Unfortunately, pesticides and air pollution increasingly contaminate it. Surface water is the term used for water that can be found in canals, rivers, lakes and streams. It is freshwater that is available from the earth's surface and thus easily accessible for economic use. Pollution of surface water often occurs in the form of algae, sludge and bacteria. (Vanassche, 2005)

Figure 2: Freshwater resources' size by continent



Source: (United Nations Environment Program, 2008a)

The availability of water depends on the region we live in. Some regions suffer from droughts, others from floods and, unless appropriate system like reservoirs and canalizations are installed, those regional inefficiencies will continue to occur. In table 1, the water distribution per continent is compared with its percentage of the world population. Asia contains 56% of the world population and only 26% of the world's freshwater resources, whereas Europe has 11% of the world population and 14% of the world's freshwater resources. (PASS, 2013)

Table 1: Continental inequality in water availability

Continent	% Of World population	% Of available freshwater resources
South-America	8%	34%
North-America	5%	12%
Asia	56%	26%
Europe	11%	14%
Africa	19%	11%
Australia	1%	3%

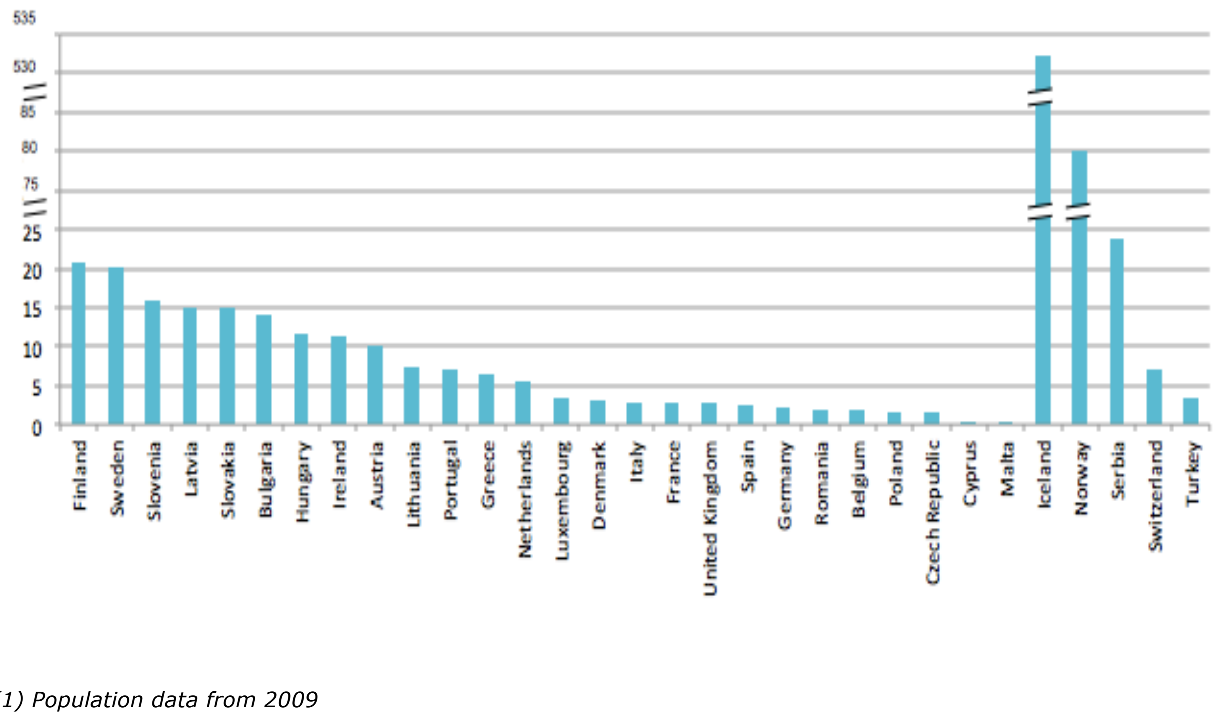
Source: (PASS, 2013)

Around 20% of the annual rain falls in the Amazon, which is inhabited by only 10 million people. The Congo River receives 30% of Africa's rainfall while it is inhabited by only 10% of Africa's population. Nine countries, namely Brazil, Russia, China, Canada, Indonesia, USA, India, Columbia and Democratic republic of Congo, account for 60% of the global freshwater resources. (PASS, 2013) The Middle East is one of the driest regions in the world as it only contains 1% of the total renewable freshwater resources. (WEF, 2009, p. 45)

In Europe, the average water resources seem to be sustainable, although parts of Southern Europe may face water scarcity problems. When looking at the annual water resources available per inhabitant (see figure 3), Finland and Sweden record the highest, whereas France, Italy, the UK, Spain, Germany and Poland (the 6 largest Member States) as well as Belgium, Romania, Czech Republic, Cyprus and Malta report the lowest annual water resources available per inhabitant. A low population density of the former as compared to the latter countries can explain this. (Eurostat, 2012b)

Some non-European countries like Iceland, Norway and Serbia are added to the graph and have a very high level of freshwater resources per inhabitant. Iceland has a very small population and a lot of mountains and glaciers. Norway is not densely populated, has a lot of snow and from end November until January only very few hours of sun. Serbia has an abundance of surface and groundwater. A lot of rivers flow through the country including the Danube, one of Europe's largest rivers (around 20% of the Danube is located in Serbia).

Figure 3: Average Freshwater Resources per Inhabitant per Year (in 1000m^3)



(1) Population data from 2009

Source: (Eurostat, 2012b)

2.2.4 Water Stress and Scarcity

According to the Falkenmark water stress and scarcity indicator (WSI), when an area is experiencing water stress this means that the annual renewable water lies below 1.700 m^3 per person per year. When the water supply drops below 1.000 m^3 per person per year, we are talking about water scarcity, as it then begins to obstruct human health and economic development. (WBCSD, 2006)

Another way to measure water scarcity is by using the Relative Water Stress Index (RWSI), used by the IMF and the World Bank among others. It is defined as the ratio between the total water use and the total renewable water supply, available through rainfall, streams, and rivers. When this ratio is above 40% we talk about water stress, and a ratio above 75% indicates physical water scarcity. (OECD, 2009) The OECD's water stress indicator is the ratio of total annual water withdrawal and the annual availability (also non-renewable water supply). Here, water stress is defined as low, when the ratio is below 10%, moderate when between 10 and 20%, medium when the ratio is above 20% and severe when above 40%. (OECD, 2009)

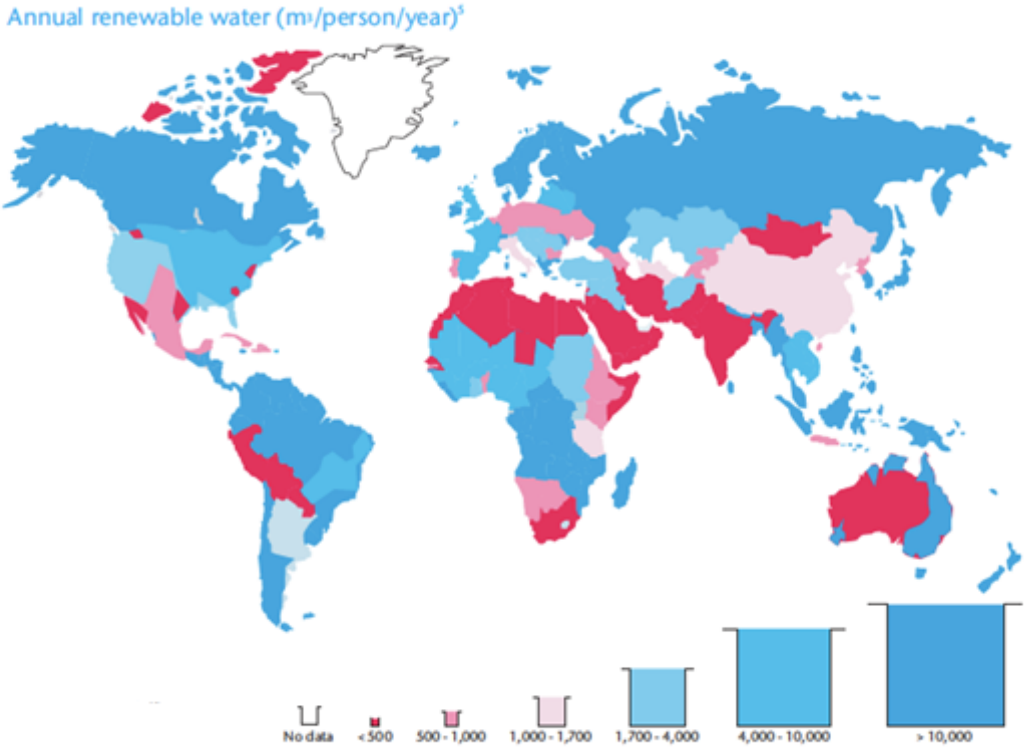
We can subdivide water scarcity into two types. Physical scarcity appears when total supply of water cannot fulfil the total demand of water, including the nature's or the ecosystem's demand. (United Nations Environment Program, 2008c) Declining water resources over time due to overuse are a proof of physical water scarcity. Economic water scarcity means that people get no access to freshwater because of a lack of human infrastructure that brings water to the people. (United Nations, 2013a)

At this point in time, one billion people have to rely on non-renewable groundwater resources for their water supply, such that water resources are getting depleted or polluted. By pumping water out of aquifers, those can get filled with saltwater, thereby reducing the amount of freshwater available on the planet. Climate change causes an increase in the sea level with as a consequence floods and droughts. Measurements show that in the 20^{th} century the sea level rose by 10 to 20 cm due to an increase in temperatures that caused the melting of land ice and more rain. (Vanassche, 2005)

Contrary to popular opinion, not only Africa is facing water problems. In America, about 210 million people live in the neighbourhood of a damaged water resource and in Europe bad irrigation systems still form a problem. (Geukens, 2013) In Europe, only four countries (or 18% of Europe's population) are considered to be water stressed: Cyprus, Malta, Spain and Italy. Those countries may face a problem of groundwater over-abstraction and thus water resource depletion and saltwater infiltration. (Benito, 2009) A UNESCO report in 2003 showed that around 48% of the world population lives in towns and cities and it is estimated that this figure will rise to about 60% by 2030. This rapid increase in urbanization will have effects on the freshwater supply to the cities that often depend on old and inadequate water supply systems. (WEF, 2009, p. 35)

Using the Falkenmark WSI we can say that today, 700 million people (almost 20% of the world's population) from 43 different countries are living in areas with water scarcity. A study undertaken by the 2030 Water Resources Group shows that water scarcity is affecting every continent and that Sub-Saharan Africa is the most water-stressed country in the world. (See figure 4) (WEF, 2009) The WEF (2009, p. 31) states that by 2025, 3 billion people (or 35% of the world's population) will live in a region with water stress. The UN (2013) estimates this figure to be almost 50% by 2030. Freshwater is in rapid decline across our planet. Europe alone increased from 15 to 28 countries with droughts in the period 1970-1980 to 2001-2011. (EEA, 2012a)

Figure 4: Water scarcity in the world



Source: (WBCSD, 2006)

The 2030 Water Resources Group states that India will face severe water deficit by 2030 if no action is taken. India's current water supply is around 740 billion m^3 per year. In the future this will grow to 1,5 trillion m^3 per year, most of which will be used for producing rice, wheat and sugar. To this we need to add India's growing population, which will be moving towards a middle-class diet in the future. China's water demand is expected to reach 818 billion m^3 in 2030, of which 50% will be used for the production of agricultural products, especially rice. Its current water supply is around 618 billion m^3 per year. A clear improvement in China's water management is needed in order to meet its future water demand. (Water Resources Group 2030, 2009)

In some rural areas, the access to freshwater may be difficult and piped water systems may be uncommon. In Africa for instance, people (especially women and children) walk around 6 km a day to bring 20 litres of water to their family. (Water and Sanitation Program, 2013) Meanwhile, they are not able to go to school in order to be educated and develop better systems to make water available for the population. According to the United Nations, 900 million people have no access to safe drinking water closer than 15 minutes walking distance (economic scarcity). People spend two to three billion days per year on fetching water. It is thus essential to develop closer drink water facilities for those people and to teach them hygienic behaviour.

According to the World Health Organization (WHO) (2013), each euro spent on water and hygiene in developing countries, yields 35 euros, as it reduces the amount of money required for health care. Moreover, the time that is lost on collecting water is evaluated at 5 billion euros per year. It is estimated that families in Africa could gain 600 euros a year by having a drink water facility in their neighbourhood. (Vandepopuliere, 2009)

However, our habits should not be imposed in developing countries. After Vivaqua (Belgian freshwater production and distribution enterprise) realised a project in Morocco to install water taps in the houses of a village, they noticed people were not using them. The reason is that women in those villages like to fetch water at the well, as it is a place where they can socialize with other women. Installing a well with controlled water quality would have been a better way to reduce economic scarcity in those villages.
(Kindermans, 2014)

2.3 Freshwater Demand

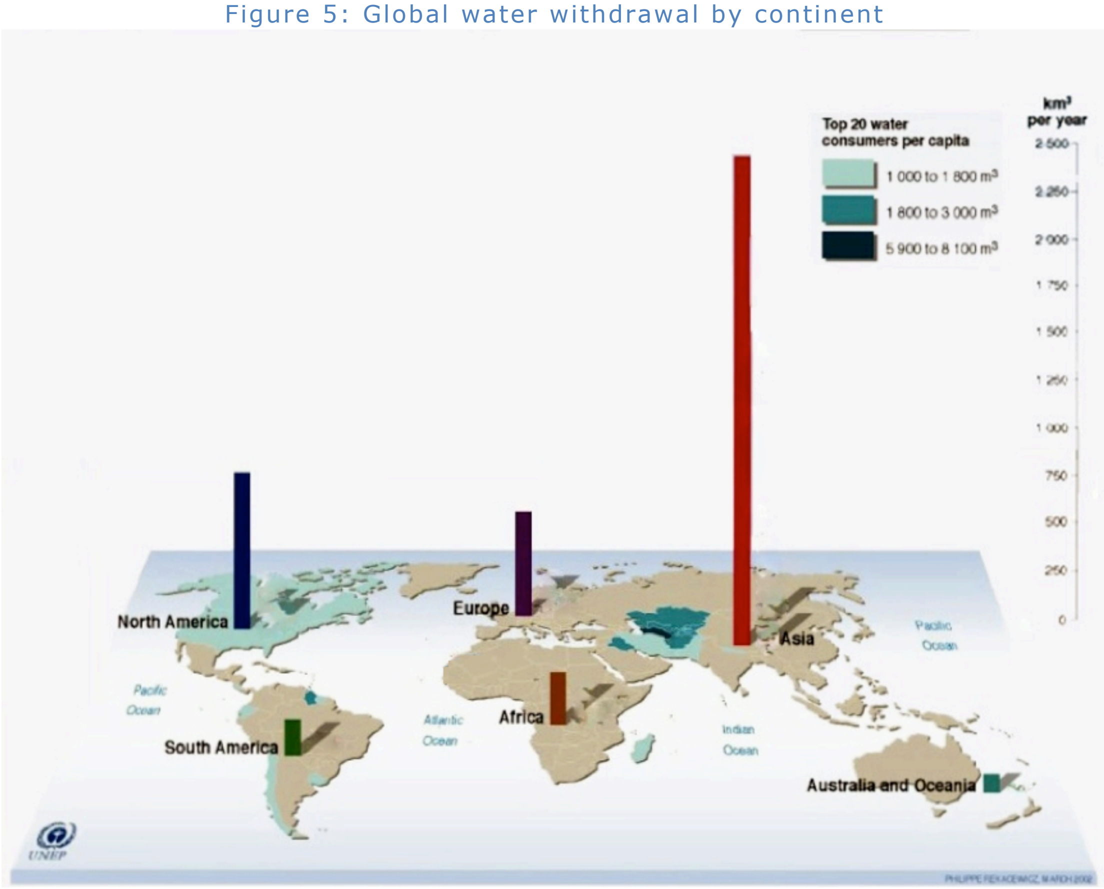
2.3.1 Minimum Water Needs

What is the minimum water need of a person? According to the WHO (2013), for domestic use, 7,5 lcd (litres per capita a day) will satisfy most people under most conditions, whereas 20 lcd should be counted for basic body and food hygiene. According to the World Water Assessment Program of the UN (2013), a minimum of 20 to 50 litres of water a day is needed to complete basic drinking, cooking and cleaning needs.

2.3.2 Water Demand per Continent

In 1995, the total water withdrawal for domestic, industrial and agricultural purposes together equalled 3.906 billion m^3 per year. (Rosegrant, 2002) Global water requirements in 2009 added up to 4.500 billion m^3 per year and, according to the Water Resources Group 2030 (2009), this amount might increase towards 6.900 billion m^3 by 2030. (Remember from part 2.2.2 that only 4.200 billion m^3 of freshwater are available for human uses) Figure 5 gives an overview the global water withdrawals by continent. Especially Asia is withdrawing a lot of water, mainly for the agricultural sector. Some of the most water consuming countries in per capita terms can also be seen in the figure such as the US, Canada, Chile and the Middle East.

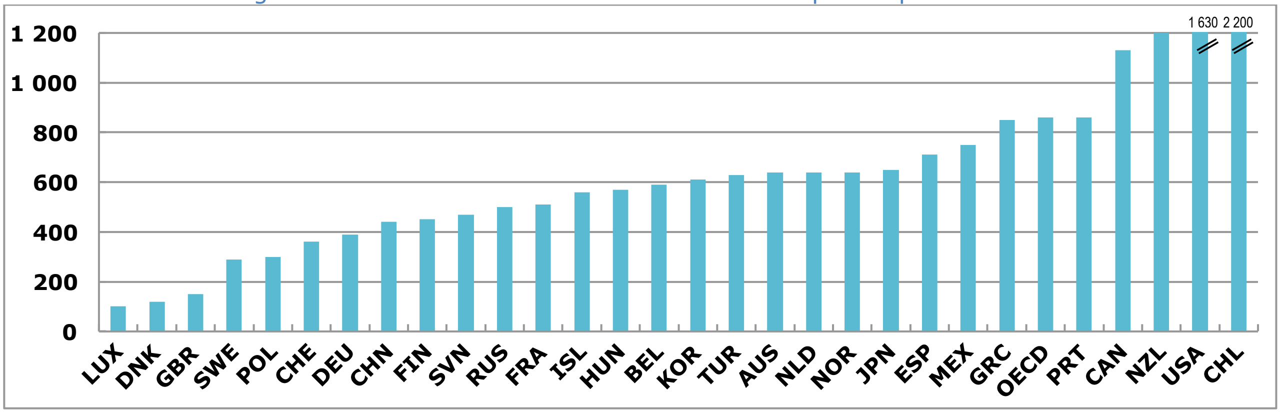
Figure 5: Global water withdrawal by continent



Source: (United Nations Environment program, 2008b)

In figure 6, the per capita withdrawals of some OECD countries are given. Chilli (6.027 lcd), The US (4.465 lcd), New Zealand (3.287 lcd) and Canada (3.096 lcd) record the highest per capita water withdrawals. The high water withdrawals in Chilli can be attributed to the copper mines, the large fruit and wine exports and the generation of hydropower. (OECD, 2011)

Figure 6: Annual water abstraction in m^3 per capita(1)



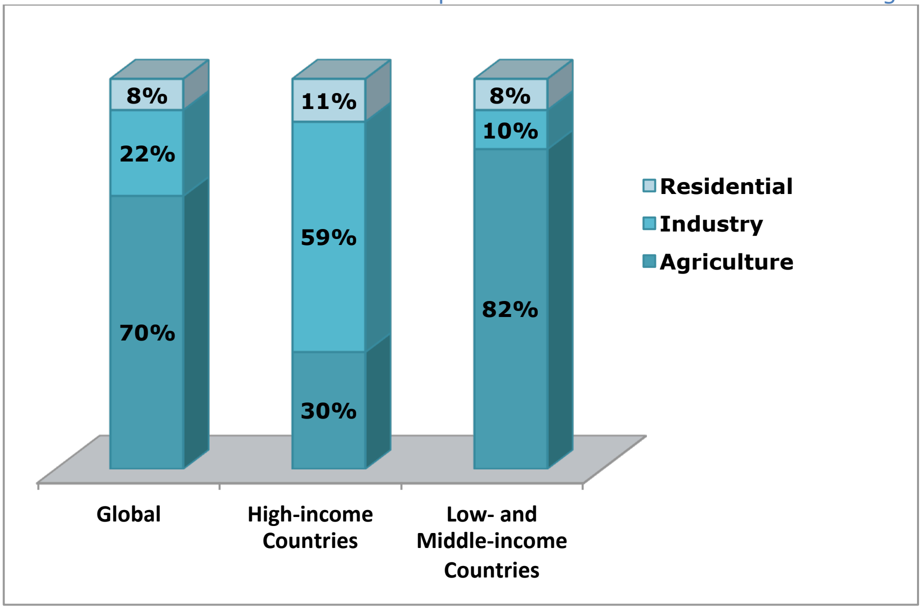
(1) Data from 2009 or latest available year

Source: (OECD, 2011)

2.3.3 Water Demand per Sector

A distinction can be made between high- and low-income countries' water consumption. (See figure 7) Industrial water use increases with income from 10% for low- to 59% for high-income countries. Domestic use also increases from 8 to 11% from low- to high-income countries. However, an inverse relationship exists between agricultural water use and income, mainly because of the less developed technologies for irrigation in developing countries. Low-income countries spend 82% of their total water on agriculture whereas for high-income countries this is only 30%. Industrial use is the biggest water consumer in high-income countries, whereas for low-income countries, the agricultural sector takes the lead. (Lazlad, 2007) On world scale, the agricultural sector remains the biggest water consumer, with a consumption of 70% or 3.200 billion m^3 annually. (Water Resources Group 2030, 2009). Agriculture is followed by the industry, using 22% of the total annual freshwater available. Only 8% (153 lcd) remains available for all domestic uses in the world. (PASS, 2013)

Figure 7: Differences in water use per sector for the main income groups



Source: (United Nations, 2003)

Table 2 shows that the industrial sector is the biggest water consumer in Belgium, followed by households and the agricultural sector. (Aquastat, 2014)

Table 2: Water withdrawals in Belgium in 2007

Total renewable water resources per capita per year= 1.736 m3	
Water withdrawals by Sector	
Agriculture	37 million m^3
Municipal	728 million m^3
Industrial	5.451 million m^3
Total	6.216 million m^3
Total per capita	589,8 m^3

Source: (Aquastat, 2014)

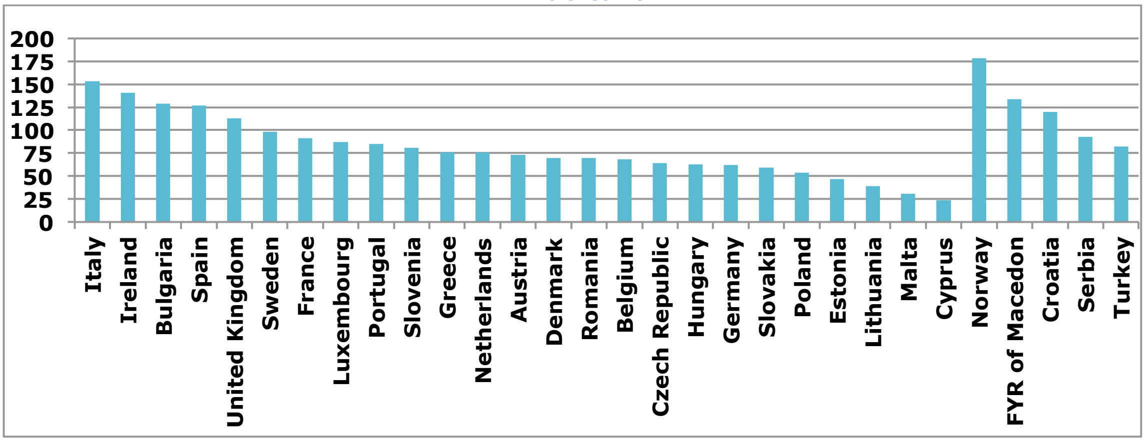
2.3.3.1 Water Demand for Households

Domestic water consumption includes water for washing, cleaning, cooking, toilet usage, but also clothes washing as well as watering plants. According to the OECD (2002), 35 to 40% of domestic water is used for personal hygiene (showering and bathing), another 20 to 30% is used for toilet flushing and 10 to 20% is used for washing clothes.

Domestic water consumption depends on the level of economic development of a region. (Water and Sanitation Program, 2013) Water demand of an African person is estimated at 20 litres a day, whereas a person in the Sahara only uses around 5 litres a day (1825 litres per year). (Lazlad, 2007) In contrast, for European and American citizens domestic water consumption equals 150 and 300 litres a day, respectively. (PASS, 2013) In 1900, an average American household consumed only 10 m^3 or 10.000 litres of water per year. Nowadays, this figure goes up to 200 m^3 or 200.000 litres of water per year. The main reason for this is that, by the beginning of the 20^{th} century, water was not easily available to households outside the large cities, whereas nowadays almost every American has easy access to water. (WHO, 2013)

In figure 8, the public water supply in the EU is shown, as it gives an idea of the water volumes directly consumed by households. In the same figure we see that most EU Member States have an annual public freshwater abstraction between 50 and 100 m^3 per inhabitant. A very high annual public water abstraction per inhabitant is seen in Ireland (141 m^3 or 386 lcd), where the public water supply is still free of charge. Other countries with a high public water abstraction rate per inhabitant are: Norway, Yugoslavia, Macedonia, Bulgaria and Croatia. Countries with a low public water abstraction rate per inhabitant are Estonia, Lithuania (due to low connection rates to the public water supply), Cyprus and Malta (as they replaced part of groundwater by desalinated seawater). (Eurostat, 2012a)

Figure 8: Annual freshwater abstraction by public water supply (2009) in m^3 per inhabitant



(1) Data from 2008 for Spain, Italy, the Netherlands, Portugal, Austria, the UK and Turkey.
(2) Data from 2007 for Germany, Ireland, Greece, France, Slovakia, Sweden and Norway.
Source: (Eurostat, 2012a)

2.3.3.2 Water Demand for the Industry

The amount of water needed in the industrial sector varies depending on the type of industry. (WBCSD, 2006) In general it is used for 3 main purposes: cooling, steam generation and as cleaning equipment. (Benito, 2009)

Non-food products require a very high amount of water to be produced. As can be seen in table 3, to produce one car, 150.000 litres of water are needed, mainly to cool the steal. An electronic chip requires 30.000 litres of non-renewable and high quality water and for 250 grams of cotton, 25 full baths are needed. (PASS, 2013)

Table 3: Water consumption of some non-food goods

Non-food good	Water consumption in Litres
1 car	150, 000
1 electronic chip	30, 000
1 jeans	10, 850
1 pair of shoes	8, 000
1 cotton T-shirt	2, 720
1 notebook	180
1 woollen sweater	150

Source: (PASS, 2013)

Energy production consumes around 15% of total water withdrawals and is therefore the biggest water consumer of the industrial sector. (IEA, 2014) In 2010, global water abstraction for energy production was estimated at 563 billion m^3. (IEA, 2012) Energy and water are interdependent of each other: energy is needed for the extraction, processing and the distribution of water, whereas water requires energy for the cooling of power plants, the creation of hydropower and for fuel extraction and production. (The World Bank, 2014)

Next to energy production, the food and beverages, metal, chemical and paper industries are also very water consuming within Europe. In the metal industry, water is needed during the manufacturing processes for cooling and heating of the machines. In the chemical industry, water is used for diluting the chemicals. The paper industry is one of the most water consuming industries, as a lot of water is contaminated during the production process. (Benito, 2009)

The International Energy Agency (2014) expects the energy consumption to increase in the future. However, as a consequence of decreasing water availability, some power plants in the US are already reducing their power generation. In Europe, nuclear power capacity will decrease between 6 and 19% from 2031 to 2060 due to a lack of cooling water. Water scarcity problems in China and India might cancel the expansion of coal and power plants. (The World Bank, 2014)

"Thirsty Energy" is an initiative from the World Bank to address water-energy problems in the future. It helps Governments prepare for future challenges in the energy sector and demonstrates the importance of a joint water management. (Thirsty Energy, 2014) Governments providing electricity at a lower price through subsidies can induce consumers to use more electricity than necessary and thus over-abstract groundwater. (Rodriguez, 2012) "AquaFit4Use" is a project of the European Commission, within the 7th Framework Programme, to make industrial production processes less dependent on freshwater. Four main industries (the paper, chemical, food and textile industries) have been analysed in detail. (AquaFit4Use, n.d.)

Europe's largest manufacturing sector is the food industry, as it provides jobs for over 4 million people and an annual turnover of more than 900 billion euros. Water is a key element in the production of food and drinks and water quality is of high importance for health issues. Re-use techniques and water management strategies are being developed to provide new water saving opportunities for this industry. (AquaFit4Use, n.d.)

The paper industry generates 6,5% of the manufacturing industry's turnover. More than 20 m^3 of water is needed for the production of one ton of white products, whereas brown products only require 1 to 2 m^3 of water per ton. During the last decades, a lot of efforts have been made to reduce this industry's water consumption. It is the leading industry in water recycling processes and re-use, but it remains the second largest water consumer. Some constraints are reducing the water consumption and contamination, without affecting the quality of the paper. A lot of research is going on in this field and several paper companies are joining forces to find appropriate solutions. (AquaFit4Use, n.d.)

The chemical sector is also trying to reduce its water consumption by increasing energy efficiency and improving production processes. It has focussed its attention on the treatment of wastewater. Most companies in Europe are committed to reduce the amount of water used per unit of production. (AquaFit4Use, n.d.)

The textile industry remains a very important water consumer in Europe (around 600 million m^3 per year), especially for the dyeing and printing of clothes, which require many rinsing steps and thus, a lot of water. It is also a big water polluter because of the chemicals needed to process the textiles. Wastewater treatment and water re-use are the exploited solutions in this industry. (AquaFit4Use, n.d.)

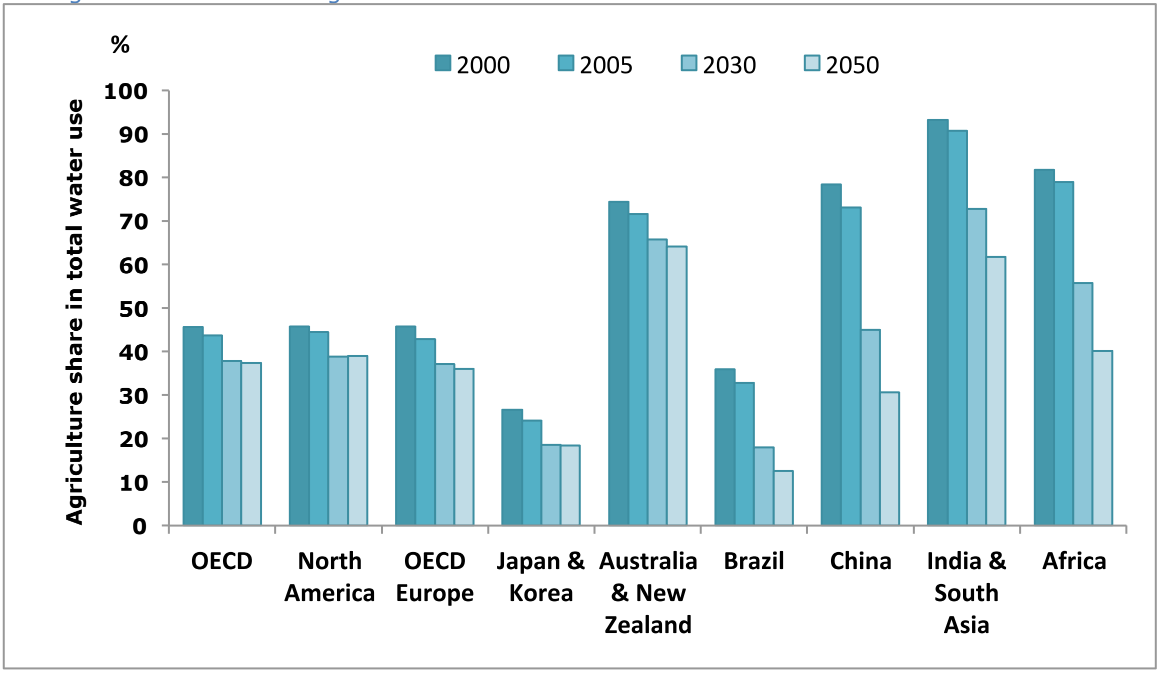
In Belgium, industries have to pay a lot more for their wastewater treatment than households, as the common purification centres are not always adapted to purify polluted water from the industry. It often results cheaper for industries to have their own, adapted wastewater treatment installation. (Kindermans, 2014)

2.3.3.3 Water Demand for Agriculture

The biggest water consumer in agriculture is irrigation. Today, around 250 million hectares of land are irrigated worldwide. This is about five times more than at the beginning of the 20th century. Food production had to grow in order to stabilize prices and to increase output for a growing population. Unfortunately, bad water management has lowered groundwater tables, decreased the water quality and depleted resources around the world. (Rosegrant, 2002) Irrigated farming accounts for 83% of total water withdrawals in Greece, 68% in Spain, 57% in Italy and only 10% in North European countries. (Berbel, 2006)

The Institution of Mechanical Engineers (2013) says that water demand in agriculture will triple and meat demand will increase by 73% by 2050. The OECD (2013) also states that agricultural production is expected to grow by more than 50% by 2050 due to the increasing population. Nowadays, 70% of agricultural land is dedicated to livestock. We can conclude that there will not be enough space, nor water to supply meat for a growing population. (ARTE, 2013) Farmers will have to use water in a more efficient way, for instance by installing water saving irrigation techniques or by planting crop varieties that are drought or flood resistant. In figure 9, expectations for the share of agriculture in total water withdrawals are shown for some regions. (OECD, 2013) By increasing efficiency, the agricultural share of total water withdrawals can be reduced, even with a growing population. However, the agricultural share of water withdrawals remains high.

Figure 9: Share of agriculture in total water withdrawals from 2000 to 2050.



Source: (OECD, 2013)

Every product that we use or food we eat requires huge amounts of water to be produced. The total amount of water needed to produce a good along its whole production process is called the "Water Footprint" (WF) of a product. It shows the invisible link between consuming goods in one part of the world and its impact on distant water resources. This method was originally developed by Allan (1998) who saw those virtual water imports as a solution for the water scarcity problems in the Middle East. (Lazlad, 2007)

Animal products have a high WF compared to vegetables because of the water needed to grow their food. (Hoekstra, 2010) It takes three years to grow an animal that produces 200 kg of boneless beef. The animal needs 1.300 kg of grains and 1.200 kg of roughages, such as dry hay, to grow. To produce these grains and roughages, 3.060.000 litres of water are needed plus 24.000 litres of water the cow drinks and 7.000 litres for the slaughtering process. In total, 3.091.000 litres of water are required to produce 200 kg of boneless beef or 15.455 litres of water for 1 kg of beef. (Morelli, 2013) According to the Institution of Mechanical Engineers (2013), to produce 1 kg of meat between 5.000 and 20.000 litres of water are needed, whereas 1 kg of wheat only requires between 500 and 4.000 litres.

As we can see in table 4, to produce 1 kg of chocolate, we need 17.196 litres of water, which is even more than what is needed to produce meat. One hectare of rice consumes three times more water (between 2.000 and 5.000 litres) than one hectare of sorghum, while it delivers less proteins, minerals, calcium and iron. (Institution of Mechanical Engineers, 2013) However, these averages hide a large variation in the WF for each product. For animal products, the WF will vary depending on the age and diet of the animals. For industrial beef production, 1 kg of meat requires 15.500 litres. In a grazing system, cows will eat more grass and less grain so they will have gained less weight and provide less meat. However, the grazing system will have required rainwater, whereas the industrial system will use more irrigation water to grow the feed. It is thus important not only to look at the total WF but also at the kind of water that is used: green, blue or grey. These three kinds of water will be further explained in paragraph 3.3.3. (Hoekstra, 2010)

Table 4: Volume of water required to produce food

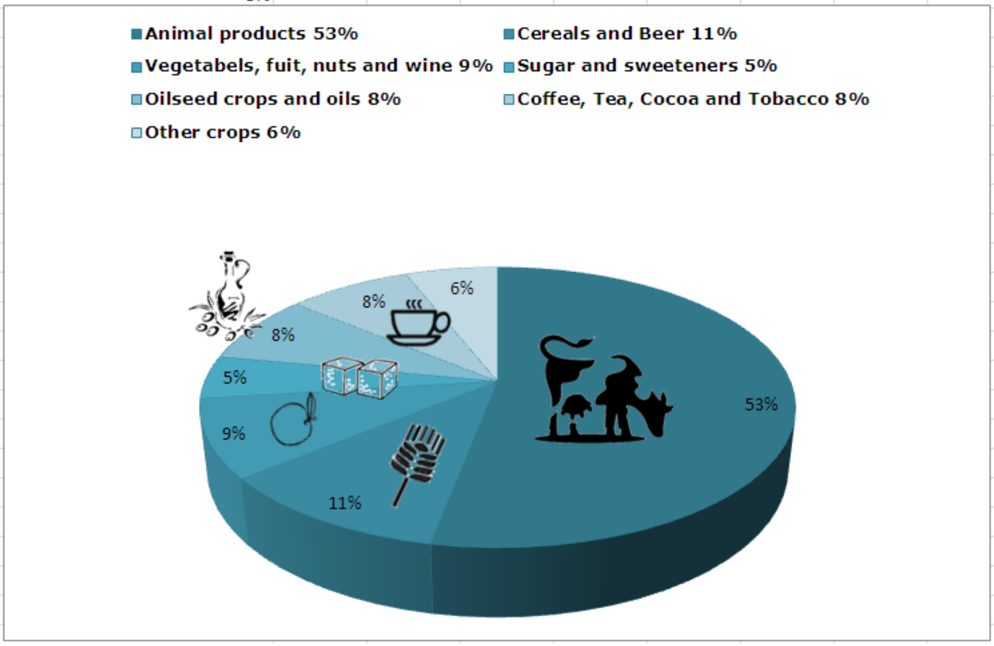
Food	Quantity	Water Consumption in Litres
Chocolate	1kg	17.196
Beef	1kg	15.415
Sheep Meat	1kg	10.412
Pork	1kg	5.988
Butter	1kg	5.553
Chicken Meat	1kg	4.325
Cheese	1kg	3.178
Olives	1kg	3.025
Rice	1kg	2.497
Cotton	1x 250g	2.495
Pasta (dry)	1kg	1.849
Bread	1kg	1.608
Pizza	1 unit	1.239
Apple	1kg	822
Banana	1kg	790
Potatoes	1kg	287
Milk	1x 250ml glass	255
Cabbage	1kg	237
Tomato	1kg	214
Egg	1	196
Wine	1x 250ml glass	109
Beer	1x 250ml glass	74
Tea	1x 250ml cup	27

Source: (Institution of Mechanical Engineers, 2013)

The WF of a person consists of a visible and an invisible part. The visible part includes all domestic water consumption. According to Morelli (2013), an average of 137 lcd of water is consumed for domestic uses. The invisible part consists daily of 167 litres of water for industrial products (paper, cotton and clothes) and of 3.496 litres for food. This means that 92% of our water consumption is hidden in our food. The invisible part of the water consumption is also called the "virtual water".

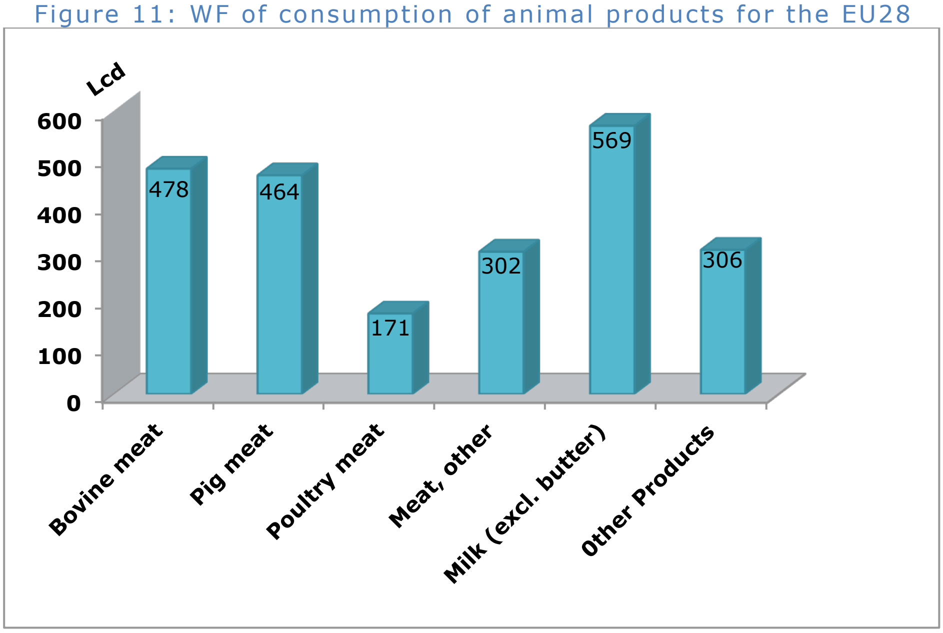
According to Vanham and Bidoglio (2012), an average European citizen consumes 113 litres of water a day directly and 4.815 lcd indirectly, whereas The Institution of Mechanical Engineers (2013) states that a family of four in our Western civilization consumes 25.700 litres a day indirectly through food. The amount of water being wasted growing crops that will never reach human consumption is estimated at 550 billion m^3 per year. (Institution of Mechanical Engineers, 2013) In figure 10, the daily per capita consumption of agricultural goods in the EU 28 can be seen. Animal products use over 50% of the total water required for food production and are therefore divided into subcategories in figure 11. This figure shows that milk products are the biggest water consumers followed by bovine and pig meat.

Figure 10: WF of consumption in the EU28



Source: (Vanham & Bidoglio, 2012)

Figure 11: WF of consumption of animal products for the EU28

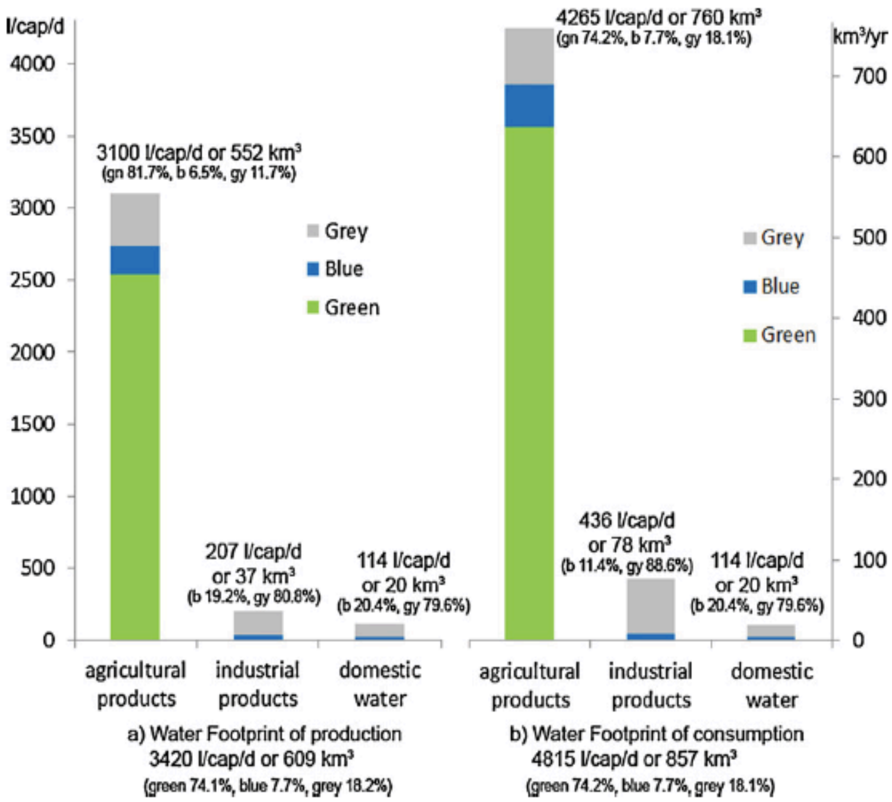


Source: (Vanham & Bidoglio, 2012)

Water footprints can also be calculated for geographical areas. The EU 28's WF of production (the European water used to produce agricultural and industrial goods) equals 690 billion m^3 of water a year (3.420 lcd), whereas the WF of consumption of the EU 28 (all water required outside of Europe to produce the goods consumed in the EU), equals 857 billion m^3 of water a year (4.815 lcd). The EU 28 imports more virtual water (water needed to produce the goods it imports) than what it exports and is therefore called a "virtual water importer". (Vanham & Bidoglio, 2012) France is the only virtual water exporter of the EU 28. All others use less water to produce the goods they export than that is required to produce the ones they import. Coffee and cacao beans are 2 products with a high WF that are imported by the EU and thus contributing to the EU's status of virtual water importer. (Vandenbussche, 2009) Australia, Canada, the US, Brazil and Argentina are virtual water exporters because of their trade in animal products. Japan, China, Italy and Russia on the other hand are virtual water importers. (Hoekstra, 2010) It is estimated that per year one billion m^3 of virtual water is traded in the world. (Vandenbussche, 2009)

The agricultural part of the European WF is the largest: it constitutes 91% of the WF of production and 89% of the WF of consumption. (Vanham & Bidoglio, 2012) (See figure 12) The traditional focus for water reduction has been on domestic and industrial use. However, increasing efficiency in the agricultural sector can provide a lot of improvement. (Buysse, 2014) Consumers should thus start looking at their diet rather than at their domestic water consumption if they wish to decrease their WF.

Figure 12:WF of a) production and b) consumption for the EU28 for the 3 sectors



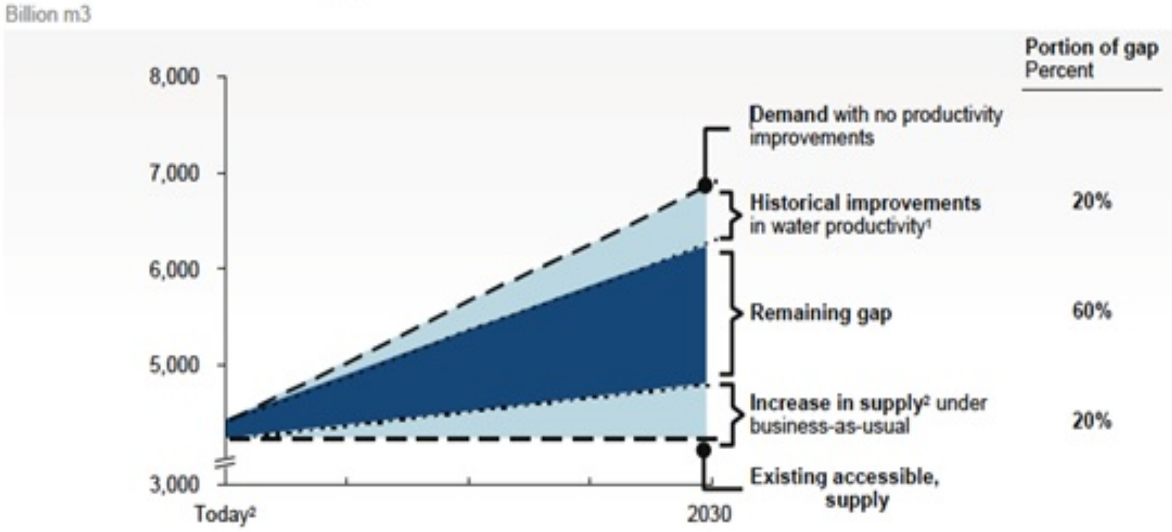
Source: (Vanham & Bidoglio, 2012)

The virtual Water Content (VWC) of a product measures the efficiency of producing a good in one region as compared to another. It also takes into account natural conditions including the climate of a region and the irrigation techniques used. For example: within Europe, it would be more water friendly to produce wheat in Western (Denmark: 788 m^3 per ton) or Northern Europe (UK: 607 m^3 of water per ton) as compared to Eastern (Romania: 1.779m^3 per ton) or Southern Europe (Spain: 1.476m^3 per ton). (Vanham & Bidoglio, 2012)

2.4 Conclusion

With the BAU trends, there is a clear gap between demand and sustainable supply that will result in depleted reserves. (See figure 13) Historic efficiency improvements will only be able to cover 40% of the projected supply-demand gap. (Water Resources Group 2030, 2009) To face this gap, additional supply (desalination) as well as demand side measures (reducing consumption & increasing efficiency) should be considered. Hamilton (2011) is somewhat more optimistic by stating that global water supplies will meet 60% of the demand by 2030 and up to 60 billion USD will be spent on trying to bridge this gap. In "The Blueprint to Safeguard Europe's Water Resources", Europe (2012) also estimates that the global water supply shortage may reach 40% by 2030.

Figure 13: Business-as-usual approaches will not meet future demand for freshwater



1) *Based on productivity improvements in agriculture and industry from 1990-2004*
2) *Increase in water supply through infrastructure (excluding unsustainable extraction)*

Source: (Water Resources Group 2030, 2009)

On the supply side we concluded that worldwide, 4.200 billion m^3 of renewable water remain available for all human uses, after having satisfied the nature's demand. This amount divided by a world population of 7 billion gives us an average of 1.643 lcd. The developed countries are consuming 3.496 lcd for food alone. An average European citizen consumes around 4.928 lcd, so that the annual renewable water supply only covers about 33% of demand.

Until now, water has mostly been considered as a local resource. Water saving solutions have been analysed at the river basin level without considering that many water problems are related to consumption elsewhere. The increasing complexity of our food system hides the existing link between the food we buy and the associated impact on natural resources. (Hoekstra, 2010) The European Union is a virtual water importer and is partly responsible for the depletion of distant water resources.

The supply of water is quite fixed, whereas the demand for freshwater in the world is ever increasing. Where will this lead us? Can we bridge this gap and guarantee a world with sufficient freshwater for the next generations?

3 World Water Challenges

3.1 Introduction

The world population increases by 85 million people every year and water consumption in the 20th century multiplied by seven. (PASS, 2013) Adding to this the water availability and the population density by region, it is not surprising that by 2025, 35% of the world population will face water stress. In this chapter the following issues concerning the water scarcity problem are raised: Can water scarcity escalate to international water wars? Can water rich regions help water scarce ones through water transfers? Can water be seen as an economic good and should its price merely be based on demand and supply, or is there more to take into account? What is the right price for water? Can privatization of water offer a solution when public agencies fail to supply quality water to everyone?

3.2 Water Problems leading to Conflicts

Due to the rising temperatures in the coming century (between 1,4 and 5,8 °C), the amount of melting pole and land ice will increase and thus, the sea level as well. By 2100, the sea level is expected to have risen by 10 to 90cm. (De Rijck, 2005) Increasing temperatures are affecting glaciers as well, which are melting at a very high speed. In Central Asia they have shrunk by 33% since 1949. Ice on the Andes has also diminished by 25% in the past 30 years. In China and Tibet the WEF (2009, p. 31) states that most glaciers may disappear within the century.

Moreover, an increasing number of countries are using up their groundwater. Those reserves are then being refilled with seawater, which makes the quantity of freshwater diminish quickly. The clearest example is Mexico City, where 70% of the water supply is groundwater and where seawater infiltration is a major issue. (Stikker, 1998, p. 56) Water tables are falling by more than one meter a year in regions such as China, India and Yemen. The groundwater overdraft (extracting water at a rate that exceeds long term refilling rates) in China equals 25% and 56% in India. (PASS, 2013)

Wars for water seem realistic, as humans have been fighting about any precious and scarce resource, such as land or oil. International water wars did not take place yet, but conflicts in which water has played a role certainly did. The UN identifies 300 zones of potential conflicts linked to water problems. (PASS, 2013) Some examples can be found in Israel and China. In 1967, a six days war took place in the Middle East, which was partly due to Jordan's proposal to divert the Jordan River. When Jordan and Syria started constructing dams on the Yarmouk, a side river of the Jordan, Israel bombarded it. Water is thus a delicate subject between Israel and its neighbours. (The Economist, 2010)

A lot of lakes and rivers have diminished in size. In 1960, the Aral Sea in Central Asia was almost as big as Belgium. Fifty years later, only 20% of its original size is left because of the intensive water needs in the cotton industry. (See figure 14) Between

1850 and 1980, 543 medium and large sized lakes have disappeared due to irrigation projects in China. When rivers and lakes cannot reach the sea anymore, people use water increasingly at upstream levels. Some major rivers (like the Colorado in the United States, the Yellow River and the Yang-Tze river in China, the Ganges in Nepal and Bangladesh and the Nile in Africa) are not able to access the sea during some parts of the year. In China, to ensure enough water for domestic use, they built the biggest dam in the world on the Jang-Tze River: the Three Gorges Dam. As a consequence, rivers are drying up and river deltas become arid and unliveable for any human, animal or vegetable life. Ecosystems are destroyed and less food is available. In the long run this might result in famines and poverty. Water is a fundamental resource to survive and when it becomes scarce, people start fighting for it. (PASS, 2013)

Rivers flow through several countries and international river basins cross borders of 145 countries. The Congo, Nile, Niger, Zambezi, Rhine and Danube (flows through 19 countries) are examples of rivers shared by nations. This makes water problems very difficult to manage. The Mekong is another river that flows through a number of countries such as China, Myanmar, Laos, Thailand, Cambodia and Vietnam. Lately the river has however become thinner, a partial result of the dams that the Chinese Government has built. (The Economist, 2010) In the Nile basin, Sudan is threatening to cut off water flows to Egypt and Ethiopia by consuming more and more water from the river upstream. Turkey, with the Tigris and the Euphrates, is also an area of potential conflicts over water. (PASS, 2013) It is the area of origin of the river and has the power about the water that flows towards Syria and Iraq. It installed several dams to control the water supply of the Euphrates towards Syria. Syria on its turn controls how much water the Euphrates supplies to Iraq. (Delbeke, Cuypers, & Degryse, 2002)

Figure 14: Size of Aral Sea shrinking dramatically

Source: (Offsetwarehouse, 2010)

The co-operative approach offers a possibility to solve such water disputes. Senegal, Mali, Guinea and Mauritania have agreed to share the “benefits” of the Senegal River rather than only sharing “water”. Two countries can agree that one of them builds a dam and that the other benefits from part of the electricity that it produces. (The Economist, 2010)

3.3 (Virtual) Water Transport and Transfers

Water is difficult and very costly to transport. The water infrastructure urgently needs restructuring, as a lot of water is still lost due to bad canalizations. (WEF, 2009, p. 34) In well-run water utilities in the OECD, 10 to 20% of the water production is wasted through leakages, and frequently even exceed 40%. In developing countries, water losses even reach 70%. (OECD, 2009) However, it is important to notice that the figures might be biased as they also include unrecorded consumption. The global budget required to improve the water infrastructure by 2030 is estimated at 11.700 billion USD. (The Economist, 2014)

3.3.1 Water and Trade Agreements

Environmental groups are worried about the trade of water under the GATT (General Agreement on Tariffs and Trade). Under the "Harmonized Tariff Schedule" (HTS) paragraph 2201 includes a harmonized tariff for trade in water of all kinds (except seawater). This means that shipments of freshwater are allowed and that no country can restrict exports of water. However, Gleick, Wolff, Chalecki and Reyes (2002) mention two clauses that could be used by a national Government in order to restrict water trade:

"Article XX (b) necessary to protect human, animal or plant life or health;
Article XX (g) relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption." (Gleick, Wolff, Chalecki, & Reyes, 2002)

Those exceptions are very difficult to prove, as water resources could be considered both, renewable (through rain) and non-renewable (when over-pumping groundwater resources that cannot be replenished).

The NAFTA (North American Free Trade Agreement) between the US, Canada and Mexico also have a Harmonized Tariff Schedule (HTS) for "ordinary natural water of all kinds" (Gleick, Wolff, Chalecki, & Reyes, 2002). This means that all kinds of water could be traded. However, in 1933, the three NAFTA-members decided to add an explicit protection for their water resources: water in lakes and rivers, reservoirs, basins and aquifers is not "a good" and therefore not covered by any trade agreement. It states that no party can be obliged to export its water by any trade agreement. It is arguable whether such declaration is legally binding. Clearly, better legislation with respect to the trade of bulk water is needed in the context of globalization of water resources. (Gleick, Wolff, Chalecki, & Reyes, 2002)

3.3.2 A Market in Water Rights

Better regulations are needed, but global bulk transport of water is not likely because of its cost and difficulty to realise. More likely is a market in water rights, where property rights can be traded between buyers and sellers. This kind of market exists in West America, Chilli, South Africa and Australia. It ensures sufficient water quantities to meet environmental needs and it provides water security for the user. (OECD, 2010a) If such a market develops globally, clear rules and regulations have to be set up. (WEF, 2009, p. 42)

In Australia, state and territory Governments administer water rights for the access and use of water. The Australian water market varies greatly depending on the area. The largest water trading system can be found in the Murray-Darling Basin area. A water access right means that one has the right to hold or take away water from a resource. There are several types of water rights. A "Riparian water right" is a consequence of ownership of land that touches a river or lake. (OTA, 1993) This right however is only tradable with land and is available for rural landowners for on-farm purposes like drinking, fishing and domestic use. With "appropriative rights" there is no relation between land and water. These rights are given for a specific amount, location and purpose. Unlike riparian rights, those rights are often sold or transferred to other users. (OTA, 1993) Water trading provides the opportunity to allocate water resources between several users. (Australian Government, 2011)

"Carryover arrangements" allow water users to transfer a percentage of their unused water into the next year, incentivizing people not to waste. The Australian Government is now working on the development of enforcement of the water regulation system, to ensure penalties are given for water theft. (Australian Government, 2011) The underlying idea is that one can only access more water if he finds someone who accepts to use less. Strong governance is needed to prevent people from using more water than what was originally allocated to them. The Government needs to be very well informed concerning the amount of water that is needed by ecosystems for this system to function efficiently. (EEA, 2012b)

According to the "Impacts of water trading in the southern Murray-Darling Basin Report", water trading increased Australian GDP by 220 million Australian dollars, as the value of water licenses increased rapidly. (EEA, 2012b) The report also mentions benefits for the irrigators by for instance providing more certainty about seasonal water availability. (Australian Government, 2011) Today, consumers can even obtain a water license through a mortgage and irrigators can view how much water they have left by creating an account on the Internet. (EEA, 2012b)

3.3.3 Virtual Water Trade

The WF of products could help us to transport water in an indirect way. (Lazlad, 2007) We can divide the WF into three main categories: the green, the blue and the grey WF. The green WF is the water used through soil moisture or the quantity of rainwater consumed. It is the quantity of water evaporated through crop growth. The Blue WF refers to the consumption of surface water of rivers and lakes and groundwater. It includes the evaporation of water as well as irrigation; industrial and household water use that does not return into the system from which it came. The grey WF indicates the freshwater pollution and is expressed in terms of litres of water needed to dilute polluted water so that it becomes harmless. (Lazlad, 2007) The main strength of this concept is that it shows the impact of consumption on global scale and it can improve awareness. Its main weaknesses are that it does not take into account other resources like availability of land, floods or infrastructure (Vanham & Bidoglio, 2012)

The efficiency of water use can be increased through wise trade in water intensive commodities. By looking at the WF, we could transfer the production of water intensive goods from water abundant regions to water stressed regions. Asia could save around 12% of irrigation water by importing cereals instead of producing them in-land. Unfortunately, agricultural exports have been decreasing during the last decades, from 46% in 1950 to 9% only in 2001, as a result of high tariffs, subsidies and trade barriers. Another problem is that in most developing countries around 70% of the labour force is employed in agriculture, which represents 33% of their GDP. By 2030, 55% of the world's population will have to rely more on agricultural imports from other countries as a way to cope with water scarcity. (WEF, 2009, p. 22)

Water is a global resource and local water stress will urge nations to reconfigure their international "virtual water" trade. Unfortunately, if nothing is done, this will lead to selfish bilateral trade agreements where water poor countries will be competing to make deals with water rich countries instead of making sure everyone gets enough. Global economic governance will play a key role in setting up fair trade agreements to guarantee a world where everyone can enjoy the benefits of global (virtual) water trade. (WEF, 2009, pp. 28-29) Several countries like China, Saudi Arabia, East and North Africa, the United Arab Emirates, Egypt and Libya are already acquiring agricultural land overseas in well-watered underdeveloped regions in order to meet the food production needs of their population in the future. (WEF, 2009, p. 28) This is clearly an example of failure of cooperation between Governments to address the water scarcity issue.

3.4 Quality of Water

Freshwater is vulnerable; it can be polluted easily. (Lazlad, 2007) Chemicals that are used in agriculture pollute rivers and groundwater, and the investment needed to develop water-cleaning technologies is big. In poor regions, the quality of the resource remains a big issue. One of the results of the UN Water Conference in Argentina (1997) is the decrease in the amount of people having no access to safe drinking water. Yet, the amount remained between two and three billion in 2000. (Stikker, 1998, p. 59) Today still 1,1 billion people have no access to safe drinking water, 2,6 billion people lack adequate sanitation and 900 children die daily due to waterborne illnesses. In Sub Saharan Africa, 5% of the GDP is spent on curing diseases due to poor sanitation. (WEF, 2009, p. 36) In fact, as the Water and Sanitation Program (2013) states, more people nowadays have access to a mobile phone than to safe sanitation.

In Europe, tap water undergoes very strict controls and is about 500 to 600 times cheaper than bottled water. The WHO is setting the basic norms for tap water and the European Union makes them even stricter. In total, it has to comply with over sixty norms. Moreover, it is healthy, as it contains a lot of minerals like Calcium, Fluor, Iron, Magnesium, etc. (The Economist, 2010) Yet, most people in Europe keep on buying bottled water. (Claes, 2009)

In the North of Europe, rain has increased on average by 10 to 40% compared to the previous centuries. Floods increase the spread of contaminated substances and microbes because the sewerage networks cannot absorb the totality of water at once. As a consequence, clean water is mixed with dirty water. Therefore, one flood can cause severe damage to the clean water supply. (De Rijck, 2005)

There are two types of sewerage networks: the separated and the mixed one. The mixed system mixes rainwater and wastewater in the sewerage, whereas a separate system absorbs rainwater separately from wastewater. In case of floods the latter system is better as it prevents the wastewater sewerage network to overflow and to cause unnecessary pollution. In 1991, a European Directive has been created that obliged all Member States to develop a sewerage network that collects and purifies wastewater by the end of 1998 for urban areas with more than 10.000 inhabitants. (Vanassche, 2005) In 2004, Belgium already got a warning for non-compliance with the directive. A lot of work was done from then on, but in 2011, the European Commission dragged Belgium a second time to Court and had to pay a fine of 10 million euros for its non-compliance during 9 years. (De Standaard, 2013)

3.5 Water as an Economic Good

The Water Conference of 1992in Dublin set out a very controversial principle, namely that water should be treated as an economic good. An economic good is defined as "any good or service that has value to more than one person and that is scarce compared to its demand". (Gleick, Wolff, Chalecki, & Reyes, 2002) If water is seen as an economic good, pricing should encourage sustainable use. (Anderson, 2008) Others, like Savenije (2001), argue that water has some special characteristics, which distinguishes it from other economic goods. If water is merely seen as an economic good, it could cause poor people to be unable to buy it. Gleick, Wolff, Chalecki and Reyes (2002) state that water has characteristics from both, an economic as well as a social good. A public or social good is defined as one that has benefits for a lot of people. It is a good that is non-excludable: you cannot prevent another one from enjoying it; and non-rival: if one person gets the good, it does not mean another person will get less of it. (Gleick, et al., 2002)

One cannot enjoy a litre of water already consumed by a person. Water is thus to some extent a rival good: if some people over-consume it, in the long run, there will be less water available for others. Moreover, water is non-excludable: if one person pollutes it, others will have to bear the consequences as well. Water could thus be seen as a non-excludable and rival good, also called a common good. With these kind of goods, free riding problems may occur. Everyone wants to enjoy water of a good quality, but not everyone is willing to contribute.

Water issues are likely to drive economic decisions in the future, as limited accessibility to safe water and sanitation impede a country to remain competitive. China is a good example as it is losing yearly 8 to 12% of its GDP to environmental degradation and pollution. In Sub Saharan Africa, a water crisis impedes economic growth and in India there is a direct correlation between investing in irrigation and a decrease in poverty. Irrigated parts have a poverty rate of 25%, whereas non-irrigated parts have a poverty rate of 70%. (WEF, 2009, p. 35)

In July 2010, the UN recognized the access to safe drinking water as a fundamental human right. (PASS, 2013) The 145 countries that signed the Convention of Human Rights are thus obliged to organise access to water in a just and non-discriminatory way. Water is essential for survival. Therefore, it is questionable whether it should be treated as an economic good. (PASS, 2013) Water is a right, but unlike liberty or freedom of expression, it is a commodity that is costly to provide and consequently, a right price needs to be paid. Under pricing might result in excessive use but, when putting a price on water, poor people might be unable to afford it. (The Economist, 2006) A possible solution could be to provide a minimum amount of water for free.

3.6 The Right Price for Water

3.6.1 Why pay for Water?

Why would we pay for water, a resource that is vital for our survival and critical for basically everything we know? The answer the OECD (2009) gives to this question is that it is costly to supply it. It has to be available for everyone, but this does not mean that it has to be for free. We consider it as normal that by opening the tap, water comes out, but we forget that this is a luxury. The OECD (2009) considers water pricing as a good incentive to reduce waste, extend supply and invest in new infrastructure. Stikker (1998, p. 60) mentions a study of the World Bank, which shows that the price paid for water only covers about 35% of the cost of supplying it. According to the OECD (1999), this figure equals 10 to 50%. This, on its term, is only 10 to 50% of what it is worth in terms of agricultural productivity. So to bring demand and supply into equilibrium, the price would have to rise substantially.

If we want the price of water to reflect its full cost, it should comprise three main elements:

- an environmental cost: the cost of damaging the environment, such as the impact on ecosystems and the degradation of soils, also called negative externalities,
- an opportunity cost: the value of the best foregone opportunity: when a water resource is depleted beyond its natural rate of recovery, other activities cannot take place anymore, and
- a financial cost: the cost of providing water, including maintenance and operating costs.

Positive consequences of water pricing are a decrease in demand, more capital to increase the supply and a more efficient resource allocation. Negative aspects that are associated with water pricing are that it generates less equity and a worse sustainability of the resource, as at a higher price, suppliers will want to supply more. However, if legal and environmental policies complement each other, increasing prices can lead to an equity and sustainability improvement. (Rogers, 2001)

3.6.2 Water Prices in Belgium

From 2005 to 2011 the drink water price in Belgium has increased quickly, mainly due to the increased purification expenses. This is a consequence of the European Water Directive (Europe wants to achieve a better ecological status of its water by 2015) that forms the basis of the Belgian water sector reorganization. Nowadays, there are around 800 purification centres in Belgium. (VMM, 2012)

In table 5, the average water price in the three regions (Flanders, Wallonia and Brussels) is compared as well as the average price of water in the neighbouring countries (the Netherlands, England, Germany and France). From the figures it becomes clear that on average, the drink water prices from Flanders are the lowest. Germany is the most expensive country, followed by England and France. However, only the data of the

Netherlands and Germany are complete. For England, only the data of the clients with a water meter are used, which represents only 39% of the total clients affiliated to a water company. The data for France is based on 62% of the population. (VMM, 2012)

Table 5: Average Price of Water in Belgian Regions and neighbouring Countries (2011)

People per Family	Consumption of Drink Water	Flanders (€/year)	Wallonia (€/year)	Brussels (€/year)	The Netherlands (€/year)	England (€/year)	Germany (€/year)	France (€/year)
1	50	118	129	125	113	123	150	122
2	77	140	192	162	146	170	195	163
3	108	169	264	211	184	223	247	210
4	132	186	321	239	214	264	287	246

(1) Wallonia: prices of 2012
(2) England: only 39% of the clients
(3) France: prices from 2009, representing only 62% of the population

Source: (VMM, 2012)

Even in a small country like Belgium, it is difficult to put an average price on water, as different sources show different numbers. A study done by the FOD[1] Economy of Belgium shows that an average Belgian household consumes around 100 litres of domestic water a day or 36,5 m^3 per person a year. For a family of three people, this is around 100 m^3 of water per year. According to this study, the cost for a family of three is on average € 383,39 a year or € 1,05 a day. This study states that prices for water in Flanders equal € 348 to €420 per 100 m^3 of water. Wallonia is the most expensive region with an average price of €421 to €437 per 100 m^3 of water. (FOD Economie, n.d.) The cheapest region is Brussels, with a price of € 274 to € 347 per m^3 of water. (Niclaes, 2013) In 2011, the cost of water in Belgium was on average € 3,85 per m^3, whereas the average cost in 2005 only equalled € 2,35 per m^3 of water. This means that the price has increased by 63,9%. (FOD Economie, n.d.)

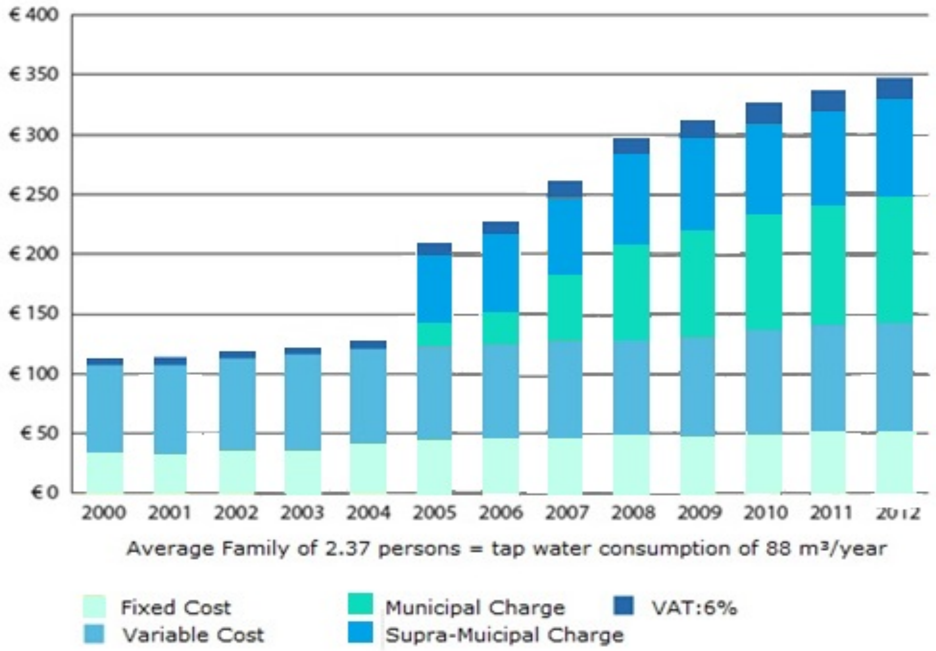
Those price differences in Belgium are a consequence of the several pricing schemes. In Brussels, a progressive rate is installed where the price per m^3 of water increases with blocks: an increasing block tariff (IBT). (Kindermans, 2014) They also have to pay a regional and communal wastewater price, which increases per block. (HYDROBRU, 2013) In Wallonia, since 2005 a reform has taken place and they introduced the "reality cost" or "*coût vérité*" in their water tariffs. Each person in Wallonia pays a fixed cost for the installations, an IBT for their water consumption, a wastewater and a distribution cost. Both the remediation and distribution costs are calculated per m^3 of consumption. In Wallonia, people tend to live further from each other, which increases the cost of canalization that has to be financed. (AquaWal, 2013)

Since 2005, the water sector in Flanders has undergone a big reorganization and the "integral water bill" was adopted. Households have to pay for the production, the distribution, the collection and purification of the used tap water, whereas before the cost only consisted of a fee for the production and delivery of the water. The cost of the integral water bill has thus heavily increased in Flanders since the beginning of 2005, as

[1] Federale Overheidsdienst= Federal Public Service

we can see in figure 15. The last five years (2008-2012) the water bill for an average family in Flanders increased by approximately 17% and it is expected to keep on increasing in the future. The first 15 m^3 of water are for free in Flanders. This means that only the variable cost out of the total cost does not have to be paid on these 15 m^3. (VMM, 2012)

Figure 15: Evolution of the integral water bill and its components for an average Flemish household (2000-2012)



Source: (VMM, 2012)

Despite the sharp increase in prices, a research done by the FOD Economy with data of 2010 illustrates that the integral water bill has a relatively small impact on the average household budget. The proportion of costs to pay for water consumption is only 0,69% (compared to 0.38% in 2000) of the average total income of a Flemish household, 0,78% in Wallonia and 0,69% in Brussels. To compare, electricity represents on average 2,16% of the total income of a Belgian family. (VMM, 2012)

3.6.3 Water Prices per Sector

3.6.3.1 Water Prices for Households

On international level we also face some obstacles when comparing water prices. Each country has different pricing schemes in which it includes different factors. The allocation of costs, taxes, subsidies and charges are different in each country. (Kraemer, 1998) Moreover, there are several ways to price water: flat rates, volumetric rates and IBTs. Decreasing block tariffs can still be found in the US and flat fees can be found in Canada, Mexico, New Zealand, Norway and the UK. (OECD, 2009)

The OECD (2009) says that the water infrastructure should be financed through the three T's, Taxes, Tariffs and Transfers. The water users should pay through Tariffs, Taxes (to complemented the financing by some public funds) and Transfers (to aid poor countries in order to enable them to offer minimum services in terms of water and sanitation).

Public water supply and wastewater services are increasingly priced in OECD countries. However, to price water right, we have to measure it right. Water meters are necessary to measure consumption in order to price correctly. It might sound obvious, but many countries, including some OECD countries, still do not have them. In fact only 2/3rd of the OECD member countries measure residential use of one-family houses. For the OECD population living in apartments, the metering often reflects the water supplies entering the building rather than individual consumption. (Jones, 2003)

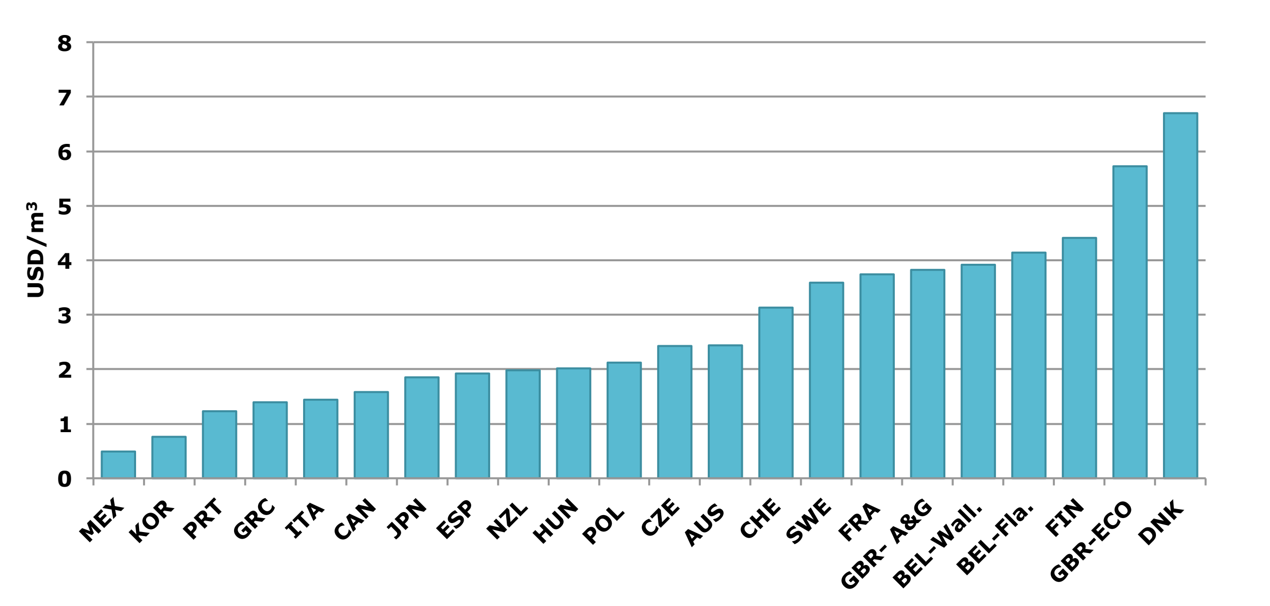
In countries where water meters are not used, water users pay based on other criteria like the size of the house or the number of family members. The price they pay for water does not change according to their consumption and thus, people are not aware that they should use water sensibly. This is the case in London, where citizens pay a flat rate for water consumption based on the value of their residential property. Water demand has started to increase in England in the past decades due to an increasing population. Since then, water companies are allowed to change their pricing scheme into a volumetric system. Customers are able to choose whether to install a water meter or not. In 1993, only 3% of domestic water consumers had a water meter, while this proportion rose to 40% by 2010. (EEA, 2012a) In Ireland, still no direct price for water is charged. (OECD, 2009)

If water meters would be installed in countries without water meters, it would reduce water consumption by up to 20%. (OECD, 2009) Unfortunately, on a global scale, water metering remains a controversial issue. (Jones, 2003) Even in Belgium, in the province of Antwerp, water meters are only obligatory since 2008. (Kindermans, 2014) Since 1990, between 1/4th and 1/3rd of the OECD countries have reduced their water use thanks to a better water pricing. In OECD countries, pricing tends to be based on the volumetric use of water, rather than paying a fixed price. This means that the more water one consumes, the more one will pay. This system is used in Hungary, Poland and the Czech Republic. In the Czech Republic, water prices increased since 1990, which resulted in a 40% domestic consumption decrease. Another clear trend in the OECD is the increasing price per unit. This means that each additional unit of water used or wastewater treated will cost more than the previous one. Hence, high volume users pay relatively more for their water than low volume users. (OECD, 2009)

In some reports of the OECD it is shown that the industry and households pay up to 100 times more for their water use than agriculture. (Jones, 2003) Industry and households increasingly pay the full cost of their water consumption. This is often done through tariffs, which reflect the actual consumption, the treatment cost of wastewater and the cost of abstracting and supplying water to the consumers. Those tariffs vary significantly across OECD countries as can be seen in figure 16. (OECD, 2013) Mexico has the lowest price of 0,5 USD/m^3 of water whereas Denmark almost prices its water supply to households at 7 USD/m^3, or 0,007 USD/litre of water.

In Denmark the water price includes the construction or renovation of water pipes. It is also important to mention that this graph does not take into account the quality of drink water. Mexico might thus have the lowest cost, but their tap water might be of doubtable quality. Belgium lies in the upper average with a price around 4 USD/m^3 of water. (Buysse, 2014)

Figure 16: The price of water supply and sanitation services to households, including taxes



(1) Data from 2009

Source: (OECD, 2013)

3.6.3.2 Water Prices for the Industry

The prices for industrial public water use can vary widely between countries as they are fixed at a local level. The two part tariffs (including a fixed and a variable element) are most commonly used. Decreasing block prices are used in the UK and in a part of the US. Direct abstraction for industrial water supply is also often used as an alternative to public water supply. The sources of abstraction can be ground or surface water on which a fee is levied. The main reason industrial users do this is because water of lesser quality is needed for specific purposes. (OECD, 1999)

In general, industrial users tend to face a higher charge than domestic users for their water. In Poland, industrial users face a cost that is 6 to 47 times higher for public water supply than households. In Germany however, water intensive industries can obtain rebates. In the Netherlands industries can claim subsidies if they inject surface water into the aquifer before groundwater is abstracted. In Italy, a 50% reduction is given to industrial users when they use water saving techniques. (OECD, 1999)

3.6.3.3 Water Prices for Agriculture

Table 6 gives an overview of what several OECD countries include in their water cost to farmers. The "full supply cost" includes operation and maintenance costs, such as repairing the irrigation infrastructure, as well as capital costs: constructing new dams and replacing irrigation canals. This table shows why farmers in countries such as Denmark, UK, Finland and Sweden have a high water cost compared to countries like Italy, Mexico, Korea or Greece. (OECD, 2010b)

Table 6: Full supply cost recovery for surface water delivered to farmers across some OECD countries

Cost Recovery	Countries
100% Recovery of Operation, Maintenance and Capital Costs	Austria, Denmark, New-Zealand, Sweden, United Kingdom
100% Recovery of Operation and Maintenance Costs, but less than 100% Recovery of Capital Costs	Australia, Canada, France, Japan, United States
Less than 100% Recovery of Operation, Maintenance and Capital Costs	Greece, Hungary, Ireland, Italy, Mexico, the Netherlands, Poland, Portugal, Spain, Switzerland, Turkey, Belgium
Less than 100% Recovery of Operation and Maintenance Costs, with Capital Costs fully supported	Korea

Source: (OECD, 2010b)

In the agricultural sector, huge subsidies are distributed, which result in inefficient water use. The price paid for agricultural water often only reflects 20% of the cost in Europe. This is partly the fault of the CAP (Common Agricultural Policy) that provides subsidies for producing water intensive crops, like maize in France and sugar beet, cotton and cereals in Spain. (EEA, 2012b) CAP subsidies reward more generously farmers that install irrigation infrastructure, indirectly giving rise to an increase in irrigation water demand. (Roth, 2001) The biggest problem with subsidies is that they are not consistent with the polluter pays principle and that once established they are very difficult to remove. (The World Bank, 2006)

3.7 Privatization of Water

Why did the issue of privatization gain importance in recent years? First of all, public agencies have failed to provide water to all humans. A second reason is the growing pressure of multinational enterprises to take over public water agencies. A last reason is that many recent privatizations failed. Many organizations like the World Bank, and the World Water Council are in favour of privatization, but as they lack common principles, opposition is growing from Unions and Human Right Organizations. In the past, development organizations were the ones helping the Government to provide basic services such as sewerage and water. Nowadays, those same organizations try to advance privatization as a new solution. (Gleick, Wolff, Chalecki, & Reyes, 2002)

Privatization in the water sector means the transfer of a part of- or all- the assets and operations of the public water system into private hands. (Gleick, Wolff, Chalecki, & Reyes, 2002) A diverging interest exists between the profit seeking private sector and the service providing public sector, which is difficult to compromise. Urban growth in the mid 1800s made privatization of the water systems grow in a lot of European and North American cities in need for greater efficiency. At the end of the century however, those systems proved to be corrupt, costly and inefficient and most of them were returned to public ownership. (Prasad, 2006)

In 2002, the World Summit on Sustainable Development (WSSD) in Johannesburg set ambitious goals to reduce by 50% the amount of people with no access to clean water or adequate sanitation in poor countries by 2015. To be able to achieve this goal, the main subject of discussion during the Third World Water Forum[2] of 2003 in Kyoto has been the privatization of water supplies. (The Economist, 2003) Non-Governmental Organizations were strongly against this idea. Their main argument was that private companies would only care about profits and disregard human health and diseases. Gleick (2003) mentions that there are many risks involved with privatization: impacts on ecosystems, the inequities between several income groups, water quality and efficiency may all be neglected. Another concern he mentions is that private companies are not in favour of water conservation. On the contrary, the more water they sell the better.

The main argument in favour of privatization is the need for global investment to improve the water supply systems and to ensure everyone gets access. About 95% of the world water is publicly supplied, often charging prices without ensuring quality. (Gleick, Wolff, Chalecki, & Reyes, 2002) The OECD (2012) states that water will be the biggest part of global investment in infrastructure by 2025. The BRIC (Brazil, Russia, India and China) and the OECD countries will have spent around one trillion USD by 2025 on water infrastructure. The McKinsey Global Institute (2014) states that from 2013 to 2030, the global water infrastructure investments required will amount to 11,7 trillion USD. Low income countries need money to build networks that reach a bigger part of their population, whereas middle income countries need money to maintain the existing infrastructure. (Rodriguez, 2012)

On the 17th of February 2014, the first European Citizen Initiative ever reached the European Commission about the implementation of the "Right2water" in the European legislation. After having received over 1,6 million valid statements from 13 countries, the European Commission had to recognize and implement the right to water and sanitation for all citizens of the European Union. It is a clear initiative from the European citizens against the privatization of water services. (EU, 2014a)

There are many forms of privatization. The main debate in recent years is about full privatization or the transfer of operation and management in hands of the private sector. (Gleick, Wolff, Chalecki, & Reyes, 2002) In Europe, 48% of the population is served by water supply systems that are under "direct public management". This means that the public entity is fully responsible for the provision and management of the water services. This system is used in Denmark, Sweden, Austria, Finland and Ireland. A "delegated public management system" serves 15% of Europe's population and it can be found in

[2] Every three years, the World Water Council organizes a World Water Forum. It is one of the biggest international events in the field of water. The World Water Council is an independent international organization that fights for a better water management in the world. (World Water Council)

Portugal, Scotland, Greece, Italy, Germany, The Netherlands and Belgium. In this case the Government appoints a management entity, in which the ownership often remains in the hands of the public sector. Under "direct private management", all management tasks are in the hands of private operators and public entities' tasks are limited to the regulation and control of the activities. This system is only used by 1% across the EU, namely in England and Wales since 1989. The last option is a "delegated private management", used by 20% in the EU, where a municipality makes a contract with a private entity for a certain period of time and the infrastructure remains owned by the state. This way of working can be found in Spain and France. (EEA, 2013)

France engaged in a Public Private Partnership (PPP). The Government remains owner of the water sources and makes a contract with a private company like Suez to manage the water system. The contracts in France are often made for a period of about 20 years and contain a clause, which stipulates that an inventory of fixtures will be made at the starting and ending period of the contract. The damages made to the network will have to be paid by the company operating during that time. (Kindermans, 2014)

In 1990 in Argentina, water services were fully privatized in some areas, which increased productivity, profitability, and substantially, while childhood mortality fell by 8%. Other examples of successful water privatization are Abidjan (one of the few municipal water supply systems that work in Africa), provided by a private company, and Chilli, where private water suppliers have raised the water charges to cover the full cost. The poor receive water stamps to make sure they have a minimum access to clean water. Now, 95% of the population in Chilli has access to clean water. (The Economist, 2003) China has been privatizing part of its water utilities too, mainly to foreign firms. The Government distributes vouchers to the poorest, which they can exchange for water. Another way to help the poorest is to deliver a basic amount of water for free, as happens in South Africa. In India, water supply lies in the hands of the state, which has no money to invest in better infrastructure. A lot of water is wasted through leakages in pipes, water meters are broken and prices are unrelated to costs. (The Economist, 2010)

In Manila, the Philippines, water is privatized since 1997, but it has however not been a success story. Since the privatization, prices have increased by 700% whereas the quality of water has decreased. The Government was suffering a big budget deficit mainly due to inefficiencies in its water service (58% of water was lost due to leakages in their supply system). To reduce this deficit, the Government decided to privatize its water system. The World Bank was in favour of this idea, as they believed more capital would ameliorate the infrastructure and the delivery service of water. Unfortunately, once it was privatized, the prices were manipulated and the service did not improve. (The Economist, 2010)

Any decision on privatization should be accompanied by a set of principles, such as guaranteeing basic water needs for the population and ecosystems. The purpose should be to improve the efficiency and productivity of water services and the affected parties should be included in decision-making. Moreover, strong public regulations, openness and transparency should control the private entities. Public-Private agreements should be set up to monitor private companies and to make sure that the public interest and ecosystems are protected. When Governments are weak, the risk of failure of water privatization is highest. Yet, it is often those countries where privatization can offer the biggest change. (Gleick, Wolff, Chalecki, & Reyes, 2002)

Gleick, Wolff Chelecki and Reyes (2002) give some guiding principles and standards for successful privatization agreements:

- Water should continue to be managed like a social good that meets the basic human and ecosystem needs. Subsidies should be provided for the poor.
- Sound economics should be used: providing water and water services should be done at a fair rate.
- Strong Government regulations should control and overlook the private organizations. They should establish control of water resources, monitor and enforce water quality laws. Contracts should clearly mention the responsibility of each partner and comprehensible dispute settlement procedures should be developed.
- Moreover, all affected stakeholders should be included in the transparent privatization process.

Two big players in the water privatization sector are the French companies Veolia and Suez. (Prasad, 2006) Those two companies are involved in water projects in more than 120 countries and serve each around 100 million people. Other big players are Thames Water and United Utilities in Great Britain, Bechtel and Enron in the US and Aguas de Barcelona in Spain. (Gleick, Wolff, Chalecki, & Reyes, 2002)

3.8 Conclusion

International water wars did not yet arise, but scarce resources can lead to conflicts and abuse of power. Better regulations in the water field are necessary and the vision of water as a global resource, rather than a local one, should be promoted. Water is unevenly distributed around the world and difficult to transport. This resource should gain importance in Trade Agreements and clear rules have to be set up about the transport of this commodity. Global bulk water trade seems unlikely, but in case a region would need water, clear, internationally enforceable rules should govern in order to avoid conflicts. We believe that in case of physical scarcity (as a consequence of extreme droughts and only in case strict water saving measures have been taken to avoid water scarcity) a region should be helped.

A global market in water rights would be unfeasible, as water would be reduced to a pure economic good. Moreover, a lot of rules and a clear enforcement system would be needed as well as exact information about the water quantity available. A market in water rights can be a solution in smaller areas, where water is scarce and clear rules apply. Through global trade, water withdrawals in dry areas could be reduced, but this requires cooperation on a global scale. In our opinion, tariffs should be put on water intensive goods that were produced in dry areas. This would reduce exports of products that depleted water resources during their production process.

We believe water has a price, as it is costly to supply water of a good quality. But water should not be seen as a pure economic good, as it is essential for nature, and proclaimed as human right. Putting a price on water makes it less accessible for the poor. However, using market mechanisms can help increase consciousness about the scarcity of the resource. (Stikker, 1998, p. 57) Water stamps, subsidies and free minimum amounts can be distributed to ensure everyone gets access.

Privatization of the water sector is increasingly seen as a solution to guarantee water access to everyone, especially in developing countries, where the Government cannot provide safe water access for the whole population. During last decennia, the trend towards privatization has increased, however not without problems. Countries that are most in need of financing are often unable to enforce regulations. For privatization to work, prices and quality of water should be toughly controlled, as water is a resource that could easily lead to a monopoly. The risk is that big companies, like Suez, try to control the water market in third world countries. Public-Private Partnerships are a good alternative to have the public and the private sector cooperate. However, privatization decisions should only be done where enforcement of rules and clear contracts are possible.

4 Solutions to face the Water Scarcity Problem in the Three Sectors

4.1 Introduction

In the past, building dams, constructing pipelines and drilling for groundwater avoided water shortages. Nowadays, those supply side solutions are not sufficient anymore and an additional focus on demand side measures is needed to guarantee enough freshwater in the future without depleting resources.

A lot of initiatives have been taken already to reduce the water consumption for households and the industrial sector. However, improvement in the agricultural sector, the biggest water consumer, still needs to be made. (Buysse, 2014) In this part, common solutions for all sectors will be discussed first, followed by individual solutions per sector, with a special focus on agriculture.

4.2 Common Solutions for the Three Sectors

4.2.1 Educational Projects and Awareness Raising

Raising awareness and changing people's mentalities, so that water scarcity is not considered the neighbour's problem anymore, is a crucial step towards a better water future. Without this awareness, few changes can have a real impact.

The water scarcity issue is not given sufficient importance on world level. International organizations, like the World Water Council and UN Water (explained in part 4.2.3), exist, but are not given enough weight to have a real impact. Water should become a hot topic in the media and in electoral campaigns, for people to become conscious of the value of this resource.

Young generations are the future water consumers and educational projects are the perfect way to raise awareness from childhood onward. Some educative steps are already taken in Belgium. Hidrodoe in Herentals makes kids discover all kind of water facts in an interesting and informative way and Aquafin organizes school trips to explain the working of their sewage treatment plant. Also, a website for children has been created, www.kids.dewatergroep.be, on which all kind of information on water is taught in an interactive way. (Buysse, 2014)

The European Water Partnership (EWP) is a non-profit organization of the EU that promotes European expertise in the water field. The objective is to achieve a sustainable water resource management and guarantee universal access to safe water and sanitation. The EWP also has some programs, such as the European Water Awareness Program that raises awareness on sustainable water issues among political decision makers by making information available. (EWP, 2014)

4.2.2 Improve Statistics

Clear data and statistics on the water consumption of people and products are needed to raise awareness. However, water statistics are very unclear. A lot of confusing data is available on the amount of water demanded by sector and on the prices of water. Moreover, it is not always clear what is included in those data. For example, data on agricultural water withdrawals often include domestic water use in rural areas, and industrial water use frequently include water for cooling of the power plants. This water is often taken straight from the river and after returned to the river, so it is arguable whether this should be seen as consumption or not. Also for municipal water, withdrawal ambiguities exist. Frequently, public water supply data are used to analyse domestic water consumption, whereas also some part of it can be used for irrigating agriculture or urban industry. (Kohli, 2010)

Different terms are often used without really stating what they mean and whether they are used as substitutes or not. In Aquastat (programme of the FAO of the UN) for instance, the terms "water withdrawal" and "water use" are described as follows: the term "withdrawal" stands for all water that is removed from nature. The term "water use" is seen as the water that is effectively used by the society. This is not the same as "withdrawal" as water can be lost through leakages or used illegally, and the ones withdrawing water are often not the same as the ones using it. Moreover, the term "use" is further defined as "any action through which water provides a service". (Kohli, 2010, p. 1) Another term that causes confusion is "water consumption", which Aquastat defines as the water that is contaminated or has evaporated. (Kohli, 2010, p. 5)

Within Europe, data on Member States are lacking, which makes comparison difficult. Each country has its own regulations concerning water pricing, and even within one country, different rules apply. More accurate information and harmonization efforts are needed to better guide policymakers in the water field. (OECD, 2010b)

4.2.3 Legal Mechanisms

The development of water laws should be done in a transparent way, such that all stakeholders are involved: NGOs, academic institutions, ministries, water users, etc. To develop new water legislation, former legislations and their weaknesses need to be analysed. Each country should have a water code; a fundamental law on water ownership, accessibility and protection, that should fulfil the international water requirements. (Dukhovny, 2009)

A good water policy should include several aspects: (Polycarpou, 2011)

- proper pricing schemes,
- minimizing leakages and losses,
- safeguarding the water quality,
- protecting aquifers from seawater intrusion,
- ensuring a fair allocation of the water resources between the three sectors and
- exploiting new technologies to prevent excess water use in the three sectors.

Waterways do not stop at the border and coordination between countries in the water management field is very important. Organizations such as the World Water Council, UN-Water and the Global Water Partnership (GWP) want to transform the fragmented Government responsibilities into a single authority responsible for a river basin area. (Rijsberman, 2005) "UN-Water" is the United Nations' mechanism for all issues related to freshwater and sanitation. It was created in 2003 to complement existing programmes and it promotes coherence and coordinated action in the water field. (UN-Water, 2014)

In 1996 the World Water Council was set up. It is an independent international organization that fights for a better water management in the world and guides decision makers in the water management field. (World Water Council, n.d.) Since its creation, the World Water Council organizes a World Water Forum every 3 years, where global issues in the water field are discussed. The GWP is an international network that was created to promote an "Integrated Water Resources Management" (IWRM). IWRM's broad principles are:

- Use a multi-sectorial approach to ensure water for people, food, energy and the environment. (Global Water Partnership, 2006)
- Encourage participation of all stakeholders (households, industry and agriculture) in decision-making and make them responsible for their consumption. IWRM provides opportunities for sectors to work together and share knowledge and information. (ILEC, 2005) This will improve acceptance of decisions and the quality of the alternatives considered. It also increases the likelihood of compliance with the agreements reached. (Hirji, 2009)
- Use economic instruments and involve the private sector. (Hirji, 2009)

One of the main difficulties of IWRM is that policy development is made at a national level whereas the water management should be made at a basin level. This is particularly difficult when dealing with cross-border river basins in countries with different policy and legal frameworks. National institutions often do not want to hand over their power to basin level organizations. Institutional structures should be changed to reflect IWRM's broad principles. (Hirji, 2009)

In 2003, the GWP conducted a survey to assess the readiness of national Governments to implement a more integrated water management. It concluded that the readiness towards a more integrated approach has increased, but the implementation of it lags behind. (Global Water Partnership, 2006)

On European level, two well-known frameworks that guarantee the quality and quantity of water in the future are the "Water Framework Directive" (WFD) and the 2012 "Blueprint to Safeguard Europe's Water". The WFD of 2000 is a common policy framework that obliges all EU Member States to develop a policy that protects the European waters by 2015. (Vanham & Bidoglio, 2012) The Blueprint was designed to facilitate the achievement of the goals set out by the WFD by directing efforts and actions where needed. It tries to find EU policy responses to challenges such as over extraction and water scarcity. (EU, 2012) However, the assessment of the European Environment Agency (2012) shows that by 2015, almost 50% of Europe will not be able to reach the "good water status" target. (European Environmental Bureau, 2012)

Since 2005, water companies in Flanders (Belgium) have become obliged to clean the water they deliver. But even with this, it will still not be able to reach the requirements by 2015. (Buysse, 2014) In the US, the Clean Water Act (CWA) of 1972 sets out rules to guarantee the water quality. It regulates the discharges of pollutants into the US' waters. (The World Bank, 2006)

In Article 9 of the WFD, issues relating to an adequate cost recovery of water services, based on the "polluter pays principle" (PPP), can be found. By 2010, Member States had to ensure water-pricing policies incentivizes consumers to use water efficiently. The WFD did not specify a full cost recovery, but the full cost of water should be made clear to the users. (Anderson, 2008) With this framework, the EU is first in recommending the implementation of economic principles with regard to water. (Kolokytha, 2003)

Governments should stimulate efficient water use. Two examples where city management has been a success are Albuquerque in the US and Singapore. Albuquerque reduced its water consumption per person by 38% (from 950 to 662 lcd) since 1995 and has saved more than 380 billion litres of water since then. It has done so by handing out more than 14 million dollars of rebates for installations like low-flow toilets, waterless urinals and high efficiency washing machines. Moreover, 20 USD is paid to residents that attend classes on water conservation. Fines are distributed for citizens that turn on their sprinklers during daytime (11 am till 7 pm) from April to October and residential consumer bills have increased by 154% since 1995. (Hamilton, 2011)

The world leader in water conservation is Singapore. This densely populated island has a lot of rain but no space to store it. Moreover, its sandy ground does not absorb groundwater. As a consequence it has to import 1,4 billion litres of water a day (40% of its consumption) from Malaysia. By 2061 it wants to achieve water independency and it thus has to move quickly in promoting conservation, exploiting new technologies and recycling techniques. To collect the annual rainfall, rivers have been dammed, 17 reservoirs have been created and all rain that falls in the sewers is cleaned as drinking water. Desalination of water from the sea permits the city to supply another 10% of the water demand. With their wastewater recycling system they recycle all household water from toilet to shower through Reversed Osmosis (RO) (see 4.2.3) and UV lights for purification. This water is not used as drinking water but as cooling water for air-conditioning and for the industry. Water efficient appliances are strongly encouraged and the Government penalizes excess water use. (Hamilton, 2011)

4.2.4 Pricing

By increasing prices in the three sectors, water withdrawals can be reduced by 18% per year. (Rosegrant, 2002) The difficulty in right water pricing is to find the equilibrium between the financial sustainability of the system and the affordability for the consumer. Prices should increase to cover the full costs, but as water is a human right, customers should be able to afford it. (OECD, 2009)

With a business-as-usual (BAU) scenario, the water prices for domestic households are expected to be one and a half times higher by 2025 in developed countries and up to two times higher in developing countries. A similar price increase is expected for the industrial sector. (Rosegrant, 2002) Higher water prices do not only help to raise consumer awareness, but it also helps Governments raise funds to improve the infrastructure.

With the BAU scenario, water prices in agriculture are expected to double in developed countries and even triple in developing countries. (Rosegrant, 2002) Water pricing in the agricultural sector is not always representing the cost and thus not incentivising an efficient use of the resource. In most parts of Southern Europe (where water is most scarce), a flat rate for agricultural water pricing is applicable, often based on the surface of the irrigated area. This gives little incentives to farmers to reduce their consumption. (EEA, 2012b) In Northern countries, water for agriculture is mostly priced by volume and often cover operating costs and the depreciation of the infrastructure. Price increases in the agricultural sector happen less quickly than in the domestic and industrial sector, resulting in significantly lower prices. (Roth, 2001)

Illegal water abstraction (through exploitation of surface water without authorization or abstraction with pending licenses) is another frequent problem that should be tackled in the agricultural sector. (WWF, 2006) Moreover, agricultural subsidies should be reduced in order to make farmers more aware of their water consumption. (EEA, 2012b) Water price increases in agriculture should be implemented through incentive schemes: Governments could give subsidies to farmers that use water in an efficient way and who are willing to install water saving measures. (Rosegrant, 2002)

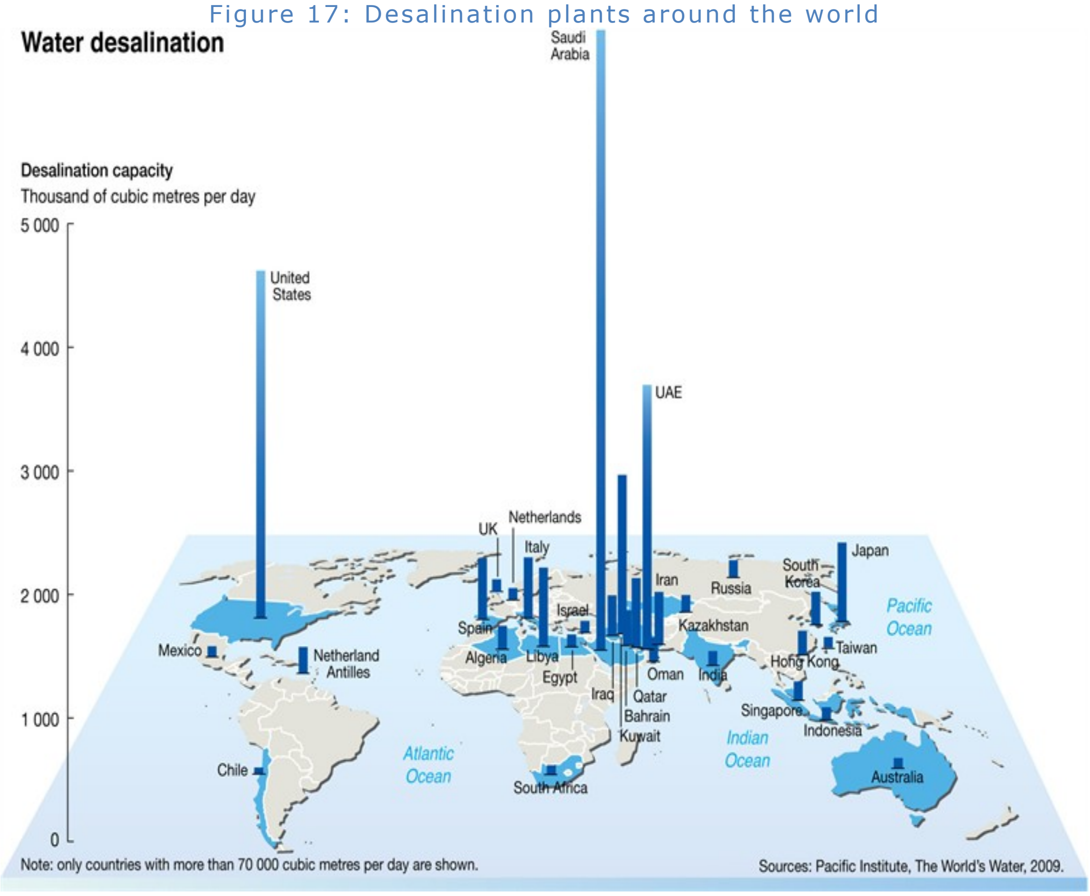
Seasonal water schemes can be a good way to reduce water consumption. Higher prices in summer (when evaporation is highest) and during daytime can be a good way to incentivise farmers to irrigate at night. Full cost recovery should include the price of the negative externality on the environment. To avoid full cost water pricing creating equity problems, it should be implemented in a comprehensive way. To make the price increase more acceptable towards consumers, it is necessary to inform them well and provide clear information on their water bills. Moreover, the increase in the water price should be a gradual one to avoid opposition. (Roth, 2001)

4.2.5 Desalination

As a lot of salt water is available on the planet and desalination techniques exist, why are we still worried about a lack of freshwater in the future? The potential benefits of desalination are great, but the costs are high. Recently, interest in desalination has risen, technologies have improved and prices have dropped, but it remains an expensive water supply solution. Moreover, in many parts of the world, alternatives such as treating low quality water, encouraging regional water transfers, improving efficiency and conservation and wastewater recycling and reuse can provide the same freshwater benefits at a lower cost. (Cooley, Gleick, & Wolff, 2006) Besides, desalination plants cannot always be installed as close to the city as a wastewater recycling plants. (UNESCO, 2007) Other options, that are less costly and less environmentally damaging should thus be considered first. (Cooley, Gleick, & Wolff, 2006)

Worldwide, there are about 15.000 desalination plants producing 64 billion litres of water a day. Desalination is becoming increasingly popular around the globe. As can be seen in figure 17, 52% of the desalination capacities are located in the Middle East, mostly in Saudi Arabia, where alternatives are limited and where the public is willing to pay high prices. (Cooley, Gleick, & Wolff, 2006) The rest is located in America (16%), Asia (12%), Europe (13%), Africa (4%), Central America (3%), and Australia (0,3%). (WEF, 2009, p. 24) In Europe, Spain makes most use of desalination, followed by Greece, Italy and Cyprus. (EEA, 2012a)

Figure 17: Desalination plants around the world

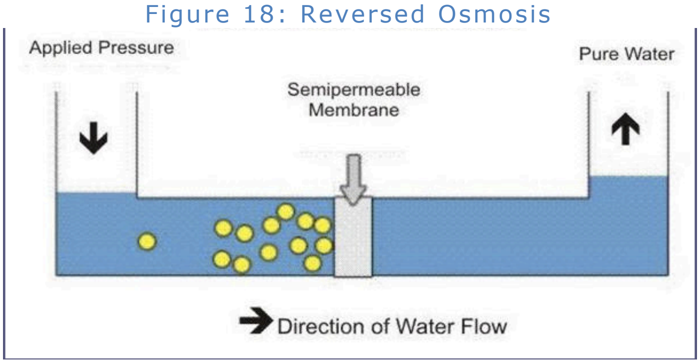


Source: (Pacific Institute, 2009)

The old technique of water distillation is still used in 50% of the desalination plants. With this technique, water is first heated and vaporized. Then, the non-salty water is collected and condensed again. Unfortunately, the heating of the water requires a lot of energy. Nowadays, water companies tend to use new desalination technologies that are more energy friendly, like reversed osmosis (RO). (See figure 18)

With RO, salt water is put under very high pressure and forced through a semipermeable membrane that lets water pass but not the salt. Unfortunately, also this technique requires a lot of energy and although the cost has been decreasing over the years, it remains quite high. (De Vos & Asper, 2006)

Figure 18: Reversed Osmosis



Source: (Source Water Team)

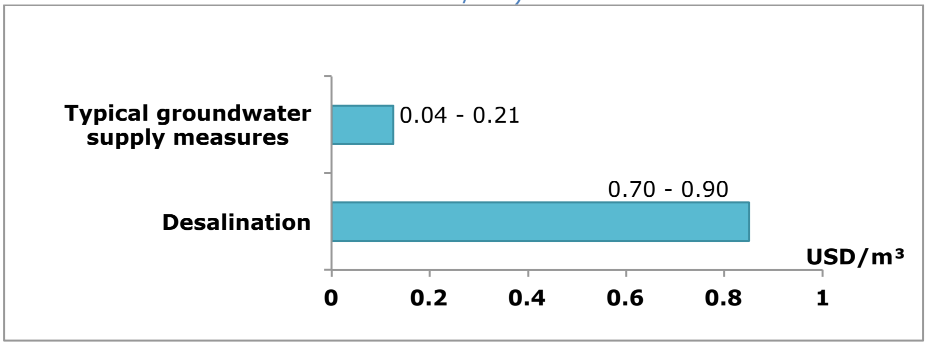
To produce 1 m^3 of desalinated water, 8 to 10 kWh of electricity was required in the past, whereas today 2,5 kWh of electricity is enough. (De Vos & Asper, 2006) A study in Melbourne (Australia) also compared the installation of a desalination plant with that of a water recycling plant. The conclusion is that desalination requires up to 10 times more energy than recycling wastewater. Desalination in this plant requires 4 kWh/m^3, whereas recycling only requires 1,2 kWh/m^3. Nowadays, newer, improved technologies exist to reduce energy consumption in desalination plants. A first refinement has been performed on the membranes: they perform the same task as before with a lower energy input. A second improvement is that the energy used during the desalination process can be partly recuperated after the water passed through the membrane. Those advancements make the cost of desalination converge with the cost of other water treatment techniques. (Duffy, 2008)

It is hard to compare prices of desalination, as data often fail to clearly mention the year, the energy price used, the plant size and the salinity of the water source. (Cooley, Gleick, & Wolff, 2006) Moreover, different currencies are used. According to Khayet (2013), in 1970, the water production cost[3] for one m^3 of desalted water was 5 USD, whereas in 2013, it was reduced to 1 USD/m^3. For brackish water (a mix of sea and river water) the cost is only around 0,6 USD/m^3. RO has a higher water production cost of 2,37 USD/m^3 for small plants (about 1,14 million litres a day) and a cost of 0,55 USD/m^3 for large plants (about 113,56 million litres of water a day). According to Cooley, Gleick and Wolff (2006) the cost of desalinating water in California never falls below 0,79 to

[3] The water production cost includes the annual operating costs (such as energy, labour and membrane replacement), indirect capital costs (insurance, administrative and legal fees) and direct capital costs (installation and buildings). (Khayet, 2013)

0,92 USD/m^3 even for large, efficient plants and can be as high as 2,21 USD/m^3. This price is clearly more than what customers generally pay. According to Sheehan (2009) the average cost of wastewater recycling lies between 0,2432 and 1,05 AUD/m^3. The cost of wastewater recycling depends on several factors such as the level of treatment and the infrastructure needed, such as pipes. In figure 19, The Water Resources Group 2030[4] compares the cost of desalination with the cost of typical groundwater abstraction methods. Once again, desalination seems to be the more expensive option.

Figure 19: Cost of desalination vs. typical groundwater abstraction measures (in USD/m^3)



Source: (Water Resources Group 2030, 2009)

Another inconvenience of desalination is that it consumes a lot of energy and emits big amounts of carbon. (Hamilton, 2011) A solution would be to use renewable energy sources such as wind or solar energy to desalinate salt water. (EEA, 2012a) Unfortunately, solar panels and windmills require a high investment. (De Vos & Asper, 2006) Water, unlike energy, can be stored for future use. If wind blows at night, the energy could be used to desalinate water that is then stored in a reservoir for future use. (Duffy, 2008) In Perth, the desalination plants are powered fully by wind and solar energy, but households have to pay extra costs for the additional supply. (Hamilton, 2011) When countries have no other options and can bear the costs, desalination plants are installed.

Also, desalination plants have a bad impact on the environment and sea life, as the brine returned to the sea after RO has twice the concentration of salt as compared to normal seawater. The impact on ecosystems nearby the desalination plants can thus be a problem. (Kowitt, 2009) However, in most desalination plants in Europe and North America, the brine has to be diluted with seawater before discharging it back into the Ocean, such that the salinity is only slightly higher than the original water. Moreover, to make the discharging process more efficient, desalination plants are build next to energy plants, so that the water used for cooling can also be used for diluting the brine. (Duffy, 2008)

Desalination plants are a very site-specific solution. Alternatives should be considered and costs should be weighed against benefits before undertaking a project. They can be a solution to prevent depletion but they should only be installed when no other cost effective, less environmentally damaging solution is possible. (Duffy, 2008)

[4] The Water Resources Group 2030 was formed in 2008 to find new insights about the water scarcity problem.

4.3 Solutions per Sector

4.3.1 Solutions for Households

4.3.1.1 Develop Mandatory Regulations

Since 1999, it is obliged by Belgian law to construct a rainwater cistern in new or renovated houses. The place of the rainwater cistern has to be mentioned on the building plan and has to satisfy a number of criteria: it has to contain a minimum of 3.000 litres. The size of the cistern further depends on the size of the roof area. An overflow also has to be placed in case the cistern would be full. This overflow should be separated from the sewerage. Some municipalities in Belgium subsidize rainwater installations for older houses. (Vanassche, 2005)

Until now, we are the only country in Europe that obliges its citizens to install a rainwater cistern by law. (Buysse, 2014) In Europe, rainwater collection should become obligatory. The implementation of this measure is easy and it would be a great example to follow for other countries in the world.

4.3.1.2 Reduce Domestic Water Consumption

Although small in volume as compared to the industry or agriculture, individuals' water consumption is expensive to treat and to deliver, and it is therefore important to manage it in a respectful way. (The Economist, 2010)

Some well-known tips are:

- Avoid water leakages, as this is bad for the environment as well as for the wallet. Table 7 gives an overview of the water consumption of several leakages and their estimated cost in Belgium. (Kindermans, 2014)

Table 7: Water consumption of some non-food goods

Leakage	Litres Wasted/Hour	Average Price of 2.41€/m^3
Drip by drip	4 l/h or 35 m^3/year	84,35 €/year
Gentle stream of water	16 l/h or 140 m^3/year	337,4 €/year
Stream of water	63 l/h or 552 m^3/year	1330,32 €/year
Leakage at the toilet flushing	25 l/h or 219 m^3/year	527,79 €/year

Source: (Kindermans, 2014)

- Install individual water meters in all countries to raise consumer awareness and reduce water waste.
- Store "grey water" from showers, baths and washing machines and reuse it to flush the toilet. (EEA, 2012b)
- In cities, use gravel or pavements instead of concrete to allow rainwater to penetrate into the soil. (PASS, 2013)
- Save water by installing a dual flush button (for small and big volumes) and by using rainwater instead of drinking water. (PASS, 2013) Toilets use approximately 9 litres per person 5 times a day. (Benito, 2009)

- Install saving showerheads: those showerheads create water droplets that mix with air and, as a consequence, reduce the water flow. With a good water saving shower head one can save up to 50% of water and thus only use 6 to 7 litres of water a minute instead of 12 to 16. (PASS, 2013) Table 10 gives an overview of the consumption of three household appliances and the average reduction that could be achieved by installing a more efficient product.

Table 8: Water consumption and saving potential for households

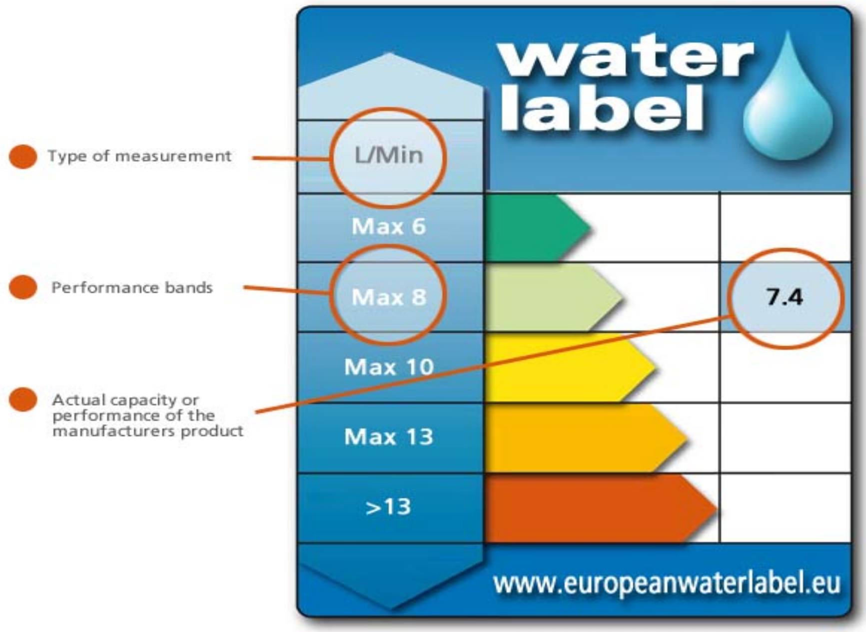
Water using Devices	% Of total household water consumption	% Of reduction in household consumption using a more efficient product
Toilets	31	13.7
Showers	33	6.2
Taps	10	2.2

Source: (Benito, 2009)

4.3.1.3 Impose Labels for Household Appliances

To encourage consumers to buy water saving products, the "European Water Label" was created. This label, which can be obtained through simple application by any manufacturer, shows the volume of water the product consumes in litres per minute. (See figure 20) It is applicable to all water using household appliances (including dishwashing machines, taps and showerheads) and is used throughout Europe, Israel, Switzerland, Russia, Ukraine and Turkey. (CEIR, 2012)

Figure 20: European water label for household appliances



Source: (The Water Label Company, 2013)

In Australia, the WELS (Water Efficiency Labelling and Standards) has been developed to provide information about water consuming products. The label looks like the energy rating label with a zero to six star rating to allow quick comparison between the products: the more stars, the more water efficient the product is. (Australian Government, 2013)

To date, Governments have made very little regulations concerning the water consumption of appliances. They seem to prefer the voluntary approaches such as information instruments and labels. However, Benito (2009) has shown that regulatory instruments seem to be more efficient in achieving their goals, but they fail to raise environmental awareness, as compared to voluntary measures. Moreover, as labels are a voluntary measure, they create little incentive for a manufacturer to increase the efficiency of its products. Mandatory labels could change this situation and stimulate producers to develop water efficient machines. No labels exist yet for industrial and agricultural water consuming devices.

4.3.2 Solutions for the Industry

4.3.2.1 Policies

A lot of action has already been taken to improve water management in the industry. Europe has set up standards that control industrial discharges. Pre-treatments of wastewater are required to make sure no heavy metals are discharged into municipal sewerage systems. (Scheierling, 2013) Governments could further establish policies and guidelines to encourage investments in wastewater treatments. (EEA, 2012b) Recycling wastewater and changing to less water consuming production processes could increase industrial water efficiency. The industrial sector could work together with the scientific community to develop new technologies. (WBCSD, 2006)

The EIP (European Innovation Partnership) for water is meant to boost the number of innovations in the water sector. (Buysse, 2014) It is an initiative from the European Union that is meant to bring expertise and resources of the public and private sector together. (European Commission, 2014) "INNOWATER" is another project of the EU, which was created to help new technologies and innovations in the water domain reach the market. (EU, 2014b) Those initiatives can be useful in the industrial sector, where research for new water saving and recycling techniques is expensive.

4.3.2.2 Water Quality

An interesting solution for the industry is to deliver water of a different quality depending on the required use. Cooling water does not need to be high quality water. As the industrial sector has very specific machines and needs, it could be a good idea to make this technique obligatory in the industrial sector around the world. (Kindermans, 2014)

AquaFit4Use (described in more detail in 2.3.3.2) is a project within the 7th Framework Programme of the European Commission, which tries to make the water quality fit to the needs of the industry (EU, 2014c)

4.3.3 Solutions for Agriculture

The water used in agriculture is often not piped water. This is a good thing as the quality needed to water the land is not the same as the water quality needed for domestic use. Farmers frequently use rainwater or water from a well to irrigate their land. The problem is that the quantity is not always measured nor priced, and therefore wasted. Farmers see water as a resource, just like their land, and they do not understand the need to reduce their consumption. (Kindermans, 2014) The OECD suggests some action that policy makers can take to move towards a more efficient water management in agriculture, such as the strengthening of property rights, the reflection of full cost of water supply to agriculture and the development of crops that can cope with extreme weather conditions. (OECD, 2010b)

4.3.3.1 Improve Irrigation

Irrigation efficiency consists of two parts. The first part is called "conveyance efficiency", which is the percentage of the water abstracted that is finally delivered to the field. In the EU, the amount of water that could be saved by improving conveyance efficiency is estimated at 25% of the water abstracted. The second part is called "field application efficiency", which equals the water consumption of a crop divided by the amount of water supplied to it. It shows how well an irrigation technique is able to transport water to the roots of the plant. Furrows have a field application efficiency of 55%, whereas sprinklers and drip systems have an efficiency of 75% and 90% respectively. The worldwide irrigation efficiency (the amount of water evaporated compared to the amount of water delivered to the field) was estimated to be around 63% according to Postel (1993).

Drip irrigation is a technique where water slowly goes to the roots of the plant through tubes, emitters and pipes, without having to water the whole field. (EEA, 2012a) Some techniques have been developed to measure the evapotranspiration per field. Sensors are used to measure the consumption of water through a satellite, such that farmers could take more intelligent decisions about where to plant their crops and when to water them. (The Economist, 2010) Watering plants at the time they need it can improve water efficiency substantially by allowing less evaporation. However, improved irrigation techniques do not always lead to a reduction in water consumption, as people might decide to increase their production. In Spain for instance, giving subsidies for drip irrigation in the region of Valencia, did not help to reduce total water consumption for irrigation. (EEA, 2012a) Stricter rules should apply in order to get access to the subsidies.

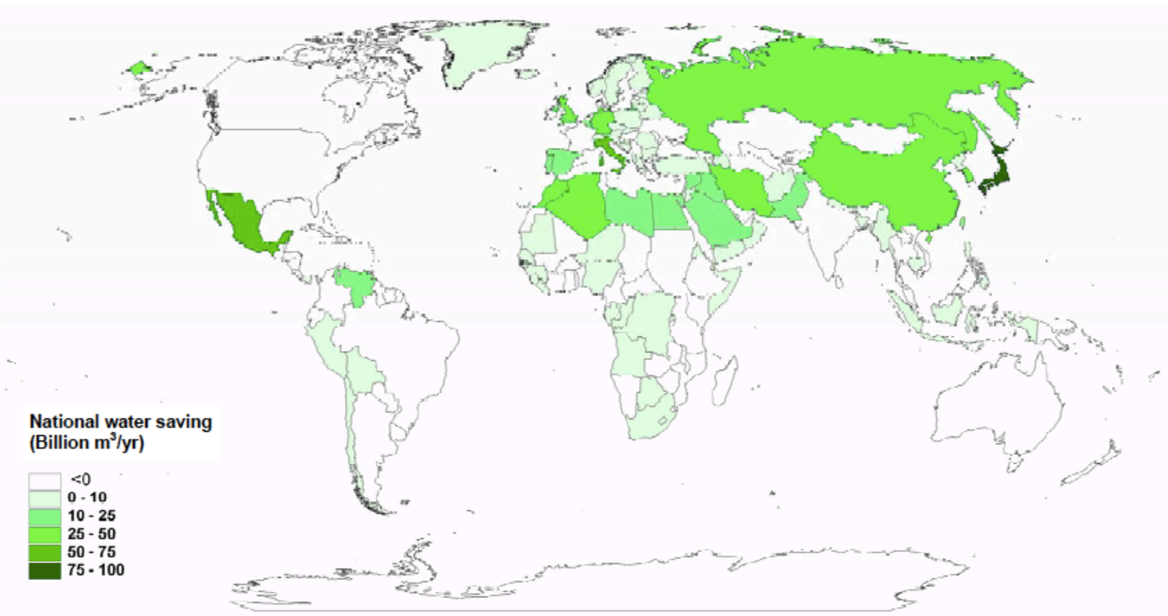
As water resources are becoming scarcer, wastewater is increasingly considered as a solution to expand available water supply. It can be used for the same purposes as freshwater, as long as it undergoes the necessary treatment. Because of the growing urbanization, agriculture increasingly takes place close to urban areas. As a consequence, recycled urban wastewater could be reused for agricultural purposes. (Scheierling, 2013) Making use of rain fed agriculture also has a great water saving potential and it puts less pressure on freshwater resources. When irrigating, a substantial amount of water is lost through evaporation or because of leakages in the transport or storage system. (Falkenmark, 1997)

4.3.3.2 Increase Virtual Water Trade

Another solution towards the global water shortage is to increase the trade of virtual water. As explained above, goods contain water and by re-allocating the production of water intensive goods to water rich countries, and low water goods to drier areas, efficiency on an international level could be raised. (The Economist, 2010) Chapagain, Hoekstra and Savenije (2005) calculated that the global water savings associated with the trade of agricultural products (crops and livestock) equalled 352 billion m^3 per year from 1997 to 2001. (See figure 21) The biggest saving potential comes from the international trade of crops, as they are often traded from water efficient to less water efficient regions. (Chapagain, 2005)

The idea to save domestic water resources in water scarce countries through the concept of virtual water imports seems attractive. However, it puts extra pressure on the water resources of the exporting country. To make it sustainable, the exporting country should include the opportunity cost and environmental externalities in the prices of its goods. With clear rules, trade could help putting less pressure on- and avoid the depletion of- water resources in dry areas. Unfortunately, global trade is rarely done with the purpose to address the water scarcity problem. (Chapagain, 2005)

Figure 21: Annual national water savings related to international trade of agricultural products

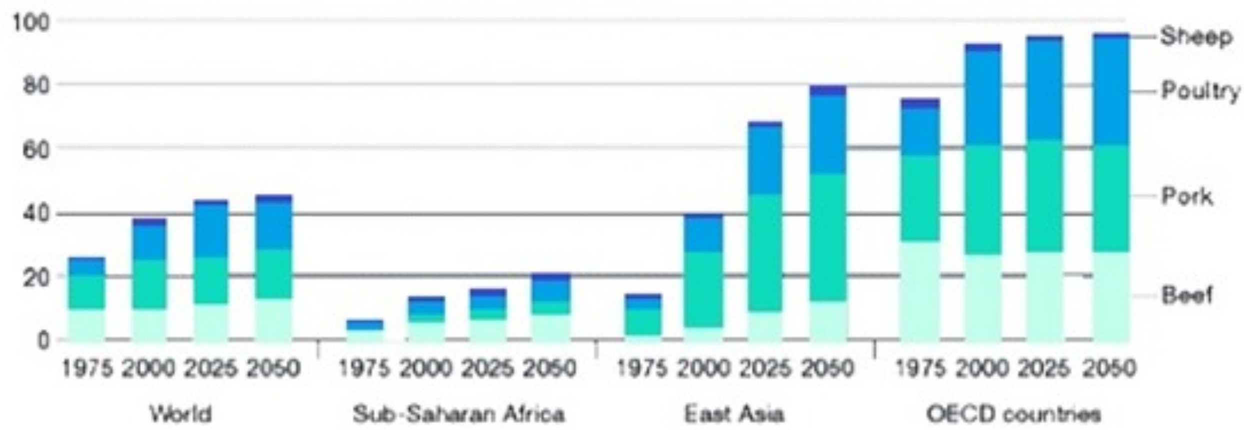


Source: (Chapagain, 2005)

4.3.3.3 Change People's Diet

As stated by the WEF (2009, p. 21), to be able to feed the entire population by 2050, food production will have to double. In figure 22, one can see the average meat consumption projections for 2050 in Africa, Asia and the OECD countries.

Figure 22: Meat consumption increase in future decennia(1)



(1) Data in kilograms per person per year

Source: (IWMI, 2007)

A possible way to reduce one's indirect WF is to stop consuming water intensive products, for instance by becoming vegetarian. In the EU, too high animal and vegetal protein intake characterize the average diet. Vanham, Mekonnen, and Hoekstra (2013) analysed the WF for different diets in the EU and came to the conclusion that for a healthy diet (2.200 kcal/day), 23% less water is needed (or 974 lcd) than for an average diet. Considering a normal diet of 2.700 kcal, Falkenmark (1997) estimates the water requirement for food at 1.570 m^3 per capita per year. According to Hoekstra (2010) the average calorie intake in industrialized countries is around 3.400 kcal per day, of which about 30% are animal products. An average intake of animal products requires 2,5 litres of water per kcal. Vegetables on the other hand require only about 0,5 litres of water per kcal.

According to the WEF (2009, p. 21), producing food for a person for one day in industrialized countries requires 3.600 litres of water. In developing countries, an average person has an intake of around 2.700 kcal per person per day, out of which only 13% is from animal origin. Such a diet only requires 2.050 litres of water per day. China's meat consumption is estimated to be around 150 grams per person a day whereas for an American, this lays around 350 to 400 grams per person a day. (WEF, 2009, p. 21) In table 9, the WF of different diets can be compared. In the industrialized countries, switching to a vegetarian diet reduces the food related WF by 36%; in case of the developing countries, only 15% of water is saved by switching to a vegetarian diet. (Hoekstra, 2010) Clearly, reducing meat consumption could help diminish our indirect WF.

Table 9: WF of two different diets for industrialized and developing countries

	Meat diet	Kcal/ day	Litre/day	Vegetarian diet	Kcal/day	Litre/day
Industrialized Countries	Animal Origin	950	2.375	Animal Origin	300	750
	Vegetable Origin	2.450	1.225	Vegetable Origin	3.100	1.550
	Total	3.400	3.600	**Total**	3.400	2.300
Developing Countries	Animal Origin	350	875	Animal Origin	200	500
	Vegetable Origin	2.350	1.175	Vegetable Origin	2.500	1.250
	Total	2.700	2.050	**Total**	2.700	1.750

- *The numbers are equal to the daily caloric intake of people in the period 1997-1999.* (FAO, 2009)
- *The vegetarian diet still contains dairy products*
- *Food from vegetable origin is assumed to have a water consumption of 0.5 litres per kcal and food from animal origin is assumed to have a water consumption of 2.5 litres per kcal.*

Source: (Hoekstra, 2010)

It is however not likely that people will give up their eating habits; a more realistic solution is that they will switch to alternatives. (Hoekstra, 2010) To produce sugar from sugar cane is more water intensive than producing sugar from sugar beet. Wine requires 870 m^3 of water per ton, whereas beer only requires 300 m^3 of water per ton. Drinking tea instead of coffee and wearing artificial fibre instead of cotton are other excellent ideas to reduce one's indirect WF. (Mekonnen & Hoekstra, 2011) But also for meat, alternatives exist

4.3.3.4 Promote Alternatives to Meat

Nowadays, 70% of agricultural land is dedicated to livestock. As global meat demand is expected to increase by 2050, we can conclude that there will not be enough space to keep on supplying meat for the whole population. Cultured beef is thus an excellent solution to save land and water. In-vitro hamburgers are made out of muscle stem cells of cows. Those stem cells serve to repair the muscle when it is injured. They can divide and multiply so that out of one stem cell, 10.000 kg of meat can be made. (Auriol, 2013)

Another alternative to meat are soy burgers and soy proteins. In the Netherlands, Pol Boom is a farmer that owns a particular butcher shop, namely one with no meat inside. All products he sells look like meat, but are, in reality, made out of soybeans and wheat proteins. The problem with those alternatives is that they are rather expensive, but the hope is that, by increasing sales in the future, the price will drop. (Boom, 2013) A study of Ecrin, Aldaya, and Hoekstra (2011) shows that the WF of soymilk and soy burgers is much smaller than the equivalent animal products. Soymilk only requires 28% of the WF of cow milk and only 7% of the average WF of a beef burger is needed to produce a soy burger.

Another alternative to meet the nutritional needs of a growing population is to start producing food with higher protein content.

4.3.3.4.1 Entomophagy

Insects are an interesting, environmental-friendly solution to prevent a water shortage in the future. The consumption of insects by humans is also called “entomophagy”. (InnovaTech, 2013) Crickets and larvae have a high nutritional value and need very little space, food and water to grow. A steak of 100 grams contains the same amount of proteins than 160 larvae or 40 crickets. (Auriol, 2013) It might sound futuristic, but around two billion people worldwide are already eating them. Moreover, we do already eat shrimps, mussels, oysters and snails. It is thus a psychological and cultural barrier that keeps us from eating insects. (Dhont, 2013) The nutritional value of insects depends on the stage of their lifecycle and on their nourishment. However, it is generally accepted that insects provide nutrients of high quality and that most species are rich in proteins, fatty acids (like in fish), fibres and minerals such as iron, copper, magnesium, zinc, etc. (InnovaTech, 2013)

In an interview with Damien Huysmans, co-founder of Green Kow, he reveals that to obtain 1 kg of beef, 15.500 litres of water and 10 kg of fodder for animals are needed. For 1 kg of insects, only 2 litres of water and 2 kg of fodder are needed. Out of 10 kg of fodder we can get 1 kg of beef, 3 kg of pork, 5 kg of chicken and 9 kg of grasshoppers. (InnovaTech, 2013) Moreover, only 13 weeks are needed to produce insects against several months for bovine meat. (Green Kow, 2013)

Green Kow is a Belgian enterprise and the first in Europe to offer products containing insects to organic food stores. In figure 23, Green Kow’s logo can be seen. Until now, they have created four toast spreads that contain 5 to 10% of mealworms. For now, integrating the entire insect in meals is impossible because of the cultural barrier. To make the integration of insects into our alimentation easier they are included in tapenades. (Green Kow, 2013) The FASFC (Federal Agency for the Safety of the Food Chain) of Belgium is the first organization of sanitary control in Europe to allow the commercialization of about 10 types of insects. (FASFC, 2014)

Figure 23: Green Kow

Source: (InnovaTech, 2013)

4.3.3.5 Develop Food Labels

In case people are not ready to switch to alternatives like soy burgers or insects, they should be given the possibility to buy products that consumed less water during their production process. This solution requires proper product information for consumers to be able to make the right choices. To provide this information, businesses should make an effort to create product transparency and Governments should install the necessary regulations. (Hoekstra, 2010)

An eco-label for food products was discussed within the European Parliament in the past, but has been rejected. (Byrne, 2009) Such a label could however encourage a more efficient water use in the production process of food. It should be used in the same way as the "Fair Trade" label, but in this case to encourage consumers to buy products that are water wise (consume little water). If customers adapt their buying behaviour, they could incentivize the producers to qualify for this label, and thus reduce their water consumption. A label makes the invisible link between products and their WF clear to consumers; a link that has been hidden until now. The difficulty is that, to analyse the WF of a good, its whole supply chain should be analysed and this requires interaction from a lot of parties. (Hoekstra, 2006)

In figure 24 we see several steps that need to be taken into account when calculating the WF of an animal product. The first step: "growing the feed" is by far the biggest contributor to the total WF of animal products. However, this step is the furthest removed from customers and that explains why they are generally not aware of the fact that animal products require a lot of water. Businesses have a key role in communicating this link. Retailers are the intermediaries between farmers and consumers and hence, they can put pressure on farmers to reduce their products' WF and to provide transparent information. (Hoekstra, 2010)

Figure 24: Supply chain of animal products

Source: (Hoekstra, 2010)

We created a label that could be used on agricultural products that used water wisely during their production process. (See figure 25) It represents a drop of water with as shadow its footprint, that consumes less water than would be needed without any water saving effort. Food that has been produced using water saving measures and thus having a lower WF than similar products, could apply to obtain such a label. Only after having checked the information, the producer would be able to use the logo on its products. This logo will only stay valid for a limited time period, as the average WF used by products will decrease due to technological developments. A limited time period will incite producers to continuously reduce their WF and improve their water saving measures.

Figure 25: Water label: own creation

Source: (Vandernoot, 2014)

In summary, the potential functions of a water wise label are the following:

- it communicates water scarcity to customers and creates public awareness,
- it encourages businesses to check their supply chain and to change water consuming practices and
- it enables customers to choose for the less water intensive products. (Benito, 2009)

4.4 Conclusion

Solutions do exist to guarantee a future with sufficient freshwater. However, they require cooperation of sectors, countries, Governments, consumers and institutions. Some new techniques to improve the supply of water, like desalination, can be very efficient in certain regions; but their huge cost, energy consumption and site-specific requirements keep them away from being the ideal solution.

Governments should become more sensible to the water scarcity issues. This can be achieved by providing better and more transparent information. A lot of statistics on water can be found, but often, different numbers show up, which makes the data difficult to understand and interpret. Harmonization of statistics by setting standards should make sure comparison of numbers makes sense.

Once informed, Governments can make a real change by promoting awareness and giving the water issue more weight. Legal mechanisms have to be put in place to incite customers to use water in a wiser way. Younger generations are the future water consumers. Educational projects are a good way to raise awareness and reduce future demand. Governments should also ensure water is available to all sectors and that everyone is paying a right price for it. Volumetric pricing schemes and individual pricing meters are tools that make customers aware of the value of water. Although water should be priced, it is very difficult to find the right balance between sustainability of the system and affordability of the customer.

Action should also be taken at supra-national level. Therefore, Governments should be willing to hand over their power to organizations that ensure a good water management at the river basin level. If rivers cross borders of several countries, a joint management is necessary to ensure no mismanagement occurs.

To put less pressure on freshwater resources, mandatory rainwater collection could be implemented. In the Industry, water of a different quality can be used for different purposes. Moreover, industries around the world should have the obligation to clean their own wastewater, as is already the case in Europe. In the agricultural sector, a lot of improvement opportunities exist. More efficient irrigation techniques, such as drip irrigation, should be obliged, especially in dry areas where a lot of water is wasted through evaporation. A change in people’s diet would have a major impact on a nation’s WF. Unfortunately, the likelihood of people changing their eating habits is low. If prices of meat products increase, consumers might decide to switch to other protein rich alternatives such as soy burgers, in-vitro hamburgers or insects. Although these alternatives may become reality in the future, water labels are a better starting point to make the link between food and water consumption clear to customers in the years to come.

5 General Conclusion

Water scarcity already exists and will continue to spread throughout the globe in the years to come. Nevertheless, in this report we manage to answer the Central Research Question about how to guarantee a future with sufficient freshwater for everyone.

Although a lot of literature is available about water, uniform information concerning the pricing and the abstraction of water is lacking. Harmonization of definitions on water use, withdrawal and consumption as well as harmonization of water stress and scarcity indicators are necessary to provide clear information. Consistency of statistical data in the water field needs to be improved and norms about what to include should be developed such that comparison between (and within) countries becomes possible. In the EU, data is lacking about a majority of Member States and, when data is available, it is not always clear what they include. On European level, each country should be obliged to give clear and transparent information on their water consumption and pricing schemes, according to uniform standards.

To be able to take measures on European level, water awareness needs to be raised. To a lot of water users in developed countries, the water scarcity issue is unknown or perceived as unrealistic, because of the easy access to the resource. Unfortunately, the global water problem continues to be seen as the neighbour’s problem. Local Governments and supra-national organizations have the responsibility to communicate to users that this resource is not ever renewable and that care should be taken of it. The water problem has to become a hot topic in future electoral campaigns. Further, advertising can be organized to reach the public.

Of course, some progress has already been achieved in the past. Nowadays, organizations like the World Water Council and UN-Water exist, whose mission is to promote water awareness and increase political commitment. In our opinion, such organizations should receive more attention and weight on a global level.

Yet, more improvement can be achieved. It came as a surprise to us that no regulation concerning water meters exists in Europe. We believe this should be obligatory in new constructions in all Member States and apartments should switch from a general water meter to an individual one. Mandatory rainwater collection also has to become the norm in all Member States and rainwater has to be used in toilets as well as for watering the garden. In the price field, another step towards progress can be made. All nations should oblige their customers to pay in a way that incentivizes responsible water consumption. Flat rates and decreasing block tariffs should be changed for volumetric rates as well as increasing block tariffs.

Water has a price, and the fact that it is necessary for life, does not mean that it should be for free. Pricing water justly will reduce waste. However, everyone should have access to a minimum amount of water to live. Pricing and guaranteeing a minimum access to the resource are combinable, as long as strict rules apply. Delivering an amount of water for free can overcome the water affordability problem of the poor. Within Europe, water-pricing policies vary widely: some countries installed a progressive water price, whereas others do not incentivize efficient water use at all. Also here we believe a supra-national organization could help ensure that free riders make a gradual change in their water policy.

A good water-pricing scheme for households in European countries would resemble the system in Belgium. To ensure poor people have access to a minimum amount of water, 15 m^3 per person a year (41 lcd) should be given for free. An IBT should be installed for the remainder of the water consumption. The next 100 lcd (365 m^3 per person a year) should be charged at a relatively cheap price, just enough to cover all costs, including distribution costs, wastewater collection and purification expenses and the infrastructure. We chose 100 lcd, as this can ensure a comfortable way of living in Europe. All water consumption above this 141 lcd should be charged at a high price compared to the first 100 litres, as luxury has a price. The extra funds should then be used to finance water infrastructure to avoid leakages and new developments in the water field. Whether the involvement of the private sector is needed for financing, is questionable, as no one else than the public sector can better govern the public interest. We believe in a good cooperation between both, where good contracts ensure fair cooperation.

For the industrial sector, water of different qualities should be exploited depending on the use. Prices of water should increase to cover the full cost of supplying and cleaning it. Moreover, all industries should have their own wastewater treatment installation. Giving subsidies should encourage the use of water saving appliances. In the agricultural sector, water prices should increase sharply and regulations should prohibit illegal water use. In case farmers still want to obtain agricultural subsidies, they should install water saving measures such as drip irrigation.

In our analysis, we mainly focussed on the agricultural sector. Till now, policy makers tried to regulate water use at a local or river basin level and they did not take into account the amount of water that was embedded in products. This should change to ensure water is used sparingly along the whole supply chain of a product. Consumers, when water aware, may start demanding more product transparency and information about the products they buy. They can choose the products with a lower WF whenever the information is available. Governments can put regulations in place, in the form of international agreements, which urge businesses to create product transparency. Distributors can use their power in the supply chain to pressure manufacturers to provide product transparency. Moreover, water intensive products made in countries where water is scarce should be sold in the EU at a higher price by imposing import tariffs. This would make water wise products relatively more attractive. Moreover, water wise labels can help modify the consumer’s behaviour and as a consequence, supply will adapt to demand.

In the long run, people may have to adapt their diet and get used to new eating habits. In-vitro hamburgers, soy burgers and insects are excellent substitutes for animal meat and need less water to be produced. Without any doubt they will form part of our diet in the near future. Further, awareness campaigns and educational projects in schools are important, as younger generations will be the future water consumers. Water is a common inheritance. Customers, Governments and businesses around the world have a shared responsibility to manage it well.

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