Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Bachelor Thesis

Solutions to Global Water Scarcity

Krasovskyi Dmytro

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

Dmytro Krasovskyi

Business Administration

Thesis title

Solutions to Global Water Scarcity

Objectives of thesis

The goal of this thesis is to clarify reasons and explain ways of prevention of water scarcity in developing countries by comparing and proposingthe potentilly best sollution.
In the theory part of this Thesis will be discussed the reasons which lead to food and water scarcity and what can we do to decrease their influence or even prevent the issue. In the practical part the 3 potentially good methods for water scarcity prevention will be observed and compared.

Methodology

In the theoretical part will be used descriptive method to depict existing problems and ways of solving it using own knowledge about water scarcity and e-sources, which will prove and expand it. To demonstrate the issue, its effects and reasons, to reveal methods of solving completely, the statistical data from trusted resources will be provided.

In the practical part statistical data will be observed and analyzed. Consequently, the 3 potentially good possible water scarcity solution will be proposed by comparing method.

The proposed extent of the thesis

40-50 pages

Keywords

scarcity, deficit, food, water, water pollution, agriculture, ineffective irrigation, global problem

---

Recommended information sources

FAO, 2011, Global food losses and food waste – Extent, causes and prevention. Rome ISBN 978-92-5-107205-9

FAO. 2018. Asia and the Pacific Regional Overview of Food Security and Nutrition 2018 – Accelerating progress towards the SDGs. Bangkok. ISBN 978-92-5-130845-5

GLEICK P.H et al. (2014). The World's Water: The Biennial Report on Freshwater Resources. Washington, DC: Island Press ISBN 978-1-61091-483-3

HELLE MUNK RAVNBORG, 2004, Water and Conflict "Conflict prevention and mitigation in water resources management", ISBN: 87-7605-029-7

CHERYL A. DIETER, MOLLY A. MAUPIN, RODNEY R. CALDWELL, MELISSA A. HARRIS, TAMARA I. IVAHNENKO, JOHN K. LOVELACE, NANCY L. BARBER, AND KRISTIN S. LINSE (2015) -Estimated Use of Water in the United States in 2015, U.S. Geological Survey, Reston, Virginia: 2018 Supersedes USGS Open-File Report 2017–113

Expected date of thesis defence

2018/19 SS – FEM

The Bachelor Thesis Supervisor

Ing. Pavel Kotyza, Ph.D.

Supervising department

Department of Economics

Electronic approval: 12. 3. 2019

prof. Ing. Miroslav Svatoš, CSc.

Head of department

Electronic approval: 12. 3. 2019

Ing. Martin Pelikán, Ph.D.

Dean

Prague on 14. 03. 2019

Declaration

I declare that I have worked on my bachelor thesis titled "Solutions to Global Water Scarcity" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 14.03.2019 ____________________

Acknowledgement

I would like to thank Ing. Pavel Kotyza, Ph.D. for support and advice during my work on this thesis.

Řešení globálního nedostatku vody

Souhrn

Cílem dané bakalářské práce je upozornit lidi, aby věnovali pozornost globálnímu problému nedostatku vody. Nedostatek vody je aktuální problém, ale zda to je globální problém, o kterém se mluví v každém článku nebo je to jenom přeceněno? Milióny lidí žijí v každodenní potřebě vody. Nerovné rozdělení vody v afrických zemích, nedostatek vody v Asii atd. vynucuje lidstvo se každý den setkávat s umírajícími lidmi z důvodu deficitu vody. Každý den lidstvo potřebuje víc a víc vody, a to ne jen z důvodu zvyšujícího se počtu obyvatel, ale i kvůli narůstajícím potřebám. Nedostatek vody také způsobují takové faktory, jako jsou například – zvyšování produkce průmyslu, zavlažování, atd. Otázka je, jak řešit problém nedostatku vody?

V této tezi bude navrhnuto několik potenciálních řešení pro zabránění rozvoje daného problému, nebo dokonce jeho úplnému skončení. Budou rozebrány 3 potenciální metody pro zabránění nedostatku vody a hodnocení jejich způsobilosti v současných podmínkách.

Klíčová slova: nedostatek, deficit, voda, znečištění vody, zemědělství, zavlažování, globální problém

Solutions to global water scarcity

Summary

The purpose of this thesis is to make people pay attention to such global problem as scarcity of water. Water deficit is the most ambitious problems of contemporary, but is it a global problem as it is said in every article or the problem is overestimated? Millions of people live in a constant need of water. Unequal distribution of water in African countries, water deficit in Asia, etc. makes mankind to face people dying from permanent lack of water every day. Because of population growth as well as peoples` needs, humans need more and more water every day. Increasing in industries` production, irrigation`s withdrawal rising, etc. help to develop water scarcity problem. So, what can be the way out from the dramatically developing deficit?

In this Thesis, potential solutions for preventing issue development or even stop its manifestations will be proposed. 3 the most potential methods for prevention will be observed and the rating for their suitability under conditions of contemporary.

Keywords: scarcity, deficit, water, water pollution, agriculture, irrigation, global problem

Contents

List of Figures and Tables

1.Introduction

Water consumption increased greatly for the last 100 years. And it seems that the reasons are simple. Population growth, unclean water, climatic factors and expanded people needs. Almost everyone is convinced that the main reason of water scarcity is the result of population growth. On the one hand, it is true. More people-more consumption. Nevertheless, population growth is not the main reason of emergence such problem as deficit of water.

The main reason is incompetent use of financial resources. Amount of money which is spent on agriculture, water treatment technologies, etc. is impermissibly low and authorities know it, but political factors, wrong priorities and sometimes even humans` greed do not allow people to act correctly. Some people do not even know about water scarcity problem. It is more convenient to think that if now water deficit is not concerning the country they live in, then there is no sense to worry about it, but it is wrong. Or not?

2. Objectives and Methodology

2.1. Objectives

The goal of this thesis is to clarify reasons and explain ways of prevention of water scarcity in developing and developed countries by comparing and proposing the potentially best solution.

In the theory part of this Thesis will be discussed the reasons which lead to water scarcity and what can people do to decrease their influence or even prevent this issue. In the practical part the 3 potentially good methods for water scarcity prevention will be observed and compared. Which of the methods will be potentially best? Will it be possible to use worldwide? What return on investments should government and people expect if they invest in water collecting systems? All these and more questions will be answered in this Thesis.

2.2. Methodology

In the theoretical part will be used descriptive method to depict existing problems and ways of solving it using own knowledge about water scarcity and e-sources, which will prove and expand it. To demonstrate the issue, its effects and reasons, to reveal methods of solving completely, the statistical data from trusted resources will be provided.

In the practical part statistical data will be observed and analyzed. Consequently, the best possible water scarcity solution will be found by comparing method and proven. To find the best way to prevent water deficit, all three methods will be analyzed for price, return on investment, capacity and applicability. Also, the influence of external/internal factors will be analyzed and the proven best way of improving will be provided.

3.Literature Review

To begin with it is important to mention that such global problem as Water Scarcity cannot be described fully in one Bachelor Thesis. Nevertheless, the specific examples using certain countries situations and case studies will help to understand the origins of the problem and can be applied to almost every same situation.

To define the problem ranges, measurable and objective water reserves and its usage will be defined. As long as Thesis go deeper, hard-measurable reasons and origins of Water Scarcity will be explained. At the very end there is subjective but proved information such as the possible ways of prevention the problem.

3.1. World water reserves

Our planet consists of 70% of water and only 30% of land, which makes the world water reserves almost inexhaustible for at least couple more thousands of years. However, there is a big problem mankind face. The fresh water deficit. The *Figure 1 (p.8)* perfectly demonstrates uneven distribution of saline and fresh water on the planet Earth. The problem humanity must solve. (GLEICK P., 1993)

Figure 1: Global water distribution

One estimate of global water distribution
(Percents are rounded, so will not add to 100)

Water source	Water volume, in cubic miles	Water volume, in cubic kilometers	Percent of freshwater	Percent of total water
Oceans, Seas, & Bays	321,000,000	1,338,000,000	--	96.54
Ice caps, Glaciers, & Permanent Snow	5,773,000	24,064,000	68.7	1.74
Groundwater	5,614,000	23,400,000	--	1.69
Fresh	2,526,000	10,530,000	30.1	0.76
Saline	3,088,000	12,870,000	--	0.93
Soil Moisture	3,959	16,500	0.05	0.001
Ground Ice & Permafrost	71,970	300,000	0.86	0.022
Lakes	42,320	176,400	--	0.013
Fresh	21,830	91,000	0.26	0.007
Saline	20,490	85,400	--	0.006
Atmosphere	3,095	12,900	0.04	0.001
Swamp Water	2,752	11,470	0.03	0.0008
Rivers	509	2,120	0.006	0.0002
Biological Water	269	1,120	0.003	0.0001
Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York).				

Source: P.Gleick, 1993, Water in Crisis: A Guide to the World's Fresh Water Resources

3.1.1. Salty water

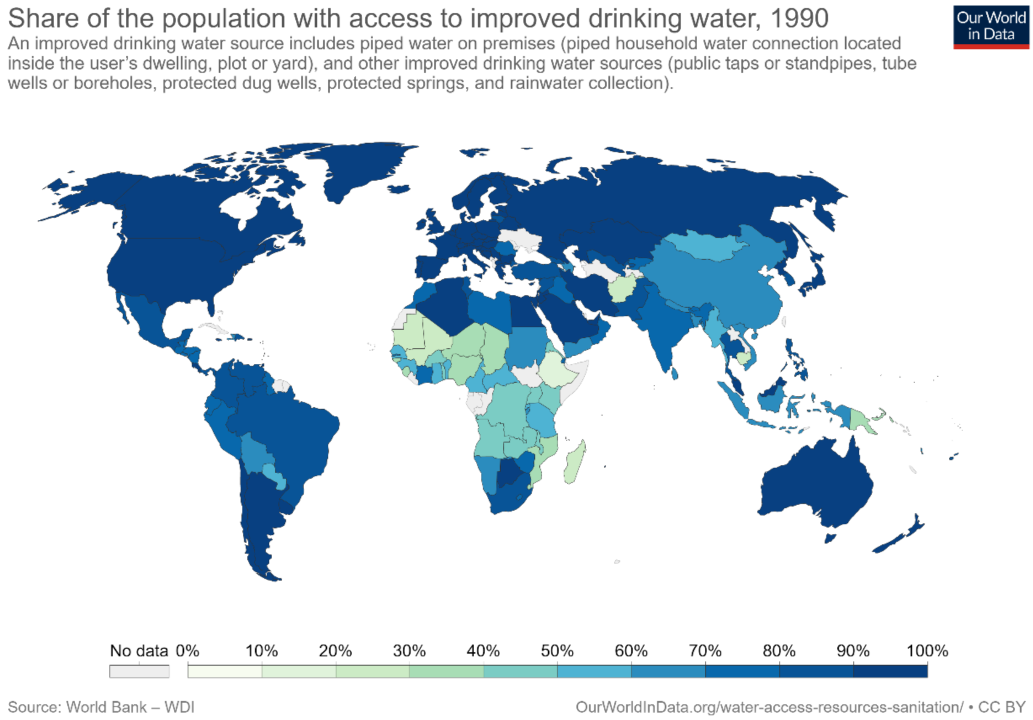
71% of our planet surface is covered with water. Almost 1.4 billion km3, which is immense volume. Main and the most needed resource for life on our planet. Unfortunately, the biggest part (97%) of planet`s water is salty and unsuitable for human use. Sea water is impossible to drink because of the high content of salts and minerals, for the removal of which the body requires more water than its drunk amount. Moreover, it can`t be widely used for agriculture, because it changes type of soil, making it too salty and consequently unproductive for most of crops. Nevertheless, salty water is still useful resource for industries and humans. Below it will be talk about desalination and how exactly salty water can be used as it is. (GLEICK P., 1993)

3.1.2. Fresh water

Evidently, if 97% of all water on the Earth is salty, then remaining 3% is for fresh water. Such water contains low percentage of salts or sometimes none of it. Rivers, lakes, bogs, etc. All of them is a surface sources of fresh water. Surface waters are easily accessible and easy to use, but there is a danger to exhaust them. Nevertheless, rivers and lakes are not the biggest sources of fresh water. ¾ quarters of fresh water are frozen and it is hard to reach it, though now humanity tries to chip parts of icebergs to get fresh water out of them and every year amount of fresh water, which was get out of icebergs, goes up.

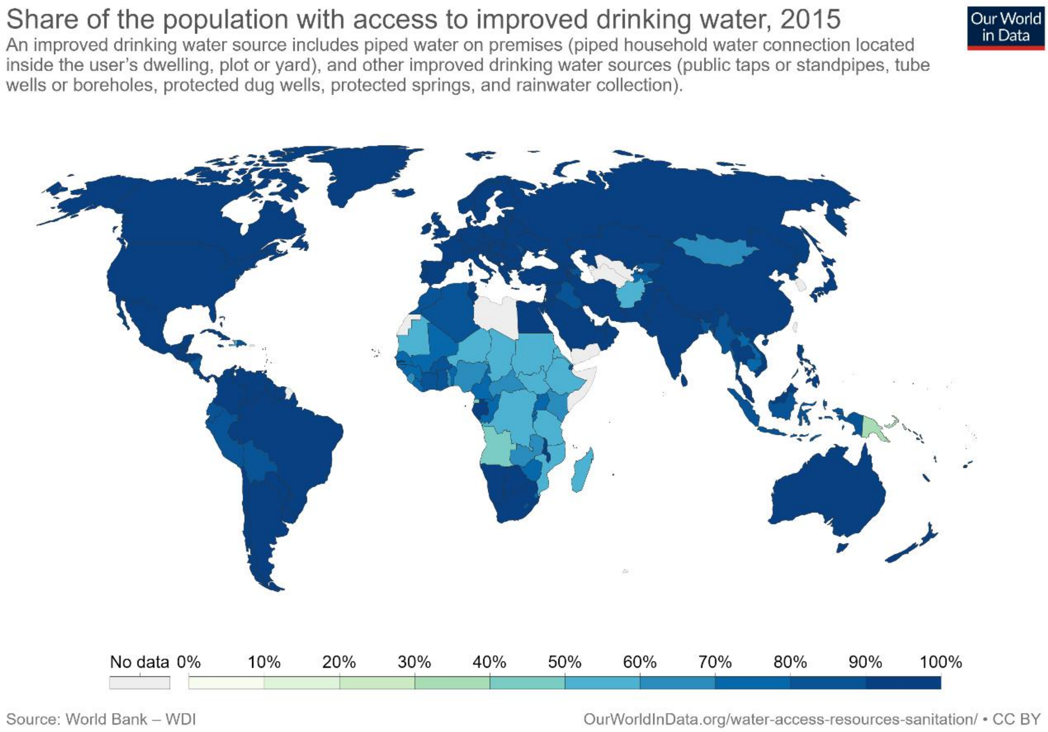
Also, there is such sources as groundwaters and atmospheric moisture, but they are extremely hard and expensive to extract. Moreover, the problem of fresh water is not only its scarcity, but also, its uneven distribution on the Earth surfaces, so some countries suffer a lot and some of them are provided by nature abundantly. Fortunately, the situation with drinking water access demonstrates improvement over the period from 1990 to 2015 year as shown in *Figure 2, 3* *(p.10)* (WORLD BANK, 2015)

Figure 2: Share of the population with access to improved drinking water, 1990



Source: World Bank - WDI

Figure 3: Share of the population with access to improved drinking water, 2015

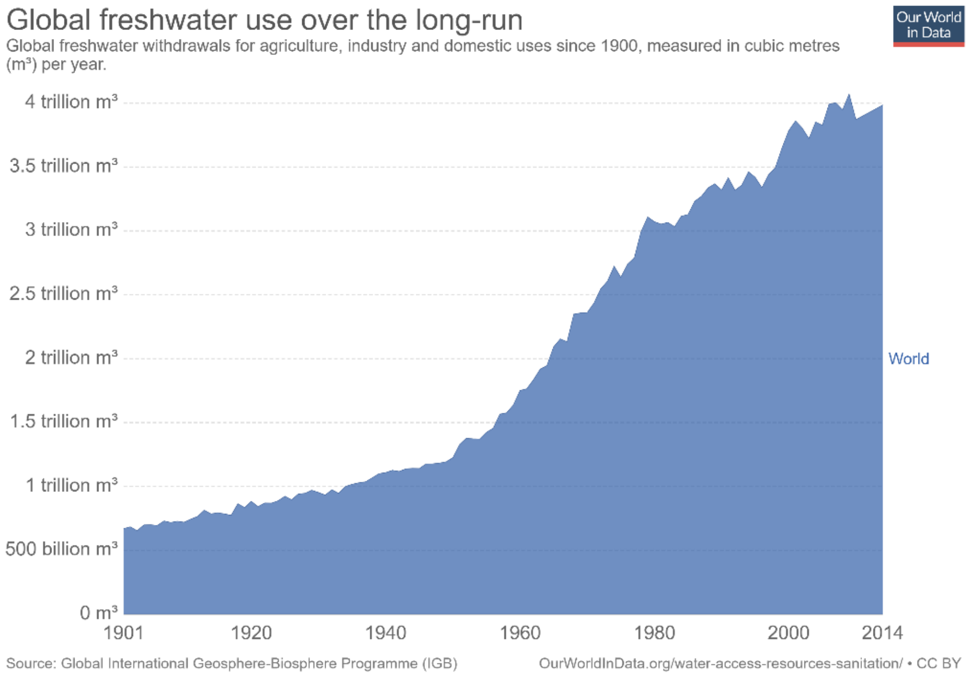


Source: World Bank - WDI

3.2. Water Usage

The water supply is quite limited, but as popularity is growing, the more water humans need. *The Figure 4 (p.11)* demonstrates what is happening from year to year and how dramatically humans` needs increase. (GLOBAL INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME (IGB), 1901-2014)

Figure 4: Global freshwater use over the long-run



Source: Global International Geosphere-Biosphere Programme (IGB)

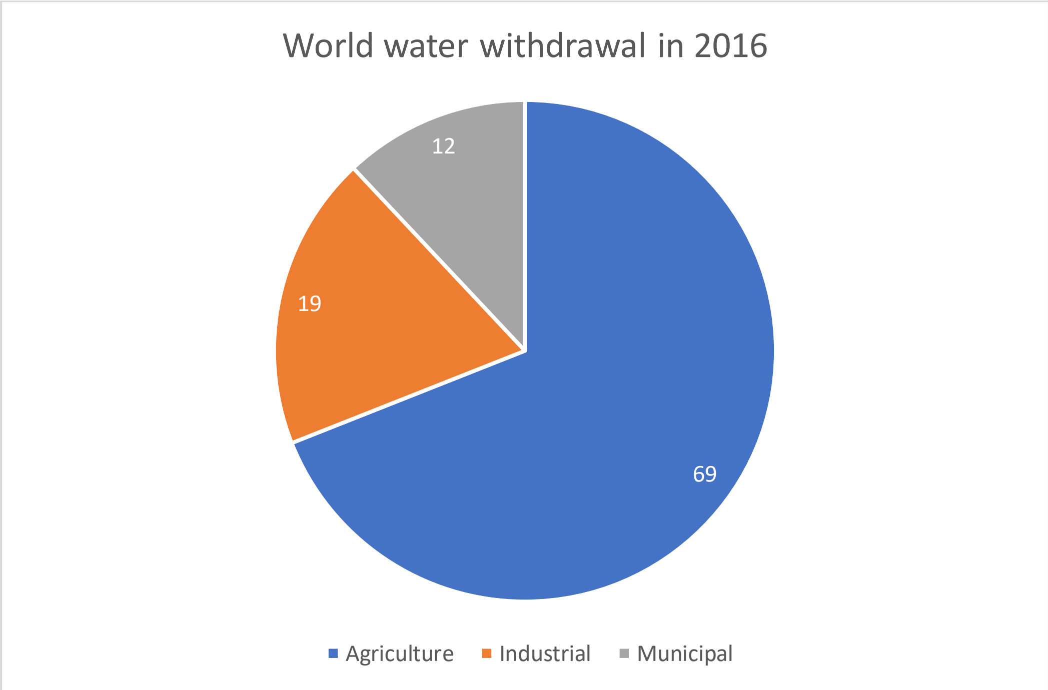
The most logical question which can be asked here is "How to prevent or limit annual increase?". To answer this question, it is important to know what water is used for.

3.2.1. Water in Agriculture

In most countries, one of the leading industries has always been agriculture. Even in those countries where a significant share of the national economy occupies light and heavy industry or engineering, agriculture plays too important role and it is impossible to ignore it, since this sector literally feeds the population of the country.

There is no such branch of the national economy, where water was required in such quantity, as in Agriculture. *Chart 1 (p.12)*

Chart 1: World Water Withdrawal in 2016



Source: Own processing based on FAO, 2016

Every day, even a small settlement requires huge amounts of water, which goes to provide for the economic needs of people living in the village, as well as livestock and poultry farms, for watering fields and greenhouses, for processing agricultural products and other needs.

Unfortunately, if, for example, heavy industry uses low-quality water or even sea-water, because it is used only for cooling, then in agriculture people are forced to use disinfected, filtered water with certain amount of salts and microelements.

Irrigation and food industry are taking immense volumes of fresh water. For the processing of different food crops, a different amount of water is required, depending on the product, the technology of production and the availability of water of appropriate quality in sufficient quantities. In the United States, from 1,600 to 2,000 litres of water is used to produce 1 kg of bread. In Europe for receiving the same amount of bread only 1,000 litres of water are spent. However, as observations remark meat products, amount of required water goes up in geometrical progression. Thereby, to get 1 kg of pork mankind spend 6,000 litres of water. To produce 1 kg of beef humanity must gift 15,000-25,000 litres of water.

You can find more information about water usage for food growing in the *Figure 5 (p.13)* (MEKONNEN M.M, 2010)

Figure 5: Water withdrawal for Food Industry

	Litre per kg	Litre per kilocalorie	Litre per gram of protein	Litre per gram of fat
Sugar crops	197	0,69	0	0
Vegetables	322	1,34	26	154
Starchy roots	387	0,47	31	226
Fruits	962	2,09	180	348
Cereals	1644	0,51	21	112
Oil crops	2364	0,81	16	11
Pulses	4055	1,19	19	180
Nuts	9063	3,63	139	47
Milk	1020	1,82	31	33
Eggs	3265	2,29	29	33
Chicken meat	4325	3,00	34	43
Butter	5553	0,72	0	6,4
Pork	5988	2,15	57	23
Sheep/goat meat	8763	4,25	63	54
Beef	15415	10,19	112	153

Source: Own processing based on M.M.MEKONNEN AND A.Y.HOEKSTRA, 2010.

3.2.2. Water withdrawal for Industries

As it was mentioned above, agriculture is a sector, which requires more than half of all water, but all remaining industries also spend a lot of water resources. To produce cars more water is used than for filling the pools. Some industries more intensively consume water than others. So, here will be listed the ones, which spend the biggest water volumes.

The pulp and paper industry

It is one of the most intensive water-consuming industry because of the huge volume of processed raw materials. To produce one ton of pulp and paper, an average of 54 m^3 of water is spent in the U.S. (FLUENCE NEWS TEAM, 2018)

Textile industry

This industry requires a lot of water for soaking raw materials, cleaning and washing, bleaching, dyeing and finishing fabrics. To produce each ton of cotton fabric it is spent from 250,000 to 350,000 litres of water, wool demands up to 300,000 litres.

However, popular nowadays synthetic fabrics requires a little bit less, than natural materials (up to 200,000 litres). According to USEPA a unit producing 20,000 lb / day of fabric consume 36000 litters of water. (MUHAMMAD A., 2009)

Mining industry

Every day in the US 15 million m^3 of water is used to get iron, sand, oil, etc. Corporations generously squander precious resource to get another one.

The numbers are huge, and it is hard to believe that people are not suffering from thirst yet. (DIETER, 2018)

3.3. Reasons of water scarcity

3.3.1. Population growth

The population of the Earth is around 7.5 billion people. An annual increase reached 80 million and this value is rising greatly. Each year, 25 million cubic meters of water more needed. According to UN experts, in 2030, 47% of the world's population will live under the threat of water shortages. The loss of fresh water increases with the growth of its consumption per capita and associated with the use of water for economic needs. Most often it happens due to the imperfection of technology in industrial, agricultural production and utilities. Large losses of fresh water occur in the development of mineral deposits, melioration of wetlands, and artificial soil drainage. (UNESCO, 2009)

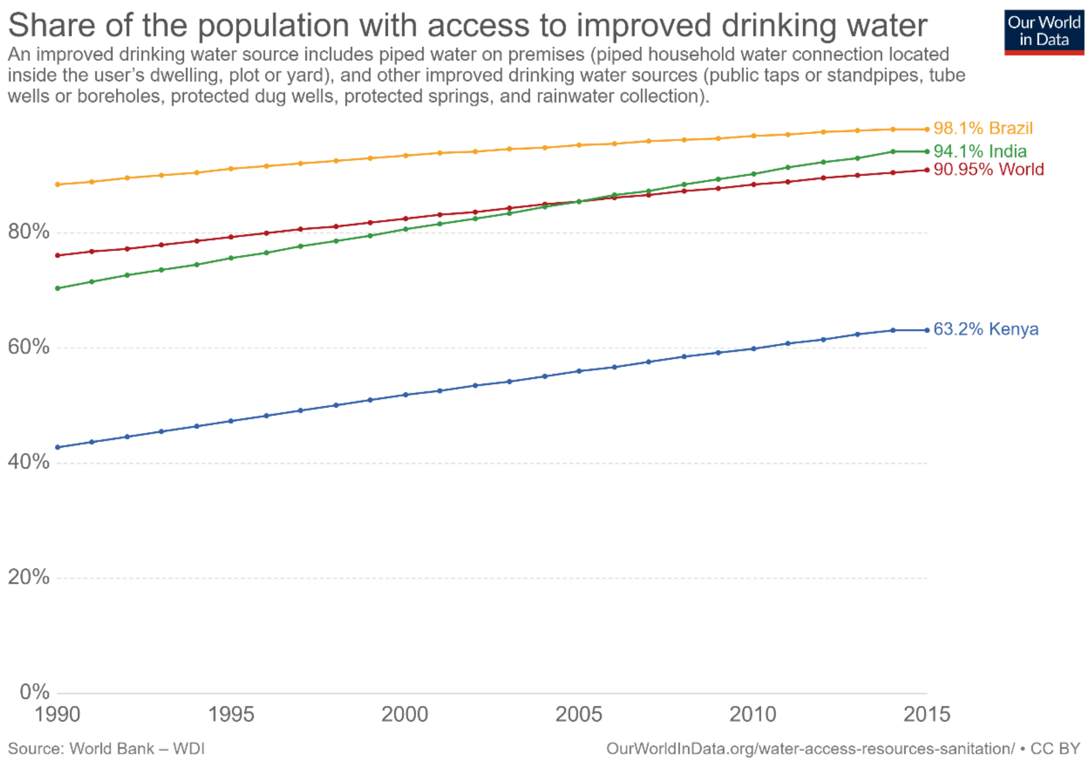
Water distribution

Distribution of fresh water on the globe is extremely uneven. In Europe and Asia, where 70% of the world's population lives, only 39% of the river waters are concentrated. According to the UN at the beginning of the 2000s, more than 1.2 billion people live in a constant deficit of fresh water, about 2 billion people suffer from it regularly. By the middle of the XII century, the number of people living with a constant water shortage will exceed 4 billion people.

Moreover, the problem of water distribution also exists within the countries. Even if the country has enough amount of water resources, frequently it is hard to transport water, because of low development of transport ways. Number of roads, quantity of ports, airports, water storages, etc. influence availability of water.

However, It is possible to say that this problem slowly gets better. According to *Figure 2, 3 (p.10) and Figure 6 (p.15)* it is remarkable that nowadays (2015) access to drinkable improved water has 91% of Earth population comparing to 76% in 1990. Even in such country as Kenya where only 42.8% of population had access to improved water in 1990, there is positive reaction over time which helped to reach the mark of 64%.

Figure 6: Share of the population with access to drinking water



Source: World Bank-WDI. Graph is made by H. Ritchie, OurWorldInData.

3.3.2. Climate

Changes in climate play quite a big role in water scarcity problem. Global warming, greenhouse effect, melting glaciers, etc. The greenhouse effect is becoming more and more evident. An increasing number of gases are emitted into the atmosphere. The Earth's climate is getting worse every year. There is a significant redistribution of atmospheric precipitation, the emergence of droughts in countries where this should not be. Snowfall in Africa, unprecedented frosts in Italy, Spain and other European countries – all these unexpected changes are a consequence of the greenhouse effect and global warming.

The result of such changes may be a decrease in crop yields, an increase in the number of plant diseases, an increase in the number and types of harmful insects. Everything goes to the fact that the ecosystem becomes unstable, it cannot adapt to such rapidly changing conditions. (RANVEER A.C, 2015)

3.3.3. Pollution

Water pollution is a serious problem for the Earth's ecology. Fresh water, suitable for consumption, accounts for only 0.003% of its total. (GIANFRANCO N., 2011) Water pollution is the biggest problem of fresh water scarcity. Chemical and radioactive substances, pesticides, synthetic fertilizers, sewage… All this poison water and makes it unsuitable for drinking. Even salt can be classified as a Contaminant.

There are a lot of reasons for water pollution such as wastewater, mining activities, marine dumping, animal wastes, acid rains, urbanisation, oil leakages, solid waste, thermal water pollution, etc. Below, some of them will be observed in order to understand why it is important to treat water and why such problem as water scarcity appear to be even bigger issue.

Wastewater

Household sewage often contains synthetic detergents that fall into rivers and seas. Inorganic substances affect water inhabitants and reduce the concentration of oxygen to water, which leads to the formation of so-called "dead zones", which in the world are already around 400.

Often, industrial effluents containing inorganic and organic waste are descended into rivers and seas. Every year thousands of chemicals fall into the water sources, whose effect on the environment is not known. Although industrial wastewater is in many cases pre-cleaned, they still contain toxic substances that are difficult to detect. (SHASHANK N., 2018)

Acid rains

Acid rain is caused by the release of exhaust gases into the atmosphere, produced by metallurgical enterprises, thermal power plants, refineries, as well as other industrial enterprises and vehicles. These gases contain sulphur and nitrogen oxides that combine with moisture and oxygen in the air and form sulfuric and nitric acids. Then these acids fall to the ground - sometimes at the distance of hundreds of kilometres from the source of air pollution. In countries such as Canada, USA, Germany, thousands of rivers and lakes were left without vegetation and fish because of acid rains. (EPA)

Solid waste

If there are many suspended solids in the water, they make it opaque to sunlight and thereby interfere with the process of photosynthesis in water. This causes disturbances in the food chain in such pools. In addition, solid waste causes siltation of rivers and shipping canals, which leads to the need for frequent dredging. (CHADAR SN, 2017)

Oil waste

Spilled oil often leads to colossal consequences for the environment, both immediate and prolonged. Oil spreads over the surface of the water for many kilometres, and when it reaches the coastline, it clings tightly to each stone. Due to oil pollution, all vegetation, which was in oil zone, dies. Cleaning such water costs much more expensive and harder than usual filtrating. (ENVIRONMENTAL POLLUTION CENTERS, 2017)

Thermal pollution of water

Thermal pollution of water is caused by thermal or nuclear power plants. Thermal pollution is introduced into the surrounding ponds by used cooling water. As a result, an increase in water temperature in these reservoirs leads to acceleration in them of certain biochemical processes, as well as decreasing the oxygen content, which dissolved in water.

Such water becomes unsuitable for drinking or irrigating processes. There is also a violation of finely balanced cycles of reproduction of various organisms. (O’DONNEL J., 2018)

3.4. Ways of prevention

So, how people can prevent such problem as fresh water deficit? There are a lot of ways how to reduce water waste. If people will apply at least half of possible options, water consumption will decrease up to 80%.

Preservation of fresh water in reservoirs.

This allows not only to protect water resources, but also to have a supply of water in case of unforeseen cataclysms. Furthermore, preservation of water in reservoirs limits its flow to the world's oceans. Moreover, if people will construct special underground reservoirs, it can help to prevent water evaporation. Nowadays, all artificial reservoirs are local and used only in certain countries for industry purposes only.

Desalination of salt water.

Technologies for processing salt water into fresh (desalination) are becoming more sophisticated every year and require fewer material costs. The most popular and cheap way of getting fresh water is becoming thermal desalination. Several years ago, it was considered that required amount of heat for evaporation can be reached only with abnormal energy consumption, but now people have a lot of excessive warmth energy from, for example, nuclear power plants, engines, different electrical mechanisms, which is needed to be cool. As it was written above, nowadays people use salty water to cool nuclear power plants, so it will be logically to set special station for desalination and treatment close to them. So, the transformation of salt water into fresh water is the best solution for the problem of fresh water. The price for water is becoming lower and lower each year and now the cost of $1m^3$ desalination is from $0.60 (Fujairah F1 Extension SWRO) to $1.86 (Carlsbad Desalination Project). (GHAFFOUR NOREDDINE, 2012)

Water Harvesting

Water harvesting means collecting the rains` water which is already filtered from salt by nature. It is not the most effective way to get water, nevertheless it has huge potential. If in the future people invent the technology which allows to get almost every drop of rain, it will help greatly, because of no need to filter water as salty, but as dirty fresh one, which is much cheaper. (CHE-ANI A.I., 2009)

Wells and glaciers

It was already mentioned in this thesis, that huge fresh water reserves are concentrated in glaciers. If humanity melt some of them, it is possible to release a significant amount of water. Another option for extracting fresh water is drilling deep wells, but it is even harder to do it because of great depth.

There are some ways how to get clean fresh water, but how to decrease its usage?

Selection methods for agricultural crops

With the help of modern technologies of genetic selection, it became possible to get crops that are resistant to saline soils. Such plants can be watered with salt water, and it saves a considerable amount of fresh water.

Drip irrigation

Another interesting way to save fresh water when watering plants is the technique of drip irrigation. To do this, agricultural land is supplied with a system of branched pipes of small diameter through which water gets directly to the plant or its roots (with the underground location of the system) and this dramatically reduces the consumption of fresh water. It varies from 5% to 50% water savings depending on compared irrigation methods and crops. [16, 22, 24]

Wastewater usage

Since agriculture consumes a very large amount of water resources, it is possible to use wastewater for watering plants. (without complicated expensive filtration stations) This practice is not applicable in all cases, but it gives an effective result when used.

Foresting

An unusual solution to the problem of the lack of fresh water in the arid regions of the world is the creation of an artificial forest in the deserts. It will take not only huge amount of labour, financial, natural resources, but also it demands significant time. In practice, such projects have not yet been implemented, but scientists think about it and probably in the nearest future such projects will be applied. Also, foresting in suitable climatic zones can potentially help to prevent water deficit for future generations. Unfortunately, foresting will not affect the modern world people live nowadays and now it is applied only for oxygen renewal reasons in experimental small sizes. (GARTNER T., 2018)

Water treatment

Water treatment is not something what can stop water deficit, but in in the realities of the modern world it must be mentioned since almost any collected fresh water can be used until it will be purified.

Household and waste water must be treated, cleaned and used again. This saves a considerable amount of fresh water. In addition, people already know quite effective methods of water treatment and the only one problem is an insufficient amount of financial resources for building required number of purification plants.

3.5. Water Conflicts

Predictions that the next major war will erupt because of water resources are widespread. But how much does this correspond to reality? Nowadays only several countries use a significant part of fresh water in water basins. No wonder, that countries, which have low water resources will protest such injustice. The most serious factor of tension in relation to water resources is the discrepancy between the number of inhabitants and freshwater supplies. As a result, conflicts at the local level may arise due to water resources. For example, conflicts between tribes for grazing rights or ownership of wells, as happened in Ethiopia. Tension can also arise due to the construction of a dam or canal, since these works affect the supply of water to countries where the rivers flow. Even though 28 percent of the water-related tensions were conflicts (RAVNBORG H.M., 2004), there was not a single event that was too extensive to call it a war. No one officially announced War over water resources, and there was no case that, due to water resources, the countries voluntarily united in one state. It is low chance of war for water, but danger of increasing amount of conflicts still exists. So, how people can prevent it them?

To prevent potential conflicts and radicalism due to water resources, it is necessary to assure the poor groups that they have access to the resources necessary for life. Both states and international organizations have a role to play. From now, to achieve greater security, it will be necessary not to compete, trying to provide themselves with water resources, but to cooperate.

4.Water scarcity prevention

In the practical part the theory part will be analyzed deeper and with the help of given statistics and data, the future for such problem as water scarcity will be predicted. Every case, situation, graph will be explained by such methods as trends lines creation and analysis, time-frame analysis, finding dependences and comparing the possible ways to prevent development of water deficit. The goal of practical part is to evaluate the possible danger of water scarcity, to find the best possible solution to prevent or slow down the widespread of this problem. The water deficit issue will be observed from objective numerable point of view using statistic not only from national and worldwide sources, but also from universities` and charity organizations` researches.

As mentioned above, there are some potentially good options, which will be observed and analyzed here. The most applicable and likely to work in the nearest future will be analyzed deeply.

The list of options to prevent water scarcity:

- Preservation of fresh water in artificial reservoirs
- Water treatment (filtration)
- Desalination of salt water,
- Water harvesting
- Wells and glaciers usage
- Selection for agricultural crops
- Drip irrigation
- Wastewater reuse
- Foresting

The potential competitors will be taken subjectively, based on recommendations of tens of resources, popularity of the method is mentioned.

Preservation of fresh water in artificial reservoirs

Water preservation is a great thing for preventing lack of water during unpredicted disasters. It is local and secure, nevertheless, to influence water scarcity as a world global problem it demands huge financial and time resource. It is strategical way to save water, but since an option for "right now" solution needed, there are much better ways to do it than reservoirs.

Desalination of salt water

One of the most prospective option to get over the water scarcity problem. Cheap and potentially fast. There are already enough technologies invented to use desalination plants efficiently. Despite high price and many requirements to fulfill, desalination plants will be one of the analyzed options for water scarcity prevention.

Water harvesting

Water harvesting is not efficient enough everywhere since harvesting is limited by many factors, starting from size of area suitable for harvesting ending with rains frequency. Nevertheless, it is used in certain countries where it is impossible to get fresh water from somewhere else for personal use. Furthermore, almost every developed big city collects rainfall water and pours it to the nearest lake, reservoir or river. This water can be used later after it will be purified and disinfected. Considering how much water rains gift to the people, after a while, it will be quite good way to stop water deficit.

Wells and glaciers usage

Limited source of water. Glaciers are actively used for humanity needs in fresh water and it will be used for at least 20 years more despite global warming and glaciers melting, nevertheless, wells and glaciers are not the option to prevent water scarcity, but something that gives time to find the solution.

Selection for agricultural crops

As known the agriculture nowadays takes 70% of fresh water and the amount of water needed to harvest crops is immense. Selection allows to save a lot of fresh water, using salty water instead. Agronomists are trying to make as many crops as possible resistant to salts, so probably one day they will succeed. Unfortunately, researches take time and results are not comforting, so it is hard to name "the solution of water crisis".

Drip irrigation

Drip irrigation is one of the best ideas in agriculture for the last 30 years. It saves from 20% to 50% of water comparing to a regular sprinkler, moreover it saves energy, labor and finances. Worthy candidate for the title “Water saver”. (CASWELL, et. Al.,1984)

Wastewater reuse

Wastewater reuse is widely used in the modern world. The treatment technologies become more and more effective. Nowadays 69% of wastewater is properly purified and reused. This method is effective, nevertheless it is already used almost on its maximum limit, so it will not be participating in comparing as low-potential. (IWA, 2018)

Foresting

Artificial forests nowadays are created only for oxygen renewal, but scientists believe that one day humanity will be able to green deserts and solve problem of water distribution. Unfortunately, it requires immense amount of financial support and time, so humanity of today has no choice but to wait for new technologies which would allow to forest desserts or to leave thousands of seeds and grow them for future.

Water treatment (filtration)

Not an independent option to prevent water deficit, since water treatment is more about water quality than scarcity, but water treatment is inevitable part to make any collected water usable. It is the most important process in every country which has access to fresh, but dirty water, which needs to be purified. Moreover, it is one of steps of desalination and wastewater reuse, so it should be noticed, cause one day, the power of purification stations can limit collected water amount.

4.1. Methods Analysis

As described above, the biggest potential for preventing water crisis are such methods as:

- Desalination
- Water harvesting
- Drip irrigation

To find the best way to prevent water deficit, all three methods will be analyzed for:

- Price (for m^3),
- Return on investment (comparing to the average global price $2/$m^3$ water tariff) *
- Capacity (km^3/year),
- Applicability (% of population with an opportunity to use)

4.1.1. Desalination

There are two the most popular desalination technologies:

- Thermal desalination (TD)

  It also breaks into Multiple Effect Distillation (MED), Multi-Stage Flash Distillation (MSF) and Mechanical Vapor Compression (MVC).
- Reverse Osmosis membrane separation (RO)

The 95% of all desalination plants are either TD (35%) or RO (60%). The price difference between these 2 plants for m^3 is in average 336%. However, the outcome price is compensated by location, launching costs and depends on a lot of factors as water access, electricity costs, etc. In average, there is no sense to explore each type of plant separately. To evaluate the desalination as a method to prevent water scarcity, it is enough to analyze them as a whole. (ADVISIAN, 2012)

*$2/$m^3$ price is an average rounded number of all countries with not-hidden utility costs.

Price

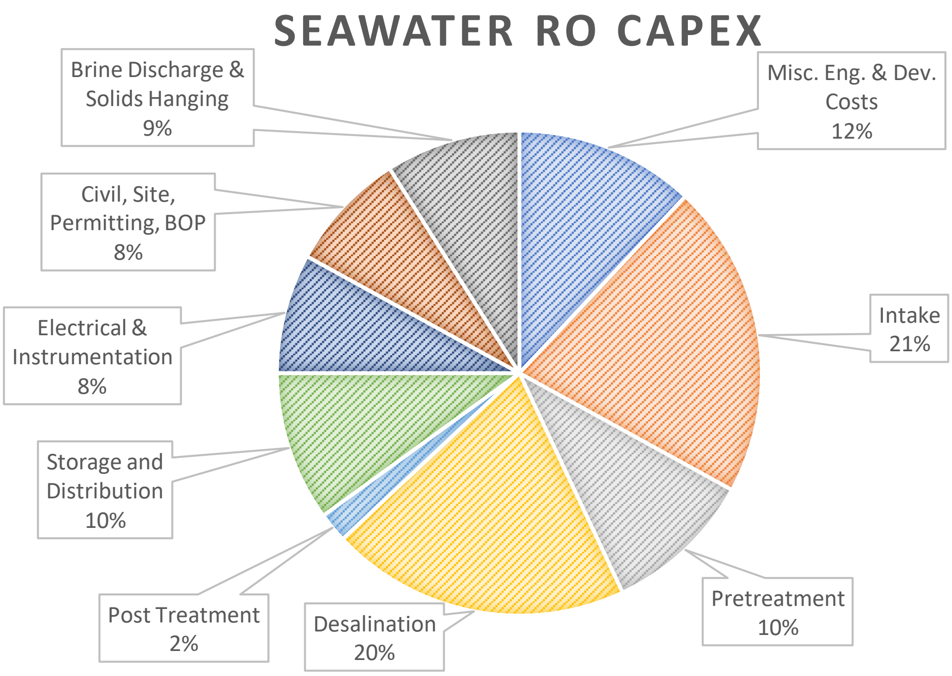
Nowadays desalination is one of the most expensive ways to get fresh water. The price of desalination consists of CAPEX (Capital Expenditure) and OPEX (Operational Expenditures) costs. The final desalination costs will be calculated as total CAPEX and OPEX, but for clarity, CAPEX and OPEX will be divided to explore each of them deeper.

<u>CAPEX</u>

CAPEX consists of the direct costs, which are such costs as equipment, buildings, pipes, etc. and indirect costs, which are different fees, engineering, administrative costs, etc. The most desalination components can be further divided into nine parts: intake and raw water conveyance; pretreatment; desal treatment; post-treatment; product water pumping and storage; electrical and instrumentation system; plant buildings, site and civil works and balance of plant; brine discharge and solids handling; and miscellaneous engineering and development costs. The price of one medium-size desalination plant varies from 12 million dollars (3,800m^3/day) to 600 million dollars (380,000m^3/day). However, price depends on not only the capacity, but also environmental, permitting, building, etc. factors and it is hard to predict what will be the exact price of the next plant.

The Chart 2 (p.26) demonstrates detailed proportions of Capital costs.

Chart 2: SWRO CAPED

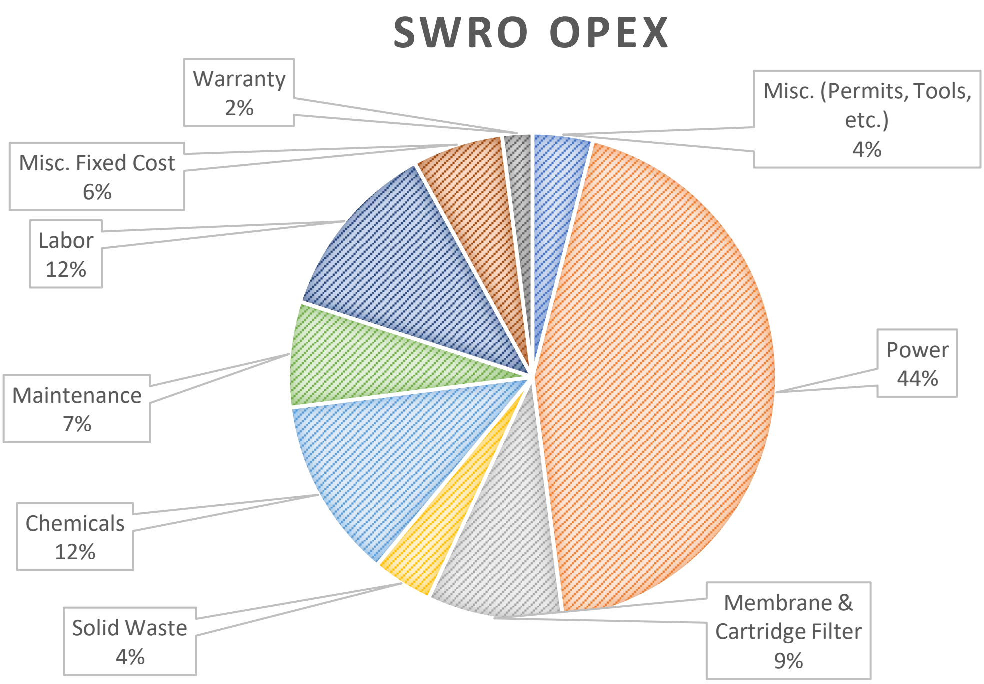


Source: ADVISIAN, 2017

OPEX

As well as CAPEX, operating costs fall into nine parts starting from power consumption, finishing with equipment warranty. The full list of expenditures you can find in the *Chart 3 (p.27)*

Chart 3: SWRO OPEX



Source: ADVISIAN, 2017

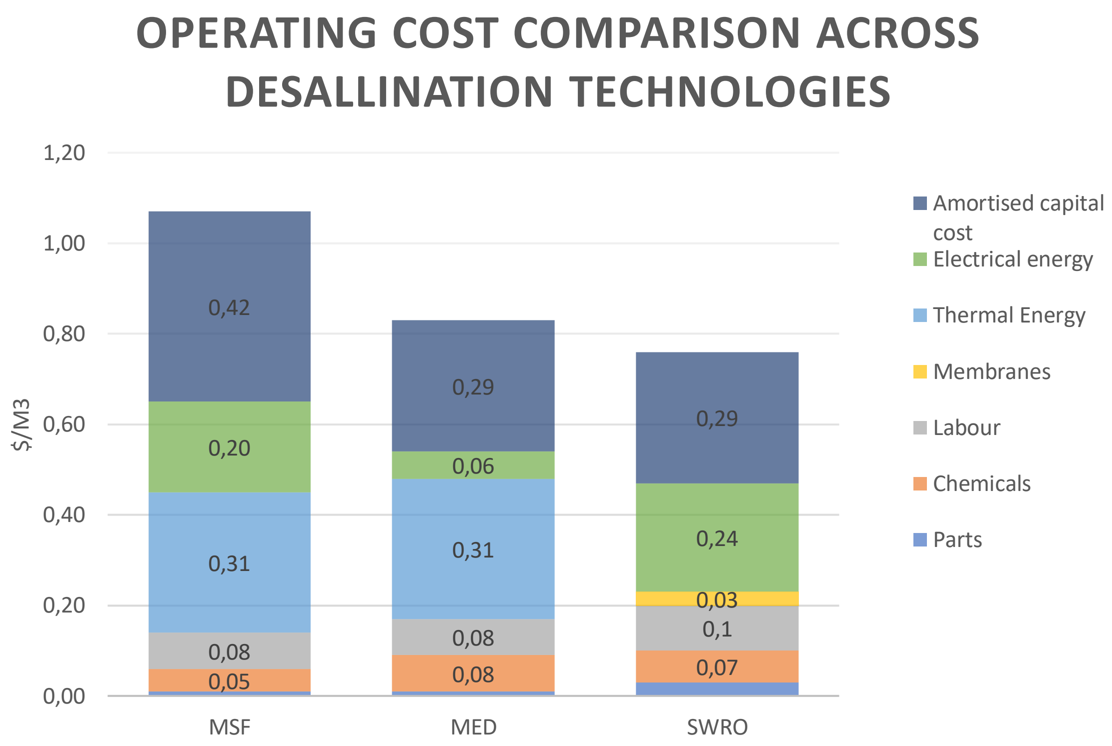
Total costs

Because of too many variables in CAPEX and OPEX, the total costs can be extremely different depending on location, water intake, law regulations, plants` size, etc. Nevertheless, it is possible to take average number from every plant which is in use nowadays and calculate an average price for m^3 of produced desalinated and treated water. (WATEREUSE ASSOCIATION, 2012)

Brackish water desalination prices are from $0.11/$m^3$ to $1.10/$m^3$.

More costs are following on *Chart 4 (p.28)*. (GWI Desal Data & IDA, 2018)

Chart 4: OPEX Comparison across desalination technologies



Source: GWIDesalData

Return on investment

Average price for m³ of desalinated water is $0.816. Average market price of fresh water is $2.

Calculation.

In order to find estimated term for investment to return, the first thing which is needed to be done is profit calculation.

$2 - $0,816 = $1.184 (Profit for 1m³)

Then the costs for plant`s building and maintaining should be calculated. It is incorrect to take price of already built plant or any separate plant in order to avoid the gap between countries. As it was mentioned above, the most expensive, regular-size plant costs $600,000,000 and the smallest costs $12,000,000. The average between them will be taken.

$612,000,000 / 2 = $306,000,000 (average price for desalination plant)

The next thing to find is produced volume of fresh water and here it is incorrect to take also an average number between biggest and smallest plant productivity, however, thanks to WateReuse research, it is possible to say that the capacity of $306,000,000 plant will be 51 MGD (million gallon per day), which is 193056 m^3/day. Now it is possible calculate the daily profit of given plant.

193,056 * 1.184 = $228,578 (per day)

$306,000,000 / $228,578 = 1339 (average days to return investments) = 3.7 years

Note.

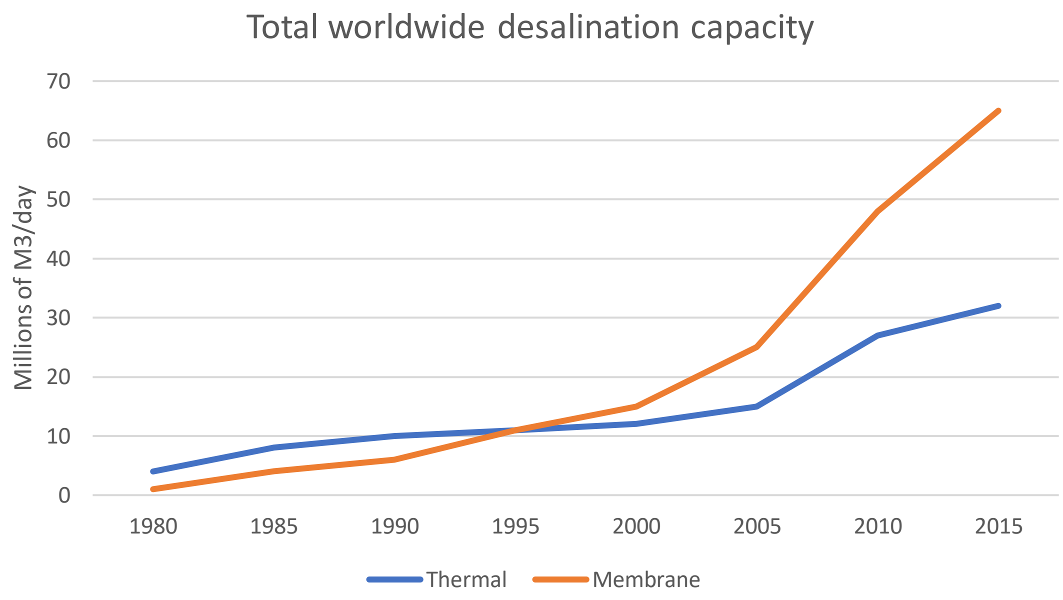
Because of many dependencies, it is needed to take range from 900 to 1700 days to cover minimal and maximal costs for water and possible inaccuracy.

Capacity

The capacity is strongly dependent on location and financial resources of the country. Thereby, the biggest productions of desalination water are in the Kingdom of Saudi Arabia, the USA, UAE, Australia, China, Kuwait and Israel. As seen, the biggest producers of desalinated water are the wealthy countries with access to the seas, oceans or bays.

The desalination capacity is growing rapidly in the last 25 years. If in 1995 the amount of desalinated water was 22 million of m^3 daily, then in 2015 this amount grew to 94 million, which is 4 times more. *Figure 7 (p.30)* (GWI Desal Data & IDA, 2018) = 34.31 km^3/year.

Figure 7: Total worldwide desalination capacity



Source: GWI Desal Data & IDA

Applicability

Not every country can build and maintain desalination plants. There are two main factors which must be performed in order to get fresh water by desalinating. First, country needs access to the sea, bay or ocean in order to get salty water directly from there, avoiding transportation or massive pipes` constructions. Secondly, the country must have strong financial opportunities. Insufficient budget makes a big threat of non-finishing the plant and damaging the budget too much making the economic situation unstable. The percentage of countries which suits these requirements is around %30, %23 of countries left have unstable or weak economical state. (INTERNATIONAL MONETARY FUND, 2019) Unfortunately, the population of the countries which can use desalination plants is even lower, 16% of total population, which is in conditions of no exportation is dramatically low result.

Other

Nowadays, scientists invent more and more materials making membranes for desalination as well as technologies are getting better. Building technologies and transportation are getting cheaper and cheaper. Eventually, the price for building a plant will lower to the level where desalination plants are the advantageous investment.

4.1.2. Water harvesting

Water harvesting is one of the technologies which directly collects fresh water. The nature makes thermal desalination for humanity and the only thing which is left to do is to collect evaporated water and treat it. Simple water treating is much cheaper than the process of desalination, so water harvesting potentially can be cheaper method to get fresh water than desalination.

Price

Water harvesting systems can be sold as a private **domestic** system for local collection. Such systems usually cost from $100 (UK), which is just a 200-littre container with no filtration system for domestic use to $4,000 for fully functioning domestic system with filtration and pipes connections. With all possible optional improvements, such as gutter mesh, pumps, filters, screens, etc. the cost can reach $11,500 for one system. (250m^3 roof square). It is also important not to forget that water harvesting system can be made even for $10, which will be just a membrane with a small tank. Moreover, such systems will be much more widespread than professional ones, because people which in need for water harvesting do not have appropriate budgets and even providers to buy such systems.

Such systems are also used in **commercial** purposes. For instance, The National Trust installed 4800-litre tanks at Calke Abbey in Derbyshire which cost $16,000.

When it comes to global city-size water-collecting system, the price depends of too many factors, starting from the city size, finishing with the location and price for water treatment.

In water harvesting case, it is proper to count price for water as $0 since there are no expenditures for water gaining, however, to find out the return on investments, it is appropriate to count savings or opportunity costs of water which are $2 per m^3 According to the *Chart 5 (p.33)* in the Europe you can collect approximately 344 liters of water daily. To make calculations realistic, every year will be charged $200 for maintenance. (THERENEWABLEENERGYHUB, 2018)

Return on investments

In the case with water harvesting it is too hard to calculate the return on investments globally or even for 1 country. In the majority of cases when water harvesting system is used, there is no aim to sell water or to return money. In the case of water harvesting it is possible to calculate returns based on price of harvesting system. However, it is even incorrect to find the average, so the calculations will be made separately for the cheapest system for 250m^2 and the regular water harvesting system in the U.K.

Regular water harvesting system in the U.K.

Price of the harvesting system, as mentioned above, $4,000. Capacity of such system is 141.26m^3/year. (The precipitation number is taken as average with no connection to the region!)

141.26 * $2 = $282.51

Maintaining the collector for $200 per year (filters and gutters cleaning, tanks checking, etc.) leaves you $82 only. Such profit brings the result of 48.8 years (17812 days), which is not really promising. Nevertheless, if the collector maintained by owner, the precipitations are higher than average or living far from civilization, it is great option. Moreover, for 1-time investment, you get lifetime water supply for free. The most optimistic prediction is selling all collected water for $6, to maintain by yourself and to live in central America, selling then the profit will be around $2160 per year and it will return investments in less than two years.

Cheapest water harvesting system

There is a chance to get such system even for free, however, it is appropriate to take the average price for regular harvesting system proposed in India. Such system costs Rs20,000 = $286 for 250m^3 (ASHWINI H, 2018)

Maintaining is $30 for 1 year. According to average collected precipitation the return on investment will be

$282 = 365 days

$316 ($286+$30 for maintaining) = 316*365/282=409 (days to return on investment)

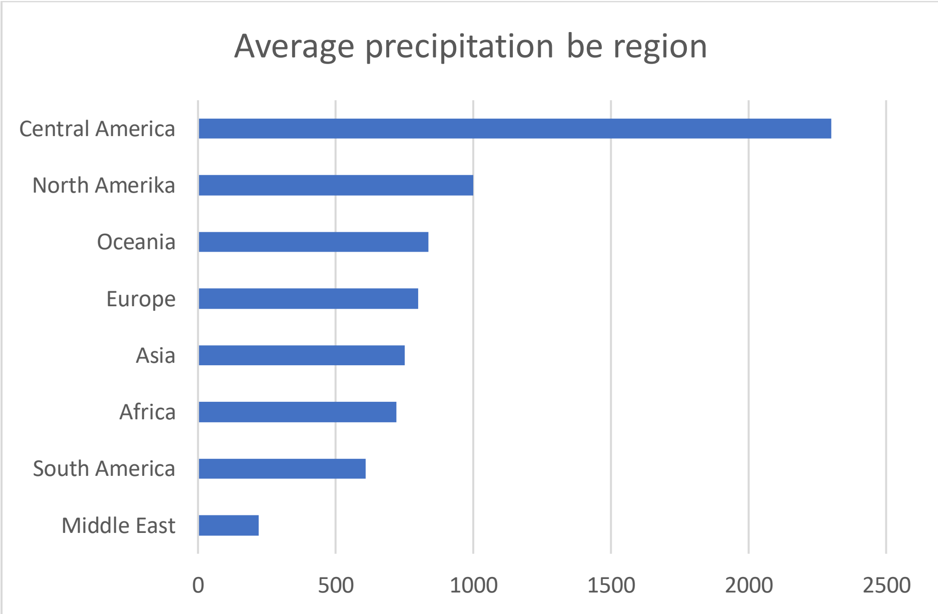
If water rates for India will be taken, which can vary from $0.23 to $1.35 for m^3, such results as 3,548 and 994 days respectively. (GONSALVES O., 2018)

Note. The maximum term of return on investment for water harvesting system can be immeasurably long, so for the maximum the infinite will be taken.

Capacity

Capacity of harvested water strictly depends on the amount of rains in the area. As follows from *Chart 5* *(p.33)*, the average global precipitation is around 900mm/year. (FOOD AND AGRICULTURE ORGANIZATION,2018)

Chart 5: Average precipitation by region



Source: Own processing based on Food and Agriculture Organization, 2018

Using *Chart 6* *(p.34)*, it is possible to predict what amount of water can be collected per year to calculate price and compare water harvesting method to the other ones. The water harvesting system covers in average 250m^2. The average global amount of precipitations is 904mm/year. (2,48mm/day).

Calculations.

2.48mm * 250m^2 =0.620m^3 (per day)

To get the real numbers, the received number should be divided by 1.6 (Measured by empirical way). This percentage includes amount of evaporation, infiltrated sediments, loss of water due to overpressure in the filtrating system while pouring into the tank, etc.

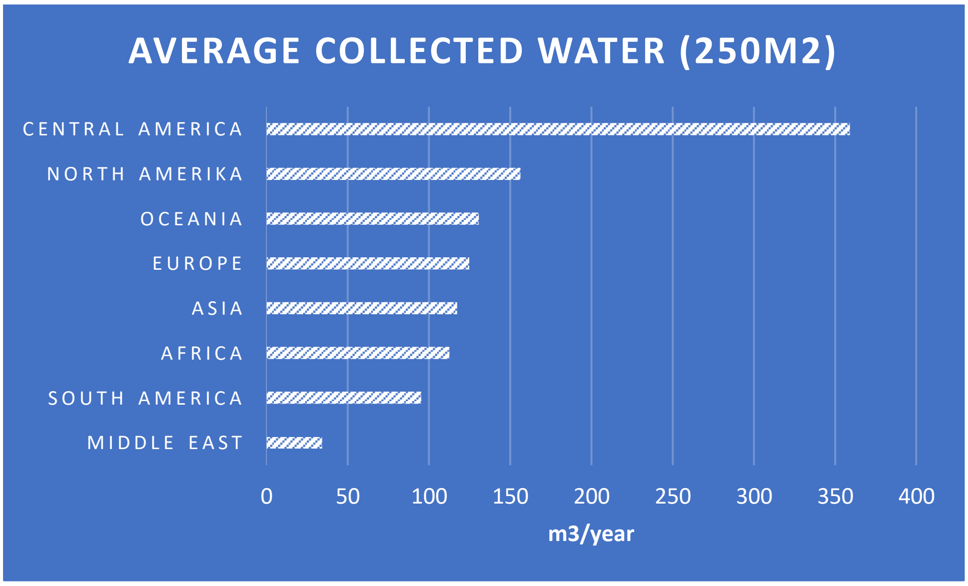
620/1.6=387 l/day= 0.387 m^3/day

Result.

387 l per day = 141.26m^3/year. (250m^2)

The *Chart 6* *(p.34)* below demonstrates the all the rest regions calculated accordingly.

Chart 6: Average collected water (250m²)



Source: Own processing based on Food and Agriculture Organization, 2018

It is impossible to count global capacity. However, it is possible to use 90% (fair prediction, considering already installed water drainage systems) of all developed city squares and 30% for villages and cities with no drainage systems. According to the Schneider A., cities occupy 0.5% of all land (148.94 million km^2), which makes 7.45 million km^2 (villages are included). In average, 60% of water can be collected from this area, which is 4.47 million km^2. (Green zones excluded) 250m^2 = 141.26m^3/year. 4.47 million km^2 = 252,572,880 m^3/year = 0.25 km^3/year. Nevertheless, the potential intake can be much more, if mankind invents the technology to collect rainfalls from not only urban areas, but also from all the land territory, which is not covered by greens or even from the oceans. However, humanity is far from it and for today there is no opportunity to make this work. (SCHNEIDER A. et. Al., 2009)

Applicability

The water harvesting system can be working efficiently in any country with average or high precipitation. It does not demand high investments or professional tools. Water harvesting can be applied even on a primitive level in the poor countries by individuals. As a combination of all factors, the water harvesting system can be working literally everywhere. The most inefficient use of water harvesting system will be in Middle East due to low amount of precipitations. It is also important to mention that collected water must be purified before use, which makes it unusable for at least 15% of population globally. However, the last 85% is a good result.

4.1.3. Drip Irrigation

Drip Irrigation is not a method to collect, but a way to save the collected water. However, in order to prevent water scarcity, the method which can help to save huge amount of agrarian water, looks potentially good. Drip irrigation systems can be used in almost any crop and substitute regular sprinkler in the majority of cases.

Price

Conventional drip irrigation systems cost from $1,200 to $6,000 per hectare (10,000m^2). There are no private drip irrigation systems for garden use, as they cost up to $200,000 per hectare and it has no sense to take these numbers into consideration. Price depends on region, field size, slope, labor expenses, patterns for different crops, etc. An average between the USA (as one of the most expensive irrigation systems) and India (Big agrarian country with low prices) will be taken. For drip irrigation in India you will have to pay approximately $2,125. In the USA the price would be around $7,800. The average is $5,462 but taking into consideration that most agrarian countries are developing countries with weak economic, these factors decrease this result by 34% (The average between all main agrarian countries) and get $3,823. (SIMPSON S.D., 2012, Top Agricultural Producing Countries) 1ha demands in average 253m^3 of water using regular sprinklers irrigation. (SMITH A., 2008)

Calculations.

First of all, it is necessary to find average for drip irrigation cost.

8800 + 2125 = $5462

$5462 is an average price for 1ha drip irrigation system between the USA and India

Taking into consideration percentage and economics of big agrarian countries the received result will be lowered for 34%.

5462 * 66% = $3604

$3604 is fair average global price for 1ha drip irrigation system.

Mentioning that drip irrigation system is saving water, the only one option to show the profit is to compare to the most popular alternative for today. Sprinkler. According to

M.Caswell, drip irrigation system saves from 20 to 50% comparing to regular sprinklers. An average of 35% will be taken and applied to the final result in order to find out what amount is saved due to using drip irrigation systems. The price for water usage with sprinkler is taken as a range between minimum and maximum possible price for water. (U.S. and India)
$120-420 (sprinkler for 1ha) * 65% = $78-273 (Drip irrigation system)

Result.

Drip irrigation system will save 88.75m^3/ha ($42-$147). (TODAY'S HOMEOWNER, 2018)

Return on investments

The return on investment in irrigation savings are extremely dependent on season, watering frequency and volume, crops, soil slope, etc. The potential maximum can reach up to couple years in case of buying drip irrigation systems in the end of annual season and use it only for new season. The possible minimum is calculated below

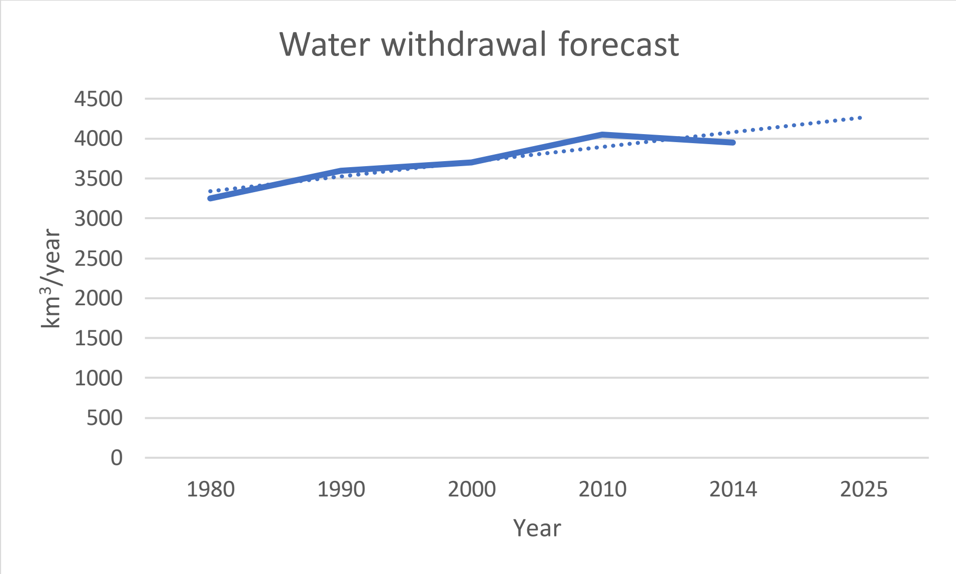
$3604 / $42 = 86 (days)

$3604 / $147 = 24.5 (days)

Capacity

According to FAOSTAT data the global water withdrawal in 2014 year was 3,950km^3 per year. Comparing this result to the past decades, it is possible to predict approximate trendline for future withdrawals.

Figure 8: Total water withdrawal forecast



Source: Own processing based on Food and Agriculture Organization, 2018

As it is seen on a trendline, the possible water usage in 2025 will be around 4,300km^3/year. Taking 69% of this number will result as 2,970km^3 of water which is spent for agriculture annually.

Unfortunately, drip irrigation system can be used for crops only, it cannot save water for cattle or poultry growing. As mentioned in the *Figure 5 (p.13)* crops require much less water than animals do. Furthermore, not every crop is eligible for drip irrigating and most of them are seasonal. Only 40% of water in agriculture is spent for irrigation in the USA. In developing agrarian countries in average this percentage vary up to 93% (India) (U.S. GEOLOGICAL SURVEY, 2000) (DEHADRAI P.V., 2003)

Calculations.

To calculate as precisely as possible, it is appropriate to focus again on agrarian countries as China, India, Brazil, etc. correcting the result by 34% in their favor. Also, the 35% will be substituted from the final result as crops which are not suitable for crop irrigation and as already installed and used drip irrigation systems.

To start with the total amount of water spent for agriculture will be calculated.

4300 * 69% = 2967km^3/year

Then the average for irrigation percentage will be found.

(40% + 93%) / 2 = 66.5%

Shift the number by 34%

93 - 66.5 = 26.5

26.5 * 0.34 = 9.01

66.5 + 9.01 = 75.51% (Fair average global irrigation water withdrawal)

Finding annual average water spending for World.

2967 * 75.5% = 2240 km^3/year

There is about 25% of all grown crops capacity cannot be grown using drip irrigation systems, so expected numbers will be

2240 * 75% = 1680 km^3/year

Calculating average savings due to drip irrigation systems appliance.

1680 * ((20+50)% / 2)) = 588 km^3/year

The difference between sprinklers and drip irrigation systems.

253,75m^3 (water withdrawal with sprinkler for 1ha) * 65% = 165m^3 (water withdrawal with drip irr. system)

Applicability

Drip irrigation systems can be used in every developed and in the most of developing countries. The costs of drip irrigation systems are not overpriced and affordable to almost any farmer. The only issue with drip irrigation systems is unsuitable crops, which is insufficient number. The applicability for drip irrigation systems will be counted for farmers only. It will give comprehensive evaluation of percentage of the people which can use this technology. In the case with drip irrigation systems, almost every farmer can afford to buy a drip irrigation system and use it in case of need. Nevertheless, it is important to mention that governments directly cooperate with farmers and in case of need, the drip irrigation systems can be provided by state. So, it is fair to tell that around 95% of farmers will start using drip irrigation systems in case of need.

4.2. Comparison

During the comparison, methods will get subjectively assigned points, which are based on objective and calculated indicators. Each point will be explained.

- Price

  The water price is an important criterion to understand if the method can be used by people with no sacrificing all their budgets for water. In observed methods global water scarcity problem can be solved by governmental financing or by peoples` investments. However, there are 2 methods out of 3 possible or intended for personal use and both of them are either saving the water or collecting it for free due to one-time investment. The only method which has price for water gain is desalination, which can be used by state only. Moreover, gained water is not for private use but for citizens and exporting. As only states with sufficient funds are observed, the Return on Investment becomes much more important indicator comparing to the water price, since the investments which potentially pay off are safer than funds ejection for problem distancing. Therefore, the points for price evaluation will be 0.5 points (pt.) for 1st place, 0.25 pt. for 2nd place and 0 pt. for 3rd place.

- Return on Investments (ROI)

  Return on investments plays an important role in methods evaluating. ROI is an indicator of safety and accuracy of made investments. It is questionable decision to invest funds in something which will not bring any profit of even cause damage to economic of state/person/farmer/etc. Return on investment could be less important in conditions of urgent need or lack of alternative options. However, under given conditions of contemporary, ROI will be one of decisive factors for applying certain method either for person and for state.

  The fastest return on investment will give 2 pt., 1 pt. for 2nd place and 0 pt. for 3rd place.

- Capacity

  As the global scarcity problem develops, population grows and human needs expand, the more capacity of fresh water needed, which makes capacity one of the most determinant indicator for decision making. The methods with insufficient amount of produced water can be useless despite all their pros. Capacity is directly influencing on total fresh water reserves and as a result on water deficit issue development.

The biggest capacity will give the leader 2 pt., 1 pt. for 2nd place, 0 pt. for 3rd position.

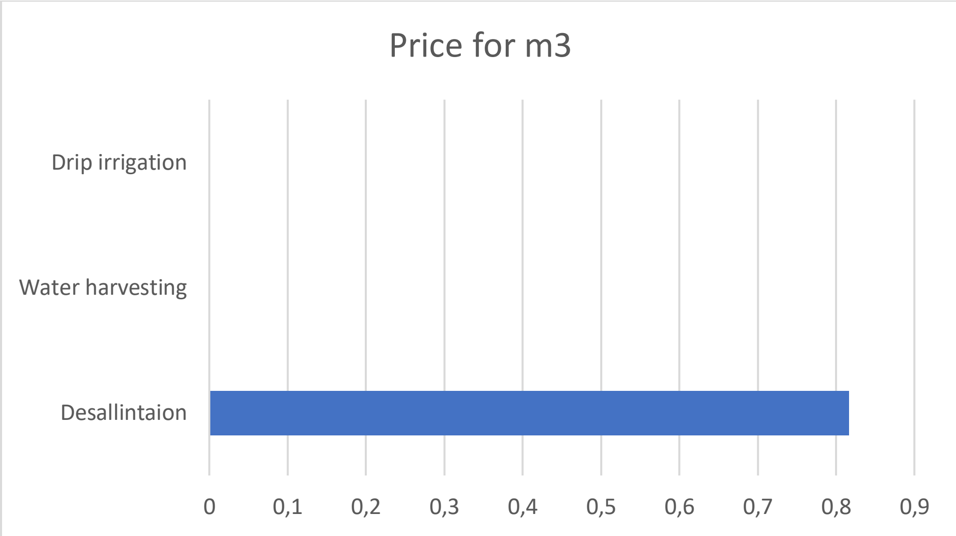
- Applicability

  Applicability determines what percentage of population/potential users will be able to access the technology. Applicability is a complexity of location, financial power, available technologies, etc. It is significant indicator of how broad the method can be applied. As it is discussed above, the problem of water scarcity pronounced highly in certain regions, while in the most parts of the world, such problem in less. Therefore, the applicability of methods will influence local scarcity, as a part of global, more than any of above factors. Nevertheless, the applicability cannot fully resolve water scarcity as a global issue, therefore the highest applicability percentage will give the winner 1 pt., 0.5 pt. for 2nd place and 0 pt. for 3rd place.

4.2.1. Price

Drip irrigation system and water harvesting do not cost anything because none of them paying for fresh water gain. Drip irrigation is the way to cut water withdrawal and savings cost nothing. Water harvesting is not obliged by any tax and does not require any investment in water gaining, except system maintaining, which is included in system`s cost. Due to same results, drip Irrigation and Water harvesting share 1st place, receiving 0.5 points each. *Chart 7* *(p.41)*

Chart 7: Price comparison

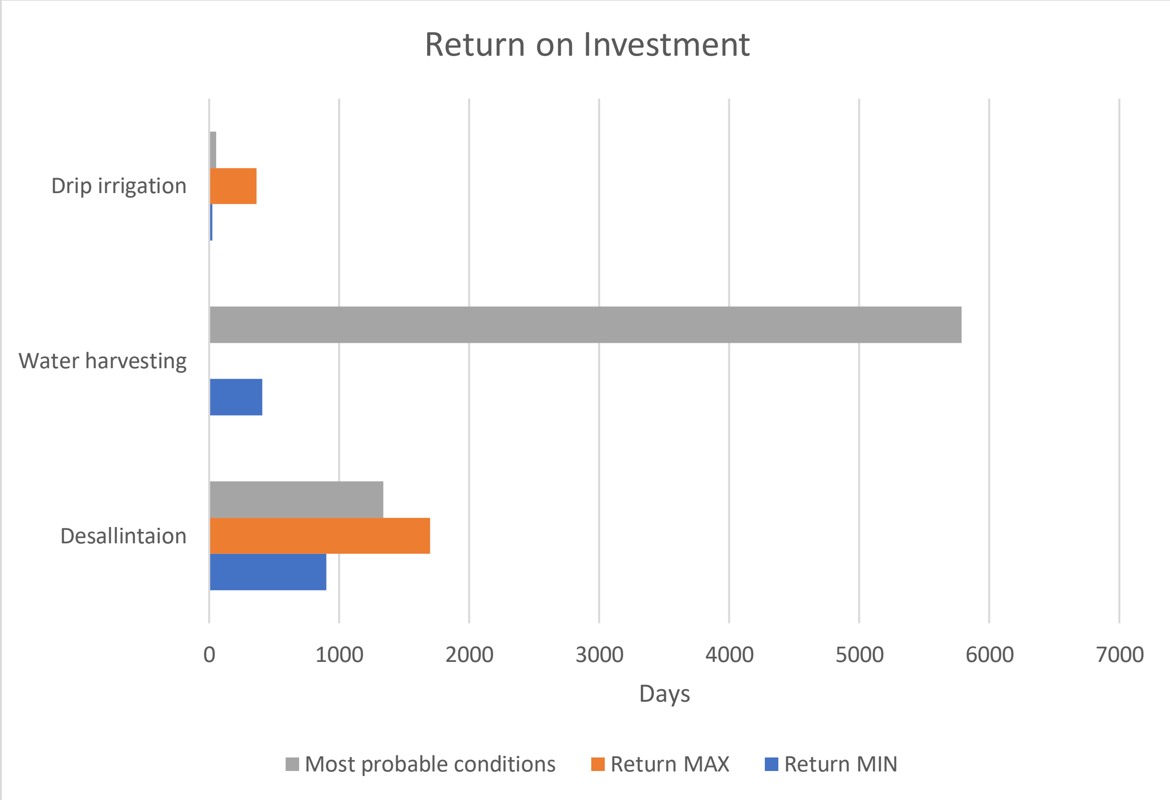


Source: Own calculation based on received results

4.2.2. Return on investment (ROI)

In return on investments it is possible to take an average based on minimum and maximum possible. However, such way of calculation is not suitable for every technology and cannot be objective since in the real-world scenario such technology as, for instance, water harvesting systems would never be applied in the conditions of low precipitations. In the case with return on investment the most appropriate way to compare received results is to compare each method for minimum and maximum ROI, but! for some methods the most appropriate conditions will be applied, and results compared. After separate comparing, all results will be combined and compared once again as a whole in order to get an objective result. The leader in the most probable conditions will get 2 points for ^{1st} place, 1 and 0 for 2^{nd} and 3^{rd} respectively. Results in minimum and maximum fields will be assigned as 1 point each since in case of no need to separate results, these two indicators would be combined to an average. As a result, 2^{nd} place in minimum or maximum comparing will be appreciated for 0.5 points.

Chart 8: Return on Investment Comparison



Source: Own calculation based on received results

<u>Minimum and maximum</u>

According to *Chart 8* *(p.42)* the maximum days to ROI is taking water harvesting, second place is taking desalination technology and the best result is shown by drip irrigation systems.

The results in minimum days to ROI are slightly different. The minimum days is taking drip irrigation. Second place goes to Water harvesting and the third place left for Desalination.

<u>The most probable conditions.</u>

For **desalination plants** the most probable conditions can be determined by received average, which is **1339** days. **Water harvesting** systems can be used globally with any amount of precipitations. It is impossible to predict what are the appropriate conditions for water harvesting, so the only way to average possible result is to find the average between simple water harvesting system in India and regular water harvesting system in U.K. The amount of precipitations will be considered as global average. The average approximate number of days for ROI is **5788**. To find most probable conditions for **drip irrigation** systems it is enough to take an average for two minimal numbers, since there is no need to buy irrigation system in the end of cropping season. The result is **55** days.

Results

After comparing all received numbers, it is possible to state that the best solution for fast return on investments is drip irrigation systems, which got 4 points, the best possible result.

Second place is taken by desalination plants which got 1.5 points.

Thirds place goes to Water Harvesting systems with a result of 0.5 points.

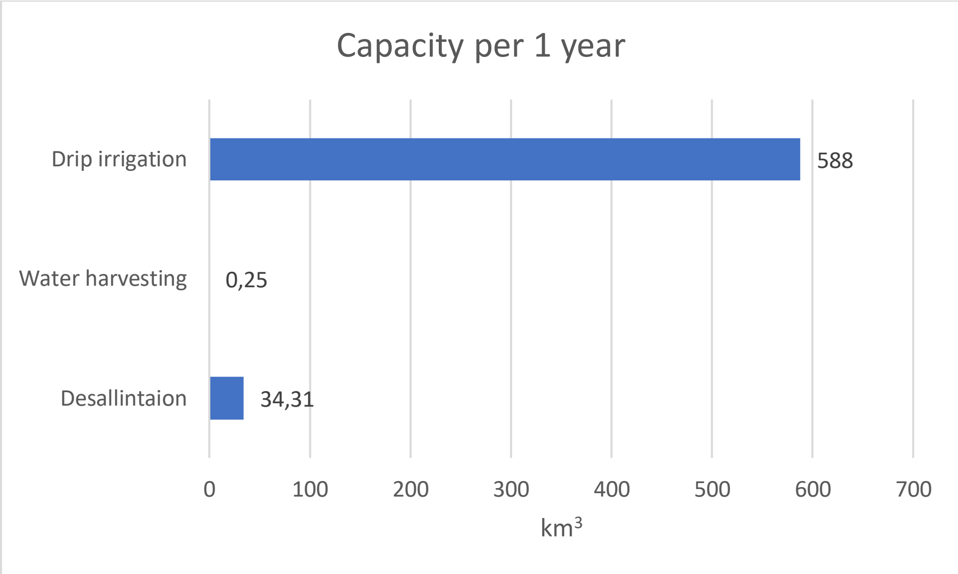
4.2.3. Capacity

As it is seen from *Chart 9* *(p.44)* Drip irrigation systems have potentially the highest volume of saved water. Up to 588 km^3 per year. Due to huge amounts of water which is spent for irrigation, savings are also significant.

Second place with a result of 34,31 km^3/ year take desalination plants. However, this number is taken according to current number of desalination plants which is 18,426 for 2015 (Provided by IDA). As a result, potentially, with proper funding, desalination plant could be a great solution for preventing water scarcity.

Water harvesting amounts are not so impressive. Because of low percentage of possibly covered area, the amount of collected water is not so high, 0.25 only. Despite such amount of water is enough for peoples` personal needs as drinking and domestic use, it is impossible to harvest enough water nowadays for agriculture and industries` use.

Chart 9: Capacity Comparison



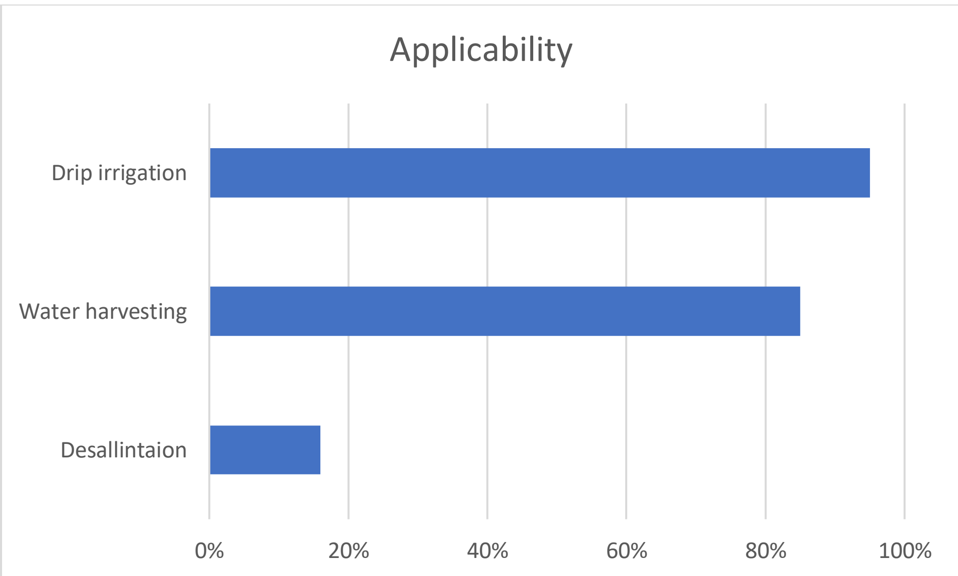
Source: Own calculation based on received results

4.2.4. Applicability

Desalination plants are expensive, and it is hard to set even with appropriate locational and financial conditions. On the contrary Water Harvesting and Drip irrigation are available to almost everyone privately and does not require immense budgets.

Applicability in details was described in Parts 4.1.1-4.1.3.

Chart 10: Applicability Comparison



Source: Own calculation based on received results

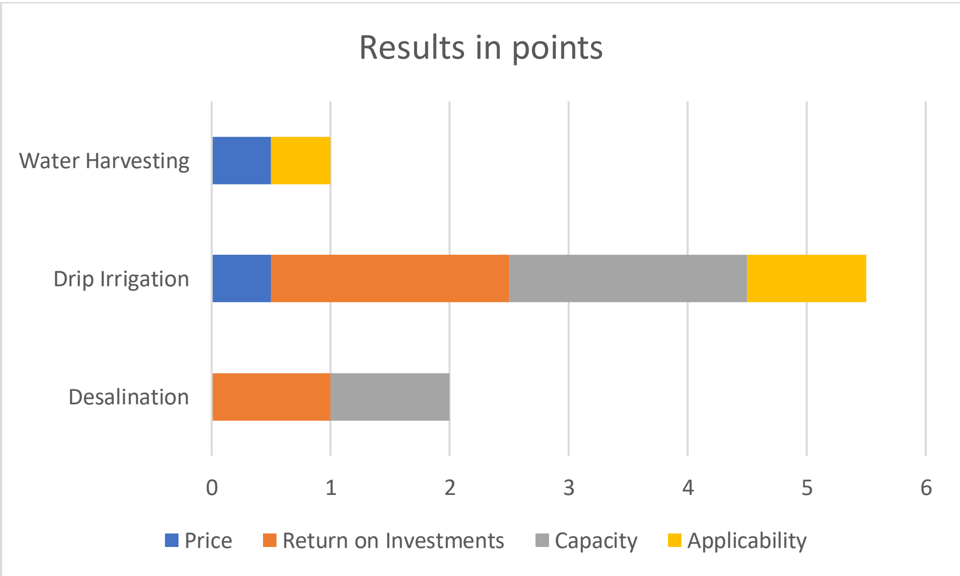
4.3. Results on water scarcity prevention

As was calculated, all the methods are worth to use in order to prevent water scarcity. By earning the most points, **drip irrigation** (5.5pt.) becomes a number one method which can be used to save water reserves. It is easy, cheap and reliable to set. Furthermore, it does not influence on product quality. Saved water = collected water. Drip irrigation can be potentially good solution not to prevent, but to distance global water scarcity for years.

Desalination method (2pt.) is giving significant capacity of collected fresh water, which can slow down water scarcity issue. Unfortunately, this method is expensive, takes long to return investments and it is tightly tied to location with access to salty water. This method is precisely good and requires no additional technologies to action in case of urgent need to solve water deficit issue. Desalination method becomes more and more widespread every year and if the same rates of growth will be saved or even increased, the humanity will forget about water scarcity for a long time.

Water harvesting (1pt.) is potentially good; however, temporary mankind does not have technologies to collect enough amount of precipitations to satisfy all their needs. Nowadays water harvesting can be a solution for people who want to invest money in future or suffering from impossibility of water transporting to their region. Water harvesting can prevent some local water crisis and help in the future, but in 2019 it is not the best possible way for water scarcity prevention to propose.

Chart 11: Results of Comparison



Source: Own calculation based on received results

5.Conclusions

The analysis of water deficit showed that the problem of water scarcity exists and slowly getting bigger. However, humanity still have enough time and resources to stop the growth and to postpone the problem for years. As it was observed there are some potentially good options to prevent water scarcity and in a case of urgent need, governments can quickly solve the problem. The only thing why it is not done yet is money. There are enough financial resources to solve this problem for years in couple years, however, since the problem is not too acute, it is cheaper to use habitual methods as taking fresh water from natural reservoirs as glaciers, lakes, etc. As soon as the problem will become a real threat, it will be solved in a short time by using reserves in federal budget or even can be taken from people by adding small "water scarcity preventing" tax.

Observing the methods to collect/save water showed that in the case of threat of water scarcity and inaction of government, the majority of people are able to provide domestic amount of water for drinking and living. However, water harvesting is not able to provide enough amount of water for agriculture and industries, so in case of sudden limitation of fresh water, people will not be able to continue eating as much as they want. The problem will concern food industry as far as according to *Figure 5 (p.13)* the food growing takes huge amounts of water.

It is also worth to mention, that water economy systems, such as drip irrigation systems save significant amounts of water, which distance the water deficit quite far away from contemporary.

The water deficit is not the problem for modern world and humanity has time to build desalination plants, to apply modern irrigation technologies, etc., the problem is unequal distribution and impossibility to provide water to some regions because of weak economy, wars, transportation problems, etc.

Since the humanity already have technologies for efficient desalination of ocean water, which capacity is enough to provide fresh water for any possible need and birth rate control tools, the problem can be distanced for hundreds of years any time. Solving of financial problems, conflicts, transportation problems will give more significant results nowadays.

6.Referencing

ADVISIAN, 2012, The cost of Desalination. Available at https://www.advisian.com/en-gb/global-perspectives/the-cost-of-desalination# [Accessed 22.02.2019]

CASWELL MARGRIET, DAVID ZILBERMAN, GEORGE E. GOLDMAN, 1984, Economic implications of drip irrigation. Available at http://calag.ucanr.edu/download_pdf.cfm?article=ca.v038n07p4 [Accessed 06.03.2019]

CHADAR SN* AND KEERTI CHADAR, 2017, Solid Waste Pollution: A Hazard to Environment, ISSN: 2575-8578. Available at https://juniperpublishers.com/rapsci/pdf/RAPSCI.MS.ID.555586.pdf [Accessed 11.03.2019]

CHE-ANI A.I., 2009, Rainwater Harvesting as an Alternative Water Supply in the Future, EuroJournals Publishing, Inc., ISSN 1450-216X. Available at https://www.researchgate.net/publication/237821822_Rainwater_Harvesting_as_an_Alternative_Water_Supply_in_the_Future [Accessed 11.03.2019]

DEHADRAI P.V., 2003, Irrigation in India. Available at http://www.fao.org/3/y5082e/y5082e08.htm#TopOfPage [Accessed 13.03.2019]

DIETER, C.A., MAUPIN, M.A., CALDWELL, R.R., HARRIS, M.A., IVAHNENKO, T.I., LOVELACE, J.K., BARBER, N.L., AND LINSEY, K.S., 2018, Estimated use of water in the United States in 2015: U.S. Geological Survey Circular 1441, ISBN 978-1-4113-4233-0. Available at https://doi.org/10.3133/cir1441 [Accessed 05.03.2019]

ENVIRONMENTAL POLLUTION CENTERS, 2017, Oil Spill Pollution. Available at https://www.environmentalpollutioncenters.org/oil-spill/ [Accessed 11.03.2019]

EPA, 2018, What is Acid Rain? Available at https://www.epa.gov/acidrain/what-acid-rain [Accessed 11.03.2019]

FAO, 2011, Global food losses and food waste – Extent, causes and prevention. Rome. ISBN 978-92-5-107205-9

FAO. 2018. Asia and the Pacific Regional Overview of Food Security and Nutrition 2018 – Accelerating progress towards the SDGs. Bangkok. ISBN 978-92-5-130845-5

FLUENCE NEWS TEAM, 2018, Pulp and Paper Industry Facing Water Issues. Available at https://www.fluencecorp.com/pulp-and-paper-industry-water-use/ [Accessed 10.03.2019]

FOOD AND AGRICULTURE ORGANIZATION, 2018, Average precipitation in depth. Available at https://www.indexmundi.com/facts/indicators/AG.LND.PRCP.MM [Accessed 03.03.2019]

GARTNER TODD and MULLIGAN JAMES, 2018, 3 Ways Forests Can Solve the World's Water Crises. Available at https://www.wri.org/blog/2018/03/3-ways-forests-can-solve-worlds-water-crises [Accessed 11.03.2019]

GHAFFOUR NOREDDINE, THOMAS M. MISSIMER, GARY L. AMY, 2012 “Technical review and evaluation of the economics of water desalination: Current and future challenges for better water supply sustainability.” Water Desalination and Reuse Center KAUST, October 2012.

GIANFRANCO NITTI, 2011, "Water is not an infinite resource and the world is thirsty". The Italian Insider. Rome.

GLEICK PETER H., 1993, Igor Shiklomanov's chapter "World fresh water resources" in Water in Crisis: A Guide to the World's Fresh Water Resources (Oxford University Press, New York).

GLEICK, P.H ET AL, 2014, The World's Water: The Biennial Report on Freshwater Resources. Washington, DC: Island Press, ISBN 978-1-61091-483-3

GONSALVES OLIVER, 2018, India’s Industrial Water Rates and Supply. Available at https://www.india-briefing.com/news/industrial-water-rates-india-supply-16547.html/ [Accessed 11.03.2019]

GOSLING SIMON N., NIGEL W. ARNELL, 2016, A global assessment of the impact of climate change on water scarcity

IDADESAL, 2019. Available at https://idadesal.org/ [Accessed 12.03.2019]

INFOPLEASE, 2016, A Profile of the World, 2016. Available at https://www.infoplease.com/world/general-world-statistics/profile-world-2016 [Accessed 06.03.2019]

INTERNATIONAL MONETARY FUND, 2019. Available at https://is.gd/pXWwCL [Accessed 13.03.2019]

IRIN, 2017, Mapped - a world at war. Available at https://www.irinnews.org/maps-and-graphics/2017/04/04/updated-mapped-world-war [Accessed 07.03.2019]

IWA, 2018, The reuse opportunity. Available at http://www.iwa-network.org/wp-content/uploads/2018/02/OFID-Wastewater-report-2018.pdf [Accessed 05.03.2019]

MUHAMMAD AYAZ SHAIKH, 2009, Water conservation in textile industry. Available at https://sswm.info/sites/default/files/reference_attachments/SHAKIH%202009%20Water%20conservation%20in%20the%20textile%20industry.pdf [Accessed 10.03.2019]

O’DONNEL JOSY, 2018, What You Need to Know about Thermal Pollution And Its Causes. Available at https://www.conservationinstitute.org/thermal-pollution/ [Accessed 11.03.2019]

RANVEER ANIL C., POOJA LATAKE, POOJA PAWAR, 2015, The greenhouse Effect and its Impacts on Environment, ISSN: 2454-5988. Available at https://www.researchgate.net/publication/302899977_The_Greenhouse_Effect_and_Its_Impacts_on_Environment [Accessed 11.03.2019]

RAVNBORG HELLE MUNK, 2004, Water and Conflict "Conflict prevention and mitigation in water resources management", ISBN: 87-7605-029-7

RENEWABLEENERGYHUB, 2018, Rainwater Harvesting System Cost. Available at https://www.renewableenergyhub.co.uk/rainwater-harvesting-information/rainwater-collection-cost.html [Accessed 03.03.2019]

RITCHIE HANNAH, 2015, Water Use and Sanitation, Our World in Data. Available at https://ourworldindata.org/water-use-sanitation [Accessed 22.02.2019]

SCHNEIDER A., FRIEDL M.A. AND POTERE D., 2009, A new map of global urban extent from MODIS satellite data. Available at https://nelson.wisc.edu/sage/data-and-models/schneider_erl2009.pdf [Accessed 06.03.2019]

SHASHANK NAKATE, 2018, Sewage Water Pollution: A Deadly Threat to Biodiversity. Available at https://helpsavenature.com/sewage-water-pollution [Accessed 11.03.2019]

SIMPSON STEPHEN D., CFA, 2012, Top Agricultural Producing Countries. Available at https://www.investopedia.com/financial-edge/0712/top-agricultural-producing-countries.aspx [Accessed 05.03.2019]

SMITH AMY, 2008, Low-Cost Drip Irrigation. Available at http://web.mit.edu/D-LAB/resources/nciia_files/tb-di.pdf [Accessed 03.03.2019]

THERENEWABLEENERGYHUB, 2018, Cost of Installing Rainwater Harvesting System. Available at https://www.renewableenergyhub.co.uk/rainwater-harvesting-information/rainwater-collection-cost.html [Accessed 03.03.2019]

TODAY'S HOMEOWNER, 2018, How to Calculate Lawn Irrigation Water Usage and Costs. Available at https://www.todayshomeowner.com/calculating-lawn-irrigation-costs/ [Accessed 05.03.2019]

U.S. GEOLOGICAL SURVEY, 2000, Estimated Use of Water in the US in 2000. Available at http://pubs.usgs.gov/circ/2004/circ1268/htdocs/text-ir.htmlExternal [Accessed 05.03.2019]

UNESCO, 2009, Water in a changing World, UNESCO ISBN: 978-9-23104-095-5

UNICEF, 2015, World Health Organization (2015) Progress on Sanitation and Drinking Water - 2015, MGT assessment

WATER REUSE ASSOCIATION, 2012, "Seawater Desalination Costs," on January 2012.

WATEREUSE ASSOCIATION, 2012, Seawater Desalination Costs. Available at https://watereuse.org/wp-content/uploads/2015/10/WateReuse_Desal_Cost_White_Paper.pdf [Accessed 06.03.2019]

WATEREUSE, 2012, Seawater desalination costs. Available at https://watereuse.org/wp-content/uploads/2015/10/WateReuse_Desal_Cost_White_Paper.pdf [Accessed 06.03.2019]

WORLD BANK, 2008, World Development Report (2008): Agriculture for Development. Washington, DC: World Bank