SUSTAINABILITY IN WATER RESOURCES

الاستدامة في مصادر المياه

by

MOHAMED ARIF MOHAMED SAEED AL-ALI

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Abstract

This dissertation is dedicated to a detailed investigation of the sustainability of water resources in the United Arab Emirates. Due to high water consumption rates, the utilization of thermal methods for water generation, and the insufficient use of desalination and wastewater recycling instruments in the country, the nation faces the threat of water scarcity. This study aimed to investigate the sustainability of water resources in the UAE in detail and offer practical recommendations concerning the ways in which the government could make its water management systems more sustainable.

The study used a quantitative research methodology and the research method of a survey to collect a significant amount of quantitative data on the problem under investigation. I will conduct an online survey among 186 experts and in an attempt to explore the specifics of water use and water management in the country and the potential of different instruments to ensure that the nation uses its water resources in a sustainable way.

The study collected a significant amount of information about the key problems and challenges related to water management and offered a number of practical recommendations, such as encouraging a shift towards reverse osmosis in water desalination, separation of grey and black wastewater during the process of wastewater recycling, and changes in residents' water consumption patterns.

All these recommendations are discussed in detail in the dissertation, which makes its findings valuable both from the practical and from the theoretical perspective.

نبذة مختصرة

هذه الرسالة العليمة مخصصة للبحث حول موضوع استدامة الموارد المائية في دولة الامارات العربية المتحدة. تواجه الدولة خطر في نقص مصادرالمياه و ذلك بسبب ارتفاع معدلات استهلاك المياه، استخدام الطرق الحرارية لتوليد المياه، الاستخدام الغير كاف لعمليات تحلية واعادة تدوير مياه الصرف الصحي في الدولة . تهدف هذه الرسالة الى البحث في موضوع استدامة الموارد المائية في الدولة بعمق و بالتفصيل، وستقدم هذه الدراسة مقترحات عملية تحدد الطرق التي تمكن الحكومة من تحقيق الاستدامة في أنظمة إدارة المياه.

تستخدم في هذه الدراسة منهجية البحث الكمي و الدراسة الاستقصائية في عملية البحث لجمع عدد كبير من البيانات الكمية عن موضوع الدراسة. سيتم عمل دراسة استقصائية عبر الانترنت التي ستضم 186 خبير للقيام بدراسة اولية عن تفاصيل استخدام المياه و ادارة المياه في الدولة و قياس امكانيات الادوات المختلفة للتاكد من ان الدولة تستخدم مصادر المياه بالطريقة التي تضمن استدامتها.

الدراسة جمعت عدد كبير من المعلومات عن المشاكل الاساسية و التحديات المتعلقة في ادارة المياه و تقدم عدد من المقترحات العلمية والعملية، مثل تشجيع الانتقال الى عملية التناضح العكسي في تحلية المياه، و استخدام طريقة فصل الاجزاء الرمادية عن الاجزاء السوداء في عملية اعادة تدوير مياه الصرف الصحي، وتغيير انماط استهلاك المياه للافراد. كل هذه المقترحات سوف تناقش بالتفصيل في هذه الدراسة العلمية، مما يجعل نتائج البحث فعاله من المنظورين العملي و النظري.

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Chapter 1. Introduction

1.1. Research Background and Significance of the Research Problem

The world population has been rapidly enlarging since the beginning of the 20th century. During the period between 1955 and 1970, the rate of this increase exceeded 2% (Haugan 2016). Nowadays, the pace of the population growth is significantly lower; nevertheless, the overwhelming majority of countries continue reporting an increase in the number of residents. In accordance with the forecast of most experts, there will be more than 11 billion people living on Earth by 2100 (Bacci 2017). Such a significant pattern contributes to the topicality of the problem of resources' scarcity, which has been already pointed out by many scholars. In order to satisfy the needs of the growing population, states should design new instruments of generating resources, such as food and water, which would be grounded on a sustainable basis. The development of such mechanisms has become a popular object of many studies.

This academic paper is dedicated to the investigation of the problem of water sustainability. As it is known, water is the largest natural resources in the modern world; however, only approximately 3% of it is represented by freshwater, and no more than 33% of it are accessible for use (Plessis 2017). Retrieving the remaining 77% of water seems challenging because it either exists in a frozen form or resides deep underground (Karar 2016). Nowadays, aquifers serve as the main source of fresh water for almost a fourth of the world population; however, an increase in water consumption resulted in the depletion of more than a half of the largest aquifers. Furthermore, a further increase in consumption is expected to lead to a further 40% decrease in the amount of freshwater reserves (Tignino & Brethaut 2018).

The problem of water scarcity is becoming increasingly popular since approximately 20% of modern cities could be regarded as water stressed. Cities use more than 500 billion

liters of water in order to hydrate their residents and businesses, outstretching watersheds beyond their capacity. More than 70% of water resources are used by the agricultural sector, which already faces occasional situations in which the demand starts exceeding the supply (McFarland 2017).

All the numbers above illustrate the crucial importance of finding the ways to ensure the sustainability of water resources. Many international organizations and states have already designed strategies to mitigate the unsustainable use of water. For example, the period between 2005 and 2015 was announced by the United Nations as "the decade of action on promoting water and sanitation use" (Hess 2016). There are also many promising advancements in the agricultural industry. In particular, many countries encourage farmers and other stakeholders of the sector to engage in wetlands' preservation, agroforestry, and food-energy-water nexus. In regards to agroforestry, authorities try to work closer with herders in order to ensure that cattle is in the shade of trees, which simultaneously enhances the pastures' productivity and reduces water consumption. The preservation of wetlands combines numerous projects aimed at maintaining streams and lakes while helping farmers withstand some of the climate change's effects (Wehr, Sheath & Kociolek 2015). Finally, many countries and international organizations launched large programs that sought to promote the sustainability of water, energy, and food as a single holistic system, thus promoting the ecosystem's sustainability.

Despite the efforts of many stakeholders, the problem of water sustainability remains topical and challenging. Therefore, many scholars, experts, and government officials continue looking for a way to address this problem in particular countries and ensure that both residents and businesses are able to satisfy their needs in fresh water. This research paper is one the studies taking this approach. With the help of the quantitative research methodology, I will analyze the problem of water sustainability in the United Arab Emirates in order to identify the

key aspects of this issue and recommend practical solutions concerning the improvement of water resources' sustainability within the country.

The chosen research problem is especially topical for the United Arab Emirates because this state is among the most water-scarce countries in the modern world. Like most other Arab states in the region, the UAE has been reporting a rapid population growth, which puts a pressure on water resources; furthermore, it is also important to emphasize that the water consumption of its residents currently stays at approximately 55 liters per day, which is one of the highest numbers in the world (Kumar 2017). At the moment, the country faces several disturbing challenges related to the process of water management. In particular, the country suffers from the scarcity of groundwater reserves, problems with collecting and treating wastewater in rural regions, limited practices of reusing water, and a high prime cost of drinking water. Moreover, it is also important to point out that the existing groundwater, which exists in limited amounts, is characterized by high salinity levels.

In order to address these issues, the country has to invest in the development of water efficiency technology and relevant infrastructure; however, recent budget reductions following a decrease of energy prices resulted in the closure or postponement of some projects that have been already launched. At the moment, the UAE government tries to reduce the demand on water consumption via three directions: educational initiatives, desalination of water, and adoption of innovative technologies that increase the efficiency of water management. Authorities also started the process of reducing the existing subsidies on water and power.

In 2019, the country allocated $1.6 billion on projects aimed at promoting the sustainability of water resources via energy and water projects (IBP, Inc 2016). The majority of water that is used for satisfying the nation's demands comes from groundwater; at the same time, almost 30% of it is generated as a result of desalination practices and water retreatment (Amery 2015).

In order to address the problem of water scarcity, the country has developed Water Security Strategy 2036, which aims to ensure a sustainable access to water. The strategy has several specific quantifiable objectives, including the reduction of water demand by 21%, an increase in water productivity to $110 per m^3, a reduction of the index of water scarcity by at least 3°, an enlargement of the nation's capacity of water storage to at least 2 days, and an increase in the reuse of water treatment to 95% (The UAE Government 2019). At the moment, the government has only started implementing this strategy; therefore, it is early to comment on its effectiveness. Nonetheless, it is already evident that its implementation will face a number of challenges; thus, an analysis of the ways in which the UAE could improve the sustainability of its water use addresses a promising research problem.

1.2. Research Goal and Research Objectives

The main research goal of this academic paper is to investigate the problem of water resources' sustainability in a systematic manner and analyze the ways in which the United Arab Emirates could improve the sustainability of its water resources. In particular, the study will address the following objectives:

- To highlight the importance of ensuring high sustainability of water resources;
- To investigate the potential of desalination processes to sustain water and reduce the cost of producing clean water in the United Arab Emirates;
- To analyze the ways in which changes in the operations related to water transmission and distribution could reduce the wastage of water in these processes in the United Arab Emirates;
- To research the potential of recycling sewage water in the United Arab Emirates;
- To study the option of finding a new water resource for the United Arab Emirate.
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1.3. A Brief Description of the Research Methodology

This study will rely on the research philosophy of realism, the descriptive research design, and the quantitative research methodology. With the help of an online survey, I will collect a sufficient amount of quantitative data from experts who possess knowledge of the specifics of water resources in the UAE and have informed opinions on the ways to make the use of water within the country more sustainable. In order to recruit respondents for the sample, I will utilize the word-of-mouth method to find those individuals who are supposed to be proficient in the problem of under investigation, such as government officials, scholars, and students at universities whose degree is directly connected with environmental sustainability.

All these people will be asked to share their opinions on the topicality of the problem of water scarcity in the UAE, the need to ensure the sustainability of water use in the country, and practical ways to achieve this goal. The main part of the questionnaire will consist of specific questions about the potential of different options, such as water desalination and sewage water recycling, to reduce the cost of producing clean water for the nation. The survey will include both close-ended and open-ended questions; therefore, respondents will have an opportunity to share their insights into the problem under investigation.

The data collected from them will be then analyzed in MS Excel and discussed in light of the literature review's findings. The research will not require the use of any complex statistical instruments, such as regression analysis or extrapolation, because its main aim is to retrieve respondents' opinions on a set of specific questions. The percentage of the study's participants who provided certain answers to questions, therefore, will serve as the main basis of data analysis in the study. A detailed description of the research method used in the study and the procedures of data collection and data analysis could be found in Chapter 3 of this dissertation.

1.4. Expected Theoretical and Practical Contributions of the Study

It is expected that the research will generate a substantial amount of significant theoretical and practical contributions. In the theoretical domain, the research will be one of the first ones of its kind to provide a detailed analysis of the problem of water use sustainability in the United Arab Emirates and outline the key instruments that could help address this challenge. It is important to emphasize that the study will approach this problem, focusing on a number of relevant aspects instead of concentrating in some narrow issues, which is the case for most other studies on the sustainability of water use.

From the practical perspective, the research attempts to generate some useful recommendations for the government of the UAE regarding the ways in which it could succeed in the implementation of Water Security Strategy 2036. It will separately analyze the options that are available for the government in its attempt to ensure high sustainability of water resources within the country. In particular, the dissertation will present the scenarios of developing desalination processes to sustain water and reduce the cost of producing clean water, optimizing the process of water transmission and distribution, recycling sewage water, and finding new water sources. After that, I will highlight the most promising options shaped in the form of practical recommendations.

1.5. Organization of The Dissertation's Structure

In accordance with the existing academic guidelines, this dissertation will consist of five chapters, which could be found in almost any dissertation and thesis: introduction, literature review, methodology, findings, and conclusion. The literature review is dedicated to a detailed analysis of the literature relevant to the problem under investigation with an emphasis of those constructs that will be used empirical part of the study. The chapter will include three parts, which, in turn, will be sometimes divided into their own subsections. The literature

review will start with outlining the problem of water scarcity in the modern world and justifying the importance of ensuring high sustainability of water resources. In addition to an overview of the studies on these matters, this subsection will also include statistical data on the amount of water resources in different countries, the patterns of water use, and recent trends concerning water resources' sustainability. After that, I will present a thorough investigation of the most popular instruments of ensuring the sustainability of water use, including water desalination, optimization of water transmission and distribution processes, recycling of sewage water, and looking for new water resources. Finally, the last part of the literature review will focus on the water use and water resources of the United Arab Emirates.

The research methodology will systematically describe all the pertinent aspects of the empirical stage of this research, including the justification behind the choice of a certain research philosophy, approach, methodology, time horizon, and research design (Baran 2016). After defining the frame in which the study is put, I will describe the procedure of using an online survey for collecting quantitative data required for this research. In particular, this part will include information about the sampling method, the mechanisms of respondents' recruitment, and the specific procedures of data collection. It will also elaborate on the data analysis techniques and describe the measures taken by the me to comply with basic ethical requirements.

The fourth chapter of the research will be devoted to the presentation and a thorough analysis of the survey's results. I will discuss all the findings and compare them to the findings of scholars whose works have been previously analyzed in the literature review section. Finally, in the last chapter of the dissertation, I will summarize all the findings and report on the completion of research objectives formulated in the introduction. The conclusion will also include information about the directions that could be pursued by other scholars who are

interested in investigating the problem of water use and sustainability of water resources in the UAE and practical recommendations for the UAE government concerning the implementation of Water Security Strategy 2036.

Chapter 2. Literature Review

2.1. The Significance of Sustainable Water Use

2.1.1. The Problem of Water Scarcity in the Modern World

Even though the implementation of sustainable water use technologies has long been an object of debates among politicians, representatives of international organizations, social activists, journalists, and regular citizens, many people still do not entirely realize dangers associated with the problem of water scarcity. Because of this reason, it is of paramount importance to start this literature review with briefly describing the scale of water scarcity in the modern world and outlining trends inherent to this phenomenon. An understanding of the possible problems in which the ignorance of the phenomenon of water scarcity may result is the first step towards realizing the need to develop sustainable practices of water use.

As it is known, water covers approximately 70% of Earth. At the same time, most of it cannot be use for drinking. Only 3% of the water that could be found on the planet is freshwater, and, as stated in the introduction, only approximately a third of these resources could be accessed (Lin, Watson & Suffet 2018). In this situation, it becomes clear that the exhaustion of freshwater is a real although very long-lasting scenario. Nowadays, around 1.1 billion people in the world do not have a stable access to freshwater; at the same time, close to 2.7 billion people experience the problem of water scarcity for at least one month in a year. In addition to the lack of an access to freshwater, many people face challenges related to sanitation. In particular, 2.4 billion individuals expose themselves to various water-borne diseases, such as cholera, as a result of improper sanitation (Russell 2016). Diarrhea alone is a result of two million deaths on a yearly basis. All these numbers illustrate that the provision of an access to clean freshwater is a topical problem.

The problem of water scarcity is a result of many social, economic, and environmental processes. A rapid increase in the world population, an improvement of the quality of life, a transformation of water consumption patterns, and the extension of the irrigated agricultural sectors are the most evident ones among them. At the same time, fresh water is also vulnerable to climate change and some of its implications, such as pollution of lakes and rivers, forestation, and droughts. In general, the existing population of the world meets its water needs; however, in some nations experience temporal problems with water due to seasonable trends, which results in occasional scarcity of water during certain periods of a year (Wehr, Sheath & Kociolek 2015). It is important to emphasize that the overwhelming majority of factors contributing to water scarcity are direct or indirect results of human activities. An intensified economic development increases the risks of water scarcity; however, a number of causes associated with it could be successfully mitigated.

From the quantitative perspective, the amount of available water resources is sufficient for satisfying the needs of the current population; moreover, they could even support a further increase in the number of people living on Earth. In accordance with various estimations, there are currently approximately 14,000 kilometers^3 of surface and ground water, but only close to 5,000 of them are being regularly used and reused (Miller & Spoolman 2015). Accordingly, the problems with water scarcity are rather connected with regional trends than with global patterns. In addition to environmental conditions, water scarcity in certain parts of the world results from the extensive utilization of these resources in the agricultural sector and industrial development. The consumption of water in developed countries is approximately 10 times higher than the consumption of water in developing states. In order to satisfy the needs of residents of developed countries, enterprises extensively use water in developing states, which sometimes contributes to water pollution and results in occasional water scarcity problems.

In the most general view, water scarcity can occur in two forms: as physical and as economic scarcity. The phenomenon of physical water scarcity is closely connected with the lack of natural water resources as the existing ones are unable to satisfy the needs of a population. Approximately 20% of the world's population are forced to live in places that are to a certain degree affected by physical water scarcity. Countries with an arid climate, such as Egypt, Saudi Arabia, and the UAE, often face the threat of water scarcity (Cahan 2017). This problem might also occur in those regions where governments or local stakeholders overuse water resources or initiate inefficient projects, such as dams, which results in environmental degradation.

The problem of economic water scarcity derives from the insufficient efforts of stakeholders to retrieve water from relevant sources or the lack of resources to do so. In other words, in places with economic water scarcity, the population's needs could be successful satisfied with the existing water resources; however, due to some economic and social factors, these resources are not adequately used. There are many African communities that are currently suffering from this form of water scarcity (Behnassi & McGlade 2017). Without an adequate political organization and economic capacity, they are unable to develop instruments of retrieving groundwater or transferring it from surface sources. As a result, many people are forced to travel during challenging periods in an attempt to be closer to freshwater. This trend negatively influences the quality of their life, contributing to hunger and poverty.

The overuse of water, which is usually a direct cause of water scarcity, results not only in devastating consequences for residents but also in catastrophic implications for the environment. This factor contributes to the depletion of water resources, which sometimes applies even to large water resources, such as rivers. An excessive use of water by the agricultural sector leads to a number of disturbing processes in the environment, including the

exhaustion of wetlands, pollution, and salinity. The depletion of wetlands is one of the most topical problems associated with water scarcity, which attracts the attention of numerous experts, social activists, and regular people (Goldstein 2016). As a result of unsustainable human practices, many wetlands shrank or completely disappeared, which destroyed the natural environment for many animals, deteriorated the conditions for growing agriculture, and eliminated protection mechanisms that used to prevent residents from natural disasters, such as floods and storms.

The shrinking of Aral Sea is known as one of the most discussed environmental disasters illustrating the negative impact of human interventions on wetlands. Due to irrigation projects implemented by the Soviet Union, Aral Sea started shrinking in the 1960s. Nowadays, it constitutes only around 10% of its original size, which negatively affects the environment in Kazakhstan as well as it fishing sector (Kibert 2016). Furthermore, it is also important to emphasize that the water in Aral Sea has become more saline, which made it harder to use it as freshwater. This example demonstrates how unsustainable human practices can lead to the lack of water even in those areas where there are no signs of physical water scarcity.

In addition to obvious consequences, such as health problems, a water crisis can also result in many indirect results. In particular, water scarcity leads to an increase in water prices, which, in turn, triggers a growth of food prices as well. The existence of this correlation could be explained by the fact that water is used during the production of food crops. For instance, a 10% increase in water prices may be responsible for a 30% increase in the cost of producing oranges (Dinar & Dinar 2017). Such pattern, which can be also observed in the production of most other fruits and vegetables, negatively affects public health since it makes the consumption of healthy food more expensive.

An increase in food prices, which, as showed above, may be caused by the growth of water prices, raises the likelihood of social conflicts, manifestations, and even hostilities. There are many examples in developing countries showing that the scarcity of food and water might heighten conflicts (Ghazouani, Molle, Swelam, Rap & Abdo 2015). Finally, an increase in water prices also puts a pressure on the overwhelming majority of industries, including electronics and fashion sectors, which require essential amounts of water. Therefore, a decline of water resources in a certain country can lead to major negative political, economic, and social implications.

The available evidence provides a premise to believe that the problem of water scarcity is becoming increasingly popular. In accordance with the United Nations, which defines water stress as a situation when one person is provided with less than 1,700 m^3 per year, around 17% of the world's population could be considered as water stressed. Sub-Saharan Africa, China, and India face significant threats of water scarcity; for instance, in China, approximately 538 million people are water stressed. At the same time, Middle East is currently the most water stressed region in the world as an average person living in Middle East has only around 1,200 m^3 per year, which is only a little higher than 1,000 m^3 per year, a rate that is defined by the UN as the sign of water scarcity (Ward & Ruckstuhl 2017).

2.1.2. The Ways to Overcome Water Scarcity

There are currently many different mechanisms of overcoming water scarcity that depend on the specifics of a particular situation and the cause of a water crisis. In particular, if a water crisis is caused by some temporary factors, such as hostilities or infrastructural problems, local authorities can engage in collaboration with nearby communities and use its resources, providing residents with a stable access to at least 1,000 m^3 per year. They may also initiate some initiatives aimed at cutting water use, such as restricting water use to certain

periods of a day or asking residents to cut water use with the help of social campaigns. Cape Town water crisis is one of the brightest examples of such scenario. When faced with the threat of the water resources' exhaustion, the city's authorities implemented significant restrictions that managed to achieve a decrease in water use by almost 50%. In case if the water level of its dams fell below 13.5%, authorities would completely switch off municipal water supply, providing people with a certain ration of water (Pannirselvam, Shu, Griffin, Philip, Natarajan & Hussain 2018). Fortunately, the city managed to prevent such scenario; however, its example illustrated the significance of the problem of water scarcity in the modern world and demonstrated the radical measures that authorities can take to prevent water shortage.

In order to overcome the problem of water scarcity and ensure the sustainable use of water, stakeholders are required to identify the cause of water scarcity in a particular region and manage the supply or demand of water. In most situations, responses to this problem could be grouped into three large categories that are related to the policy domains of water, agriculture, and national food security. In the domain of water, authorities can regulate the demand by investing in the efficient use of water in different sectors and make the intersectoral allocation more effective, making sure that all the communities are provided with sufficient amounts of water (Harris, Goldin & Sneddon 2015). In the sphere of supply, there are many different options that can solve the problem of water scarcity. In particular, authorities can develop infrastructure for retrieving groundwater, control pollution levels of surface water and groundwater, design innovative desalinization techniques, and divert rivers.

Considering that a significant part of drivers of water scarcity are connected with agriculture, it seems natural that a substantial number of solutions refer to the management of supply and demand in this field. By encouraging farmers to keep their storage, participate in the development of groundwater, and recycle and re-use water that they have already utilized

in production, countries can significantly reduce the negative influence of this industry on the sustainability of water resources (Majumder 2015). Furthermore, the academic literature offers many solutions connected with the regulation of demand, such as investments in the productivity of crops, an increase in the efficiency of their production, and the introduction of restrictions on irrigated cropped areas.

Finally, negative scenarios associated with water scarcity could be also prevented on the national level. In order to increase the supply of water, governments can import food, thus reducing water consumption by the agricultural sector, store food and water reserves, and distribute the existing resources more efficiently (Huttl, Bens, Bismuth & Hoechstetter 2015). It might be also a promising strategy to optimize the existing food chain by decreasing its waste as well as alter the existing dietary habits of the population, encouraging them to contribute to the sustainability of water use.

Unfortunately, it is barely possible to present a holistic framework that would incorporate all the existing measures against water scarcity; however, the available evidence allows defining some of them as mechanisms that have already proved their effectiveness in various countries. Thus, it seems rational to review the most well-known ones among them. The use of educational programs to change consumers' behavior and the supply chains of corporations is one of the most promising tools of preventing water scarcity scenarios. For instance, the education of people in South Africa is considered by its authorities as one of the key instruments of preventing water pollution and optimizing the use of water by households (Grafton, Daniell, Nauges, Rinaudo & Chan 2015). In a similar manner, education of people living in areas vulnerable to water crises can ensure that all the residents are provided with sufficient amounts of water throughout a year.

Ensuring a more sustainable use of energy is another vital mechanism. By shifting to the use of sustainable energy, businesses contribute to the environmental preservation, thus decreasing the likelihood of a water crisis. Recycling wastewater is also a popular instrument that is often mentioned when discussing the sustainable use of water. The case of Wichita Falls in Texas exemplifies the successful implementation of this strategy. The city faced the threat of a water crisis due to drought conditions; therefore, officials launched a wastewater recycling program on a temporary basis. With the help of the project, the city managed to product almost 2 billion gallons of freshwater a year, which encouraged authorities to start constructing a permanent program (Ewg. Org 2017).

The improvement of agricultural practices has been already discussed in this subsection. Considering that the majority of water is consumed by this sector, it seems natural that a movement towards sustainable agricultural projects is supposed to make a positive impact on the sustainability of water resources. There are many different initiatives that fall under this category, such as minimization of water and air pollution, maintenance of healthy soils, rotation of crops, and promotion of biodiversity. The study by Pretty, Thompson and Hinchcliffe (2011) found that sustainable agriculture not only positively influences water resources but also has a major impact on the productivity of the industry, providing people with more food and boosting emerging economies.

Initiating an increase in water prices may be one of radical measures aimed at preventing the scarcity of water. With a radical increase in the quality of life, many people, especially those living in developing countries, do not consider water as a valuable resource (Pohle 2015). As a result, they often engage in unsustainable patterns of water use, such as purchasing a bottle of water, drinking only a certain part of it, and then throwing it away. By

raising prices on water, authorities could encourage residents to show more responsibility in this sphere.

Desalination is a sphere that incorporates many different approaches towards managing water consumption patterns. In particular, capitalization on energy reserves is the basis of most desalination plants in the Middle East. At the same time, there are also many new directions in this sphere, such as the use of solar-power plants, which will be pursued in Saudi Arabia, and the establishment of small facilities for the agricultural sector, which is practiced in the United Kingdom (United Nations Economic and Social Commission for Western Asia 2016). In those areas where an access to ground or surface water is problematic, effective systems of harvesting and water catchment can provide a stable flow of water, providing people with water resources during challenging periods of a year. The study by Shadeed and Lange (2010) illustrated the success of rainwater harvesting techniques in Faria Catchment, Palestine, where this instrument allows collect water during rainfalls, thus reducing a gap between the supply and demand.

2.1.3. Sustainability of Water Resources and Water Use

The concept of sustainability is one of the most popular notions in the contemporary academic literature. In the most general view, sustainability refers to situations when stakeholders consider not only their current needs but also the needs of further generations, thus ensuring that resources can be continuously used. In the context of water use, sustainability is a characteristic describing the use of water resources that does not lead to their exhaustion. In accordance with the academic literature, sustainable use of water resources requires maintaining a systematic long-term strategy that includes a variety of instruments regulating the supply and demand sides of water use (Loucks 2009). This way, states can prevent water crises.

The need for maintaining such strategy started influencing policymaking in the 2000s. As Mitchell (2006) explains, authorities came to a conclusion that they had to manage a "total water cycle" by "adopting new forms of management that emphasize demand management and supply, using non-traditional water resources and the concept of fit-for-purpose and decentralization" (p. 91). In order to maintain such strategy, authorities have to develop water infrastructure, facilitate structural change, foster a favorable investment climate, improve water efficiency, encourage intersectoral trade-offs, and protect water resources.

In order to ensure the sustainable management of water resources, countries should consider this problem as a part of the overall goal to apply a holistic approach towards management of ecosystems. In particular, they have to implement a global strategy to achieve this goal, which implies seeking sustainable farming systems, economic sustainability, social sustainability, environmental sustainability, and the adequate use of water for specific crops. The sustainability of farming systems can be achieved by complying with five principles. First, it is necessary to consider the unique specifications of each farm on the planning stage. Such consideration can help select a proper location for starting the production process, building relevant storage and harvesting facilities if necessary, and planning response measures to potential pollutants (Oxford Business Group 2015). Farmers also have to maintain an effective integrated crop management strategy by controlling diffuse pollution, using conservation tillage, setting conservation riparian buffers, calibrating sprayers, and producing crops in a certain recurring order.

The use of integrated pet management systems is another vital component of sustainable farming. By selecting low-risk solutions, farmers can minimize the negative influence of their operations on the environment, thus reducing the likelihood of a water crisis (Rosenberg, Easterling, Crosson & Darmstadter 2016). The instruments of blocking runoff

pathways and reducing soil erosion can contribute to soil protection, which positively influences the sustainability of water resources.

In accordance with the study of Qian (2016), the sustainable management of water resources requires compliance with four principles: the control of demand and preservation of water, the control of pollution levels, the use of wastewater, and the prevention of floods by turning rainwater into a valuable resource. Even though the findings of this study mainly apply to the Chinese context, its recommendations still could be considered valuable for the international community. Such instruments as the recycling of wastewater are known among scholars as effective mechanisms of shifting to sustainable water use.

In order to ensure the sustainable use of water in cities, their authorities have to engage in many initiatives in the spheres of planning, resilience, efficiency, and water quality. In the sphere of planning, cities have to develop soft infrastructure to prevent the occurrence of disasters and recover from them as fast and effective as possible. Furthermore, they should also consider unique specifics of different areas during planning (United States. Congress. House. Committee on Natural Resources 2015). The adaptive planning of Mission Creek in San Francisco exemplifies an approach towards planning that entails thoroughly assessing the vulnerability of a certain district towards natural disasters and finding sustainable solutions to minimize the likelihood of these disasters.

The strategy of resilience incorporates many directions of change that can be initiated by cities to promote sustainability of water resources. First, they can develop green space and design attractive recreation areas that would also improve the cities' ecosystem, thus reducing water pollution. The collection of rainwater is another popular instrument that contributes to sustainability. The capture of storm water in Los Angeles and rainfalls in Singapore and Melbourne are bright examples of such strategy (Thune 2017). Even though that water

collected this way does not always as freshwater, it still contributes to the process of water preservation. For example, in Melbourne, the water collected from roofs is used law watering and toilet flushing, which allows not using freshwater for these purposes.

Desalination is also known as a vital aspect of sustainable water use. As explained in the previous subsection, it exists in many different forms. In some regions, such as the Middle East, desalination of water from the oceans is among the few available options for satisfying the population's needs in water; therefore, it is natural that most countries on the Arab Peninsula have invested substantial amounts of money into the research and development of desalination projects (World Bank 2017). In addition to desalination, the sustainable management of water resources also requires effective practices of reusing wastewater. Interestingly, due to the significant progress of this industry, the water that is retrieved in this way is often utilized not only for secondary use but also for drinking purposes.

The efficiency of water use is at the heart of the concept of sustainable water resources. In order to ensure that a particular country, city, or community uses its water resources in a sustainable way, relevant stakeholders should possess detailed knowledge of the specifics of water resources, their distinctive features, and scenarios that predict the consequences of various patterns of water use. In general, authorities as well as residents must understand the capacity, vulnerability, and risks inherent to a particular system of water resources (Newton 2016). Pertinent government bodies must regularly collect information about the elements of water management infrastructure and report on their vulnerability and effectiveness. The achievement of sustainability goals in regard to water use requires a detection and replacement of all the obsolete and broken elements of the infrastructure in a timely manner.

2.2. Desalination

As showed in the previous chapter, desalination techniques are one of the crucial components of the concept of sustainable water resources. In the most general view, the term "desalination" refers to the retrieval of mineral components from saline water. The goal of desalination is to take away salts and minerals from a particular substance (Ning 2015). This process is conducted in order to produce water that is suitable for irrigation and consumption. In some situations, this process is conducted on ships, although the majority of desalination operations are conducted on appropriate plants.

The need to desalinate water is evident for the overwhelming majority of stakeholders. As stated above, approximately 97% of the existing water has salt (Olsson 2015). Consequently, desalination is a significant attempt to refer to the problem of water shortages that is present in highly populated regions. Nowadays, the focus of the desalination process is on making its procedures more cost-effective. Because of energy consumption, the desalination techniques are usually more expensive than the process of using water from rivers, water conservation, or recycling. At the same time, such methods might lead to the problem of reserves' depletion. In the modern world, only 1% of population depends on water that has been desalinated (Hilal, Ismail, Matsuura & Radcliffe 2017). However, the situation might change by 2025 as, in accordance with the forecasts of most experts, up to 14% of the population might use desalinated water (Murad, Baydoun & Daghir 2017). Kuwait currently desalinates the highest proportion of water in comparison with other states; furthermore, it relies on desalination as the key source of freshwater (Sarp & Hilal 2018).

The available evidence provides a premise to believe that there are three methods of conducting desalination. These options are electrical, thermal, and pressure processes. Owing to the thermal method, plants can gather steam that is emanated during the boiling of water,

which allows getting rid of salt (Guyer 2018). The need to use a significant amount of energy for vaporization is one of the major disadvantages of this method.

The thermal desalination method exists in various forms, such as solar water desalination, multi-stage flash distillation, cogeneration, multi-effect distillation, and vapor compression evaporation. Solar water desalination, which the first type under consideration, is usually applied for small-scale operations. The main principle of this method is to evaporate water from salt water with the help of the solar energy. The second type of thermal desalination is a multi-stage flash distillation, and this process implies desalinating via different chambers. With the help of this technique, it is possible to boil the feed water at high pressure, move it to the first champer, and then release a high pressure to cause the heating of water and the consequent evaporation process (Yonar 2017).

Cogeneration is an instrument of desalination that provides an opportunity to use energy for dual aims: desalination and generation of electric power. Therefore, cogeneration may be considered as a sustainable multi-purpose solution for a community. Moreover, it is also necessary to pay attention to multi-effect distillation, which was widely used in the period between 1950s and 1960s. This process applied the same principles as the method of multi-stage flash desalination described above. However, during the multiple effect distillation process, these principles are used in the contrary manner, which results in a number of different effects.

Multiple effect distillation also applies principles of evaporation and condensation at decreased circling pressure. The available evidence provides a premise to believe that in the process of the multiple effect distillation, there is a great number of evaporator effects that make water on the basis of lower pressures. When this pressure reduces water heats at low

temperature, then water evaporates from the first chamber, resulting in a heating tool for the second evaporation (Yonar 2017).

Finally, the method of vapor compression evaporation is performed individually or applied in the process of MED. During this process, heat for evaporating appears from the compression of vapor. A mechanical compressor and a steam jet are necessary in order to conduct this process. The mechanic compressor, which works with the help of electric power, is applied to perform the heat for evaporation. At the same time, in a case of using a steam jet, its venture orifice makes vapor and then extracts water from it (Yonar 2017).

In addition to the methods described above, desalination is also often carried out with the help of the electrical method. This technique implies taking ions through a selectively fordable membrane holding the disjunct salt ions. The main feature of electric desalination is that the energy depends on the amount of salt that is present in water at the initial stage. Therefore, this is appropriate for water with initial salt concentrations. However, this method is highly tense for seawater from the perspective of energy. Finally, the third method of desalination, which implies using pressure, may be defined as the reverse osmosis, and it is conducted when pressure is applied in order to drive water via a selectively fordable membrane, leaving water behind (Ning 2015).

The choice of an appropriate desalination mechanism is an important and challenging process that depends on a number of relevant factors. The available evidence provides a premise to believe that the thermal method needs a great usage of energy in order to boil water. At the same time, membrane techniques also require energy for carrying out mechanic processes. Finally, reverse osmosis is the most efficient method among the three mechanisms described above. In addition to this, it is also of paramount importance to pay attention to the degree of necessary purity, the cost of chemical preparations, and the degree of production

(Eyvaz & Yuksel 2018). These issues can predetermine the choice of a desalination method for a particular country.

The use of desalination processes for providing the population with freshwater is a popular practice that could be found in many different countries. This method is of paramount importance for countries in the Middle East and especially for Kuwait, Bahrain, Saudi Arabia, the UAE, and Qatar. Moreover, the region as North Africa also relies on water desalination as the strategic mechanism of preventing water scarcity. From the perspective of volume capacity, the largest users of desalinated water are Japan, Kuwait, the UAE, Spain, Saudi Arabia, and the USA (Beelessiotis, Kalogirou & Delyannis 2016). Approximately 70% of drinking water in Saudi Arabia is retrieved as a result of the process of desalination, and this number is expected to increase in the nearest future. In such states of the USA as Virginia, California, Florida, and Texas, approximately 5.6 million cubic meter of water after the desalination is drunk every day (Amer, Adeel, Boer & Saleh 2016). All the numbers above illustrate that water desalination playing an increasingly important role in the development of sustainable water use practices.

To sum up, a rapid extension of environmental pollution in the modern world creates significant obstacles in front of countries and communities. Without any substantial changes to the patterns of water use, the existing water reservoirs are likely to exhaust. In this situation, the use of desalination processes seems to be a promising solution of the problem as the desalination of water from seas and oceans could help take advantage of the existing water resources.

It is important to emphasize that desalination of water does not aim exclusively to enlarge the existing amounts of freshwater. Results of empirical studies also show that desalination of water positively influences the performance of the agricultural sector. Because

of this reason, many stakeholders in the industry already started adopting desalination practices for developing their business. For instance, in Spain, approximately 22% of desalinated water is currently utilized for agricultural purposes while more than a half of the Australian population is under the impression that desalination of water is the key long-term solution of the problem of water scarcity (Mechell & Lesikar 2010). In other words, the use of water desalination in the agricultural sector is a promising strategy.

A successful implementation of a water desalination project results in a direct improvement of the quality of irritation water that is used in the agricultural industry. As a result, this technique decreases the likelihood of soil salinity incidents, which can make a negative influence on the growth of crops and the properties of soil. The study by Nofal (2015) showed that desalination techniques result in the enlargement of land available for cultivation and the number of crops that are cultivated. Moreover, it can improve the quality of crops and their productivity. The same research also found a direct correlation between the scope of desalination processes and farmers' incomes (Nofal 2015). In this situation, it seems justified to conclude that the embracement of water desalination techniques is beneficial for farmers.

2.3. Wastewater Recycling

The available evidence provides a premise to believe that recycling of wastewater might be considered as a part of sustainable water management that provides an opportunity to take advantage of an alternative source of freshwater for communities. This instrument decreases scarcity and mitigates pressures on groundwater and other natural sources. In order to achieve sustainable sanitation standards, the management of wastewater requires putting an emphasis on actions connected with resource management, which allows keeping a substantial amount of required resources for satisfying productivity needs of the population (Freedman & Enssle

2015). In general, this process contributes to the maintenance of the human wellbeing and wider sustainability.

The mechanism of water recycling is known as one of the paths towards achieving sustainable water use; however, it is highly expensive. The processes of recycling wastewater for re-usage and launching relevant distribution systems have relatively high costs in comparison with the use of imported and ground water and the appliance of water onsite from homes (Ma, Xue, Gonzalez-Meija, Garland & Cashdollar 2015). The available evidence provides a premise to believe that such hurdles as inconsistency of agencies' priorities and public misperception make the process of implementing water recycling projects challenging.

As stated above, it is expected that by 2025, around 1.8 billion people may face the problem of water scarcity. Wastewater is full of carbon and nutrients. Therefore, if gathered and treated appropriately, it can become a valuable source of clean water. A great number of wastewater treatment plants have already been launched in order to recover nutrients and bioenergy along with the re-use of water. At the same time, approximately 80% of wastewater continues flowing away to the environment, polluting it with feces (Rahman, Hagare & Maheshwari 2016). The main reason behind this situation is that wastewater systems are highly expensive in construction, maintenance, and operation. Many large cities operate effective wastewater recycling plants; however, smaller cities often experience problems with taking advantage of this instrument due to low-quality infrastructure and the lack of competent employees who could complete and maintain sewage water recycling projects.

The case of SUEZ exemplifies the situation in which recycling of wastewater could be an organic component of the sustainable water use framework. SUEZ has recently worked out an environmentally friendly water filtration system for artificial aquifer researching that does not require the use of chemicals. This system helps to re-use urban wastewater in order to

obtain a stable flow of drinking water (SUEZ 2019). The quality of water does not change when being in this aquifer, which allows considering such system as a promising way to integrate the process of recycling water into a wider water management model.

As it is known, ESA has recently developed a prototype of a water recycling unit that has a focus on grey water. Beginning from 2005, this system was used at Concordia, which is a French-Italian research facility in Antarctica. Moreover, a wastewater recycling unit based on MELiSSA was launched at the University of Kentira, Morocco, and it offers drinking water to a community and helps to reach sustainable management of water in that region (Buenestado, Zorzano & Martin-Torres 2015). In this situation, it seems justified to conclude that recycling of wastewater is becoming an increasingly popular instrument.

The need for recycling waste water is especially evident for developing countries. In Guatemala, only 5% of small cities have water treatment plants; furthermore, 12% of residents living in the Atitlan Lake Basin do not have an access to any sanitation systems. At the same time, in accordance with the information provided by the United Nations Population Fund, the population of small cities in Latin America might double in the next 15 years, which will contribute to the existing challenges to water treatment (Salado 2008). Therefore, it is of paramount importance to develop wastewater management in this region, which is mainly conducted in Latin America in the form of septic tanks that require regular maintenance.

The available evidence provides a premise to believe that building decentralized wastewater treatment plants in affected communities might be an effective solution to the problem of water scarcity. Such plants can engage in the treatment of raw wastewater that is produced at a certain place. The academic literature illustrates that the maintenance of such plants can provide local communities with an access to clean water and decrease environmental pollution in rural areas (Dolnicar, Hurlimann & Grun 2011). Because of a small size and low

carbon tracks, the negative influence of these facilities on the environment is lower in comparison with larger plants. In addition to this, such plants suit local climatic conditions and water quality.

Recycling wastewater may be considered a rational choice from the perspective of environmental sustainability. Gathering and exploiting wastewater is highly feasible and justifiable from the financial perspective (Voulvoulis 2018). With the help of this instrument, communities can ensure that wastewater does not become a source of environmental pollution. Moreover, it might become an affordable and sustainable source of nutrients, energy, and other recoverable materials. To sum up, recycling wastewater may be considered an effective mechanism of ensuring sustainable water management and overcoming the problem of waster scarcity in regions that experience physical water scarcity.

2.4. Optimization of Water Transmission and Distribution Processes

The available evidence provides a premise to believe that the contemporary water industry faces a number of challenges. Decreasing revenues due to a lower demand on water, outdated infrastructure, and the lack of experienced professionals are the most well-known ones among them (Sarbu & Valea 2014). That is why it is of paramount importance to design local coordination techniques in order to decrease operating costs and required investments relevant to water facilities that use technologies for unification and optimization of water supply infrastructure (Vanbriese, Dzombak & Zhang 2013). In other words, optimization of water transmission and distribution processes becomes a topical task.

Centralization of management might be one of possible solutions related to regional coordination. The efforts in this direction can help decrease expenses via improved operational efficiency (Koizumi, Takahashi, Koibuchi & Fukumoto 2017). The available evidence provides a premise to believe that the sharing of infrastructure is a form of regional

coordination that might improve water utilities by taking advantage of a comprehensive business model. Infrastructure sharing implies consolidating present infrastructure and decommissioning those facilities that have not been operated for a long period of time (Vanbriese, Dzombak & Zhang 2013). This way, local communities will be able to reduce their water management expenses.

At the same time, such consolidation is associated with a number of challenges. The first possible problem is connected with the need to identify the location and capacity of water treatment plants, pumping stations, and service reservoirs. The second challenge is to decrease the length of piping networks that have to be founded in order to unite consolidated infrastructure (Porse et al. 2017). Without addressing this second issue, the reduction of water management costs might become problematic.

The presence of urban water supply infrastructure in developed counties has led to crucial improvements in the quality of life. At the same time, nowadays, this infrastructure sometimes requires enhancement or even replacement since its maintenance did not always occur in line with the recommended guidelines. Moreover, most these systems were developed in the past century, and they may not entirely correspond to the needs of modern populations anymore (Vanbriese, Dzombak & Zhang 2013). Possible problems with water availability and a gap between the growing water needs of communities and limited water resources encourage authorities to develop water source management systems.

Urban water supply infrastructure has to be widened in order to face new water requirements connected with enlarging populations and growing economies (Poustie & Deletic 2014). A number of scholars believe that the infrastructure that exists nowadays has to be modified, enhanced, and replaced in order to satisfy the evolving water needs of the population not only in terms of the amount of water but also in terms of its quality (Huskova, Matrosov,

Harou, Kaprzyk & Lambert 2016). To make water supply systems more sustainable and more efficient for the future, new approaches and new technologies are needed along with information management and system control.

New achievements in the sphere of cyberinfrastrcture, sensing, computing, and information management might greatly influence the transition of the existing water infrastructure to a highly sustainable system (Huskova, Matrosov, Harou, Kaprzyk & Lambert 2016). In addition to this, accessing low quality sources through membrane technologies can also become a solution of the problem under consideration, as the wide usage of membranes is justified by the universal scope of this treatment and its competitive price.

To sum up, sustainable water supply systems are the ones that can offer a supply of water at sufficient levels in terms of quantity and quality that are required for satisfying the needs of local communities. Optimization of the existing infrastructure and replacement of outdated systems in order to ensure that infrastructure is sustainable from the financial and environmental perspectives are crucial for ensuring the sustainability of water use. Sustainable water supply systems have to be based on the idea that connects natural and engineering systems. If authorities improve urban water infrastructure and ensure superior operational efficiency, they will have an opportunity to receive freshwater of a sufficient level in terms of quality in order to support an urban population.

2.5. Discovery of New Water Resources

Because of the rapid growth of the world's population and the phenomenon of urbanization, the problem of water scarcity is becoming increasingly important. Since the options of desalination, recycling of sewage water, and optimization of water transmission and distribution processes are relatively expensive, many authorities continue searching for new water resources, which could allow preventing the threat of water scarcity without spending a

significant amount of money (Tundisi 2008). As it is known, scientist have recently found a sea of fresh water that is located under the ocean. This is a subterranean pool that starts about 600ft below seafloor, stretches for at least 50 miles of the US Atlantic coast, and has stores of low-salinity water with twice the volume of Lake Ontario (Coren 2019). Such reserves could be a viable solution to the upcoming problem of water scarcity.

In addition to the option of retrieving water from under the ocean, scientists also believe that the discovery of new sources of water could be enabled by the development of space exploration. The fact that water exists in other places the solar system is at the heart of most theories concerning the existence of life on other planets. As it is known, water also exists on Mars in a form of ice. However, there is only a small quantity of water there, as it vapors in the atmosphere. The place where water ice is visible is at the north polar ice cap. Ice of approximately 21 million km^3 has also been found at or near the surface of Mars, although it is limited to traces of moisture from the atmosphere (Joseph, Dass, Rizzo & Cantasano 2019). The available evidence provides a premise to believe that there are no huge bodies of water on Mars's surface, as atmospheric pressure there averages 600pascals (Joseph, Dass, Rizzo & Cantasano 2019). Nonetheless, the option of retrieving water from Mars at a certain point is worth consideration.

Nowadays scientists deal with data they acquired from Mars, and they mull over the ways in which it would be possible to determine whether this planet could sustain life. Rovers, orbiters, and landers that were sent by NASA to Mars were created in order to find water and an environment where life could be sustained in the future (Orosei, Lauro, Pettinelli & Cicchetti 2018). Unfortunately, it is too early to comment on the success of these initiatives at the moment.

To sum up, it has been identified that it is highly challenging to find alternative sources of freshwater. While the option of discovering a large reservoir of freshwater seems promising, the plausibility of such scenario is low for most countries. Moreover, most new sources of this resource, such as a large sea of freshwater under the ocean or water reserves on some other planets, will require immense retrieval efforts and costs, which leads to a conclusion that authorities should prioritize other options discussed in this literature review.

2.6. Water Scarcity and Water Sustainability in the United Arab Emirates

The available evidence provides a premise to believe that the United Arab Emirates is one of the countries with the highest rates of water scarcity in the world. At the same time, this country's water consumption per day, which resides at 55 liters, is one of the highest. Considering that the state's population has been rapidly growing, it becomes evident that the problem of possible water scarcity is becoming a threatening scenario for the nation (Szabo 2011). In this situation, an investigation of the ways to prevent this problem within the country may be considered as a promising research problem.

Because of the threat of water scarcity, the topicality of water-saving initiatives is increasing. The government has recently introduced UAE Water Security Strategy 2036, which aims to provide an access to freshwater to all residents of the country. It can be assumed that this strategy has been worked out from a comprehensive national perspective (The UAE Government 2019). It encourages relevant institutions and authorities to engage in close cooperation with each other in order to integrate their efforts within a single framework and design the framework of sustainable water management.

In accordance with this strategy, it is planned to use integrated water sources management via decreasing total requirements of water resources by 21% and raising water productivity to $110 per cubic meter. Moreover, the strategy also focuses on increasing the

efficiency of water usage through different sectors in order to ensure sustainable withdrawals and provide freshwater to prevent the threat of water scarcity. The available evidence provides a premise to believe that Water Security Strategy 2036 can also help improve the quality of water via decreasing pollution, dumping, and risks of hazardous chemicals. Furthermore, the government also seeks to increase wastewater recycling by 95% (The UAE Government 2019). All these goals illustrate the commitment of authorities towards the embracement of the principles of sustainable water management.

The cooperation of Eshara Capital and Veragon Water Solutions has recently led to the development of the technology that develops sustainable mineralized water with the help of harnessing humidity from air. Owing to this technology, which is financially efficient, the nation can receive up to 1,000 liters of freshwater every day. In addition to this, this water has already been certified in accordance with World Health Organization requirements, and it has been approved for the usage in the UAE (Alghafli 2016). The technology exemplifies the efforts that can help the country achieve the goals declared in UAE Water Security Strategy 2036.

As stated above, an access to freshwater is an important problem in the UAE; therefore, it is of paramount importance to design a sustainable desalination strategy in order to meet long-term water requirements. The available evidence provides a premise to believe that unification of desalination technologies and renewable energy might become an appropriate solution of the problem (National Committee on Sustainable Development Goals 2017). Unfortunately, it is currently impossible to comment on the effectiveness of this solution since the implementation of UAE Water Security Strategy 2036 has just been started.

Chapter 3. Research Methodology

3.1. Introduction

The problem of water scarcity has not become a topical threat to most countries yet; however, the risks of a possible water crisis have already made many countries consider the need to develop sustainable water management techniques. The main research goal of this study is to investigate the problem of water resources' sustainability in the UAE and identify the key channels through which the nation could ensure the sustainable use of its water resources. In particular, the research will address the following objectives: highlighting the importance of ensuring high sustainability of water resources, investigating the potential of desalination processes to sustain water and reduce production costs in the UAE, analyzing the ways in which optimization of transmission and distribution processes could reduce the wastage of water in the state, researching the potential of recycling sewage water in the country, and studying the option of finding a new source of freshwater in the UAE. The previous part of the dissertation provided a significant amount of information about the problem of water scarcity, the importance of water sustainability, and the options that are available for national and local authorities in the field of ensuring sustainable water management.

After reviewing the main theoretical aspects of this problem, it seems justified to launch an empirical study in which it would be possible to apply this theoretical knowledge to investigate the case of a particular country. Unfortunately, as stated above, even though the UAE Water Security Strategy 2036 includes a number of ambitious goals, its implementation is currently still on the initial stage; therefore, it is hard to comment on the success of this global program. In this situation, investigating the problem of water scarcity in the United Arab Emirates and considering possible instruments that could help the government provide local

communities with an access to clean freshwater in line with the principles of sustainable water management could be considered a topical task.

This chapter elucidates in detail all the aspects of the research methodology that was chosen for this study. Its structure is divided into the four sections. The first one justifies the choice of a research philosophy, approach, time horizon, and research design. All these paradigms are important for comprehending the overall framework of data collection and data analysis employed in the research; therefore, it is of paramount importance to explain what guided their selection in this particular study. The second subsection presents theoretical considerations relevant to the choice of the quantitative methodology and the method of an online survey.

The third subsection is dedicated to an extended description of the data collection techniques that were utilized in the research. In addition to the reflection on these techniques, I will also share demographic characteristics of respondents in this section. The fourth part of the chapter will focus on data analysis instruments and approaches. Finally, the last subsection will cover ethical considerations relevant to this research and the ways in which the I have addressed them.

3.2. The Research Framework

The problem of water scarcity has received a significant amount of attention in the academic literature. Moreover, many scholars have justified and described the instruments of promoting and maintaining the sustainability of water resources. At the same time, there is not much information on the channels of ensuring sustainable water use in the UAE. Even though a number of online sources present some general trends pertinent to this problem, they can barely produce a systematic framework that could evaluate the potential of different channels and instruments to drive the sustainability of water resources in the country.

The arguments presented in the previous paragraph illustrate that neither an exploratory nor an explanatory research design could be viable options for this study. As it is known, an exploratory design is used in those situations when a research problem or research phenomenon is underresearched; therefore, authors try to gain an initial understanding of some basic patterns inherent to a phenomenon in order to analyze them in a detailed manner in the future (Sahu & Singh 2016)). In turn, explanatory investigations are suitable only when scholars use an established theoretical framework and well-researched variables in order to study their relationship in some particular case (Devi 2017). In theory, both these designs could be used for investigating some aspects of water scarcity and sustainable water use in the UAE. For instance, an exploratory study could help discuss some unusual option that has not been seriously considered before, such as an opportunity to retrieve water from other planets via an effective space program in the future. At the same time, an explanatory study could be utilized for analyzing the relationship between some specific variables, such as the work experience of employees and the efficiency of sewage recycling plants in the UAE.

Considering that this dissertation focuses on analyzing the global problem of water resources' sustainability in the country, it seemed justified to select a descriptive research design. This paradigm allows using the existing information and findings of other scholars to focus on investigating a research problem within some specific settings in order to describe its various aspects (Management Association & Information Resources 2016). With the help of the descriptive research design, I managed to concentrate on investigating a wide array of problems surrounding the water consumption in the UAE and analyze them in light of the literature review's findings.

The research philosophy of realism seems to be the most suitable option for this research. Traditionally, scholars distinguish between the philosophies of realism, pragmatism,

positivism, and interpretivism, and all these four paradigms may be applied under certain circumstances (Edson, Henning & Sankaran 2016)). Interpretivism is optimal for those cases when there is no other way to retrieve information about a certain phenomenon of interest other than by using the perceptions, opinions, and thoughts of individuals (Yanow & Schwartz-Shea 2015). Positivism is the opposite of interpretivism as it seeks to use only those data that have been collected in an objective manner and that do not depend on the interpretations of a researcher (Caldwell 2015). This is the main reason why positivism is usually utilized in natural sciences. The applicability of this philosophy in social sciences usually boils down to the investigation of some objective trends that do not require interpreting responses of studies' participants, such as the number of residents of some area who support a certain politician (Cappelen, Gendler & Hawthrone 2016). The arguments above illustrate that neither positivism nor interpretivism were viable options for this research.

Pragmatism is an interesting choice of a research philosophy for those studies in which authors try to analyze the opinions of varied stakeholders and reconcile the use of different research methods. The paradigm of pragmatism allows combining separate sets of data within the same framework and use them in a way that is the most beneficial for a particular research (Kurum 2018)). Considering that I did not plan to utilize varied sets of data or use a mixed research methodology, this paradigm did not seem necessary for the study.

Finally, realism is known as one of the most popular research philosophies with a significant potential in social sciences. In line with the main principles of this paradigm, the reality can be accessed by using the perceptions and sensations of individuals; however, as critical realism argues, it is necessary to carefully analyze these sensations since people tend to use their own lenses when perceiving various phenomena and include their own biases in their opinions (Denzin & Giardina 2016). The philosophy of realism is optimal for this study because

I planned to investigate the prospects of various instruments of ensuring the sustainability of water resources in the United Arab Emirates by using the informed opinions of experts.

The study utilizes the cross-sectional time horizon because it was necessary to conduct one empirical study at a certain period of time. I did not intend to carry out several researches to understand how the opinions of respondents have changed over time; therefore, the option of a longitudinal time horizon was irrelevant for this dissertation (Sforza & Sterle 2017). Concerning the use of research approaches, it is of paramount important to emphasize that both an inductive and a deductive research approach contributed to the achievement of the research goal and the completion of research objectives. A deductive approach guided the application of theoretical findings generated in other studies and the knowledge accumulated in the academic literature to the analysis of the problem of water resources' sustainability in the United Arab Emirates. In turn, an inductive approach helped analyze the particular cases of different instruments of ensuring sustainable water management in the country and employ them to comment on the broad prospects of using these instruments to overcome water scarcity and optimize the management of available water resources.

3.3. Research Methodology and Research Method

Traditionally, an empirical study can use either a quantitative or a qualitative research methodology. Qualitative methods are preferable in those situations when a scholar is interested in discovering some deep drivers of people's opinions and perceptions. They are especially effective when a study seeks to identify new information about a research phenomenon (Coe, Waring, Hedges & Arthur 2017). However, in this particular dissertation, there is no need in detecting some aspects of research phenomena that were previously unknown. In contrast, the study aims to evaluate the existing options concerning the

optimization of water resources' management. In this situation, the use of a qualitative research methodology would not be a suitable choice.

A quantitative methodology is a popular option that is utilized when scientists are interested in quantifying certain variables and analyzing a relationship between them (Higginbottom & Liamputtong 2015). Considering that this research seeks to evaluate various options related to the improved management of water resources in the United Arab Emirates, quantitative research methods surely are more suitable than qualitative ones. With the help of the quantitative methodology, I planned to scrutinize the phenomenon of water use in the country and analyze its various aspects.

There are many different research methods that are associated with the quantitative research methodology. After thoroughly investigating all of them, it was decided to select an online survey. As it is known, a survey is currently the most popular quantitative technique. It has numerous advantages, including the relative simplicity in use and the lack of significant requirements to a researcher (Laaksonen 2018). While an interviewer has to possess significant knowledge of a research phenomenon in order to ensure that interviewees provide relevant opinions that can be valuable to a particular study, the tasks of a person who conducts a survey boil down to the administration of a survey, which implies getting in touch with potential respondents, convincing them to take part in a research, giving them a questionnaire, and then processing a survey's results (Wolf, Joye, Smith & Fu 2016). It is also important to emphasize that a survey is one of the least expensive research techniques.

Unfortunately, sometimes organization of a survey might become challenging due to the need to spend a substantial amount of time on tracking down respondents and engaging each one of them in a survey. Because of this reason, an online survey might be a more optimal option for a study in which the author cannot use the services of other people for organizing a

survey and processing its results (Callegaro, Manfreda & Vehovar 2015). In this particular research, I did not have significant resources for the empirical part of the research; therefore, an online survey was a promising option due to its time-efficient nature.

The academic literature indicates that there is no significant difference between the results of online surveys and other applications of this method, such as email, telephone, or face-to-face surveys. If a survey is adequately organized, then the channel through which respondents fill in a questionnaire is unlikely to make a negative impact on the reliability and validity of its results (Lorenc, Smith & Bavdaz 2018)). Furthermore, it is important to emphasize that there is some evidence suggesting that online surveys might be actually superior since they minimize the amount of pressure put on a respondent (Johnson, Pennell Stoop & Dorer 2018). As a result, a person might spend more time on thinking about questions and putting more effort into answering to open-ended questions.

The arguments above illustrate that an online survey is a viable option for contemporary scholars. Considering the limited amount of resources available to me and the need to engage a significant number of people into a sample, it was decided to conduct an online survey for collecting quantitative data on the ways to ensure the sustainable use of water resources in the UAE. All the processes of data collection were conducted in SurveyMonkey. This platform has received wide popularity in the academic literature as one of the most popular instruments for conducting online surveys and processing their results (Callegaro, Manfreda & Vehovar 2015). It has a number of unique advantages as compared to other instruments that stretch beyond the technical side of its operation. In particular, unlike many other programs, SurveyMonkey allows switching off the function of storing data on the IP addresses from which users fill in a questionnaire, which aids in addressing the ethical concern of respondents' anonymity.

The questionnaire utilized in this study comprises of 25 questions aimed at evaluating different aspects of water use and water resources in the United Arab Emirates. All the questions could be found in Appendix A of this dissertation. The majority of questions are close-ended; however, the questionnaire also has two open-ended questions that aimed to collect respondents' insights into the future of water management in the UAE and the success of the UAE Water Security Strategy 2036. The structure of a questionnaire includes six sections and a demographic part. The first one asked respondent to share their opinions on the problem of water scarcity and the need to shift towards water resources' sustainability in the UAE. It also aimed to retrieve data on the most topical problems for the country in this sphere.

The next four sections are dedicated to specific instruments of ensuring sustainable water management in the state, including desalination processes, optimization of water transmission and distribution processes, recycling of sewage water, and a potential discovery of new water resources. Respondents have answered a series of questions about these instruments, including their perceived effectiveness, their potential to generate a significant amount of freshwater in the UAE, their role in the UAE Water Security Strategy 2036, and the ways in which the nation could take a full advantage of them. The sixth section of a questionnaire focuses on recommendations that, in the opinion of respondents, could help the country achieve the goals of sustainable water management and the sustainable use of its water resources. Finally, the seventh part of the survey includes several questions about respondents' demographic characteristics.

The sampling is traditionally one of the most challenging and important aspects of any survey (Buckland, Rexstad, Marques & Oedekoven 2015). In this particular study, it was necessary to find people who would have sufficient knowledge of the specifics of water use and water management in the UAE as well as of water resources of this country. Unfortunately,

considering the complex nature of the problem, it was hard to identify a group of people who were supposed to be competent in the problem under investigation. After considering all the possible scenarios, it was decided to focus on finding people from the next groups:

- Employees of the UAE Ministry of Energy & Industry whose responsibilities are connected with water management and/or who participated in the development of the UAE Water Security Strategy 2036;
- Employees of the UAE Water Aid Foundation;
- Employees of the UAE Red Crescent whose work is related to water management;
- Employees of the UNDP Regional Bureau of Arab Studies whose work is related to water management;
- Students of UAE universities studying at the department of Water and Environmental Engineering or other departments that cover the topics of water management and water scarcity in the UAE.

Each respondent had to display knowledge of water management in the UAE. I used the convenience sampling method for recruiting potential respondents for this research. The main emphasis was placed on the efforts of people who could be directly approached by the researcher. In turn, these individuals helped spread information about the study to their acquaintances through social media, thus creating a network that allowed recruiting a sufficient number of respondents.

3.4. Data Collection Procedures

With the help of the word-of-mouth method and the convenience sampling technique, I managed to engage 186 respondents in this study. Even though this number does not seem very high, it might be considered as sufficient for collecting respondents' opinions on the main patterns concerning water use and water management in the United Arab Emirates. All these

people could be considered experts in the problem under investigation, and all of them came from groups listed in the previous paragraphs. The table above provides a detailed description of the demographic characteristics of these respondents.

Table 1. *Demographic Characteristics of Respondents*

Age	**N of R**	**% of R**	**Gender**	**N of R**	**% of R**
18-22 years old	14	7.53%	Male	132	70.97%
23-27 years old	23	12.37%	Female	54	29.03%
28-30 years old	25	13.44%	*Total*	*186*	*100.00%*
31-35 years old	28	15.05%	**Education**	**N of R**	**% of R**
36-40 years old	26	13.98%	High school	77	41.40%
41-45 years old	22	11.83%	Bachelor	54	29.03%
46-50 years old	19	10.22%	Master's	49	26.34%
51-55 years old	16	8.60%	Ph.D.	6	3.23%
56-60 years old	7	3.76%	*Total*	*186*	*100.00%*
> 60 years old	6	3.23%			
Total	*186*	*100.00%*			

As it could be observed in Table 1, the distribution of demographic characteristics among respondents seems natural. The number of males in the sample is significantly higher than the number of females; however, this trend is in concordance with the current social trends inherent to the UAE society. Even though the country has achieved a significant progress in the field of extending women's rights, females are still underrepresented both in the educational system and on the labor market. As a result, it is not surprising that the overwhelming majority of students and government officials who participated in this study were males.

The fact that most respondents are students explains why more than 40% of the sample do not have any degree higher than a high school diploma. Most of these people are currently studying to obtain a Bachelor's degree; thus, they are in the process of improving their educational background. From the perspective of the aging factor, it is important to emphasize that I managed to include respondents of different ages in the sample, which will help receive data from people representing varied aging groups and even different populations.

Table 2. *The Residence and Respondent Groups of the Study's Participants*

Residence	**N of R**	**% of R**	**Respondent Group**	**N of R**	**% of R**
Abu Dhabi	58	31.18%	Students	129	69.35%
Dubai	66	35.48%	Others	57	30.65%
Sharjah	25	13.44%	*Total*	*186*	*100.00%*
Umm Al Quwain	2	1.08%			
Ras Al Khaimah	12	6.45%			
Ajman	16	8.60%			
Fujairah	7	3.76%			
Total	*186*	*100.00%*			

From the geographic perspective, the majority of respondents currently live in Abu Dhabi or Dubai. All the other emirates combined account for less than 44% of the sample. This distribution looks natural considering that approximately 70% of the UAE's population live in these two emirates. At the same time, it is important to emphasize that I managed to recruit respondents from each emirate of the state and that the distribution of respondents from these emirates represents the actual distribution of residents between them.

Almost 70% of the sample are students who are currently studying at various UAE universities to obtain a Bachelor's or a Master's degree in a field that is directly related to water management, water engineering, or some other area relevant to the problem under investigation. The fact that such many respondents are students could be explained by the fact that is was much easier to recruit students for this study than government officials or employees of large organizations, such as Red Crescent. Since all the students are studying at departments with curriculums that cover the problems of water scarcity and water management in the UAE, it seems justified to argue that all these people could be considered experts in the problem of water resources' sustainability.

Initially, I found 259 persons who agreed to take part in the research. However, after sending them messages in social media, I received only 238 positive responses. Among these 238 individuals, only 222 persons confirmed that they had received an information leaflet about the study and agreed with all its terms. I sent a link to a SurveyMonkey questionnaire to all these 222 people; however, only 176 of them clicked on it and filled out a questionnaire in the next three days. After waiting for three days, I sent another messages to the remaining 46 individuals with a reminder to take part in the survey and a link to a questionnaire. Ten persons have filled out a questionnaire after reading this message within the next five days. It was decided not to send another message to those people who still had not clicked on a link because it was obvious that these individuals were not interested in participating in the research. During the entire process, none of respondents has asked any additional questions about the study or required any clarifications concerning the research.

3.5. Data Analysis

As elucidated in the introduction, this research did not require the use of any complex statistical instruments because I did not seek to measure a correlation between some variables

with the help of the regression analysis or apply any other statistical methods. Therefore, the process of data analysis was relatively simple and primarily included the calculation of mean values of respondents' responses and a number of respondents who had given a certain answer to a specific question in MS Excel.

The process of data analysis could be divided into three stages. On the first stage, I have processed respondents' answers to questions from the demographic section. These answers did not play a significant role in the process of data analysis; at the same time, it was important to review them in order to determine whether an inadequate representation of some demographic groups could negatively influence the eventual results of the survey. For example, if the sample had primarily included employees of the UAE Ministry & Energy, it would have been considered as a negative sign because these people are likely to analyze the phenomena of water use and water resources' sustainability in the country mainly from the perspective of the Ministry, which would have been undesirable in this study. In a similar manner, it was also important to ensure that the sample included residents of different emirates as it could help analyze the problem in a systematic manner by considering the patterns of water management not only in the two largest emirates but also in other parts of the state.

The second stage of data analysis implied calculating the number of respondents who had given a certain answer to a specific question. There were many questions in which respondents had to choose between several alternative options. By calculating the number of people who had chosen a certain option, I could make conclusions concerning the experts' opinions on certain phenomena and processes relevant to the use of water resources in the UAE. Finally, the last stage entailed calculating the mean values of responses to those questions that required evaluating certain options with the help of a scale from "1" to "10". For instance, respondents had to use this scale to share their opinion on the effectiveness of current water

recycling projects in the United Arab Emirates. This procedure helped quantify variables and compare them with each other, which enabled me to discuss the current effectiveness of water management in the country and the potential of different instruments to prevent the threat of water scarcity.

3.6. Ethical Considerations

This study had to address a number of ethical considerations connected with the administration of a survey. First, like in any other survey, it was of paramount importance to ensure that the anonymity of the study's respondents would be kept throughout the entire study. In order to address this issue, I did not ask for respondents' names. During the survey, participants had to answer a set of questions about their demographic characteristics; however, there is no premise to believe that these data could be used to recognize particular people. To minimize the likelihood of this scenario, it was decided not to include the information about respondents' employment and place of education in the final version of the dissertation.

I have switched off the function of storing data on IP addresses of respondents in SurveyMonkey, thus eliminating the possibility that respondents could be recognized based on their IP addresses. Furthermore, I have also deleted all the messages sent to these people from social media after completing the study. Throughout the entire study, results of the survey and raw quantitative data were kept on my personal computer that was password protected; therefore, only me had access to them. Considering all the arguments presented above, it seems justified to conclude that I managed to take all the appropriate measures to protect the anonymity of respondents.

There is no premise to believe that participation in the study could make any harm to a respondent because respondents were not expected to share any sensitive information that could harm their career or reputation. In theory, one can imagine a situation in which a

government official could experience certain discomfort in case if his or her boss would see that he or she shared some negative opinions about insufficient efforts of the government to resolve the problem of water scarcity. At the same time, it is important to emphasize that the content of all the questions of this survey is neutral and does not create any significant risks for respondents related to this matter.

The second important ethical consideration that should be discussed in this chapter is connected with the permission of superiors. This problem was not relevant for students because they could participate in this study without asking for the permission of any other person since this survey did not discuss their educational experience. In turn, employees of government organizations, especially Ministry of Energy & Industry, could not agree to take part in a study without asking for the permission of their superiors since the content of the investigation was directly connected with one of the strategic directions of the Ministry's operations. Therefore, each government employee received a brief form in which I asked his or her superior to allow an employee to take part in the research. Fortunately, there were no cases in which employees failed to obtain such permission.

The third relevant matter related to ethical considerations is the ability of respondents to make an informed decision on whether to take part in the survey. After contacting potential respondents and making sure that they are interested in participating in the study, I sent them an information leaflet. This document included an itemized list of all the rights possessed by respondents. In particular, it elucidated in an exhaustive manner that the participants of this study could request further clarifications concerning the study at any point of time, fill in a questionnaire from any location and at any time that would be the most comfortable for them, and asking me to remove their responses from the raw quantitative data. In addition, this document also contained a description of the main specifics of the dissertation and its empirical

part, the research goal and expected contributions of this investigation, and the role that respondents were expected to play in the study.

In line with the existing academic guidelines, I tried to minimize the amount of possible discomfort that could be experienced by respondents during or as a result of their participation in this survey. In particular, it was decided to send only one message to a person who had received a link to a questionnaire but did not click on it in the next three days. Moreover, I emphasized in a message that a person could fill in a questionnaire at any time that was the most comfortable to them. All the messages were written in a respective manner; therefore, there is no premise to believe that the participation in this study offended respondents in any way.

Chapter 4. Data Analysis and Discussion

4.1. Trends Relevant to Water Scarcity and Water Resources' Sustainability in the UAE

As stated in the methodology chapter, the survey's questionnaire included six sections and a demographic part. Therefore, it seems rational to present quantitative data retrieved from these sections in a subsequent order. The first part of the survey focused on analyzing general trends relevant to the problem of water scarcity in the United Arab Emirates and general patterns characterizing the government's efforts to ensure the sustainability of water resources.

Results of the study show that, in the opinion of the respondents, the problem of water scarcity is a significant issue that should be seriously considered by the government.

Table 3. *Mean Values of Respondents' Answers to General Questions*

Statement	Mean Value
Significance of the problem of water scarcity	6.83
Sustainability of the use of water resources	5.42
Respondents' satisfaction with measures taken to ensure sustainable water use	7.81
Respondents' satisfaction with the UAE Water Security Strategy 2036	8.93

The mean value of 6.83 indicates that the significance of the problem of water scarcity is relevant for the UAE. At the same time, it seems justified to assume that, in accordance with the respondents, the country faces many much more pressing challenges that require rapid measures. In other words, experts do not consider water scarcity as an issue that may arise in the short-term perspective. It is rather an undesirable long-term scenario that might take place only if the government fails to systematically promote the sustainable use of water resources.

The sustainability of the use of water resources has received a low mark from respondents. The value of 5.42 indicates that the overwhelming majority of the study's

participants suppose that the state uses its water resources in an unsustainable way. The available evidence provides a premise to believe that such point of view is justified. A significant part of wastewater is currently not re-used in the country; moreover, almost all the desalination plants work on the basis of fossil fuel combustion, which does not harmonize with the principles of sustainable development (Guyer 2018). At the same time, the patterns of water distribution and use illustrate that residents of the country are not ready to contribute to the improvement of the situation as they continue consuming much larger amounts of water than required for satisfying their needs.

Even though the country does not use the existing water resources in a sustainable way, respondents argue that the government has taken radical measures to mitigate the problem. In particular, the quantitative data collected in this study shows a relatively high level (7.82) of experts' satisfaction with these measures. Development of the UAE Water Security Strategy 2036, information campaigns, and incentives for businesses investing in innovative desalination techniques are apparently considered by respondents as promising initiatives that can bring the nation closer to the sustainable use of water resources. In general, experts are satisfied with the content of the UAE Water Security Strategy 2036, which is evident in the satisfaction level of 8.93. This number does not provide any valuable information about the progress of the strategy's implementation; however, it illustrates that the priorities and objectives included in it could be considered as appropriate and realistic.

The literature review showed that the role of citizens in the promotion of the sustainable use of water resources is significant. In this situation, it seems important to investigate how and to what extent residents of the UAE are prepared to help the government reach the goals announced in the Water Security Strategy 2036. Interestingly, the urgency of shifting towards water sustainability received the mean value of 6.83, which is a relatively low number. This

result confirms the conclusion expressed above that, in the opinion of respondents, the country currently faces more pressing challenges than water scarcity; thus, even though a shift towards the sustainable use of water resources is required, it might be not rational to prioritize it at the moment.

One of the questions of this survey was dedicated to possible measures that people could take in order to contribute to the sustainability of water use. The table below shows that even though participants of this study realize the importance of sustainable water management, they are not ready to take radical measures in order to support the achievement of this goal.

Table 4. *Measures that Respondents are Ready to Take in Order to Support Sustainable Water Management in the UAE*

Statement	**Mean Value**
Changing water consumption habits (for instance, switching water while brushing teeth)	7.83
Reducing the amount of water used for household needs	6.24
Paying more for drinking water	5.79
Paying additional taxes to improve water infrastructure	5.82
Purchasing sustainable products and services, such as waterless toilets	5.14

Table 4 illustrates that although the participants of this study are fully aware of the dangers of water scarcity and realize the importance of ensuring the sustainable use of water resources to prevent this threat, most of them are not ready to take radical measures in order to contribute to this process. Most of respondents apparently are not willing to purchase sustainable products and services, such as waterless toilets, in case if it may create certain discomfort for them. Furthermore, the mean values of 5.82 and 5.79 indicate that the majority

of experts are not willing to pay additional taxes to improve water infrastructure and pay more for drinking water respectively. A more optimistic pattern could be observed regarding the readiness of the study's participants to reduce the amount of water that they use for household needs. A change of water consumption habits is currently the only aspect of environmentally conscious behavior that respondents are ready to complete.

While the numbers presented in Table 4 seem relatively low, it is important to emphasize that they are barely representative of the entire Saudi population. Experts who took part in this research possess deep knowledge of the specifics of water management in the country and the unique characteristics of the UAE water transmission and distribution infrastructure. They are also supposed to realize much better than most other citizens that the support and commitment of residents can make a substantial contribution to the development of sustainable water management in the country. In other words, it seems justified to assume that participants of this study are better informed about the problems that the UAE faces in the sphere of water management and, accordingly, are more willing to take some measures by themselves to help the country prevent the threat of water scarcity. In contrast, most other citizens are supposed to be much less concerned about the situation in this field and be less willing to engage in actions described in Table 4. Considering the arguments lied out above, one may presume that the Saudi population is currently not ready for fully engaging in water sustainability initiatives.

The fact that the sustainability of water resources should be an important priority for the government is uncontested. At the same time, there is currently no agreement among experts concerning the most topical problems that the country faces in this field. Respondents' answers to a question about the key problems in the sphere of water management confirm this statement.

Table 5. *The Key Problems in the Field of Water Resources' Use in the UAE*

	N of R	% of R
High water consumption rates	182	97.85%
The use of fossil fuel combustion for wastewater treatment	152	81.72%
Inefficiency of desalination processes	148	79.57%
Inefficient water transmission and distribution processes	116	62.37%
Outdated infrastructure	58	31.18%
The lack of a consistent government strategy	42	22.58%
The absence of incentives for business	145	77.96%

The numbers in Table 5 show that while some problems seem evident to the overwhelming majority of experts, others are objects of debates. Almost 90% of respondents agree that high consumption rates are a crucial problem for the UAE water management system. As explained in the literature review, the usage of water per capita constitutes 550 liters as opposed to the world's average rate of 250 liters per capita (Kumar 2017). In other words, UAE residents tend to consume more than twice as much water as residents of most other countries. In this situation, it is not clear why more than 2% of the sample did not agree that such consumption rates are a pressing problem for the nation. Apparently, they are under the impression that other challenges are more significant.

The use of fossil fuel combustion for running wastewater treatment facilities was indicated as a significant problem by 81.72% of the sample. While the recycling of wastewater is an unalienable element of the concept of sustainable water use, running recycling facilities on fossil fuels is barely an environmentally friendly solution (Guyer 2018). While there are already some signs pointing at possible progress in this sphere, such as the establishment of

several small wastewater treatment plants that use solar energy, the applicability of such initiatives has been limited so far.

148 out of 186 participants of the survey believe that the existing desalination processes in the UAE are inefficient. The main goal of desalination is to provide residents of the country with freshwater; unfortunately, economic aspects of this process are often not seriously taken by government officials. As a result, the academic literature characterizes desalination in the UAE as an energy intensive and inefficient process (Szabo 2011; The UAE Government 2019). As in the case with wastewater recycling, there are some signs of possible improvements in this sphere, such as the introduction of solar-powered reverse osmosis desalination plants in Dubai. However, at the moment, a transition to environmentally sustainable desalination practices has not been completed yet, which explains why so many participants of the study are concerned about the inefficiency of water desalination processes.

A little more than 62% of the sample believe that the existing water transmission and distribution processes that are used in the state are inefficient. This number is relatively low as compared to those reviewed above. In the opinion of respondents, the key challenges faced by the UAE in the field of water management are connected with the generation of water and not with its transmission and distribution. At the same time, the fact that 116 out of 186 respondents believe that transmission and distribution processes are inefficient illustrates that the country experiences certain problems in this sphere too.

Less than a third of the sample are under the impression that the government must modify or even replace its water management infrastructure. Other respondents apparently agree with the findings of the majority of scientists and government officials who believe that the existing infrastructure that the UAE uses in water management is adequate in most regions. Interestingly, only 22.58% of the sample claim that the state does not have a consistent

government strategy towards the achievement of the water resources' sustainability. Apparently, such a low number could be elucidated by the introduction of the UAE Water Security Strategy 2036, which outlined the key priorities and plans of the government in the field of water use and offered specific and quantified objectives in different spheres of water management.

Unfortunately, the country has not achieved significant success so far in cooperating with the commercial sector. There are some examples of successful cooperation, such as the transmission and distribution of desalination water produced by commercial companies; however, in the opinion of many experts, the private sector has not penetrated the industry enough. Numbers in the last line of Table 5 demonstrate that the government does not offer sufficient incentives for businesses at the moment that would encourage a variety of entrepreneurs and investors to operate in markets relevant to the problem under investigation, such as water recycling and desalination.

4.2. Wastewater Recycling

The second section of the questionnaire was dedicated to the potential of wastewater recycling projects in the UAE. In the opinion of respondents, the government does not take a full advantage of this source of water at the moment.

Table 6. *The Potential and Current Effectiveness of Wastewater Recycling in the UAE*

Statement	**Mean Value**
Potential to Contribute to Sustainable Water Management	6.79
Effectiveness of the Instrument's Current Use	3.61

The fact that the government of the United Arab Emirates fails to utilize all the benefits of wastewater recycling is obvious. Only approximately 7% of water used in the country comes

from wastewater recycling, which is a very small number considering that this source is responsible for a substantial percentage of water used in developed countries (The UAE Government 2019). Moreover, wastewater recycling is a more environmentally sustainable solution than most other options, which makes it one of the best instruments of ensuring sustainable water management (Freedman & Enssle 2015). It is possible that the reluctance of the government to prioritize this instrument may be connected with high costs, which usually characterize most wastewater recycling projects (Ma, Xue, Freedman & Enssle 2015). In addition, the technology has not been fully tested yet on the national level, which makes it hard to launch a large-scale implementation of wastewater recycling programs.

In the opinion of respondents, the potential of wastewater recycling projects to promote sustainable water management in the country is relatively high; at the same time, the mean value of 6.79 indicates that many participants of this study are skeptical about the potential of this solution. It seems justified to assume that this skepticism might be explained by two factors: concerns about high costs of wastewater treatment solutions and the traditional emphasis on water desalination that is made by most government officials when discussing the future of water management in the UAE.

There is no doubt that an effective implementation of wastewater recycling projects could contribute to the sustainable use of water resources in the country because wastewater treatment is considered as an organic component of sustainable water management in any modern country (Freedman & Enssle 2015). Simultaneously, it is important to emphasize that the potential of this solution to generate freshwater is slight as water retrieved in such way is usually employed for secondary use or tertiary use. As of 2019, there is no premise to believe that wastewater treatment solutions in the UAE can generate water for secondary use in a more effective way than desalination technologies. Accordingly, the rationale behind the use of this

instrument is rather connected with an intention to eliminate negative effects of untreated wastewater to the environment than with an attempt to prioritize this tool as the key instrument of preventing the threat of water scarcity in the UAE.

One of the questions required determining whether respondents advocated for the establishment of a centralized or a decentralized system of wastewater treatment in the country. As it is known, it is possible to organize the treatment of wastewater in a centralized or a decentralized manner. It is easier to control infrastructure supporting a centralized treatment of wastewater; however, it is usually less efficient than a decentralized one because authorities are forced to create complex infrastructural layers in order to transfer the Treated Secondary Effluent to locations in which it is required (Dolnicar, Hurlimann & Grun 2011). In the opinion of the overwhelming majority of respondents, the choice of a centralized or a decentralized approach towards wastewater management should be made separately for each region and city on the basis of its unique natural resources and the specific requirements and needs of its residents.

Table 7. *Preferred Type of a Wastewater Management System*

	N of R	**% of R**
Centralized system	17	9.14%
Decentralized system	42	22.58%
A combinatino of centralized and decentralized systems	127	68.28%
Total	*186*	*100.00%*

The fact that more than 90% of the sample believe in the need to introduce decentralized elements into the water management system illustrates the need of the government to consider this option. From this perspective, the findings of this study harmonize with the literature

review's findings. The evidence introduced in the literature review showed that constructing decentralized wastewater treatment plants might be an effective solution of the problem of water scarcity for local communities. They enable these communities to treat raw wastewater that was produced at a certain place. In addition to a potential to generate clean water and decrease environmental pollution, such plants have low carbon tracks, which minimizes their negative impact on the environment (Dolnicar, Hurlimann & Grun 2011). In light of these arguments and the results of this study, it seems justified to argue that the country's emirates should embrace decentralized components of a wastewater management system, providing local authorities with more power in this sphere and helping them engage private businesses in this process.

The need to ensure that a wastewater management system combines the signs of a centralized and a decentralized model was one of the most popular options offered by respondents as answers to an open-ended question about the best ways to take advantage of wastewater treatment in the United Arab Emirates. There were also a number of other recommendations that were mentioned by 2% – 10% of respondents. Most of them could be grouped into three categories: increasing the efficiency and effectiveness of infrastructure, enlarging the variety of types of waste, and broadening the scope of water re-usage. In particular, many respondents emphasized the need to insert bio trickling filters into sewer pumping infrastructure and ensure that wastewater stations manage oil, grease, and fat waste. Moreover, it is also important to ensure an adequate scope of the use of water generated with the help of wastewater management. For instance, in addition to irrigation, the water can be also utilized for flushing toilet, cleaning, cooking, and even washing equipment of pumping stations that create this water.

4.3. Desalination

Unlike wastewater recycling, desalination projects are currently an important source of freshwater for the UAE. As stated in the literature review, a significant part of potable water used in the country is produced with the help of this method (The UAE Government 2019). Simultaneously, in the opinion of most respondents, the way in which the government utilizes this instrument is not sustainable. As some of them explained in the recommendation section, even though the government already uses the instrument, it is necessary to utilize it in a more sustainable way by shifting towards renewable energy.

Table 8. *Respondents' Perceptions of Desalination Projects in the UAE*

Statement	**Mean Value**
Potential to Contribute to Sustainable Water Management	8.82
Effectiveness of the Instrument's Current Use	6.74
Efficiency of the Instrument's Current Use	3.64
Sustainability of the Instrument's Current Use	2.77

In the opinion of the participants of this study, the instrument of water desalination is adequately used by the government of the UAE; at the same time, the mean value of 6.74 shows that there is a substantial space for improvement in the sphere of the tool's effectiveness. This opinion looks natural considering that the UAE is one of the few countries that managed to turn water desalination into a powerful source of freshwater for the population (The UAE Government 2019). At the moment, only approximately 1% of the world's population relies on water desalination; therefore, the UAE is currently among the pioneers in this field (Hilal, Ismail, Matsuura & Radcliffe 2017). At the same time, respondents' responses indicate the existence of a significant problem with the mechanism's efficiency. This statement harmonizes with the literature review's findings. The country applies thermal methods and powers

desalination processes with the help of fossil fuel combustion, which is expensive (Guyer 2018). Until the country manages to shift towards the method of reverse osmosis, it will need to spend immense amounts of resources on powering desalination plants.

It is also important to emphasize that the thermal method of water desalination is dangerous for the environment. It emits significant amounts of hazardous brine, which can be then directly released into the sea (Guyer 2018). This substance threatens the marine life, as it is usually more saline and warmer than water in the sea. Instead of securing this byproduct underground or putting it in evaporation ponds, plants often choose an unsustainable method of brine discharging, which contributes to the environmental pollution. In this situation, it seems justified to conclude that proceeding with the existing mode of using thermal methods of water desalination is not in harmony with the principles of the sustainable use of water resources.

Table 9. *Respondents' Recommendations Concerning the Choice of Desalination Techniques*

	N of R	**% of R**
Extending the use of thermal methods	2	1.08%
Completely shifting to reverse osmosis	75	40.32%
Shifting to reverse osmosis but keeping evaporation techniques	109	58.60%
Total	*186*	*100.00%*

Interestingly, there is no agreement among respondents regarding the way in which the country should embrace the use of reverse osmosis. While 40.32% of the sample believe that the government should entirely shift to reverse osmosis, 58.60% of the sample insist that it should be more cautious in this sphere and keep evaporation techniques. The fact that almost 99% of the study's participants claim that the country should start prioritizing reverse osmosis

as the key method of water desalination derives from the extensive research that has been conducted on this problem as numerous scientists confirmed that reverse osmosis is a more efficient and sustainable technique of water desalination than thermal methods (Eyvaz & Yuksel 2018). Simultaneously, apparently, most respondents do not believe that it could become a panacea for solving all the problems of the UAE in the sphere of water management.

The available evidence provides a premise to believe that high salinity levels of water in the UAE could become the rationale behind this point of view. With such high salinity levels, reverse osmosis might be limited in terms of water purification, as it would require added costs. In this situation, keeping evaporation techniques may be a logical solution for the country from the perspective of maintaining a high efficiency level of desalination processes. In general, this study showed that water desalination is expected to become increasingly important for the nation. It was stated in the literature review that approximately 14% of the population is likely to rely on desalinated water by 2025 (Murad, Baydoun & Daghir 2017). Without a doubt, residents of the UAE will be among these people, which illustrates the topical need for designing innovative solutions for maintaining high efficiency and sustainability of desalination techniques.

4.4. Optimization of Water Transmission and Distribution Processes

Results of the study show that optimization of water transmission and distribution processes is a vital component of sustainable water management.

Table 10. *Respondents' Perceptions of the Optimization of Water Transmission and Distribution Processes*

Statement	**Mean Value**
Potential to Contribute to Sustainable Water Management	8.35
Effectiveness of the Current Optimization Efforts	6.48

The mean value of 8.35 is relatively high; it indicates that the overwhelming majority of respondents agree with the need to optimize the existing transmission and distribution processes in the UAE in order to contribute to sustainable water management. Unfortunately, the specifics of a survey did not allow clarifying what problems in this sphere respondents noticed. The table below shows that all the options offered by me are considered as ineffective by the majority of respondents; therefore, the nature of the existing problems in the transmission and distribution processes in the UAE remains unclear.

Table 11. *Respondents' Recommendations Concerning the Optimization of Transmission and Distribution Processes*

	N of R	**% of R**
Replacement or modification of infrastructure	56	30.11%
Changes in centralization patterns	59	31.72%
Infrastructure sharing	44	23.66%
Collaboration with the private sector	48	25.81%

Surprisingly, none of the four options proposed in Table 11 has a significant level of support from respondents. Apparently, the majority of respondents believe that there is no pressing need in replacing or modifying the existing infrastructure. Only 30.11% of the sample supported this option, which is almost the same with the percentage of respondents from Table 5 who mentioned outdated infrastructure as one of the most important problems that the UAE water management system faces. This statement seems natural in light of the literature review's findings because the problem of outdated infrastructure is rarely mentioned in the UAE Water Security Strategy 2036.

Surprisingly, only 31.72% of the sample agreed that changes in centralization patterns can be an effective solution that could optimize the existing transmission and distribution processes in the UAE. The literature review showed that an inconsistency between the operations of various private companies responsible for the transmission and distribution of water or an excessive centralization of these processes reduce the efficiency of water management, creating significant costs for state authorities (Koizumi, Takahashi, Koibuchi & Fukumoto 2017; Vanbriese, Dzombak & Zhang 2013; Sarbu & Valea 2014). However, surprisingly, most respondents do not believe that changes in centralization patterns could help optimize transmission and distribution processes in water management.

In a similar way, surprisingly, only 23.66% of the sample are under the impression that infrastructure sharing can become a viable solution for optimizing the system of transmitting and distributing water in the UAE. Furthermore, almost three quarters of the sample believe that there is no need for the government to intensify cooperation with the private sector in this sphere. For instance, in Abu Dhabi, all the water distribution processes are conducted exclusively by subsidies of Abu Dhabi Distribution Co. while private businesses are excluded from this process. Apparently, in the opinion of respondents, allowing private companies to enter this market might not be in the interest of local communities. Unfortunately, the quantitative data collected in this study do not provide sufficient answers to a questions about the reasons behind this point of view.

An analysis of the respondents' recommendations concerning the optimization of transmission and distribution processes reveals that there are several essential areas in which the government should seek improvements in its systems of water transmission and distribution. In particular, it should focus on decreasing the pumping time, ensuring adequate maintenance of all the relevant systems, regulating the rate of a pumping flow, standardizing

and simplifying requirements for spare parts, providing enough manpower to ensure the continuous operations of all the pertinent processes, and expanding the system when necessary. One of the few practical recommendations expressed by a significant number of experts was to use pressure energy in transmission pipelines in order to increase the efficiency of the water transmission process. Some respondents also proposed to focus on increasing the water storage capacity of the state.

4.5. Finding a New Source of Water

As it is known, the existing water resources in the country are scarce; therefore, it seems justified to discuss the possibility of finding some new sources of water. However, in the opinion of respondents, any scenarios concerning such findings are unrealistic. Indeed, the process of retrieving groundwater is expensive and inefficient; furthermore, groundwater in the UAE is usually more saline than seawater, which puts an additional financial burden on desalination plants (Amery 2015). In this situation, the need to search for new sources of groundwater seems questionable as desalinating seawater is supposed to be a more efficient and sustainable solution.

Table 12. *Respondents' Answers to the Question "Do You Agree that the UAE Government Uses All the Existing Sources of Water?*

	N of R	**% of R**
Yes	54	29.03%
Rather yes than no	93	50.00%
Rather no than yes	32	17.20%
No	7	3.76%
Total	*186*	*100.00%*

As Table 12 indicates, almost 80% of the sample believe that the government currently uses all the existing sources of water. In some situations, authorities do not entirely take advantage of all these sources; however, they use all of them to a certain extent. In the opinion of those individuals who have chosen the options "rather no than yes" and "no", the government does not put enough effort into collecting rainwater in urban areas, which leads to the loss of a significant amount of this valuable resource. Nonetheless, in general, the available evidence provides a premise to argue that the key to ensure the sustainable use of water resources is rather to find a more sustainable and efficient way of using the existing water resources and treating wastewater than to find some new sources of water.

4.6. Recommendations

Certain recommendations concerning the improvement of the existing system of water management in the UAE could be found in all the previous sections of the questionnaire. At the same time, it was important to ask respondents about their opinion on this matter one more time so that they could cover those issues that are not directly connected with the phenomena of wastewater recycling, optimization of transmission and distribution processes, water desalination, and discovery of new sources of water. This section only included one question; however, respondents' answers to it helped collect a significant amount of data relevant to the problem under investigation.

In the most general view, the most popular recommendations of respondents could be divided into the 5 groups and 18 subgroups as shown in the table below.

Table 13. *Respondents' Recommendations Concerning the Achievement of the Sustainable Use of Water Resources*

Subgroup	Recommendation	N of R	% of R
New technology for domestic use	Auto samplers	12	6.45%
	Water meters	21	11.29%
	High-quality pipes without leakage	18	9.68%
	Water efficient faucets	9	4.84%
	Water efficient toilets	17	9.14%
Behavioral changes	Encouraging citizens to refrain from using water when it is not necessary	105	56.45%
	Encouraging citizens to optimize the consumption of potable water	68	36.56%
	Encouraging citizens to contribute to the success of water treatment	33	17.74%
Practical measures to reduce demand	Raising prices on potable water	12	6.45%
	Cutting subsidies	26	13.98%
	Restricting water use in certain areas	6	3.23%
	Conducting information campaigns on the importance of water resources' sustainability	157	84.41%
Provision of tax incentives to companies	Firms that use reverse osmosis for water desalination	122	65.59%
	Firms that separate grey and black water and treat them separately	51	27.42%
	Companies that offer innovative technologies in the spheres of water recycling and wastewater treatment	125	67.20%
Other recommendations	Engaging foreign experts to help solve the brine problem	43	23.12%
	Enhance rainfall capturing technologies	69	37.10%

	Engaging in continuous cooperation with other countries, especially Gulf states, in finding new solutions to ensure sustainable use of water resources	80	43.01%

The table above contains information about all the recommendations expressed by at least five respondents. In regards to the employment of new technologies for domestic use, respondents mentioned five devices that could optimize the use of water in households. However, the number of respondents who have recommended such devices is low. Most of other respondents either are not aware of these technological solutions, which seems unlikely, or believe that these devices are not among the most promising drivers of sustainable water use. This trend contradicts the literature review's findings, contributing to an assumption that residents of the UAE have not yet fully realized the role that their efforts could play in the improvement of water management in the country.

Only a little more than a half of the sample mentioned the need to encourage citizens to use water only when it is necessary. Some of them also advocated for the optimization of potable water consumption and the engagement of citizens in water treatment projects. The need to reduce the consumption of water through changes in citizens' behavior seems obvious due to the inadequately high water consumption rates in the UAE. Unfortunately, it seems that a significant number of citizens of the country do not accept the rationale behind this statement, which is another confirmation of the assumption made in the previous paragraph.

In theory, a significant number of respondents argue that the government should encourage citizens to reduce the amount of consumed water. However, only 6.45% and 13.98% of the sample recommended rising prices on potable water and cutting subsidies respectively. Simultaneously, only 6 out of 186 participants of this study offered to restrict the use of water in certain areas on a temporary basis as a way to prevent a water scarcity scenario. All these

numbers harmonize with the conclusions made above about the unwillingness of the UAE population to participate in a shift towards the sustainable use of water resources. Most of them are ready to be exposed to information campaigns on the importance of water sustainability as shown in Table 13; however, they are barely willing to engage in practical actions in order to contribute to the success of water sustainability initiatives.

In the opinion of the experts who took part in this study, the provision of tax incentives and exemptions to private companies investing in sustainable water management are a powerful instrument of ensuring the sustainable use of water resources. More than 80% of the sample mentioned tax incentives as one of their recommendations. The majority of those respondents who specified the recipients of these incentives mentioned firms that use reverse osmosis for water desalination and companies that separately treat grey and black water. The fact that such a significant number of respondents mentioned the need to offer tax incentives to the private sector illustrates that the UAE government should consider engaging in a closer cooperation with commercial companies in order to ensure the sustainable use of water resources. In addition, authorities may also consider intensifying their collaboration with neighboring countries in the field of improving water management and engaging foreign experts to help solve the brine problem that arises as a result of the use of a thermal method of water desalination.

Chapter 5. Conclusion and Recommendations

This study was dedicated to a detailed exploration of the phenomenon of water sustainability in the United Arab Emirates. By using a quantitative research methodology, I have collected a significant amount of data from experts who have deep knowledge of the specifics of water management systems in the country. As it is known, the threat of water scarcity and the low efficiency and sustainability of water desalination and wastewater recycling techniques that are used in the state increase the topicality of research problems connected with the ways to ensure the sustainable use of water resources, which was the main research goal of this dissertation.

It was found in this study that the problem of water resources' sustainability is currently topical for the UAE. The state primarily relies on groundwater as the main source of freshwater for the population; however, it is becoming increasingly expensive and challenging to retrieve groundwater. Furthermore, this water has higher salinity levels than seawater, which reduces the efficiency of groundwater use even more. Desalination and wastewater treatment plants rely on fossil fuel combustion for generating water. Unfortunately, while it helps them provide the population with a stable flow of water, it negatively influences the environment, contributing to the environmental pollution in several ways, such as emitting brine. In this situation, the need to find environmentally friendly instruments of water management becomes evident.

It was found that high water consumption rates and unsustainable habits of water use are among the most important problems faced by the national system of water management. In addition, respondents also mentioned such challenges as the inefficiency of desalination projects, inefficiency of water transmission and distribution processes, and the absence of adequate incentives for businesses that could enter relevant economic sectors.

Wastewater recycling, which is not adequately utilized in the country at the moment, can significantly contribute to the achievement of sustainable water management goals. In order to achieve this aim, the government should effectively combine elements of centralized and decentralized systems of wastewater treatment, customizing the system of wastewater recycling to the unique needs and specifics of particular areas and their populations. In addition, the government should also insert bio tricking filters into sewer pumping infrastructure, ensure that wastewater stations manage oil, grease, and fat waste, and broaden the scope of using water generated by wastewater treatment facilities.

It was found in the study that desalination should become the key instrument of generating freshwater for the UAE population. At the national level, the state does not take a full advantage of this instrument, even though in some areas, such as Abu Dhabi, desalination techniques constitute the key source of freshwater. Unfortunately, the efficiency of this instrument remains low due to high energy costs. The majority of desalination plants work on fossil fuel through the thermal method, which makes them unsustainable from the environmental perspective. The option of shifting to reverse osmosis as the key instrument of water desalination seems to be promising. At the same time, it is crucial to continue using evaporation techniques because high salinity levels of water can reduce the efficiency of this method in the United Arab Emirates as compared to most other countries.

Optimization of water transmission and distribution processes in the UAE is a mandatory component of the sustainable use of water resources in the country. At the same time, it was found that the existing systems of water transmission and distribution could not be labeled as inefficient, although they leave some space for improvement. Infrastructure sharing, collaboration with the private sector, changes in centralization patterns, and modification and replacement of some infrastructure objects could be considered as promising drivers of

achieving higher levels of sustainability in the UAE's system of water management; at the same time, none of them can radically improve the efficiency of water transmission and distribution processes in the country. In addition to the measures describe above, the government should also consider decreasing the pumping time, ensuring adequate maintenance of all the relevant systems, regulating the rate of a pumping flow, standardizing and simplifying requirements for spare parts, providing enough manpower to ensure the continuous operations of all the pertinent processes, and expanding the system when necessary.

The study did not find any evidence suggesting that searching for new sources of water resources could prevent the threat of water scarcity in the country. Even if the state manages to locate new reserves of groundwater, their retrieval and desalination will be more expensive than desalination of seawater or wastewater treatment. Thus, the goal of ensuring sustainable water use in the country can be completed not through discovering new sources of this resource but through developing and adopting innovative, efficient, and sustainable technologies of using the existing water resources.

In addition to the recommendations formulated above, this study also offered many other relevant policies and initiatives that could help improve the sustainability of water resources' use. In particular, the government should encourage citizens to refrain from using water when it is not necessary, optimize the consumption of potable water, and conduct information campaigns that could motivate citizens to engage in a more responsible behavior in terms of water consumption. It might be a promising idea to implement policies promoting the insertion of new technological devices that help save water and optimize its usage, such as auto samplers, water meters, efficient toilets, efficient faucets, and high-quality pipes without leakage.

From the perspective of the business environment, the government may consider offering tax incentives to those companies that use reverse osmosis for water desalination, separately treat black and grey water, and utilize other innovative technologies that harmonize with the principles of sustainable water use. Finally, the government is also recommended to intensify its cooperation with neighboring countries in the field of sustainable water management and engage foreign experts to help solve the most topical problems faced by the water management system, such as brine emission.

In general, the study showed that the UAE population is currently not ready to fully commit to the goal of ensuring the sustainable use of the nation's water resources. Even people who are aware of the threats of water scarcity are not ready to engage in practical actions to support this aim and are under the impression that the achievement of this goal is solely the responsibility of the government authorities. At the same time, most of the participants of this study recognized the need to change water consumption patterns and stop using water when it is not necessary. Accordingly, conducting information campaigns that encourage this change and raising the population's awareness of the problem of water scarcity should be among the foreground priorities of the UAE government as well as governments of emirates.

This study generated a significant amount of information about water management in the United Arab Emirates and introduced many recommendations that could help prevent the threat of water scarcity and make the use of water resources in this country more sustainable. At the same time, this study primarily focused on general trends; therefore, it did not offer a sufficient amount of specific details about all the instruments discussed in the text of this dissertation. Therefore, it seems justified to recommend other scholars to continue studying the problem of water sustainability in the UAE and focus on more specific areas of this issue. In particular, it might be useful to scrutinize the existing water transmission and infrastructure in

the country and discuss various options that could help optimize it. Unfortunately, the current study did not investigate this aspect of the problem in enough depth. Moreover, scientists may also consider focusing on the cases of different emirates and cities in order to explore specific patterns inherent to the use of their water resources.

The current study has four important limitations that should be considered by any scientist, government official, or other stakeholder who is interested in using the findings of this research in some theoretical or practical purposes. First, it is important to emphasize that the sample of this study consisted of experts who are fully aware of the specifics of water management in the country and realize the problem of water scarcity. Accordingly, their opinions are not representative of the opinions of the UAE population because most other citizens of the country are supposed to be less informed about these issues. Second, I focused on investigating general patterns inherent to the UAE system of water use; however, in practice, most solutions discussed in this dissertation are applied to some specific regions or cities.

Third, the survey included a list of various recommendations concerning the transformation of the water management system in the UAE in the beginning of the survey. It is possible that some respondents who have answered this question could be inclined towards considering the same options when offering their own recommendations to ensure the sustainable use of water resources in the country. In other words, there is a certain possibility that the formulation of some close-ended questions in the survey have made some influence on respondents' answers to open-ended questions. Despite these limitations, it seems justified to argue that the findings generated by this research could be considered valuable both from the theoretical and from the practical perspective, as this dissertation is one of the first studies that has systematically investigated the phenomenon of water management in the UAE and offered

a set of practical recommendations concerning the ways to ensure the sustainable use of water resources in this country.

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List of Appendices

Appendix A. The Survey's Questionnaire

Good day! Thank you very much for taking part in this study! As you will see, there are three types of questions in this questionnaire: close-ended, open-ended, and those in which you have to evaluate certain variables on a scale from "1" to "10". Please pay attention to the questions' formulations as some close-ended questions allow choosing only one answer while others allow selecting multiple options. In open-ended questions, you can share your opinion in any manner that feels comfortable to you. Finally, when you asked to indicate a degree to which you agree with a certain statement or to evaluate some parameter, please write one number within a range between "1" and "10" where "1" is the lowest mark and "10" is the highest mark.

1. Do you think that water scarcity is a significant problem in the UAE? Please evaluate its significance on a scale from "1" to "10" ("1" is the minimum value while "10" is the maximum value") _____
2. Please evaluate the sustainability of the use of water resources in the UAE _____
3. Please indicate to what extent you are satisfied with the measures taken by the government to ensure the sustainable use of water in the country _____
4. Please indicate to what extent you are satisfied with the UAE Water Security Strategy 2036 _____
5. Please indicate the degree to which you are ready to take the following measures in order to support sustainable water management in the UAE

Statement	**Your mark**
Changing water consumption habits (for instance, switching water while brushing teeth)	
Reducing the amount of water used for household needs	
Paying more for drinking water	
Paying additional taxes to improve water infrastructure	
Purchasing sustainable products and services, such as waterless toilets	

6. What factors from the list below do you consider as the key problems in the field of water resources' use in the UAE? (you can choose multiple options)
   - High water consumption rates;
   - The use of fossil fuel combustion for wastewater treatment;
   - Inefficiency of desalination processes;
   - Inefficiency of water transmission and distribution processes;
   - Outdated infrastructure;
   - The lack of a consistent government strategy of water management;
   - The absence of adequate incentives for businesses.
7. Please share your opinion on the potential of wastewater recycling to contribute to sustainable water management and the effectiveness of the way in which this instrument is currently used in the UAE.

Parameter	Your mark
Potential	
Effectiveness	

8. What is your opinion on the preferred type of a wastewater management system? (please chose one option)
   - The system should be centralized;
   - The system should be decentralized;
   - The system should be mixed.
9. Could you please share your recommendations that could help utilize wastewater recycling methods in a way that contributes to the sustainable use of water resources in the UAE?

   _____

   ___
10. Please evaluate various dimensions of water desalination in the UAE

Parameter	Your mark
Potential to contribute to sustainable water management	
Effectiveness of the instrument's current use	
Efficiency of the instrument's current use	
Sustainability of the instrument's current use	

11. What is your recommendation concerning the choice of desalination techniques in the UAE? (please choose one option)
    - Extending the use of thermal methods;
    - Completely shifting to reverse osmosis;
    - Shifting to reverse osmosis but keeping evaporation techniques.
12. Do you have any other recommendations that could help use desalination techniques in a way that contributes to the sustainable use of water resources in the UAE?

_____

13. Please evaluate the potential of the optimization of water transmission and distribution processes to contribute to sustainable water management _____
14. Please evaluate the effectiveness of the current efforts of government authorities to optimize water transmission and distribution processes _____
15. What recommendations can you offer to optimize water transmission and distribution processes in the UAE? (you can choose multiple options)
    - Replacement or modification of infrastructure;
    - Changes in centralization patterns;
    - Infrastructure sharing;
    - Collaboration with the private sector.
16. Do you have any other recommendations that could help optimize water transmission and distribution process in the UAE?

    _____

    ___

17. Do you agree that the UAE government uses all the existing sources of water? (please choose one option)
    - Yes;
    - Rather yes than no;
    - Rather no than yes;
    - No.
18. If you have chosen the options “rather no than yes” or “no” to the previous question, could you please indicate what sources of water are not currently used by the UAE government?

    _____

    ___
19. Could you please share all your recommendations that could help ensure the sustainable use of water resources in the UAE? Please mention those issues that you did not cover in your answers to previous questions.

    _____

    ___
20. Could you please share your age? _____
21. Could you please share your gender? _____
22. Could you please share your current highest educational level? _____
23. Could you please share your current residence? _____
24. Could you please share your place of work or study?

Thank you very much for taking part in this survey!