Integrated Water Resources Management Plan for the UAE

الخطة المتكاملة لإدارة الموارد المائية لدولة الإمارات العربية المتحدة

by

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Shaikha Ahmad AlShaikh

Abstract

Increased human populations, rapid economic developments, and climate change have driven many countries in the Middle East to suffer acute water shortages. Additionally, they have caused a decline in the supply and quality of water and led to an increase in the cost of its production. In the last three decades, the United Arab Emirates has experienced rapid urbanization due to steady economic growth. Expansion of the economy is accompanied by a sharp rise in population, which has put pressure on its water resources. At present, the government has put in place strategies to reduce the population pressure on its scarce water sources by developing a system for managing the supply and demand sides for its resources. This research study aims at examining the current water management approach and challenges through qualitative and quantitative analysis. This paper draws attention to the need for the UAE to accelerate the integration of technology in production and supply, building public awareness, improving legislative framework on green building code, and collecting non-revenue water among others. This recommendation stems from a review of several publications on water management, which show that the future of water sustainability in arid regions lies in addressing demand-side problems and not supply-side challenges. It also is based on a survey that was conducted among professionals that work within the water and wastewater sector. More specifically, key tenets of this paper highlight the need for authorities to consider adopting smart water management principles that would see them operate more efficiently and create a greater and more positive impact on the country.

ملخص البحث

لقد دفعت زيادة أعداد السكان والتطور الإقتصادي وتغير المناخ العديد من البلدان في الشرق الأوسط إلى المعاناة من نقص حاد في موارد المياه. بالإضافة إلى ذلك، فإن انخفاض كمية المياه تسببت في انخفاض إمدادات المياه ونوعيتها و جودتها، وأدت إلى زيادة في تكلفة إنتاجها. شهدت دولة الامارات العربية المتحدة خلال العقود الثلاثة الماضية توسعا عمرانيا سريعا بسبب النمو الاقتصادي المطرد. ويقترن توسيع الاقتصاد بارتفاع حاد في عدد السكان، و هو الأمر الذي ادى إلى الضغط على الموارد المائية. وفي الوقت الحالي ، وضعت الحكومة استراتيجيات للحد من الضغط الناتج من زيادة نسبة السكان على مصادر المياه من خلال وضع نظام لأداره جانبي العرض والطلب لمواردها. وتهدف هذه الدراسة البحثية إلى دراسة النهج الحالي لأدارة المياه والتحديات الموجودة من خلال التحليل النوعي والكمي. يلفت هذا البحث على الانتباه إلى ضرورة قيام دولة الامارات بالإسراع في دمج التكنولوجيا في الإنتاج والتوريد ، وبناء الوعي العام ، وتحسين الإطار التشريعي بشأن قانون البناء الأخضر المستدام، وجمع المياه الغير المدرة للعوائد. وتنبع هذه التوصية بعد الاستعراض على عدة منشورات عن إدارة المياه ، و الذي تبرز بان مستقبل استدامه المياه في المنطقة يكمن في معالجه المشاكل المتعلقة بجانب الطلب وليس التحديات التي تواجه جانب توصيل المياه. وتستند التوصيات أيضا إلى دراسة استقصائية أجريت بين العاملين في قطاع المياه و مياه الصرف الصحي. بالتحديد ، يسلط البحث الضوء على ضرورة نظر المؤسسات الموزعة للمياه و السلطات المعنية في هذا القطاع على اعتماد مبادئ ذكية لإداره المياه لرفع نسبة كفاءة الشبكات و بدورها تخلق اثرا إيجابيا الدولة.

Dedication

To my family, my friends, my colleagues and every person that ever inspired me to want to achieve and excel; thank you.

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First and foremost, I would like to extend my sincerest gratitude and appreciation to my thesis advisor, Dr. Alaa Ameer, who has insisted on pushing me to leave no stone unturned. His continuous support and open-door policy allowed me to steer this research paper to a version that I am proud of. I would also like to thank all the professors that shared their knowledge and experience in our lecture halls. In addition, I would like to thank my classmates that have assisted me along the way, whether it's through running the required analysis or helped spreading my survey. Above all, I would like to thank the British University in Dubai for providing us with an environment that always exuded academic excellence and collaboration.

My interest in this research topic was stemmed through my work with water experts in the region. Without their insights and shared knowledge, my fondness for an Integrated Water Resource Management wouldn't have thrived. For this, I thank my colleagues.

Most importantly, I would like to thank my family; my parents and siblings. Their unwavering support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis got me to this point. This accomplishment would not have been possible without them.

Shaikha Ahmad AlShaikh

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Integrated Water Resource Management Plan

Chapter 1: Introduction

1.1 Introduction

Water is an important resource for the sustainability of human life. Similarly, it supports the socioeconomic development of many countries and helps to maintain healthy ecosystems that nurture life. This important role of water to human and environmental ecosystems has led many researchers to derive a relationship between the sustainability of water resources and urbanization (Issa & Al Abbar 2015, pp. 1-3). Similarly, they have linked these two factors with climate change. Although the three variables (sustainability, urbanization and climate change) affect each other, they all fall define two points of one continuum – demand and supply of water. The supply of this precious commodity is mostly affected by the availability of ground and surface water reserves, while the demand is influenced by human factors, such as population growth, industrialization, and urbanization (Yigzaw & Hossain 2016, p.1). Most of these human factors are intertwined with socioeconomic growth issues and affect the general demand for water. For example, population growth has been linked with rapid urbanization. Similarly, analysts have linked lateral urbanization with an increased strain on environmental resources (Ramadan 2015, p. 179). In the same breadth of analysis, they have associated population density increases with a surge in water demand.

The United Arab Emirates occupies an area of about 83,600 km2. The seven Emirates that make up the UAE are Abu Dhabi, Dubai, Sharjah, Ajman, Ras Al Khaimah, Umm Al Quwain and Fujairah. These Emirates have an expansive coastline of 1318 kilometers where most of the non-conventional and conventional water resources are located. Over the years, urbanization has increased the population pressure and demand for water. At present, more than

70% of the UAE population lives in urban areas (Merabtene, Siddique & Shanableh 2016). Specifically, 65% of this population occupies a stretch of 5km coastline. The UAE Water Security Strategy 2036 was unveiled by the Ministry of Energy and Industry in 2017 to ensure that access to water during emergency and normal conditions is sustainable within the internal standards, local regulations, and the nation's vision of prosperity. This strategy has frameworks for reducing demand for different water resources by up to 21% and expand productivity index of water to $110 per cubic meter. The plan also intends to lower the water scarcity index by three degrees and increase the reuse of treated water by 95% (Lubega & Farid 2014). The UAE relies on conventional and non-conventional water resources to meet the even rising demand for usable water. Among the notable conventional water sources are groundwater, falajes, springs, ad seasonal floods. Non-conventional water resources are treated sewage and desalinated water. The current conventional water resources in the UAE include 3 Mm3/yr from several permanent springs, 20 Mm3/yr from falajes discharges, 22 Mm3/yr from seasonal springs, and 109 Mm3/yr from aquifer recharge (Dakkak 2015). The non-conventional resources are 150 Mm3/yr from reclaimed water and 475 Mm3/yr from desalinated water (Madden, Lewis & Davis 2013). It is projected that future robust development in the UAE might increase the seasonal springs and falaje discharges to 40 Mm3/yr (Lubega & Farid 2014a). The Emirates have an arid climate with lower than 100 mm/year f rainfall, low groundwater recharge rate of less than 4% of the water used annually, high rate of evaporation estimated at 2-3 m/year and limited reliable surface water (Merabtene et al. 2016). The UAE is a downstream water user sharing her trans-boundary water sources with Oman and Saudi Arabia (Meldrum et al. 2013). The sharp population increase and rapid economic development over the last two decades have resulted in expanded reliance on the primary unconventional water sources such as desalination (Alawar 2014). The increasing demand has led to development and expansion of alternative conventional supply measures for the water resources such as storage dams, recharge dams, as well as recharge wells (Dakkak 2015). At present, groundwater is the primary conventional water source in the UAE. This resource constitutes 80% of all the freshwater supply per year. Other sources of freshwater for the Emirates are wastewater re-use at 3% and desalination plants at 17%. The consumption of water in the UAE is for amenity, forestry, agricultural, commercial, industrial, and domestic purposes. At present, the largest water user is within the agricultural sector at 58% annually (Merabtene et al. 2016). The industrial, domestic, and commercial water usage stands at 17%. The estimation of groundwater share is done by the government agencies on the basis of demand and availability of the desalination plant production. This means that sustainable yield of UAE's groundwater aquifer is dependent on the duration it takes for such aquifer to replenish. However, the ever-rising demand for water in the Emirates has put intense pressure on the scarce water resources and is currently threatening the quality of production and supply. Thus, it will be essential to effectively estimate the rate of replenishment of water resources in order to create proactive management strategy for this national resource (Madden et al. 2013). Since the study is focused on the entire UAE, recharge rate estimations will be linked to recent national practices of using desalinated water for agricultural purposes. This practice was necessitated by the government's hindrance policy for use of groundwater for irrigation in order to recover overexploited storage. Moreover, the hesitancy of individual water users to continuously carry out irrigation using treated water raised a lot of social concerns (Kraft 2013). As a result, "any surplus of treated wastewater is, hence, dumped in desert lagoons imposing additional input to the groundwater storage" (Lubega & Farid 2014b, p. 7). These factors catalyzes the immense usage of desalinated water in the UAE irrigation fields, which eventually replenishes the grounder as a source of aquifer input. The shifting water resources use and production in the last ten years has resulted in substantial fluctuations in the UAE water table to the "extent that groundwater level has surprisingly risen considerably in some areas in Al-Ain" (Government.ae 2018). The rise in water table is also associated with other factors such as increasing need for landscaping and farm areas to meet the rapid urbanization needs. Overtime, it is estimated that the even grounding urbanization in the UAE might have an effect on the country's hydrological cycle and lead to variations in groundwater discharge and recharge rates (PJM-ISO 2013). As a result, there are immense threats looming in the UAE water management such as deterioration of road infrastructure, flooding of houses, damage to construction project foundations, land subsidence, and other long-term environmental degradations associated with contamination of groundwater and soil (Merabtene et al. 2016). This study will review the current situation in integrated sustainable water resources management in order to suggest an ideal approach for addressing any challenges identified.

1.2 Background of the Problem

The World Economic Forum has identified water security as an evitable resource for sustainable development in a country or region. According to Lubega and Farid (2014a), water security is "the ability of a population to safeguard its access to adequate quantities of acceptable useable water for sustaining livelihoods, population well-being, and socio-economic development" (p. 8). Moreover, water security addresses the aspect of integration of a resource management system within an ecosystem for long term benefits (Meldrum et al. 2013). As a segment of water sustainability planning, the UAE government has put in place several strategies to guarantee water security. Since the Arab region climate is arid, water resources that are portable have become a concern to the UAE government and other members of the GCC (Luomi

2014). Specifically, the World Bank estimates that the UAE and other Arab countries will become drier in the next few decades besides increased population growth against constant sources of water supply (World Bank 2016). Moreover, rapid development as the UAE becomes urbanized has increased water consumption, especially for non-oil based firms (PJM-ISO 2013). This means that the seven Emirates should come up with a strategic plan for addressing the consumption and climate challenges in order to create a sustainable and effective water management system.

Integrated Water Resources Management (IWRM) is a complex concept that has received a lot of attention as a significant instrument for improving the operational framework for existing water resources systems in the UAE (Dakkak 2015). Despite the fact that this concept has been in existence for close to a century, its effective implementation is laden with challenges associated with the inherent and complex nature of water management systems (Merabtene et al. 2016). Specifically, these systems integrate the scientific, technical social, economic and political considerations to create a universally acceptable water resources management approach. Specifically, "in order to reach a robust integration among all these elements, the management strategy mist be multi-disciplinary to account for all these aspects related to the water system under consideration" (Lubega & Farid 2014b, p. 9). In this study, water budget will be used as a tool for describing the hydrologic cycle by summing water resource inputs and outputs of the study area over a specific duration. Since any hydrological cycle is controlled by the mass conservation law, the study will establish if there has been a rise or fall in the water table depending on the variations between the total water outputs and inputs from the current system. Specifically, in the event that the results indicate that the water inputs are less than outputs, the researcher will concluded that there is a decline in the water table and vice versa (Santhosh, Farid & Youcef-Toumi 2013). In this study, the components of water budget that will be examined include inputs such as runoff, precipitation, surface water inflow, groundwater inflow, and diversions (Madden et al. 2013). On the other hand, the output components include water diversions, residential uses, industrial uses, irrigation surface water outflow, groundwater outflow, transpiration, and evaporation. The UAE is over dependent on groundwater to sustain the demand for different uses. Over the years, the consumption rate has exceeded the natural recharge leading to an imbalance between outputs and inputs of water in the current system (Lubega et al. 2014). As a result, the groundwater and seawater has deteriorated. Although desalination plants have been set up by the government to take care of any shortfall in the existing conventional water resources, the demand is growing faster than the supply. Specifically, the groundwater resources depletion and ever rising demand for water in the UAE has increased pressure on the seven Emirates to create an integrated sustainable water resources management. The current shortages have threatened development sustainability and placed the UAE in the list of countries that are poor in terms of availability of water resources (Mansour 2017). This research dissertation discusses water resources in the UAE in terms of how the resources are managed, exploited, and setting a framework for future sustainability strategies (Dakkak 2015). Specifically, the study is focused on understanding the existing challenges in water security governance in the UAE and steps that might be implemented to curb these setbacks in order to sustain water resources management.

1.3 Research Problem Statement

Out of all countries in the Arab League, the UAE has among the highest water consumption rates. The Federal Electricity and Water Authority affirm these statistics by saying that the average UAE resident consumes up to 550 liters of water per day (UAE Statistics

Center). This volume is higher than the average global consumption of water per person which is pegged at between 170 liters – 300 liters (UAE Statistics Center). Relative to these findings, Al Awar (2015, p. 1) says that the UAE has among the highest per capita water consumption levels in the world. Donat (2013, p. 581) puts these statistics in context and says that the main sources of water for the Gulf Nation are desalination and groundwater only. Consequently, many cities in the country are "starved" of this vital resource. The situation is made worse by the seemingly inequitable use of water resources in the country because major economic hubs in the bustling nation tend to get the largest allocation of water sources. For example, the study by Al Awar (2015, pp. 3-5) reveals that Dubai consumes up to 98% of the total water generated from desalination. This statistic means that other regions of the country have to rely on alternative sources of water (mostly groundwater), which are limited in supply.

Many researchers have pointed out that the demand for water in the UAE has steadily increased in the last ten years (Gonzalez et al. 2016, p. 415). In fact, within the same period, it is only in 2011 that a slight decrease was observed. The demand for potable water has also adopted a similar trend because in the year 2000, it was about 1,000 million liters per day, but in 2012, this figure had dramatically increased to 3,700 million liters per day (Nunes 2018).

The UAE's heavy dependence on desalinated water has also come with a significant environmental cost to the nation because desalination has a heavy carbon footprint on the environment. Its emissions contribute to global warming, which in turn adds to climate change, which has worsened environmental conditions in the Middle East. Based on the above dynamics, the options for UAE to develop sustainable water solutions are slowly decreasing, especially because it cannot depend on rainfall, which is often low and erratic. Cloud seeding has been proposed as an alternative for mitigating the problem, but as Arnbjerg-Nielsen et al. (2013 p. 16) points out, there is little scientific evidence to back up its use. Furthermore, studies have shown that it only has less than a 30% success rate (Arnbjerg-Nielsen et al. 16). Based on these findings, there is a growing threat of inadequate water supply for millions of UAE residents because climate change, changes in water management systems, rapid urbanization, and an increase in population have caused a strain on the country's water resources. Consequently, many Emirates in the country are struggling to show resilience in the face of this crisis by trying to improve their efficiency and at the same time maintaining high levels of water quality for their residents.

1.4 Significance of the Study

The main purpose of this study is to improve sustainable water management in the UAE. It will undertake a a comprehensive examination of water supply and availability in the Emirates in order to comprehend the challenges faced by the UAE government in effectively maintaining a stable, secure, and quality water supply for the population and industries. The proposed research will also attempt to explore quantifiable solutions for possible challenges in water resources management at present and in the future as a result of the ever-increasing demand levels, pollution, and climate changes.

This study is significant to policymakers around the world who are grappling with the problem of finding sustainable solutions to water scarcity in their jurisdictions. Indeed, many governments around the world (especially in developing nations) strive to provide their citizens with this vital resource with difficulty because they cannot seem to provide viable alternatives fast enough to keep up with the demand for water. The findings of this paper would also be significant to policymakers because they would help them to formulate a solid and proper management structure of water resources, as well as to encourage them to find new solutions to the water management problem in the country.

A severe water shortage in cities also comes with its political, social, and economic costs. For example, such a problem could have an impact on the health care standards of the affected communities because the lack of clean and fresh water often leads to a deterioration of water quality and the eventual development and spread of diseases (Parneet et al. 2016, p. 364). There is also a social impact to the problem because human populations are known to migrate to areas that have clean water. Therefore, the lack of a proper water management framework could lead to this problem because population displacements may occur in regions where such a crisis is acute. Research studies have also shown that the failure to address water management issues could stifle development. Such is the case pointed out by Hasanean and Almazroui (2015, p. 578) who say, “Thirsty cities do not grow”. This problem could be disastrous for major cities in the gulf region that are depending on rapid economic development for their own survival. For example, Dubai is one city that is transitioning from oil dependency by expanding other economic sectors, such as the service and hospitality industries that depend on the availability of water to thrive. The failure to manage the city’s water resources will not only affect the industries, but also lead to energy and food insecurities for residents. Such a possibility should concern policymakers around the world because studies by Hasanean and Almazroui (2015, p. 578) demonstrate that the global production of food and energy needs to increase by up to 60% to match the demand for water caused by human population and economic growth.

1.5 Research Aims and Objectives

The primary aim of this paper is to examine and explore sustainable water resource management solutions that could improve the supply of the valuable resource in the UAE. The objectives of the research are as follows:

1. To establish the current system of water security management within the UAE
2. To identify the current and future challenges in the integrated sustainable water resources management from a risk perspective
3. To discuss the existing policies by the UAE government aimed at addressing water security in the seven Emirates
4. To recommend improvements that the UAE government might adopt to create an effective integrated sustainable water resources management system

1.6 Research Assumptions and Limitations

Since limited research has been carried out to establish the effectiveness of the current water resources management in the UAE, the proposed study many not give an accurate picture since it relies on available data that might not be updated. The researcher has made an effort to include only credible journal articles and websites to address this assumption. The statistics presented in this report are relative to current estimates of water production and distribution. The technologies highlighted in this paper are also those that are presently available in the market. The UAE government or any other agency will have to associate the current and future projections highlighted in the study to establish an appropriate and systematic water management approach for sustainable consumption.

1.7 Thesis Organization

Research Commencement. This stage of the research study involves proactive analysis of different research topics from which the researcher has to pick one topic and define the rationale for the choice. In the case, the researcher chose the topic *Integrated Sustainable Water Resources Management in the UAE* because there is a lot of literature besides being relevant to the research on sustainable water consumption for effective resource governance and security.

Choosing the case study. Choosing the case studies within the UAE is expected to be challenging, considering the fact that the researcher is targeting all the regions within the UAE, that is, coastline and mainland. The researcher will have to decide on the most appropriate research approach. Moreover, the researcher has to choose relevant research variables to ensure that the scope of the study is well addressed.

Background research. Since the topic has several past literature materials, the researcher will not have many challenges in creating the research background. The role of the researcher at this stage will be to merge different literature materials to the research topic to determine the direction to follow during the actual research.

Conducting the literature review. This stage will be the most demanding, considering that fact that the researcher will have to carry out empirical and theoretical literature. The researcher will then relate the existing literature to the case study topic. Among the sources of information that the researcher will explore are academic journals, course notes, reports on the UAE water resources management system, and books.

Collecting and analyzing data. This stage was very demanding since the researcher had to balance different tools to gathering the required information in order to analyze them for the purpose of this study. The research will have to scrutinize data collected to ensure that the analysis makes scientific sense by adhering to ethical principles of carrying out social research. The research will also have to design the research questions and test them for comprehensiveness and relevance. A survey was designed was independent and dependent variables to assess whether those variables play a role in the topic of the research or not. The researcher will have to apply different data analysis tools to make sense of the raw data collected. At the stage, the researcher will ensure that proper coding and transcription is done to achieve the desirable results.

Research conclusion. After the analysis stage, the researcher will identify the themes that have emerged to offer appropriate interpretation of the findings. The researcher will have to compile the outcome of the study and determine whether the research hypothesis has been proven or not. This section will also involve submission of different attachments related to the research.

1.8 Summary

This chapter shows that efficient water management is an important undertaking for countries that suffer from acute water shortages. The UAE is one such country. Its water management strategy has been undermined by an increased demand for the same resource. A surge in population and rapid economic growth has worsened fanned the problem because they have created an increase in the demand for water. Consequently, the country has to think of new ways of addressing the water supply gap that exists today.

Chapter 2: Literature Review

2.1 Introduction and Conceptual Framework

This chapter is a literature review of what other researchers have said about the research topic. It contains an analysis of the water crisis in the Middle East and presents a detailed review of the main sources of water in this region. The scope of review is however not limited to the gulf region alone, because this chapter also contains evidence of what other countries outside this locus have done to manage their water problems, including an understanding of the applicable technologies that help them to do so. Nonetheless, at the center of this review is the need for authorities to assess their water resources.

The conceptual framework is angled on the current water management system in the UAE as related to current challenges, government policies, and necessary improvements to expand on the aspect of integrated sustainability in the water management approach (Lubega et al., 2014). As discussed in the first chapter, the UAE government has combined processes, mechanisms, and institutions to exercise administrative, economic, and social control over the available water reprocess. The terms water resources governance will be used to denote management approach or system in place to develop and control water infrastructure in the UAE from production, supply, and rejuvenation of the sources (Merabtene et al., 2016). The conceptual framework is drawn from good water resources management through integration of two ideal water governance models by the OECD and USAID (see table 1 and figure 1). The OECD principles were used to review the evidence related to the UAE integrated water resources management system.

Figure 1: OCED Water Management Principles

(Al Awar 2014)

	USAID water governance framework	OECD Water governance framework
Description	**Founded by the government of the United States of America, the USAID has a comprehensive framework for managing water resources in a sustainable manner.**	**Abbreviated as OECD, the Organization for Economic Co-operation and Development provide ideal principles of water governance for its members**

Application	**The USAID water governance framework is functions on five factors of participation, transparency, rule of law, integrity/accountability, and responsiveness**	**The OECD water governance framework functions on principles of effectiveness, trust and engagement, and efficiency**
	The USAID model operates on the functions of building water sector capacity, strategic planning, allocation of water resources, and regulating the usage.	**Through an integrated water governance cycle, the OECD water management principles are managed through four stages, which are formulation of policies and strategies, implementation, monitoring, and evaluation" (Odhiambo 2017, p. 2478).**

Table 1: Conceptual framework modeled from the USAID and OECD water governance approaches

Based on the OECD principles, the analysis and recommendation in the proposed research will integrated the variables of effectiveness, efficiency, and engagement or trust (Morillo et al. 2014). As part of the conceptual framework, the variable of effectiveness will be used to evaluate the policies and processes defining sustainable water resources management policies against set targets over a period of time in the UAE (Al-Otaibi, El-Sadek & Al-Zubari 2013). This variable will integrate the sub-principles of role and responsibility setting, inclusive scale for managing water resources, policy coherence within the player sectors, and capacity adaptability (OECD 2016). The second variable of efficiency will be used to examine the benefits of effective governance in a sustainable management approach to the current water system. The research will also examine the current strategies put in place in the UAE to maximize sustainable water management benefits at low cost under the sub-principles of "producing and sharing data and information, mobilizing and allocating water finances efficiently, effective implementation of regulatory frameworks, and promoting innovative practices" (OECD 2015, p. 11). The last variable to be considered within proposed conceptual framework is engagement or trust to examine how the relevant water management authorities build public confidence and promote inclusiveness among stakeholders (Santhosh et al. 2013). This variable will be examined using the OECD's sub-principles of "mainstreaming integrity and transparency practices, promoting stakeholder engagement, encouraging water governance frameworks and promoting monitoring and evaluation of water policy and governance" (OECD 2015, p. 12).

In addition, this study includes four key pillars of water management: increasing reuse levels, storing more water, conserving available water resources or looking for new sources of the same. At the center of efforts to manage water resources is the understanding that water resource management is a system and not an "event." At the end of this system is an understanding of the main sources of water, such as groundwater seawater/brackish and surface water. The second step of the process involves the extraction and storage of the same commodity. Treatment and distribution processes thereafter follow and they pave the way for the use of water across different economic sectors. Figure 2 explains the conceptual framework.

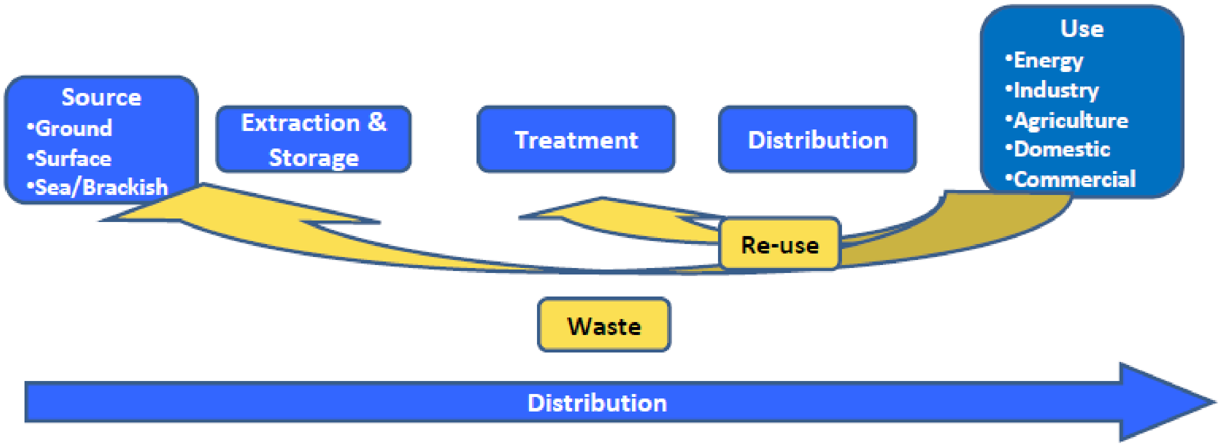

Figure 2: Conceptual Framework

(Nunes 2018)

2.2 Global Water Resources and Sustainability

Over the years, concerns for sustainable water resources across the globe have increased as governments and other international bodies put in place policies for effective management systems. The leading policy makers for global water resources sustainability are the United Nations and World Bank (Meldrum et al. 2013). These institutions have classified each region across the globe as either having adequate water supply or at a threat of unsustainable water resources. Global water resources sustainability integrates administrative, political, and economic authority to proactively manage different sources and effectively supply them for consumption in an environmentally friendly manner (Lubega & Farid 2014a). It involves holistic combination of processes, mechanisms, and institutions of governance to have full control of how water is produced, supplied, consumed, and sustained (Mansour 2017). This means that water resources governance at the global level combines a series of elements such as "statutes, including policy mandates; administrative rules and guidelines; and institutionalized rules and norms" (Al Awar 2014, p. 25). Water resources governance across the globe is not limited to limited to individual government interventions, but a collection of policies managed with obligations of private and public organization partnerships. According to Santhosh, Farid, and Youcef-Toumi (2014), an effective water resources governance is important for guaranteeing a balanced mix in the social, economic, and environmental outcomes of any integrated water management system (see figure 3). Good resource governance is instrumental in producing effective and sustainable outcomes (Svendsen 2014). For instance, an effective water resources management approach should integrate accountability, inclusiveness, transparency, participation, responsiveness, and predictability for the system to serve its purpose in the short and long term (Odhiambo 2017). According to Al Awar (2014 p. 25), water governance is the "range of political, social, economic, and administrative systems that are in place to develop and manage water resources, and delivery of water services, at different levels of society". At global level, water resources and sustainability is organized into formulated and well-developed policies with a primary objective of sustaining any the development of any water management system. Implementation of these policies involves primary stakeholders and actors for the process to remain effective (Santhosh, Farid & Youcef-Toumi 2013). In relation to the proposed study, the research intends to integrate the water governance principles of the United Nations, World Bank and Organization for Economic Co-operation and Development (OECD 2015) to review the current situation in the UAE from the perspective of integrated sustainable water resources governance.

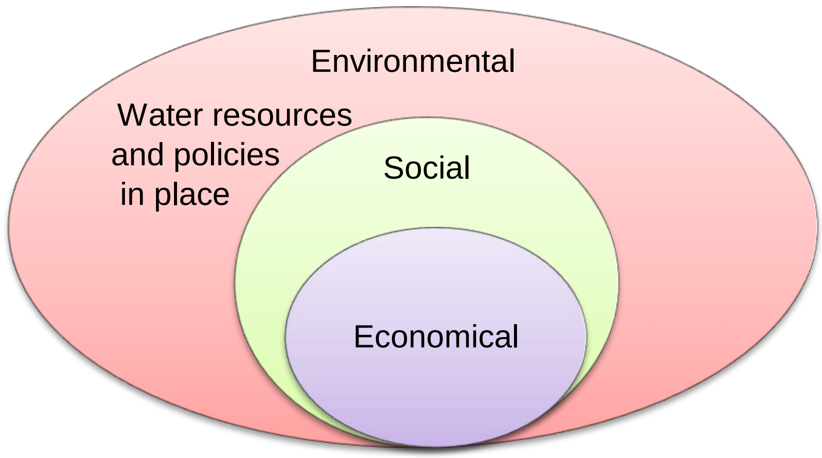

Figure 3: Sustainable water resource management priority indicators

(Meldrum et al. 2013)

Researchers have pointed out that there are three elements to a sustainable water future. They include efficiency, resiliency and quality (Consultancy 2016). The concept of resiliency refers to water resources, water-related disaster risks, and vulnerabilities. The second concept of efficiency refers to leakage, metering water reuse, continuity coverage, and charges (Consultancy 2016). Lastly, the concept of quality refers to health, sanitation, pollution, and environmental effects of water production and extraction. Global rankings of cities have used these categories to assess how they perform, in terms of water management.

In line with this view, the resiliency sub-index include waters stress, green space, water-related disaster risk, flood risk, water balance, and water reserves as its main constituents (Consultancy 2016). The efficiency sub-index includes leakage, water charges, service continuity, wastewater, metered water, drinking water, and sanitation. The last sub-index (quality) includes drinking water, sanitation, treated wastewater, water-related disease, water pollution, and threatened fresh water species (Consultancy 2016). Figure 4 below summarizes these elements, which experts have cited as integral to a sustainable water future.

Figure 4: Sustainable water future

(Consultancy 2016)

2.3 Water Resource Management

The United Nations Development Program's report of 2013 on water resources in the Arab region notes that a myriad of factors are associated with restricted progress in water governance such as "unclear and overlapping responsibilities, inefficient institutions, insufficient funding, centralized decision-making, limited public awareness and ineffective regulations and enforcement (UNDP 2013, p. 1). Siddiqi and Weck (2013) conceptualized effective water resources governance as putting in place social learning and adaptive governance systems that are adequate for managing the social-ecological in the event of an abrupt change. For instance, recent changes in the global weather patterns have openly highlighted the weaknesses and challenges in the present water resources management systems. Moreover, the lack of an effective and multiagency water resources governance approach across the globe has magnified these challenges in the backdrop of an existing scarcity concern (Santhosh, Farid & Youcef-Toumi 2014). Therefore, it is critical to comprehend the significance of sustainable water resources governance in the events of global climatic variations as well as scarcity concerns in the Arab regions such as the UAE (Svendsen 2014). According to Dakkak (2015), in order to effectively alter the existing water resources governance, governments of the day should incorporate societal and social learning in any management system. Specifically, social learning ensures that government bodies, interested parties, and general public are brought on board before a major policy is implemented (Mansour 2017). For instance, the social learning needs might be hampered when the management of water resources is contracted to a private institution (Al-Otaibi, El-Sadek & Al-Zubari 2013).

Water resources management is incomplete when the aspect of water security is not addressed. According to Al-Otaibi, El-Sadek and Al-Zubari (2013 p. 89), water security is dependent on the "global climatic change, availability of natural water resources, and socio-economic scenario". A combination of these factors facilitates the actions of any institution mandated with the responsibility of managing an integrated water resources system (Santhosh, Farid & Youcef-Toumi 2013). Water security or management can be achieved through a systematic decreasing is predictable and non-predictable negative impacts while increasing positive actions within the current and future socio-economic development initiatives of a region (Susskind & Zaerpoor 2017). Water resources management is dependent on the political goodwill of a region and its availability. Within the Arab region, water security and management has been a major concern for the last four decades in nations such as Egypt, the UAE, Syria, and Iraq among others (Siddiqi & Weck 2013). These regions have experienced a myriad of water resources security challenges due to inadequate quality and quantity of water, "which affected their capacity to meet their development plans and resulted in social unrests" (Al-Otaibi, El-Sadek & Al-Zubari 2013, p. 24). In the GCC, there is a general high dependency one water resource that is shared among the members, "which sometimes becomes the reason for conflict" (Al-Otaibi, El-Sadek & Al-Zubari 2013, p. 28). The sustainability and availability dimensions of water resources management examine the security of a steady supply of water for consumption. The majority of the GCC countries' water supply comes from desalination plants. Guaranteeing effective water resources management would ensure that reservoirs are adequate to fill any supply gap in the event of insufficient water resources from desalinated plants for a prolonged period of time. According to Al-Otaibi , El-Sadek and Al-Zubari (2013 p. 29), water resources management is a "multidimensional concept that recognizes that sufficient good quality is needed for social, economic and cultural uses while, at the same time, adequate water is required to sustain and enhance important ecosystem functions".

The primary themes associated with water resources management are availability or quantity, vulnerability or hazards, human needs, and sustainability. The theme of availability is associated with water management assessment indices on water shortages and stress. Evaluations measure the level of water stress as a ratio of water availability and use against the estimated impacts of demand-driven scarcity. The second index examines water shortage or crowding by quantifying the number of persons sharing a unit of a water resource (Siddiqi & Weck 2013). This means that sufficient water supply is the ideal unit for measuring water security (Madden, Lewis & Davis 2013). The second theme of vulnerability or hazard is discussed by the UNESCO as advocacy for systems and infrastructure involving protection of water resources from drought, flooding, and other related hazards (Santhosh, Farid & Youcef-Toumi 2013). This theme also addresses the concerns of water contamination as a result of human factors such as terrorism in the current volatile political climate in Arab region. As part of water resources management under this theme, engineers are mandated with the task of using ordnances, guards, and gates to create a secure water infrastructure (Svendsen 2014). The theme of human needs covers human development, food security, and access concerns (Odhiambo 2017). Thus, an ideal human needs theme is a condition occurring when required quality and quantity of water supplied is efficient, affordable, and meet the long and short term needs (Susskind & Zaerpoor 2017).

The United Nations Development Program report has summed these needs as any aspect of human development pertaining to management and use of water resources. This theme also proposes integral safeguarding of water and human security as part of the ecosystem for sustainable balance (Santhosh, Farid & Youcef-Toumi 2014). The last theme is defined by Alawar (2014 p. 26) as “water security at any level from the household to the global arena means that every person has access to enough safe water, at affordable cost, to lead a clean, healthy and productive life, while ensuring that the natural environment is protected and enhanced”. To effectively address this theme, it is important to examine the variables of protecting ecosystem, secure food supply, basic needs, risk management, and wise water valuation or governance.

2.4 Main Water Resources in the UAE

Water shortage in the UAE is prevalent in the country because of insufficient rainfall and the arid nature of the Middle East. Many people are concerned about this issue because they are worried about the unreliability of the current water management structure, which seems unable to cope with the future demand of this vital resource (Yigzaw & Hossain 1). Observers have singled out the agricultural sector as the top consumer of water in the UAE because reports indicate that this economic sector could account for up to 70% of the total water produced in the country (UAE Statistics Center). For example, an article by Al Awar (2014 p. 4) reveals that up to 120 million trees have been planted in the UAE and it has reduced the availability of natural water by 200 m^3 per capita.

The UAE is part of the southern Arab peninsula, which is largely a desert region with little or no rainfall in a year. At the same time, it is characterized by high evaporation rates. Recent reports show that the highest and lowest rainfalls reported in Abu Dhabi were 2.8 mm and 150 mm respectively (UAE Statistics Center). In Dubai, the lowest and highest rainfall levels recorded were 8mm and 112 mm respectively (Al Awar 2014, p. 5). Generally, the UAE could experience heavy rainfall once every decade. Comparatively, the rate of evaporation could be as high as 200 mm annually (Al Qaydi 2016, p. 155). This high evaporation rate means that little water is preserved for future use, especially after the rainfall period.

Rapid urbanization in the UAE has seen an increase in human populations especially from expatriates who are either living or working in the country. Experts project that the current population could be in excess of 5 million people (Al Qaydi 2016, p. 155). The high population increase means that the UAE is experiencing among the highest demand for quality water in a century. For a long time, the UAE has relied on groundwater for its water supply. Consequently, many people got their water from major aquifers to meet their daily needs. However, this source of water is highly dependent on rainfall, which is scarce in the first place. Consequently, the demand for water has been unable to keep up with nature's ability to replenish the reserves. This situation has created an imbalance in the demand and supply of water, which has further caused the deterioration in quality of water retrieved from water aquifers (Parneet, Al Tenaiji & Braimah 2016, p. 364).

Water resources in the UAE are categorized into conventional and non-conventional sources. Conventional sources are dependent on rain volume and include falajes, groundwater, flashfloods, and springs. Non-conventional sources are comprised of treated wastewater and desalinated water. Previously, the UAE depended heavily on conventional sources, but other alternatives such as non-conventional desalinated water have been added to the supply grid (see figures 5 and 6).

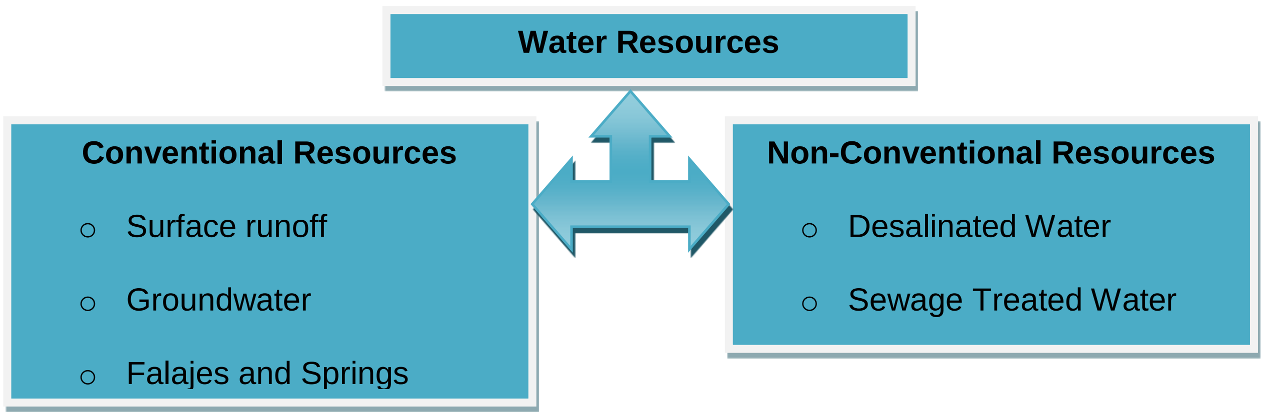

Figure 5: Water sources in the UAE

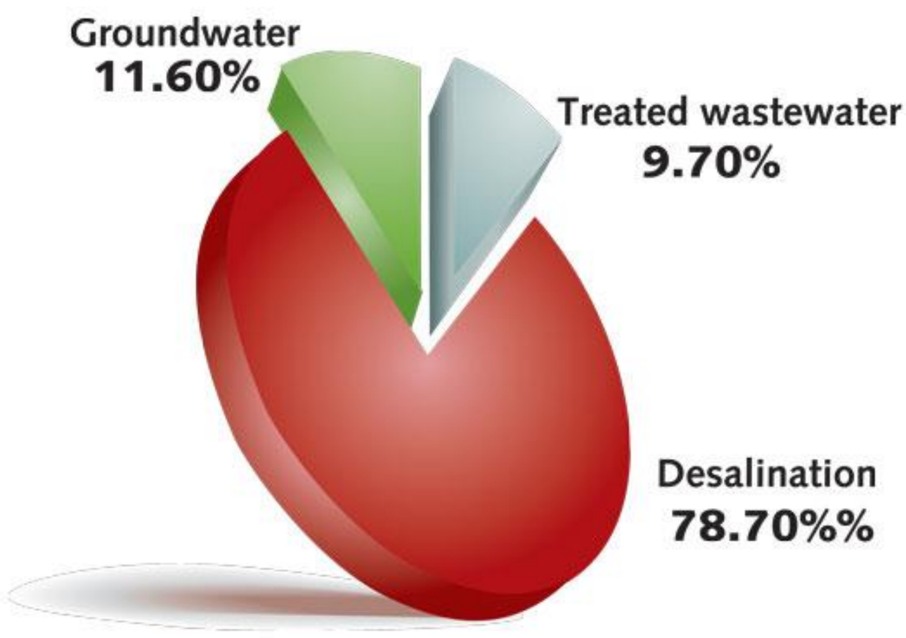

Figure 6: Water production per source

(Meldrum et al. 2013)

A surface runoff source is a conventional water resource having temporary and limited availability due to high evaporation and low rainfall rates. The estimated surface source in the UAE is 0.15 billion m^3 per year. The government has constructed 114 dams with capacity of 31,152 million gallons across the seven Emirates to collect and protect flood water, which is then used to recharge groundwater (Issa & Al Abbar 2015, p. 3). In the next 20 years, the Ministry of Climate Change and Environment has plans in place to build 68 more dams to hold 26,400 million gallons (Dakkak 2015). More than half of these dams are set to be built in the eastern region of the country. Based on the limitations of surface water, it is important to point out that this source of water is not popular in the UAE. Furthermore, this type of water source is only available in the Northern and Eastern parts of the country, which receive short rains.

Several springs in the UAE, such as Khatt, Maddab, and Bu Sukhanah, among others, are also a conventional source. Until ten years ago, falajes were the primary arteries of the water source in the eastern region of the UAE. However, many of these Falajes are now dry due to prolonged draught and excessive pumping of groundwater (Santhosh, Farid & Youcef-Toumi 2014).

The main conventional water source in the UAE is groundwater. The volume of water extracted from ground wells can be assumed to fall into two broad categories: renewable resources and non-renewable resources. Chandran et al. (2015 pp. 3-5) says it is generally difficult to find water in shallow aquifers because of the over extraction of the commodity through this resource and the low amounts of rainfall received throughout the year.

The quantity of groundwater being produced in the UAE is slowly decreasing as is reported in the findings of Hasanean and Almazroui (2015 p. 578), which reveal that in the year 2010 the production volume was 35,557 million gallons, while in 2016, it was 20,033 million gallons. The main agencies involved in water production have also reported similar declines in numbers because in the year 2000, four agencies (ADWEA, DEWA, SEWA and FEWA) extracted 12429, 2792, 9907, 10429.25 million gallons respectively, but in 2006, the quantity of water produced had declined to 476.17, 3230, 9407.3, 6920.46 million gallons respectively (UAE Statistics Center). Based on the above figures, the statistics obtained suggest that the total production of groundwater may have declined by more than 92%. However, Hasanean and Almazroui (2015 p. 578) say that this situation is not applicable to all Emirates because the production of groundwater in Dubai has remained relatively stable throughout the last decade. In fact, Al Awar (2014 p. 5) adds that in 2006, there was a slight increment in the total production of groundwater.

Different agencies have also reported varied findings on water production because a graphical analysis of the total water production by SEWA showed that there was a slight decline in the volume of water produced in 2004, but in 2006, the same agency reported an increase in production (UAE Statistics Center). Comparatively, FEWA reported a decrease in production in 2006 by 33.65%. Figure 7 shows that most of these agencies have witnessed a decline in production numbers.

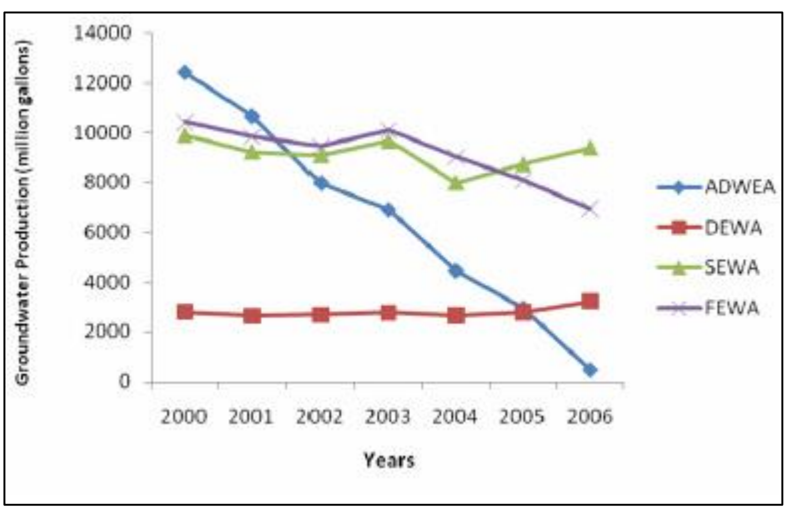

Figure 7: Groundwater production in the UAE between 2002 - 2006

(UAE Statistics Center)

Based on statistics provided by the UAE Statistics Center above, Abu Dhabi has the best record in managing its groundwater resources because recently, it curtailed the unregulated extraction of groundwater by increasing the production of the same commodity through the desalination processes. Nonetheless, related studies show that although such a move is commendable, the extraction of groundwater and the reduction in the same means that the quantity and quality of this type of resource has significantly declined.

A general overview of the figures presented in government reports and independent publications reveal that there are variations in the consumption and production of groundwater across different Emirates (UAE Statistics Center). Consequently, it is correct to assume that the production of this resource varies across different years and across different Emirates. The dependency on groundwater as a percentage of the total production of water in Abu Dhabi is about 14% (UAE Statistics Center). In Dubai, the percentage is 6, while in Sharjah and Eastern parts of the country, it is 47% and 64% respectively (UAE Statistics Center).

Generally, an assessment of current figures shows that the demand for groundwater in Abu Dhabi and Dubai, which are among the most developed Emirates in the UAE, has slowly declined amid an increased production of fresh water from unconventional sources such as desalination and water treatment. Even with this drop in the demand for groundwater, it is still important to point out that it is still higher than the rate at which this water source could be replenished. Statistics from Issa and Al Abbar (2015 p. 3) affirm this position because they say that the total demand for groundwater is about 237,000 million gallons, while the aquifers recharge only 33,000 million. Here, there is a deficit of more than 200,000 million gallons, which will have to be filled through the production of water, using non-conventional means. The huge deficit has been attributed to an increase in population growth and rapid economic development in the UAE. Several publications sampled in this study have also revealed that the deficit is a product of the vibrant agricultural sector, which consumes up to 70% of the groundwater supply. Therefore, the reduction in the quality and quantity of groundwater has made it difficult for the UAE to rely on it as a main source of water.

Notable groundwater aquifers include “the limestone aquifers in the north and east, fractured ophiolite rocks in the east, the gravel aquifers flanking the eastern mountains from the east and west and the sand dune aquifers in the south and west” (United Nations 2013, p. 29). At present, the largest fresh groundwater reservoir in the UAE is located in piedmont plains alluvial deposits within the eastern mountains called the eastern and western gravel aquifers. However, increasing pumping activities have affected groundwater in several locations due to saltwater intrusion.

Since most of the groundwater exhibits high to low brackish salinity, use is limited to agriculture (Lubega et al. 2014). Hydrochemistry of groundwater sources varies and consists of calcium bicarbonate, sodium chloride, and magnesium sulfate, among others (Al-Otaibi , El-Sadek and Al-Zubari 2013). Over the years, the estimated total annual groundwater production has gradually decreased from 35,557.25 million gallons in 2000 to 20,033.93 in 2015 (Government.ae 2018). SEWA produced 9,907 million gallons of groundwater in 2000, but production dropped to 9,407.3 million gallons in 2015 (see table 2). Through a groundwater dependency management policy, SEWA has managed to reduce “this dependency from 47.22% in 2000 to 33.22% in 2010” (Alawar 2014, p. 27). At present, groundwater dependency is decreasing substantially as the UAE has switched to non-conventional sources such as treated wastewater and desalinated water. However, groundwater use is still high in comparison to annual recharge rate and production. Should this trend persist, a deficit in reservoirs providing groundwater is projected, which must be covered by expensive desalinated water production (Susskind & Zaerpoor 2017). The substantial variation between recharge points and groundwater abstraction is associated with increasing demand for water in the UAE related to economic development and population growth (Santhosh, Farid & Youcef-Toumi 2013). Moreover, expanded agricultural practices accounting for more than 70% of groundwater consumption are also associated with increased demand. At present, the continuing groundwater deterioration and reduction are a hindrance to sustainability of this water source in the UAE.

Source	**Quantity (MCM)**	**Percentage (%)**
Groundwater	1,850	43.7
Treated water	615	14.5
Desalinated water	1,750	41.4
Surface water	16	0.4
Total	**4,231**	**100**

Table 2: Water sources percentages

(Clean Energy Business Council 2014)

The seven Emirates are supporting existing deficits in conventional water sources by using non-conventional alternatives such as desalination of brackish water and seawater. By the end of 2006, the government had built more than 36 desalination plants across the seven regions (Farid 2015). Production of desalinated water across the UAE has increased over the years. The volume of desalinated water produced in the UAE increased from 134,412.8 million gallons in 2000 to 277,942.14 million gallons in 2013. Specifically, SEWA was able to increase its production of desalinated water from 11,075 million gallons in 2000 to 18,438.54 million gallons in 2013 (Domonkos 2014). In parallel, dependence on desalinated water has increased from

52.78% in 2000 to 69.22% in 2013. Over the last five years, the UAE government has invested more than AED 3 billion in desalinated water plant development or improvement projects as this source is one of the most reliable and sustainable. According to Gonzalez et al. (2016 p. 415), the dependence on desalinated water varies across different regions because the Northern and Eastern parts of the UAE rely on a blend of both groundwater and desalinated water for their operations, while Abu Dhabi and the Dubai mainly rely on desalinated water for their operations. The reason for this disparity is informed by the fact that the northern and eastern parts of the UAE rely on groundwater because they are closer to the refill areas. However, experts estimate that the reliance on groundwater will drop within the next decade and they will soon join their counterparts in Abu Dhabi and Dubai in relying on desalinated water.

Based on the above developments, desalination is a critical source of water for the UAE. The Abu Dhabi government has recently strived to increase the quantity of water produced in this manner. For example, a report by the UAE Statistics Center reveals that between 2005 and 2015, the quantity of water produced this way increased by 57.6%. From 2014 to 2015, there was also an increase of 1.4% in the quantity of water desalinated in Abu Dhabi. Figure 8 below provides a summary of the production of desalinated water, as reported by the Abu Dhabi Water and Electricity Company.

(Million cubic meters)

Item	2005	2011	2012	2013	2014	2015
Total of available desalinated water	**742.7**	**1,000.0**	**1,085.7**	**1,113.2**	**1,152.4**	**1,170.5**
Production	637.5	855.3	884.2	901.1	924.7	936.5
Supply from Al - Fujairah station	105.3	144.7	201.5	212.1	227.6	234.1

Source: Abu Dhabi Water and Electricity Company

Figure 8: Production of desalinated water

(UAE Statistics Center)

According to Saif, Mezhar and Arafat (2014 p. 329), the annual consumption of desalinated water in Abu Dhabi is about 1,154.6 million cubic meters. The daily consumption rate is about 3.16 million cubic meters, while the daily per capita average is 1.14 cubic meters. Abu Dhabi leads all other Emirates in the UAE in the consumption of desalinated water because reports show that the desalination process supports 57% of its domestic water consumption (UAE Statistics Center). Comparatively, Al Ain and Al Gharbia regions consume about 28.6% and 14.4% of the total water desalinated respectively, making them the second and third highest dependants of desalinated water for domestic consumption (UAE Statistics Center). Figure 9 below shows a summary of the average consumption of desalinated water between the year 2005 and 2015, according to the Abu Dhabi Water and Electricity Company (ADWEA).

Year	Annual consumption	Average daily consumption	Average daily consumption per capita*
2005	667.1	1.83	1.33
2011	962.4	2.64	1.22
2012	1,060.1	2.90	1.25
2013	1,083.5	2.97	1.19
2014	1,128.8	3.09	1.16
2015	1,154.6	3.16	1.14

Figure 9: Average consumption of desalinated water between the year 2005 and 2015

(UAE Statistics Center)

Together with Kuwait and Saudi Arabia, the UAE completes a trio of countries, which are the main users of desalinated water in the Middle East. In fact, an excerpt of a report by Dakkak (2015) shows that these three countries account for up to 70% of the total production of desalinated water in the Middle East. The first desalination plant was installed in Abu Dhabi in the mid 1970s (Ouarda et al. 2014, p. 258). This plant had a capacity of 66,000 gallons of water per day (Ouarda et al. 2014, p. 258). Relative to these facts, different researchers have pointed out that the water problem in the UAE is an old one and its existence today implies that it has worsened over the decades.

Since the population of the country is increasing and local industries are demanding more water, the UAE has found the need to build more desalination plants. By the end of 2006, 36 desalination plants were in operation (Issa & Al Abbar 2015, pp. 1-3). Additionally, FEWA operated 10 more desalination plants in the Northern and Eastern parts of the country (Issa & Al Abbar 2015, pp. 1-3). Nonetheless, most of these facilities are in Abu Dhabi, Dubai and Sharjah, which collectively host 24 desalination plants. Additionally, Umm Al Quwain has two plants (Issa & Al Abbar 2015, pp. 1-3).

However, Abu Dhabi and Dubai still register the highest production of desalinated water because they have a huge population of immigrants who are seeking stability and residence in these Emirates. At the same time, the two regions have significantly high levels of economic development, relative to other Emirates. Today, there is a strong dependency on desalinated water in all Emirates, compared to past years, where groundwater was the main source of water in the UAE.

Many agencies within the nation are also increasingly relying on desalinated water to carry out their activities. For example, ADWEA's operations rely on the desalination process by more than 90% (UAE Statistics Center). This percentage is in sharp contrast to past years when it only relied on the desalination process to support 80% of its operations. DEWA is another agency, which relies extensively on desalinated water. Reports show that 95.2% of its activities are supported by the production of desalinated water (UAE Statistics Center). Comparatively, in the year 2006, 92% of its operations relied on desalinated water. SEWA and FEWA have had a significantly lower dependence on desalinated water (UAE Statistics Center).

The second non-conventional water source is treated wastewater. This source is categorized by the UAE government as a supportive or backup to the water used from agricultural activities, which take up to 70% of all groundwater production (Abu Dhabi Food Control Authority). At present, treated wastewater accounts for 8.9% of total annual water production (Al-Otaibi, El-Sadek & Al-Zubari 2013). Since conventional water resources have experienced unpredictable shortages, production of treated wastewater in the UAE is steadily increasing by about 10% annually since this source can also be used for domestic purposes (Farid 2015). More than 34 wastewater treatment plants are operating in the UAE with an estimated capacity of 42.438 million gallons daily. Expansion of treated wastewater production relates to shortages in water availability, presenting a serious risk to the agricultural sector (Chowdhury, Mohamed, & Murad 2016). At present, more than 70% of all treated wastewater is consumed in irrigation and landscaping. Ever-increasing production of treated wastewater has been necessitated by water shortages that might seriously affect the agricultural industry (Farid 2015). The number of waste water treatment plants have also increased recently because there are about 19 million waste water plants in the country, which have a capacity of 233,502 million per gallon (in terms of water production) today (UAE Statistics Center). Since 2006, experts estimate that the production of freshwater from wastewater has increased by up to 92% (Abu Dhabi Food Control Authority). Dubai has witnessed some of the most dramatic increases in wastewater production because from 2006 to 2015, the total volume of water produced from this type of water source increased from 19,008 million gallons to 37512.424 million gallons (UAE Statistics Center). Sharjah is home to seven wastewater treatment plants in the UAE. Ajman does not have the same number of wastewater treatment facilities, but is on course to build a few of them and allow the Ajman Sewage Service Limited to manage them (UAE Statistics Center). Comparatively, Fujairah is home to six water treatment facilities with an estimated production capacity of 3.1 million gallons of water per day. The wastewater treatment process in the UAE involves preliminary treatment, secondary treatment, tertiary treatment, sludge treatment, and pumping to storage tanks (Mamoon & Rahman 2017). Generally, great efforts have been made by the UAE government to address the challenge of water scarcity through use of conventional and non-conventional water sources. However, the problem of persistent scarcity is still troubling the UAE water management system. Therefore, this research proposes strategies for improving the water resources management system to guarantee better optimization of any management policy or plan for sustainable functionality.

2.4 Water Resource Management in the UAE

All the Emirates' regions have a hyper-arid to arid climate characterized by infrequent rainfall and high temperatures. During summer, the average temperature is about 45 degrees Celsius, and humidity averages 97%. On a daily basis, the average rate of evaporation is 8.2 mm with about 9.8 hours of sunshine. Annually, the mean rainfall is 120mm (Government.ae 2018). All Emirates have noted the significance of conserving water resources as a foundation for present-day and future policy-based sustainable development. Since the UAE region is endowed with marine, coastal, and terrestrial ecosystems, the government has put in place national legislation focused on addressing environmental issues such as sustainable water resource management (Mamoon & Rahman 2017). Notwithstanding the arid climate, the UAE has an expansive and thriving farming industry propelled by modernized and mechanized irrigation using water resources from desalination plants, wastewater treatment plants, and groundwater aquifers (Santhosh, Farid & Youcef-Toumi 2014). As result, it is not possible for the UAE's agricultural industry to expand as large tracts of land are currently being farmed. At present, more than 100,000 hectares of land are being cultivated and irrigated annually to produce vegetables, fruits, fodder, and more (Government.ae 2018).

Every year, the total demand for water in the UAE is gradually increasing. The demand currently stands at 4.5 billion cubic meters (BCM) annually, while the UAE's renewable freshwater resources are about 150 million cubic meters per year (Todorova 2014). Therefore, it is estimated that if the current demand rates and pattern persist for the next five to ten years, the annual water demand is projected to double to about 9 to 10 billion cubic meters, which is double the current rate (Mamoon & Rahman 2017). Specifically, the greatest increase is expected to come from the rising urban demand for water for commercial, industrial, household, public facilities, and institutions due to commercial and population growth (Domonkos 2014). Moreover, forestry and agricultural water demand is also "expected to decrease relative to current values as a result of depleting groundwater resources, unless treated wastewater or desalinated water resources are used as alternative sources" (UNDP 2013, p. 9). The rising need for desalination could be attributed to oil discovery since revenues from these natural resources are used by the UAE to invest in the water resources management system and other economic development initiatives. These investments have resulted in increased economic development accompanied by an influx of workers, which has expanded water consumption over the last two decades. Saif, Mezhar and Arafat (2014) have noted that desalination needs will rise in the future. Fortunately, the government has invested heavily in this area, which is an indication of forethought and awareness in planning for future integrated sustainable water resources management.

The UAE has also put in place a proactive Water Conservation Strategy (WCS), created in 2010 under the Ministry of Climate Change and Environment (Todorova 2014). The WCS offers frameworks for systematic and sustainable water resources management in the UAE to the year 2021 (Gelil 2013). These frameworks are accompanied by eight strategic initiatives, such as “developing an integrated water management approach, improving natural water resources management, developing a national agricultural policy to conserve water, managing efficiently desalinated water, rationalizing water consumption, developing water pricing and subsidy policies, and better managing wastewater”(Government of Abu Dhabi 2014). However, despite these actions and activities, the UAE government has never issued a comprehensive report discussing progress in achieving the WCS initiatives.

2.5 Water Consumption in the UAE across different sectors

Water Consumption in the UAE varies from one sector to another, with the agricultural industry taking the largest share of 60%, while the domestic sector consumes 25%. The industrial sector takes a 9% share, and commercial and municipal segments take up to 31% (see table 3 and figure 10). Despite accounting for about 1% of the total UAE GDP, irrigated agriculture is the primary water user with an annual average of 60% of all produced water. Of this share, 39% is consumed in productive agriculture, while 11% is used in landscaping and greening (Gelil 2013). The rest is utilized in forestry. According to Voss et al. (2013 p. 904), the agricultural sector is among the leading consumers of water in the UAE because it accounts for about two-thirds of all water consumed in the nation. The main reason for its position as the leading consumer of water is the rising population of the UAE, which has caused a significant surge in the demand for food. Some researchers have cautioned that this sector could also be responsible for some level of wastage of this precious resource (Voss et al. 2013, p. 904). Those who advance this view say that low levels of efficiency in irrigation methods are largely responsible for this problem. Current statistics show that it takes about 15 liters of water to irrigate a $1m^2$ of agricultural land in the UAE (Voss et al. 2013, p. 904). About 30% of the water used in this type of irrigation is lost through evaporation (Dakkak 2015).

Of total water consumption in the UAE, 40% is used in the municipal/commercial and industrial sectors. Most of the water used in the industrial sector is for purposes of machine maintenance. The wastewater often accumulates as run-offs and is released into the environment as impurities. However, as Joodaki, Wahr and Swenson (2014 p. 2679) point out, this water is not necessarily lost because it could be used for purposes of irrigation. Irrigation water is often not used efficiently due to the fact that most farmers still use the furrow and flooding techniques in cultivating high-water-uptake crops with low yield value (Clean Energy Business Council 2014). Recently, the government has come up with improved technologies that are more efficient than the traditional flooding approach, such as drip irrigation, which is expected to reduce wastage by up to 35% (Todorova 2014). Since 70% of the UAE population lives in urban areas, rapid urbanization projects and massive real estate construction have increased municipal and commercial water consumption to 31%.

Year	**2002**	**2005**	**2010**	**2015**	**2020**	**2025**	**2050**
Household (MCM)	830.7	1,045.5	1,571.9	2,363.2	3,274.6	4,923.2	6,646
Industrial (MCM)	332.9	381	477.1	597.3	715.1	895.4	1,791
Agricultural (MCM)	2,340.6	2,753	3,637.8	4,865.5	6,207.1	8,561	8,561
Total (MCM)	**3,504.2**	**4179.5**	**5,686.8**	**7,826**	**10,196.8**	**14,379.6**	**19,138**

Table 3: Water consumption per sector from 2002 with projection to 2050

(Government.ae, 2018)

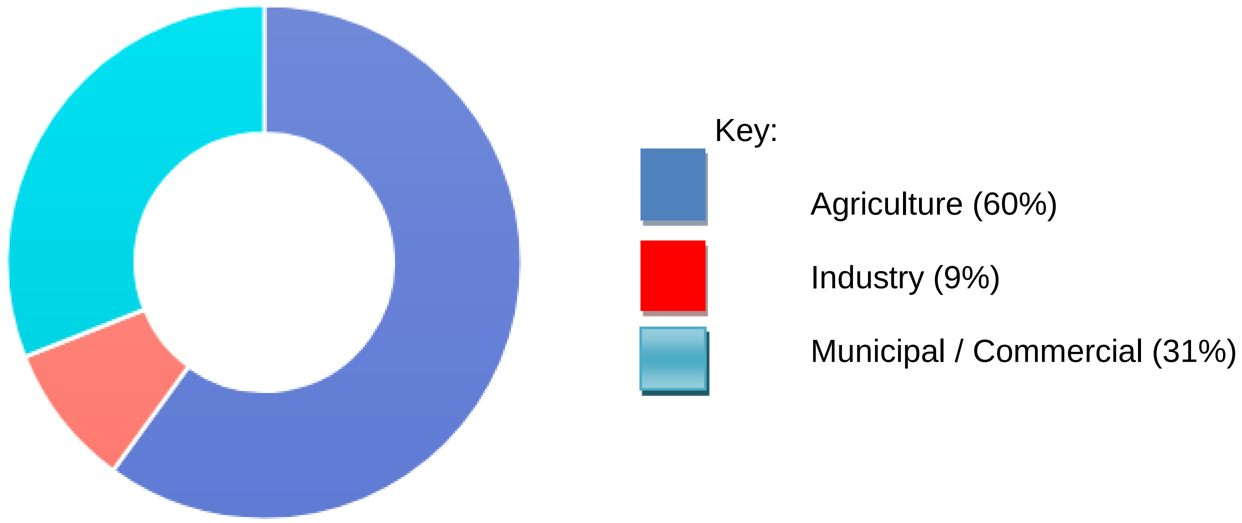

Figure 10: Water consumption per sector

(Farid 2015)

The domestic sector is also a considerable water user in the UAE. According to Al Awar (2015 pp. 3-5), it accounts for about 24% of the total water consumed in the country. In this sector, a large quantity of the water is used for air conditioning purposes because it is inevitable that a large majority of homes would have such a system due to hot temperatures all year round (Al Awar 2015, pp. 3-5). Most air conditioning systems not only use large quantities of water in cooling pipes, but also contribute to a high cost of energy through the electricity that powers them. A deeper review of the consumption of water patterns in the domestic sector shows that the UAE has among the highest per capita consumption of this resource in the Middle East (285 liters annually) (Joodaki, Wahr & Swenson 2014, p. 2679). Most of the water is used to produce bottled water using the desalination process.

A general analysis of the consumption of desalinated water in the UAE shows that different economic sectors have different consumption needs. The commercial and industrial sectors are the top consumer of desalinated water followed by domestic water consumption, government, and agriculture. Figure 11 below shows a detailed analysis of the percentages of water consumption associated with different economic sectors.

(%)

Sector	Abu Dhabi	Al Ain	Al Gharbia
Domestic	57.1	28.6	14.4
Commercial	69.1	16.3	14.6
Government	56.4	24.1	19.5
Agriculture	47.7	50.0	2.3
Industry	68.6	25.5	5.9
Other Sectors	0.0	100.0	0.0

Figure 11: Percentages of water consumption associated with different economic sectors

(UAE Statistics Center)

Experts project that filling water bottles from the desalination process could cost up to 11.8 billion AED annually (Dakkak 2015). The ratio of bottled water production standards vis-à-vis the quantity of water used is also inefficient because producers of bottled water use up to three liters of water to make one liter of bottled water (Joodaki, Wahr & Swenson 2014, p. 2679).

Still in the domestic water use sector, observers have pointed out that water misuse is an impediment to the effective management of water in the UAE (UAE Statistics Center). For example, several of them have noted that the use of spray irrigation for purposes of landscaping and water gardening leads to the ineffective use of water (Dakkak 2015). Since such methods cause water wastage, environmental experts have proposed a raft of measures that people could use in their households to reduce their overall water consumption levels (Dakkak 2015). They include the introduction of new tariffs based on the current water billing system, increased sensitization of the public about water conservation methods, the promotion of new and efficient ways of irrigation (mostly drip irrigation), and the supply of safe drinking water through taps (Dakkak 2015). Based on these recommendations, authorities have been challenged to rethink their strategies of water conservation in the country.

2.6 Regional Breakdown of Water Use and Sustainability Index in the UAE

Different regions of the UAE have varied water consumption patterns and needs. Indeed, an analysis of the water consumption patterns by Kumar and Ouarda (2014 p.119). across different regions also show disparities in water use patterns. According to the Abu Dhabi Water and Electricity Company, Abu Dhabi is a leading water consumer in the UAE at 4,323 MCM because it has more agricultural land in addition to intense urbanization projects. Figure 12 below shows a regional breakdown of the leading consumers of desalinated water in the Abu Dhabi. Dubai is at 1,234 MCM per annum (Todorova 2014). The third and fourth positions are occupied by Sharjah at 897 MCM and Ras Al Khaimah at 675 MCM, respectively. The Emirates of Ajman, Umm Al Quwain and Fujairah display an annual consumption of 259, 567, and 643 MCM, respectively (Al-Zubari et al. 2017). In terms of regional consumption, the coastal region consumes 69% of annual water production compared to the mainland's 31% usage.

(Million cubic meters)

Region	2005	2011	2012	2013	2014	2015
Total consumption	**667.6**	**962.4**	**1060.1**	**1083.5**	**1128.8**	**1154.6**
Abu Dhabi	414.3	593.1	653.6	657.5	683.9	695.1
Al Ain	161.3	259.3	286.6	293.4	294.4	316.7
Al Gharbia	92.0	110.0	119.9	132.6	150.5	142.8

Figure 12: Regional breakdown of the leading consumers of desalinated water in the Abu Dhabi

(UAE Statistics Center)

Although Abu Dhabi is a leading consumer of water in the UAE, it is also ranked among the highest in the country in terms of water sustainability index (UAE Statistics Center). Dubai is also another Emirate that shares the same ranking. These indices are global, as pointed out by the Arcadis' Sustainable Cities Water Index, which has explored how different global cities rank in terms of water sustainability, based on three key criteria: efficiency, resiliency and quality. Although these rankings show that Abu Dhabi and Dubai lead other Emirates in terms of water sustainability, different experts have urged the UAE government to invest more in other Emirates to improve their water sustainability levels (Kumar & Ouarda, 2014, p. 119). The goal is to improve their resiliency in water management, based on the rising urbanization levels in the country.

2.7 Challenges in Water Resource Management in the UAE

Periodic evaluations of the water management practices in the UAE have helped experts to find out the nature of the gap that exists between the supply and demand of water sources in the Gulf Nation. As mentioned in this chapter, water resource management in the country is being plagued by a declining supply of water. A review of the findings developed by several researchers who have delved into this issue shows that there is an uptake in the production of desalinated water compared to groundwater, which is decreasing in prominence (Kumar & Ouarda, 2014, p. 119). This situation means that the current water consumption trend is geared towards the adoption of non-conventional water resources as the main source of the commodity in the country. One of the most obvious challenge facing agencies that are involved in the management of this resource in the UAE is the desert climate of the country.

The location of the country is an arid area means that it will also have to experience the challenge of high evaporation rates. Relatively, statistics show that up to 75% of the UAE's rainfall is lost in this way (Almulla et al. 2014, p. 1318). At the same time, groundwater that is located close to the surface of the earth is affected by this phenomenon. Furthermore, studies have shown that rainfall quantity can also be affected by high evaporation rates before it reaches the ground (Almulla et al. 2014, p. 1318). Such a phenomenon often leads to a deterioration of the quality of groundwater. This decline is often visible because there is a huge demand for water in the UAE.

Abu Dhabi and Dubai have the lowest concentration of rainfall in the entire country (Almulla et al. 2014, p. 1318). This is why the two Emirates have been known to rarely rely on groundwater sources. Nonetheless, there is a relationship between rainfall patterns and the production of desalinated water, as is visible in Sharjah. Researchers have used this emirate to show that the amount of rainfall received does not necessarily contribute to an improvement in the water situation when all other factors, such as a rise in human populations remain constant (Almulla et al. 2014, p. 1318).

Groundwater salinity is also another problem in the production of freshwater in the UAE. It mostly affects the extraction of groundwater, which becomes limited in use especially when salinity levels are high. Consequently, people are left to rely on desalination, which is often an expensive process of water production (Bienkowski 2015). Here, it is important to point out that different regions of the UAE have varied salt levels. Furthermore, over time, experts have notice changes in salt levels, as has been reported in the northern and eastern parts of the UAE, which have experienced tripled salinity levels (Bienkowski 2015). The central parts of the UAE have also seen a doubling of the salinity levels.

Another challenge associated with water management in the UAE is the burgeoning human population, which has been mainly fanned by an increase in economic activities. Many immigrants around the world come to look for work opportunities and find the UAE a viable location to live and reside. Therefore, the number of immigrant workers in the country has increased the demand for water (Gonzalez et al. 2016, p. 415). Comparatively, an increase in the birth rates within the nation has also added to the pressure. The surge in human population has also spurred an increase in food production, which has a domino effect on the agricultural sector that has recently registered an increase in water demand for purposes of food production (Gonzalez et al. 2016, p. 415).

Since groundwater production is declining, an increase in the reliance on desalinated water also accentuates the financial challenges associated with the process because experts have confirmed that setting up and maintaining a desalination facility is expensive (Bienkowski 2015). In the US, they estimate that a thousand gallons of water produced from the desalination process could cost citizens up to $5 (Bienkowski 2015). Comparatively, it would cost the same person only $2 to get this resource from conventional water sources (Bienkowski 2015). The establishment of desalination plants also comes with huge energy demands because collectively, it is estimated that these plants consume about 200 million kilowatts each day (Bienkowski 2015). To put these figures in context, one cubic meter of freshwater produced from the desalination process could consume about 10 kilo-watts of energy, while freshwater only takes less than 1 kilo-watt of the same energy (Bienkowski 2015). Relative to this data, energy is considered a significant cost of production for such plants because it accounts for up to 55% of operation costs (Gonzalez et al. 2016, p. 415). The desalination process also comes at a significant cost to the environment because it could affect salt water levels in the ocean. This outcome may affect marine animals that live around water extraction zones. At the same time, the process involves huge extractions of water from the sea, thereby affecting sea levels. Although the desalination process is energy-intensive and expensive, it is an old technology in the Middle East because, for many centuries, communities often evaporated brackish water and used the condensed by-product for domestic and agricultural use. The concept has often been simple – remove salt from the water. However, over time, the process has become more complex because of the wide scale nature of water demand experienced today.

Middle Eastern countries have dominated the desalination industry out of necessity because of the harsh climatic conditions in the region. Around the world, experts estimate that there are 17,000 desalination plants, which are located in more than 140 countries (Bienkowski 2015). Although nations, which have harsh climate, are leaders in the adoption of the desalination technology, an increasing demand for water around the globe have seen countries that do not share the same climate also adopt the same water production method. The International Desalination association says that the industry's capacity is growing at an annual rate of 8% per annum (Bienkowski 2015). Australia and Singapore are some regions of the world where heightened activities in the establishment of desalination plants have been reported (Bienkowski 2015). However, currently, the Middle East is still home to more than 70% of the world's desalination plants (Issa & Al Abbar 2015, pp. 1-3). The leading gulf countries that have adopted this technology are Saudi Arabia, the UEA and Kuwait. Other countries that have also embraced this method of fresh water production are Bahrain and Qatar (Issa & Al Abbar 2015, pp. 1-3). Collectively, they are investing hundreds of billions of dollars to set up desalination plants. Saudi Arabia alone has invested up to $25 billion to improve its water desalination infrastructure (Bienkowski 2015).

Although this method of freshwater production is promising, experts have warned Middle Eastern countries that the process could soon become unsustainable because when the wastewater (brine) is pumped back into the sea, it further increases the salinity levels of the water, thereby making it much more difficult and expensive to extract fresh water from the same source (Bienkowski 2015). This phenomenon has been referred to as the "peak salt" phenomenon. In fact, reports show that brine could be twice as salty as the seawater from which the initial desalination water was extracted (Issa & Al Abbar 2015, pp. 1-3). The UAE faces a challenge of preventing further contamination of its seawater reserves because geologists have warned that this source of water is not adequately reliable because the gulf coastline is shallow (more like a lake, as opposed to an ocean) (Bienkowski 2015). Its depths have been estimated at only 35 meters (averagely) (Bienkowski 2015). Most of the rivers that feed the water body have been diverted upstream, further increasing the salt levels in the sea. When these factors are combined with the deposit of brine in the same water body, it becomes easier to see how the desalination process could become more expensive for the GCC countries.

2.8 What the Government is doing

Based on the current water problem experienced by the UAE, the government has tried to take proactive measures to alleviate the situation by injecting desalinated water into strategic water reserves (UAE Statistics Center). The initiative has been spearheaded by associated government agencies, such as the Environment Agency (EGA) and Abu Dhabi Water and Electricity Authority (ADWEA). The strategic reserves are known as aquifers and they are expected to provide water supply for up to 90 days (UAE Statistics Center 2018). However, the reserves are not intended for everyday use because their application has been limited to times of peak demand or emergencies (Government of Abu Dhabi 2014). Stemming from such guidelines, some water conservation experts in the Middle East have proposed the adoption of more immediate government intervention to set standards for the use of water-saving installations (UAE Statistics Center 2018).

According to the Government of Abu Dhabi, the water management strategy for the UAE is divided into different jurisdictions. Every emirate has its water management plan. For example, Abu Dhabi has its water management plan, which is in line with its vision 2012 strategic plan (Government of Abu Dhabi 2014). The Abu Dhabi Executive Council (in conjunction with the national government) spearheads the plan and it strives to promote a 5-year roadmap that would see the emirate improve its water management strategy (Government of Abu Dhabi 2018). The overarching goals of the water management strategy are as follows:

1. Set the overall direction of the water management plans including the set targets and how to achieve them
2. Provide necessary guidelines for every stakeholder involved in the water management sector for purposes of improving alignment and coordination
3. Set a framework to monitor and evaluate progress made in the realization of the aforementioned goals.
4. Inform all stakeholders in the water management sector (including private and public partners) about the importance of better water management techniques for purposes of inculcating proper water management strategies in their lives.

The general design of the water sustainability framework is to help people understand where the country is in terms of water management, where it should be, and how it should get to the desired goal.

The government of the UAE has been in the forefront of promoting sustainability and conservation through creating open access to awareness campaigns, online consumption calculators, statistical information, and public participation. These strategies are integrated in supply and demand management techniques (World Economic Forum 2016). Under its supply management strategy, the UAE government has been proactive in research to find alternative technologies for effective desalination processes that can save costs and improve sustainability (Malek 2013). Since 80% of the UAE's potable water is from desalination plants, the government has been experimenting with alternative offering lower energy use. Several policy approaches have been created to manage the supply aspect of water resources management. According to Al-Otaibi, El-Sadek and Al-Zubari (2013), the UAE government has defined a four-scenario narrative to be accomplished by 2050. This strategy integrates "Markets First, Policy First, Security First and Suitability First scenarios" (Al-Otaibi, El-Sadek & Al-Zubari 2013 2013, p. 31). The 'Market First' scenario emphasizes strategic economic growth irrespective of cost implications. Through internalization of technological advancements for development of the UAE economy, it is expected that environmental and natural resources such as water will be depleted, thus increasing health risks (Chowdhury, Mohamed & Murad 2016). In order to avoid this situation, the government has opted for a public-private partnership in water resources management in order to lower the economic burden while attracting investments in the sensitive water resources sector (United Nations 2013). The 'Policy First' scenario envisages public participation, constitutional review, and transparency in water resources management (Malek 2013). This scenario emphasizes environmental protection and the well-being of the UAE citizens. The 'Security First' scenario envisions appropriate budgetary allocations directed toward water governance from environmental, economic development, and social perspectives (Al-Zubari et al. 2017). However, current investment in research and development for other non-conventional water resources in the UAE targets private companies. The 'Sustainability First' scenario aims to address solutions to current challenges in water resources management in the seven Emirates. Specifically, this scenario recommends integration of long-term strategic planning through heavy investment in training, capacity development, and educational programs (Clean Energy Business Council 2014). For example, the UAE government has increased investment in research and development over the last 20 years to attempt to solve such water problems as unpredictable supply, climate change, and contamination of the network (Government of Abu Dhabi 2014).

The ‘Sustainability First’ and ‘Policy First’ approaches in the UAE have resulted in quick and positive progress without compromising economic development. These technological advancements, achieved through continuous research and development and proactive government investment in the current water resource infrastructure, have created a relatively stable integrated water resources management system (Chowdhury et al. 2016).The UAE government has also been proactive in managing demand for water resources by employing strategies designed to lower demand while increasing supply. According to Saif (2014), the government has given demand management more attention than supply management to minimize new and unplanned investment in water infrastructure. For example, the UAE is currently using 60-90% of its groundwater resources to meet agricultural needs (World Economic Forum 2016). Out of this quantity, it is estimated that more than 45% of these water resources are wasted due to poor farming practices (Government of Abu Dhabi 2014). As a result, the government has increased research and piloting of better irrigation strategies to increase food security while sustaining water usage (Clean Energy Business Council 2014). In managing the demand side in its water resources strategy, the UAE government has been working on several technical efficiencies associated with water usage such as smart meters, consumption regulators, and tax breaks for effective large-scale water users (Al-Zubari et al. 2017). The government is also promoting water conservation through increasing access to public awareness and participation.

2.9 Conclusion

The literature review has extensively acknowledged the significance of sustainable water resources management within the UAE. The topic is wide and should be approached in a scientific manner in order to address matters of priority in use and sustainability of water resources in the short and long term, especially in terms of policy governance and planning. The challenges in the current integrated sustainable water resources management system should be solved in the UAE, especially considering the ever-rising population and increasing demand for water. Although the government has implemented policies and measures to balance the water supply and demand management through its Water Conservation Strategy, the benchmarks for tracking progress and effectiveness are not clear. Admittedly, the government's actions constitute positive steps toward formalized management of water resources, but challenges in aspects of the effectiveness and efficiency of these policies remain.

The literature review has identified several factors that the UAE government faces in securing its water resources. One identified literature gap involves lack of reports that highlight and track the progress of the current water resources management initiatives. Therefore, it is difficult to quantify the performance of these strategies. This research paper attempts to address this gap by examining the progress and possible recommendations for creating a proactive integrated sustainable water resources management system for the seven Emirates making up the UAE. The recommendations will also facilitate the improvement of effectiveness, efficiency, engagement, and trust in water resources governance.

Chapter 3: Methodology

3.1 Introduction

This chapter examines the method to be applied in collecting data and analyzing the results. Since this study was focused on a specific location, the UAE, the researcher gathered data for quantitative and qualitative data analysis, and conducted a survey among professionals working in the water and wastewater sector. The choice of quantitative and qualitative analysis was informed by the need to properly facilitate a proper understanding of attributes related to water resources management as influencing sustainability (Sherif 2018). From the research survey of 56 respondents, mainly managers and supervisors of the UAE water management institutions, the research will analyze the results in order to identify the current policies, strategies, and challenges as part of sustainability governance. Application of this approach is necessary in facilitating identification of different statistical patterns emerging from the collected data as related to the variables of study (Mason, 2017). The collection of water consumption data relating to the UAE for quantitative analysis was carried out using reliable government and scholarly sources.

3.2 Research Design

The research design approach was through filling out a scale based survey targeting managers and supervisors in both government and private institutions that work in the water and wastewater sector. The survey was also sent to end users and/or consumers of the supplied water and recycled water. This approach was combined with quantitative data collected from secondary sources. The rational for a mixed research design was informed by the need to emphasize on qualitative results supported by published government data on water consumption to expand statistical accuracy (Sherif, 2018). In addition to the survey, the research included involving scholarly sources, journal articles and data from UAE water and statistical management institutions. Since the proposed study is dynamic, subjective, and focused, the researcher used mixed method to accommodate several tools of analysis and minimize the potential margin of error.

3.3 Research Questions

This research paper is aiming to overall answer the following questions:

1. Which approaches could be implemented to enhance sustainable water management in the UAE?
2. What approaches could be implemented to improve water resource management in the UAE?
3. What's the level of public awareness on the high level of water consumption rate?

3.4 Setting and Sample

The researcher begun by compiling relevant themes captured in the literature review on water resources management best practices and current state in the UAE. This was followed by compilation and probing of the survey questions. The researcher then pre-tested the questions by asking two officials to confirm their reaction and relevance of the proposed interview questions (Sherif, 2018). The responses from the pilot study were used to generate the final list of questions. The setting for conducting the survey was through sending out the survey link to a list of individuals identified as water professionals, as well as posting the link on social media in order to get some end users and consumers to partake.

3.5 Survey Variables and Hypothesis

The purpose of the survey was to explore and give an insight into various variables which influence the efficiency, consumption rates, and water management in the Integrated Water

Resource Management (IWRM) practices. Upon concluding the literature review, a few variables were highlighted to have an impact on an Integrated Water Resources Management Plan. Those variables were divided into two types: dependent variables and independent variables. The dependent variables were the water network's efficiency (E), the water management plan (WM) currently followed and the user's consumption rates (CR). This research is also exploring other routes that policy makers can follow in order to optimize their water usage in order to properly manage their water resources. Therefore, the independent variables are the usage of Treated Sewage Effluent (TSE), increasing Public Awareness (PA), installing Smart Water Metering Systems (SWS) and adopting Green Building Codes (GBC). Based on those variables, the following conceptual framework was developed to run the 3 hypothesis models against the collected answers:

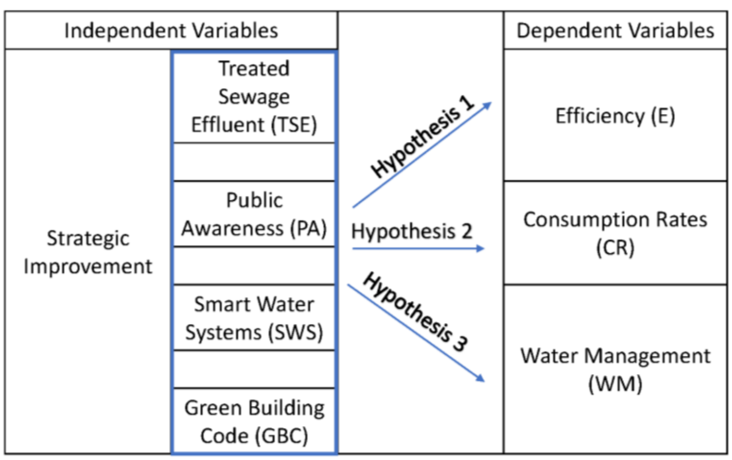

Figure 13: Conceptual Framework of Hypothesis Development

Each dependent variable was modeled against all four of the independent variables, and linear regression analysis was run to assess their dependency on each other. Therefore, the 3 developed hypotheses are as follows:

Hypothesis 1: The network's efficiency (e) rate when treated sewage effluent is being utilized more, when there is an increase in public awareness, if smart water metering systems were heavily installed and if green building codes were made mandatory.

Hypothesis 2: Dropping down the end user's consumption rates (CR) if they had more access to treated sewage effluent, if the public knew that the can have access to more TSE or about how the quality of TSE being produced is high, managing the access to potable water and therefore promoting the use of TSE, and installing ESMA approved appliances that save water which the green building codes support.

Hypothesis 3: Having a water management plan (WM) which then promotes the use of TSE, sharing the plan with the public in order for them to follow, insisting on government entities and developers to install smart water metering systems and implement green building codes in the country's building specifications.

3.6 Data Collection

For the survey, the data was collected via the online survey website, and then analyzed through SPSS software. In addition, this study relied on secondary data as the main source of information. The researcher selected this data analysis method for the study because its scope was nationwide, thereby making it difficult to adopt other methods of data collection without considering the possibility of a budget escalation. Secondary data was mostly obtained from reliable sources of information such as the Abu Dhabi Water and Electricity Authority (ADWEA) and the Federal Electricity and Water Authority (FEWA). Other research data sources that were included in the study came from the Dubai Electricity and Water Authority (DEWA), and the Sharjah Electricity and Water Authority (SEWA). Additional information was obtained from journals and credible websites. Generally, the data collection strategy pivoted on four keywords namely: UAE, water, resource, and management. Research materials were obtained from credible sources of data, such as Emerald, Sage publications and Google scholar. From the process, 70 articles were retrieved using this data collection strategy.

3.7 Data Analysis

Both qualitative and quantitative data analysis were performed by the researcher. The qualitative analysis was based on the survey results that were tabulated to identify a common trend (Bryman & Bell 2015). Quantitative data analysis involved reviewing published water conservation and consumption data from Federal Electricity and Water Authority (FEWA), Abu Dhabi Water and Electricity Authority (ADWEA), Dubai Water and Electricity Authority (DEWA), Sharjah Electricity and Water Authority (SEWA), and Competitiveness and Statistics Authority. The data captured was for a period of ten years, that is, from 2001 to 2015. The researcher organized the collected published data into sector wide consumption, authority wide consumption, and population growth. This set of data was selected because they would facilitate a proactive analysis of challenges in water resources management and general consumption sustainability (Sherif 2018). For instance, population growth rate data was used to analyze the impact of population expansion on consumption of water resources. Generally, an increasing growth in population is expected to put pressure on consumption of water besides increased expenditure to meet demand. Moreover, the sector and authority wide sets of data were collected to examine the rise or fall in water consumption and create a trend for future projections. The collected published data indicated that consumption of water resources has increased steadily in the last ten years, especially in agricultural and domestic sectors (Mason 2017). The rationale for using two sectors in the analysis was informed by the segregated nature of data from other consumption sectors. In addition, quantitative data from the conducted research survey was collected. 22 questions made up the survey, with 56 respondents taking part.

3.8 Assumptions in the Study

This study was premised on the use of secondary research data to answer the research questions. Using published information comes with its own merits and demerits, some of which form the basis for the assumptions, limitations and delimitations of this study. For example, one basic assumption in this study is that the data collected from the secondary sources are credible and reliable. This view comes from the fact that the data relied on in this study were developed by other researchers. While it is easy to account for a researcher's bias in primary research, it is difficult to account for the same in secondary research. Therefore, while the current paper relies on secondary data, the basic assumption is that the researchers took all necessary care to produce quality findings.

A second assumption of the study is that the technology applications proposed in this paper for improving water resource management are freely available and could be implemented in the UAE without much resource limitations or legal constraints. Here, the premise of this assumption is that there is a general willingness for local authorities and UAE residents to improve their water conservation efforts by employing better and more efficient technologies in their water resource management.

3.9 Limitations of the Study

The main limitations of this study are enshrined in the quality of information collected. For example, some of the materials used in the current research may be influenced by research biases related to the original studies. In other words, it is difficult to know whether the original authors of the documents reviewed may have had biased views, which could also have affected their findings. Relative to this concern, the current research was only focused on including credible and reliable research documents for assessment. Furthermore, to overcome this limitation, precaution was taken to only include quality secondary research materials by closely scrutinizing their origins. Additionally, careful attention was given to evaluate the reliability and validity of the materials used. The process involved a keen review of how the primary researchers, collected, analyzed and presented their data.

Another limitation of this study is that the secondary information obtained for review in this paper is not proprietary. In other words, the information relied on for purposes of conducting the research was not meant for the study; instead, it was produced to meet other research goals. Consequently, the researcher has no information advantage to employ in the paper. Another limitation of this study is that some of the statistics, facts, and technologies mentioned in this paper, as possible and useful contributions to the UAE water management strategy, may change over time and differ in form, design or application. Therefore, their application is limited by the relevance of their contribution to current water management problems in the UAE.

Time was also another limitation of the study because the study had to be submitted within a specified period. This reason explains why it was difficult to undertake a primary research. Therefore, the researcher had to analyze the findings and present it within a relatively fixed duration. Lastly, the findings of this study may also not be applicable to countries that do not share the same water problem or climatic conditions as the UAE. For example, some of the technologies proposed in this paper for supporting water management may not necessarily be applicable to countries that do not share the same resource constraints as the UAE. Similarly, some of the information highlighted in this paper may not be applicable to all Emirates in the UAE because of geographical differences, which may affect water production and conservation efforts. Furthermore, the UAE does not have uniform water problems across all regions; some of them have dire water management challenges, while others have a relatively manageable water crisis.

3.10 Delimitations of the Study

The delimitations of a study refer to processes that the researcher deliberately chose not to undertake. One of the delimitations of this study is the exclusion of research materials published outside a five-year time scope. The aim of doing so was to make sure that the information included in this research was current and relevant to the research topic. Evidence gathered and analyzed in this paper also only applied to arid and semi-arid regions. In other words, the data relied on in the study were particularly relevant to countries that have similar environmental conditions as those of the UAE. The aim of doing so was to come up with technology applications that would be relevant to the UAE and Dubai. This expectation is cognizant of the fact that certain types of technologies may not be applicable in Dubai or countries that have arid and semi arid climate.

Another delimitation was deciding not to conduct interviews with professionals in the water resource management sector. This was mainly due to the difficulty of setting interviews with government officials and consultants. As a part-time student, I hold a full time job, which makes setting up meetings with the officials and professionals in their after-hours quite challenging.

3.11 Conclusion

The qualitative research involved direct interviewing a sample of individuals that work in both government and private water resources management institutions in the UAE. The quantitative research was carried out through collection of published data on water consumption in the UAE for a period of 15 years. Another quantitative approach was through running a survey and creating a framework with which we were able to assess if the identified variables will help or improve the water resources management plan currently being followed in the UAE. The small sample space might result in biases from limited insight. However, the research will probe and code each question to guarantee consistency and accuracy in presentation and analysis. The rationale for selecting a mixed research design was informed by the need to establish the current insight in water management policies and relate them to the trend from secondary data.

Chapter 4: Research Findings

4.1 Introduction

This chapter presents the results from the survey conducted and the secondary data that was used to explore the research topic. More than 70 articles were generated from the process, but not all of them were included in the review, based on an examination of the same articles using the exclusion and inclusion criterion mentioned in the chapter above. The findings analyzed within the framework of the four themes (preservation of the environment and water sources, improvement of the policy and legal environment, application of smart systems to enhance water conservation, and setting up of new systems to enhance water quality and supply) are highlighted in this chapter.

4.2 Survey Data Findings

For the qualitative data, the survey was sent to 75 professionals, and 56 only have completed it, making the response rate 74.6%. The results and findings of the survey were obtained from linear regression models using Statistical Packages for Social Sciences version 23 (SPSS 23.0). It is understood that there are various softwares which can be used to give statistical results. However, SPSS is capable of creating highly valuable information which can lead to more reliable conclusions and decision making (Paura & Arhipova 2012). The results of the study areas discussed below. As summarized in table 4, the respondents work in the following water and wastewater sectors:

Entity	# of Respondents	%
Authority/Government	**21**	**37.50**
Consultancy	**15**	**26.79**
Contractor	**9**	**16.07**

Supplier/Vendor	**1**	**1.79**
End User/Consumer	**10**	**17.86**

Table 4: Respondent's sector demographic

The regression analysis was used to show how various factors influenced the respective endogenous variables. In addition, Analysis of Variance (ANOVA) was used to show the level of statistical significance of F statistic.

Hypothesis 1: Regression results on Efficiency (E)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	GBC, PA, TSE, SWS[b]	.	Enter

a. Dependent Variable: E

b. All requested variables entered.

Figure 14: Input Variables for Hypothesis 1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.949[a]	.900	.892	.24495

a. Predictors: (Constant), GBC, PA, TSE, SWS

Figure 15: R Reading of Hypothesis 1

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.436	4	6.859	114.317	.000[b]
	Residual	3.060	51	.060		
	Total	30.496	55			

a. Dependent Variable: E

b. Predictors: (Constant), GBC, PA, TSE, SWS

Figure 16: ANOVA Results of Hypothesis 1

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.488	.229		2.130	.038
	TSE	.661	.063	.790	10.404	.000
	PA	.162	.067	.135	2.406	.020
	SWS	.159	.063	.196	2.523	.015
	GBC	-.089	.070	-.095	-1.262	.213

a. Dependent Variable: E

Figure 17: Coefficients result of Hypothesis 1

In the regression model to determine influence of the independent variables on efficiency, the independent variables that were regressed are, Treated Sewage Effluent (TSE), Public Awareness (PA), Smart Water Systems (SWS) and Green Building Code (GBC). ANOVA results showed a statistically significant F test statistic with P value less than 0.001. Also, from the results, it can be seen that the goodness of fit (R) was 0.949. this shows that 94.9% of the efficiency is explained by the variables in the model, thus only 5.1% depends on other residual factors or random shocks in the environment. Moreover, the P values of the coefficients of the regressors shows that TSE showed the highest statistically significant positive influence on Efficiency at 1% significance level (P= 0.000). PA and SWS also showed statistically significant positive influence on Efficiency at 5% significance level respectively. GBC showed a negative influence. The constant also showed positive influence with P-value showing statistically significance influence on Efficiency (P= 0.038).

Hypothesis 2: Regression Results on Consumption Rates (CR)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	GBC, PA, TSE, SWS[b]	.	Enter

a. Dependent Variable: CR

b. All requested variables entered.

Figure 18: Input Variables for Hypothesis 2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.852[a]	.725	.704	.37578

a. Predictors: (Constant), GBC, PA, TSE, SWS

Figure 19: R Reading of Hypothesis 2

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19.003	4	4.751	33.642	.000[b]
	Residual	7.202	51	.141		
	Total	26.204	55			

a. Dependent Variable: CR

b. Predictors: (Constant), GBC, PA, TSE, SWS

Figure 20: ANOVA Results of Hypothesis 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.620	.351		1.763	.084
	TSE	.316	.097	.408	3.245	.002
	PA	.174	.103	.157	1.690	.097
	SWS	.306	.096	.409	3.177	.003
	GBC	.024	.108	.028	.223	.825

a. Dependent Variable: CR

Figure 21: Coefficients result of Hypothesis 2

In the regression model for the determinants of consumption rates, variables GBC, PA, TSE, and SWS were run as the independent variables. The results of the analysis showed Goodness of Fit at 0.852. this means, approximately 85.2% of the consumption rate is dependent on the regressed factors. Thus, 14.8% of the consumption rate is left to be determined by other factors not reflected on the model. This is a good show of fit, however, it shows that there is a need for other insightful studies to come up with other factors not explained in the model. Nonetheless, from the results, the coefficient of TSE still shows the highest positive impact on the consumption rates of water at 0.316 compared to coefficients of other variables. The P value of the variable (TSE) is also lowest, thus showing a higher level of statistical significance of the variable on the consumption rates. Finally, the constant coefficient also revealed a positive correlation with the consumption rate with P-value showing statistically significant level (p= 0.084). Just as in the case for determinants of efficiency, GBC did not show any statistically significant effect on consumption rates.

Hypothesis 3: Regression Results on Water Management (WM)

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	GBC, PA, TSE, SWS[b]	.	Enter

a. Dependent Variable: WM

b. All requested variables entered.

Figure 22: Input Variables for Hypothesis 3

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.760[a]	.578	.545	.56318

a. Predictors: (Constant), GBC, PA, TSE, SWS

Figure 23: R Square Reading of Hypothesis 3

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.142	4	5.535	17.453	.000[b]
	Residual	16.176	51	.317		
	Total	38.317	55			

a. Dependent Variable: WM

b. Predictors: (Constant), GBC, PA, TSE, SWS

Figure 24: ANOVA Results of Hypothesis 3

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.484	.527		2.819	.007
	TSE	.403	.146	.430	2.760	.008
	PA	-.068	.154	-.051	-.439	.663
	SWS	.474	.145	.523	3.282	.002
	GBC	-.126	.161	-.121	-.784	.437

a. Dependent Variable: WM

Figure 25: Coefficients result of Hypothesis 3

Similar to the influence on efficiency and consumption rates, the four independent variables were again used in a regression model to show their impact on water management. From the ANOVA results, F statistic showed a statistically significant difference with $P<0.001$. R was relatively lower (0.760) compared to the other two models. The almost average R square is evident to the fact that water management is not so much dependent on the predictors on the model. 76% of water management is explained by determinants, the rest depends on residual factors not included. This calls for more exploratory study to come up with more factors that will strongly predict the dependent variable. From the results, SWS showed statistically significant and strong positive correlation with Water Management (P=0.002). the results were also similar for TSE with the second highest positive coefficient among the variables (P=0.008). The constant also posted statistically significant positive correlation with P=0.007. Public awareness, as well as Green Building Code, did not show any statistically significant influence on Water Management.

4.3 Secondary Data Findings

Based on the evidence gathered in this paper, it is difficult to understand the importance of water resource management, without comprehending how it fits within the wider analysis of sustainable development. Their relationship is defined by the fact that sustainability is the overall goal of community development, while integrated water resource management is a strategy to achieve it. There is little debate regarding whether water is a dwindling resource, or not, in the UAE; the main point of discourse has been how best to address this problem. In line with this goal, the adoption of effective and sustainable water management practices appear to be the best solution to addressing the problem. Although the UAE has been a leader in spearheading sustainable development initiatives in the UAE, there is little evidence to show that the same goal is trickling down to how residents of the country use water. Indeed, as Arnbjerg-Nielsen et al. (2013, p.16) point out, the evidence gathered from the UAE regarding water resource management seem to demonstrate inappropriate water use patterns that are worsening the problem. Evidence supporting this fact appears in studies and reports that have shown how the bustling country has among the highest water consumption per capita in the Middle East and arguably around the world. In this regard, it is ironic that a country that has few water resources is among the highest water consumers in the world. Integrated water resource management should help to highlight this problem because it advocates for a holistic approach to water management.

Five key factors have been identified as having the greatest impact on the current water resources management practices in the UAE. These factors are climate change, water source, population growth/consumption, and sector-based consumption. Climate change is a threat to water management initiatives in the UAE since it affects the water cycle. Changes in the climate contributes to lower rainfall, higher temperatures, rise in sea level, extreme weather, and high evaporation rates. Since climate change is a natural condition, tackling its effects is challenging since their occurrence is unpredictable.

Nonetheless, current water management strategies in the UAE have been mainly focused on promoting a top-down management structure, where authorities and the government try to increase the nation's capacity of water production without tackling the rising demand of water, which is equally a significant contributor to the problem. For example, many communities in the UAE are digging deeper wells to tap into groundwater resources, but they fail to realize that this strategy will soon max out their reserves. Similarly, other communities have chosen to pipe their water from distant surface water sources (Al Qaydi 2016, p. 155). These strategies could provide short-term relief, but they come at an incalculable cost to the environment.

4.3.1 Smart Systems

Smart water management strategies have been voiced as a viable solution for the management of water resources (International Water Resources Association 2018). Its application has not only been confined to countries that have an acute water problem because cities and nations that have the resource, but want to manage it more efficiently, also use it (International Water Resources Association 2018). Smart water management is unique from other types of water management solutions because it uses information technology tools to manage water. At the same time, it relies on the use of large quantities of data for the same purpose (International Water Resources Association 2018).

The application of smart water management systems to solving problems associated with water resource management is widespread and covers different aspects of the same problem. For example, several reports sampled in this study show that it has the potential to be applied in the improvement of water quality, efficient agricultural use of water, increase in water quantity, drought and flood mitigation among many others (International Water Resources Association 2018; Al Awar 2015, p. 3). The same studies have shown that different tools exist in the management of water resources through the smart system. GIS technology, satellite mapping, smart meters and sensors are among the most commonly used resources because they are readily available technologies and have a proven record of accomplishment in different fields (and not just water quality management) (International Water Resources Association 2018).

Most of the literatures sampled in this paper and that focus on the smart system of water management have confined their analysis within the context of sustainable development (International Water Resources Association 2018; Al Awar 2015, p. 3). Therefore, the adoption of smart systems in water management is an offshoot of a larger framework of sustainable development that not only includes water resource management, but also energy management, and materials development. Sustainable water management is a subsection of resource management, which Dubai and many developing cities have included in their general visions and goals. This view is not only limited to the economic sector, but also in the social development sector, as is visible in the transformation of the global millennium development goals (MDGs) to sustainable development goals (SDGs).

Different researchers have varied opinions about smart water management systems, relative to what they believe are its constituents (International Water Resources Association 2018; Al Awar 2015, p. 3). However, most of them agree that this model tries to tackle the economic and social behavior of water users as a management strategy to conserve this resource (Donat 2013, p. 538; International Water Resources Association 2018; Al Awar 2015, p. 3). For example, the International Water Resources Association says this model should include principles of water resource economics within a management or policy context. It also adds that attention should be paid to the financial challenges that poor water resource management cause and the possible adoption of sophisticated management strategies to remedy the problem (International Water Resources Association 2018). One notable suggestion made by different researchers who have explored such smart management solutions is the introduction of smart meter pricing models (Donat 2013, p. 538; International Water Resources Association 2018; Al Awar 2015, p. 3). Relative to this context, some of them suggest that smart meters could be used to bill customers in a way that reflects the realities of water management and conservation standards (Donat 2013, p. 538; International Water Resources Association 2018; Al Awar 2015, p. 3). Particularly, the article developed by the International Water Resources Association suggests that such a smart water-billing model could open new horizons in water management because authorities would start to understand the importance of lining the consumer demand of this valuable resource to short-term and long-term water scarcity issues. Specifically, such proposals have been designed to influence consumer behavior.

Smart systems emerge as critical aspects of water resource management, which should be protected and supported. Three reasons underlie why this necessity exists. The first reason is centered on the fact that the smart system is instrumented (Donat 2013, p. 538; International

Water Resources Association 2018; Al Awar 2015, p. 3). This feature means that Dubai now have the ability to measure, sense and see what is happening on practically every stage of the water management process. The second reason focuses on the principle of interconnectedness, which means that people, systems and objects can easily be integrated in the smart system to develop or coordinate new ways of water management. The intelligence system that is embedded on the smart system could also be beneficial to Dubai and the wider UAE (including countries that want to adopt the model for water management) because it allows them to respond to changes quickly and accurately. Similarly, it allows the same entities to respond to changes faster and more accurately (Donat 2013, p. 538; International Water Resources Association 2018; Al Awar 2015, p. 3). Predicting and optimizing for future events allows them to do so much more efficiently.

4.3.2 Policy and Legal Environment

Many studies examined in this review did not expressly point out the importance of the policy and legal environment in influencing water management standards in the UAE. However, they alluded to this fact when outlining some proposals that would be useful in improving water resource management. Some of these proposals are highlighted in the subsequent chapter. Nonetheless, the policy and legal framework underlying water resource management in the UAE appears to be a prerogative of specific water management authorities (Abu Dhabi Food Control Authority n.d.). The national government formulates the overarching policy framework that guides all other processes involved water management, but specific Emirates also have an input into how such frameworks are implemented (Abu Dhabi Food Control Authority n.d.). The influence of the policy framework in water conservation efforts could have a significant impact on the outcome of water management in the nation because it is unlimited in the scope of its application. In other words, by tweaking the policy framework, it is possible to influence both demand and supply side issues of water management.

The UAE policy and legal framework governing water management appears to be segmented in the sense that different Emirates have specific powers that influence how they manage water in their jurisdictions (Abu Dhabi Food Control Authority n.d.). These disparities are partly informed by variations in water supply and economic potential to extract water or improve its infrastructure (Government of Abu Dhabi 2014). Understandably, population pressures and differences in economic activities also influence how such regions choose to manage their water resources. However, the problem created by such a system is the lack of coordination in water resource management. Similarly, there is a lack of a big picture perspective in the production and distribution of this resource. This problem could be highlighted from the failure of one emirate to understand how its economic activities or water management initiatives could affect the operations of another emirate. Therefore, the policy and legal framework that influences water resource management is disjointed in this regard.

4.3.3 Setting up of New Systems to Enhance Water Quality and Supply

The third theme that emerged in the review was the establishment of new systems to enhance water quality and supply. Extensive studies sampled in this review did not show better alternatives of supplying water besides surface water sources, groundwater sources, and desalination plants. As highlighted in chapter two of this paper, surface water sources in the UAE are rare because of the harsh climate. Similarly, those that are available are overstretched and have declined water quality because they have been overexploited over the years. The same fate characterizes the extraction of water from groundwater sources because water levels have been steadily declining and climate change has made rainfall more erratic and unpredictable.

This way, the water source does not replenish as fast as it is being depleted (because of human activities).

4.3.4 Preservation of the Environment and Water Sources

The preservation of the environment and water sources emerged as the last theme of this paper. Several studies sampled showed that the extraction of water through groundwater and the desalination process were destructive to the environment. More importantly, the greatest environmental impact associated with water production in the UAE was the energy-intensive nature of the process, which many researchers pointed out to have a significant carbon footprint on the environment (Almulla et al. 2014, p. 1318; Bienkowski 2015). They also showed that an expansion of the country's infrastructure to support the process could have a significant impact on marine life because the desalination process often leads to the production of brine, which affects alkalinity levels in the water, thereby affecting plant and animal life in the sea. The extraction of groundwater in the UAE has also been associated with a decline in water quality standards (Almulla et al. 2014, p. 1318; Bienkowski 2015). Collectively, the review showed that the UAE faces an environmental problem with the current methods of water extraction.

4.4 Conclusion

The findings of this paper drew the researcher's attention to four themes in the study. The themes were about the preservation of the environment and water sources, improvement of the policy and legal environment, application of smart systems to enhance water conservation, and setting up of new systems to enhance water quality and supply. These areas of discussion show that Dubai and the UAE in general have unique opportunities to address their water management problems, but limitations in understanding the nature of the issue inhibit their ability to act decisively.

Chapter 5: Discussion

5.1 Introduction

As highlighted in this paper, several factors have caused a serious strain on the available water resources in the UAE. It is untenable for the country to continue relying on its available water supplies and the associated technology without thinking of new and better ways of increasing its water supply. Consequently, this chapter highlights specific areas the country could focus on to address this problem. It connects the results of the study to current challenges in water resources management in an attempt to present alternative supply and demand governance that integrates the elements of trust/engagement, efficiency, and effectiveness. Innovation is key among them.

5.2 Summary of Survey Data Findings

With the purpose of the survey being to determine the influence of various independent factors of Integrated Water Resource Management on Efficiency, Consumption Rates and Water Management, the results obtained from ANOVA and simple regression reveal mixed findings. TSE and SWS were found to show positive and statistically significant influence on the three dependent variables. Public awareness showed statistically significant influence on Efficiency and consumption rates, while GBC had no significant effect for all the dependent variables. In relation to the outcome the hypotheses that, there is no significant effect of TSE, SWS and PA on Efficiency, Consumption Rates are rejected. Also, the hypotheses that, there is no significant influence of TSE and SWS on water management are rejected. The hypothesis that there is no significant influence of GBC on efficiency, consumption rates and water management is accepted. Finally, the hypothesis that there is no significant effect of PA on water management is also accepted. From the results there is mixed consistency and contradiction with previous findings, thus need for more research to come up with conclusive information.

Consistent results were obtained for PA and SWS respectively. For example, SWS was found in previous studies to show a positive correlation with Efficiency in water management by reducing monitoring cost and helping to predict future demand by giving a predictability of consumption changes (Davies et al. 2014). The findings are consistent with other empirical studies which have revealed that, when wastewater is well treated, it boosts consumers' confidence, thus increases the likelihood of its consumption. However, this goes hand in hand with the level of public awareness of such mitigation measures (Wang et al. 2018). From the results, public awareness also showed a positive impact on Consumption rate with P-value showing statistical significance level ($P = 0.097$). In the study conducted in China, multinomial logistic regression model revealed that there was a significant positive correlation between PA and levels of water consumption in a given residential area (Wang et al. 2018). Also, there was a strong positive correlation between SWS and consumption rates with P-value showing statistically significant effect ($P<0.005$). This is a finding similar to work obtained in previous empirical studies which revealed that water consumption rates are sufficiently dependent on Smart Water Systems. For instance, in a study, "Water-saving impacts of Smart Meter technology: An empirical 5 year, the whole-of-community study in Sydney, Australia.", a smart water system was found to be very important in monitoring consumer behavior in terms of consumption patterns and reduction of losses on consumption data (Davies et al. 2014). The smart water systems provide households with information regarding their level of consumption in real time, thus better management of demand and supply patterns. In a study to determine the level of sustainability of water as a resource, Treatment of Sewage Effluent was found to have a significant impact in the reuse of water, thus minimizing wastage. In an experimental approach, the United States Environmental Protection Agency have revealed, TSE has a significant impact on environmental sustainability by saving water and reducing energy consumption, thus positive spillover effects on the management of resources. The findings, therefore, reveal consistency to other previous studies.

5.3 Summary of Secondary Data Findings

As expounded in the literature review, the research study framework was based on examining the water resources management in the UAE and current challenges using the OECD's resource governance principles of engagement, effectiveness, and efficiency. A paradigm shift is suggested in the water management approach through integration technology, change of public wastage culture, and focused policy to guarantee sustainability. In specific terms, the integrated sustainable water resources management system in the UAE should include the principles of efficiency, effectiveness, and engagement. The effectiveness principle institutionalizes policies and processes, defining proper sustainability goals that target all water governance levels. This principle entails meeting and implementing set targets through a policy-oriented establishment of clear roles for stakeholders and water governance using appropriate scales. The framework should be coherent for all sectors for ease of enforcement. For example, a comprehensive capacity-building plan could address the challenges associated with end-user wastages to increase water sustainability. Water governance should be centralized for ease of managing data as opposed to the current fragmented approach, which is limiting the effectiveness of the UAE's Water Conservation Strategy (WCS) through increased inefficiencies. The efficiency principle in an integrated water resources management scheme examines the benefits of optimal supply and demand management at the least cost to the UAE society. In order to achieve this principle, it is recommended for all Emirates to share information and data through a centralized communication network, efficient allocation and mobilization of finances, heightening research innovation, and proactive building of regulatory frameworks. As noted in the OECD principles, a centralized data management in water governance would reduce fragmentation associated with inefficiencies. Moreover, there is a need for expanded investment in the water infrastructure to curb the current shortage and align production to demand through the use of new technologies. Reviews of several articles that have focused on water management show that few technologies have been introduced to solve the problem. The same finding is applicable even in some of the most developed nations of the world because they use the same technologies of water production and extraction that have existed since the 1970s. The desalination process seems to be the direction most countries in the gulf region and that have a serious water problem as the UAE are pursuing (Gonzalez et al. 2016, p. 415). Desalination is an expensive prospect because of direct and indirect costs to the environment. Therefore, using new technology would increase the level of efficiency. This principle is complete with relevant and comprehensive legislative and regulative frameworks being integrated. These frameworks will address extraction, production, supply, and usage within standard global consumption per capita. The government of the UAE is implementing most of the GCC initiatives on water resources sustainability, despite budget constraints. However, the consumption data indicated that more needs to be done to meet the demand of an ever-growing population in the face of depleting water resources.

Innovation in water sustainability is a relatively underexplored area of water management. There are few examples of the same in the world and more particularly in the Middle East. However, the UAE government has spearheaded an initiative to include the same strategy in the development of new and sustainable cities in the Nation. Masdar city is one such example.

The developers of Masdar city built it as a model metropolis centered on the theme of sustainable development. Sustainability is not only factored in the development of the city's infrastructure, but also on the resources that make it work (International Trade Administration 2018). Water is one such resource. However, based on the challenges that the UAE faces in terms of increasing the supply of this precious commodity, Masdar city experiences the same issues other cities within the country face. Nonetheless, what is unique about it is its design and management.

Unlike other cities in the UAE, which have grown organically over the years, Masdar city is planned and designed to be a sustainable one (International Trade Administration 2018). As such, there have been different experiments done within this city's framework to make sure that it operates sustainably. These experiments have focused on improving energy sustainability, encouraging the use of sustainable materials for infrastructure development, and maintaining the use of sustainable modes of transport (among others) (International Trade Administration 2018). Water sustainability is a key part of the city's sustainable framework as well because through the accomplishment of this goal, other cities within the UAE cold adopt the same model. In line with this vision, the UAE government has invested many resources in making sure that Masdar city has a water sustainable future. Its investments are still centered on extracting water through non-conventional sources.

As part of the innovation strategy, the UAE should consider implementing smart systems to improve its water management record. This approach is essential to the overall accomplishment of its strategic goals because the system will help it to better gather and analyze information more efficiently. We could use the model proposed by the International Water Resources Association to understand how the country could benefit from the adoption of such a water system management technique. This model has three main components that include smart water, smart traffic and smart energy (International Water Resources Association 2018).

The first concept of smart water is relevant to this analysis and it outlines how the UAE would benefit from the integration of smart technology to help in water use and management. This system could also help in the reduction of water use as well as create a decline in the use of related chemicals and energy that are often involved in water production and extraction. Broadly, the adoption of smart technology in the management of water resources would give the country an opportunity to rethink its water management strategy by acting more intelligently. One way of doing so is the efficient flow of data that would enable authorities to act faster and have a broader access to relevant information (International Water Resources Association 2018). Evidence exists that show how smart water management would also benefit the country by increasing the importance of water management to different aspects of community and organizational development. Since the UAE is engaging in the expansion of its infrastructure, the smart water management technology would help it to focus its efforts on developing the most important aspects of water infrastructure and get the maximum returns from returns.

As part of the focus on innovative solutions to address water problems in Dubai and the UAE, there have been proposals made by some experts for the UAE government to introduce concessions/discounts for people and organizations, which use water below a set minimum threshold (Donat 538; International Water Resources Association; Al Awar 3). Other researchers have proposed that since the UAE greatly relies on ground and surface water to meet its water demand, it should formulate policies that link the two (Donat 2013, p. 538; International Water

Resources Association 2018; Al Awar 2015, p. 3). In other words, the country's policy framework should acknowledge the relationship between the two because the management of surface water could have an impact on groundwater and the management of groundwater could equally have an impact on surface water quantities. Therefore, researchers who support this view say future planning and management processes should acknowledge this relationship (Donat 2013, p. 538; International Water Resources Association 2018; Al Awar 2015, p. 3). Furthermore, the government should make sure that there are adequate resources to make these approaches effective.

Relative to the above proposals, for a long time, the UAE government has been willing to introduce subsidies on different economic sectors to boost economic development and at the same time improve the standards of living of its residents. Water subsidies have been a huge part of this plan because this resource is essential for the sustainability of life. Similarly, it determines largely the quality of life of its residents. As part of its mandate to ensure proper water management, the UAE government has been cutting this subsidy. The recent subsidy cut happened in 2016 and another one preceded it in 2015 (Abu Dhabi Food Control Authority n.d.).

In terms of managing its water resources, some researchers have also proposed that the UAE needs to synchronize its water sustainability strategies to create a more comprehensive one that will not only appeal to the needs of each emirate, but also address the country's water requirements in general (Donat 2013, p. 538; International Water Resources Association 2018; Al Awar 2015, p. 3). This view stems from findings that have shown how each emirate has its own unique water sustainability plan. For example, as highlighted in the literature review section (chapter 2), Abu Dhabi and Dubai have their own unique water sustainability plans aligned with the vision of the respective Emirates (Government of Abu Dhabi 2018). This framework means that what Abu Dhabi is doing could possibly not be related with what Dubai is doing. Worse still, the strategies chosen by Dubai could inhibit the effectiveness of the water management plan of Abu Dhabi. Such a disjointed strategy in water management could prove to be costly for the UAE because it may breed the lack of coordination and synchrony in the management of water (Ramadan 2015, p. 179). Of importance is the need to understand that the resource is a natural one and it is for the entire country. A proper management of the same would require a holistic understanding of the management framework.

Relative to this finding, the evidence gathered in this paper has shown that there are multiple agencies in the UAE involved in water management. While this approach may be instrumental in covering different areas of water management, some researchers have said the UAE could improve its water management strategy by giving one organization the mandate to oversee the process (Donat 2013, p. 538; International Water Resources Association 2018; Al Awar 2015, p. 3). This approach could prevent incidences of duplication of roles or multiplicity of functions. This one body should further improve the coordination of water management initiatives across different sectors (such as the industrial, agricultural and domestic sectors, which are the biggest water consumers in the UAE). Since different tasks are associated with water management, such as education, awareness, distribution and production, the central water management body should also be in a position to institutionalize partnerships among different agencies that are assigned to undertake unique responsibilities within the water management chain.

Part of the problem with the current water management structure in the UAE is its failure to provide a holistic understanding of stakeholder involvement in the process. Within the principle of building trust and engagement, the UAE government should be proactive in their intervention mechanisms. Safeguarding stakeholder inclusiveness and building public assurance through promoting proactive engagement and transparency in water resources management may improve sustainability. Future strategic approaches of water management should make sure there is adequate public participation and stakeholder involvement in the process because their input is essential in the formulation and implementation of water management plans.

Public awareness of their high per capita consumption rate has to be in the forefront. The consumers are the source of the increase of supply due to their ever-increasing demand for water. Educational campaigns have to be more prominent, and included in the school's curriculums to plant a seed of conversation in our up and coming generations. The UAE is a country known for always giving to its people and residents, but we have reached a focal point where the people and residents have to assist the government is protecting this valuable commodity. A simple reduction in demand or per capital consumption management would lower pressure on the supply side. Increasing water prices to encourage conservation through reduced consumption has to be revisited.

As highlighted in previous chapters of this paper, the management of wastewater is also an important tool for improving the water sustainability standards of the UAE. The government has recognized this fact and is expanding its capacity to collect and treat this resource. In Abu Dhabi, the Emirate's water and sewerage company has spearheaded such an effort through the Strategic Tunnel Enhancement program, which aims to expand the region's infrastructure to collect more wastewater and treat it (Government of Abu Dhabi 2014). Estimates show that such a project could expand the current capacity of 450,000m^3 to 800,000m^3 (Government of Abu Dhabi 2018). More than $1.6 billion has been invested in such a facility (Government of Abu

Dhabi). The expansion is expected to cover anticipated growth in demand within the next decade.

Such projects are adopted within a larger understanding that there is a lot of potential in wastewater management that could help improve the efficiency of the country's water management system. For example, evidence shows that most wastewater collected in the country happens at the tertiary level and 45% of it is treated and reused (Government of Abu Dhabi 2014). This statistic means that up to 55% of wastewater could be treated and reused if the country expands its capacity to do so.

5.4 Conclusion

Researchers have proposed different opportunities for the UAE to improve its water management strategy. Most of the proposals highlighted in this paper are designed to improve the supply of water. Few innovative solutions have been sought. More importantly, few suggestions reported in this chapter have a long-term appeal. The last section of the paper below addresses how these concerns could be mitigated. The survey results also support the case of implementing smart water metering systems, raising the public's awareness on their high consumption rates and increase the utilization of treated sewage effluent.

Chapter 6: Conclusions, Recommendations, and Suggestions for Future Research

6.1 Recommendations

6.1.1 Enforcing green building codes for water efficiency and installing smart water metering systems

The UAE government should consider expanding the existing Unified UAE Water Strategy to ensure that the green building codes are enforced for water efficiency. Green building includes water conservation as a key component of its implementation. The United States Green Building Council also advocates for its adoption and it recommends that the first step contractors should make is to ascertain the quantity of water used in a building (Clemen n.d.). More importantly, they recommend the ascertainment of the relationship between water and energy consumption because both concepts affect water management (Clemen n.d.). By doing so, it would be easier for users to make well-informed decisions about their water use patterns. Modern technologies and innovations have led to the production of appliance systems and models for transforming water management practices. The government can formulate appropriate strategies to ensure that all private buildings and developments are fitted with advanced technologies for supporting water management (Ravishankar, Nautiyal & Seshaiah 2018). Installing smart water metering systems will improve leakage and pressure incidents, allow the consumer to monitor their own water consumption and help the relevant entities track the amount of water entering the system, and the amount that reaches their consumers. The current situation is that the government's decision to have similar systems in public or governments developments and structures has resulted in positive outcomes. If this proposal is to remain sustainable, the UAE government can go a step further to offer incentives and design attractive tariffs for the targeted owners. Various departments can be involved in order to deliver positive results (Russo, Alfredo & Fisher 2014). For example, sectors focusing on land use, water conservation, and sustainable building should come together to empower investors and guide them to embrace the proposed Integrated Sustainable Water Resource Management plan. Appropriate tariffs will encourage private owners to focus on this recommendation in an attempt to contribute to desirable water management practices. Similarly, monitoring water consumption levels could provide a strong ground for which users could monitor the performance of their water conservation programs. Moreover, government agencies will be empowered by a more focused enforcement policy that offers a clear legal framework (Madden, Lewis & Davis 2013). Green building codes could be institutionalized across the water management authorities and other relevant government bodies into a coherent policy to avoid current challenges in enforcement such as poor coordination among stakeholders. Furthermore, green building codes could be centralized during enforcement to improve on water efficiency (Singh & Singh 2014). For example, it would be appropriate to open offices across the seven Emirates to enforce the codes with their headquarters in Abu Dhabi. This will avoid the scattered approach and internal divisions among enforcement agencies. The data gathered revealed that FEWA recorded an annual shortage of 4,000 MIG (Lubega et al. 2014). Through effective endorsement of green building codes, this shortage could be reduced substantially and might even end over a longer period of correct mapping (Dawlabani 2013). Green building is a solution that should be adopted in the UAE to improve the demand-side issue part of its water management efforts. This approach also aligns with the quest for countries that suffer from such acute water challenges to manage their water consumption levels.

Generally, the following three types of technologies that are green building code friendly could complement water management efforts in the UAE, can be enforced:

6.1.1.1 Aerator Taps

Green buildings are designed to maximize the efficient use of water. Different approaches could be used to reduce water consumption in such types of buildings. For example, the use of mixed taps could help to regulate the temperature of water used in the buildings, thereby leading to low energy consumption and improved levels of comfort for users. In line with this technology, experts propose that contractors could install aerator taps to reduce the quantity of water used in these buildings (Rodin Group Company 2018). This technology most involves the installation of filters on taps to regulate the flow of water in buildings. Studies show that aerators could lead to up to 87% savings in water use because they use isoflow technology, which minimizes water flow by providing a steady, but minimal, water flow for users (Verità 2016; Rodin Group Company 2018). The isoflow technology is different from conventional technologies used in regular taps because it ensures the precise control of water. Notably, it has the ability to maintain the flow of water, despite fluctuations in its pressure (Rodin Group Company 2018).

These kinds of taps often have a pressure-sensitive membrane, which regulate the water flow at any given time. Similar taps also contain a distributor disc, which, if in perfect working condition, make sure that the water runs steadily (Rodin Group Company 2018). This technology also draws in more air, thereby making the aerator gentler with the flow of water. By doing so, users get to experience a comfortable and even water supply. Studies show that well-functioning aerators could save between 40% and 60% of water (Rodin Group Company 2018). When properly installed and used well, these aerators are able to pay for themselves in water, cost and energy savings within a couple of weeks

(Rodin Group Company 2018). Their unique design also allows the taps to be self-cleaning, thereby requiring little maintenance compared to regular ones. Additionally, the filter design makes sure that no dirt particles obstruct water flow because when dirt passes through the fine stainless steel filters, they are trapped and released through the coarse filter (Rodin Group Company 2018). Since the water supply is centralized in the taps, it becomes difficult for any trapped dirt to affect the water spray through the nozzle. This type of technology also prevents taps from dripping. Relative to this view, the Rodin Group Company says that dripping taps could cause several thousands of water annually. Such a technology could also reduce the quantity of water wasted through negligence. If applied well, this technology will provide a constant supply of water in buildings without any compromise to the comfort and effectiveness of the commodity's supply. Aerators have a wide application base because there is evidence of their use in different institutions, such as universities, sports facilities, schools, gyms, industrial washrooms, offices, care homes, and hotels (Rodin Group Company).

6.1.1.2 Preservation of Rainwater

Although this paper showcased that the UAE's region receives little rainfall in a year, it is possible to save the little quantity of water received during the rainy season. This is possible through the adoption of water harvesting technology. Such a technology is not widely adopted in the UAE because few building contractors consider rainwater to be a reliable source of the commodity. However, research shows that it is better to harvest the little water available rather than letting it go to waste (Rodin Group Company 2018). According to Clemen (n.d.), rainwater should be harvested from the rooftops of buildings and stored in a percolated reservoir. Doing so could help to reduce the quantity of portable water that would be used in a commercial or residential property.

Besides installing pipes and rails for trapping rainwater, contractors should also be required to install panels on the roofs to help in energy management. A key feature of this technology is the reliance on green energy to power facilities that will be used in the buildings. The most common application of this technology in the construction sector is the use of solar panels as part of the roofing structure. Old buildings have also adopted the same concept through the addition of solar panels on their roofs. Most contractors prefer to use this technology because of its ability to convert solar energy into electricity (Clemen n.d.). This type of technology could be easily adopted in the UAE because it does not require extra space to install; instead, the solar panels are easily mounted onto existing roofs. Even though households in the UAE that have adopted this type of technology get to harvest significant volumes of water during the rainy season, they mostly use it for irrigation and gardening purposes (Rodin Group Company 2018). However, its application could be widened to include the restoration of groundwater. If collected and treated well, this type of water collected could help boost water conservation efforts in the UAE. Comprehensively, this green building technology could help to save water that would otherwise go to waste whenever rain falls.

Naturally, rainwater is acidic because it mixes with carbon dioxide in the atmosphere (Rodin Group Company 2018). Consequently, it needs to be stored in plastic or metallic water tanks. Experts have proposed the use of a concrete or limestone tanks for domestic water storage (Rodin Group Company 2018). They have also shown that such types of technology are in line with green building solutions. In many parts of the UAE, rainwater is rarely recuperated and even when this happens, its use is mostly confined to irrigation purposes. The use of green building technologies provides an opportunity for people to optimize rain water in ways that would make UAE households to be autonomous in rainwater management.

6.1.1.3 Thermostatic Meter Taps

There are different kinds of thermostatic meter taps that are often used in green buildings. They include taps that use infrared technology for water conservation and those that use short-lever thermostatic processes. The latter is among the most widely adopted features of green building technology and is commonly known for its ability to prevent scalding. It is also simple and easy to install because most of its parts are readily available and done on the surface level of the water basin. This design feature ensures little "down time" in the installation of the same. It also has flexible water inlet pipes for easy installation and could be used in different types of buildings. Experts have recommended its use in different kinds of projects because it is compatible with many plumbing systems (Rodin Group Company 2018). The taps also contain a level with sequential control, which could allow users to shift between hot and cold temperatures. Nonetheless, schools and hospitals (or environments which have a high safety standard) often use it.

Taps that have the infrared technology normally provide a pre-mixed supply of water, which gives users an option to get water at the right temperature (automatically), whenever they open the tap. An infrared sensor is often included in the design of such taps and its purpose is to regulate the temperature of water at any given time. It also leads to significant water quantity savings because the taps only pass six liters of water per minute (Rodin Group Company 2018). The maximum time that the tap could run is 2 minutes and then it automatically shuts itself to conserve water. It is also easy to maintain because it has in-line filters.

The installation of thermostatic meter taps could lead to the realization of water savings in Dubai because it helps to save water that would be otherwise lost when people adjust the temperature for water use. Some literatures refer to this technology as the "adaptive heating unit" process (Rodin Group Company 2018). It works in the same way as the thermostatic meter taps because it adjusts the water temperature to the right measure before a consumer starts to use it. By regulating the power distribution accordingly, residents are not only able to save on water, but also on energy. Although the above-cited recommendations are likely to yield an increase in water savings in the long-term, it is important to mention that their efficiency depends on the existing knowledge of green building solutions and the correct estimation of water demand of the UAE in the short-term and long-term.

It is important to point out that the adoption of green building solutions could improve water conservation efforts by up to 50% (Katz et al. 2016, p. 335). This view is in line with the recommendations of the Rodin Group Company (2018), which says that water conservation in an average household can be increased twofold if innovative water management solutions are adopted. It is also important to point out that the proposed green building strategies highlighted in this paper align with the goals of the UAE's water security strategy 2036. The same strategies proposed in this paper discuss assisting to reduce the demand for water and its associated energy input. They also contribute towards the improvement of water productivity index by a significant margin because they are part of the UAE's efforts to reduce its reusability capacity. Based on a reduction in water demand, it is also possible to project a situation where there would be a decline in water scarcity in the future. Since most of the green building technologies adopted in this study have a low cost of implementation, it is easy for early adopters to see its payback. The adoption of demand-side solutions for water management has been done in different parts of the world. The following section of this paper explains some of these examples.

6.1.2 Promoting the use of Treated Sewage Effluent (TSE) for Irrigation for both public and private land

In the UAE, different municipalities have managed to embrace the TSE concept to irrigate their farms or landscapes. This practice is capable of maximizing a country's economic potential while at the same conserving this natural resource. This means that the country can tap this potential and eventually support its ISWRM plan. The outstanding recommendation is that the use of TSE is something that should become a mandatory rule across the country. This approach will create the best environment for reusing water and minimizing a wide range of problems, including pollution, droughts, and severe weather conditions. There is also a need for proper policies to ensure that private citizens and developers utilize TSE for their landscape areas. Bielsa and Cazcarro (2015) believe that the UAE government should be keen to develop laws to ensure that the quality of TSE produced is unified. This means that the recycled water will be suitable for the targeted purposes or specifications, such as agriculture and landscaping. Relevant government agencies and researchers can conduct numerous studies in an attempt to examine if TSE is utilized efficiently in all identified specifications or purposes. The case of Australia offers powerful incentives or ideas for implementing TSE as a powerful model that can promote water management and sustainability. In this country, there are policies and guidelines that all companies and municipalities should consider whenever recycling wastewater. The implementation of this initiative has resulted in a situation whereby every region uses TSE to irrigate farmlands, landscapes, parks, sports fields, parks, and racecourses. The targeted objective is for Australia to produce 12 percent of the demanded water from TSE. Similarly, different states in America have adopted meaningful policies to ensure that water is recycled to meet the increasing demand for natural resources (Zadeh et al. 2015). Gardens, landscapes, and parks have benefited from this idea. The existing policies require that specific metal compounds and hazardous chemicals are removed from the recycled water. There is a need for the UAE to consider these examples in order to improve the quality of TSE used in different landscapes and farmlands (Saliba & Finan 2016). This model will make it possible for the country to manage most of its natural resources and realize its ISWRM plan.

6.1.3 Raising Public Awareness

The third recommendation that can make a difference revolves around the use of powerful measures to raise awareness. As discussed in the previous chapters, the UAE remains one of the countries in the Middle East with the highest per capita consumption. This is a clear indication that more people might be unable to access clean water in the future unless those involved implement appropriate measures to deal with this predicament (Suh et al. 2014). With this understanding, it can be necessary for the government to raise awareness and encourage its citizens to embrace evidence-based practices for conserving natural resources. This goal can be realized if members of the public are guided and empowered to promote best practices that can result in reduced consumption rates. The UAE can begin by examining the example of Germany. Jacobs et al. (2016) indicate that German Development Cooperation (GDC) has been making a positive case for managing water since it is one of the natural resources that can reduce conflicts and empower people to achieve their potential. By involving different stakeholders, the agency has created awareness and encouraged all citizens to attend various campaigns and seminars promoting the conservation of natural resources. India is another country that has embraced the power of modern technologies to promote this idea. A new concept has emerged embraced in this country whereby farmers use their mobile devices to turn off and on their irrigations systems (Russo, Alfredo & Fisher 2014). This model has managed to reduce the amount of water different people waste. Bindra et al. (2014) go further to encourage governments to introduce water conservation as a core topic or unit for discussion in learning institutions. These measures can empower and guide more young people to minimize their water consumption rates. Government agencies should improve on their current efforts in disseminating information of water consumption and the need for increase green living as part of conservation strategies (Abusa & Gibson 2013). Private and public organizations could partner to provide nationwide consumer educational programs and initiatives. These campaigns should integrate multilingual, simplified, illustrated, and visible messages directed at building awareness in the UAE (Battor & Battour 2013). Through this approach, the relevant water management bodies will improve the value and importance of water conservation to reduce end-user wastages.

6.1.4 Updating the country's infrastructure to include smart metering systems and modern desalination plants.

The UAE has a robust economy with one of the highest rate of urbanization in the world. The commercial and municipal water consumption has been rising to serve the expanding demand. In order to sustain the supply and demand sides of water resources management, there is a need for updating the current water infrastructure through the use of reliable, efficient, and effective modern technology (Harrison 2018). For instance, integration of smart meter technology might reduce wastages associated with leakages due to end-user negligence. The smart meters could also empower the end-users to track their consumptions periodically and to be in control of how much water they consume (Al-Ansari 2015). Moreover, the smart meter can detect uneven flow or leakages in the water system (Chowdhury, Mohamed & Murad 2016). As a result, the government will be in a position to accurately manage consumption while minimizing wastages that are threatening the current water management approach (Harrison & Wicks 2013). Moreover, it is necessary for the UAE government to invest more resources in new technologies for water desalination plants to reduce the high costs associated with running these production factories. The new technology in desalination and general supply network will substantially improve the efficiency and effectiveness of the entire water network (Guiso, Sapienza & Zingales 2015).

6.1.5 Collect the non-revenue water.

As part of inclusive engagement and building trust in the water resource management approach, there is a need to implement the collection of non-revenue water as part of incentives and recognition of efficient users (Daft & Marcic 2016). These initiatives should be aimed at encouraging individuals and institutions to reduce their usage and be part of the conservation movement as positive contributors to reducing the cost of water production and supply (Chowdhury, Mohamed & Murad 2016). Non-revenue water will be able to be collected once the smart metering systems are installed. Being able to track the flow coming into the network and the amount exiting it will allow the system’s dashboard to recognize if there is any seepage or broken pipes.

6.2 Conclusion

Water is an important resource involved in the operationalization of different economic sectors. It is also central to the sustainability of different socioeconomic sectors and pivotal to the realization of human development goals. Cities that thrive around the world do so based on the platform of providing their citizens with this important resource and giving investors and stakeholders in the economic sector free access to it. Therefore, countries starved of this vital resource are at a disadvantage compared to those that have an abundance of the same because they have to be more creative in getting water and using it well. Such is the case of the UAE and the wider gulf region because they are located in arid areas that have little or no rainfall in a year. At the same time, they are experiencing probably one of these fastest growth rates in the world owing to their economic strategies of diversification from oil. The UAE is at the forefront of this economic shift because it is more visible than other gulf states in terms of international appeal to investors. Consequently, many people around the world have trooped to the country to look for economic opportunities to work and live. The UAE is also home to some of the most vibrant tourism sectors in the region and a model for how countries that rely on oil could transform their economies to be more robust.

These economic and social pressures have increased the country's water demand and strained the ability of its cities to generate and distribute enough water that would be available for all citizens. Indeed, conventional water sources, such as surface and groundwater are already on the decline and it is becoming untenable for the country to continue relying on these sources of water. The findings of this paper show that the UAE is already engaged in increasing the supply of water by investing more in the expansion of its water infrastructure. Although the government is still making some investments in increasing the supply of groundwater, the evidence gathered in this report has shown that most of the resources directed to this sector have been used to improve the quantity of water generated through the desalination process.

Understandably, this type of water resource is available for the country to continue exploiting because the UAE has access to seawater. However, the desalination process has its own challenges. Top among them is the high cost of the desalination process, which runs into billions of dollars. Heavy investments made in this sector mean that the country is losing most of its resources to a process that does not necessarily yield the best returns, relative to the investments made. At the same time, it is staring at the prospects of paying more money to desalinate seawater because brine is increasing the quantity of salt in the sea, thereby making it more salty and expensive to treat. These factors notwithstanding, the desalination process is still the best alternative for the UAE to solve its immediate water challenges. By increasing its capacity to desalinate more water, the country would be in a better position to supply more water to its "thirsty" economic sectors and provide better quality water for its residents.

Alongside the desalination process, the UAE has also tried to increase the investments made in the wastewater treatment. Several chapters in this report have shown how the country has made plans to collect more water and treat it, mostly for purposes of providing a greater supply of the resource to the agricultural sector. This sector has been known to account for up to 70% of the total water consumption in the gulf state (Almulla et al. 2014, p. 1318). Wastewater treatment is a commendable step that the UAE has made in addressing its water management problem, but it is important to point out that most of the steps taken by the government to address the crisis have all been supply-based. This paper has proposed a reexamination of this strategy by drawing our attention to the need to focus on demand-side issues, as the long-term solution to the water predicament in the UAE.

Even the evidence gathered on Masdar city to improve the production of desalinated water is a supply-side issue because the entire framework of Masdar city is premised on improving energy efficiency. Therefore, instead of looking for new ways to reduce the demand for water, Masdar city is essentially premised on making the desalination process of water production more efficient (through the use of solar powered desalination plants). Demand –side solutions need to be sought more because they provide a long-term solution to the water crisis in the country. Evidence of this view has been produced through the analysis of water resource management in Spain. In this example, researchers demonstrated that the long-term solution to water crises in arid regions is to check on the demand for the commodity.

Therefore, most of the solutions voiced in this paper for water management center on addressing the demand problem in the UAE. Doing so depends on the country's ability to institute behavioral change in water management among residents and industry players alike (Kendel & Lazaric 2015, p. 231). The example of Singapore has been highlighted to show how the UAE could better increase its efficiency in the management of this valuable resource. Therefore, while initiatives such as Masdar city are largely commendable because they could revolutionize how arid regions desalinate their water, the greater focus on water management should be in instituting behavior change. The responsibility for doing so largely rests on the government, which should introduce a smart water billing system as a first step to creating awareness about the realities of water scarcity to residents of the UAE. The current subsidized model of water payment is not complementary to the government's vision of realizing a sustainable water future because it makes it difficult for people to support initiatives aimed at saving a resource that they get at little or no cost. Therefore, the current UAE water management structure does not reflect the realities of water scarcity in the region. Thus, country should consider rethinking its water management plan and formulate one that is more realistic and representative of the current realities of water scarcity in the country. Based on the findings of this study, it is important for the UAE government to stop further investments in the extraction of groundwater because this resource is diminishing fast. Instead, it should refocus its efforts on improving the country's capacity to desalinate water.

To realize the goal of sustainable water resource management in the UAE, the public should be sensitized about the realities of water management in the region including the cost of delivery, the scarcity of the resources and the importance of conserving the same resource. This holistic view is in line with the conceptual approach of the study, which views water management as a system. Creating this awareness should be the first step to the realization of any meaningful progress in water conservation and management in the country. Nonetheless, it is important for authorities to present credible information when doing so because honesty is a key principle in Islam, which is the main religion in the UAE. However, when imams, water policy experts and the government educate the public about the realities of water scarcity in the region, they should expect the people to reciprocate the initiative through improved water conservation practices. Nonetheless, as has been highlighted in psychology, changing human behavior is a slow process. Therefore, stakeholders should not be expecting meaningful change in the short-term.

Introducing ad hoc public awareness campaigns will only make the situation worse because they would not have the expected impact on the population. Instead, authorities need to embark on a relentless public awareness campaign to sensitize the people about water conservation. The Ministry of Education should particularly be at the forefront in the development and implementation of this campaign because they have immense social and ethical responsibilities of making sure the public is informed about sensitive issues that affect their welfare.

The awareness campaigns should not merely be directed at domestic users, but also agricultural and industrial users who are also big consumers of water in the UAE. This approach will ensure that water conservation is not a burden shouldered only by domestic users of water, but also industrial and agricultural consumers of the same commodity. The need to change water consumption patterns should be regarded as a long-term approach to sustainable water management. In the current setup, the government should continue investing in increasing water supply through an expansion of water production capacity using the desalination process. However, in the long-term, water conservation should take center stage as the UAE and other Gulf Nations shift their focus from development-oriented to conservation-oriented growth.

6.3 Suggestions of Future Research

This research examined many domains related to water resources management for the entire UAE. The study also generalized the water resources and sources for all the seven Emirates. This makes the findings general and might not address unique water resources management needs for a specific region. Therefore, a further research should be carried out to examine specific domains that are unique to each of the seven Emirates in order to draw inferences that match the water resources and sources. For instance, a study on management of treated wastewater or desalinated water plants governance could make the findings more specific. Moreover, further studies should be carried out to compare the water resources policies and management across all Emirates using the framework of unitary verses federal states.

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