

Midocean University
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Utilizing Modern Water Desalination Technologies in Achieving the Initiatives of the
Green Saudi Arabia and Green Middle East Projects

A Research Paper

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Utilizing Modern Water Desalination Technologies in Achieving the Initiatives of the Green Saudi Arabia and Green Middle East Projects

1. Abstract

This research paper explores the role of modern water desalination technologies in achieving the objectives of the Green Saudi Arabia and Green Middle East initiatives, as outlined by the Saudi & Middle East Green Initiatives platform (gov.sa, 2023). With the increasing water scarcity and environmental concerns in the region, the adoption of sustainable water management practices is crucial.

The paper highlights the significance of water desalination as a solution to the water crisis, while emphasizing the need for environmentally friendly approaches. Various modern desalination technologies, such as reverse osmosis (RO) and solar desalination, are discussed in terms of their effectiveness, cost-efficiency, and environmental impact. Furthermore, the paper explores the potential synergies between water desalination and renewable energy sources to enhance sustainability.

To gather data and insights on the perceptions and attitudes towards water desalination technologies, a sample population will be targeted for research through a questionnaire. The questionnaire will be designed to capture opinions, preferences, and knowledge of individuals related to water scarcity, environmental concerns, and the adoption of desalination technologies. The sample population will include individuals from diverse backgrounds, including policymakers, industry professionals, researchers, and members of the general public. The findings from the questionnaire will contribute to the research's insights and recommendations for policymakers, industry stakeholders, and researchers involved in the Green Saudi Arabia and Green Middle East projects, as promoted by the Saudi & Middle East Green Initiatives platform.

Keywords: water desalination, Green Saudi Arabia, Green Middle East, sustainability, reverse osmosis, solar desalination, renewable energy.

Theoretical Framework of the Study

This part covers the theoretical framework to study the Utilizing of Modern Water Desalination Technologies in Achieving the Initiatives of the Green Saudi Arabia and Green Middle East Projects, focusing on the problem of the study, its importance, as well as the variables of the study.

2. Chapter one: Problem of the Study and its Importance

In this chapter, we will discuss about the problem that leads to this study and the importance of this research. The problem statement will help identify a gap in knowledge, understanding, or practice within a specific field or subject area. It highlights an issue or problem that needs to be addressed through research. By clearly defining the problem, we can contribute to filling that gap and advancing knowledge in the field.

2.1. Research Title

Utilizing of Modern Water Desalination Technologies in Achieving the Initiatives of the Green Saudi Arabia and Green Middle East Projects.

Here is the model of our research:

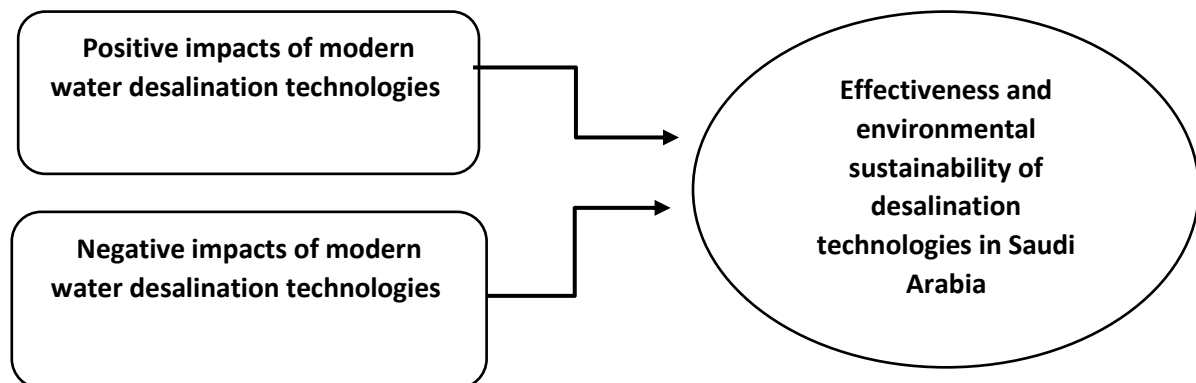


Figure I: Research Model

2.2. Research Overview

This research revolves around the utilization of modern water desalination technologies in achieving the objectives of the Green Saudi Arabia and Green Middle East projects. These initiatives, promoted by the Saudi & Middle East Green Initiatives platform, aim to address water scarcity and environmental concerns in the region through sustainable practices.

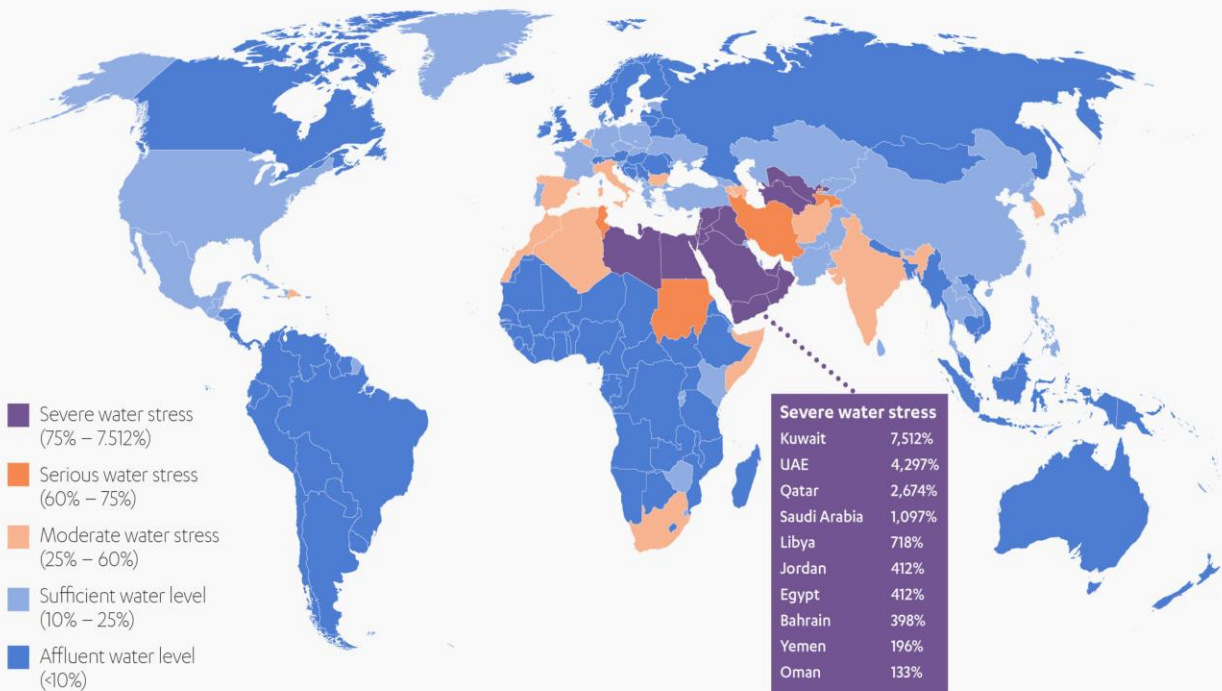
Saudi Arabia is categorized as one of the countries facing severe water scarcity globally. While the threshold for absolute water scarcity is set at 500 cubic meters per capita, Saudi Arabia's available water per capita stands at a significantly lower level of only 89.5 cubic meters per year (Jameel, 2022).

The ten countries most threatened by water scarcity are concentrated in the Middle East

The water stress ratio

Water withdrawal per capita
(cubic metres per inhabitant per year)

Renewable water resources per capita
(cubic metres per inhabitant per year)



Source: FAO Aquastat, Oxford Analytica

Figure II: Water Scarcity in Saudi Arabia and Middle East (Jameel, 2022)

Water scarcity in the region is a significant challenge that is driven by various factors. The migration of people from rural to urban areas, population growth, inadequate water

management practices, aging infrastructure, and governance issues all contribute to the worsening water scarcity problem. This situation is particularly evident in the Gulf Cooperation Council (GCC) countries, which are experiencing rapid population growth, predominantly in urban areas. The concentration of population in cities further amplifies the challenges associated with water scarcity. As of 2022, the combined population of GCC member nations exceeds 54 million, with Saudi Arabia alone accounting for nearly 36 million people.

To address the escalating demand for freshwater, water desalination has emerged as a critical solution. However, traditional desalination methods have faced criticism due to their high energy consumption and detrimental environmental impacts. As a result, there is a growing need to explore and implement modern and more sustainable desalination technologies that can effectively mitigate these issues. By adopting innovative approaches, it becomes possible to alleviate water scarcity challenges while minimizing the ecological footprint associated with conventional desalination processes.

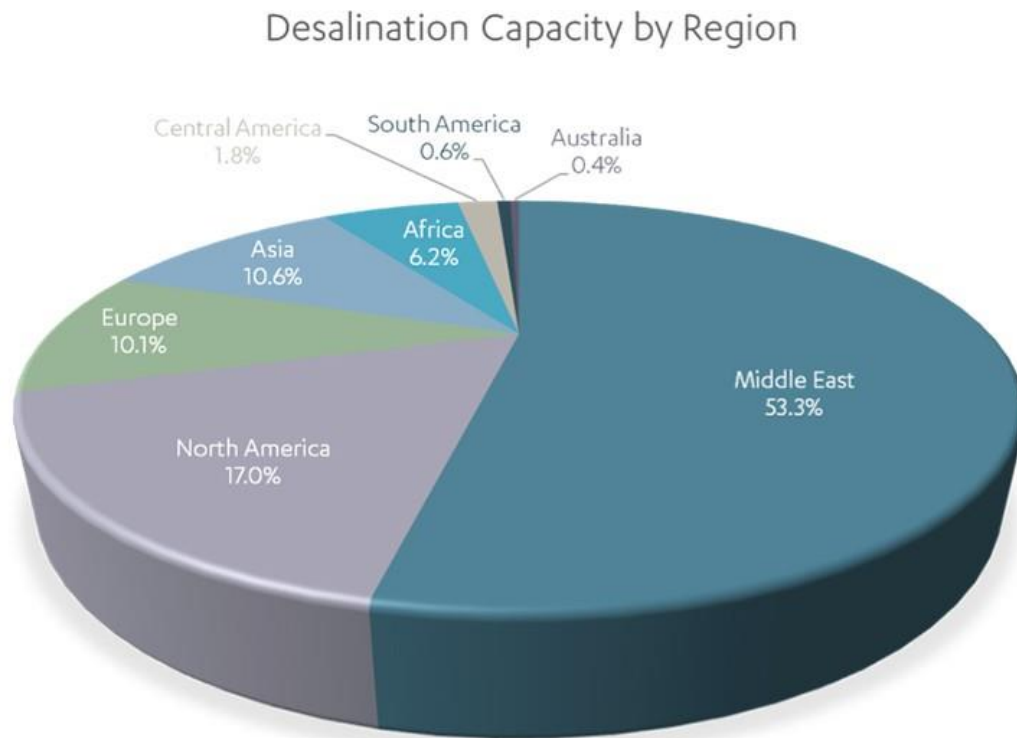


Figure III: International Desalination Association (IDA, 2019)

Thus, the research focuses on understanding the effectiveness, cost-efficiency, and environmental impact of modern desalination technologies, particularly reverse osmosis (RO) and solar desalination. Reverse osmosis is a widely adopted technology that uses a semi-permeable membrane to remove impurities from seawater, while solar desalination harnesses solar energy to produce freshwater. The study aims to evaluate the performance of these technologies and their potential integration with renewable energy sources to enhance sustainability.

By examining the utilization of modern water desalination technologies, the research aims to ultimately support sustainable development efforts in the region. Overall, this research topic addresses the pressing need to explore sustainable solutions for water scarcity in Saudi Arabia and the Middle East. By focusing on modern water desalination technologies and their alignment with green initiatives, the study aims to contribute to the achievement of the goals set forth by the Green Saudi Arabia and Green Middle East projects.

2.3. Research Objectives

The research objectives outline the specific goals and aims of our study. These objectives should be clear and concise, guiding our research process and providing a framework for achieving meaningful results.

The objective are:

- To assess the effectiveness of modern water desalination technologies, such as reverse osmosis and solar desalination, in addressing water scarcity in the context of the Green Saudi Arabia and Green Middle East projects.
- To evaluate the environmental sustainability of modern desalination technologies and their potential integration with renewable energy sources.
- To provide insights and recommendations for policymakers, industry stakeholders, and researchers involved in the Green Saudi Arabia and Green Middle East initiatives regarding the adoption and implementation of sustainable desalination practices.

2.4. Research Importance

This study holds significant research importance as it addresses the pressing need for sustainable water management practices in Saudi Arabia, specifically focusing on the effectiveness and environmental sustainability of desalination technologies. Saudi Arabia faces substantial water scarcity due to its arid climate and limited freshwater resources, making desalination crucial for meeting the growing demand for freshwater. By evaluating the influence of modern water desalination technologies, we aim to contribute to the development of sustainable solutions to address this scarcity.

One of the key aspects we investigate is the environmental impact reduction of desalination technologies. Traditional methods often exhibit high-energy consumption and environmental concerns such as greenhouse gas emissions and brine discharge. Our study examines the potential of modern desalination technologies to mitigate these issues, seeking to provide insights on reducing carbon emissions, minimizing brine discharge, and optimizing energy efficiency in the desalination process.

Furthermore, our research aligns with the objectives of the Green Saudi Arabia and Green Middle East projects, which promote environmental sustainability and the integration of renewable energy sources. By exploring the integration of modern desalination technologies with renewable energy, we aim to support these initiatives and provide recommendations for sustainable desalination practices. This can contribute to the success of these green initiatives and aid Saudi Arabia's transition towards a more sustainable future. In addition, the findings and recommendations of our study also have practical implications. Policymakers can utilize our research to develop regulations and incentives that encourage the adoption of sustainable desalination technologies. Industry stakeholders can benefit from our insights to optimize their operations, reduce environmental impact, and enhance the overall effectiveness of desalination processes. By providing guidance to policymakers and industry professionals, our study can influence the implementation of sustainable desalination practices on a broader scale.

Moreover, our research advances the existing knowledge in the field of desalination technologies. By evaluating the effectiveness and environmental sustainability of modern desalination technologies in the specific context of Saudi Arabia, we contribute to the body of knowledge in this area. The research findings can serve as a foundation for further studies, promoting ongoing advancements in sustainable desalination practices in Saudi Arabia and beyond.

Thus, this study's research importance lies in its contribution to addressing water scarcity, reducing environmental impact, supporting green initiatives, guiding policies and industry practices, and advancing knowledge in the field of desalination technologies in Saudi Arabia. Through our research, we aim to provide valuable insights and recommendations that can lead to sustainable and efficient water management practices in the country

2.5. Research Problem

The problem lies in the need for sustainable water management practices to address water scarcity in Saudi Arabia and the Middle East, given the increasing population, urbanization, and limited freshwater resources. Traditional desalination methods have limitations in terms of high-energy consumption and negative environmental impacts, necessitating the exploration and implementation of modern and more sustainable desalination technologies. Our study aims to bridge this gap by evaluating the effectiveness, cost-efficiency, and environmental sustainability of modern water desalination technologies, particularly in the context of the Green Saudi Arabia and Green Middle East initiatives.

2.5.1. Research Questions

Here are the research questions, which we will address in our research. These questions are directly aligned with our research objectives and help us investigate the problem at hand.

The questions are:

- What is the effectiveness of modern water desalination technologies, such as reverse osmosis and solar desalination, in terms of water production rate and water quality?

- What is the environmental impact of modern desalination technologies, including energy consumption and carbon emissions?
- How can modern desalination technologies be integrated with renewable energy sources to enhance sustainability?
- What are the potential challenges and opportunities associated with the adoption and implementation of sustainable desalination practices in the Green Saudi Arabia and Green Middle East projects?

2.5.2. Research Hypothesis

The hypothesis of the research are as follow:

- H0: There is no significant influence of modern water desalination technologies on the effectiveness and environmental sustainability of goals of the Green Saudi Arabia and Green Middle East projects.

This hypothesis assumes that the implementation of modern water desalination technologies does not have a significant impact on both the effectiveness and environmental sustainability of goals of the Green Saudi Arabia.

- H1: There is significant influence of modern water desalination technologies on the effectiveness and environmental sustainability of goals of the Green Saudi Arabia and Green Middle East projects.

This hypothesis assumes that the implementation of modern water desalination technologies does have a significant impact on both the effectiveness and environmental sustainability of goals of the Green Saudi Arabia.

There is two variables in the hypothesis and they are “modern water desalination technologies” and “environmental sustainability of goals of the Green Saudi Arabia”.

3. Chapter Two: First Variable of the Study

The first variable of this study is “modern water desalination technologies”. This variable refers to the utilization and implementation of advanced and sustainable water desalination technologies. It encompasses various innovative methods, such as reverse osmosis, solar desalination, membrane distillation, and other modern techniques. The focus is on evaluating the effectiveness and efficiency of these technologies in terms of water production rate and water quality.

The chapter aims to assess how the adoption of modern desalination technologies can address water scarcity challenges in Saudi Arabia and contribute to the objectives of the Green Saudi Arabia and Green Middle East projects.

3.1. Water Desalination

Water is an essential resource for all living organisms, and it covers approximately 70% of the Earth's surface (Manish Thimmaraju, 2018). Despite the abundance of water on our planet, many countries worldwide face a severe shortage of safe drinking water. Access to clean drinking water is crucial for sustaining life, even though it does not provide any nutritional value.

To address this issue, desalination of seawater and brackish water has emerged as a potential solution to water scarcity. It involves removing excess salts and minerals, transforming it into safe drinking or usable water. Advanced desalination technologies, such as reverse osmosis, have proven effective in increasing water availability. However, considerations for environmental impact and energy usage are important. Integration of renewable energy sources and responsible brine disposal are crucial for sustainable desalination practices.

Moreover, desalination can help reduce the strain on existing freshwater sources, such as underground aquifers and rivers, by supplementing the water supply. This is particularly important in arid regions like Saudi Arabia, where groundwater resources are being depleted at unsustainable rates.

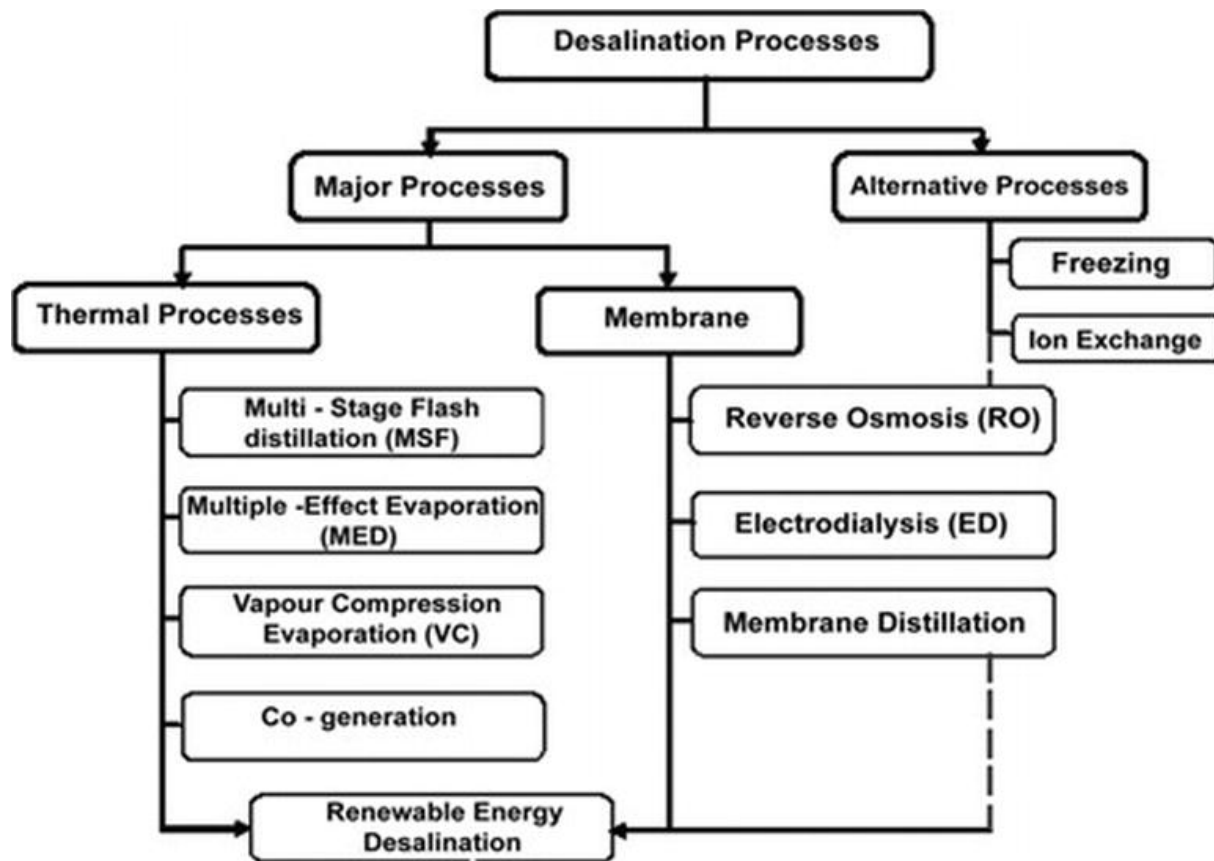


Figure IV: Desalination Process (Manish Thimmaraju, 2018)

3.2. Modern Water Desalination Technologies

Desalination technologies, which are employed worldwide to convert saltwater into fresh water, can be broadly classified into two main types: thermal and membrane technologies. These technologies serve as the foundation for various desalination processes that are utilized to extract salt and impurities from water sources.

Thermal desalination technologies involve the use of heat to evaporate water, leaving behind the salts and impurities. The most common thermal desalination process is known as multi-stage flash (MSF) distillation, where seawater is heated and passed through multiple stages or chambers at different temperatures, causing the water to evaporate and condense, while the salts and impurities are separated. Another thermal desalination process is called multi-effect

distillation (MED), which operates on a similar principle but uses a series of interconnected evaporation chambers to enhance energy efficiency.

On the other hand, membrane desalination technologies employ semi-permeable membranes to separate the salt and impurities from water. The most prevalent membrane-based desalination process is reverse osmosis (RO), where high-pressure is applied to seawater or brackish water to force it through a membrane, allowing the water molecules to pass through while retaining the salts and impurities. Other membrane processes include nano-filtration (NF) and electro-dialysis reversal (EDR), which utilize specific types of membranes and ion-exchange processes to achieve desalination.

Both thermal and membrane desalination technologies require energy to operate. Thermal processes rely on heat energy, usually sourced from fossil fuels or renewable sources such as solar energy, while membrane processes depend on mechanical pressure, which is typically generated using electric pumps. The energy consumption of desalination processes is a significant consideration for their overall feasibility and sustainability.

Within the broad categories of thermal and membrane technologies, there are further sub-categories and variations of desalination processes. These processes may incorporate additional techniques, modifications, or combinations of thermal and membrane technologies to optimize water production, energy efficiency, and cost-effectiveness.

The table below identifies and illustrates the major desalination processes, providing a visual representation of the diverse methods employed in the desalination industry.

Table 1: Desalination Technologies and processes

Thermal Technology	Membrane Technology
Multi-Stage Flash Distillation (MSF)	Electrodialysis (ED)
Multi-Effect Distillation (MED)	Electrodialysis reversal (EDR)
Vapor Compression Distillation (VCD)	Reverse Osmosis (RO)

3.3. Water Desalination and Green Saudi Arabia and Middle East

In September 2021, Saudi Arabia stood as one of the leading countries in desalination capacity due to its arid climate and limited access to freshwater sources. The country heavily relies on desalination to meet its water needs. With numerous operational desalination plants, the Ras Al Khair Desalination Plant stands out as the largest, producing an impressive 1,025,000 cubic meters of desalinated water per day (Krishna1, 2020).

To ensure water security and meet the growing water demand, Saudi Arabia has set ambitious goals for expanding its desalination infrastructure. By 2030, they plan to increase their desalination capacity to 8.5 million cubic meters per day. This expansion aims to reduce reliance on limited freshwater sources and ensure a sustainable water supply (News, 2023).

To achieve this target, Saudi Arabia is implementing various desalination technologies, including both thermal and membrane-based processes such as reverse osmosis and multiple-effect distillation. These advanced technologies improve efficiency, reduce energy consumption, and enhance the overall sustainability of the desalination process.

Beyond capacity expansion, Saudi Arabia is committed to sustainable water management and environmental conservation. They have introduced green initiatives in the desalination sector to minimize the environmental impact. Investments in research and development are underway to enhance desalination technologies, making them more energy-efficient and environmentally friendly.

As part of their sustainability efforts, Saudi Arabia is exploring alternative methods like wastewater treatment and reuse. By treating and reusing wastewater, they can reduce their reliance on desalinated water for non-potable purposes, conserving valuable freshwater resources and promoting a circular economy approach to water management.

The broader Middle East region, including countries like the UAE, Kuwait, Qatar, and Bahrain, also heavily relies on desalination for their water supply. These countries are

actively investing in advanced desalination technologies and collaborating on projects to promote sustainable water management.

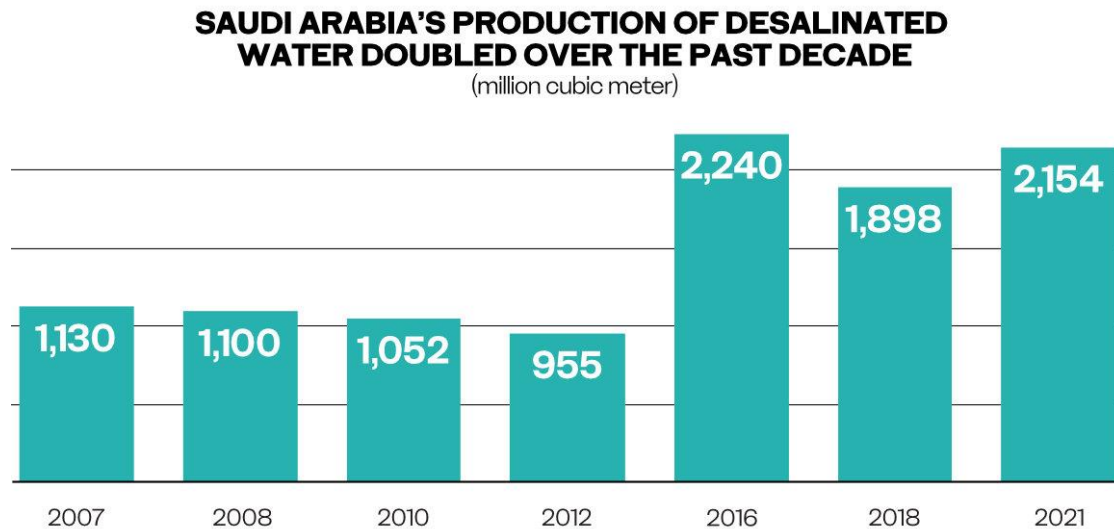


Figure V: Saudi Arab Production of Desalinated (News, 2023)

Under the Green Saudi Arabia initiative, the Saudi government has set several targets focusing on reducing emissions, greening the country, and protecting land and sea. Here are some of the initiatives implemented to achieve these targets; these initiatives collectively contribute to achieving the targets set under the Green Saudi Arabia initiative. By reducing emissions, promoting greening efforts, and protecting land and sea, Saudi Arabia aims to create a more sustainable and environmentally friendly future for the country. Initiatives taken by government are:

- **Renewable Energy Expansion:** Saudi Arabia is investing heavily in expanding its renewable energy capacity, particularly in solar and wind power. The country aims to generate 50% of its electricity from renewable sources by 2030. This initiative will reduce reliance on fossil fuels, decrease carbon emissions, and promote a greener energy sector.
- **Afforestation and Reforestation:** The Saudi government has launched the "Saudi Green Initiative" and the "Green Middle East Initiative" to promote afforestation and reforestation efforts. These initiatives aim to plant 10 billion trees in Saudi Arabia and restore 40 million hectares of degraded land across the Middle East. By increasing green

cover, the initiatives help combat desertification, enhance biodiversity, and sequester carbon.

- **Protecting Marine Ecosystems:** Saudi Arabia is taking measures to protect its marine ecosystems, including coral reefs and coastal areas. The government has established marine protected areas and is implementing sustainable fishing practices to preserve biodiversity and ensure the long-term health of marine ecosystems.
- **Waste Management and Recycling:** The Saudi government is focusing on waste management and recycling initiatives to reduce the environmental impact of waste disposal. Efforts are being made to promote recycling practices, implement waste segregation systems, and develop sustainable waste management infrastructure.
- **Sustainable Agriculture and Water Conservation:** The government is promoting sustainable agricultural practices to reduce water usage and enhance water efficiency in farming. Initiatives include implementing efficient irrigation techniques, promoting precision agriculture, and educating farmers about water conservation methods. These efforts aim to optimize water resources and minimize the environmental impact of agriculture.
- **Ecotourism Development:** Saudi Arabia is investing in the development of ecotourism sites and nature reserves to promote sustainable tourism. By highlighting the country's natural beauty and biodiversity, these initiatives contribute to environmental conservation, while also supporting local economies and creating job opportunities.
- **Research and Innovation:** The Saudi government is encouraging research and innovation in green technologies and sustainable practices. Investments are being made in research institutions and partnerships with international organizations to develop and implement innovative solutions for environmental challenges.
- **Public Awareness and Education:** The government is actively raising public awareness about environmental conservation and the importance of sustainable practices. Educational campaigns, workshops, and initiatives are being conducted to engage the public, schools, and communities in environmental stewardship.

3.4. Water Scarcity Challenges In Saudi Arabia

Saudi Arabia faces significant water scarcity challenges due to its arid climate, limited freshwater resources, and high water demand. Here are some key factors contributing to water scarcity in the country:

- **Limited Renewable Water Sources:** Saudi Arabia has limited natural freshwater sources such as rivers and lakes. The country relies heavily on non-renewable fossil aquifers, which are being depleted at an unsustainable rate. These aquifers took thousands of years to form, and their extraction is not replenished by natural processes.
- **High Water Demand:** The demand for water in Saudi Arabia has been increasing rapidly due to population growth, urbanization, industrial development, and agricultural needs. The agricultural sector accounts for a significant portion of water consumption, especially for crop irrigation, contributing to the strain on water resources.
- **Unsustainable Agricultural Practices:** Traditional agricultural practices, including flood irrigation, have been prevalent in Saudi Arabia. These practices are water-intensive and inefficient, leading to significant water wastage. The expansion of agriculture in arid regions has further exacerbated water scarcity issues.
- **Climate Change and Drought:** Climate change has resulted in increased temperatures and altered precipitation patterns in Saudi Arabia. Drought events have become more frequent, impacting water availability and exacerbating water scarcity challenges. Climate change projections indicate that the region will face even greater water stress in the future.
- **Desalination Dependency:** Saudi Arabia heavily relies on desalination to meet its water needs. Desalination plants, which convert seawater into freshwater, require significant energy inputs and financial investments. While desalination has helped alleviate water scarcity to some extent, it poses environmental challenges and is energy-intensive.
- **Water Losses and Inefficient Infrastructure:** Aging water infrastructure and distribution systems contribute to water losses through leakage and inefficient water management practices. These losses further strain already limited water resources and decrease overall water availability.

- **Increasing Population:** The country's population has been rapidly growing due to factors such as high birth rates, improved healthcare, and economic opportunities. The expanding population puts additional pressure on water resources and exacerbates the demand-supply gap.

3.5. Water Desalination Challenges in Saudi Arabia

Saudi Arabia heavily relies on desalination as a major source of freshwater due to its limited natural water resources. While desalination has helped alleviate water scarcity in the country, it also poses several challenges.

Here are some of the key challenges associated with water desalination in Saudi Arabia:

- **Energy Intensity:** Desalination is an energy-intensive process, typically requiring large amounts of electricity or thermal energy. Saudi Arabia's desalination plants consume a significant portion of the country's energy resources, primarily from fossil fuels. This dependence on energy-intensive desalination processes contributes to carbon emissions and environmental impact.
- **Environmental Impacts:** Desalination plants can have adverse environmental effects, particularly through the discharge of brine, a highly concentrated salt solution, back into the sea. The high salinity of the discharged brine can harm marine ecosystems and affect the balance of marine life. Proper management and treatment of brine discharge are essential to minimize environmental impacts.
- **Cost and Financial Sustainability:** Establishing and operating desalination plants require substantial financial investments. The high capital costs, maintenance expenses, and energy requirements make desalinated water relatively expensive compared to other water sources. Ensuring the financial sustainability of desalination projects and managing the cost of desalinated water is an ongoing challenge.
- **Dependency on Non-Renewable Water Sources:** Desalinated water is a non-renewable water source. While it helps address immediate water needs, over-reliance on desalination can lead to the depletion of the country's finite water resources, such as

fossil aquifers. Diversification of water sources and promoting sustainable water management practices are crucial for long-term water security.

- **Brine Disposal and Saline Pollution:** Proper disposal of brine generated during desalination is essential to prevent the accumulation of salt and other harmful substances in coastal areas or discharge points. Inadequate brine management can lead to saline pollution, affecting coastal ecosystems, groundwater quality, and the overall environment.
- **Technological Advancements:** Continuous research and development are necessary to improve desalination technologies, increase energy efficiency, and reduce the environmental impact. Advancements in membrane technologies, such as reverse osmosis, and the integration of renewable energy sources can contribute to more sustainable desalination practices.

Addressing the challenges associated with water desalination in Saudi Arabia requires a multi-pronged approach:

- **Renewable Energy Integration:** Promoting the integration of renewable energy sources, such as solar and wind power, into desalination processes can help reduce the carbon footprint associated with desalination and decrease reliance on fossil fuels.
- **Efficiency and Innovation:** Investing in research and development to improve desalination technologies, enhance energy efficiency, and reduce costs is crucial. Developing innovative desalination techniques, such as forward osmosis and hybrid systems, can help optimize water production and minimize environmental impact.
- **Brine Management and Disposal:** Implementing effective brine management strategies, including proper treatment and disposal methods, is essential to minimize the environmental impact of brine discharge. Technologies for brine concentration, resource recovery, and brine utilization should be explored to reduce waste and maximize the value of brine by-products.
- **Water Conservation and Demand Management:** Implementing water conservation measures and demand management strategies can help reduce the overall demand for desalinated water. Promoting efficient water use practices, water reuse, and public

awareness campaigns about water conservation can contribute to more sustainable water management.

- **Research and Collaboration:** Encouraging research partnerships and collaboration with international organizations and experts can facilitate knowledge exchange, technological advancements, and best practices in desalination. Sharing experiences and lessons learned from desalination projects globally can contribute to addressing challenges specific to Saudi Arabia.

4. Chapter Three: Second Variable and the Correlation Between Variables

The second variable of this study is the controllable variable called “environmental sustainability of goals of the Green Saudi Arabia”. Studying this as a variable, we will focus on understanding the first variable impacts on it.

4.1. Environmental Sustainability of Desalination Technologies in Saudi Arabia

Desalination technologies play a crucial role in meeting Saudi Arabia's water demands in arid regions, but their environmental sustainability is a key concern. Saudi Arabia is actively working to address environmental challenges and improve the sustainability of its water sector through desalination technologies. The country has made significant progress in enhancing energy efficiency by adopting reverse osmosis (RO) technology, which requires less energy compared to traditional methods like multi-stage flash (MSF) and multi-effect distillation (MED). Integration of renewable energy sources like solar and wind power into desalination operations is also gaining momentum, helping to reduce carbon emissions and enhance environmental sustainability.

Efforts are being made to tackle the environmental impact of brine disposal. Various strategies such as brine dilution, dispersion techniques, controlled discharge into deep ocean currents, and resource recovery from brine are being explored to minimize ecological harm and maximize utilization of brine byproducts. Saudi Arabia has implemented environmental regulations and monitoring programs, including conducting impact assessments and monitoring water quality, to ensure compliance with sustainability standards and protect marine ecosystems.

Research and development initiatives are underway to enhance desalination technologies further. Advancements in membrane technology, alternative desalination methods, and system configurations are being explored to maximize energy efficiency. Collaboration between academia, industry, and government entities drives innovation and knowledge-sharing in the field. However, challenges remain, such as minimizing the carbon footprint, optimizing brine management techniques, and promoting water-conscious behaviors among the public.

Furthermore, SWCC has participated in two renewable energy projects aligned with the Vision 2030 plan. The outlook for water desalination in Saudi Arabia presents both promise and challenges. To address this, SWCC aims to incorporate more renewable energy sources into its desalination projects. This approach aims to reduce conversion costs, improve conversion efficiency, and simultaneously cut carbon emissions.

According to a comprehensive research report from 2014, assuming the current population growth rates persist over the next 10-15 years, the Kingdom may require a desalinated water capacity of up to 4.5 billion cubic meters per year by 2040. This projection indicates a need for doubling the current production levels by 2021 (Ghanulin, 2022).

Regardless of the efficiency and productivity improvements in water desalination methods, Saudi Arabia will likely need to implement measures to reduce water demand. This could involve raising awareness through campaigns or imposing taxes on high water usage.

By addressing these challenges and continuing to develop advanced desalination technologies, Saudi Arabia aims to achieve a more sustainable and environmentally friendly water sector. The focus lies on improving energy efficiency, adopting responsible brine disposal practices, mitigating impacts on marine ecosystems, optimizing the water-energy nexus, and promoting research and collaboration. These measures will help ensure long-term availability of freshwater resources while minimizing the environmental impact of desalination operations.

4.2. Impacts of Modern Desalination Technologies on Environmental Sustainability

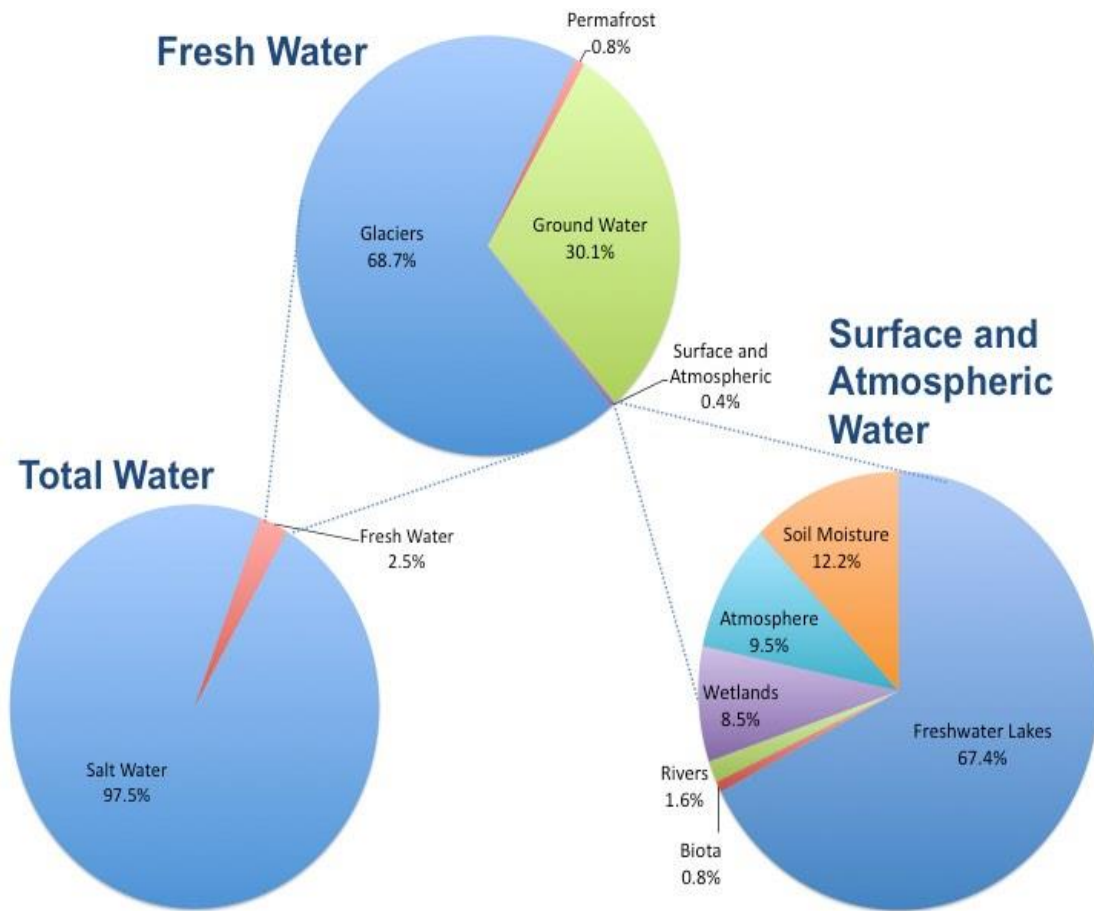


Figure VI: Earth consists of about 71% water (Peterson, 2015)

Earth consists of about 71% water; much of that water is non-potable or is inaccessible to humans (Peterson, 2015). Modern desalination technologies, such as reverse osmosis (RO) and solar desalination, have significant impacts on the environmental sustainability of desalination processes in Saudi Arabia. These technologies bring about several positive changes:

One major impact is the reduced energy consumption compared to traditional desalination methods. Reverse osmosis, for example, requires less energy than thermal-based methods like multi-stage flash (MSF) or multi-effect distillation (MED). By minimizing energy requirements, modern desalination technologies contribute to lower carbon emissions and reduced dependence on fossil fuel-based energy sources. This reduction in energy consumption helps mitigate the environmental footprint associated with desalination.

Additionally, the integration of modern desalination technologies with renewable energy sources enhances their environmental sustainability. Saudi Arabia, with its abundant solar resources, has been exploring the use of solar power in desalination projects. Solar desalination harnesses solar energy to power the desalination process, reducing or eliminating the need for fossil fuel-based energy. This integration promotes the use of clean and renewable energy, leading to a significant reduction in greenhouse gas emissions and minimizing the environmental impact of desalination.

Another important impact is the advanced water treatment processes incorporated into modern desalination technologies. These processes, including pre-treatment and post-treatment, effectively remove contaminants from seawater while ensuring the quality of the produced freshwater. By minimizing the discharge of harmful byproducts and chemicals into the environment, modern desalination technologies contribute to the conservation of marine ecosystems and reduce ecological disruption.

Furthermore, ongoing research and development efforts in the field of desalination technologies play a crucial role in improving their environmental sustainability. Scientists and engineers are continuously working on developing more energy-efficient membranes, optimizing system designs, and exploring innovative approaches to reduce the environmental impact of desalination processes. These advancements aim to enhance the efficiency and environmental friendliness of desalination technologies, further reducing their ecological footprint.

We can say that the overall, the impacts of modern desalination technologies on the environmental sustainability of desalination in Saudi Arabia are significant. These technologies contribute to the reduction of energy consumption, integration with renewable energy sources, advanced water treatment processes, and ongoing research and development efforts. By considering these factors, modern desalination technologies help minimize the negative environmental impacts associated with desalination processes and support the goals of sustainable water management and conservation.

4.3. How Desalination Technologies Helped Saudi Arabia

Desalination technologies have played a vital role in addressing Saudi Arabia's water scarcity challenges. Here are some key ways in which these technologies have helped the country:

- Meeting Water Demand:** Saudi Arabia is located in a water-scarce region, with limited freshwater resources. Desalination has enabled the country to meet its growing water demand by converting abundant seawater into a reliable source of drinking water. This has helped alleviate water shortages and ensure a stable water supply for domestic, agricultural, and industrial purposes.

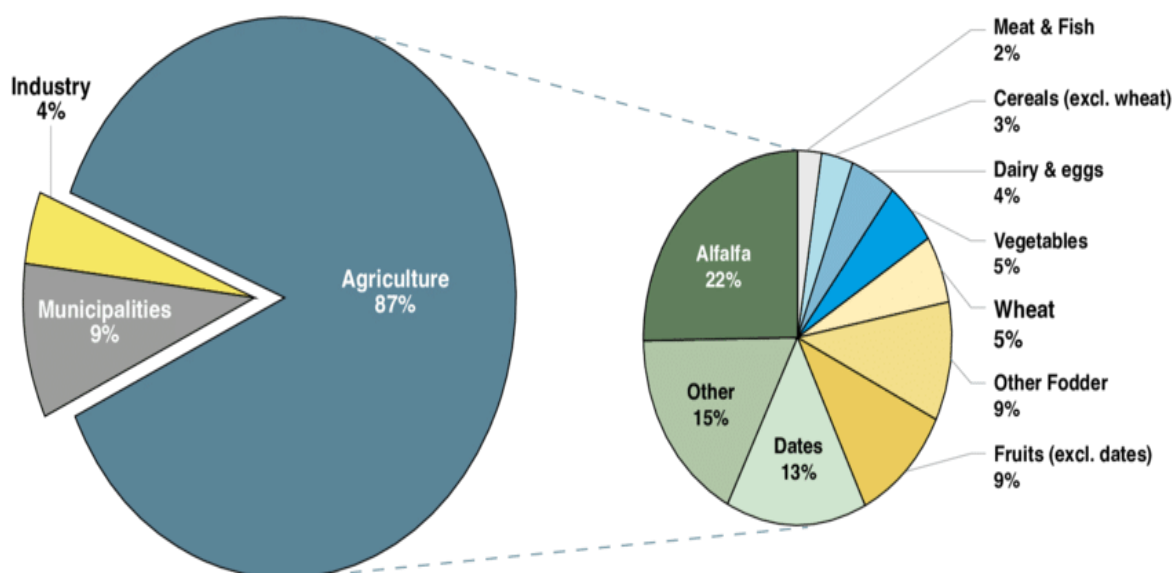


Figure VII: Extracted water use in Saudi Arabia (Wise, 2015)

- Reducing Water Stress:** By relying on desalination, Saudi Arabia has reduced its dependence on traditional freshwater sources such as underground aquifers and limited surface water. This has helped alleviate water stress on these resources, preserving them for other essential uses and maintaining ecological balance in fragile ecosystems.
- Enhancing Water Security:** Desalination technologies have significantly enhanced Saudi Arabia's water security. The ability to produce large quantities of high-quality freshwater from seawater provides a reliable and independent water source, reducing vulnerability to external factors such as droughts or disruptions in traditional water supplies.

- **Economic Development:** The establishment of desalination infrastructure has contributed to Saudi Arabia's economic growth. The availability of a consistent water supply has facilitated agricultural development, industrial expansion, and urbanization. This, in turn, has created employment opportunities, stimulated economic diversification, and supported the overall development of the country.
- **Environmental Sustainability:** While desalination processes have environmental implications, advancements in technology have helped minimize their impact. The adoption of more energy-efficient desalination methods, such as reverse osmosis, has reduced energy consumption and associated carbon emissions. Additionally, efforts are being made to optimize brine management and explore resource recovery from brine, further enhancing the environmental sustainability of desalination operations.
- **Research and Innovation:** Desalination has spurred research and innovation in Saudi Arabia. The country has invested in developing and adopting advanced desalination technologies, improving efficiency, reducing costs, and exploring alternative methods. This focus on research and innovation has positioned Saudi Arabia as a leader in the field, contributing to knowledge sharing and global advancements in desalination technology.

4.4. Saudi Arabia's Desalination Journey towards Sustainability

Saudi Arabia's geographical location in one of the driest regions globally, combined with its position as the third largest per capita consumer of water, has necessitated the widespread adoption of desalination technology. By harnessing the abundant seawater resources, Saudi Arabia has been able to convert it into a vital source of drinking water. However, the reliance on petroleum as a primary energy source for desalination processes and the government's control over the water infrastructure have posed challenges to long-term sustainability.

Recognizing the increasing water demand and the changing dynamics of the oil industry, Saudi Arabia has embarked on a transformative journey to make desalination a sustainable solution for the future. This journey involves driving innovation, adopting new technologies, and implementing strategies to address environmental concerns and optimize resource utilization.

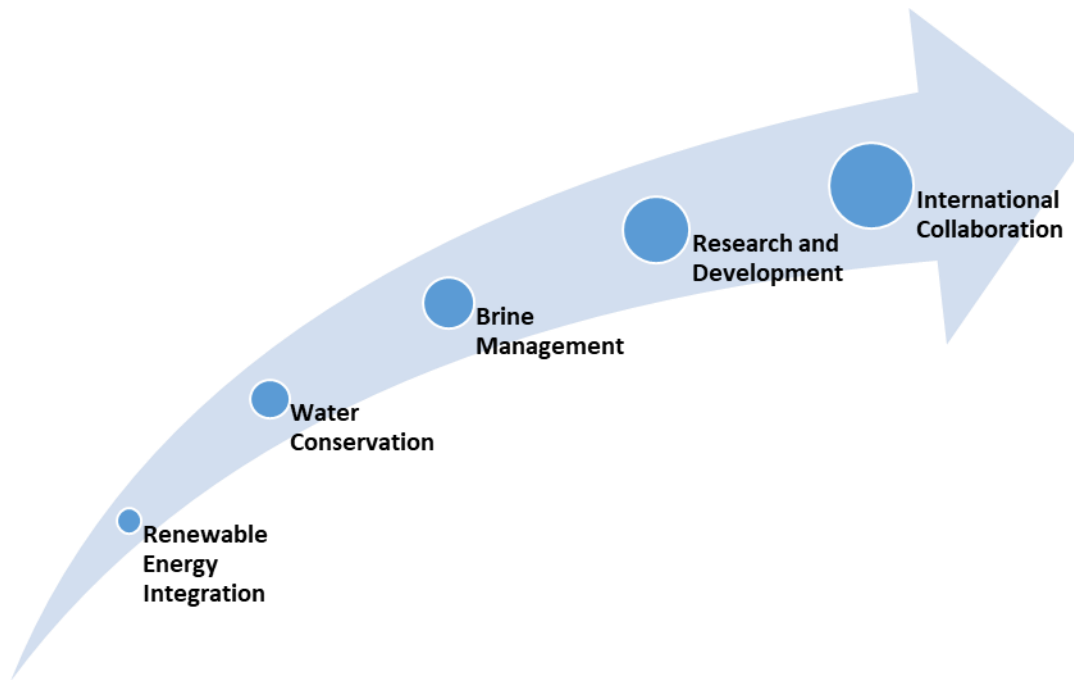


Figure VIII: Saudi Arabia's progress towards sustainable desalination practices

One of the key drivers for sustainability in Saudi Arabia's desalination sector is the need to reduce the carbon footprint associated with petroleum-powered desalination plants. The government has been investing in research and development to enhance energy efficiency and explore alternative energy sources for powering desalination processes. This includes the integration of renewable energy, such as solar and wind power, into desalination operations. By transitioning to clean and renewable energy sources, Saudi Arabia aims to minimize carbon emissions and mitigate the environmental impact of desalination.

Furthermore, efforts are being made to optimize water management practices and reduce wastage. Water conservation initiatives, including awareness campaigns and the implementation of efficient water use practices, are being promoted to minimize water consumption. By encouraging responsible water use and implementing water-saving technologies, Saudi Arabia aims to meet the growing water demand while ensuring efficient and sustainable water resource management. Brine disposal, a byproduct of desalination, has been a significant environmental concern. Saudi Arabia is actively exploring innovative brine management techniques that minimize the ecological impact of brine discharge. These include strategies such as brine dilution, controlled discharge into deep ocean currents, and

the recovery of valuable resources from brine. By maximizing the utilization of brine and minimizing its ecological footprint, Saudi Arabia aims to enhance the overall sustainability of desalination operations.

Research and development play a crucial role in Saudi Arabia's journey towards sustainable desalination. The country is fostering collaboration between academia, industry, and government entities to drive innovation and develop advanced desalination technologies. This includes advancements in membrane technology, exploring alternative desalination methods, and optimizing system configurations to maximize energy efficiency and minimize environmental impact. Moreover, Saudi Arabia's commitment to sustainability extends beyond its borders. The country actively participates in international collaborations, knowledge-sharing platforms, and conferences to contribute to the global advancement of sustainable desalination practices. By sharing experiences, best practices, and research findings, Saudi Arabia aims to accelerate progress towards sustainable water solutions worldwide.

Saudi Arabia's desalination journey towards sustainability is driven by the need to address rising water demand, the scarcity of oil resources, and the imperative of environmental responsibility. Through innovation, research, and the adoption of sustainable practices, Saudi Arabia is striving to make desalination a reliable, efficient, and environmentally friendly solution for ensuring a stable water supply for its growing population and supporting the country's sustainable development goals.

Practical Study and Its Methodological Procedures

In this section, we will discuss the practical methodologies used in the research, which include the research design, data collection methods, and analysis and interpretation. These components are crucial for understanding how the study was conducted and how the collected data was analyzed to derive meaningful insights.

5. Chapter Four: Methodological Procedures

This chapter tackles the methodology of the study; the study of population as well as its sample, the tool used in collecting data in the study were all identified. Along with a detailed presentation of the calculation of the coefficients of reliability and validity of the study tool, in addition to the statistical methods used in the data analysis.

The objective of the present study is to identify the impacts of Impacts of Modern Desalination Technologies on Environmental Sustainability in Saudi Arabia from the point of view of a sample of respondents. To achieve the objectives of the study, we have conducted primary research using an analytical descriptive approach. The analytical descriptive approach is defined as describing the phenomenon to be studied and collecting descriptions and information about it. This approach focuses on analyzing and interpreting the collected data to provide a detailed description of the research topic while also uncovering patterns, relationships, or associations among variables. With this approach, we will try to compare, interpret, and evaluate in the hope of reaching meaningful generalizations that increase the balance of knowledge on the subject.

Here is the stepwise description of employing an analytical descriptive approach in our practical study:

5.1. Study Tool

We have used the questionnaire as a tool for collecting information, as it is the appropriate tool for obtaining information in the field of study. This study tool, as mentioned by Al-Qahtani (2004), is defined as the means by which the data collection process is carried out with the aim of selecting research hypotheses or answering its questions (Qahtani, 2004).

5.2. Study Population

The study population of our study consists of policymakers, industry professionals, researchers, and members of the general public in Saudi Arabia. Their expertise and experiences can contribute to a comprehensive understanding of various aspects related to the research.

5.3. Study Sample Size

The objective of each researcher is to reach sound conclusions about the community to be studied and from which the problem stemmed. We have distributed (50) questionnaire randomly to policymakers, industry professionals, researchers, and members of the general public of Saudi Arabia.

5.4. Building the Study Tool

For building the questionnaire, we have relied on the following sources:

- References related to the subject of the study or part of the study problem.
- Previous research and studies that dealt with some of the study topics.
- The academic supervisor and the opinions of the arbitrators to whom the questionnaire were presented in its initial form.
- Interviewing some specialists in the field of study, and benefiting from their opinions about the scale used in the study and the method of formulating its statement in line with the objectives of the study.

5.5. Design the Study Tool

For designing the questionnaire, a five-point Likert scale was used. The scale scores were distributed (from 1 to 5) so that the respondent shows whether he absolutely disagrees, disagrees, neutral, agrees, or strongly agrees.

For the questions in the questionnaire, we have formulated an initial formulation of the questionnaire statements. All the statements based on the subject, objectives and questions of the study after careful reading and review of the literature and previous studies related to the problem of the study and the researcher's practical experience. After this, we have started

polling a sample of the study community, and after approval, the questionnaire consisted of two parts as follow:

- **The First Part: Primary Data of the Respondents:**

This part relates to the independent variables of the study, which includes variables related to the personal and functional characteristics of the study individuals represented in five variables, namely: Gender- Age – Education- Nationality – Industry- Organization Type.

- **The Second Part: The Study Topics:**

This part includes the topics of the study. In preparing the topics, we have adopted the closed form that determines the possible responses to each question with five-graded Likert method.

This second part consist on the impacts of Modern Desalination Technologies on Environmental Sustainability from the point of view of respondents.

Each question of the questionnaire corresponds to a list bearing the following statements (strongly disagree, disagree, neutral, agree, strongly agree), because it is easy to prepare and apply, and gives the respondent the freedom to define his position and the positive and negative degree of this position in each statement. Each of the statements was given scores according to the five-point Likert scale, and we have adopted the closed form in the numbers of the topics, which determines the possible answers for each question.

5.6. Validity & Reliability of Study Tool

In this study, validity was ensured by carefully formulating the questionnaire statements based on relevant literature, previous research, and the researcher's expertise in the field. The questions were designed to address the specific objectives of the study, ensuring that they captured the desired information.

Reliability, on the other hand, refers to the consistency of the measurements obtained from the study tool. In this study, reliability was assessed through internal consistency. Internal

consistency reliability was evaluated by analyzing the interrelatedness of the questionnaire items using statistical techniques such as Cronbach's alpha coefficient. A high Cronbach's alpha value indicates a high degree of consistency among the items.

5.7. Scale Application (Study Tool)

After collecting the study data, we performed a review to prepare it for computerized statistical analysis. During this process, we encoded the responses, converting verbal responses into numerical values. The scale used was a five-point Likert scale, ranging from "strongly agree" (5) to "strongly disagree" (1).

To determine the length of each cell on the scale, we calculated the range by subtracting the lowest value (1) from the highest value (5), resulting in a range of 4. We then divided this range by the number of cells on the scale (5), which yielded a cell length of 0.80. To establish the upper limit of each cell, we added the cell length of 0.80 to the lowest value of the scale (1). This process determined the upper limit of each cell, resulting in the following cell lengths:

- Cell 1: 1.00 - 1.80
- Cell 2: 1.81 - 2.60
- Cell 3: 2.61 - 3.40
- Cell 4: 3.41 - 4.20
- Cell 5: 4.21 - 5.00

By calculating the cell lengths based on the scale range, we established the boundaries of each response category, allowing for accurate analysis and interpretation of the study data.

5.8. Statistical Methods Used in Data Analysis

To achieve the study objectives and analyze the collected data using the study tool, several appropriate statistical methods were employed using the Statistical Package for the Social Sciences (SPSS) program. The following methods were utilized:

- **Frequencies and Percentages:**

Calculated to determine the personal and functional characteristics of the study sample and to identify the responses towards the key statements in the study tool.

- **Mean and Standard Deviation:**

Calculated to assess the average responses of the study sample to the study questions. This helps in organizing the statements based on their highest weighted arithmetic mean.

- **Pearson's Correlation Coefficient:**

Used to determine the degree of correlation between each question in the study. This analysis provides insights into the relationships between variables.

- **Cronbach's Alpha Coefficient:**

Employed to test the reliability of the study tool. Cronbach's alpha assesses the internal consistency or reliability of the measurements in the tool.

By applying these statistical methods, we have gains insights into the characteristics of the study sample, the average responses, correlations between variables, and the reliability of the study tool.

6. Chapter Five: Field Results

This chapter deals with presenting and discussing the results of the study by presenting the answers of the survey respondents.

6.1. Findings Overview & Interpretations

The questionnaire survey results indicate that the majority out of the 99 respondents are in favor of the adoption of modern water desalination technologies. This is in line with the growing global attention towards desalination as a potential technology to meet the increasing water demands. See appendix 2 for the responses of questionnaire survey that represents the need for adoption of modern water desalination technologies.

7. Chapter 6: Results and Proposal Analysis

In this chapter, we will present the research results and provide interpretations based on the proposed hypotheses. The primary objective is to analyze the data collected from the study population in Saudi Arabia. By examining this data, we aim to test the hypotheses formulated earlier and draw meaningful conclusions from the findings.

7.1. Proposal Analysis

If we look at our propose hypothesis of our research, we reject the null hypothesis and accept the alternative hypothesis that is “There is significant influence of modern water desalination technologies on the effectiveness and environmental sustainability of desalination technologies in Saudi Arabia.

7.2. Research Results

The data analysis was conducted using the survey results. Two software were used in this part. The Microsoft Excel software was used for preparing the data, and coding responses. The data was transferred to Jasp from where the analysis was done to test the hypothesis. Below are the results.

Table 2: Descriptive Statistics

	Questio n 6	Questio n 7	Questio n 8	Questio n 9	Questio n 10	Questio n 11	Question 12	Question 13
Valid	99	99	99	99	99	99	99	99
Missing	8	8	8	8	8	8	8	8
Mean	4.495	4.293	4.131	4.242	4.242	3.990	4.00 0	4.03 0
Std. Deviation	0.660	0.786	0.944	0.882	0.771	0.931	0.92 6	0.95 2
Minimum	3.000	1.000	1.000	1.000	3.000	1.000	1.00 0	1.00 0
Maximum	5.000	5.000	5.000	5.000	5.000	5.000	5.00 0	5.00 0

Table 3: Frequencies for Question 6

Question 6	Frequency	Percent	Valid Percent	Cumulative Percent
3	9	8.411	9.091	9.091
4	32	29.907	32.323	41.414
5	58	54.206	58.586	100.000
Missing	8	7.477		
Total	107	100.000		

Table 4: Frequencies for Question 7

Question 7	Frequency	Percent	Valid Percent	Cumulative Percent
1	1	0.935	1.010	1.010
3	14	13.084	14.141	15.152
4	38	35.514	38.384	53.535
5	46	42.991	46.465	100.000
Missing	8	7.477		
Total	107	100.000		

Table 5: Frequencies for Question 8

Question 8	Frequency	Percent	Valid Percent	Cumulative Percent
1	3	2.804	3.030	3.030
3	20	18.692	20.202	23.232
4	34	31.776	34.343	57.576
5	42	39.252	42.424	100.000
Missing	8	7.477		
Total	107	100.000		

Table 6: Frequencies for Question 9

Question 9	Frequency	Percent	Valid Percent	Cumulative Percent
1	1	0.935	1.010	1.010
3	23	21.495	23.232	24.242
4	25	23.364	25.253	49.495
5	50	46.729	50.505	100.000
Missing	8	7.477		
Total	107	100.000		

Table 7: Frequencies for Question 10

Question 10	Frequency	Percent	Valid Percent	Cumulative Percent
3	20	18.692	20.202	20.202
4	35	32.710	35.354	55.556
5	44	41.121	44.444	100.000
Missing	8	7.477		
Total	107	100.000		

Table 8: Frequencies for Question 11

Question 11	Frequency	Percent	Valid Percent	Cumulative Percent
1	3	2.804	3.030	3.030
3	25	23.364	25.253	28.283
4	38	35.514	38.384	66.667
5	33	30.841	33.333	100.000
Missing	8	7.477		
Total	107	100.000		

Table 9: Frequencies for Question 12

Question 12	Frequency	Percent	Valid Percent	Cumulative Percent
1	4	3.738	4.040	4.040
3	18	16.822	18.182	22.222
4	47	43.925	47.475	69.697
5	30	28.037	30.303	100.000
Missing	8	7.477		
Total	107	100.000		

Table 10: Frequencies for Question 13

Question 13	Frequency	Percent	Valid Percent	Cumulative Percent
1	4	3.738	4.040	4.040
3	19	17.757	19.192	23.232
4	42	39.252	42.424	65.657
5	34	31.776	34.343	100.000
Missing	8	7.477		
Total	107	100.000		

The descriptive statistics mean for all questions regarding Utilizing Modern Water Desalination Technologies showed that the mean was above 3, with the lowest mean at 3.99 for question 11

on the cost-effectiveness of modern water desalination technologies being an important factor to consider in their widespread implementation. From the Linkert scale used in the study, 3 represents Neutral. This shows that most people either agree (4 on the scale) on the use of modern technologies or strongly agree (5 on the scale). The same is supported by the frequency tables above.

Linear Regression

Table 11: Model Summary - Question 6

Model	R	R ²	Adjusted R ²	RMSE
H ₀	0.000	0.000	0.000	0.660
H ₁	0.108	0.012	-0.020	0.667

Table 12: ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H ₁	Regression	0.497	3	0.166	0.372	0.773
	Residual	42.251	95	0.445		
	Total	42.747	98			

Note. The intercept model is omitted, as no meaningful information can be shown.

Table 13: Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
H ₀	(Intercept)	4.495	0.066		67.717	< .001
H ₁	(Intercept)	4.766	0.391		12.201	< .001
	1. Gender: الجنس	0.010	0.126	0.008	0.080	0.936
	Education: التعليم	-0.119	0.117	-0.105	-1.021	0.310
	Age: العمر	-0.018	0.088	-0.021	-0.206	0.837

A linear regression was conducted on the data, considering the questionnaire responses. The results are as tabulated above. This was aimed at determining whether there was any significant relationship between gender, education, and age in the utilization of modern water desalination technologies. The model showed an R-squared value of 0.012, which means that the variables have a very weak linear correlation since only 1.2% of the covariates can explain the dependent variable. The p-value for the ANOVA was 0.773, which is greater than the alpha level of 0.05. This shows that the model covariates gender, age, and education do not contribute significantly

to the regression model. This further confirmed the very weak linear relationship identified above.

Residuals vs. Covariates Plots

Residuals vs. 1. Gender: الجنس

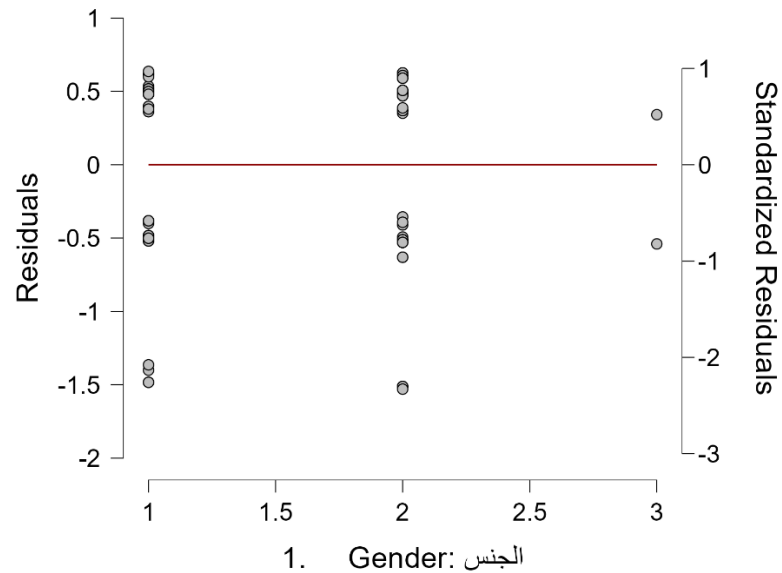


Figure IX: Residuals vs. 1. Gender: الجنس

Residuals vs. Education: التعليم

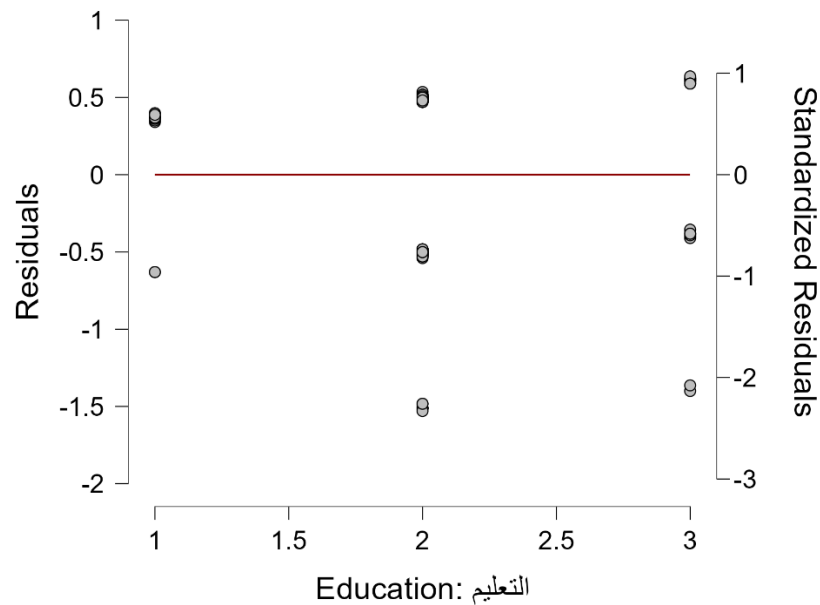


Figure X: Residuals vs. Education: التعليم

Residuals vs. Age: العمر

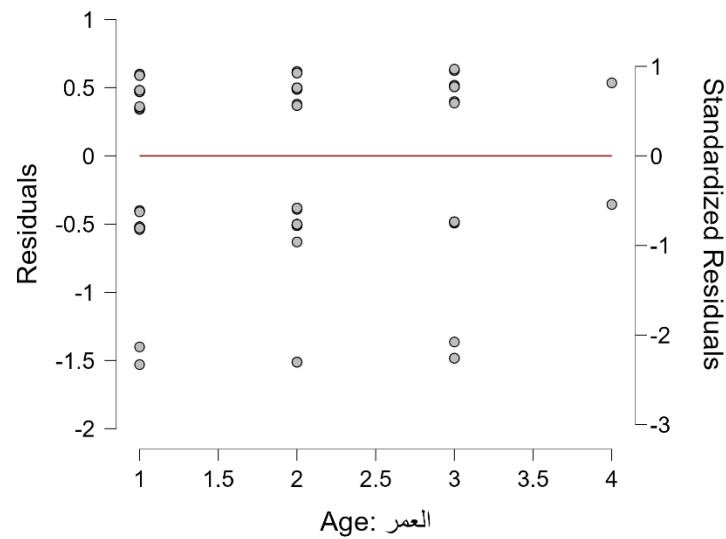


Figure XI: Residuals vs. Age: العمر

The residual versus covariates plots for the regression analysis were also made to determine whether the effect of the covariates was accounted for. The plots, as shown above, show that the effect of covariates was considered because; they are distributed above and below the zero line with roughly equal variances for all covariates. The plots also show that the effect of the covariates are negligible, as they extend more below the zero line, at a ratio of 3:1.

7.3. Discussion

From the above data analysis, it is evident that the means for the answers to the questions show that most of the respondents were in favor of the adoption of modern water desalination technologies. This is due to the means being above 3, with the least at 3.99. When the data was tested against the independent variables including age, education, gender, nationality, and industry/organization, it showed that there was no significant relationship between utilization of modern water desalination technologies and the independent variables. Therefore, the null hypothesis stated in this paper that “There is no significant influence of modern water desalination technologies on the effectiveness and environmental sustainability of goals of the Green Saudi Arabia and Green Middle East projects” is refuted, and the alternative hypothesis is upheld.

7.4. Recommendations

Based on the analysis, the following recommendations can be made for the adoption of modern water desalination technologies in Saudi Arabia:

- 1. Investment in Renewable Energy Integration:** From the analysis, it clear that integrating renewable energy sources on the environmental sustainability has a positive impact. Therefore, it is recommendable that Saudi Arabia should continue to promote and invest on the integration wind power and solar energy into desalination operations. This would be important in ensuring long-term energy efficiency, low carbon emission and a better environment conservation.
- 2. Enhanced Brine Management Techniques:** It is recommendable that more research and development efforts should emphasis on enhancing brine management techniques by considering the environmental concerns allied with brine disposal. Exploring innovative methods such as brine dilution, controlled discharge into deep ocean currents, and resource recovery from brine can minimize ecological harm and maximize the utilization of brine byproducts.
- 3. Water Conservation Initiatives:** Acknowledging the need for sustainable water management, it is recommended that Saudi Arabia implements water conservation initiatives. This could involve raising awareness through campaigns and imposing measures like taxes on high water usage to reduce overall water demand. These efforts align with the goal of achieving a balance between water availability and consumption.
- 4. Continued Research and Development:** A smooth teamwork is necessary among all the stakeholders such as government, energy industry and academic researchers for Saudi Arabia to stay at the forefront of desalination technology. It is also necessary dig deeper and highly invest in research and development. The research should dive in advancements in membrane technology, alternative desalination methods, and system configurations to promote maximum energy efficiency and minimize negative environmental effect.
- 5. Global Collaboration:** It is also crucial for Saudi Arabia to actively take part in international collaborations, knowledge-sharing platforms, and conferences. This would help in contributing to the global advancement of sustainable desalination practices. The

country can accelerate progress towards sustainable water solutions worldwide through sharing experiences, best practices, and research findings.

- 6. Adoption of Solar Desalination Technologies:** Saudi Arabia should invest in and promote the use of solar desalination technologies, powered by abundant solar energy resources in the country, to reduce CO₂ emissions and global warming.
- 7. Integration of Desalination Technologies in Agriculture:** Encouraging the use of desalinated water in agriculture, particularly for crops sensitive to salt and drought conditions, can improve crop yield, reduce dependence on fresh water resources, and promote sustainable agricultural practices.
- 8. Adoption of Royal Commission Standards/Regulation to the Kingdom:** The Royal Commission of Jubail possesses an adequately established standards and research center in agriculture, which may significantly contribute to enhancing the quality of life in urban areas. The research center investigates the plant species that are compatible with the environmental conditions of Saudi Arabia.
- 9. Implementation of Wastewater treatment Industries:** Implementing wastewater treatment facilities in all cities in Saudi Arabia, together with an efficient management system to utilize the surplus water, will contribute to the ambitious goal of planting 10 billion trees and restoring Saudi Arabia's greenery.
- 10. Community Awareness & Industries:** MA'ADEN, a global mining company, as has entered into an agreement with the Green Saudi Arabian Initiatives Forum to plan for the planting of 10 million trees on Gourmah Island in Jubail Industrial City. Mandating Industrial Companies to engage in reforestation efforts proportional to their CO₂ emissions can enhance their awareness of environmental pollution and encourage them to explore greener alternatives to mitigate greenhouse gas emissions.

7.5. Conclusion

In conclusion, this research has outlined the substantial impacts of current desalination technologies on the environmental sustainability of water desalination processes in Saudi Arabia. It has shown that the adoption of modern technologies such as integration with renewable energies, reverse osmosis and innovative water treatment process plays a major role in solving water scarcity issues and ensuring that there is a stable water supply. The

journey of Saudi Arabia's towards maintainable desalination practices replicates an assurance to decreasing the carbon footprint, optimizing resource utilization, and promoting environmental responsibility. The findings from the practical study that was conducted via an analytical descriptive method offers some significant insights awarenesses into the perceptions of officials, industry specialists, researchers, and the general public concerning the effects of modern desalination technologies.

The recommendations emphasize the importance of continuous efforts in renewable energy integration, brine management optimization, water conservation, research and development, and global collaboration. Through implementation of these recommendations, Saudi Arabia can further reinforce its position as a front-runner in sustainable desalination practices. It will not only contribute to national water security but also to the global search of environmentally responsible water solutions.

References and Appendices

This chapter presented a comprehensive list of all the sources cited in the study along with the study abstract. The abstract serves as a concise summary of the study, providing an overview of its objectives, methods, key findings, and implications. It is designed to provide readers with a preview of the research conducted.

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9. Appendices

The appendix 1 below represents the questionnaire paper of the research conducted.

Appendix 1: Questionnaire Paper

Section 1: Respondent Information

1. Gender:

- Male
- Female
- Prefer not to say

2. Age:

- 18-25
- 26-35
- 36-45
- 46 and above

3. Education:

- High school or below
- Bachelor's degree
- Master's degree

4. Nationality:

- Saudi Arabian
- Other (please specify)

5. Industry/Organization Type:

- Government
- Private sector

Section 2: Utilizing Modern Water Desalination Technologies

Please indicate your level of agreement with the following statements:

6. Modern water desalination technologies can play a significant role in addressing water scarcity in Saudi Arabia and the Middle East.

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

7. The use of modern water desalination technologies aligns with the goals and objectives of the Green Saudi Arabia and Green Middle East projects.

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

8. Implementing modern water desalination technologies can contribute to reducing the ecological impact of traditional water sources, such as groundwater pumping.
 - Strongly agree
 - Agree
 - Neutral
 - Disagree
 - Strongly disagree
9. The adoption of modern water desalination technologies can support the sustainable development of coastal regions by providing a reliable source of freshwater.
 - Strongly agree
 - Agree
 - Neutral
 - Disagree
 - Strongly disagree
10. Investing in research and development of advanced desalination technologies should be a priority for achieving the goals of the Green Saudi Arabia and Green Middle East projects.
 - Strongly agree
 - Agree
 - Neutral
 - Disagree
 - Strongly disagree
11. The cost-effectiveness of modern water desalination technologies is a crucial factor in their widespread implementation.
 - Strongly agree
 - Agree
 - Neutral
 - Disagree
 - Strongly disagree
12. Public awareness and education campaigns are necessary to promote the benefits and importance of utilizing modern water desalination technologies.

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

13. Collaboration between government, private sector, and research institutions is essential for the successful implementation of modern water desalination technologies.

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

Appendix 2: Questionnaire Responses Charts

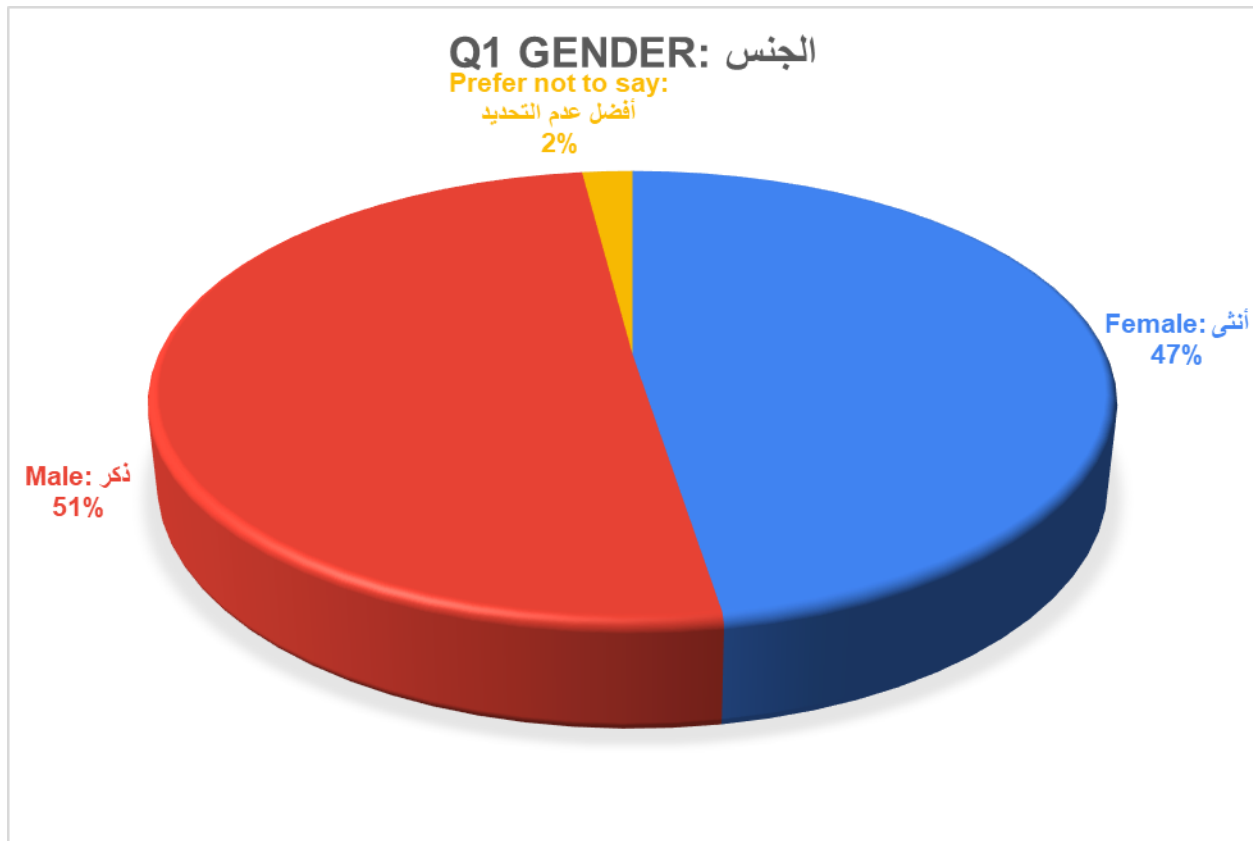


Figure XII: Gender

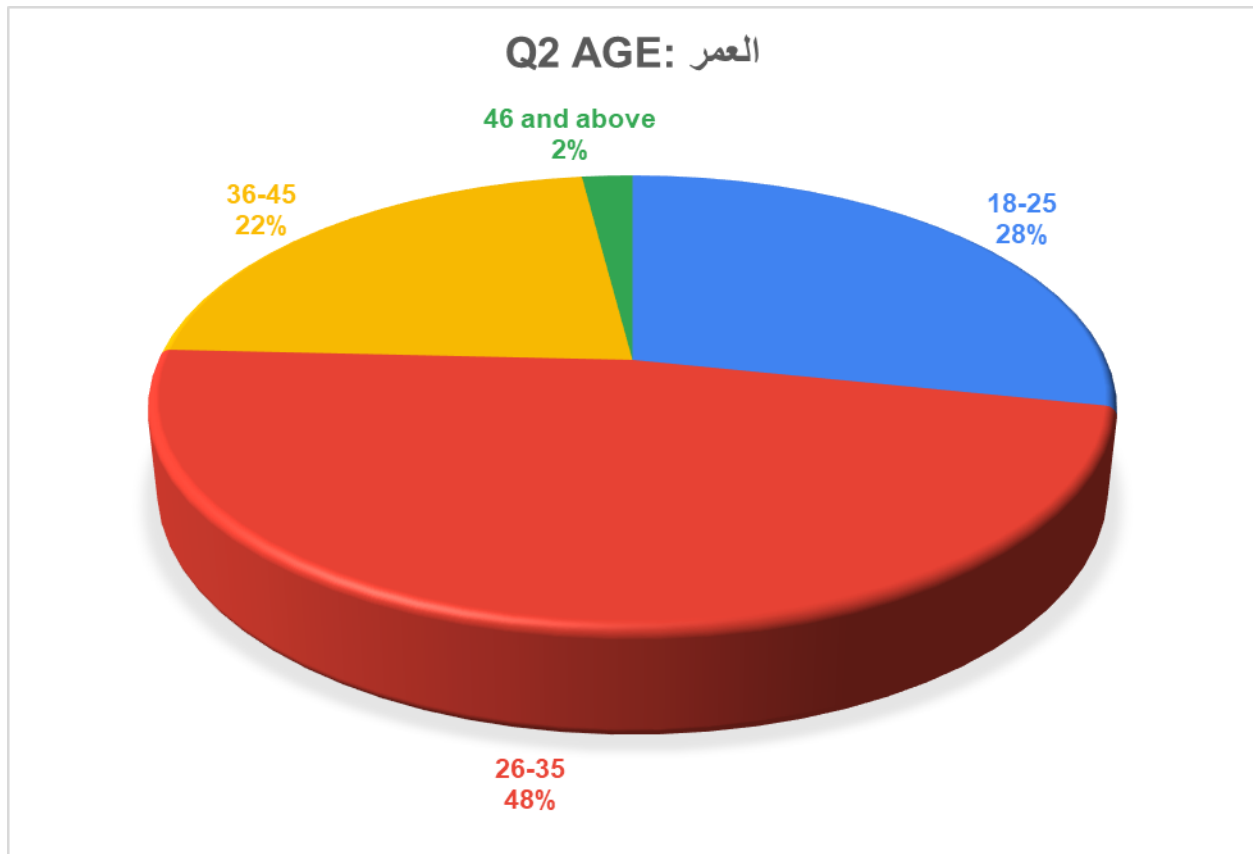


Figure XIII: Age

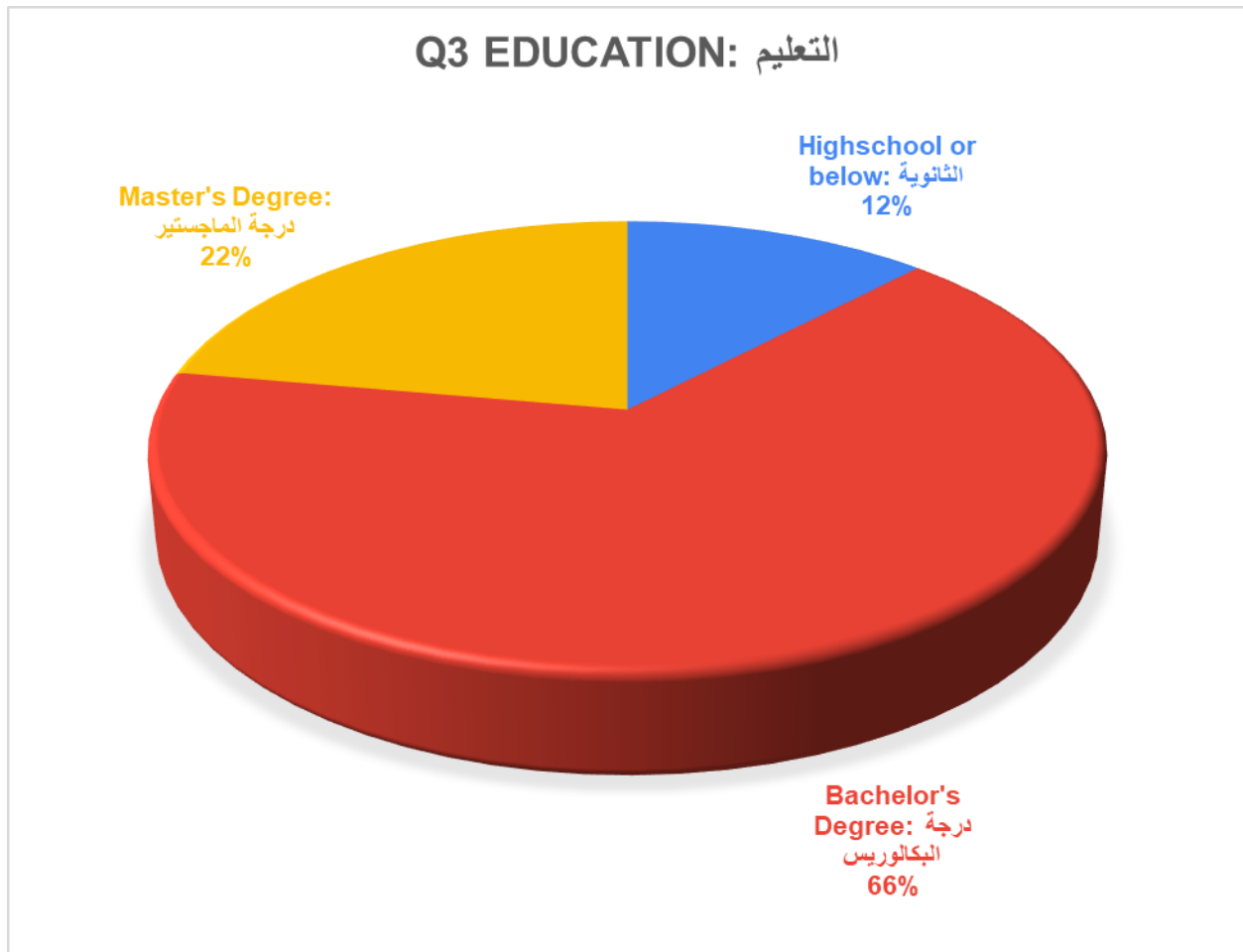


Figure XIV: Education

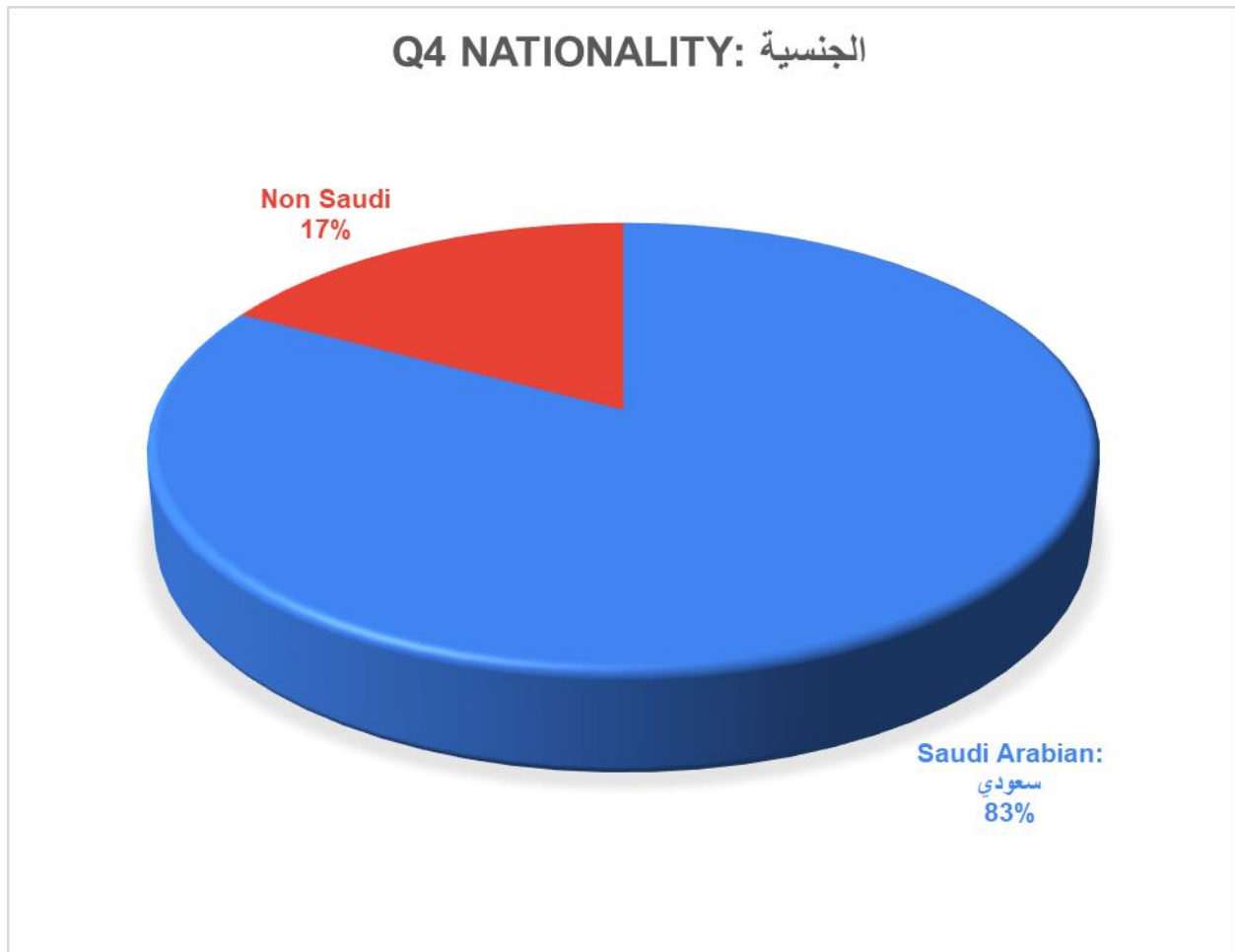


Figure XV: Nationality

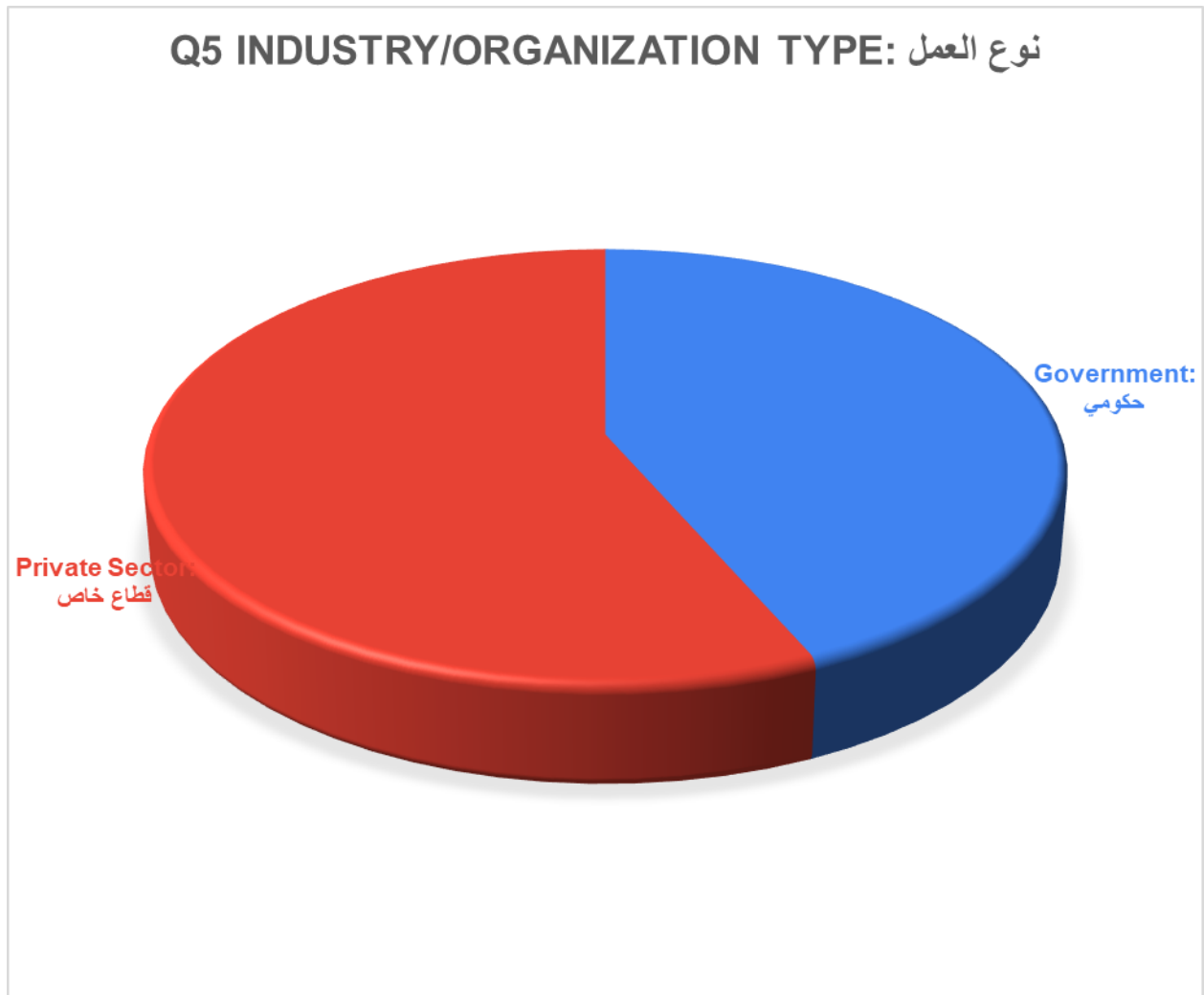


Figure XVI: Industry/Organization Type

Q6 MODERN WATER DESALINATION TECHNOLOGIES CAN PLAY A SIGNIFICANT ROLE IN ADDRESSING WATER SCARCITY IN SAUDI ARABIA AND THE MIDDLE EAST.

يمكن أن تلعب تقنيات تحلية المياه الحديثة دورًا مهمًا في معالجة ندرة المياه في المملكة العربية السعودية والشرق الأوسط.



Figure XVII: Modern Water Desalination Technologies can play a significant role

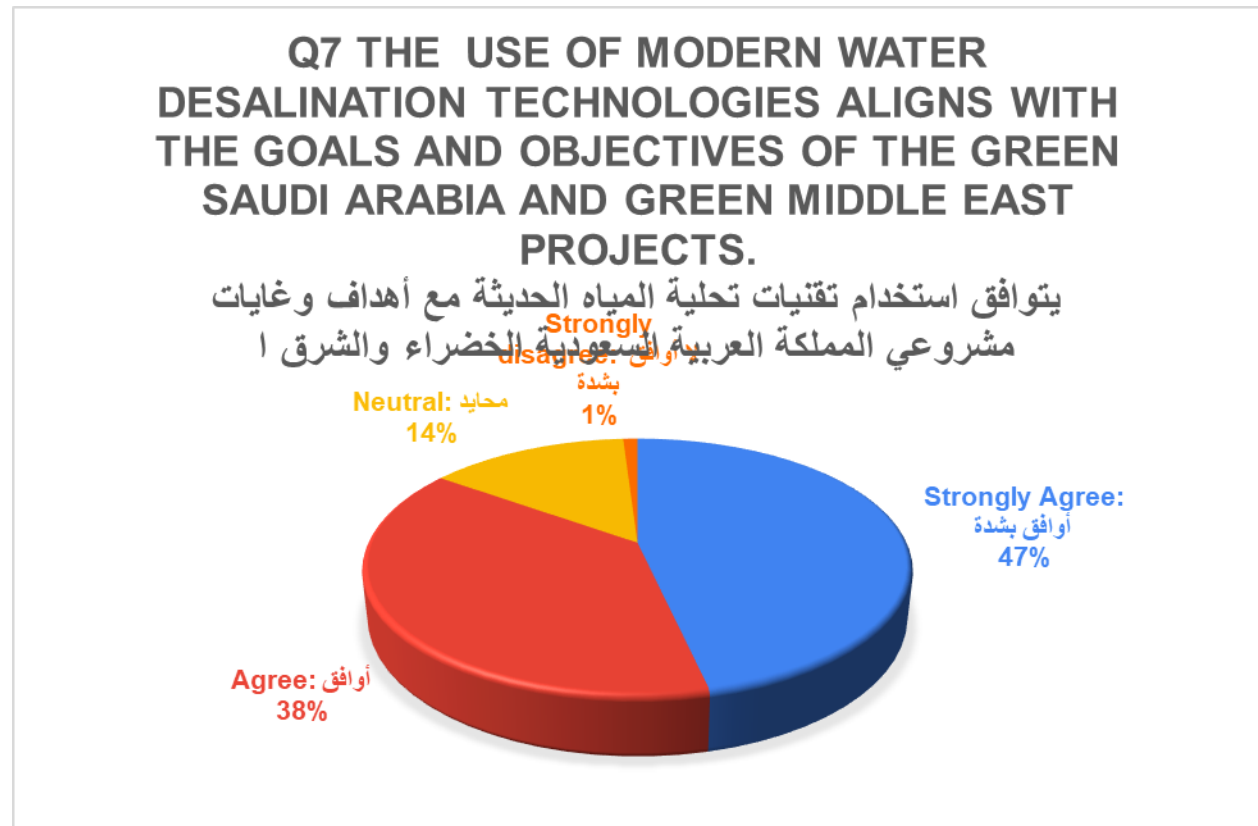


Figure XVIII: The use of modern water desalination Technologies

**Q8 IMPLEMENTING MODERN WATER
DESALINATION TECHNOLOGIES CAN
CONTRIBUTE TO REDUCING THE ECOLOGICAL
IMPACT OF TRADITIONAL WATER SOURCES,
SUCH AS GROUNDWATER PUMPING.**

من الممكن أن يساهم تطبيق التقنيات الحديثة لتحلية المياه في تقليل
التأثير البيئي لمصادر المياه

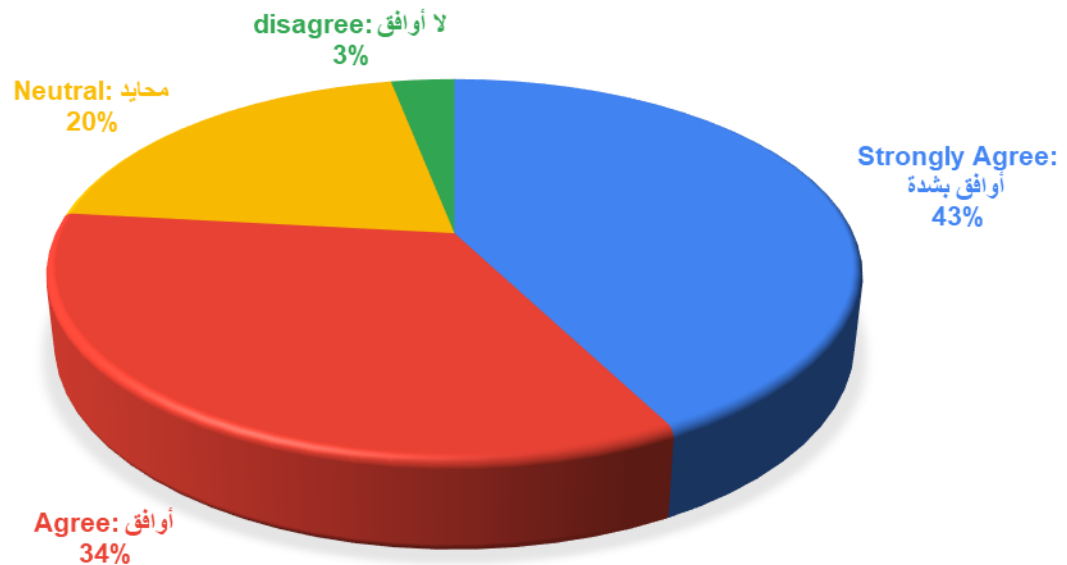


Figure XIX: Implementing Modern Water Desalination Technologies

**Q9 THE ADOPTION OF MODERN WATER
DESALINATION TECHNOLOGIES CAN
SUPPORT THE SUSTAINABLE DEVELOPMENT
OF COASTAL REGIONS BY PROVIDING A
RELIABLE SOURCE OF FRESHWATER.**

إن اعتماد تقنيات تحلية المياه الحديثة يمكن أن يدعم التنمية المستدامة
للمناطق الساحلية من خلال

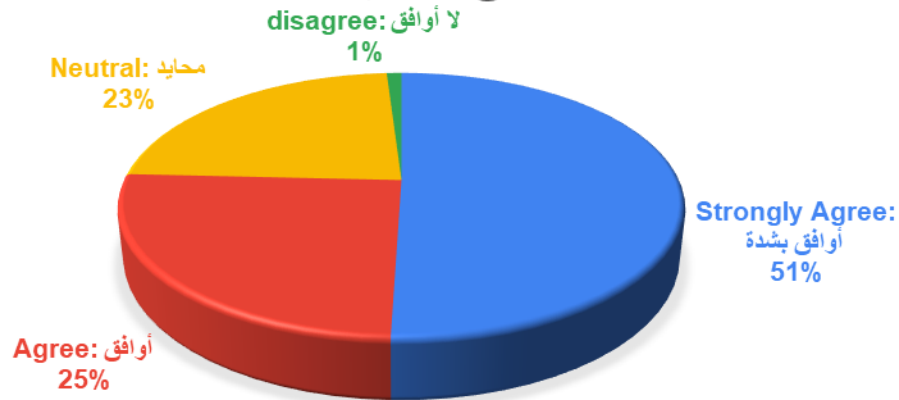


Figure XX: The Adoption of Modern Water Desalination Technologies

**Q10 INVESTING IN RESEARCH AND
DEVELOPMENT OF ADVANCED DESALINATION
TECHNOLOGIES SHOULD BE A PRIORITY FOR
ACHIEVING THE GOALS OF THE GREEN SAUDI
ARABIA AND GREEN MIDDLE EAST
PROJECTS.**

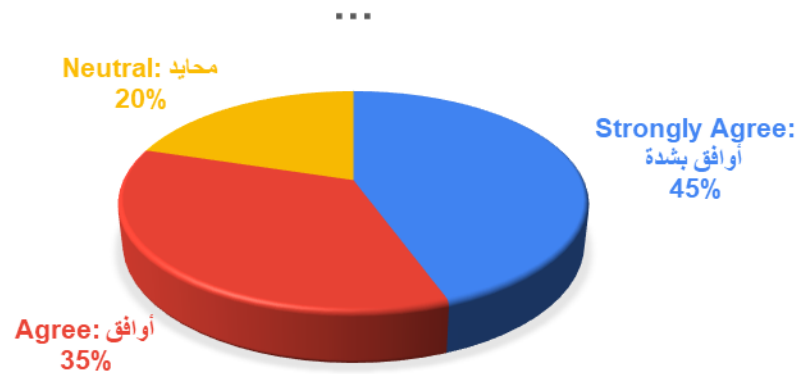


Figure XXI: Investing in Research and Development

Q11 THE COST-EFFECTIVENESS OF MODERN WATER DESALINATION TECHNOLOGIES IS A CRUCIAL FACTOR IN THEIR WIDESPREAD IMPLEMENTATION.

تعد فعالية تقنيات تحلية المياه الحديثة من حيث التكلفة عاملاً حاسماً في تنفيذها على نطاق واسع

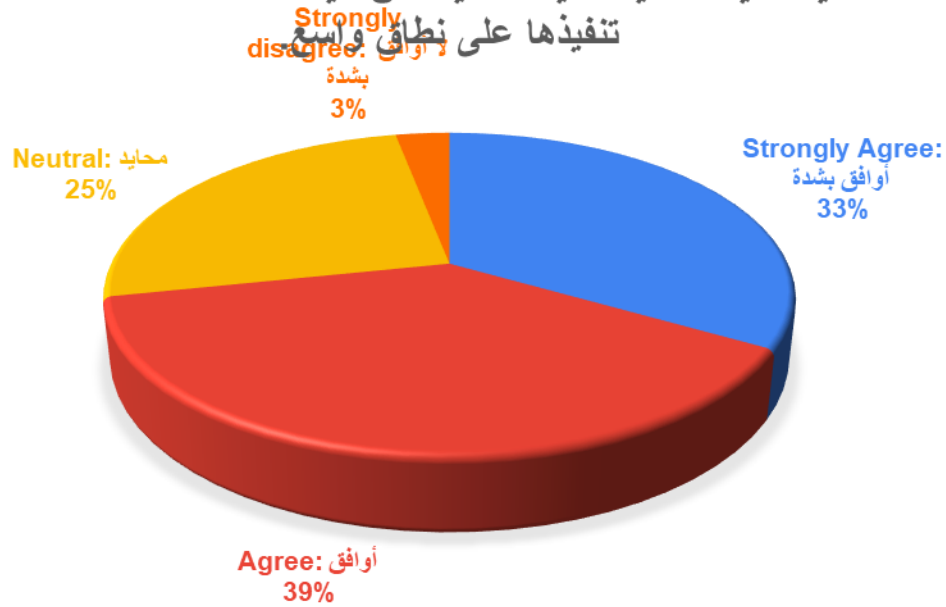


Figure XXII: The Cost-Effectiveness of Modern Water Desalination Tech

Q12 PUBLIC AWARENESS AND EDUCATION CAMPAIGNS ARE NECESSARY TO PROMOTE THE BENEFITS AND IMPORTANCE OF UTILIZING MODERN WATER DESALINATION TECHNOLOGIES.

تعتبر حملات التوعية والتعليم العامة ضرورية لتعزيز فوائد وأهمية استخدام التقنيات الحديثة لتحلية المياه.



Figure XXII: Public Awareness and Education Campaigns

Q13 COLLABORATION BETWEEN GOVERNMENT, PRIVATE SECTOR, AND RESEARCH INSTITUTIONS IS ESSENTIAL FOR THE SUCCESSFUL IMPLEMENTATION OF MODERN WATER DESALINATION TECHNOLOGIES.

يعد التعاون بين الحكومة والقطاع الخاص والمؤسسات البحثية أمرًا

ضروريًا للتنفيذ الناجح لـ



Figure XXII: Collaboration between Government and Private Sector