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**Environment and
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Challenges and Opportunities of Establishing Nuclear Power Stations in the GCC

A Thesis submitted in Partial Fulfilment of the Requirements for the
Master in Environment and Sustainable Development

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Abstract

Nuclear energy has exceptionally low carbon dioxide emissions throughout its life cycle, it can be considered a potential mitigation technique in the battle against climate change. However, there are many constraints in building those reactors on grounds due to issues related to human health and the environment. This study aimed at assessing the challenges and opportunities of establishing nuclear power stations in the Gulf Cooperation Council. A cross-sectional exploratory study was conducted between 11th December 2022 to 05th February 2023. The survey was distributed online using Google Forms. 406 responses to the questionnaire were collected. Another method used was conducting interviews for five experts in the field. The collected data was processed by Statistical Package for Social Sciences IBM SPSS (version 21) using mainly Cronbach alpha test of reliability of the questionnaire, descriptive statistics, chi-square test of independence and factor analysis. The content of the questionnaire comprised participants' profile, challenges, and opportunities of establishing nuclear power stations in the gulf cooperation council. Whereas the interview of the study explores the potential environmental impact of nuclear power plants, the benefits of joint initiatives for the Gulf Cooperation Council, the economic impact of the cost of establishing nuclear power stations, and the disposal of nuclear waste in the region. It also considers the impact of new technology on performance, safety, and environmental impact. The study found that the major challenges of the study indicates that 47.3% of the participants had agreed that the project requires sizable budget, 47.5% agreed that the existing engineers and scientists in the Gulf Cooperation Council (GCC) requires training, and 46.3% of the respondents agreed based on public awareness that there are different categories of nuclear waste disposal. On the other hand, the major opportunities indicated that 49.5% of the participants agreed that nuclear power stations may reduce the cost of electricity because nuclear power plants are expensive to build but inexpensive to operate since the management of waste, disposal, and decommissioning expenses are included into the electricity price. Moreover, 46.6% agreed that nuclear power stations will provide diversifications of energy supply. Additionally, 41.1% agreed that it generates low amount of pollution, and 41.4% of the participants agreed that it is crucial in combating climate change. In conclusion, the current study was able to give a thorough analysis of the challenges and opportunities of establishing nuclear power station in the gulf cooperation council. The findings imply that the experts in the gulf cooperation council member states have a reasonable understanding of nuclear power stations challenges and opportunities and are optimistic about joint initiatives between the gulf countries. However, potential factors influencing the challenges such as shortage of water needed for the cooling process of the plants, the university courses on nuclear studies, qualified researchers, legal framework and legislations, and the opportunity factors such as successful stories from the United Arab Emirates nuclear power plants establishment, the researchers that were sent to study abroad on nuclear studies from the Kingdom of Saudia Arabia, economic benefits of the project to the gulf region, were not assessed in this study. Thus, nuclear safety programs should be taken into consideration to overcome the catastrophe in accidents related to nuclear power plants and its safety, as this could affect the region, people, and the environment. The whole process should be carried out in line with customs, statues, laws, and legal framework of international atomic energy agency, as they work on collaborative scientific and technical application of nuclear technology.

Dedication

I dedicate this work to God Almighty, who created me and gave me my power, thoughts, knowledge, competence, and wisdom. Through this thesis, he has given me strength, and I have only been able to complete the journey through his blessings.

This thesis is also dedicated to my family, who have been there for me through all the difficulties of graduate school and life, who have always loved me despite anything, and who have taught me the value of working hard to achieve my desires.

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Chapter One

Introduction to the Study

1.1 Introduction

1.2 Research Problem

1.3 Research Questions

1.4 Research Objectives

1.5 Research Significance

1.6 Research Setting

1.7 Definition of Terms

Chapter One

Introduction to the Study

1.1 Introduction

This study is divided into four chapters, the first chapter is an introduction to the study, and it includes the research problem, question, objectives, significance, setting and terminologies. The second chapter is on the literature review, theoretical framework, and research hypotheses. The third chapter is on the research study's methodology, population and sample, tools, data collection and procedures and statistical approaches. Whereas the fourth chapter is on the results, discussion, and recommendations.

A nuclear plant consists of one or more nuclear reactors that can produce anywhere between a few and thousands of megawatts of power. The main purpose of using nuclear energy for civil purposes is the creation of heat through the nuclear fission of atomic nuclei in order to generate electricity at a nuclear plant (World Nuclear Association, 2022). The sustainable development goal number 7- (SDG 7) aims at achieving universal access to electricity and has made clear progress, yet gaps continue to exist, mostly in isolated and rural areas. The rising use of clean energy in conjunction with the adoption of nuclear power plants reactors has the potential to close such gaps as worldwide initiatives attempt to deploy clean and creative solutions (Liou, 2021). However, numerous historical occurrences caused many nations to pause before constructing nuclear power plants in their country.

There had been significant nuclear power plant accidents across history in various countries are included in table (1):

Table (1): Significant Nuclear Power Plant Incidents and Accidents based on the International Nuclear Event Scale (Dvorak et al., 2011)

INCIDENTS				ACCIDENTS		
Level 1 ANOMALY	Level 2 INCIDENT	Level 3 SERIOUS INCIDENT	Level 4 ACCIDENT WITH LOCAL CONSEQUENCES	Level 5 ACCIDENT WITH WIDER CONSEQUENCES	Level 6 SERIOUS ACCIDENT	Level 7 MAJOR ACCIDENT
Breach of operating limits at a nuclear facility. Source: International Atomic Energy Agency	Cadarache France - 1993 Spread of contamination to an area not expected by design.	Sellafield U.K. - 2005 Release of large quantity of radioactive material, contained within the installation.	Tokaimura Japan - 1999 Fatal overexposures of workers following an event at a nuclear facility.	Three Mile Island U.S. - 1979 Severe damage to the reactor core. Minimal breach to outside environment.	Kyshtym Russia - 1957 Significant release of radioactive material to the environment from explosion of a high activity waste tank.	Chernobyl Ukraine - 1986 Widespread health and environmental effects. External release of a significant fraction of reactor core inventory.

The historical background of constructing nuclear power stations started on November 4, 1943, the X-10 Graphite Nuclear Reactor in Oak Ridge, Tennessee, in the United States, it became the first nuclear power plant to produce a light bulb through the production of electricity (Nuclear Museum, 2023). The first nuclear power plant in the world, known as Obninsk, was constructed on June 27, 1954, to power the electrical infrastructure of the Soviet Union. Obninsk was referred to as the world's first completely functioning power plant (Morrissey, 2015).

The Gulf Cooperation Council (GCC) is at the forefront of a new wave of nuclear power plant construction. With bold ambitions that led to the building of these plants in the United Arab Emirates - Barakah Nuclear Energy Plant (Barakah Plant, 2023) and other countries in the Gulf Cooperation Council (GCC) are currently researching the project. A number of problems that these countries have in common serve as the formal basis for building these stations in the region. The need to achieve an energy security net by reducing reliance on importing it from external sources while simultaneously diversifying its sources is among these difficulties. Other issues include the rising demand for electric energy and distilled water as a result of population growth and economic expansion

(Al-Maamary et al., 2017). However, because the island area is unsuited for installing reactors, countries like Bahrain may have difficulty initiating the project.

This study will focus on the challenges that the Gulf Cooperation Council (GCC) member states might face in entering the world of nuclear energy, that includes high cost of investment, availability of trained human resources, climate change, infrastructure, manufacturing capacity and productivity of nuclear power stations, legal and regulatory framework, waste risk, location, waste disposal, and safety procedures.

On the other hand, is the opportunity factor in this research that aims at establishing nuclear power stations in cooperation with the Gulf Cooperation Council (GCC), in order to benefit from the following aspects: reducing the cost of electricity, environment protection through the diversification of energy supplies and hence provide secure and reliable source of energy, reach to zero – carbon emissions (Ahmed, 2022), high energy density, and smaller carbon footprints.

The region's proposed nuclear power plant projects vary from nation to nation in terms of their development, motivations, and difficulties. Therefore, coordinated efforts are necessary to develop a ground-breaking project that may benefit the Gulf Cooperation Council (GCC) member states.

1.2 Research Problem

The problem addressed in this study is the significance of the challenges in building nuclear power stations in the Gulf Cooperation Council (GCC) member states, as well as the opportunities that may serve as incentive for many other Gulf Cooperation Council (GCC) nations. Due to a dearth of research in this area, the Gulf Cooperation Council (GCC) may not be familiar with the notion of nuclear power plants. In this study, data was

gathered to ascertain the challenges and opportunities experienced, as well as the degree to which the project's objectives were accomplished. There are various issues that are highlighted in this study it includes the sizeable budget that is demanded in establishing the nuclear power plants, highly qualified human resources are required, provision of necessary training for the scientists and engineers in the Gulf Cooperation Council (GCC), climate change issues in the region and worldwide, the infrastructure needs to be enhanced for the implementation of the plants, legal and regulatory framework, financial plans, institutions and extensive planning, avoiding weapon proliferation using the nuclear power plants, avoiding placing the plants in residential areas, the disposing of nuclear power plants waste and the safety measures to be followed.

1.3 Research Questions

The extent to which specialists perceived the challenges of establishing nuclear power plants in the Gulf Cooperation Council (GCC) and the opportunities that would arise once they were constructed are the question variables posed for this study. After the data collection and analysis, as well as the literature review, are completed, this research question will have an answer.

1.4 Research Objectives

The study's objective is to determine how specialists in the area view the challenges and opportunities of establishing nuclear power plants in the Gulf Cooperation Council (GCC). As a case study, this study helps to analyse the potential and constraints from varied domains. Due to the lack of research in this field, this study was undertaken to complete the knowledge gap and add to the body of literature.

1.5 Research Significance

The Gulf Cooperation Council (GCC) places a high priority on cooperation in environmental sustainability through clean energy as it directs the actions of its plan, one of its priorities is environmental sustainability, and significant effort is being made to achieve outcomes and follow the sustainable development goals (SDGs) (Al-Saidi, 2021).

Establishing nuclear power plants is a significant topic in environmental clean energy aspects. According to the Gulf Cooperation Council (GCC), our environments are similar, but our locations and countries' infrastructure differ. This study and its findings can be addressed across the Gulf member states to provide them with a way forward. Additionally, this study helps all Gulf Cooperation Council (GCC) decision-makers understand the challenges and opportunities of constructing nuclear power plants in the region. This study will add to the body of knowledge regarding the subject in relation to the Gulf Cooperation Council (GCC) member states.

1.6 Research Setting

The study was conducted for participants from the Gulf Cooperation Council (GCC) member states. The countries that the researcher focused on in doing the survey were Bahrain, Saudi Arabia, United Arab Emirates, Kuwait, Qatar, and Oman. Other countries across the world had also added their response to the survey that was distributed, mostly professors with similar backgrounds.

1.7 Research Terminologies

- **Nuclear Power Stations** - to create steam, nuclear power plants heat water. Heat generated during nuclear fission is used in nuclear power

plants to warm water (U.S. Energy Information Administration, 2021).

A nuclear power plant or station is a type of power plant that uses heat produced by nuclear processes to produce electricity.

- **Nuclear Power Reactors** – a nuclear power plant's core is its nuclear reactor. They confine and regulate nuclear chain reactions that release heat through a mechanical process known as fission. The steam created by that heat rotates a turbine to produce energy (Office of Nuclear Energy, 2021).

A reactor is the setting for nuclear processes. In order to run a steam turbine and generate power, the facility also has equipment that extracts heat from the reactor.

- **Gulf Cooperation Council (GCC)** - Bahrain, Kuwait, Qatar, Oman, Saudi Arabia, and the United Arab Emirates make up this group of six countries in the Gulf. Together, the GCC nations decide on matters related to those nations (Cambridge Dictionary, 2023).

A treaty signed on May 25, 1981, in Riyadh, Saudi Arabia, between Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE established the Gulf Cooperation Council (GCC), considering their special alliances, geographical similarity, comparable political structures based on Islamic principles, shared destiny, and shared goals.

- **Clean Energy** – it is defined as energy produced from recyclable materials without the release of greenhouse gases (Dincer & Acar, 2015).

The term "clean energy" refers to energy that is generated using processes that do not discharge greenhouse gases or any other pollutants.

- **Sustainable Development Goals (SDGs)** – they serve as a road map for building a better prosperous future for everybody. They deal with the issues that the world is currently facing, such as famine, discrimination, global warming, destruction of the environment, peace, and equity (United Nations, 2015).

Development that satisfies current demands without compromising the capacity of future generations to satisfy their own needs is known as sustainable development.

Chapter Two

Literature Review and Theoretical Framework

2.1 Literature Review

2.2 Theoretical Framework

2.3 Research Hypotheses

Chapter Two

Literature Review and Theoretical Framework

2.1 Literature Review

Nuclear power differs from traditional forms of electricity generation in a number of ways, which presents both new challenges and opportunities for sustainable growth. Beyond the energy sector, nuclear technology also contributes to sustainable development, particularly in the provision of food, medicine, and clean water.

The previous studies in relation to challenges and opportunities of establishing nuclear power stations in the gulf cooperation council were addressed through the main concept of the research which are detailed below.

2.1.1 Challenges for Entering the World of Nuclear Energy

The Gulf cooperation council states have ambitions of establishing nuclear power plants, so they decided to conduct a joint study on the use of nuclear technology for peaceful purposes in accordance with international standards at its 27th session, which took place in Riyadh in December 2006. One of the most important joint action paths that have been taken in the recent 10 years is represented by this decision. However, there are many challenges to be faced when initiating this project due to various factors that might limit the available resources, infrastructure, frameworks, etc.

Currently, 454 nuclear power reactors, operating at a high-capacity factor of 81%, provide more than 10% of the world's electricity. 31 nations have nuclear power plants, although only five — the United States, France, China, Russia, and South Korea — produce 70% of the world's nuclear electricity (Ho et al., 2019). For nuclear energy to continue to advance in

terms of dependability, safety, and costs, several material hurdles must be effectively overcome (Zinkle & Was, 2013). As energy availability and economic opportunity are increased for billions of people, the globe faces the unprecedented task of dramatically lowering greenhouse gas emissions in the twenty-first century. We investigate this issue within the power industry, which has been generally acknowledged as an early prospect for extensive decarbonization. In most locations, supplying the anticipated increase in energy demand in 2050 while also decreasing emissions would necessitate a different combination of electrical generation resources than the one used now (Buongiorno et al., 2019).

The establishment of nuclear power plants could demand a sizable budget for the entire project. An example: United Arab Emirates constructed the nuclear reactors in the Gulf Cooperation Council and accepted a \$20 billion offer from a South Korean corporation to construct four commercial nuclear power reactors at al barakah in 2020, totalling 5.6 GWe (World Nuclear Association, 2022). A brief summary of the Asian nations that built nuclear power plants, is provided below in table (2) (World Nuclear Association, 2022):

Table (2): Asian nations that Built Nuclear Power Plants

No.	Country	Number of Reactors
1.	China	55
2.	Japan	33
3.	South Korea	25
4.	India	22
5.	Pakistan	6
6.	United Arab Emirates	3
7.	Taiwan	2
8.	Iran	1



**Fig. 1: United Arab Emirates Nuclear Power Plants – 4 Reactors
(Emirates Nuclear Energy Corporation, 2023)**

For the Nuclear power sector, highly qualified human resources are required, in order to implement a nuclear power program as part of a national energy plan, a variety of national infrastructural factors must be carefully considered. Countries starting new nuclear energy programs have the chance to build up efficient knowledge management processes and systems right away, with the extra benefit of easily accessible hardware and software systems created for the purpose. By speeding up processes, introducing technology to aid in discovering pertinent information, and implementing strategies to address low-quality outputs, well implemented knowledge management increases organizational efficiency and productivity. A key component of the efficient management of nuclear knowledge is making sure that skilled staff are always available (Kosilov et al., 2009).

The available engineers and scientist in the Gulf Cooperation Council are ready to operate nuclear power plants if they are provided with the necessary training. A well-organized, specialized human resource development program is also necessary for the nuclear power growth vision (Grover & Puri, 2013). Due to the complexity and safety concerns associated with nuclear power, staff members at nuclear power plants

typically undergo extensive and demanding training. A power plant must also exercise caution in successfully and efficiently managing its workforce, as well as in making sure that the appropriate preparations are being made to gain the requisite nuclear knowledge with proper training lead time. A utility firm without nuclear power experience has several training options at their hands. The preparation of long-term human resource development, expanding senior management and general staff exposure to nuclear power technology, performing feasibility studies, and benchmarking exercises, and enlisting the support of pertinent local and international organizations are a few of these (Kahar et al., 2017).

In Jordan a study was done to understand the education provided in this field, the study of field survey showed that senior engineering students have little awareness and knowledge of energy and renewable energy technology. The market will continue to suffer from poorly educated and skilled engineers and technicians in this industry if these barriers are not removed. Therefore, it is crucial that the responsible governmental authorities, working closely with the administrations of both state-run and private colleges, take the required steps to remedy the situation as soon as possible (Alawin et al., 2016).

Extreme weather events linked to climate change may have an impact on nuclear power plant operations at the international and regional levels. Thus, operating conditions for various energy system types, particularly power plants, have already been impacted by changes in the climate (Ahmad, 2021). Several nuclear power reactors have had to shut down recently due to extreme weather conditions that may have been brought on by climate change. These unplanned outages will happen more frequently in the future. The existence of less expensive alternatives makes it difficult for nuclear facilities to compete in the electricity market (Ahmad et al., 2023).

The sector that produces power has serious issues during cold and hot weather. Beyond their impacts on consumption, such as increased peak demand, cold and heat waves can also impair the production of electricity. This is evidently the case when very hot water unexpectedly ceases at thermal or nuclear power plants (Añel et al., 2017).

Infrastructure is needed for the successful implementation of the nuclear power station. A hierarchy of the Gulf Cooperation Council laws governing environmental safety is depicted in Fig. 2. In order to ensure the safe use of nuclear energy, safety regulations must be developed by the Gulf Cooperation Council. The supreme council laws are a comprehensive legal framework for the regulation and oversight of nuclear energy's peaceful uses. It addresses issues related to radiation safety, environmental safety, operational control, security, non-proliferation, waste management, emergency preparedness, and response, transport of nuclear and radioactive material, nuclear liability, and decommissioning and closure.

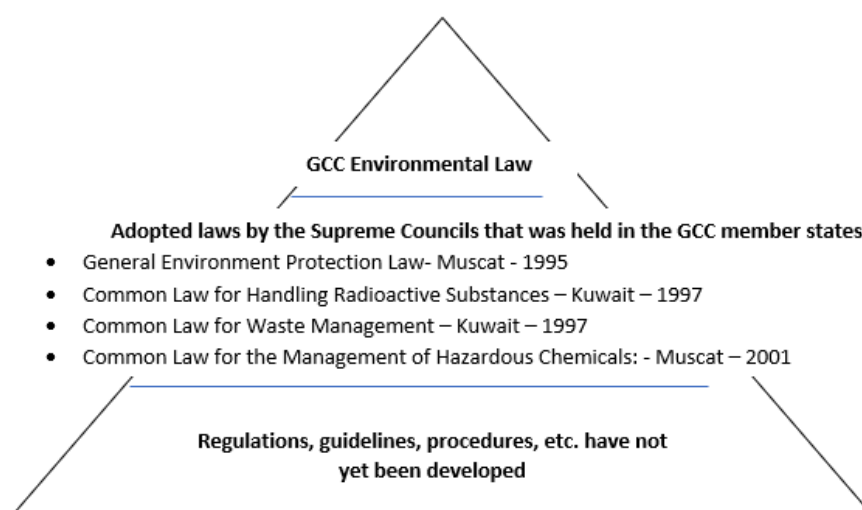


Fig. 2: Hierarchy of the Gulf Cooperation Council Laws Governing Environmental Safety

The institutions responsible for initiating nuclear power stations need to be established in order to carry out duties related to this field. Similarly, in the Gulf Cooperation Council, Emirates Nuclear Energy Corporation, which

was founded in 2009, has developed from a small energy startup with a few employees into a top-tier nuclear energy company with a staff of more than 3,500 employees. To deliver dependable and sustainable nuclear energy to the United Arab Emirates, the huge and expanding staff has a single, unwavering goal (Emirates Nuclear Energy Corporation, 2023).

The successful operation of the nuclear energy sector depends on the training and professional growth of nuclear power plant employees. Virtual reality and augmented reality technologies have quickly expanded in scope, necessitating several studies and experiments to determine how best to use and implement them (Popov et al., 2021).

For the nuclear power sector to be implemented successfully, financial plans are required. In addition to the special hazards involved and the sizeable financial investment needed, financing nuclear power plant projects has historically been difficult for prospective investors and lenders. In both domestic and international markets, financial institutions play a significant role and have a track record of doing so (Pehuet Lucet, 2018). Regarding the extent of foreign government investment, financing plans for nuclear programs in so-called "new countries" differ substantially. For instance, the national government of the United Arab Emirates retains over 80% of ownership control, in contrast to the norm in many other nations, which is 50–100% direct or indirect foreign government sponsorship (Pehuet Lucet, 2018).

Nuclear power plants require extensive planning before they can be put into operation because of their high cost. Since nuclear technology was developed in the United States and has grown there more than in any other nation, it is accorded some attention. Undoubtedly the most complex and difficult nuclear control and supervision system in the world was created by the United States. This is not meant to downplay the achievements and potential of other nations, some of which have constructed and run nuclear

power plants and are leading the way in market advancements. However, just because of its size, the United States is destined to have a significant impact on future developments. The same goes for US policy initiatives, which are frequently followed attentively and utilized as a catalyst for global action (Adamantiades & Kessides, 2009).

For countries considering nuclear power, co-generation and the use of nuclear power plant waste heat are two possibilities to consider in maximizing overall efficiency. However, if considered during prefeasibility studies, some cogeneration applications, such as saltwater desalination in dry regions, could offer an additional benefit during the building and operation of the plants. For instance, during the operation of a plant, a significant amount of industrial-grade, clean water is required for cooling plant machinery, energy conversion systems, and replenishing makeup water for continuous consumption. A desalination plant should be taken into consideration early on if there isn't a cheap source of water supply (Khamis et al., 2013).

Nuclear power plants have the potential for weapon proliferation. The prevailing wisdom contends that nuclear-armed governments are more likely to seek out or obtain nuclear weapons. However, there is a dearth of comprehensive empirical research that evaluates this claim. The relationship between nuclear energy initiatives and proliferation is overblown, according to a methodical review of the historical data. Such initiatives raise a state's technological capability to produce nuclear weapons, but they also have significant political repercussions that reduce the likelihood of proliferation. Particularly, activities involving nuclear energy raise the possibility that parallel nuclear weapons development may be discovered and subject to counterproliferation efforts; they also raise the expense of non-proliferation sanctions (Miller, 2017).

Nuclear power plants must be erected in open spaces far from residential areas and commercial areas. Along with the standard nuclear plant placement, being close to the load centres provides significant benefits. To lessen the effects of an accident, nuclear facilities are increasingly being placed in inaccessible yet isolated regions. It is simpler to adhere to regulatory standards if a new plant is situated far from crowded regions. Additionally, plants must be situated close to a ready source of cooling water, which may not be in the same place as the population centre (Khamis et al., 2013).

The disposal of waste that includes the three main categories of nuclear waste high-level, transuranic, and low-level, must be disposed of in a particular way based on the risk to human health and the environment. One of the fundamental technical challenges that must be overcome if nuclear energy generation of electrical power is to continue to be economically viable is the permanent disposal of high-level radioactive waste. The fundamental difficulty is that the waste must be effectively kept out of contact with the biosphere for millions of years. Over the past few decades, several proposals for long-term disposal have been put out and evaluated by different nations and academic institutions; now, it seems that there is general agreement that mined geologic disposal is the most practical and efficient approach. Countries that produce waste are closely examining a few options on mined geologic disposal (Birkholzer et al., 2012).

It is a difficult and divisive topic to manage nuclear waste. Transuranic waste, high-level waste, and low-level waste are some of the categories of radioactive materials for which permanent disposal is a significant challenge. Social, political, economic, and technological concerns compete and come together to decide the precise end state during the process of choosing a permanent disposal option. A permanent disposal method for these wastes must be isolated for several thousand years, with a reasonable

level of predictive certainty as to how the method will perform over this multigenerational timeframe, in order to guarantee the protection of the public's health and safety as well as the environment (Kok, 2017).

To regulate pollutants and safeguard against radiation, procedures must be put in place. The safety and reliability security requirements for nuclear power plants are highly strict and call for flexibility, reliability, and lengthy lifecycles (Silva et al., 2015). Creating safe operating conditions, preventing, and mitigating accidents, and safeguarding people and the environment from radiation or radioactive material threats are all key components of safety (Busquim et al., 2021).

Programs for radiation protection training and certification must be set up at the national level. The urgent need for skill development programs is caused by the rapid growth of nuclear innovations and nuclear energy for electricity production in developing nations. A crucial first step in assuring an adequate supply of qualified employees for the safe, responsible, and sustainable use of nuclear technologies is to ensure that there are skilled human resources available (Alam et al., 2019).

The need to address climate change mitigation has become more pressing, which has reignited interest in nuclear energy. There is a sizable body of study on greenhouse gas emissions and embodied energy of electricity produced by nuclear power.

A significant portion of the emissions of greenhouse gases in the nuclear fuel cycle occur during processing steps upstream and downstream of the plant, in contrast to traditional fossil powered power plants that nearly entirely produce emissions at the plant site (Lenzen, 2008).

2.1.2 Opportunities for Entering the World of Nuclear Energy

The sustainable development goals set very clear understandings of having clean and affordable energy for all in line with all the seventeenth goals that are set for 2030. The governments in the gulf cooperation council states are very keen in ensuring their obligations towards achieving all the aforementioned goals on time.



Fig. 3: Access to affordable, dependable, sustainable, and modern energy (SDG 7) (UNEP, 2017)

The supply of energy-related services in a manner that safeguards biodiversity, natural resources, and ecosystems is implied by the availability of modern, sustainable energy. Climate change mitigation, the preservation of aquatic and terrestrial ecosystems, and preventing resource depletion are all necessary for accomplishing the sustainable development goals – SDGs. (International Atomic Energy Agency, 2017).

The establishment of nuclear power stations in the Gulf Cooperation Council region may reduce the cost of electricity used in industry. Several studies were conducted in 2009 and 2010 using complicated theoretical

power market models. They all decided that extending the life of nuclear plants will result in lower electricity prices, a rise in GDP, and a surge in jobs (Nestle, 2012). The energy dilemma of providing base charge, clean, and inexpensive power can be overcome by nuclear power (Ho et al., 2019). The most persuasive alternative energy source, beyond wind and solar, is unquestionably nuclear power. Nuclear power is more appealing economically and geographically for the smaller Gulf Cooperation Council nations other than (Saudi Arabia and Oman). Uranium and other nuclear fuel materials are widely available. The Nuclear Energy Agency (NEA) estimates that economically viable uranium deposits, which total 5.5 million metric tons, will be available for reactor fuel for more than 200 years at the present rate (Sultan, 2013).

The international atomic energy agency after having a joint discussion with the gulf cooperation member states decided to work through seven main areas in order to establish the nuclear power plants, it included having legal framework to start the project, infrastructure to safely build the plants, infrastructure for industry and technology, national research to create an environmentally friendly plan for electricity and water, and potential nuclear power input to the latter, defining nuclear construction locations, organizing the program's employees, and the disposal of nuclear waste in the nuclear energy process (Gulf Cooperation Council Secretariat, 2013).

The establishment of nuclear power stations in the Gulf Cooperation Council region may diversify energy supplies and hence provide secure and reliable sources of energy. In a \$100 billion investment campaign to satisfy its increasing electricity demand and prepare the nation for the post-oil age, Saudi Arabia, which holds 20% of the world's oil reserves, is focusing on nuclear and renewable energy. According to Abdullah al-Shehri, head of the nation's Electricity and Co-Generation Regulatory Authority, the country regards solar energy and other non-hydrocarbon

sources as crucial to increasing its capacity to generate electricity by 50% in this decade (Sultan, 2013).

In the United Arab Emirates al barakah nuclear energy plant is fully operational, the four nuclear reactors of the Plant's APR1400 design is providing up to 25% of the United Arab Emirates electricity requirements (Barakah Plant, 2012).

The Gulf Cooperation Council nations have understood that relying solely on gas would not be a viable option due to resource limitations or adverse environmental effects, particularly greenhouse gas emissions. So, after hoisting it over in the 1990s, they gave the idea of utilizing renewable energy sources some thought. They also considered diverse methods of producing electricity, which is why nuclear energy comes into play. A predicted 9.5% increase in annual demand will necessitate more electricity and energy projects; it is anticipated to invest \$200 billion to \$250 billion among 14 and 20 energy projects by 2020. The Gulf Cooperation Council countries have a combined power capacity of roughly 75,000 MW (Alnaser & Alnaser, 2011).

Increased exports of oil and gas will undoubtedly result from this movement, which will improve the global market's stability by expanding supply and, as a result, boost revenues at the national level. In order to protect this non-renewable resource for future generations, this will slow down the rate of oil and gas depletion and lengthen the production cycle. Moreover, this will open up new opportunities for the peaceful transfer of cutting-edge technologies. Oil and gas are the main sources of energy used in Saudi Arabia to produce electricity. Future capacity plans call for nuclear and renewable energy sources to enhance this mix, freeing up oil for use in other ways that could provide income (Matar et al., 2016).

The establishment of nuclear power stations in the Gulf Cooperation Council region may have zero – carbon emissions. Whereas, in the United

Arab Emirates, the energy industry is the main source of greenhouse gas emissions. This industry is responsible for over 90% of all greenhouse gas emissions. The need for energy is increased by the rapid rise in population size, high rate of the process of urbanization, quick economic expansion, and cheap cost of energy. Energy use and greenhouse gas emissions are on an upward trend, which presents a challenge for the country (Khondaker et al., 2016).

The establishment of nuclear power stations in the Gulf Cooperation Council region may have high energy density. Whereas an ambitious but achievable objective would be to guarantee 30% of future energy and process heat demands for industrial uses as well as saltwater desalination from nuclear power by 2030, especially for the states of the Gulf Cooperation Council and the nations of North Africa (El-Genk, 2008).

Nuclear power stations in the Gulf Cooperation Council region may be crucial to our effort to combat climate change because all the wealth and luxury that the residents of the Gulf States enjoy will be impacted by climate change, which has already triggered a battle. The effects of global warming can be seen in numerous ways, including an increase in the region's average ambient temperature and a marked decline in precipitation. Human activities from year to year and decade to decade are causing a rapid change in the local climate. On numerous levels, the Arabian Gulf region is concerned about climate change, and there is a rising level of knowledge there. Food security, renewable energy production, distilled water processing, and public health are just a few of the industries and systems that could be impacted by climate change (Al-Maamary et al., 2017).

2.1.3 Executive Summary

The challenges and opportunities of establishing nuclear power stations in the gulf cooperation council member states may have various pros and cons

due to the factors that each country in the council have different abilities and factors when compared to each other. The challenges that are possible when initiating the project are a sizable budget for the entire project might be demandable, highly qualified human resources are needed to carry out the operation of the plants, providing the engineers and scientist in the gulf countries with the necessary training, keeping in mind that extreme weather events linked to climate change may have an impact on nuclear power plant operations at the international and regional levels that is already happening in many countries that have the project operated, even the infrastructure is necessary for the successful implementation of the nuclear power station as per the joint action plan in gulf cooperation council that states this very precisely in its key areas (Gulf Cooperation Council Secretariat, 2013), forming independent institutions that are specialized in nuclear power sector is essential due to the specialization of this project, similar to the United Arab Emirates as they have the emirates nuclear energy corporation, enacting a legal and regulatory framework that shall be stipulated by the environmental laws in the gulf countries, thorough financial plans to be set in order to have foreign countries build and construct the project on ground like in the United Arab Emirates a Korean company constructed the project, additionally nuclear power plants require extensive planning before they can be put into operation because of their high cost, and the gulf countries must abide with international norms and treaties because nuclear power plants are potential for weapon proliferation. Furthermore, nuclear power plants must be erected in open spaces far from residential areas and commercial areas due to its environmental challenges, as disposal of waste are classified as high-level, transuranic, and low-level, and each must be disposed of in a particular way based on the risk to human health and the environment and as well as based on the laws of disposing nuclear waste followed in the gulf states.

Other challenges include having safety measures to put in place processes for pollution control and radiation protection, and to conduct programs for radiation protection training and certification at the national level to build and enhance the knowledge of members working in this field periodically and in line with changes in technology, trends, etc.

The opportunities that are also linked to establishing nuclear power stations in the gulf cooperation council member states include reducing the cost of electricity used due its availability and surplus, diversification of energy supplies and hence provide secure and reliable source of energy because the gulf states will not only rely on oil and gas. The nuclear power plants when in operation have zero – carbon emissions unlike other conventional energy supplies and even it may have high energy density, it will also generate low amount of pollution to the environment unlike burning fossil fuels that will gradually lead to having smallest carbon footprints and it will be crucial to our effort to combat climate change.

The mix portion of both challenges and opportunities are different when it comes to each state in the gulf region, but when we think of having a joint effort by all the member states in the council, then eventually the project of establishing the nuclear power plants will have more beneficial outcomes due to the resources that are available in countries like Kingdom of Saudi Arabia, Oman, United Arab Emirates and Kuwait, hence Bahrain and Qatar geographical area is challenging due to the limited resources and water availability. Therefore, setting strategical partnership and framework under the gulf cooperation council dome will bring out more prosperity to establishing enormous projects.

2.2 Theoretical Framework

The aforementioned studies shaped the current study and developed its theoretical framework. More specifically, the current study aimed at the

challenges and opportunities of establishing nuclear power stations in the Gulf Cooperation Council. Then a questionnaire has been developed by the researcher for the purposes of the study, followed by conducting interviews with experts in this field.

The questionnaire explored several key concepts. It included the participants' profiles, the challenges for entering the world of nuclear energy and the opportunities of establishing nuclear power stations in cooperation with the gulf cooperation council. Whereas, the interview questions were on the secure establishment of nuclear power plants, the nuclear power plants effect on the environment, if the new technology that complies with international requirements for performance, safety, and environmental reduce the challenges of establishing nuclear power stations, the benefit of the gulf cooperation council from a joint initiative on establishing nuclear power stations in the region, the cost of establishing nuclear power stations effect on the economy of the gulf region and the dumping of nuclear waste.

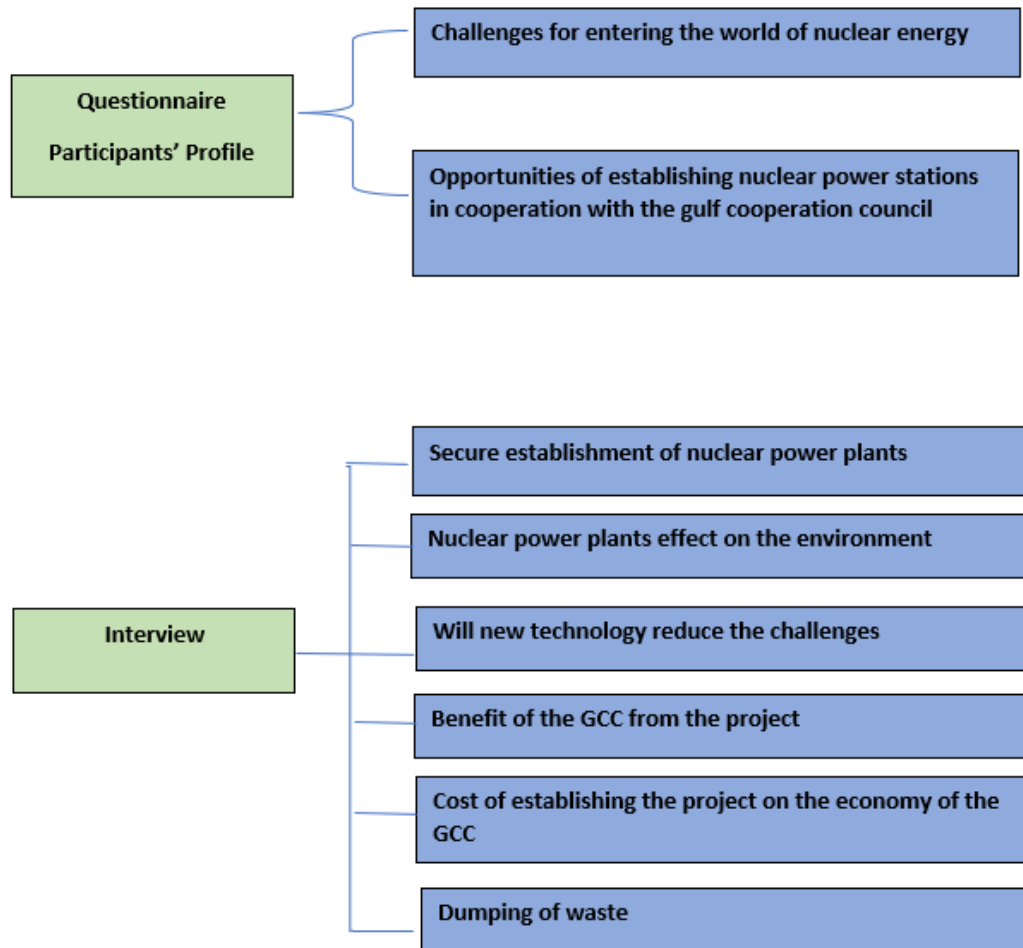


Fig. 4: Theoretical Framework

2.3 Research Hypotheses

The current study aimed at exploring the challenges and opportunities of establishing nuclear power stations in the Gulf Cooperation Council from various perspectives and hence there were no hypotheses to be tested.

Chapter Three

Methods and Procedures

3.1 Research Study's Methodology

3.2 Research Study's Population and Sample

3.3 Research Study's Tools

3.4 Data Collection and Procedures

3.5 Statistical Approaches

Chapter Three

Methods and Procedures

3.1 Research Study's Methodology

It was a cross-sectional exploratory study. It falls within the category of observational study design. The design elements of the study were the data collection techniques and methods of research data analysis. In a cross-sectional study, the researcher simultaneously examines the result and the exposures in the study subjects. Just the inclusion and exclusion criteria established for the study are used to choose the participants in a cross-sectional study. The researcher conducts the study after the participants were selected to take part in it, evaluating the exposure and results along the way. For surveys with a population, cross-sectional designs are employed (Setia, 2016).

3.2 Research Study's Population and Sample

3.2.1 Study Population

The participants of the study were from the gulf cooperation council member states of age 18 years or above to be able to understand the problem of concern.

3.2.2 Sampling Method and Sample Size

The study sample was reasonably random although it was not a random sample in the strict sense. The target sample size was:

$$n = \frac{z^2 pq}{e^2} = \frac{1.96^2(0.5)(0.5)}{0.05^2} \approx 406.$$

where:

- $z = 1.96$ (Based on a 5% margin of error. Data are assumed two-tailed (i.e., a margin of error of 2.5% on each end of a normal distribution curve), thus a value of 0.9750 will be looked up within the z-score table.)
- $\hat{p} = 50\%$ or 0.50 (This value is often pulled from previous research/ literature. If unsure, use 50%.)
- $\varepsilon = 5\%$ or 0.05 (Same value used to get the z-score estimate but provided as a decimal/ percentage.)

3.3 Research Study's Tools

In the present work a self-administered structured questionnaire has been developed specifically for the purposes of the study. The questionnaire had three main sections. The first section collected information about participants' profile, that mainly included age group, gender, nationality, educational level, and profession. The second section consisted of sixteenth questions concerning the challenges for entering the world of nuclear energy, while the third section is comprised of seven questions on the opportunities of establishing nuclear power stations in cooperation with the Gulf Cooperation Council (GCC).

The questionnaire was developed using online google forms. The question type included (multiple-choice questions, closed-oriented questions and open-oriented). It was constructed in English.

Another type of research was done through conducting interviews with five expert's participants in the field of nuclear power plants. The questions were on if nuclear power plants were secure to establish, can the environment be affected by the nuclear power plant, is new technology that complies with international requirements for performance, safety, and environmental effect reduce the challenges of establishing nuclear power stations, will the gulf cooperation council benefit from a joint initiative on establishing nuclear power stations in the region, will the cost of

establishing nuclear power stations affect the economy of the gulf region and the last question was where the nuclear waste can be dumped.

3.4 Data Collection and Procedures

3.4.1 Management of Questionnaire Distribution and Interview

The developed questionnaire was distributed through social media channels including WhatsApp, Instagram, Snapchat, Facebook, and Twitter for convenience and covered a one month and twenty-five days period from Sunday 11th December 2022 to Sunday 05th February 2023.

The interview was conducted for five experts in the field (Professor of Applied Physics, Nuclear Radiation Affairs Adviser, Professor (Renewable Energy), Executive Social Researcher-Committee on Public Utilities and Environment and Head of Committees on Services, Public Utilities & Environment Affairs) in person and through online meeting using Microsoft teams for convenience and covered a one month and twenty-five days period from Sunday 19th February 2023 to Thursday 13th April 2023.

3.4.2 Ethical Considerations

The questionnaire and interview questions were approved by the higher education committee, thesis supervisor and co-supervisor in the University of Bahrain.

3.4.3 Pilot Study

The developed questionnaire was distributed among 10 qualified persons and their feedbacks have been used to improve the final version of the questionnaire to be used for the actual study. More specifically, the question concerning the challenges were modified to reflect the gulf cooperation council member states and the Physicist was listed among the options of the profession question.

The interview questions format was sent to the supervisor and co-supervisor of the thesis to approve them before conducting the actual interview with experts. The question on where the nuclear waste can be dumped was added to the list of questions.

3.5 Statistical Approaches

The collected data was processed by IBM SPSS 21 version using mainly descriptive statistics, more specifically, for the former, the responses were summarized numerically using frequency and percentage to be tabulated and represented graphically, another test was carried out that was the Chi-square test of independence between the socio-demographic factors and all the challenges and opportunities questions, and the last test was on finding the Factor Analysis.

Chapter Four

Results, Discussion, Conclusion and Recommendations

4.1 Results

4.2 Discussion

4.3 Conclusion and Recommendations

Chapter Four

Results, Discussion, and Recommendations

4.1 Results

This chapter summarizes the results of the study which covered 406 participants in the Gulf Cooperation Council member states to investigate their perspectives towards the Challenges and Opportunities of Establishing Nuclear Power Stations in the Gulf Cooperation Council (GCC). Additionally, five experts in the same area were also interviewed for their perspectives.

The findings are presented in the below sections that align with the survey and interview questions. The first section examines the Cronbach alpha test to view the reliability of the questionnaire with all the variables, the second section is the demographic variables of the respondents to the survey that is qualitative data. Whereas the third section presents the perceptions of the respondents to the challenges of establishing nuclear power stations in the Gulf Cooperation Council (GCC). The fourth section further discusses the perceptions of the respondents to the opportunities for establishing nuclear power stations in the Gulf Cooperation Council (GCC). The fifth section was on analysing the challenges data using Chi-Square. The sixth section was on analysing the opportunity data using Chi-Square. Moreover, the seventh section was on analysing the data using factor analysis. The eighth section was based interviewees responses to the questions related to their field of expert. The ninth section was the summary of all the interviewees' responses. In order to paint the clearest image, the researcher has made a conscious effort to present the data with the least number of remarks. However, some editing was done for clarification.

4.1.1 Cronbach's Alpha Test

The degree to which a concept is measured by a group of items, or the validity of the items, is related to internal consistency. Cronbach's alpha was used to determine how closely connected the study question items that reflect each of the independent and dependent variables are combined. In comparison to values below 0.7, a Cronbach's Alpha value greater than 0,7 is regarded as reliable.

The reliability of the variables' items was determined using Cronbach's alpha test employing the SPSS Statistics. The test is performed for the entire questionnaire including the demographics, challenges and opportunities variables, Table (3) presents the test's results that shows that the alpha coefficient for the 28 items is 0,853, the items show a relatively good internal consistency. Whereas Table (4) shows the alpha coefficient for the 16 items in the study question is 0,892, the challenges items show a relatively good internal consistency and the alpha coefficient for the 7 items in the study question is 0,852, the opportunities items also show a relatively good internal consistency.

Table (3): Cronbach's Alpha for the Questionnaire

Variable	Number of items	Cronbach's Alpha
Questionnaire (Demographics, Challenges and Opportunities)	28	0.853

Table (4): Cronbach's Alpha for the Challenges and Opportunities

Variable	Number of items	Cronbach's Alpha
Challenges	16	0.892
Opportunities	7	0.852

4.1.2 Frequencies of the demographic's variables:

The demographic characteristics of the study participants are collected in Table (5) which shows that 70% of the respondents were adults (25 – 64 years), 24.9%

were youth (18 – 24 years) and 5.2% were only seniors (65 years or older). Further in, 46.6% of the study participants were females, and 53.4% were males, this provides an ideal symbol that men and women are equally represented on the questionnaire. Additionally, 40.9% of them were Bahraini, 27.3% were Saudi and 14% were Emirati, this suggests that the distribution was remarkably comparable. Furthermore, 52.5% participants were bachelor's degree holders, 16% were master's degree holders and 12.3% were PhD Degree holders. The participants' profession varied between the national assemblies, education, students, private and public sector, physicist and energy and environment consultants.

Table (5): Participants' Profile

Participants' Profile	Frequency	Percent
Age:		
Adults (25 – 64 years)	284	70%
Youth (18 – 24 years)	101	24.9%
Seniors (65 or older)	21	5.2%
Gender:		
Male	217	53.4%
Female	189	46.6%
Nationality:		
Bahrain	166	40.9%
Kingdom of Saudi Arabia	111	27.3%
United Arab Emirates	57	14%
Kuwait	30	7.4%
Qatar	16	3.9%
Others	16	3.9%
Oman	10	2.5%
Educational Level:		
Bachelor's Degree	213	52.5%
Master's Degree	65	16%
PhD Degree	50	12.3%
Diploma	46	11.3%
High School Certificate or lower	32	7.9%

Profession:		
Education	53	13.1%
Student	48	11.8%
Employee in Private Sector	73	18.1%
Self Employed	33	8.1%
Employee in Public Sector	70	17.2%
Physicist	28	6.9%
Council of Representatives	25	6.2%
Energy and Environment Consultant	20	4.9%
University Professor	16	3.9%
Supreme Council of Environment	14	3.4%
National Assembly	10	2.5%
Others	16	3.9%

4.1.3 Challenges for Entering the World of Nuclear Energy

The responses were based on the 5-point Likert Scale:

- 1 - Strongly Agree,
- 2- Agree,
- 3- Neutral,
- 4- Disagree,
- 5- Strongly Disagree

The challenges are labelled in Table (6) and the results concerning the challenges for entering the world of nuclear energy among the states of the gulf cooperation council are collected in Table (7) which indicates that 47.3% of the participants had agreed that the project requires sizable budget, 38.7% agreed that it requires highly qualified human resources, 47.5% agreed that the existing engineers and scientists in the Gulf Cooperation Council (GCC) requires training, and 43.8% agreed that climate change might affect the nuclear power plants. Additionally, 41.6% of the respondents agreed that infrastructure is needed for the implementation process, 43.1% agreed that specialized institutions are required for the implementation process, 37.4% agreed that regulatory and legal frameworks are required, and 35.2% of the respondents had neutral respond on

the demand of financial plans to establish the project. Furthermore, 34.7% agreed that extensive planning is required before putting forward the establishment, 41.1% of the respondents had neutral respond on the potential for weapon proliferation, 37.2% agreed that it should be placed far away from residential areas, and 46.3% agreed that there are different categories of waste disposal. Eventually, 34.7% of the respondents agreed and had a neutral response as well on the necessary safety measures, 36.5% had neutral respond on the safety equipment's that are similar to the conventional ones, 35% also had neutral response to the training that is required on the national level, and 37.7% of the participants had neutral response on the concept that nuclear power stations do not emit greenhouse gases.

Table (6): List of Challenges of Nuclear Energy Power Plants

Challenge	Title
Challenge - 1	The establishment of nuclear power plants could demand a sizable budget for the entire project.
Challenge - 2	For the Nuclear power sector, highly qualified human resources are required.
Challenge - 3	The available engineering and scientist in the Gulf Cooperation Council (GCC) are ready to operate nuclear power plants if they are provided with the necessary training.
Challenge - 4	Extreme weather events linked to climate change may have an impact on nuclear power plant operations at the international and regional levels.
Challenge - 5	Infrastructure is needed for the successful implementation of the nuclear power station.
Challenge - 6	Institutions that are specialized in nuclear power sector are needed for the successful implementation of the nuclear power stations.
Challenge - 7	A legal and regulatory framework is needed for the successful implementation of the nuclear power sector.

Challenge - 8	Financial plans are needed for the successful implementation of the nuclear power sector.
Challenge - 9	Nuclear power plants require extensive planning before they can be put into operation because of their high cost.
Challenge - 10	Nuclear power plants are the potential for weapon proliferation.
Challenge - 11	Nuclear power plants must be erected in open spaces far from residential areas and commercial areas.
Challenge - 12	Disposal of waste: The three main categories of nuclear waste are high-level, transuranic, and low-level, and each must be disposed of in a particular way based on the risk to human health and the environment.
Challenge - 13	Safety measures: It is necessary to put in place processes for pollution control and radiation protection.
Challenge - 14	The safety equipment used in the nuclear power plant is similar to any conventional power plant.
Challenge - 15	Programs for radiation protection training and certification must be set up at the national level.
Challenge - 16	Nuclear power facilities do not emit any greenhouse gases.

Table (7): Responses to the challenges of nuclear energy power plants based on the 5-point Likert Scale: 1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

Challenge	Likert Scale	Frequency	Percent
Challenge - 1	2	192	47.30%
	1	106	26.10%
	3	95	23.40%
	4	11	2.70%
	5	2	0.50%
Challenge – 2	2	157	38.70%
	3	131	32.30%
	1	105	25.90%
	4	11	2.70%
	5	2	0.50%

Challenge – 3	2	193	47.50%
	3	119	29.30%
	1	77	19%
	4	15	3.70%
	5	2	0.50%
Challenge – 4	2	178	43.80%
	3	125	30.80%
	1	61	15%
	4	37	9.10%
	5	5	1.20%
Challenge – 5	2	169	41.60%
	3	119	29.30%
	1	89	21.90%
	4	23	5.70%
	5	6	1.50%
Challenge – 6	2	175	43.10%
	3	127	31.30%
	1	78	19.20%
	4	22	5.40%
	5	4	1.00%
Challenge – 7	2	152	37.40%
	3	133	32.80%
	1	95	23.40%
	4	23	5.70%
	5	3	0.70%
Challenge – 8	3	143	35.20%
	2	140	34.50%
	1	97	23.90%
	4	23	5.70%
	5	3	0.70%
Challenge – 9	2	141	34.70%
	3	138	34%
	1	98	24.10%

	4	24	5.90%
	5	5	1.20%
Challenge – 10	3	167	41.10%
	2	147	36.20%
	1	49	12.10%
	4	39	9.60%
	5	4	1.00%
Challenge – 11	2	151	37.20%
	3	132	32.50%
	1	99	24.40%
	4	22	5.40%
	5	2	0.50%
Challenge – 12	2	188	46.30%
	1	112	27.60%
	3	88	21.70%
	4	11	2.70%
	5	7	1.70%
Challenge – 13	2	141	34.70%
	3	141	34.70%
	1	97	23.90%
	4	23	5.70%
	5	4	1.00%
Challenge – 14	3	148	36.50%
	2	135	33.30%
	1	53	13.10%
	4	39	9.60%
	5	31	7.60%
Challenge – 15	3	142	35%
	2	134	33%
	1	99	24.40%
	4	28	6.90%
	5	3	0.70%
	3	153	37.70%

Challenge – 16	2	138	34%
	1	55	13.50%
	4	45	11.10%
	5	15	3.70%

4.1.4 Opportunities of establishing nuclear power stations in cooperation with the Gulf Cooperation Council (GCC)

The responses were based on the 5-point Likert Scale:

- 1 - Strongly Agree,
- 2- Agree,
- 3- Neutral,
- 4- Disagree,
- 5- Strongly Disagree

The opportunities are labelled in Table (8) and Table (9) summarizes the opportunities of establishing nuclear power stations from the Gulf Cooperation Council (GCC) perspectives, this shows that 49.5% of the participants agreed that nuclear power stations may reduce the cost of electricity. Moreover, 46.6% agreed that nuclear power stations will provide diversifications of energy supply. Additionally, 39.2% of the respondents agreed that nuclear power stations have zero carbon emissions, while 38.9% agreed that it may have high energy density and 41.1% agreed that it generates low amount of pollution. However, 37.2% of the responses had neutral impact on that nuclear power stations having smaller carbon footprints. Eventually, 41.4% of the participants agreed that it is crucial in combating climate change.

Table (8): List of Opportunities of Nuclear Energy Power Plants

Opportunity	Title
Opportunity - 1	The establishment of nuclear power stations in the Gulf Cooperation Council (GCC) region may reduce the cost of electricity used in industry.

Opportunity - 2	The establishment of nuclear power stations in the Gulf Cooperation Council (GCC) region may have diversification of energy supplies and hence provide secure and reliable source of energy.
Opportunity - 3	The establishment of nuclear power stations in the Gulf Cooperation Council (GCC) region may have zero – carbon emissions.
Opportunity - 4	The establishment of nuclear power stations in the Gulf Cooperation Council (GCC) region may have high energy density.
Opportunity - 5	The establishment of nuclear power stations in the Gulf Cooperation Council (GCC) region may generate low amount of pollution to the environment.
Opportunity - 6	The establishment of nuclear power stations in the Gulf Cooperation Council (GCC) region may have smallest carbon footprints.
Opportunity - 7	The establishment of nuclear power stations in the Gulf Cooperation Council (GCC) region may be crucial to our effort to combat climate change.

Table (9): Responses to the opportunities of nuclear energy power plants based on the 5-point Likert Scale: 1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

Opportunities	Likert Scale	Frequency	Percent
Opportunity - 1	2	201	49.50%
	1	141	34.70%
	3	45	11.10%
	4	15	3.70%
	5	4	1%
Opportunity – 2	2	189	46.60%
	1	119	29.30%
	3	83	20.40%
	4	13	3.20%
	5	2	0.50%

Opportunity – 3	2	159	39.20%
	3	141	34.70%
	1	73	18%
	4	28	6.90%
	5	5	1.20%
Opportunity – 4	2	158	38.90%
	3	133	32.80%
	1	81	20%
	4	27	6.70%
	5	7	1.70%
Opportunity – 5	2	167	41.10%
	3	120	29.60%
	1	87	21.40%
	4	22	5.40%
	5	10	2.50%
Opportunity – 6	3	151	37.20%
	2	150	36.90%
	1	76	18.70%
	4	22	5.40%
	5	7	1.70%
Opportunity – 7	2	168	41.40%
	3	132	32.50%
	1	76	18.70%
	4	23	5.70%
	5	7	1.70%

4.1.5 Chi-Square Test of Independence between the Socio-Demographic Factors and the Challenges

To compare actual outcomes with predictions, statistical tests like the chi-square test are performed. This test's objective is to determine if a discrepancy between actual and projected data is the result of random variation or an association

between the variables under study. The chi-square test is therefore a perfect option for assisting in our comprehension and interpretation of the relationship between our two category variables.

Below is the Chi-square test of independence between the age, gender, nationality, educational level, and profession with all the 16 challenges. This test is performed to assert if the two variables are independent of each other. The Pearson chi- square and the p- value are displayed below in table (10), whereas if the p-value number is equal to or less than the specified alpha level, which is typically .05, the result is considered significant, otherwise not significant, and we would reject the null hypothesis if the two variables are unrelated.

Table (10): Chi- square test of independence between the socio-demographic factors and the challenges

Socio-demographic factor	Challenge	Pearson Chi-Square	P- value
Age	1	18.938	.015
	2	19.959	.010
	3	20.946	.007
	4	32.046	<.001
	5	48.736	<.001
	6	39.678	<.001
	7	27.772	<.001
	8	28.398	<.001
	9	26.848	<.001
	10	9.151	.330
	11	21.066	.007
	12	18.954	.015
	13	24.941	.002
	14	37.260	<.001
	15	26.058	.001
	16	21.530	.006
Gender	1	30.107	<.001
	2	24.646	<.001
	3	9.753	.045
	4	14.949	.005
	5	27.706	<.001
	6	13.822	.008
	7	37.873	<.001
	8	21.768	<.001
	9	19.390	<.001

	10	8.304	.081
	11	32.673	<.001
	12	12.260	.016
	13	34.237	<.001
	14	27.833	<.001
	15	25.717	<.001
	16	21.331	<.001
Nationality	1	83.883	<.001
	2	77.149	<.001
	3	30.763	.161
	4	27.227	.294
	5	51.904	<.001
	6	59.514	<.001
	7	74.875	<.001
	8	65.093	<.001
	9	69.468	<.001
	10	20.545	.665
	11	46.371	.004
	12	39.004	.027
	13	68.903	<.001
	14	95.446	<.001
	15	69.805	<.001
	16	24.734	.420
Educational Level	1	24.392	.081
	2	31.458	.012
	3	25.172	.067
	4	47.146	<.001
	5	88.035	<.001
	6	42.711	<.001
	7	47.829	<.001
	8	41.361	<.001
	9	24.947	.071
	10	17.304	.366
	11	44.375	<.001
	12	16.246	.436
	13	59.102	<.001
	14	73.408	<.001
	15	49.880	<.001
	16	38.566	.001
Profession	1	108.493	<.001
	2	100.531	<.001
	3	69.946	.049
	4	69.559	.052
	5	134.419	<.001
	6	117.610	<.001
	7	118.021	<.001

	8	96.706	<.001
	9	101.286	<.001
	10	94.556	<.001
	11	95.842	<.001
	12	84.508	.003
	13	98.856	<.001
	14	120.432	<.001
	15	96.409	<.001
	16	81.179	.006

4.1.6 Chi-Square Test of Independence between the Socio-Demographic Factors and the Opportunities

To compare actual outcomes with predictions, statistical tests like the chi-square test are performed. This test's objective is to determine if a discrepancy between actual and projected data is the result of random variation or an association between the variables under study. The chi-square test is therefore a perfect option for assisting in our comprehension and interpretation of the relationship between our two category variables.

Below is the Chi-square test of independence between the age, gender, nationality, educational level, and profession with all the 7 opportunities. This test is performed to assert if the two variables are independent of each other. The Pearson chi- square and the p- value are displayed below in table (11), whereas if the p-value number is equal to or less than the specified alpha level, which is typically 0.05, the result is considered significant, otherwise not significant, and we would reject the null hypothesis if the two variables are unrelated.

Table (11): Chi- square test of independence between the socio-demographic factors and the opportunities

Socio-demographic factor	Opportunities	Pearson Chi-Square	P- value
Age	1	12.277	.139
	2	9.120	.332
	3	13.524	.095
	4	23.094	.003
	5	32.724	<.001
	6	16.813	.032

	7	32.183	<.001
Gender	1	5.272	.261
	2	10.888	.028
	3	7.080	.132
	4	11.773	.019
	5	3.664	.453
	6	3.652	.455
	7	8.642	.071
Nationality	1	48.616	.002
	2	42.385	.012
	3	29.610	.198
	4	28.881	.225
	5	35.857	.057
	6	22.053	.576
	7	41.030	.017
Educational Level	1	19.605	.239
	2	20.654	.192
	3	19.753	.232
	4	16.445	.422
	5	22.440	.130
	6	19.456	.246
	7	18.485	.296
Profession	1	74.296	.023
	2	54.730	.371
	3	60.408	.198
	4	72.124	.034
	5	53.316	.423
	6	75.769	.017
	7	88.093	.001

4.1.7 Factor Analysis:

The factor analysis is examining the correlation between variables. The questionnaire questions ought to assess an identical underlying dimension, and since they are measuring the same thing, they ought to correlate with one another. Therefore, the factors that don't correspond with one another should be eliminated.

According to Table (12), the KMO for the Challenges questions is 0.919, that is regarded as "very good". Whereas, in Table (13) the KMO for the opportunities questions is 0.868, which is also regarded as "very good." Following are the KMOs for various variables: for this dataset, the KMO values are acceptable as

they should be higher than a minimum of .5 for each individual variable: There are more than 0.5 of each variable. Bartlett's test also produced results that were very significant, and given these findings, it is reasonable to say that factor analysis is accurately acceptable for this data.

Table (12): Factor analysis of the challenges using KMO and Bartlett's Test

Kaiser – Meyer – Olkin Measure of Sampling Adequacy		0.919
Bartlett's Test of Sphericity	Approx. Chi – Square	2682.711
	df	120
	Sig.	0.000

Table (13): Factor analysis of the opportunities using KMO and Bartlett's Test

Kaiser – Meyer – Olkin Measure of Sampling Adequacy		0.868
Bartlett's Test of Sphericity	Approx. Chi – Square	1039.093
	df	21
	Sig.	<.001

The number of the components is the next factor to consider. Since SPSS only extracts variables with an eigenvalue higher than 1, therefore, 16 components can be created as for the challenges and 7 components for the opportunities. The scree plot, which exhibits a point of inflexion after 16 elements for the challenges and 7 elements for the opportunities, lends validity to this.

Principal component analysis comes as the last stage. The factor loadings for each variable onto each factor are as the rotated component matrix. So, it lists the questions that correspond to each component. This briefly shows the challenges that load with each other and the opportunities that load together making them more accurate and valid.

4.1.8 Interviews:

In this part, five key experts from a range of fields with expertise in nuclear power plants were interviewed. They were questioned in regard to six main topics. The answers based on each expert viewpoint are listed below.

- **Respondent – 1**

1- Are nuclear power plants secure to establish?

Experts' response

It is secure, especially with the 5th generation, that has less dependency on human being, whereas, when we compare it with the first generation, it was totally dependent on humans, the second, third and fourth decreased eventually as it was based on artificial intelligence and machine learning. However, the 5th generation meant that we completely know that human faults will not appear but there might be electronic faults. So, in case of unexpected disaster then nuclear power plants can cause a disaster in the whole country.

2- Can the environment be affected by the nuclear power plant?

Experts' response

During operation, with the existing of sensors there is little emissions there, but according to the research in many countries the neighbourhood of the plants complains about certain symptoms either psychological or other, but this is monitored and countries like south Africa they didn't appoint a team to do the process of monitoring but elected people to go there and witness the process. It is controlled, but not to forget in Ukraine there was a leak in the nuclear power stations, however, Ukraine and Russia didn't announce it, it was spotted by Switzerland or Sweden, they mentioned that they were receiving high level of radiation, after suspecting it was founded by Russia that the leak was from Chernobyl plants.

3- Is new technology that complies with international requirements for performance, safety, and environmental effect reduce the challenges of establishing nuclear power stations?

Experts' response

All matters now are under the umbrella of the International Atomic Energy Agency- IAEA, even if we want to buy small radioactive for students, we will

have to receive a lot of approvals. Bahrain and all Gulf Cooperation Council (GCC) countries are a member in the IAEA, so if they give a proper advice under full monitoring process it will be accredited. So, we trust their advice, but sometimes political issues are raised like in Iran, for 40 years it was not settled, the same is with Cairo, for 30 years it is not settled, so we hope that there will not be any politics on board. Likewise, in regional countries there has been boycott, but still many objects were smuggled in there, so the environmental concerns are not certified, as they are enriching uranium. If we have a component and it is not fully tested, when it goes wrong it will cause a disaster.

4- Will the Gulf Cooperation Council (GCC) benefit from a joint initiative on establishing nuclear power stations in the region?

Experts' response

In the United Arab Emirate already four stations are running, we are sure with the Gulf Cooperation Council (GCC) network grid, it can be transferred, same wise with the Kingdom of Saudi Arabia when they establish the plants that is according to them is around 1 gigawatt of power per plant, it will also be enough once fed in the grid. Even for other countries, instead of establishing the project on their land, there can be a team that can be trained with Saudi Arabia, everyone can pay their share, for example if they are having 1 gigawatt then we can share 100 megawatts that will be from our side, and it will be charged accordingly. The same can also be done in Oman and Qatar, instead of establishing it in many places.

5- Will the cost of establishing nuclear power stations affect the economy of the gulf region?

Experts' response

We are not putting the prices of the uranium, it depends on the country that is processing it, so they can put the price so high or low, so we cannot guarantee the price. For example: if there is scarcity in uranium and it is very difficult to get it,

same wise during the COVID-19, some factories have been closed, because people couldn't go out during the pandemic, so certain chips were not produced, the production line of cars was delayed, and this caused the prices to go up. On the other hand, if it is very much available then it will be cheaper but most likely this is a depletable source the uranium, it is not renewable. The more nuclear power stations available worldwide, so there will be more demand, and this will cause the prices to be high. If less countries are establishing the stations, then the prices will be lower, the prices are not stable, and it is highly related to the political situation. Whereas, at any time there can be an international boycott and sanctions. Another example is, if we continue using the nuclear power stations, and we used about 60% of our electricity from solar and wind energy, and 20% from nuclear energy, so we are left with 20% from natural gas, so what we will do with the oil, as we are a country that sells oil, so this will affect us, as it is our main income. The gas is still in demand, so there are countries that replaced the gas with hydrogen, and we are selling this natural gas, so then there will be no demand. In the case of the economy, for example in Saudi Arabia they burn everyday 1 million barrels to produce electricity, in a month 30 million barrels and in a year 360 million barrels and the rest they will sell it. So, if we are using renewable energy, hence we are not burning the oil then there will be a surplus, because we cannot export it nor use it. Therefore, we can transform the energy to make it cleaner and then we can sell it on the other hand. But for sure it will affect the economy because energy is money.

6- Where the nuclear waste can be dumped?

Experts' response

We must see the geology of the region very well, whereas the water reserve, movements, vibration, acceleration of the ground, all these matters have to be studied very well. After the depletion of nuclear waste, it has to be in a pole for one year to reduce the emission in the water. Then it should be stored for another

10 years in the country before it is shipped, before it was allowed to ship the waste but now it should keep for 10 years before shipping and dumping it. There are a lot of talks on where the nuclear waste will be dumped and there was no answer. Some suggested dumping it in the space but still it was rejected. So where is the nuclear waste graveyard, we don't know! But it is a major environmental issue, there a lot of activists making huge fuss about plastic bottles as a waste, then what about nuclear as it takes hundreds to thousands of years to get its life to be lowered for only 50%, where are they dumped as it is more dangerous than the plastic. It is a good technology and it is used, but we have to be very careful, if we are in a country that has uranium, and we have human resource to produce the uranium, then for sure this country will proceed forward and it will be independent, but if not then similar to Europe they are dependent on Russia for the oil and gas, and for the electricity they are depending on France. There are other opinions from the Gulf Cooperation Council (GCC) on this topic, but hopefully this thesis can answer these questions.

- **Respondent - 2**

1- Are nuclear power plants secure to establish?

Experts' response

Building nuclear power plants requires rigorous site studies that include all geological and geophysical characteristics of the site, and site suitability is based on the results of such studies. Moreover, nuclear power plant designs have gone through massive improvements since the 1st generation, with modifications and improvements implemented after each and every reactor accident based on the lessons learnt, regardless of the accident scale. The modifications also include equipment, operation and emergency procedures, human resource development and other factors. In general, nuclear power plants, if properly operated and maintained, are considered the safest installations built by mankind.

2- Can the environment be affected by the nuclear power plant?

Experts' response

Nuclear power plant operation may adversely affect the environment through 3 main ways:

- Releases of radionuclides to the environment during normal operation, and such releases are usually strictly controlled and monitored by the nuclear regulatory authority in the nuclear power plant country, and in many cases monitored by the neighbouring countries,
- Accidental releases of radionuclides to the environment,
- Waste treatment and waste disposal.

3- Is new technology that complies with international requirements for performance, safety, and environmental effect reduce the challenges of establishing nuclear power stations?

Experts' response

I am not a nuclear engineer or an authority in Reactors and Reactor design to give a scientific answer to this question, but as far as I know, new reactor designs go through a very lengthy, complicated, and strict process of evaluation before such designs are approved by the countries where they are proposed.

If small modular reactors are meant here, Argentina, China, and very recently the US Nuclear regulatory Authorities have approved small modular reactors designs from their respective countries. The main challenges that small modular reactors may help to overcome are the cost, the area (space) requirements, and the emergency preparedness requirements and conditions.

4- Will the Gulf Cooperation Council (GCC) benefit from a joint initiative on establishing nuclear power stations in the region?

Experts' response

It is not a secret that the Gulf Cooperation Council (GCC) had plans for a joint nuclear power plants program during the first decade of the 21st century, but it seems that the Gulf Cooperation Council (GCC) countries decided later to go for

separate national projects. UAE has Barakah nuclear power plant with three 1.4 GW reactors currently online and the 4th is under construction. The Kingdom of Saudia Arabia is also planning for several nuclear power plants in the foreseen future.

5- Will the cost of establishing nuclear power stations affect the economy of the gulf region?

Experts' response

One of the major obstacles a country may face when it decides to go for the nuclear power choice is the funding. There are two extremes here, a big multi-reactor project like that the UAE has, and a project that relies on using small modular reactors. It is a multi-Billion dollars endeavour that includes beside the planning, design, construction, reactor and fuel cost, the cost of technical, administrative, and regulatory manpower development, and the development of a robust regulatory infra-structure for the project.

It also includes important modifications of the power transfer grid to accommodate the presence of a nuclear power plant.

6- Where the nuclear waste can be dumped?

Experts' response

This is a thorny question. In general, reprocessing plants separate the useful reusable fuel material from the waste and send the waste to the producing country for disposal. I know that this is something that the UAE regulator took into consideration when Barakah nuclear power plant was authorized for construction, but I don't know the arrangements that were made for waste treatment and disposal. I have no knowledge of any nuclear waste treatment and disposal facility or site in the region.

• Respondent - 3

1- Are nuclear power plants secure to establish?

Experts' response

No, because first, we should know the infrastructure that is available to establish nuclear power stations industry in the Gulf Cooperation Council (GCC). We need to take into consideration any risk assessment and it should be done in a very particular aspect.

2- Can the environment be affected by the nuclear power plant?

Experts' response

Of course, this is because we have nuclear waste, it will harm the environment because it is not a wasteless process. This waste is called radioactive waste; therefore, this should be taken into consideration. We don't mean waste by only the emission that comes out during the process only but the long-term waste. The source cannot be utilized to the maximum.

3- Is new technology that complies with international requirements for performance, safety, and environmental effect reduce the challenges of establishing nuclear power stations?

Experts' response

Not really, because we are talking about the regulations and the policies as we cannot establish the nuclear power stations without taking into consideration the international specifications. There is a lot of work to be done in this aspect, even if it was to be established in the Gulf Cooperation Council (GCC) or in other countries around the world. The countries that already have established nuclear power stations are working within the limitations that are available within the technology. There is no new technology, it is still the same technology, and still, we cannot maximize the extraction of the radioactive materials within the nuclear power station. So, we will end up with waste. Moreover, we cannot install nuclear power stations anywhere because the waste after it is out from the stations it should be stored in a specific location and in this place, it will stay for almost six years underground and then it will be extracted and exported through cargo in ports to be dumped. So, this process is handled through carbon footprints.

4- Will the Gulf Cooperation Council (GCC) benefit from a joint initiative on establishing nuclear power stations in the region?

Experts' response

Of course, it will if we take into consideration all the regulations but not in the areas in the Gulf Cooperation Council (GCC). It should be in specific areas where certain conditions and specifications apply. For example, we cannot state that Bahrain will establish nuclear power stations or Qatar. We are aware the United Arab Emirates started the nuclear power stations in the Gulf Cooperation Council (GCC), and the Saudi Arabia will sooner or later will follow because they already had discussions in installing 16 reactors, so therefore they may be taking into consideration this project. The issue is it is already used in countries worldwide that use large consumptions of energy power. Even in our region the energy consumption is very high, this could be one of the solutions, but it should be studied carefully, and we should be prepared before entering this process.

5- Will the cost of establishing nuclear power stations affect the economy of the gulf region?

Experts' response

No, the economy is not going to be an issue in this case, this doesn't mean that if we have nuclear power stations then we will not use the conventional fuel. The fuel will be sold to other countries across the world. On the other hand, this can affect the economy of the individual countries like for example in Bahrain the electricity is supported because we don't buy natural gas from other countries hence, we are a country that produce it. So, whatever we produce we use, therefore when we talk about nuclear power stations then this will eventually increase the electricity prices in the Kingdom of Bahrain because we don't have the source and radioactive materials, so we should buy it, from this point of view we say that it may affect the economy. When answering this question, we should be very careful because this does have a yes or no answer and we should do a

feasibility study. Moreover, any technology we consider now, the conventional fuel remains to be the cheaper. There should be a capital cost, as we will not only establish an electrical station, but we will need to have infrastructure, roads, etc. moreover, the nuclear power stations need to be located close to water surface and not in the middle of the desert to maximize the cooling process. So, we cannot transfer water to the stations from far areas, therefore there is cost for the infrastructure that we should be careful with.

6- Where the nuclear waste can be dumped?

Experts' response

There are international agreements that are ratified on this topic and there are some countries that can receive the nuclear power stations' waste and then dump it. But first it will stay in the country for a specific time and then it will be exported to other places.

• Respondent - 4

1- Are nuclear power plants secure to establish?

Experts' response

The manufacture of steel and other necessary materials used in the construction of new nuclear plants results in the production of emissions, but the emissions footprint, or the total emissions produced over the course of the nuclear power plant, is still very low because new nuclear power plants are among the safest facilities in case these stations adhere to worldwide best practices employing many layers of protection, including safety system performance, fuel dependability, and industrial accident rates. They are subject to strict international safety requirements and are strictly monitored and overseen. Whereas the performance metrics regularly demonstrate successful outcomes.

2- Can the environment be affected by the nuclear power plant?

Experts' response

It is affected if strict international safety standards are not followed, while the impact is less harmful and almost non-existent in the event that countries commit to nuclear power plants in a safe manner to preserve the environment throughout the construction and operation phase, and to monitor all related activities. Nuclear power plants generation does not emit gases A harmful greenhouse gas in the air, but it creates hazardous waste. Waste from nuclear power plants remains dangerously radioactive for thousands of years after extraction, and here lie many problems when trying to know how to store this radioactive waste.

3- Is new technology that complies with international requirements for performance, safety, and environmental effect reduce the challenges of establishing nuclear power stations?

Experts' response

Modern technology has proven to be safe, clean, and commercially feasible, and can generate large percentages of the minimum electrical power, so when we consider the social, health and environmental costs resulting from fossil fuels, compared to those resulting from nuclear power plants, the economics of nuclear power plants seem more very attractive.

4- Will the Gulf Cooperation Council (GCC) benefit from a joint initiative on establishing nuclear power stations in the region?

Experts' response

Nowadays, thanks to technological development in the field of nuclear power plants, most electricity is produced from nuclear energy through nuclear fission of uranium and plutonium in nuclear power plants in many countries of the world, and the presence of nuclear power plants is a desire to meet the growing demand of accelerating access to electricity, protecting oil exports, supporting economic growth, providing greater energy security, and reducing carbon emissions. In addition, nuclear power plants can help the Gulf Cooperation Council (GCC)

countries to diversify their basic and simple energy sources, which currently rely heavily on oil and gas.

5- Will the cost of establishing nuclear power stations affect the economy of the gulf region?

Experts' response

The total cost of nuclear power plants is comparable to other technology of power plants. However, the cost of constructing nuclear power plants is very high, and to assess the effectiveness and sustainability of any investment, the future value of its expected returns is calculated within the framework of current data. This is a financial process called discounting future cash flows and considers the time factor and the risks associated with investment. Thus, considering that factors such as technological progress or the emergence of cheaper alternatives in the field of energy would reduce the value of investment in nuclear energy. Thus, the longer the investment period or the higher the risk assessment, the higher the discount rate.

6- Where the nuclear waste can be dumped?

Experts' response

The complete disposal of nuclear power plants waste is still not resolved. Noting that no country in the world has yet begun to dispose of the most hazardous waste, which should provide safety for the surrounding environment for a period of not less than a hundred thousand years. It requires to be stored in a safe place far away from earthquakes, volcanoes, and similar geophysical phenomena that affect the terrain of the earth, and it must also be far from human hands and residential areas, and it is imperative that these wastes be completely isolated from groundwater and soil so that they do not leak into food chains and ecosystems. Bearing in mind that all these conditions must be met over geological times of millions of years, and until a solution is found, it is unlikely that nuclear energy will be on an equal footing with other energy sources.

- **Respondent - 5**

1- Are nuclear power plants secure to establish?

Experts' response

There is no doubt that the establishment of nuclear power plants imposes on states and the international community realistic challenges related to the issue of nuclear safety, especially those related to radiation protection, emergency preparedness procedures, and safety standards for installations in terms of location, design, and rules of technical and professional safety, which is what the Bahraini legislator sought to address it through international cooperation mechanisms, accession to relevant international treaties, as well as through the adoption of an effective national legislative and oversight framework; This is with the aim of ensuring that comprehensive and systematic safety assessments are conducted prior to the construction of the nuclear power plant facility, in addition to a verification procedure through analysis, monitoring, testing and inspection of the facility.

2- Can the environment be affected by the nuclear power plant?

Experts' response

The possible impacts and concerns of the establishment of the nuclear power plant on ecological life and all elements of the environmental system must be monitored. In this context, it can be stated that the Bahraini Environment Law No. (7) of 2022 is the latest national legislation in the field of the environment, whose provisions were formulated as a response to the development of international rules in the field of environmental protection and control of environmental degradation considering emerging and existing challenges. The law stipulates the need to submit environmental impact assessment data to the Supreme Council for Environment in order to undertake an environmental impact study before licensing any project. In our estimation, this includes projects for the construction of nuclear power plants, where a report is prepared. Evaluating the

environmental impact by consulting institutions and offices, with the help of experts, according to the type of project.

3- Is new technology that complies with international requirements for performance, safety, and environmental effect reduce the challenges of establishing nuclear power stations?

Experts' response

It is hoped that modern peaceful nuclear power plant technology compatible with international safety requirements will contribute to reducing the sources of environmental threat and raising the level of nuclear safety, specifically regarding the nuclear fuel cycle, radioactive waste, and implications for human health, food, climate change, and others.

4- Will the Gulf Cooperation Council (GCC) benefit from a joint initiative on establishing nuclear power stations in the region?

Experts' response

I believe that the Gulf Cooperation Council countries are working on developing their policies and moving towards renewable energy sources, and gradually reducing dependence on fossil energy sources. In this context, some Gulf countries have begun to launch their national initiatives to establish nuclear power plants, and there are serious future directions by the leaders of the region to launch a joint program in the field of nuclear power plants technology for peaceful purposes to achieve the goals of sustainable development, especially if we take into account the problem of water scarcity facing the region, which will contribute to the solution of projects to establish water desalination plants that use the safe nuclear power plants cycle in accordance with international standards and regulations.

5- Will the cost of establishing nuclear power stations affect the economy of the gulf region?

Experts' response

It can be said, in general, that the economies of the region are moving towards diversifying sources of income, expanding the production base and achieving food security by launching giant industrial, agricultural and development projects that require the provision of huge future energy resources, which makes the issue of nuclear energy part of the economic visions and a condition for the development of the economies of countries in the region and the welfare of its people.

6- Where the nuclear waste can be dumped?

Experts' response

The Bahraini Environment Law includes an entire chapter (Chapter Eleven) that deals with the issue of hazardous waste management. The executive regulations are entrusted with defining the conditions and procedures for granting licenses and the responsibilities and obligations of the licensee in relation to the production, import, export, transportation, storage, use or disposal of exported nuclear power plants materials and devices that are of ionizing radiation. The powers of the Supreme Council for Environment in this regard include controlling the production, storage, treatment, transportation, and safe disposal of waste containing radioactive materials. The law obligates the persons and projects determined by the Council to establish units to treat the hazardous waste resulting from its activity. It also requires that the ionizing radioactive sources be returned in a sealed manner to the issuing authority for disposal. As for other waste that is determined by the competent authority, it shall be disposed of in accordance with the conditions it sets for that.

4.2.1 Summary of Interviews:

The interview responses from each of the five study participants will be included in this section. There are several points of view for every question. To gain a final perspective of all the questions together, each respondent's response is analysed.

The first question was if nuclear power plants were secure to establish, the first respondent stated that compared to earlier generations, nuclear power facilities are more secure and less reliant on humans, although unanticipated tragedies can still occur. Whereas the second respondent said that nuclear power plants require rigorous site studies and improvements and are considered safe if properly operated and maintained. The third respondent mentioned that infrastructure and risk assessment are needed to establish nuclear power stations in the Gulf Cooperation Council (GCC). The fifth and sixth respondents stated that nuclear power plants are among the safest facilities due to strict international safety requirements and strict monitoring and oversight. The Bahraini legislator sought to address nuclear safety challenges through international cooperation mechanisms, accession to relevant international treaties, and adoption of an effective national legislative and oversight framework. Safety assessments and verification procedures need to be conducted prior to construction.

The second question was if the environment be affected by the nuclear power plant. The first and second respondent stated that monitoring of the environment is done by electing people to witness the process, rather than a team. Furthermore, nuclear power plant operation can adversely affect the environment through releases of radionuclides, accidental releases, and waste treatment. The third respondent said that radioactive waste should be considered, not just the emissions from the process, but the long-term waste and the fourth respondent added that nuclear power plants generate hazardous waste, which remains radioactive for thousands of years after extraction and poses many problems when trying to store it. The fifth respondent mentioned that the possible impacts and concerns of the establishment of the nuclear power plant on ecological life and all elements of the environmental system must be monitored.

The third question was if new technology that complies with international requirements for performance, safety, and environmental effect reduces the challenges of establishing nuclear power stations. The first respondent said that

if a component is not fully tested, it can cause a disaster and the second respondent added that new reactor designs must undergo rigorous evaluation before approval by countries and small modular reactors may help to overcome cost, area, and emergency preparedness challenges. Whereas the third respondent mentioned that nuclear power stations must consider international specifications to be established, and waste must be stored in a specific location for 6 years before being extracted and exported through cargo in ports to be dumped. This process has a carbon footprint. The fourth respondent said that nuclear power plants are more economically viable than fossil fuels due to their safety, cleanness, and environmental benefits and the fifth respondent stated that modern nuclear power plant technology can reduce environmental threats and increase nuclear safety.

The fourth question was related to the Gulf Cooperation Council (GCC) benefit from a joint initiative on establishing nuclear power stations in the region. Thereon, the first respondent said that in the United Arab Emirate already four stations are running, so with the Gulf Cooperation Council (GCC) network grid, there can be transfer of energy between states. However, for other countries, instead of establishing the project on their land, there can be a team that can be trained with Saudi Arabia, and every country can pay their share to have their power stations. The second respondent said that Gulf Cooperation Council (GCC) countries decided to pursue separate nuclear power plants, but then the UAE started their nuclear power plants, whereas Kingdom of Saudia Arabia is also planning for a few nuclear power plants in the foreseen future. The third respondent mentioned that yes, it will if we take into consideration all the regulations but not in the areas in the Gulf Cooperation Council (GCC). It should be in specific areas where certain conditions and specifications apply. The fourth respondent said that nuclear power plants can help the Gulf Cooperation Council (GCC) countries to diversify their basic and simple energy sources, which currently rely heavily on oil and gas. Furthermore, the fifth respondent stated that the Gulf Cooperation Council countries are moving towards renewable energy

sources and reducing dependence on fossil energy sources. They are launching initiatives to establish nuclear power plants to achieve sustainable development, considering water scarcity.

The fifth question was if the cost of establishing nuclear power stations can affect the economy of the gulf region. The first respondent said that the prices of uranium depend on the country that is processing it, so they cannot be guaranteed. If there is scarcity in uranium, the prices will go up. If more nuclear power stations are established, the prices will be higher. If less countries are establishing the stations, the prices will be lower. If renewable energy is used, there will be a surplus of natural gas, which can be transformed to make it cleaner and then sold. This will affect the economy, as energy is money. The second respondent added that nuclear power is a multi-billion-dollar endeavour that includes planning, design, construction, reactor and fuel costs, manpower development, regulatory infra-structure, and modifications of the power transfer grid. The third respondent said that nuclear power stations can affect the economy of individual countries, such as Bahrain, by increasing electricity prices. To answer this question, it is important to do a feasibility study and consider the cost of infrastructure, roads, and cooling processes. Moreover, any technology we consider now, the conventional fuel remains to be the cheaper. The fourth respondent added that the total cost of nuclear power plants is comparable to other forms of energy. However, the cost of constructing nuclear power plants is very high, and to assess the effectiveness and sustainability of any investment, the future value of its expected returns is calculated within the framework of current data. Moreover, the fifth respondent stated that nuclear energy is essential for the development of the economies of the region and the welfare of its people.

The sixth question was on where the nuclear waste can be dumped, whereas the first respondent said that the most important details are that nuclear waste must be stored for 10 years before shipping and dumping it, and that it is more dangerous than plastic bottles as it takes hundreds to thousands of years to get its

life lowered for only 50%. The second respondent mentioned that reprocessing plants separate useful fuel material from waste and send it to producing countries for disposal, but there is no nuclear waste treatment and disposal facility in the region. The third respondent added that there are international agreements that are ratified on this topic and there are some countries that can receive the nuclear power stations waste and then dump it. But first it will stay in the country for a specific time and then it will be exported to other places. Whereas the fourth respondent mentioned that nuclear power plants waste must be stored in a safe place away from earthquakes, volcanoes, human hands, and groundwater and soil to ensure safety for a hundred thousand years, and until a solution is found, nuclear energy will not be equal to other energy sources. The fifth respondent added that the Bahraini Environment Law outlines the conditions and procedures for granting licenses and the responsibilities and obligations of the licensee in relation to the production, import, export, transportation, storage, use or disposal of nuclear power plants materials and devices of ionizing radiation.

4.2 Discussion

The establishment of nuclear power stations in the Arabian gulf region has many challenges and opportunities, however a few problems that these countries have in common serve as the formal basis for building these stations in the region. There has been finite published data on nuclear power stations establishments, particularly in the Gulf Cooperation Council (GCC) member states. The present study results concerning the challenges for entering the world of nuclear energy among the states of the gulf cooperation council indicates that 47.3% of the participants had agreed that the project requires sizable budget. Nuclear power plant projects may require significant budgets, as seen in the United Arab Emirates reactors, as South Korea offer was around \$20 billion for building four reactors (World Nuclear Association, 2022).

Whereas in this study 38.7% agreed that it requires highly qualified human resources. A key component of the efficient management of nuclear knowledge is making sure that skilled staff are always available (Kosilov et al., 2009). Moreover, 47.5% agreed that the existing engineers and scientists in the Gulf Cooperation Council (GCC) require training. A well-organized, specialized human resource development program is also necessary for the nuclear power growth vision (Grover and Puri, 2013).

Furthermore, 43.8% agreed that climate change might affect the nuclear power plants. Climate change-related extreme weather events may affect nuclear power plant operations globally, affecting energy system conditions and power plant operations (Ahmad, 2021). Additionally, 41.6% of the respondents agreed that infrastructure is needed for the implementation process. The supreme council laws of the Gulf Cooperation Councils regulate nuclear energy peacefully, addressing radiation, environmental, operational, security, waste management, emergency preparedness, transport, liability, and decommissioning (Gulf cooperation council secretariat, 2013).

The study's results showed that 43.1% agreed that specialized institutions are required for the implementation process. An example to this is the Emirates Nuclear Energy Corporation, founded in 2009, has grown from a startup to a top-tier company with over 3,500 employees, focusing on dependable, sustainable nuclear energy for the United Arab Emirates (Emirates Nuclear Energy Corporation, 2023).

Interestingly, 37.4% agreed that regulatory and legal frameworks are required for the establishment of nuclear power stations. Virtual reality and augmented reality technologies have quickly expanded in scope, necessitating several studies and experiments to determine how best to use and implement them that includes all regulatory and legal frameworks (Popov et al., 2021). In addition to the other challenges, 35.2% of the respondents had neutral respond on the demand of financial plans to establish the project. Financing plans for nuclear programs in

so-called "new countries" differ substantially. For instance, the national government of the United Arab Emirates retains over 80% of ownership control, in contrast to the norm in many other nations, which is 50 –100% direct or indirect foreign government sponsorship (Pehuet Lucet, 2018).

The present study indicates that 34.7% agreed that extensive planning is required before putting forward the establishment. US nuclear technology is complex and difficult, with the US developing the most complex control system globally. Other nations have also built and run nuclear power plants and advanced market strategies (Adamantiades & Kessides, 2009). Moving forward with other challenges it was found that 41.1% of the respondents had neutral respond on the potential for weapon proliferation. Particularly, activities involving nuclear energy raise the possibility that parallel nuclear weapons development may be discovered and subject to counterproliferation efforts; they also raise the expense of non-proliferation sanctions (Miller, 2017). Other responses in this study showed that 37.2% agreed that the establishment of the plants should be placed far away from residential areas. Plants must be situated close to a ready source of cooling water, which may not be in the same place as the population centre (Khamis et al., 2013). The present work furthered showed that 46.3% agreed that there are different categories of waste disposal. Permanent waste disposal method must be isolated for thousands of years, ensuring public health, safety, and environmental protection (Kok, 2017).

Eventually, 34.7% of the respondents agreed and had a neutral response as well on the necessary safety measures to be carried out. Creating safe operating conditions, preventing, and mitigating accidents, and safeguarding people and the environment from radiation or radioactive material threats are all key components of safety (Busquim et al., 2021). Moreover, 36.5% had neutral respond on the safety equipment's that is like the conventional ones. The safety and reliability security requirements for nuclear power plants are highly strict and call for flexibility, reliability, and lengthy lifecycles (Silva et al., 2015). Interestingly,

35% also had a neutral response to the training that is required on the national level. Ensuring skilled human resources is crucial for safe, responsible, and sustainable nuclear technology use (Alam et al., 2019). The final response on the challenges was that 37.7% of the participants had neutral response on the concept that nuclear power stations do not emit greenhouse gases. Nuclear fuel cycle emissions primarily occur in processing steps upstream and downstream, unlike fossil-powered plants' emissions occur at the plant site (Lenzen, 2008).

The present study results concerning the opportunities for entering the world of nuclear energy among the states of the Gulf Cooperation Council indicate that 49.5% of the participants agreed that nuclear power stations may reduce the cost of electricity. Nuclear power has the potential to solve the energy crisis of delivering base charge, affordable, clean power (Ho et al., 2019). Beyond wind and solar, nuclear power is without a doubt the most convincing alternative energy source. Moreover, 46.6% agreed that nuclear power stations will provide diversifications of energy supply. Saudi Arabia, which has 20% of the world's oil reserves, has launched a \$100 billion investment move to meet its rising electricity demand and get the country ready for the post-oil era. Saudi Arabia is concentrating on nuclear and renewable energy to replace the conventional power plants run with fossil fuel. Additionally, 39.2% of the respondents agreed that nuclear power stations have zero carbon emissions which is a fact. The primary contributor to greenhouse gas emissions in the United Arab Emirates is the energy sector. Over 90% of all greenhouse gas emissions come from this sector. The speedy economic expansion, high rate of urbanization, and low cost of energy all contribute to an increase in the demand for energy. The nation has a difficulty because of the rising energy demand and greenhouse gas emissions (Khondaker et al., 2016).

The study interestingly showed that 38.9% agreed that nuclear power stations may have high energy density. In contrast, an ambitious but attainable goal would be to guarantee 30% of future energy and process heat demands for industrial

uses, as well as saltwater desalination, from nuclear power by 2030, especially for the countries of the Gulf Cooperation Council and those of North Africa (El-Genk, 2008).

In the current study, 41.1% agreed that nuclear power stations generate a low amount of pollution. The local climate is changing quickly because of human activity from one year to the next and from one decade to the next. However, 37.2% of the responses had neutral impact on that nuclear power stations having smaller carbon footprints and 41.4% of the participants agreed that it is crucial in combating climate change. The Arabian Gulf region is increasingly aware of climate change and is concerned about it on many levels. A few of the sectors and systems that could be influenced by climate change include food security, the generation of renewable energy, the distillation of water, and public health (Al-Maamary et al., 2017).

4.3 Conclusion and Recommendations

In conclusion, the current study was able to give a thorough statistical analysis of the challenges and opportunities of establishing nuclear power plants in the Gulf Cooperation Council. The data found in the study showed that the respondents had a clear understanding of the challenges and opportunities of this research, as many of them agreed and also had neutral stance in interpreting each related factor. The data collected from the respondents was then compared to the expert's responses and similar outcomes were also assessed in comparison to the questions in the survey and interviews. Furthermore, the technical analysis of each data set (demographics, challenges, and opportunities) using various analysis statistical tests gave us the end results of how each variable loads with each other and the validity of the entire study. The thorough interpretation of the 16 challenges and 7 opportunities are discussed and compared to actual data received are mentioned in the discussion section of this thesis.

The objectives of the study showed that the gulf member states are welcoming the initiative and the United Arab Emirates had already started the nuclear power plants in the region with four reactors under operation, but the results indicated that the rest of the member states may have shortage of resources because of many factors including the infrastructure, size of the country, budget required, qualified human resources, climate, waste disposal issues, specialized institutions, etc. The distilled water scarcity was another obstacle to this study, but it was included in the limitation of the study due to the complexity of its topic. Whereas the increasing demand of electricity requires many countries in the region to shift to nuclear power stations and first of all was the Emirates, and Saudia Arabia is in the process of obtaining a license to initiate the project. Another objective of the study was achieving the sustainable development goals and in the gulf member states almost all the countries are racing towards them, this was analysed further in the study as it was based on goal 7 and the targets are clearly stating the need for shifting towards modern, clean, and affordable energy. Another opportunity in which respondents of the survey and experts interviewed agreed on was that nuclear power stations may diversify the countries sources of income, and this was through exporting electricity to neighbouring countries by adding a benefit to the economy nationally and regionally.

The findings imply that the experts in the gulf region are aware of the consequences that the nuclear power plants may have when established. However, the opportunities were also welcomed on the other hand by the experts. Thus, Governments will have a lot of responsibilities in relation to nuclear power plants. Additionally, the biggest obstacle is not considering the implications but rather how the Gulf Cooperation Council will persuade the responsible bodies to implement such a project and how far they are ready to go for it.

The limitation of the study shall be that the data collected through the survey could have been more enhanced if it was distributed to the personnel members of nuclear facility in the United Arab Emirates, hence they have a very clear

background because they already initiated the nuclear power plants, and even actual interviews with the experts from the facility was not conducted to get to know more on the obstacles and incentives of initiating the project on ground and running the reactors. Furthermore, potential factors influencing the challenges such as shortage of water needed for the cooling process of the plants, the university courses on nuclear studies, qualified researchers, legal framework and legislations, and the opportunity factors such as successful stories from the United Arab Emirates nuclear power plants establishment, the researchers that were sent to study abroad on nuclear studies from the Kingdom of Saudia Arabia, economic benefits of the project to the gulf region, were not assessed in this study. These would have been helpful in gaining a better grasp of the challenges and opportunities of establishing nuclear power plants in the Gulf Cooperation Council.

Therefore, it is recommended to improve understanding of the nuclear energy industry, universities of the GCC Countries should introduce major in nuclear-related fields and subjects. So, more research and knowledge-based studies will be available in hand before initiating the nuclear power plants on ground because there are a lot of shortage in resources in each country in the Gulf Cooperation Council that should be further studied.

Another recommendation suggests that a special authority or ministry shall be established to carry out duties and frameworks related to the nuclear power stations work related matters in line with other countries worldwide who established similar projects.

In reality, the current questionnaire highlights the need for more comprehensive understanding of the current climate change situation and other future prospects that would help the region to overcome all the challenges and benefit from the opportunities to initiate the nuclear power plants in a member country or more in the Gulf Cooperation Council through joint initiative as per the agreements in the region and this country will have shares of other Gulf countries in there, in order

to have coordinated project that will help other countries that have shortage of resources.

On the other hand, there should be more studies on the dumping of nuclear waste and its consequences, as well as the limitation of water available that will be needed in the cooling process of the nuclear power plants. Authorities would benefit from using both mainstream and human resources in conducting these studies, based on the levels of understanding and new technology that is trending in the field of building nuclear power reactors worldwide.

Nonetheless, nuclear safety programs should be taken into consideration to overcome the catastrophe in accidents related to nuclear power plants and its safety, as this could affect the region, people, and the environment. The whole process should be carried out in line with customs, statutes, laws, and legal framework of International Atomic Energy Agency, as they work on collaborative scientific and technical application of nuclear technology. To promote global peace, security, and achievement of the United Nations Sustainable Development Goals 2030, the agency works to ensure that nuclear science and technology are used in a safe, secure, and peaceful manner.

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Appendices

Appendix A: Questionnaire

Challenges and Opportunities of Establishing Nuclear Power Stations in the Gulf Cooperation Council

Dear Participants,

This study aims at assessing the challenges and opportunities of establishing nuclear power stations in the GCC. The researcher is a master student of the Environment and Sustainable Development Program offered by the University of Bahrain. The study is conducted as part of the requirements for the thesis course and the results will be used for research purposes. We would like to seek your kind cooperation in participating in this survey and completing the questionnaire. Your response is very important, and all your time and effort in completing this survey will be appreciated. This study is aimed on receiving responses from participants from the Gulf Cooperation Council.

Participants' Profile

In this section, you will be asked to provide us with some personal details.

1. Age Group:

1. Youth (18 – 24 years)
2. Adults (25 – 64 years)
3. Seniors (≥ 65 years)

2. Gender:

1. Male
2. Female

3. Nationality:

1. Bahrain
2. Kingdom of Saudi Arabia
3. United Arab Emirates
4. Kuwait
5. Qatar
6. Oman
7. Others

4. Educational level:

1. High School Certificate or Lower
2. Diploma

3. Bachelor's degree
4. Master's degree
5. PhD Degree

5. Profession:

1. Student
2. Education
3. Physicist
4. Self Employed
5. Employee in Public Industrial Sector
6. Employee in Private Industrial Sector
7. Others

Section 1: Challenges for entering the world of nuclear energy

Please answer the following questions based on the 5-point Likert Scale:

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

1. The establishment of nuclear power plants could demand a sizable budget for the entire project.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

2. For the Nuclear power sector, highly qualified human resources are required.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

3. The available engineering and scientist in the GCC are ready to operate nuclear power plants if they are provided with the necessary training.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

4. Extreme weather events linked to climate change may have an impact on nuclear power plant operations at the international and regional levels.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

5. Infrastructure is needed for the successful implementation of the nuclear power station.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

6. Institutions that are specialized in nuclear power sector are needed for the successful implementation of the nuclear power stations.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

7. A legal and regulatory framework is needed for the successful implementation of the nuclear power sector.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

8. Financial plans are needed for the successful implementation of the nuclear power sector.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

9. Nuclear power plants require extensive planning before they can be put into operation because of their high cost.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

10. Nuclear power plants are the potential for weapon proliferation.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

11. Nuclear power plants must be erected in open spaces far from residential areas and commercial areas.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

12. Disposal of waste: The three main categories of nuclear waste are high-level, transuranic, and low-level, and each must be disposed of in a particular way based on the risk to human health and the environment.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

13. Safety measures: It is necessary to put in place processes for pollution control and radiation protection.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

14. The safety equipment used in the nuclear power plant is similar to any conventional power plant.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

15. Programs for radiation protection training and certification must be set up at the national level.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

16. Nuclear power facilities do not emit any greenhouse gases.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

Section 2: Opportunities of establishing nuclear power stations in cooperation with the GCC

Please answer the following questions based on the 5-point Likert Scale:

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

1. The establishment of nuclear power stations in the GCC region may reduce the cost of electricity used in industry.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

2. The establishment of nuclear power stations in the GCC region may have diversification of energy supplies and hence provide secure and reliable source of energy.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

3. The establishment of nuclear power stations in the GCC region may have zero – carbon emissions.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

4. The establishment of nuclear power stations in the GCC region may have high energy density.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

5. The establishment of nuclear power stations in the GCC region may generate low amount of pollution to the environment.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

6. The establishment of nuclear power stations in the GCC region may have smallest carbon footprints.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

7. The establishment of nuclear power stations in the GCC region may be crucial to our effort to combat climate change.

1 - Strongly Agree, 2- Agree, 3- Neutral, 4- Disagree, 5- Strongly Disagree

Appendix B: Interview Questions

Challenges and Opportunities of Establishing Nuclear Power Stations in the GCC

1. Are nuclear power plants secure to establish?
2. Can the environment be affected by the nuclear power plant?
3. Is new technology that complies with international requirements for performance, safety, and environmental effect reduce the challenges of establishing nuclear power stations?
4. Will the GCC benefit from a joint initiative on establishing nuclear power stations in the region?
5. Will the cost of establishing nuclear power stations affect the economy of the gulf region?
6. Where the nuclear waste can be dumped?

المخلص

تتميز الطاقة النووية بانبعاثات منخفضة للغاية من ثاني أكسيد الكربون طوال دورة حياتها، ويمكن اعتبارها تقنية تخفيف محتملة في مكافحة تغير المناخ. ومع ذلك، هناك العديد من العوائق أمام بناء تلك المفاعلات لأسباب تتعلق بصحة الإنسان والبيئة. تهدف هذه الدراسة إلى تقييم التحديات والفرص لإنشاء محطات الطاقة النووية في دول مجلس التعاون الخليجي. حيث تم إجراء دراسة استكشافية شاملة لعدة قطاعات في الفترة ما بين 11 ديسمبر 2022م إلى 5 فبراير 2023م. كما تم توزيع الاستطلاع عبر الإنترنت باستخدام نماذج تطبيق جوجل، وجمع 406 رد على الاستبيان. وكانت الطريقة الأخرى المستخدمة في الدراسة هي إجراء مقابلات مع خمسة خبراء في هذا المجال. وبعدها قمنا بتحليل البيانات التي تم جمعها بواسطة المجموعة الإحصائية للعلوم الاجتماعية IBM SPSS (الإصدار 21) باستخدام اختبار Cronbach alpha لموثوقية الاستبيان، والإحصاءات الوصفية بشكل أساسي، واختبار chi-square للاستقلالية وتحليل العوامل. تضمن محتوى الاستبيان نبذة عن المشاركين وتحديات وفرص إنشاء محطات الطاقة النووية في دول مجلس التعاون الخليجي. حيث أن أسئلة المقابلة كانت حول ما إذا كانت محطات الطاقة النووية آمنة لإنشاء، وهل يمكن أن تتأثر البيئة بمحطة الطاقة النووية، وهل التكنولوجيا الجديدة التي تتوافق مع المتطلبات الدولية للأداء والسلامة والتأثير البيئي تقلل من تحديات إنشاء الطاقة النووية، وهل سيستفيد مجلس التعاون الخليجي من مبادرة مشتركة لإنشاء محطات للطاقة النووية في المنطقة، وهل ستؤثر تكلفة إنشاء محطات الطاقة النووية على اقتصاد منطقة الخليج، والسؤال الأخير هو أين يمكن التخلص من النفايات النووية. وتوصلت الدراسة إلى أن التحديات تشير إلى أن 47.3% من المشاركين وافقوا على أن المشروع يتطلب ميزانية كبيرة، و47.5% وافقوا على أن المهندسين والعلماء الموجودين في دول مجلس التعاون الخليجي يحتاجون إلى تدريب، حيث وافق 46.3% على أن هناك فئات مختلفة للتخلص من النفايات. ومن ناحية أخرى، أشارت الفرص إلى أن 49.5% من المشاركين وافقوا على أن محطات الطاقة النووية قد تقلل من تكلفة الكهرباء. وعلاوة على ذلك، وافق 46.6% على أن محطات الطاقة النووية ستوفر تنويع إمدادات الطاقة. وبالإضافة إلى ذلك، وافق 41.1% على أنه يولد كمية منخفضة من التلوث، ووافق 41.4% من المشاركين على أنه أمر بالغ الأهمية في مكافحة تغير المناخ. وفي الختام، تمكنت الدراسة الحالية من تقديم تحليل شامل لتحديات وفرص إنشاء محطة للطاقة النووية في دول مجلس التعاون الخليجي. وتشير النتائج إلى أن الخبراء في الدول الأعضاء في مجلس التعاون الخليجي لديهم فهم معقول للتحديات والفرص التي تواجه محطات الطاقة النووية، وأنهم متفائلون بشأن المبادرات المشتركة بين دول الخليج. ومع ذلك، فإن العوامل المحتملة التي تؤثر على التحديات مثل نقص المياه اللازمة لعملية تبريد المحطات، والتخصصات الجامعية في الدراسات النووية، والباحثين المؤهلين، والإطار القانوني والتشريعات، وعوامل الفرص مثل قصص النجاح من دولة الإمارات العربية المتحدة حول إنشاء محطات الطاقة النووية لتوليد الكهرباء، والباحثون الذين تم إيفادهم للدراسة بالخارج من المملكة العربية السعودية، والفوائد الاقتصادية للمشروع على منطقة الخليج، لم يتم تقييمهم في هذه الدراسة. ومن هنا يجب أن تؤخذ برامج السلامة النووية بعين الاعتبار للتغلب على كارثة الحوادث المتعلقة بمحطات الطاقة النووية وسلامتها، لما لذلك من تأثير على المنطقة والناس والبيئة. وينبغي تنفيذ العملية برمتها بما يتماشى مع العادات والأنظمة والقوانين والإطار القانوني للوكالة الدولية للطاقة الذرية، حيث تعمل على التطبيق العلمي والتقني التعاوني للتكنولوجيا النووية.

جامعة البحرين

برنامج البيئة والتنمية المستدامة



كلية العلوم

التحديات والفرص لإنشاء محطات الطاقة النووية في دول مجلس التعاون الخليجي

أطروحة مقدمة كجزء من متطلبات الحصول على درجة الماجستير في البيئة والتنمية المستدامة

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