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Ready for Nuclear Energy? A Road to Peaceful Nuclear Power Generation Development in the Kingdom of Saudi Arabia: Vision 2030

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Abstract – *The global electricity demand, volatile fossil fuel prices, and the need to reduce greenhouse gas emissions are pushing power producers towards green energy sources, including renewable energy and nuclear technologies. Civil nuclear power generation is seen as a reliable contestant in the green energy race, with 437 nuclear power plants operable in 32 countries worldwide. This paper discusses the Kingdom of Saudi Arabia's (KSA) efforts to meet its growing electricity demand and reduce its dependency on fossil fuels through the introduction of nuclear energy into its national energy mix. KSA's aims to achieve a renewable energy mix of 50% by 2030, including nuclear energy. The paper describes KSA's progress in developing its nuclear power infrastructure, including the establishment of the King Abdullah City for Atomic and Renewable Energy (KA-CARE) and the Saudi Nuclear Energy Holding Company (SNEHC). To achieve its goals, Saudi Arabia has followed the IAEA "Milestones Approach" and conducted the first Integrated Nuclear Infrastructure Review (INIR) at KA-CARE headquarters in 2018., which showed that the country has made noteworthy progress in the development of its nuclear power infrastructure and is ready to invite bids or negotiate a contract for its first nuclear power plant. The paper emphasizes KSA's commitment to fulfilling international conventions and treaties related to nuclear power generation and its desire to achieve its VISION 2030 nuclear power generation targets.*

Keywords: Peaceful Nuclear Power Generation, Saudi Arabia VISION 2030

I. Introduction:

Significant growth in global electricity demand, volatility in fossil fuels prices, and global warming are diverting the attention of power producers to look for alternative green energy sources, like renewable energy (RE) and nuclear technologies to meet their electricity demand and reduce the dependency on fossil fuels [1]–[3]. In the green energy contest, civil nuclear power generation is considered one of the highly reliable contestants. In 2021 nuclear plants supplied 2653 TWh of electricity, up from 2553 TWh in 2020. Until 2022, worldwide in 32 countries 437 civil nuclear power

plants are operable, 60 are under construction, and 204 were shut down as depicted in Figure 1[4]: For efficient and low cost electricity production reactor technologies plays a vital role, for this purpose nuclear technologies encompass a diverse range of advanced systems designed to harness nuclear energy. These technologies vary from traditional pressurized water reactors (PWRs) to innovative designs like molten salt reactors (MSRs) and fast breeder reactors (FBRs). Each of these technologies operates on distinct principles, offering unique advantages in terms of efficiency, fuel utilization, and safety features [5].

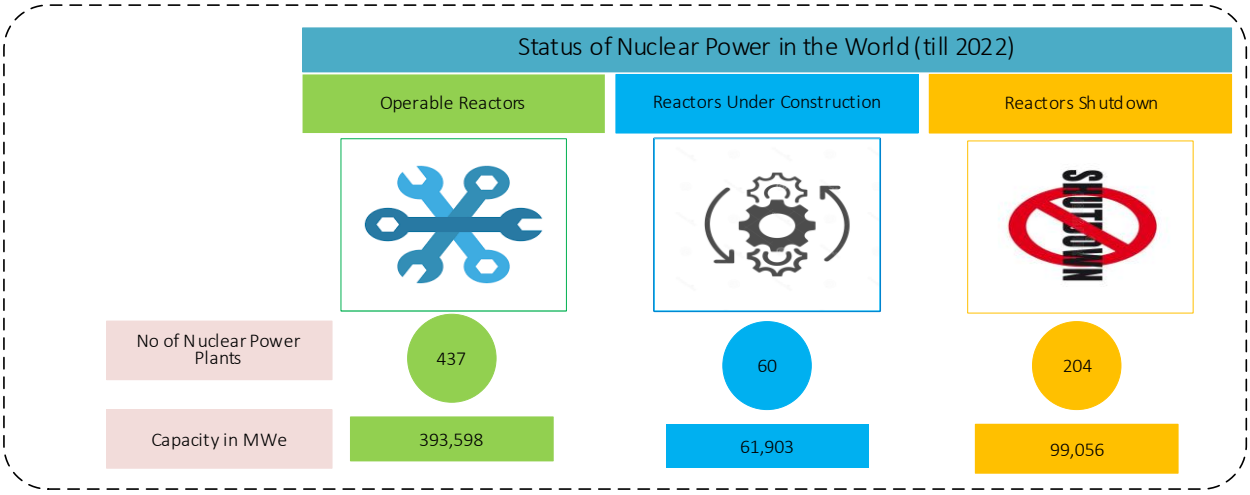

Figure 1. Status of Nuclear Power in the World Today [4]

Furthermore, in green energy technologies, nuclear power generation is considered the second lowest in carbon dioxide (CO_2) emission after wind energy. Based on life-cycle analysis (LCA), it emits just a few grams of CO_2 equivalent per kWh of electricity produced. A median value of 12g CO_2 equivalent/kWh has been estimated for nuclear similar to wind, which is lower than all types of RE power generation technologies including solar energy as depicted in Figure 2 [6].

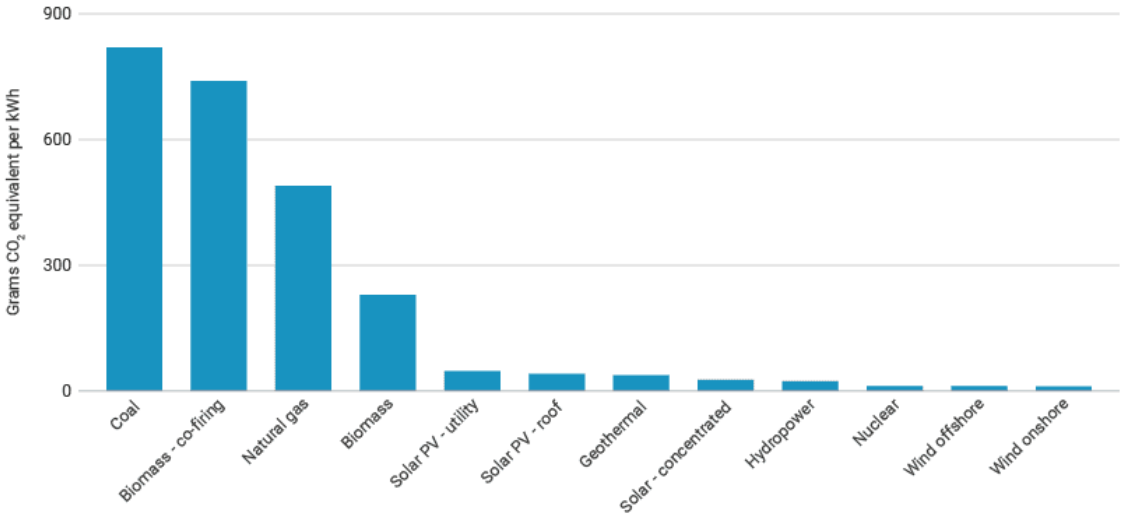

Figure 2. Average life-cycle CO2 equivalent emissions [6]

For successful and safe execution of NPP its safety system, waste management and non-proliferation safeguards are the important factor to considered.

- safety systems critical components of any nuclear facility, designed to ensure the protection of both personnel and the environment. These encompass redundant layers of safety measures, including passive and active systems, emergency shutdown procedures, and containment structures. These robust systems are engineered to mitigate potential accidents and contain any unforeseen incidents within the facility's boundaries.
- Waste management plays a pivotal role in the nuclear energy life cycle. It involves the handling, processing, and disposal of radioactive waste generated during the operation of nuclear reactors. Advanced technologies such as reprocessing and deep geological repositories are employed to effectively manage and contain these materials, minimizing their impact on the environment and public health.
- Non-proliferation safeguards are international measures and protocols put in place to prevent the diversion of nuclear materials and technologies for military purposes. These safeguards are administered by organizations like the International Atomic Energy Agency (IAEA), which oversees the peaceful use of nuclear energy worldwide. Through rigorous inspections, accounting practices, and international cooperation, non-proliferation safeguards help maintain the integrity of the global nuclear non-proliferation regime.

Saudi Arabia's GDP is profoundly dependent on oil export and the country's electricity consumption demand is increasing steadily, it means that more fuel will be required to produce more electricity to fulfill the country's requirements and less crude oil will be available for export which is the only source of KSA economy. It has diverted the attention of KSA to introduce nuclear energy into the national energy mix [7], [8].

The Kingdom of Saudi Arabia (KSA) has a diverse topographical position with a big coastal area that makes the deployment of nuclear attractive. KSA has recognized the value of civil nuclear technology to its long-term economic prosperity and commitment to paving the way to net zero emissions by 2060. In KSA VISION 2030 Kingdom has the ambitious target of 50% renewable energy electricity generation mix including nuclear in its total power generation system by 2030 [1][3].

II. Milestones Approach: Successful Development of Nuclear Power Plant

The International Atomic Energy Agency (IAEA) has developed the milestones approach for the successful deployment of nuclear power program guidelines crosswise three phases (consider, prepare, construct). It is a phase-wise detailed explanatory method to support and assist those countries that are considering or planning their first nuclear power plant. As per IAEA guidelines and experience, it is suggested that from the initial consideration to the first nuclear power plant operation by any new country is about 10–15 years as depicted in Figure 3 [9].

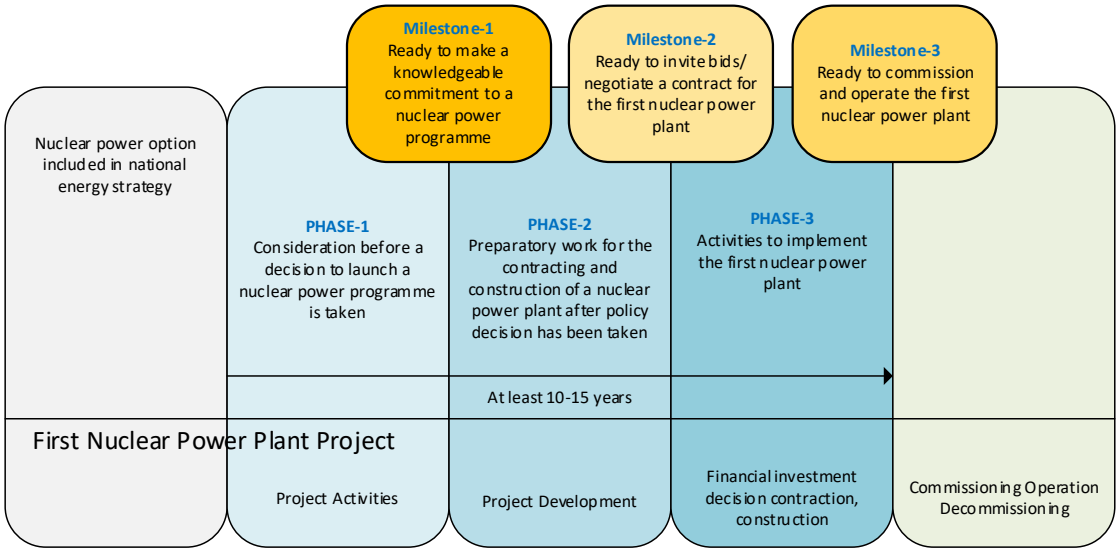

Figure 3. Milestones for Nuclear Power Plant Development [9]

III. Historical Overview of KSA Nuclear Power Generation Deployment:

Kingdom of Saudi Arabia initiated its plans to bring nuclear power plants in 2006 with all the GCC countries, but later on, in 2009 the Saudi government announced that they are considering a nuclear power program on its own and established the King Abdullah City for Atomic and Renewable Energy (KA-CARE) in 2010. Until now KA-CARE is responsible for monitoring and supervising the works related to nuclear energy and radioactive waste projects in the Kingdom of Saudi Arabia. In 2022, the Kingdom of Saudi Arabia confirmed the establishment of the Saudi Nuclear Energy Holding Company (SNEHC). A road to the successful deployment of the nuclear power generation system is sketched in Figure 4.

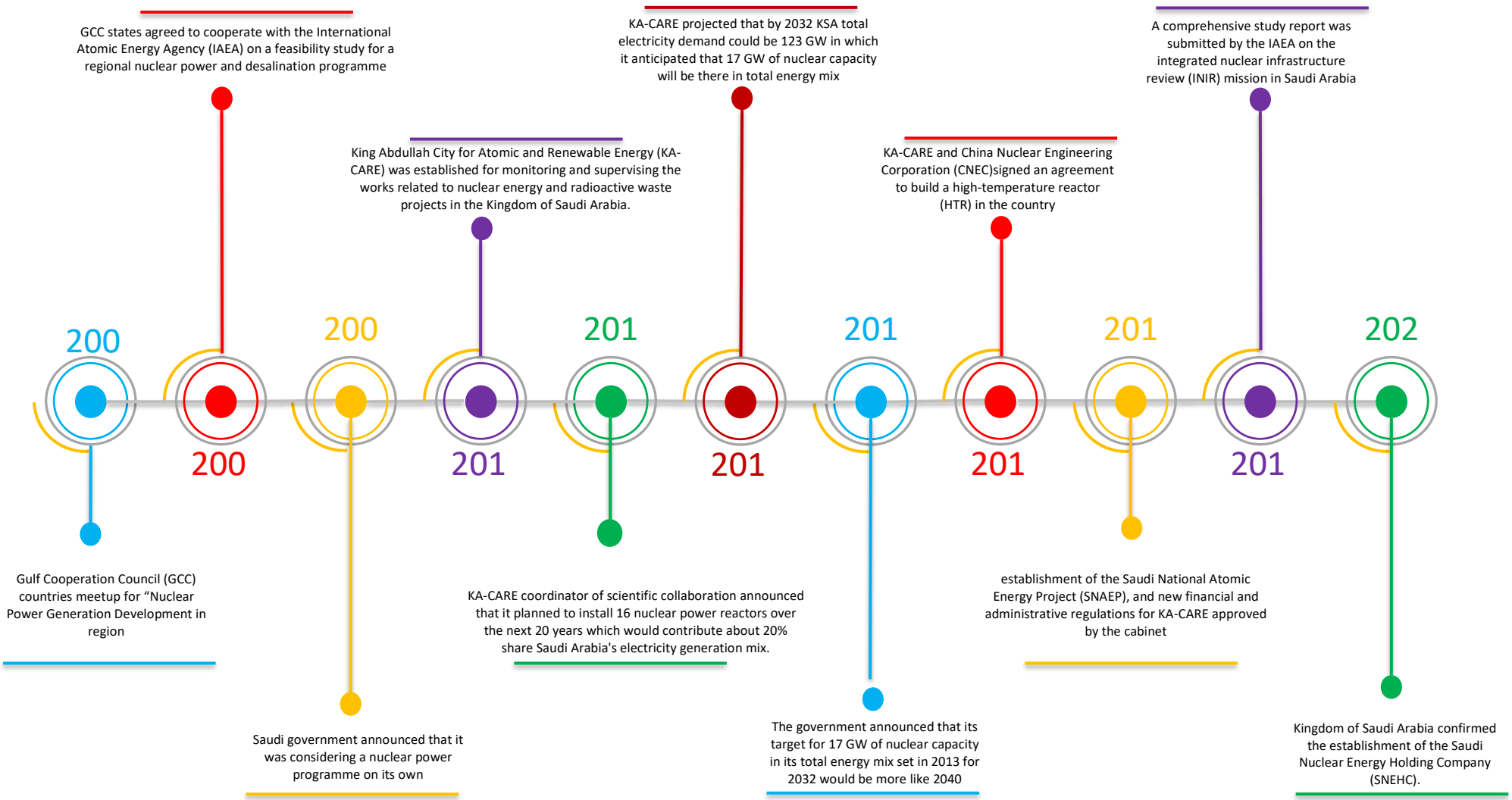

Figure 4. Saudi Arabia Road to Nuclear Power Generation System

However, the Kingdom of Saudi Arabia's desire to achieve its VISION 2030 nuclear power generation targets, and its commitments to adopt and adhere to all the obligations as defined by international conventions and treaties. In pursuance of international treaties and the Kingdom has adopted the following basic characteristics and principles in its Atomic Energy Program as elaborated in Figure-5 [10]:

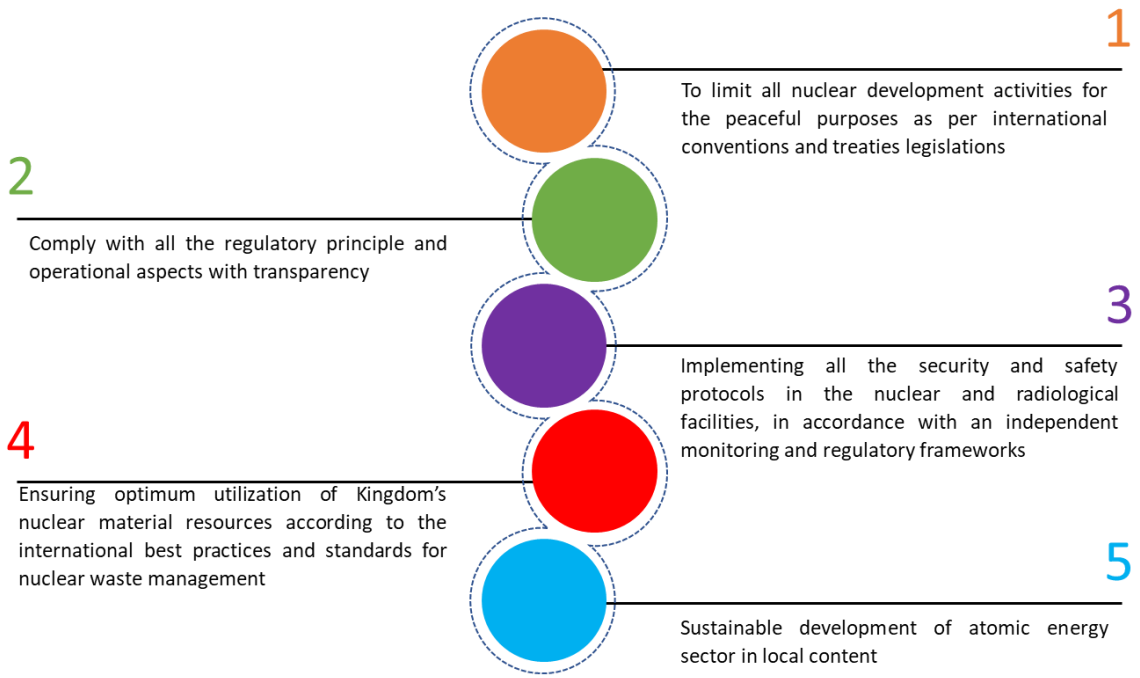

Figure 5. Saudi Arabia's Nuclear Development Milestones

Based on Saudi Arabia's steps taken as described in the aforementioned Figure-5 by following the IAEA "Milestones Approach" and its commitments to fulfill international conventions and treaties, the first Integrated Nuclear Infrastructure Review (INIR) was done at KA.CARE headquarters, Riyadh in July 2018.

The INIR experts reviewed the nuclear infrastructure development status of Saudi Arabia by means of the IAEA's Milestones Approach Phase 2 criteria. The end of Phase 2 describes the readiness of a country to invite bids or negotiate a contract for its first nuclear power plant [11].

The INIR experts appreciated the steps taken by Saudi Arabia for the development of the nuclear power plant in accordance with international conventions and treaties. Furthermore, it was reported by experts that Saudi Arabia has made noteworthy progress in the development of its nuclear power infrastructure. As well KSA has established a legislative framework and is carrying out comprehensive studies to support the next steps of the program at Phase 3 of the IAEA milestones approach.

IV. Suggestions and Recommendations:

In light of Saudi Arabia's aspiration to meet the targets of its "Vision 2030" initiative and to achieve peaceful civil nuclear deployment as a means to meet its growing demand for electricity, the following recommendations and suggestions are proposed for the successful and peaceful deployment of civil nuclear power plants in Saudi Arabia in accordance with the guidelines set by the International Atomic Energy Agency (IAEA).

1. Collaborate with international organizations: Saudi Arabia should continue to work closely with international organizations such as the

2. International Atomic Energy Agency (IAEA) to ensure that their nuclear program is in line with international standards and regulations.
3. Develop robust safety measures: Safety must be the top priority in the development and operation of nuclear power plants. The Saudi Arabian government should implement robust safety measures to prevent nuclear accidents and ensure the safe handling of nuclear waste.
4. Enhance emergency response capabilities: Saudi Arabia should establish comprehensive emergency response plans and regularly conduct drills to ensure that they are prepared to handle any emergency situations that may arise.
5. Increase public awareness and education: The government should invest in public awareness and education programs to increase public understanding of the benefits and risks associated with nuclear power. This will help to build public trust and support for the program.
6. Promote transparency and accountability: To build confidence in the nuclear program, the Saudi Arabian government should ensure transparency and accountability in all aspects of the program, including the decision-making process, safety measures, and waste management.
7. Foster local expertise and talent: The government should invest in training and education programs to develop a skilled workforce capable of operating and maintaining nuclear power plants. This will reduce reliance on foreign expertise and promote local talent.

By following these recommendations, Saudi Arabia can deploy civil nuclear power plants in a peaceful and safe manner, while contributing to their long-term economic prosperity and commitment to net zero emissions by 2060.

V. Conclusion:

The global shift towards green energy sources has led to the exploration of alternative energy options such as nuclear power. The Kingdom of Saudi Arabia has recognized the importance of diversifying its energy sources and reducing its reliance on fossil fuels for electricity generation. As a result, the country has set ambitious targets for renewable energy and nuclear power in its energy mix, with a goal of generating 50% of its electricity from renewables, including nuclear, by 2030. To achieve these targets, the country has established the King Abdullah City for Atomic and Renewable Energy (KA-CARE) and the Saudi Nuclear Energy Holding Company (SNEHC) to oversee the development of its nuclear power infrastructure. The first Integrated Nuclear Infrastructure Review (INIR) conducted by the International Atomic Energy Agency (IAEA) has confirmed that Saudi Arabia has made significant progress towards the development of its nuclear power infrastructure and is ready to invite bids or negotiate a contract for its first nuclear power plant. Overall, the country's commitment to adhering to international conventions and treaties and its efforts to develop a comprehensive legislative framework for its nuclear power program demonstrate its dedication to ensuring the safety and reliability of its nuclear energy infrastructure.

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