

Nuclear Plants Trends for Development Planning in Egypt

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ABSTRACT

Fossil fuel combustion is blamed for global climate change and associated greenhouse gases (GHG) are the main types of pollution created by GHG emissions from combustion (i.e., CO₂) and as such an ever-increasing level of CO₂ emissions make GHG, their pollutants and the complications of climate change awareness more significantly urgent. There is significant concern from policymakers concerning, fuel consumption, energy security and the challenges of GHG emissions created by fossil fuel consumption has created a focus on alternative, cleaner sources of energy both from public policy analysis and political perspectives. As such, clean sources of energy (i.e., nuclear and renewable sources of energy) are being promoted as alternative sources of energy and provide effective tools for mitigating the negative impacts of climate change and are being used as part of a new energy policy strategy. There has also been much discussion among various countries with regard to the need for increasing share of energy supply from nuclear energy, thereby diversifying the energy supply chain, decreasing reliance on imported fossil fuels that may be subject to significant price volatility and improving energy security. The present work will contribute to knowledge development and interface towards improving the power generation infrastructure of nuclear energy in Egypt through a study of the relationship of nuclear energy, the economy and CO₂ emissions using the experience from other developed countries.

تجاهات محطات الطاقة النووية في تخطيط التنمية في مصر

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الكلمات المفتاحية

مشاريع الطاقة النووية
تكاليف الاستثمار
توليد الكهرباء
التنمية المستدامة
مصر

الملخص

يُلقى باللوم على احتراق الوقود الأحفوري في التغير المناخي العالمي، وتعد الغازات الدفيئة (GHG) المرتبطة به هي الأنواع الرئيسية من التلوث الناتجة عن انبعاثات الغازات الدفيئة من الاحتراق (أي ثاني أكسيد الكربون)، وبالتالي فإن المستويات المتزايدة باستمرار من انبعاثات ثاني أكسيد الكربون تجعل من الغازات الدفيئة، وملوثاتها، وتعقيدات الوعي بتغير المناخ أمورًا أكثر إلحاحًا. هناك قلق كبير من صانعي السياسات بشأن استهلاك الوقود، وأمن الطاقة، والتحديات الناتجة عن انبعاثات الغازات الدفيئة التي يسببها استهلاك الوقود الأحفوري، مما أدى إلى التركيز على مصادر الطاقة البديلة والنظيفة سواء من منظور تحليل السياسات العامة أو من المنظور السياسي. وبناءً عليه، يتم الترويج لمصادر الطاقة النظيفة (أي الطاقة النووية والمتجددة) كمصادر بديلة للطاقة وتوفر أدوات فعالة للتخفيف من الآثار السلبية لتغير المناخ، وتُستخدم كجزء من استراتيجية جديدة لسياسة الطاقة. كان هناك أيضًا الكثير من النقاش بين مختلف الدول بشأن الحاجة إلى زيادة حصة إمدادات الطاقة من الطاقة النووية، وبالتالي تنوع سلسلة إمدادات الطاقة، وتقليل الاعتماد على الوقود الأحفوري المستورد الذي قد يتعرض لتقلبات كبيرة في الأسعار، وتحسين أمن الطاقة. سيساهم هذا العمل في تطوير المعرفة وتعزيز التفاعل من أجل تحسين بنية توليد الطاقة النووية في مصر من خلال دراسة العلاقة بين الطاقة النووية والاقتصاد وانبعاثات ثاني أكسيد الكربون، مستفيدًا من تجارب الدول المتقدمة الأخرى.

Introduction

By the end of 2025, global electricity generation reached approximately 30,850 TWh, with fossil fuels (coal, gas and oil) providing about 58%, renewables (hydro, wind, solar, bioenergy and geothermal) around 32%, and nuclear around 10%. The global electricity demand is rising fast, projected to increase by 4.5% in 2025, making sure future generations have enough energy is a huge challenge for any country trying to grow sustainably [1,2]. Egypt feels this pressure even more as electricity demand keeps climbing and its fossil fuel resources just don't stretch far enough. To keep up, the

country needs to shake up its energy mix and really lean into renewables. Right now, Egypt's aiming to get 20% of its electricity from renewables by 2020, and nuclear energy is starting to play a bigger role too—especially since gas is in short supply. By sticking to these plans, Egypt isn't just keeping the lights on. It's also building up its engineering and industrial sectors, setting itself up to compete—and maybe even lead—across the whole region.

Indicators of Nuclear Projects in Egypt

Nuclear energy packs a serious punch when it comes to protecting the environment. Right now, nuclear power plants

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in 29 countries crank out about 15% of the world’s electricity. That’s not all—they keep more than 2 billion tons of carbon dioxide out of the air every year. To put that in perspective, that’s over 20% of the global carbon emissions from electricity generation wiped out.

For Egypt, nuclear energy just makes sense. It’s reliable, safe, and clean, and it’s proven itself in the real world. Plus, it can handle a big chunk of the steady, always-on electricity the country needs. But the benefits go deeper than just power. Egypt’s nuclear program is actually a driving force for modernizing education, industry, and production. It’s not just about energy—it’s about building a stronger, more diverse economy and making sure the government stays committed to that vision.

In This Second Section, the Following Points Will Be Presented

First axis: Economic indicators for evaluating the feasibility of different technologies in Egypt

Second axis: Efforts made to achieve environmental sustainability in Egypt

The first axis: Economic indicators to evaluate the feasibility of different technologies in Egypt

First: Indicators of the Costs of Nuclear Projects in Egypt

In Egypt, building nuclear and coal-fired power plants costs a lot upfront, but once they’re running, they don’t cost much to operate. Gas plants, on the other hand, are cheaper to build but more expensive to keep running. Solar technologies—both photovoltaic [3,4] and solar thermal [5,6]—still have really high investment costs, even though sunlight is free. That’s a big reason you don’t see them everywhere yet. If you look at figure 1, you’ll notice solar energy is still the priciest option, while gas plants are the most affordable to set up. Wind power lands somewhere in the middle; it’s actually cheaper to invest in wind than in coal plants here in Egypt [7].

Operation and maintenance costs don’t stay the same—they shift as technology gets better and everyone keeps pushing

for cheaper, more efficient solutions. When people really understand what new tech and advanced reactor designs can do, they find ways to cut costs and boost performance.

The chart shows something pretty striking: by 2050, operation and maintenance costs for nuclear energy are set to drop by about half. That’s lower than any other energy technology out there. This opens up a real chance for nuclear power to grab a bigger piece of the Egyptian energy market. It’s already making the region rethink nuclear as a core part of its energy mix. Still, if governments want to move ahead with nuclear, they need to plan for big up-front costs and be ready for possible delays along the way [8].

Second: Analysis of the impact of introducing nuclear power plants and their environmental impacts in Egypt

The impact of integrating a nuclear power plant into the Egyptian electricity grid on prices, carbon dioxide emissions, water consumption, and fossil fuel consumption is analyzed.

Land requirements for nuclear power plants

When assessing the effects of power plants on land use based on the area they occupy throughout their operational life, it becomes evident that certain renewable energy technologies necessitate significant land use; for instance, a wind farm generating 1,000 megawatts will demand approximately 85,240 acres of land (equivalent to about 133 square miles). Evaluating a spectrum of capacity factors (ranging from 32 to 47 percent) indicates that between 1,900 megawatts and 2,800 megawatts of wind power will be required to generate the same quantity of electricity as a 1,000 megawatt nuclear power plant annually [9].

As indicated in the preceding Table 1, the land area necessary for solar energy to produce an equivalent amount of energy as nuclear power ranges from 45 to 75 km². Table 1, illustrates the estimated land requirements for both wind and solar energy to equal the annual electricity output of a 1,000 MW nuclear power facility; in comparison, nuclear power plants occupy less land than other energy sources.

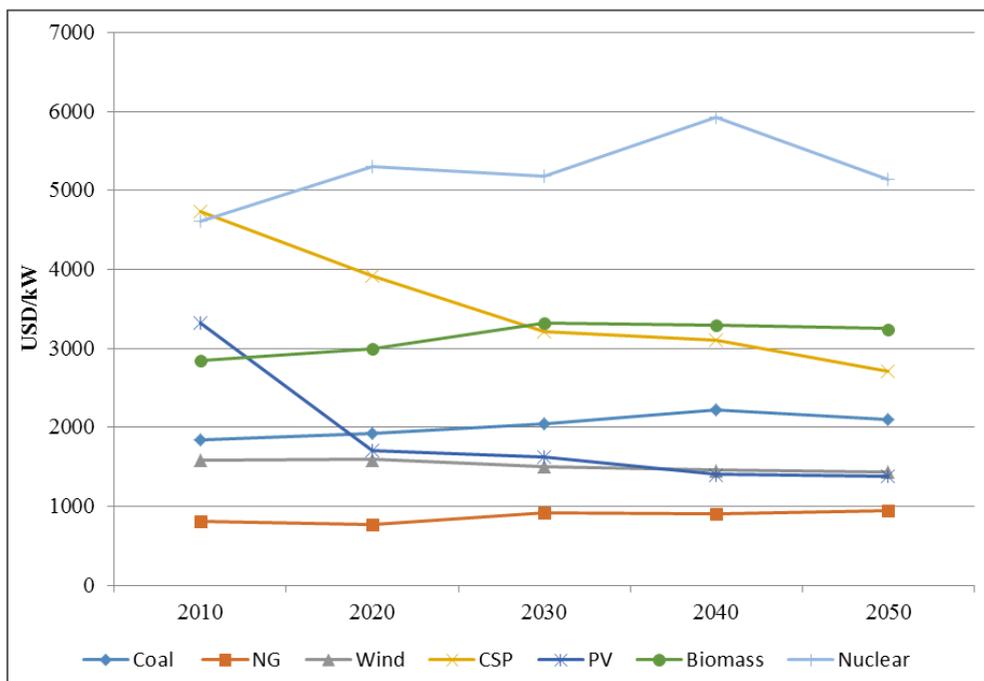


Figure 1: Future forecast of investment costs for technologies under evaluation in Egypt [10]

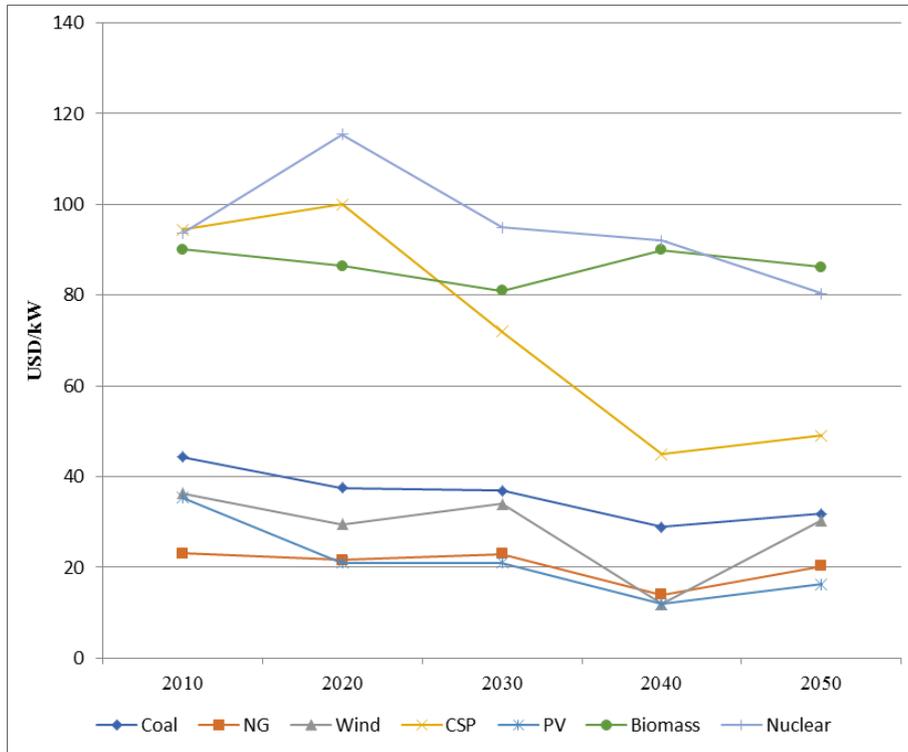


Figure 2: Future forecast of operating and maintenance costs for technologies under evaluation in Egypt [10]

Table 1: Approximate area required for wind and solar compared to the electricity produced annually by a 1,000 MW nuclear power plant [11]

Technology	%Capacity Index	Square Miles Required for 1000 MW
Wind	32-47	260-360
Solar	17-28	45-75
Nuclear	90	1.3

Land Use for Nuclear Power Plants in Egypt

For comparison purposes, as shown in the figure, the land area required to produce 1,000 MW of nuclear energy is approximately 1.3 square miles. This estimate is based on the average of the 59 nuclear power sites in the United States.

Figure 3 illustrates that the environmental effects of nuclear power projects are economically viable, given that nuclear power plants require significantly less land area in comparison to solar and wind power facilities; specifically, a solar field necessitates 45-75 square meters to produce the same amount of energy as a 1000 MW nuclear power plant, which only needs 1 square meter.

Water resources for electricity generation

A substantial nuclear power facility (utilizing a single-stage cooling system) can extract between 800 million and 1 billion gallons of water daily, and these facilities are typically located adjacent to rivers, lakes, or oceans. The water consumption metrics for electricity generation technologies differ significantly within their respective categories, with the least operational water consumption metrics being associated with wind power [12], solar photovoltaic [13,14], concentrated solar power [15], and natural gas cycle plants [16] that employ dry cooling technologies.

Developing Human Capital for Nuclear Facilities in Egypt

Egypt will possess the essential skills to oversee the nuclear energy program, as well as to engage in the implementation and safe, efficient operation of nuclear power plants. In light of this vision, there is a necessity for a workforce to establish the foundations of research, safety, and industry; consequently, the government must concentrate on a structured educational plan aimed at creating a specialized workforce for the national nuclear program, in alignment with both national and international nuclear standards, while considering the following: [17]

- 1) Quality control initiatives must encompass recruitment based on merit and adhere to international standards.
- 2) The journey towards a nationalized nuclear program requires the involvement of local industry in national action plans.
- 3) Emerging nuclear energy nations that embrace new reactor technologies should allocate additional time for human resource development.
- 4) National quota policies ought to be adaptable to the requirements of new nuclear programs.

Third: The impact of nuclear energy on sustainable development in Egypt

The primary goals established by Egypt are to attain national involvement in achieving self-sufficiency in the design, construction, operation, and maintenance of nuclear power plants. The Egyptian industry is also capable of contributing to the production of a significant portion of the various components of the plant, in addition to the manufacturing of fuel and the generation of heavy water. The advantages of these plants are as follows:

Nuclear energy offers safe and diverse energy supplies by decreasing reliance on imported energy, thereby enhancing the independence of the energy sector. Using 1 kg of uranium fuel produces 50,000 kilowatts of electricity:

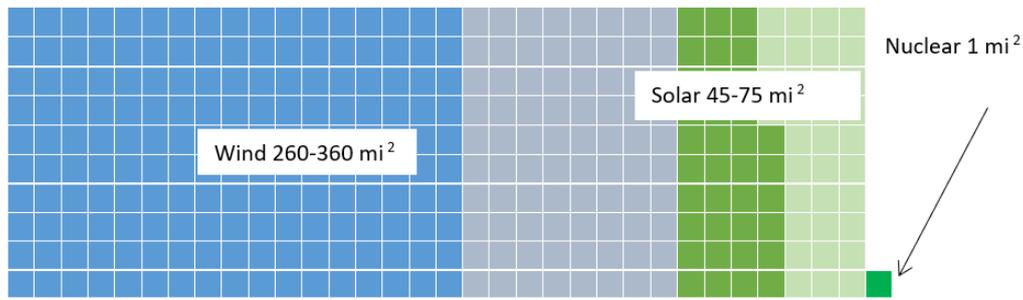


Figure 3: Comparison of 1000 MW nuclear power plants with wind and solar power plants that produce the same capacity annually [18]

- 1) Per hour, compared to producing 1 kg of coal fuel, which generates 3 kilowatts of electricity per hour.
- 2) Egypt's uranium reserves are estimated to be around 1900 tons, with 1 kilogram of uranium capable of producing 24 gigawatts per hour. Consequently, the nuclear energy potential in Egypt is projected to be approximately 536.47 terawatts per hour. Additionally, Egypt faces a scarcity of water resources, prompting a shift towards nuclear desalination as a viable source of affordable drinking water. The co-generation of electricity and fresh water presents a practical and feasible solution for this issue:
 - a. The nuclear energy initiative represents a financially sustainable option for Egypt over the long term. The Dabaa nuclear power facility is projected to fulfill 15% of Egypt's overall electricity demand, enabling the country to enhance its energy resource exports at elevated prices relative to domestic consumption.
 - b. Nuclear energy allows Egypt to satisfy the demand for potable water and to increase its production capacity twofold; furthermore, it alleviates tensions between Egypt and Ethiopia regarding the Nile River matter [19].

Fourth: Criteria for selecting the nuclear reactor market in Egypt

The survey of the global market in nuclear power plants resulted in identifying about 15 potential suppliers willing and interested in supplying Egypt with suitable nuclear reactors that represent the latest state of the art technology. It was found that there are many designs available that meet the acceptance criteria in Egypt in terms of safety, reliability, economic competitiveness and financial viability.

In light of this, the countries of origin of potential suppliers are Canada, China, France, Germany, Japan, Korea, Russia, South Africa, Sweden and the United States of America, and the types of power reactors include light water and heavy water reactors in the range of 600 MW to 1500 MW.

In contrast, when designing a nuclear power plant, the specific characteristics of the site, operational aspects and future decommissioning plans must be considered to achieve the highest levels of safety. A comprehensive and accurate safety assessment is also mandatory to ensure an adequate level of protection for workers, the public and the environment. The main criteria for establishing a reliable cogeneration plant that ensures public confidence and acceptance in Egypt are listed below. They are as follows:

First Construction and Operation

- 1) Design maturity: by providing guarantees so that the licensing and construction schedule can be met without delay.
- 2) Operational experience and performance improvement:

The proposed reactor should have good in-service performance by applying regular improvements in areas such as shutdown control and reactor refueling.

Second Safety and Security

- 1) The proposed plant should be licensed in the country (of suppliers) as an indication of its safety and compliance with safety regulations and standards in the country of origin, and in addition it should be licensed in Egypt and comply with national regulations and safety rules.
- 2) The proposed plant should be designed and built in accordance with internationally accepted nuclear safety principles in addition to national safety standards as appropriate.
- 3) Safety and environmental concerns in nuclear desalination are primarily about eliminating the possibility of radioactive traces penetrating the desalination system [20].

Thirdly, economic competitiveness

The proposed plant must be cost competitive and guaranteed at the time of construction as it has a strong impact on the national economy; in addition to the costs of waste management and decommissioning, and adjustments will be made to these costs to reflect any additional costs expected to be created in Egypt. In the event that Egypt hosts the first nuclear power plant, it must follow a conservative approach with a very strong contingency plan.

To clarify the vision, nuclear power plants can be viewed as sources of fresh water through desalination of seawater, especially if the increasing need for water in the future is taken into consideration. From a foreign policy perspective, the nuclear program gives Egypt an opportunity to strengthen its regional position. Egypt's possession of nuclear energy strengthens its comprehensive power in various foreign policy circles, whether in the Middle East or in the Nile Basin region, as it allows Egypt the opportunity to present its image as an energy exporter and a regional center for its exports, especially natural gas, and to return to being an exporting country rather than an importer of various energy sources, and to seek to become a pivotal region in linking three continents through electrical interconnection operations, in addition to its possession of nuclear energy in a regional environment in which attempts to possess a nuclear program are widespread by some Arab countries such as the Emirates, Saudi Arabia and Iran.

It is worth noting that nuclear energy is a sensitive technology for national security, as it provides a low-cost electricity option; in addition, carbon prices make nuclear energy more economically attractive compared to fossil

technologies, and therefore Egypt needs a new approach to energy planning and modeling that is linked to infrastructure planning; including a diverse mix of renewable energy, fossil energy and nuclear energy; and enhancing investments in power generation through innovation and technological advancement are crucial for the efficiency and resilience of the entire energy system in the long term.

We note that there is a need for favorable policies and strong political will from the government to make changes that take into account the various decentralized energy sources and allow users to choose the best energy option, and investments aimed at improving energy performance may strengthen the local economy and increase the global impact on society; By creating additional capital projects that contribute significantly to generating growth and providing more job opportunities, and to ensure financing, financial mechanisms can be used to create an enabling environment for electricity to help the government put in place the necessary structures to further enhance industrial development in Egypt [21].

Second axis: Efforts made to achieve environmental sustainability in Egypt

First: Egypt's plans to generate electricity to achieve sustainable development

Energy consumption in Egypt is increasing at a faster pace than the expansion of the capacities of power generation stations, and accordingly it has become clear that the nuclear energy program is an economically successful solution for Egypt in the long term, and the increasing need for energy is not the only motive behind Egypt's interest in the nuclear program; as Egypt is the leader of the Arab world, and therefore the decision to pursue nuclear energy serves political purposes at the local and international levels, sparking a regional nuclear race, in order to achieve stability in the balance between supply and demand to enhance the effectiveness of the country's entire energy system.

As a result, the Egyptian government plans to transform Egypt into a centre for energy generation, and the goal is not only self-sufficiency but also generating energy for export; The nuclear energy that will be generated from the Dabaa plant will be a valuable addition to the Egyptian energy mix, and its construction will also contribute to the development of Egyptian industry through a long-term program to establish nuclear plants in which the share of local manufacturing increases according to a clear and committed plan. Egypt's energy policy focuses on the following:

- 1) Analyzing the Egyptian economic situation for nuclear power generation systems.
- 2) Assessing the capabilities of local participation and the impacts on Egyptian development efforts.

To clarify this, we point out that nuclear energy is a viable and necessary option for Egypt's energy mix, however, its suitability is conditional on several critical factors that act as binding constraints such as planning, implementation costs and operating life. In light of this, there are two scenarios for the future of Egypt's energy mix. The main difference between the ambitious and conservative scenarios lies in the use of natural gas. At the same time, the shares of renewable energy sources (hydro and wind) and nuclear are the same in both scenarios.

Moreover, both scenarios assume the introduction of efficiency applications that will cover part of Egypt's energy needs, as shown in the figure, both scenarios involve an energy deficit, representing only 15% under the ambitious scenario compared to 37% under the conservative case. This confirms that hydroelectric and wind energy can only cover part of the deficit in energy production, and the Egyptian government still needs to find other energy alternatives to meet these needs, with the possibility of filling part of the 15% deficit through solar, nuclear, and other energy.

Looking at the figure 4, it is expected that Egypt's ambitious energy mix in 2022 will consist of: fossil fuels and natural gas 61% (of which 20% is oil and 41% is natural gas), renewable energy 9% (of which 7% is wind, 2% is hydro), 7% is nuclear, 8% is implementation efficiency, however, it is expected to fall by 15% from meeting the expected energy demand in 2022.

Second: The economic feasibility of applying nuclear energy in Egypt

The Dabaa nuclear plant represents a national technological security for Egypt; it adopts the philosophy of transferring and localizing nuclear technology in Egyptian factories, with the aim of upgrading Egyptian industries to reach the level of global quality, in order to increase export opportunities abroad, and increase the national income in hard currency, as the ultimate goal of the Dabaa nuclear plant is "national technological security".

The Dabaa nuclear power plant will be able to meet 15% of Egypt's total electricity consumption, which reduces the cost of importing fossil fuels; because it reduces dependence on foreign countries in the region such as Israel, Kuwait, Oman and Iraq, while on the other hand allowing Egypt to increase its exports of energy resources due to the high prices compared to the domestic prices consumed.

According to estimates by the World Nuclear Association, nuclear reactors will be built with water desalination facilities in Dabaa. Each nuclear reactor in Dabaa will have the capacity to produce 170 thousand cubic meters per day; at a cost of less than one dollar / cubic meter, compared to the costs of desalination from gas turbines; the costs of desalination of nuclear water are approximately half the costs of a gas station, and thus Egypt will save half the costs required to supply gas turbines with fossil fuels, and nuclear energy will enable Egypt to double the production capacity of drinking water [23].

1- The economic and social impact of operating the Dabaa plant in Egypt

The cooperation between Egypt and Russia represents an enrichment of future technology, represented in creating new opportunities for creativity and balance in engineering thought and management and implementation of nuclear power plant projects in the field of electricity. The introduction of this advanced technology also provides a major boost to local industrial, scientific, technical and economic development in Egypt; It allows the Egyptian grid to accommodate an additional nuclear unit within the currently available energy range. The economic and social impact of operating the Dabaa plant is as follows:

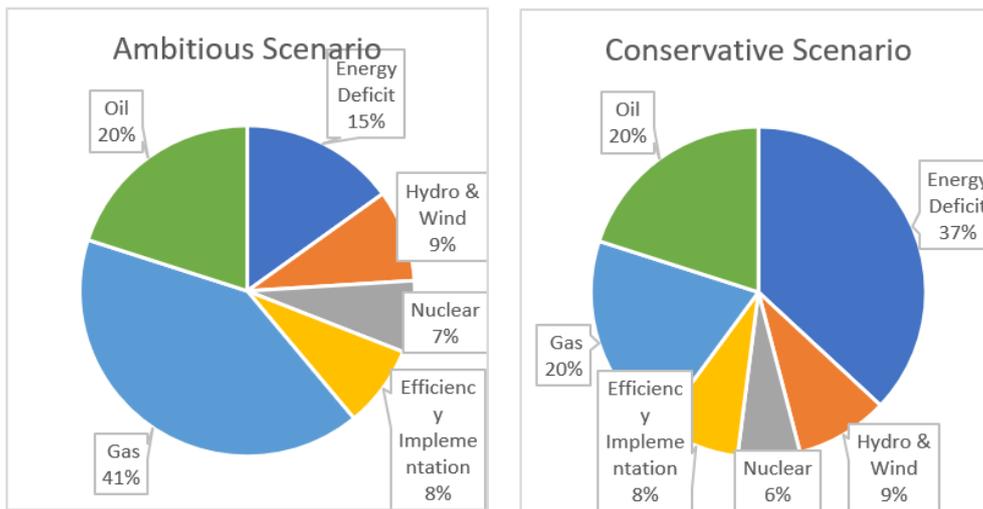


Figure 4: Future energy mix in Egypt 2022 [22]

Financing: The plant will consist of four nuclear reactors capable of producing 1.2 gigawatts each. The first unit is expected to start commercial operations in 2026. Russia will finance approximately 85% of the construction cost of the Dabaa nuclear power project, and will provide a loan worth \$ 25 billion under a financing agreement signed between the Egyptian Ministry of Finance and the Russian Ministry of Finance. The loan will be repaid over 22 years at an interest rate of 3% per annum, while the remaining 15% will be collected by Egypt from private sector investors, encouraging their participation in the electricity market.

Nuclear Fuel: The contractual scope also includes the provision of nuclear fuel over the entire operational life of the plant and assistance in its operation and maintenance during the first ten years of operation. Rosatom will also build storage and supply containers to store spent fuel.

Providing jobs: The construction of the plant will provide up to 50,000 job opportunities, and these jobs come with improved training and education opportunities for the nuclear industry in Egypt. The Russian company Rosatom, the main contractor for the Dabaa NPP project, will conduct training in both Russia and Egypt for 2,000 specialized cadres, and it also has joint programs for nuclear education for Egyptian students and partnerships with leading universities in Egypt such as Alexandria University. Rosatom plans to expand the scope of these programs with the selection of about 300 Egyptian students to study nuclear sciences in Russia in the next few years.

Desalination plants: Desalination of seawater is expected to play an increasing role in alleviating the future deficit in potable water supplies, especially in remote desert areas. Given the limited energy resources of fossil fuels and

hydropower, which are almost entirely used, Egypt is moving towards introducing nuclear energy to generate electricity. The nuclear reactor that provides electricity to the grid can in principle also provide electricity or heat to the desalination plant. The Dabaa site on the Mediterranean coast has been selected and qualified as the site for the first Egyptian nuclear power plant.

Economic development: The plant is expected to provide up to 50% of Egypt’s electricity generation to meet the growing demand for electricity, and to boost the country’s economy and industrial development by stimulating growth in related non-nuclear industries such as construction and utilities, as well as in the consumer services sector, and the purchasing power of the population. Russia will also build factories in Egypt for the local manufacturing of nuclear plant components, providing the required expertise in addition to building reactors. Infrastructure investments in regional transmission networks and local power lines will be required, as shown in Table 2.

The Central Agency for Public Mobilization and Statistics announced that the electricity sector is the main source of carbon dioxide emissions resulting from the consumption of petroleum products, and that the amount of carbon dioxide emissions resulting from the consumption of petroleum products and natural gas amounted to 119,583 million tons in 2016, compared to 279,878 million tons in 2030, as shown in Table No. (12). A warmer climate could also mean smaller supplies of fresh water, with adverse effects on the overall economy, and this change could lead to a great deal of political and social instability.

The power generation mix based on the optimal choice of fossil, nuclear and hydraulic energy is the most suitable way to produce electricity in Egypt. Therefore, diversifying

Table 2: Total annual income of Dabaa Nuclear Power Plant [25]

Time period	Energy quantity	Energy quantity/day	Income (per day)	Total income per year	Total annual income (85%) for the Government of Egypt
Time period Ideal (daily consumption over 24 hours)	4,760,000 (kw)	114,240,000 (kWh/ per day)	\$45,696,000	\$16,679,040,000	\$14,177,184,000
Realistic (65% of daily consumption or 15.5 hours)	4,760,000(kw)	73,780,000 (kWh/per day)	\$29,512,000	\$10,771,880,000	\$9,156,098,000

production from a system dominated by fossil fuels and gas to a system that includes increased use of natural resources helps maintain national security in Egypt while maintaining gas exports and foreign currencies, reducing the amount of imported fuel, and protecting against environmental impacts.

In summary, this study is an exploration of the future of energy in Egypt within the framework of alternative policy options and provides insight into the implications of technologies that the government in Egypt could pursue. The future of energy development that Egypt chooses will not only affect the country, but will also have implications for both energy producers and importers of Egyptian energy sources as trade and interconnection between electricity grids increase. A stronger and more diversified Egyptian energy sector will help support the broader regional economy, in addition to contributing to a better climate in Egypt's future. [24]

4. A Roadmap for Implementing and Operating Integrated Nuclear Power Plants in Egypt

Developing an integrated roadmap capable of implementing initiatives in a detailed manner would clearly define the tasks and responsibilities of the policy-making body to implement all initiatives related to economic frameworks, and ensure the optimal use of national resources and effective localization of national projects. Therefore, when formulating and implementing the stages of initiatives, clear roles and responsibilities should be assigned to each of the concerned partners in order to ensure the success of the energy sector development program, and to make investments exploit market opportunities. It is worth noting that the strong political will of the government will help establish a national project that goes a long way in mobilizing resources in order to make concerted efforts to establish a successful nuclear energy sector in Egypt. [26]

Requirements for Nuclear Security and Safety Systems in Egypt

Technical Standards for Nuclear Security and Safety

Developing a national strategy to design a safety requirements structure is one of the necessary elements for establishing an effective nuclear security system; as it contributes to protecting people, property, society and the environment from the harmful consequences resulting from radiation exposure, by enhancing the state's ability to support institutional, human and technical capabilities in various aspects; Such as monitoring and securing radioactive sources and exercising regulatory and supervisory tasks in the field of planning, preparing for and responding to nuclear and radiological emergencies, and coordinating with governmental and non-governmental bodies concerned in the Authority's areas of work. The safety requirements and mechanisms for implementing the technical aspects of nuclear safety are represented in the following: [27]

1. Providing the necessary infrastructure to meet nuclear safety requirements, including providing all the necessary equipment and technical equipment for nuclear safety, providing human expertise familiar with nuclear protection and safety procedures, and the necessity of having an effective administrative organization within each nuclear facility that undertakes the task of organizing that human

expertise in the best possible way.

2. Building and forming a national scientific, technical and professional cadre specialized in nuclear energy affairs, peaceful uses and protecting the environment from the harms of exposure to radiation, and working to refine them through training by linking them to training programs in various nuclear sciences and technologies organized by specialized international bodies or that can be granted by advanced nuclear countries, provided that this body includes a group of the best scientific and technical cadres with competencies and in various universities and similar government facilities related to the peaceful uses of nuclear energy.

3. Providing specific procedures to ensure the safety and security of the nuclear reactor, starting from the engineering design, construction and selection processes, and ending with the normal and emergency operation of the reactor. The most prominent of these procedures are: A- Ensuring the quality of the components of the nuclear power plants according to the established engineering and technical design specifications. B- Designing highly efficient safety devices that have permanent and diverse readiness to face operating conditions. C- Designing systems to prevent major, unlikely accidents; such as loss of primary coolant, human errors, and severe natural events (earthquakes, hurricanes, and floods) and other security and safety procedures taken to ensure the safety and security of the nuclear reactor.

4. Establishing national committees that organize the rules governing all practices involving ionizing radiation or radioactive sources, and that these committees undertake the task of spreading awareness of nuclear risks, spreading the culture of safety among workers with radiation or radioactive materials at all levels, monitoring the implementation of all nuclear measurements necessary to achieve the required protection, and supervising the development of advanced and effective plans in the event of an emergency known in advance to workers, by developing scenarios for various possible accidents based on available experience.

5. Develop accurate lists that include detailed information - quantitative and qualitative - about all materials used inside the nuclear facility, and review these lists periodically and systematically; so that they are not exposed to theft or smuggling abroad.

6. Activate the work of national atomic energy bodies in each country, expand their competencies, powers, technical, scientific and administrative staff, and approve the financial budget and what is sufficient to implement the tasks and competencies assigned to them, especially with regard to protecting the environment, population and the country from the possibility of exposure to radiation and radioactive nuclear materials.

7. Establish a database for nuclear information and peaceful uses and the results of geological, physical, chemical and other studies and research related to nuclear energy affairs, provided that multiple departments with scientific and technical specializations are established within the national atomic energy bodies; As a department of radioactive materials, it includes more specialized branches, and each branch is named after the radioactive element that it specializes in following up on all its aspects and components.

Table 5: Integrated Implementation Roadmap for Nuclear Energy Projects [28]

Timelines and Milestones	Q1 2016	Q2 2016	Q3 2016	Q4 2016	Q1 2017	Q2 2017	Q3 2017	Q4 2017	Q1 2018	Q2 2018	Q3 2018	Q4 2018
Clarifying the role of business partners	Defining roles		End of consultations				Policy setting with defined roles					
Setting renewable energy goals and mandates	Collecting inputs				Setting policy with objectives and mandates				Setting objectives			
Implementing the Economic Framework for Renewable Energy		Defining the economic framework		End of consultations			Establishing a procurement					
Policy Development Model for the Dissemination of Alternative Energy Use	End of consultations		End of campaigns				Establishment of the Nuclear Safety Authority					
Implementation of the economic framework for alternative energy	Defining the economic				End of consultations			Establishment of a nuclear waste management authority				
Providing financial support	Completion		of all financing requirements		Establishment of the Finance Authority			Establishing public-private coalitions				
Establishing complexes and a comprehensive service center for alternative and renewable energy	Finalize location and services				Establish a comprehensive service center							
Supply chain development	Setting localization goals				Formulating supplier relationships for renewable				Establishing a trade forum for alternative			
Human capital development	Completion of Incubator Plan		Curriculum Design			Preparing the educational curriculum			Establishing the incubator center			
Technical capital development	Design of the R&D Program		Completion of the design of the			Notification of R&D Budgets			Establishment of the			
Energy Support Management	Completion of the study of electricity and fuel						Start communicating with business partners					
Integrated Resource Planning	Establishment of the Integrated Resource Planning Committee						Develop the first comprehensive plan					
Integration of renewable energy and energy efficiency	Develop renewable energy and energy efficiency initiatives						Update existing energy efficiency					

8. Seeking to participate effectively in scientific and technological cooperation activities with international bodies, such as the Arab Atomic Energy Agency, the International Atomic Energy Agency, and official bodies affiliated with nuclear countries, to establish the basic infrastructure for the peaceful nuclear uses program and protect the environment

from the harms of exposure to radiation.

9. Organizing training courses on nuclear safety and security procedures in nuclear-fueled power plants, and for the competent nuclear energy authorities to organize these courses in cooperation with the International Atomic Energy Agency. Such courses aim to help nuclear safety experts in

the country concerned to develop their expertise in the field of nuclear safety, secure power plants, and establish the best possible safety conditions in new plants. [29]

Safe waste management

Waste management is a prominent source of concern for the public - although one of the advantages of nuclear energy compared to other energy sources is the small volume of waste it produces. Accordingly, safe waste management requires sufficient financial resources and systems to control all radioactive sources. As for the management and final disposal of high-level radioactive waste, decisions need to be made to build final repositories for its storage [30].

From another perspective, nuclear risk management should not be left to individual states. The best possible way to manage risks is for neighbouring states to cooperate to promote their common interests. This requires neighbouring states to develop a robust regional risk management framework, one that takes into account the transnational dimensions of nuclear energy and whose main objective is the equitable distribution of benefits and risks. This regional framework includes an agreement on building national emergency response systems that neighbouring states can accept, and it will create a network of manpower, knowledge, technology and financial support resources that can be disseminated throughout the region [31,32].

However, all technologies involve risks, but no technology is more dangerous than nuclear energy; its risks do not depend on technical issues only, but organizational and institutional capabilities play a fundamental role; as the risks of nuclear energy in less developed countries are related to the institutional field more than to specific designs of reactors and safety systems, and accordingly, governments in the developing world must establish good systems for nuclear governance; the foundations of this nuclear governance include three things, the most important of which are transparency, accountability, trust, and activating international cooperation [33].

Conclusion

We conclude from this research that all these considerations justify the massive integration of nuclear sources into the long-term energy supply strategy, and its adoption of an energy policy based on finding actual alternative elements that achieve the preservation of its depleting petroleum resources and their exploitation and management with high efficiency in order to support the process of sustainable development in Egypt.

Based on these previous indicators, this research verifies that nuclear energy becomes a major contributor to global energy production in order to mitigate greenhouse gas emissions, and has the technical characteristics of the electricity sales industry at low prices, although the cost of establishing a nuclear plant is the largest among other energy sources, but the cost of nuclear fuel in the cost component of electricity production from nuclear energy is considered small, and does not significantly affect energy prices with the difference in fuel value, compared to fossil energy sources.

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