Egypt and nuclear energy: aspects, reasons and future

D A Cauich-López1*, L F Barrera Payan1, A M N Abdelhalim1, V V Izrantsev1, V G Knorring1, G A Kondrashkova1, Yu M Pankratov1, L R Mukhametova2 and A A Sinitsyn3

1Peter the Great St. Petersburg Polytechnic University, Power Plant Engineering, Saint Petersburg, Russia
2Kazan State Power Engineering University, Kazan, Russian Federation
3Vologda State University, Heat Gas Supply and Ventilation, 160000 Lenin st., 15, Russia

* Corresponding author: daniel.cauich@gmail.com

Abstract. This article tries to give an analysis of the current energy situation in Egypt and to the Egyptian nuclear program giving a spot light on the history of the nuclear program and the reasons that made the nuclear energy a possible and applicable solution to the energy problems in Egypt. Also, it shows the Russian – Egyptian cooperation in the field of nuclear energy and the role of the Russian side in development of the Egyptian nuclear program

1. Introduction

Energy is defined as the ability to do work, and it is one of the most fundamental parts of our universe. Everything we do in our life requires energy, moving, thinking, sports, etc.

The cornerstone of the development of each country is to be able to meet its demand of energy. That’s why each country started to look for various types of energy and to develop techniques and methods to increase the amount of energy production and to find new resources of energy in order to be able to satisfy its needs of energy. In particular electrical energy is playing a vital role in countries economy, while it’s considered basic unit in achieving sustainable development.

Egypt has the third-largest population and the third highest gross national income (GNI), in Africa, according to the World Bank.

Over the last decade, Egypt’s energy policies and energy sector have witnessed fundamental changes. Accordingly, several characteristics of the country’s energy sector could be identified. Egypt’s growing population and economic (industrial) development led to a significant rise in the demand for energy products in all sectors.

After 2011 revolution the country experienced a sharp decline in tourism revenue and foreign direct investment, according to the International Monetary Fund (IMF). According to the IMF, financial support from some Persian Gulf countries has helped Egypt meet its domestic energy demand.

Nevertheless, starting from late 2014 and shortly after new Egyptian president Abdel Fattah El-Sisi implemented a new strategy to improve the energy sector and to be able to face the increase in energy demand by increasing number of energy production units and expanding the energy infrastructure and find more energy resources and increase the share of renewables, also the strategy included future plans to depend on the nuclear energy.
2. Energy Resources in Egypt

2.1 Oil, Petroleum and Natural gas:
According to U.S. Energy information administration report about Egypt, Egypt is the largest non-OPEC (Organization of the Petroleum Exporting Countries) oil producer in Africa and is the largest consumer of oil on the continent [1]. The country’s use of oil accounts for 20 percent of Africa’s total consumption. Moreover, Egypt has Africa’s largest oil refinery capacity.

Egypt's total primary energy consumption was 1.7 million barrels per day (b/d) of oil equivalent in 2013, according to the BP 2014 Statistical Review of World Energy [2]. Natural gas and oil are the primary fuels used to meet Egypt's energy needs.

![Figure 1. Primary Energy consumption by fuel in Egypt, 2013 [2].](image1)

While being a major producer, Egypt is also an importer of oil because the country’s consumption of oil has been increasing by approximately 3 percent per year due to economic and population growth.

Egypt also is accounting for about 20% of petroleum and other liquids consumption and 40% of dry natural gas consumption in Africa in 2013.

![Figure 2. Petroleum and other liquid production in Egypt [1].](image2)

In 2014, Egypt's petroleum and other liquids production averaged 708,000 b/d, unchanged from the previous year. About half of Egypt's oil production comes from the Western Desert and the remainder comes from the Gulf of Suez, Eastern Desert, Sinai, Mediterranean Sea, Nile Delta, and Upper Egypt. Most of Egypt's production is derived from relatively small fields that are connected to larger regional production systems.
Most of the natural gas consumed in Egypt is used to fuel electric power plants. The Egyptian government encourages households, businesses, and the industrial sector to consider natural gas as a substitute for petroleum products and coal.

Egyptian consumption of natural gas has been increasing by approximately 7 percent per year over the past decade.

According to the American security background report about Egypt, with the increasing level of consumption combined with the decreasing level of production Egypt will begin to import liquefied natural gas (LNG). Cairo signed an agreement with Algeria in December 2014 to import LNG between April and September 2015. Egypt signed a contract in February 2015 to import natural gas from an Israeli offshore gas field in the future. Cairo also signed an agreement with Gazprom to import LNG from Russia.

2.2 Hydro-power:
According to the Annual report of the ministry of Electricity and renewable energy [3], Hydropower is Egypt's third-largest energy source after natural gas and oil. Egypt generated Power of hydroelectricity, accounting for about 9% of Egypt's total power generation. Most of the country's hydroelectricity comes from the Aswan High Dam and the Aswan Reservoir Dams across the Nile River

| Plant       | 12/13  | 13/14  | Variance % |
|-------------|--------|--------|------------|
| High Dam    | 9113   | 9364   | 2.1        |
| Aswan Dam 1 | 1502   | 1559   | 3.8        |
| Aswan Dam 2 | 1596   | 1603   | (0.8)      |
| Esna        | 473    | 538    | 13.0        |
| Naga Hamady | 437    | 481    | 3.2        |
| Total       | 15121  | 1552   | 1.8        |

According to the American security background report about Egypt [4], In January 2015, the Egyptian government announced that it plans to build additional hydroelectric power stations with the help of China; however the new stations are not likely to make a big change in Egypt’s hydroelectric capacity

2.3 Solar and wind energy:
According to the Annual report of the ministry of Electricity and renewable energy for 2013/2014 [3], Egypt's first solar-thermal power plant, located in Kuraymat just south of Cairo, has the capacity to generate 140 MW of solar-thermal energy, and it has been operational since June 2011.

Also, Egypt is planning to establish a 140 MW solar power plant along the Red Sea coast and a 100 MW plant in Kom Ombo. Egypt plans to make an increase in the solar generation capacity by 3,500 MW by 2027.
Egypt generates wind power mainly from the 545 MW Zafarana wind farm and the 5 MW Hurghada wind farm.

According to the Annual report of the ministry of Electricity and renewable energy [3], the energy council approved the strategy that helps to increase the amount of generated energy by renewables to 20% by 2020, at which 12% will be from wind energy. The plan includes the establishment of new shared wind projects with the private sector to increase the total capacity to 7200 MW by 2020.

3. Energy situation in Egypt

According to the reports of the ministry of electricity and renewable resources and the nuclear power plants authority in 2015 [5], the electrical energy generation in Egypt can be shown as follows:

![Energy Distribution Graph](image)

**Figure 5.** Distribution of energy generation in Egypt - Taken from Nuclear power plants authority report (January 2015) [5].

According to the annual report of the ministry of electricity and renewable energy for year 2013/2014 [3], the annual rate of growth for the peak load in Egypt was 3.5% in the period between 2009 and 2014.

![Peak Load Curve](image)

**Figure 6.** Electricity peak load curve [3].

In May 2015 and according to U.S. Energy information administration report about Egypt and Middle East economic survey, Egypt’s generation capacity of electricity were 31.45 GW while the expected peak demand was 30 GW and according to research done by the ministry of electricity and renewable energy in 2015, the peak load is expected to reach 61 GW by year 2027.

In the same report it was mentioned that 70% of Egypt’s electricity consumption is fueled by Natural gas.
The shortage of natural gas and problems in distribution and generation due to aging infrastructure, Egypt suffered from several blackouts.

4. Why Nuclear energy in Egypt?
For the above mentioned reasons, the Egyptian government is trying to increase the capacity of electrical generation to be able to match the increase of electricity demand expected in the future. The government started to boost the renewable energy in form of solar and wind energy; these plans are in parallel with the strategic plan to increase power generation using fossil fuels resources.

The Egyptian government started to discuss the usage of nuclear energy and building nuclear power plants to improve electricity production and generation and to ensure the ability to match the demand in the future.

The Egyptian Government realized that Nuclear energy can be considered a key solution to the energy problems in Egypt and found that it has a lot of advantages and benefits.

In the report issued by the nuclear power plants authority in 2015 [5], nuclear power was considered one of the best possible ways to generate electricity and meet the demand in the future.

Egypt has consumptions of fossil fuels higher than the amount the government can supply knowing that most of the natural gas consumed in Egypt is used to fuel electric power plants. With these limited resources and high consumption, Egypt is forced to find another source of energy to meet its demand and since nuclear power doesn’t depend on the fossil fuels so it’ considered the best substitute for energy generation.

Also, the market of fossil energy resources isn’t stable and prices vary according to the dollar price and political circumstances which makes it hard to be imported.

Nuclear energy is considered a clean source of energy, The World Nuclear Association carried out a review of over twenty studies assessing the greenhouse gas emissions produced by different forms of electricity generation [6–8]. The results was shown in the chart below show that generating electricity from fossil fuels cause greenhouse gas emissions higher than when using nuclear energy or using renewable energy.

![Greenhouse gas emissions chart](chart.png)

**Figure 7.** Greenhouse gas emissions for different types of fuel used for electricity generation - World Nuclear Association.

The nuclear energy has almost full utilization of hydropower. A power plant generates electricity by boiling water to steam, and uses the steam to turn the turbine and then the turbine is connected to the generator which generates the electric power. Cooling systems are required to cool the steam back to water so the cycle can continue.

Nuclear energy has a low operation cost, after construction of the nuclear power plant the operation cost and maintenance cost is very low compared to fossil fuels [9].
Operating costs include operating and maintenance (O&M) and fuel. Fuel cost figures include used fuel management and final waste disposal. These costs, while usually external for other technologies, are internal for nuclear power (i.e. they have to be paid or set aside securely by the utility generating the power, and the cost passed on to the customer in the actual tariff).

Uranium has the advantage of being a highly concentrated source of energy which is easily and cheaply transportable. The quantities necessary for operating the nuclear power plant are very much less than for coal or oil.

5. Egyptian Nuclear Program

Egypt started to think about nuclear energy long time ago and the Egyptian nuclear program has been an on-and-off process due to several political and economic circumstances.

The Egyptian program started officially in 1955 with the establishment of the atomic energy committee. In the same year, Egypt took the first step in the nuclear program by signing an agreement with the Soviet Union to acquire Light water reactor of capacity 2 MW as a research reactor. Egypt started the construction of the reactor in 1958 and in 1961 the reactor was operated.

The Egyptian Nuclear program was disturbed for long time due to the political circumstances and the war till 1975 when USA agreed to support the Egyptian nuclear program, but the conditions that USA introduced to Egypt in 1976 were unacceptable to the Egyptian government.

By the end of 1976, Egypt and France reached an agreement to develop the research reactor, but under the pressure from the U.S government, France changed the terms of agreement with Egypt and the co-operation between the two countries collapsed.

As a part of new regulation and steps to enhance the management and planning for the nuclear program, the Egyptian government established the Nuclear power plants authority in 1976.

From 1981 to 1984, Egypt signed several cooperation agreements with USA, France, Germany and Switzerland in the field of civil usage of nuclear energy and nuclear power plants due to political circumstances.

In 1986, Egypt suspended its nuclear plans after the disaster of Chernobyl Nuclear power plant, but in 1992 Egypt signed an agreement with to Argentinean Company INVAP to construct light water research reactor of capacity of 22 MW. The construction of the plant started in the same year and it was first operated in 1997.

After 10 years of silence about the Egyptian nuclear program, Egypt and Russian agreed on starting cooperation in the field of nuclear energy during to the visit of President Mubarak to Russia in 2008.

The Egyptian government announced the creation of new regulations to support the nuclear program in 2009 and these regulations were discussed and finally issued in 2010 [10]. In the same year the IAEA had approved (El-Dabaa site – near Alexandria) an acceptable site for Egypt to build its nuclear power plant.

The Nuclear program stopped again after that due to the political circumstances in Egypt and the Egyptian revolution in January 2011. Egypt approached the Russian side to renew the agreement signed in 2008 concerning the Egyptian nuclear program in April 2013.

6. The Egyptian Russian Nuclear reactor

The Egyptian Russian cooperation has a long history since the revolution of July 1952, building the 1st research reactor in 1958 and the Russian support to Egypt during the 1973 war and the building of the High Dam in Aswan.

As mentioned before that in April 2013, Egypt approached Russia to renew the agreement of nuclear cooperation. The Russian foreign minister announced in November 2013 that Russia is ready to finance and support the Egyptian Nuclear Program and the building of the nuclear power plant. This became possible as Russian scientists and economists have a significant experience in nuclear power plant operating technology development [11–22].

In February 2015, The Russian and Egyptian presidents announced the Russian Egyptian cooperation in building Egypt’s first nuclear power plant [23]. The ministry of electricity and Rosatom signed a
primary agreement to establish the nuclear power plant that will be formed from 4 units of VVER 1200 Nuclear power plants with total capacity of 4800 MW [24,25]

The agreement includes building nuclear fuel storage facilities to supply the nuclear plant with the required nuclear fuel along the 60-year operational period. Rosatom will also manage nuclear waste, maintenance and operation, and training Egyptian experts.

The station will be completely safe, especially since Rosatom will provide them with the VVER-1200 safety protocols to protect against internal and external factors and influences.

7. Future of Nuclear energy in Egypt
The success of the First NPP will be built in Egypt is the key to start an ambitious program to build more NPPs in Egypt to insure that the amount of energy generated is more than the peak demand in the future.

The ambitious of the Egyptian government to build a competitive industrial infrastructure will help in pushing forward the nuclear program to insure the stability of these projects. The plan is to build 6 more NPPs in case of the success of the first project.

8. Conclusion
Egypt nuclear program is based on infrastructure with two research reactors and regulatory mechanisms for the planning and control of nuclear development. Due to the increasing domestic demand for electricity to improve the energy infrastructure which will help in the development of the industrial sector too, Egypt has strong interest in nuclear energy and building nuclear power plants. As its current energy industry relies mainly on oil and gas, with some wind power, the nuclear power will be considered a possible and applicable approach to help in the development of the energy sector.

The Russian – Egyptian cooperation in the development of the Egyptian nuclear program will increase the chances of the success of the program and the possibility of the construction of more nuclear power plants due to the high technology offered from the Russian side and training for Egyptian experts and engineers.

References
[1] U.S.E. information Administration 2014 International energy data and analysis – Egypt (June 2014)
[2] BP 2014 BP 2014 Statistical Review of World Energy
[3] The Ministry of Electricity and renewable energy 2014 Annual Report (2013/2014)
[4] American Security Project report 2015 Energy In Egypt – Background and issues
[5] Nuclear power plants authority report 2015 An Overview of the Egyptian Nuclear Power Project
[6] Electricity generation - what are the options? Available at http://www.world-nuclear.org/nuclearbasics/electricitygeneration-what-are-the-options.aspx
[7] World Nuclear Association report Nuclear Energy and Climate Change
[8] World Nuclear Association report The Economics of Nuclear Power
[9] Rogner H-H 2008 Nuclear Power: Benefits and Risks
[10] N.P.P.A. (NPPA) and WorleyParsons 2010 Egyptian Nuclear Power Plant Program History and Status p 18
[11] Arefiev N, Mihkalev M, Zotov D, Zotov K, Vatin N and Nikonova O 2015 Physical modeling of suspended sediment deposition in marine intakes of nuclear power plants Procedia engineering 117 pp 32–8
[12] Legkostupova V V and Sudakov A V 2015 Estimated and experimental research of separation part of SPP-500-1 MATEC Web of Conferences 23
[13] Malinina T and Murina V 2015 National policy in the area of spent fuel management in Russia Proceedings of the 8th International Scientific Symposium on Electrical Power Engineering, ELEKTROENERGETIKA pp. 425–6
[14] Davydov V V, Dudkin V I, Velichko E N and Karseev A Y 2015 Fiber-optic system for simulating
accidents in the cooling circuits of a nuclear power plant *J. Opt. Technol.* 82 pp 132–5

[15] Obraztsov E P, Belikov A N, Menshikov N N and Popkov E N 2016 Electrical calculation code relecs in css “veb” for npp designs 2 pp 1131–40

[16] Skvortsova O, Dashkina A, Petrovskaia E, Terleev V, Nikonorov A and Badenko V 2016 The Classification of Accidental Situations’ Scenarios on Hydropower Plants *MATEC Web of Conferences* 53

[17] A.M. Pankin and N. V Korovkin, Diagnostics Indicators in Monitoring the Technical State of Direct Charge Sensors in Nuclear Reactors, At. Energy 122 (2017), pp. 284–9

[18] Laaksonen J 2012 Profitable nuclear power generation *Nucl. Plant J.* 30 pp 32–7

[19] Kuznetsov Y N 2006 A simple & passively safe reactor *Nucl. Plant J.* 24 pp 36–7

[20] Kuznetsov Y N, Romenkov A A, Yarmolenko O A and Alekseev A I 2001 Prospects for the development of innovative simplified boiling-water reactor VK-300 *Nucl. Plant J.* 19 pp 31,33,35–36

[21] Gabaraev B A, Kuznetsov Y N, Moskin V A, Reshetov V A and Rylov I I 2002 Leasing of nuclear power plants *Nucl. Plant J.* 20 pp 37–40

[22] Oshkanov N 2005 Plant profile: Beloyarsk NPP, Russia *Nucl. Plant J.* 23 pp 48–50

[23] Agreement between Russian federation government and The Egyptian government for construction of Nuclear power plant in Egypt, 2015

[24] Shay S 2015 *The Egyptian Russian Nuclear Deal* (IDC Herzliya, Institute for Policy and Strategy, Lauder School of Government, Diplomacy and Strategy)

[25] Egypt’s Nuclear dream realized with Russian technology after 60 years delay. Available at http://www.dailynewsegpy.com/author/m-farag/