Opportunities and Challenges of Nuclear Energy Introduction in Bangladesh

A Research Project Submitted
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Abstract

The urgency of installation of nuclear power plant becomes conspicuous for mitigating the rising demand of electricity in Bangladesh. Nuclear energy can play a major role in large-scale production of electricity in safe. Presently, technology transfer and financing for NPP have great prospects due to the favorable change in international attitude. Though the public panic of the nuclear energy is a matter of concern, it can be assured that this method of electricity generation is no less safe than other methods. Thus, in addition to ensuring environmental and political safety, the nuclear power may turn into a source of safe energy, which will become one of the scarcest resources in near future. This article explores the opportunities and challenges of nuclear energy introduction and development in Bangladesh and also proposes some suggestions to pave the way of the development of this potential source of energy in the country.

Acknowledgements

First and foremost, all the praise is paid to the Almighty for keeping us alive and able, giving us the knowledge, ability to think and for helping us to successfully finish the report, with His inexhaustible kindness. We express our wholehearted deep gratitude and appreciation to the respected supervisor Dr. Mohammad Shawkat Akbar, Managing Director and Project Director, Rooppur Nuclear Power Plant. His exemplary guidance, constant encouragement and careful monitoring throughout the research are so great that our profound gratitude is not enough. experience which is extremely valuable for the research. Lastly, thanks and appreciation are also extended to honorable rector, director and other respected officials of Bangladesh Power Management Institute (BPMI) for providing us with the opportunity of performing our research on such an important topic and making necessary arrangements for carrying out the research successfully.

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Introduction

1.1 Introduction

Bangladesh emerged on the world map as a sovereign state on March 26 in 1971 Since the independence, the country has been planning and taking initiatives for its development. But the nation had to stand for too long in the line of Least Developed Countries (LDC). It was projected that Bangladesh will be requiring to maintain the economic growth of 7.4% annually in the 7th Five Year Plan (7FYP) for the period from 2016 to 2020 to initially reach the standard of medium income nations. In the year 2021, the GDP growth must be attained at about 9%. Despite the external and internal challenges, the economy of our country remained strong, resilient and maintained a GDP growth of 6.5% that expanded above 7.5% in 2017. To approach towards the achievement of SDGs in 2030 and to become developed Bangladesh in 2041, the GDP growth needs to be stable at about 8% or higher in the 8th Five Year Plan (8FYP) The country is confident that it is very much possible to materialize the first road of national development timely.

Development is a direct function of energy. It is the most important infrastructure for social and economic development. The energy use (total primary or final energy) has a distinct and categorical correlation with economic development (GDP and its growth). An increase in electricity consumption could raise investment and an increase in investment positively affects the GDP growth. Many studies conducted so far in case of a LDC or developing country have shown a strong relationship between energy input and economic growth. Energy usage is either the cause or the facilitator of economic growth. On the other hand, there is a direct relationship between Human Development Index (HDI) and energy consumption per capita. This relationship associates low energy consumption with low HDI and high energy consumption with high HDI. Moreover, per capita electricity generation of a country is considered as a secondary indicator to its economic development while per capita electricity consumption demonstrates its standard of living. The percentage of electricity consumers of a country is more significant than that of per capita electricity consumption.

1.2 Present Power Scenario in Bangladesh

Present installed capacity in public, private import sector is 18,961 MW as on June 2019. Out of this, public sector possesses 9,507 MW (50%), private sector 8,294 MW (44%) import 1,160 MW (6%). At present 94% (including renewable energy) of the total population has access to electricity and per capita generation has increased to 510 kWh including captive and renewable energy [1].

1.2.1 Generation Capacity

Total installed capacity was 18,961 MW which includes 6,503 MW IPP/SIPP, 1,540 MW Rental Power Plant, 251 MW under REB (for PBS) and 1,160 MW Power Import from India. The maximum peak generation was 12,893 MW which was 17.66% higher than that in the previous year [1]. The Generation Capacity mix is shown below:

Table 1.1: Fuel-wise generation capacity mixture in 2019

By type of plant		By type of fuel	
Hydro	230 MW (1.21%)	Hydro	230 MW (1.21%)
Steam Turbine	2,344 MW (12.36%)	Gas	230 MW (1.21%)
Gas Turbine	1,607 MW (8.48%)	Furnace Oil	4,770 MW (25.16%)
Combined Cycle	6,364 MW (33.56%)	Diesel	1,370 MW (7.23%)
Power Import	1,160 MW (6.12%)	Power Import	1,370 MW (7.23%)
Reciprocating Engine	1,160 MW (6.12%)	Coal	524 MW (2.76%)
Solar PV	30 MW (0.16%)	Solar PV	30 MW (0.16%)
Total	30 MW (0.16%)	Total	18,961 MW (100%)

1.2.2 Energy Generation

Total net energy generation in FY 2019 was 70,533 GWh, which was about 12.53% higher than previous year's net generation of 62,678 GWh. Net energy generation in the public sector was 35,107 GWh and 28,640 GWh in the private sector (including REB). Another 6,786 GWh was imported from India through the interconnection in Bheramara and Tripura [1]. Total net energy generated in public and private sector power plants by type of fuel are as follows:

Table 1.2: Fuel-wise energy generation in 2019

Type of Fuel	Energy Generation (Percentage)
Hydro	725 (1.03%)
Natural Gas	48,306 (68.49%)
Furnace Oil	11,426 (16.20%)
Diesel	2,022 (2.87%)
Coal	1,230 (1.74%)
Renewable energy	39 (0.05%)
Power Import	6,786 (9.62%)
Total	70,533 (GWh) (100%)

1.3 Power System Master Plan

The Power System Master Plan 2016 (PSMP-2016) of Bangladesh government forecasted peak demand of electricity with and without Energy Efficiency and Conservation (EEC) by “GDP elasticity method” and developed high, base and low case peak demand scenarios. It is seen that the maximum growth rate will be 10.2% in 2020 and gradually decreases. The demand of high, base and low case (with EEC) will be lower than high, base and low case demand of - without EEC. The PSMP- 2016 was updated in 2017. The forecasted peak demand in cases of the updated PSMP- 2016 high, base and low case scenarios are higher than the forecasted peak power demand of the original PSMP-2016. The PSMP-2016 (updated version) projected the demand of electricity for three scenarios aiming to fulfill the Vision 2021 and achieving goals of Sustainable Development 2030 and the Vision 2041.

Table 1.3: Forecasted peak demand in MW without EEC (PSMP 2016)

Year	Peak Demand in MW		
	High	Base	Low
2020	17015	15809	14757
2021	19034	18023	16823
2025	28231	26731	24952
2030	41890	39663	37024
2035	59275	56125	52389
2040	78118	73607	68708
2041	82292	77540	72379

For energy resource constrained Bangladesh, expansion of future power system is a serious challenge. The declining feature of indigenous gas reserves, socio-economic difficulties in expanding the domestic mining of coal, almost negligible resource of crude and limited renewable potential are the major barriers in the development of the power sector of the country. For sustainable development of the power sector, Bangladesh needs to derive an optimal fuel mix over mid/long term time horizons. A diversified fuel mix that maximizes the respective advantages of different types of power sources is crucial for energy security of Bangladesh.

Considering all aspects, Bangladesh adopted a comprehensive power sector development road map. This road map has classified three timeline: (1) Short Term (up to 2020), (2) Short- to Medium-Term (up to 2025) and Medium- to Very Long-term (up to 2041). To implement the road map, the updated PSMP-2016 forecasted fuel mix in total net generation capacity for the High Case, Base Case and Low Case scenarios.

Table 1.4: Year-wise fuel mix in percentage in low case scenario (PSMP 2016)

	2021	2025	2030	2035	2041
Gas	52.6	47.4	44.6	43.5	43
Coal	10.9	24.8	33.7	37	32
Liquid Fuel	29.9	16.9	10.5	2.5	2.3
Import	5.7	7.5	6.6	11.5	15.1
Nuclear	0	2.8	4.2	5	7
Others	0.9	0.6	0.4	0.5	0.4
Total	100	100	100	100	100

Table 1.5: Year-wise fuel mix in percentage in High case scenario (PSMP 2016)

	2021	2025	2030	2035	2041
Gas	46	42	37	39	43
Coal	17	31	39.5	39	32
Liquid Fuel	31	17	10	3	2
Import	5	7	10	12	15
Nuclear	0	2	3	6	7
Others	1	1	1	0.4	0.4
Total	100	100	100	100	100

The domestic gas is likely to be depleted by 2027, all gas-based power plants thereafter needed to be operated with LNG (imported gas), which is the most expensive option. The current LNG price is about 10 times higher than that of Bangladesh's domestically produced and marketed gas. However, the generation capacity based on gas/LNG dominates the generation capacity in both the scenarios. The coal is the second dominating fuel for capacity development during the entire projected period. The technology mix in the updated PSMP-2016 scenario is driven mainly by the share of gas/LNG and coal. Bangladesh needs to strategize its power supply, which would reduce the energy security threat and, at the same time, supply reasonable clean electricity, keep power supply cost low and balance the investment and foreign exchange availability between the power sector and the rest of the economy.

The power development portfolio of Bangladesh will be consisting of well-balanced proportions of gas/CNG and coal, enhanced nuclear capacity development and electricity import and reasonable combination of liquid fuel and renewables, that will bring significant economic gains as well as energy security benefits through supply source diversification.

1.4 Necessity of Nuclear Power

Energy resources such as fossil fuels including coal, oil and natural gas are depletable resources. Their actual future availability depends on a variety of constraints: rising exploration, production and marketing costs, diminishing energy ratios, excessive environmental burdens. As energy demand rises, global societies need to utilize these energy resources properly and development of technology is required to harness them.

The first electricity generating plants were fueled by coal. Coal is the principal sources of energy for electricity generation during first half of the twentieth century. Modern society has been made possible due to the coal based power generation. The low price of coal makes it still irreplaceable fuel for developing countries, where around 1.5 billion people still don't have uninterrupted access to modern forms of energy. Recently, the growth in the consumption of coal across the globe is decreasing as a result of tougher environmental requirements in developed countries.

The oil had provided an alternative fuel for energy production. It had become an indispensable energy source from the middle of 1900s and still is the main energy source. It is expected that oil will remain the fuel with the largest share in the energy mix, nearly 28% in 2040, higher than gas and coal.

The large scale development of gas field and the development of transportation technologies has enabled natural gas to make revolutionary changes in the global fuel market for production of electricity and thermal energy over the last 50 years. Another major consumer of this energy resource is the transport sector. Natural gas continues to maintain its competitiveness in the long term.

The third source is the nuclear energy, which came about as recent as sixty years ago. Although Nuclear power has a concern of spent fuel management yet it is clean, because it does not contribute to greenhouse gas (GHG) emission that is responsible for global warming. The fourth and new sources of energy are renewable energy like wind and solar in which wind have become commercially viable and technologically feasible. Nuclear power supplies a large amount of the world's electricity needs. The efficiency of nuclear power is well-documented. For example, 1 kg of U-235 has been shown to be able to produce more than 24 million kWh worth of electricity [2]. By comparison, a wholly combustive or fission-based process yields 8 kWh worth of heat via conversion from 1 kg of coal. The same amount of mineral oil conversion results in 12 kWh [3].

The usage of fossil fuels was prerequisites for the modern civilization. Due to over dependence on the fossil fuels, these energy sources are depleting gradually. Any excessive extraction of fossil fuels will further deplete the stock and demand growth will lead to the exhaustion of remaining supplies because coal, oil, and natural gas cannot replenish themselves. It is also unfortunate that the climate system of the earth is changing due to increasing concentrations of greenhouse gases especially carbon di oxide, resulting from emissions mainly from burning of fossil fuels.

The greatest challenge to the humanity is the challenge of climate change due to the effect of anthropogenic GHG emissions. Over the last 20 years, the volume of global consumption-related emissions has increased from 21.5 to 31.5 billion tonnes of CO2, which means a per capita rise from 4.1 to 4.6 tonnes. About two-thirds of the global GHG emissions are related to the production and consumption of fossil fuels. The consequences of elevated GHG concentrations is leading to increase temperature and increasing sea levels, endangering humankind and the environment, disrupting ecosystems and inundating many low-altitude regions of the world. Human induced contribution to the observed increase of average global surface temperature between 1951 and 2010 is estimated at 0.5-1.3 degree Celsius. The average global surface temperature increase is likely to exceed 1.5 degree Celsius by the end of this century. Recent studies indicated that a three foot rise in sea level would submerge almost 20 percent of Bangladesh and displace more than 30 million people of the country.

At present, the rising global energy demand, coupled with limited resources and the increasing threat of climate change due to production and consumption of fossil fuels, means that energy has become a central concern that cuts across all sectors of society. We need to realize that the energy sources of yesterday are simply not going to work tomorrow. The NPP can generate low cost electricity for modern society's demand for dependable and affordable electricity. Nuclear energy can play an important role in supplying clean, reliable electricity that is delivered 24/7, so that people can meet their needs and aspirations without harming the environment. Nuclear energy currently produces around 11% of the world's power from about 450 power reactors, all of which is classified as "low-carbon energy." Nuclear plants are expensive to build but once it is constructed, the production cost of electricity is low and predictably stable. The clean and cheap energy of nuclear should be a goal of every country, especially in a future where energy demand is expected to rise.

1.5 Nuclear Energy Development in Bangladesh

Around 10% of the world's electricity is generated by about 440 nuclear power reactors. About 50 more reactors are under construction, equivalent to approximately 15% of existing capacity [4]. In 2018 nuclear plants supplied 2563 TWh of electricity, up from 2503 TWh in 2017. This is the sixth consecutive year that global nuclear generation has risen, with output 217 TWh higher than in 2012[4].

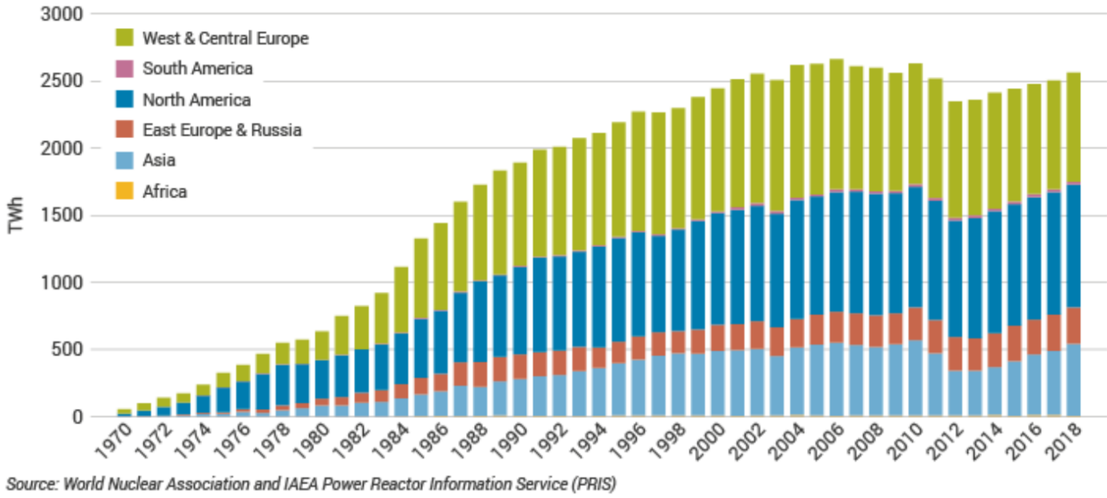

Figure 1.1: Worldwide nuclear energy generation with the passage of time

Twelve countries in 2018 produced at least one-quarter of their electricity from nuclear. France gets around three-quarters of its electricity from nuclear energy, Hungary, Slovakia and Ukraine get more than half from nuclear, whilst Belgium, Sweden, Slovenia, Bulgaria, Switzerland, Finland and Czech Republic get one-third or more. South Korea normally gets more than 30% of its electricity from nuclear, while in the USA, UK, Spain, Romania and Russia about one-fifth of electricity is from nuclear. Japan is used to relying on nuclear power for more than one-quarter of its electricity and is expected to return to somewhere near that level [4].

Bangladesh is getting experiences in the shortage of supply of gas. The commercial and industrial sectors are also strongly dependent on indigenous natural gas. Due to over dependence to this valuable, the gas production has increased drastically. The country's indigenous natural gas resources is limited and the country has been able to explore and add very little to the natural gas reserves in the last decade. The recoverable proven reserve is 20.9 TCF, of which more than 15.94 TCF had already been produced

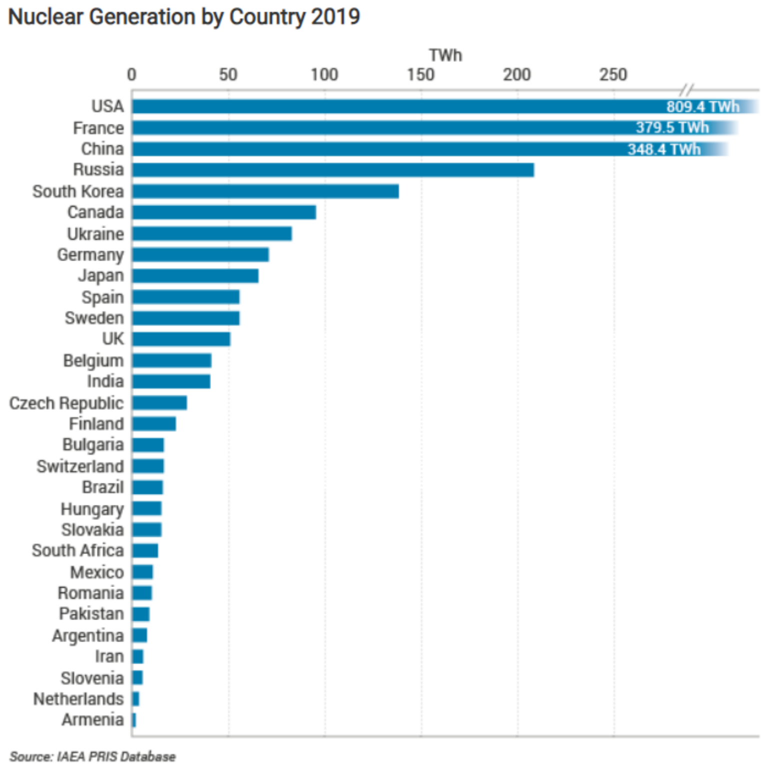

Figure 1.2: Country-wise nuclear energy generation in 2019

and consumed as of 1st July, 2018. Considering the proven and probable reserve, the total reserve of gas is 27.81 TCF (Petrobangla). On the other hand, the liquid fuel is controlled by major oil exporters. Many powerful countries are looking for long-term solutions to increase energy security by reducing dependence on foreign oil import. The country has significant reserve of coal. Among 3565 million tons (MT) of coal reserves about 1700 MT are maximum extractable so far considering 50% recovery, although the rest of the coal may not be viable for extraction because of its depth beneath the Earth's surface. About 50% of the recoverable reserves could supply coal for generation of 10,000 MW over 30 years. The nation needs to make a clear plan to use domestic coal reserve. Renewable energy is still playing an insignificant role.

Like other developing countries, Bangladesh is moving towards coal and this fuel is expected to become the major fuel for power generation in future. The government is encouraging coal based projects for mitigating looming electricity shortage and to reduce dependency on gas based expensive fuel oil based plants. The updated PSMP-2016 has a highly ambitious target of imported coal. The level of dependence on imported coal is risky, not only from the cost perspective but also from the availability perspective. Moreover, the coalfired power stations in Southern Asia surrounding Bangladesh are also increasing rapidly. As a result, the supply, the quality and the price of imported coal will become very unstable in the future. In addition, huge coal supply infrastructure has to be established. This huge amount of coal import requires huge involvement of timely construction of required deep ports, coal-receiving facilities, transportation infrastructure and also coal purchase contracts. There are also chances of supply chain getting disrupted from regional and global geo politics. Bangladesh requires further evaluation of externalities of coal-based electricity generation and long-term macro-economic implications for making a firm decision for the long-term coal based power generation.

Under these circumstances, nuclear energy is an attractive strategic option for the Bangladesh. With low levels of life-cycle GHG emissions, nuclear power contributes to emissions reduction today and potentially in the future. On the other hand, the fuel and operating costs of nuclear power generation are low compared to other base load power stations. Nuclear power plants deliver electricity 24 hours a day and 7 days a week (24/7), irrespective of weather and seasons Thus, Bangladesh has undertaken serious initiatives to commence NPPs to mitigate the ever-surging power demands. Though

Bangladesh is an agricultural country, it has undergone significant industrialization in the past two decades. The proportion of heavy industries' contribution to the gross domestic product (GDP) bears the testimony in this regard. Thus, it is hardly surprising that Bangladesh's policy makers have connected the increase of power generation to the rise of gross domestic product (GDP) growth [**?**].

Rooppur (located in Pabna district), is a joint collaborative effort with Russia's State based Nuclear Energy Corporation (ROSATOM). In May 2010, an intergovernmental understanding was marked with Russia, giving a lawful premise to atomic participation in territories, for example, siting, outline, development and operation of energy and research in atomic reactors, water desalination plants, and basic molecule enrichment agents [5]. Thus, the journey to produce the nuclear power energy has already begun. It is imperative that without a strong nuclear safety regulatory framework, it would not be possible for Bangladesh to ensure safe nuclear energy production. As with most ventures, Bangladesh's foray into the nuclear energy realm is a double-edged sword [6]. Nuclear energy surely can be a prospective medium of energy source to meet the massive energy demand in Bangladesh, however, for that, the government of Bangladesh must equip themselves with all the necessary tools before going to harness the benefit of such technology

Nuclear energy is considered to be the most dangerous process in the production of energy and that how a developing and densely populated country such as Bangladesh takes the initiatives to address the challenges should be revealed. The most important question is whether Bangladesh can survive any NPP disaster such as the Chernobyl disaster (occurred in the former Soviet Union, now in Ukraine) and the very recent Fukushima (Japan) disaster, when Bangladesh is already vulnerable to natural calamities. Japan took immediate action after the occurrence of the Fukushima disaster. However, the economic consequences and socio-political impact of the disaster seriously affected the public attitude towards nuclear power.

One of the basic purposes of present fervor for Bangladesh will be the planning and availability of qualified staff to meet the staggering necessities of the procedure and broadening program. Regardless, the path chosen to develop qualified human resources and personnel needs to consolidate each of the issues that impact human resource training; for instance, activity, organization structures, working society, atomic data organization, and individual perspectives [7]. In particular, for Bangladesh, it is rudimentary that a productive nuclear power program requires an extensive system.

Chapter 2

Overview of Rooppur Nuclear Power Plant

2.1 Nuclear Power Technology

Nuclear energy is the abundant source of heat energy which can be transferred into many useful form of energy like Electrical energy or Electricity. The heart of nuclear energy Uranium was discovered in 1789 by Martin Klaproth, a German chemist, and named after the planet Uranus. Nuclear provides about 6% of the world's energy and 13–14% of the world's electricity. U.S., France and Japan together account for about 50% in nuclear generated electricity. The IAEA (International Atomic Energy Agency) re-ported there were 439 nuclear power reactors in operation in the world. These nuclear power reactors are operating in 31 countries. The safety record of nuclear power is good when compared with many other energy technologies. Research into safety improvements is continuing. Besides this there are also some major accidents in Nu-clear Power plants. The Chernobyl disaster was a nuclear accident that occurred on 26 April 1986 at the Chernobyl Nuclear Power Plant in Ukraine (officially Ukrainian SSR), which was under the direct jurisdiction of the central Moscow's authorities. A proposed site for the first nuclear power plant in Bangladesh, was selected in a remote village called Ruppur in Pabna district in the western zone of Bangladesh near the state of West Bengal in India. The site at Ruppur, downstream of the Hardinge Bridge over the Ganges (Padma), was thus a natural choice for a nuclear power plant. After receiving the Positive response of IAEA, Bangladesh Government decided the Ruppur power plant on its own concept. At last 24th February, 2011 Bangladesh government signed a primary deal with Russia for installing a 2000 MW nuclear power plant at Ruppur in Pabna. By signing the deal, the government launched country's first Nuclear Power Plant project (NPP) which would be completed in 2017-18 at the cost of US$ 1.5 to 2 billion. A nuclear power plant or nuclear power station is a thermal power station in which the heat source is a nuclear reactor. As is typical in all conventional thermal power stations the heat is used to generate steam which drives a steam turbine connected to an electric generator which produces electricity. As of 23 April 2014, the IAEA report there are 449 nuclear power reactors in operation operating in 31 countries. Nuclear power stations are usually considered to be base load stations, since fuel is a small part of the cost of production. Their operations and maintenance (OM) and fuel costs are, along with hydropower stations, at the low end of the spectrum and make them suitable as base-load power suppliers. The cost of spent fuel management, however, is somewhat uncertain. Currently, approximately 17% of electricity worldwide is produced by nuclear power plants, but in some countries, like France, over 75% of their electricity is produced by nuclear power (How Stuff Works). The United States, on the other hand, only produces about 15% of the electricity from nuclear power.

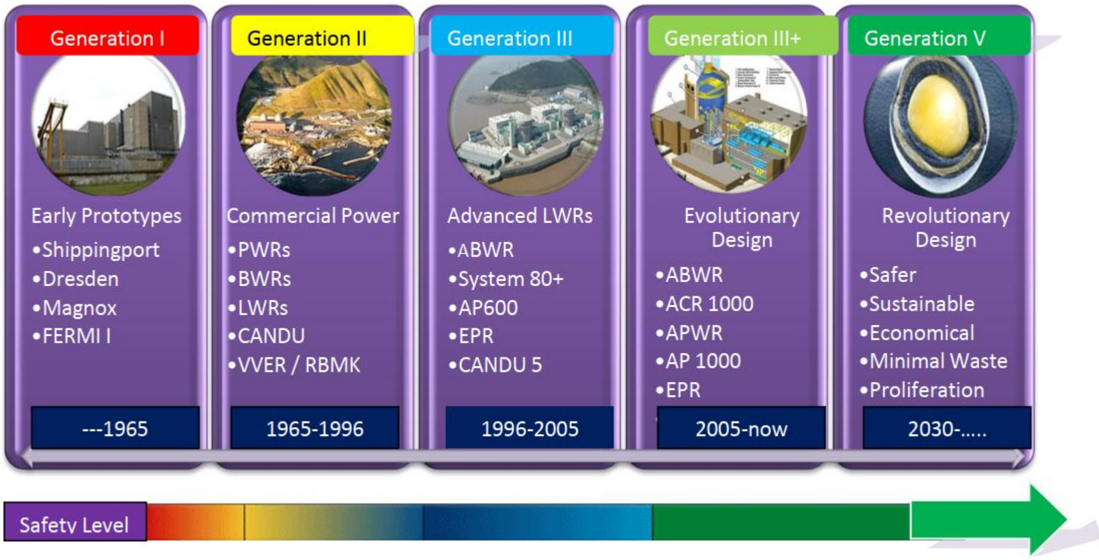

Figure 2.1: Nuclear power plant technologies on the basis of generation

2.1.1 Reactor Core and Fuel Design

The reactor cores contain 163 fuel assemblies (FA). The FAs are intended for heat generation and its transfer from the fuel rod surface to coolant during the design service life without exceeding the permissible design limits of fuel rod damage. The FAs are 4570 mm high (nominal value). When the reactor is in the hot state the height of the power generating part of the fuel rod is 3750 mm. Each FA contains 312 fuel rods. The FA skeleton is assembled of 18 guide channels, 13 spacer grids welded to them, an instrumentation channel and a support grid. The fuel rod cladding is a zirconium alloy tube. Sintered UO2 pellets with a 5% (4.95±0.05) maximum enrichment are stacked inside the cladding. The average linear heat rate of a fuel rod is 167.8 W/cm.

Normally Nuclear power plants use pellets to fuel the plants. A pellet contains approximately 3% U-235 that is encased in a ceramic matrix. 1.1 The pellets are aligned in linear arrays (fuel rods) that are interspersed with moveable control rods. The control rods act to dampen (or to stop) the nuclear reactions so that the nuclear reactions do not get out of control or to service the reactor (i.e. fuel rod change outs). The whole assembly (reactor core) is submerged in water to help keep the core cool. A power plant similar to Comanche Peak (photo above), might have as many as 13 million pellets in the reactor at a time, and they stay there for 3 to 4 years. To optimize power production, between one third and a quarter of the fuel rods are changed out every 12 to 18 months.

2.1.2 Reactor Coolant System Analysis

The reactor coolant system removes the heat from the reactor core by coolant circulation in a closed circuit and provides heat transfer to the secondary side. The reactor coolant system comprises a reactor, a pressurizer and four circulation loops, each one comprising a steam generator, reactor coolant pump set and main coolant pipelines that provide the loop equipment-to-reactor connection. The reactor vessel is housed first in a radiation shield liner and then in a containment structure. This double walled design is to make certain that communities are safe from radiation leaks (unlike old Soviet style reactors). Containment structures (the large domes in the photo from Comanche Peak) are designed to withstand the impact of a large passenger planes and other possible major accidents/attacks.

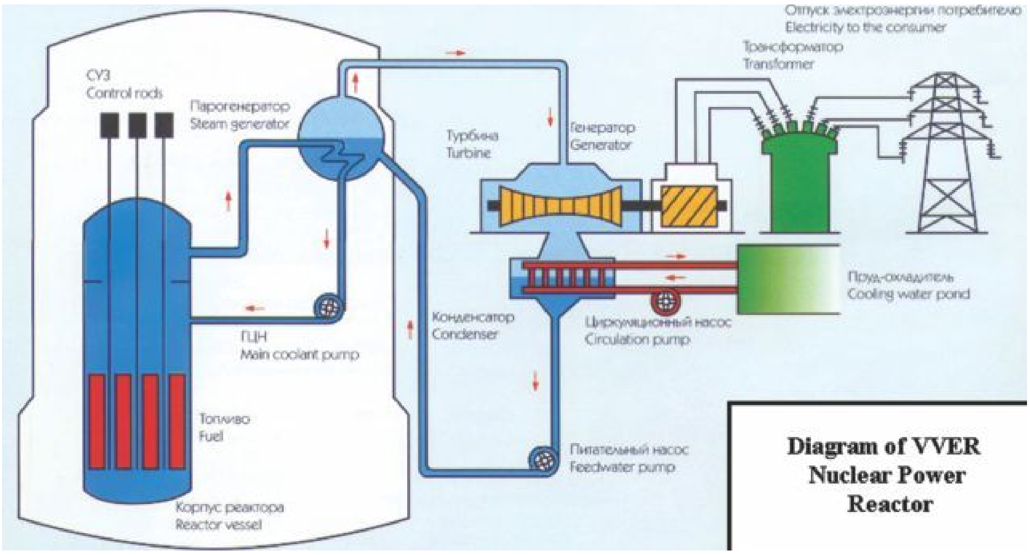

Figure 2.2: Diagram of VVER nuclear power reactor.

2.1.3 Power Plant Safety Waste Management

The VVER-1200 (AES-2006) plant was designed to meet the Russian general safety requirements issued in 1997, which were consistent with the IAEA's International Nuclear Safety Group (INSAG) recommendations. Thus all new VVER-1200 plants under construction already have design features that take fully into account the main "Fukushima lessons learned", including: long term cooling of reactor core without electrical power, long term decay heat removal that does not rely on primary ultimate heat sink, protection of reactor containment integrity with dedicated systems after a core meltdown accident, the inherent-safety principle, that is, the ability of the reactor to ensure safety based on natural, feedback processes and characteristics and defense in depth principle, that is, use of successive barriers preventing the release of ionizing.

Provision of Fundamental Safety Functions

Reliable provision of the three fundamental safety functions has been the leading principle in the design of VVER-1200(AES-2006) plants.

Control of Reactivity

All VVER-1200 reactors have a unique safety features, when compared with other PWR types or older VVERs: if the control rods are inserted into the core the reactor will stay in shutdown state even at low temperature over the long term.

Decay Heat Removal

In the VVER-1200, decay heat can be removed in three different ways Firstly, by active systems to the main ultimate heat sink or to a separate dedicated "spray pond". Secondly, by active systems to atmosphere (feed and bleed from steam generators). Finally, by passive systems to atmosphere. On the other hand, passive decay heat removal is an important advanced feature for ensuring safety of the VVER-1200.

Containment of Radioactive Material

Ensuring VVER-1200 containment integrity in the event of these circumstances is based on systems that are completely independent and separated from the systems that are intended to prevent severe core reactor damage. Containment overpressure is prevented by the Containment Passive Heat Removal System (CPHRS).

2.2 History Of Nuclear Power Program in Bangladesh

1961

Initiative to build a Nuclear Power Plant

1962-68

Rooppur, a site in Ishwardi, Pabna district was selected as the site for the country's first NPP project. 260 acres of land for the plant and 32 acres of land for residential area were acquired and developed. During this period site office, rest house, electric sub-station and few residential unit were completed.

1969-71

The then Pakistan Government gave up the plan of that 200 MW capacity unclear power plant.

1972-75

The Prime Minister of independent Bangladesh and Father of the Nation Bangabandhu Sheikh Mujibur Rahman took the initiative to build a 200 MW nuclear power plant.

1976-86

The implementation of the nuclear power project at Rooppur was considered logical through a feasibility study conducted by Messrs. Sofratum. ECNEC approves a project to build a nuclear power plant (125 MW). But the project was not implemented due to various limitations.

1986-88

A second feasibility study was conducted by two companies in Germany and Switzerland. The financial and technical rationale of the project was re-established through the said study. The study recommended setting up a 300-500 MW nuclear power plant.

1997-2000

The then chairman of the Bangladesh Atomic Energy Commission. Initiative was taken by MA Wazed Mia to implement the Rooppur Nuclear Power Project with a capacity of 600 MW. At this time some preparatory activities including human resource development were taken. Bangladesh Nuclear Power Action Plan-2000 was approved by the government.

2007-08

A commitment was made for the implementation of Rooppur NPP project by all the leading political parties of Bangladesh in their Election Manifestoes of the National Parliamentary Election of 2008. Under a development program tilled as 'Accomplishment of Essential Activities for the Implementation of Rooppur Nuclear Power plant (RNPP) Project' step was taken to perform the primary preparatory works and development of nuclear infrastructures. 2009 :A MOU was signed on 13 May 2009 between BAEC and ROSATOM, the State Atomic Energy Corporation, Russian Federation. A high-level decision making team, led by the State Minister, Ministry of Science and

Technology visited Russian Federation in October 2009 to get realistic ideas on implementation, funding, administration and organization structure of the NPP project.

2010

A Framework Agreement on cooperation in using nuclear energy for peaceful purposes was signed on 21 May 2010 between Bangladesh and Russian Federation The Nuclear Energy Program Implementing Organization (NEPIO) was formed in the form of high level governmental committee. The National parliament of Bangladesh adopted a decision on 10 November 2010 for immediate implementation of nuclear power project. Hon'ble DG of IAEA, Mr. Yukiya Amano visited Bangladesh on December 2010 and assured his support for implementation of Rooppur NPP project. A National Committee on Rooppur NPP' under the leadership of the Hon'ble Prime Minister was formed to provide directives for proper implementation of the Rooppur NPP project and establishment of national nuclear power infrastructure. A Technical Committee headed by the Hon'ble Minister, Ministry of Science and Technology; A Working group headed by the Secretary, Ministry of Science and Technology; and Eight Sub-Working Groups were formed to monitor, coordinate and address the conditions of specific infrastructure issues according to the IAEA guidelines and to support the National Committee in establishing Roopur NPP.

2011

The 1st Meeting of the National Committee on Rooppur NPP I leaded by the honorable Prime Minister was held on 2 March 2011 and decision on implementation of Rooppur

NPP project under government ownership was taken. IAEA preparatory Mission for site Evaluation visited Rooppur NPP site on 10-14 July 2011 and Bangladesh and the Government of the Russian Federation on cooperation concerning the construction of Rooppur NPP signed on 2 November 2011. The IGA appointed BAEC as the Customer and JSC Atomstroyexport as the Contractor of Rooppur NPP. The INIR mission of the IAEA conducted a visit from 9-15 November 2011 to review and provide recommendations for the national nuclear power infrastructure focusing on the Phase-I and Phase-II activities of the IAEA Milestone documents.

2012

An Inter Agency Agreement between the Russian nuclear regulatory body Rostechnadzor and Ministry of Science and Technology. Bangladesh signed on 27 February 2012. An integrated work plan for 2012-15 was development in May 2012. The 2nd Meeting of the National Committee on Rooppur NPP Headed by the Hon'ble Prime Minister held on 14 June 2012; a decision on implementation approach, funding financing mechanism of Rooppur NPP Project was taken. Bangladesh Atomic Energy Regulatory Act, 2012 was passed in the National Parliament on 19 June 2012.

2013

An Intergovernmental Credit agreement was signed between Bangladesh and Russian Federation on 15 January 2013 with the provision of a $500 million Russian credit loan for financing the preparatory phase activities of Rooppur NPP. An independent nuclear regulatory authority. ""Bangladesh Atomic Energy Regulatory Authority"" was formed on 12 February 2013. Construction of Rooppur NPP (First Phase)' project was approved on 2 April 2013 for preparatory stage construction activities of Rooppur NPP. BAEC and JSC Atomstroy export signed the First Contract on the Feasibility Evaluation, Site Engineering Survey, Environmental studies and Environmental Impact Assessment of Rooppur NPP on 27 June 2013. The 3rd meeting of the national committee was held on 7 August 2013, a decision for acquiring of additional 800 acres land was taken. Nuclear Industry Information Centre inaugurated at Bangabandhu Sheikh Mujibur Rahman Novo theatre campus on 1st October 2013 to provide information on atomic energy to the general people. Honorable Prime Minister of Bangladesh Sheikh Hasina laid the foundation stone for the Construction of Rooppur NPP (1st Phase) Project on 2 October 2013. Second contract between BAEC and JSC Atomstroy export to develop the design documentation, first priority working documentation and necessary engineering survey was signed on 2 October 2013. 2014: Bangladesh Atomic Energy Commission and JSC Atomstroy export signed the Third Contract 'Performance of First Priority Works for the Preparatory Stage of Rooppur NPP Construction' on 5 June 2014. The First meeting of joint Coordination Committee (JCC) under the IGA between the governments of the Russian Federation and Bangladesh held on 22-23 July 2014 in Moscow; decisions to start consultations for signing General Contract for Rooppur NPP Construction and Inter Governmental Credit Agreement were taken.

2015

A Company named 'Nuclear Power Plant Company Bangladesh Limited (NPCBL)' was formed on 18 August 2015 to establish and operate nuclear power Plants in Bangladesh including Rooppur NPP. The Company started functioning through its first board meeting on 23 August 2015. Nuclear Power Plant Act, 2015 was passed in the National Parliament on 16 September 2015 creating provision to set up Nuclear Power Plant Company Bangladesh Limited as the operating organization of NPPS including Rooppur NPP. Bangladesh Atomic Energy Commission and JSC Atomstriyexport signed General Contract for Rooppur NPP Construction on 25 December 2015.

2016

The 4th Meeting of the National Committee held on 3 February 2016, decisions for establishing physical protection system of Rooppur NPP, communication system, transportation infrastructure were taken. IAEA conducted a follow-up INIR mission in Bangladesh during 10-14 May 2016 to assess the progress and assist in prioritizing further infrastructure development activities based on recommendations and suggestions provided by the IN IR mission in 2011. Bangladesh Atomic Energy Regulatory Authority issued Siting License of Rooppur NPP on 21 June 2016. Bangladesh and Russian government signed the Intergovernmental Credit Agreement for the construction of the Rooppur on 26 July 2016. The Executive Committee of the National Economic Council (ECNEC) approved 'Construction of Rooppur NPP' Project NPP on 6 December 2016.

Figure 2.3: Proposed Rooppur nuclear power plant

2017

Agreement between the Russian Federation and Bangladesh on 'Cooperation Concerning Return of Spent Nuclear Fuel from Rooppur Nuclear Power Plant to Russian Federation' was signed on 15 March 2017. An inter-governmental agreement between the Government of the People's Republic of Bangladesh and the Government of the Republic of India on 'Cooperation in the Peaceful Use of Nuclear Energy' and an Inter-Agency Agreement between Global Centre for Nuclear Energy Partnership (GCNEP), Department of Atomic Energy of the Government of India and Bangladesh Atomic Energy Commission (BAEC) on 'Cooperation Regarding Nuclear Power Plant Projects in Bangladesh' was signed on April 08 2017. Hon'ble Prime Minister H.E. Sheikh Hasina addressed the opening session of 'Conference on the IAEA Technical Cooperation Program: 60 years and Beyond-Contributing to Development' on 30 May 2017 in Vienna, Austria.

Director General of the International Atomic Energy Agency (IAEA) H.E. Mr. Yukiya Amano paid a visit to the site of the Rooppur NPP project on 03 July 2017. Mr. Yukiya Amano expressed his satisfaction over compliance in implementing Rooppur NPP Project adding that Bangladesh is constructing the plant considering high standard of security measures. Agreement between the Government of the Russian Federation and the Government of the People's Republic of Bangladesh on 'Cooperation Concerning Return of Spent Nuclear Fuel from Rooppur Nuclear Power Plant to Russian Federation' was signed on 30 August 2017. Design and Construction License for Rooppur NPP was issued by BAERA in favour of BAEC on 4 November 2017. Nuclear Security and Physical Protection System Cell (NSPC) has been formed under the supervision of Bangladesh Army for security and physical protection system In line with the construction of Rooppur Nuclear Power Plant, with the formulation of necessary design documentation for preparing Nuclear Security and Physical Protection System Cell (NSPC) has been formed under the supervision of Bangladesh Army for security and physical protection system. First concrete pouring of first unit of Rooppur Nuclear Power Plant was done by the Honorable Prime Minister of Bangladesh H.E. Sheikh Hasina on 30 November 2017. With the first concrete pouring of Rooppur Nuclear Power Plant Bangladesh has entered into the World Nuclear Club and its dignity as a country has been elevated to a unique height.

Figure 2.4: Visit of IAEA Director to the site of the Rooppur NPP project

2018

In light of the Inter-Government Agreement (IGA) signed between Bangladesh and India for appointment of specialist advisors for construction of Rooppur nuclear power project, the Addendum which has been signed between Bangladesh Atomic Energy Commission (BAEC) and Global Center for Nuclear Energy Partnership (GCNEP) an agency of Indian Department of Atomic Energy of the 5th of January 2018 has been approved by the Government. Under the Inter-Government Agreement (IGA) the Joint Co-ordination Committee (JCC) formed with the co-operation of Bangladesh and Russian Federation, Took place its 3rd meeting on 6 March 2018 Russia. Several crucial decisions were taken at that meeting for operation and maintenance of Nuclear Power Plant. Design and Construction License for the second unit of Rooppur Nuclear Power Plant was issue by Bangladesh Atomic Energy Regulatory on 8 July 2018.

2020

When the COVID-19 pandemic struck Bangladesh in early 2020, many projects such as the Dhaka Metro Rail were stalled, but the Rooppur Nuclear Power Plant remained on track to be completed by 2023. Progress in this period includes Rosatom's engineering company Atommash completing hydraulic tests for Rooppur unit 1.

2.3 Feasibility Study for NPP

Bangladesh is densely populated country with a population of 16 core and small area about 1, 47,570 Square-Kilometer. Among these large population only a few section are taking the blessings of power. But now at a stage government can't give the power even to that special section. Because day by day population is increasing and also power demands is also increasing. Governments are trying to meet up the power crisis in Bangladesh by taking various steps. Like small (10-20MW) power plants, IPP, Rental power plant etc. But these are not a permanent solution. More over these rental and IPP are mainly oil and gas based, which are very costly and not very efficient. Besides these government are going with coal based power station and small scale renewable energy. But coal based power station are required very large space, its initial cost is high and create serious environmental threat. Renewable energy is not yet developed and its ef- ficiency is very poor. Though there are many problems and threats but Nuclear Power Plant can be a permanent solution for Bangladesh. Bangladesh government is now going for nuclear power plant and recently they have taken a project called Rooppur Nuclear Power Plant Project (RNPP) which is already approved in the cabinet meeting.

The heart of nuclear energy Uranium was discovered in 1789 by Martin Klaproth, a German chemist, and named after the planet Uranus. The science of atomic radiation, atomic change and nuclear fission was developed from 1895 to 1945, much of it in the last six of those years. Over 1939-45, most development was focused on the atomic bomb. From 1945 attention was given to harnessing this energy in a controlled fashion for naval propulsion and for making electricity. Since 1956 the prime focus has been on the technological evolution of reliable nuclear power plants. Nuclear provides about 6% of the world's energy and 13–14% of the world's electricity. U.S., France and Japan together account for about 50% in nuclear generated electricity. The IAEA re-ported there were 439 nuclear power reactors in operation in the world. These nuclear power reactors are operating in 31 countries. On June 27, 1954, the USSR's Obninsk Nuclear Power Plant became the world's first nuclear power plant to generate electricity for a power grid, and produced around 5 megawatts of electric power. The world's first commercial nuclear power station, Calder Hall in Sellafield, England was opened in 1956 with an initial capacity of 50 MW (later 200MW). The safety record of nuclear power is good when compared with many other energy technologies. Research into safety improvements is continuing. Besides this there are also some major accidents in Nu- clear Power plants. The Chernobyl disaster was a nuclear accident that occurred on 26 April 1986 at the Chernobyl Nuclear Power Plant in Ukraine (officially Ukrainian SSR), which was under the direct jurisdiction of the central Moscow's authorities.

An explosion and fire released large quantities of radioactive contamination into the atmosphere, which spread over much of Western USSR and Europe. It is considered the worst nuclear power plant accident in history, and is one of only two classified as a level 7 event on the International Nuclear Event Scale. The Fukushima Daiichi nuclear disaster is a series of equipment failures, nuclear meltdowns, and releases of radioactive materials at the Fukushima I Nu- clear Power Plant, following the Tohoku earthquake and tsunami on 11 March 2011. Fukushima disaster is the largest of the 2011 Japanese nuclear accidents and is the largest nuclear accident since the 1986 Chernobyl disaster, but it is more complex as multiple reactors and spent fuel pools are involved. The Three Mile Island accident (1979) the most significant accident in the history of the USA commercial nuclear power generating industry, resulting in the release of approximately 2.5 million curies of radioactive gases, and approximately 15 curies of iodine-131. Though there are some disadvantages but Bangladesh can be greatly benefited by establishing RNPP to meet up their recent power crisis with some consideration.

2.4 Safety and Security Consideration for RNPP

To establish the nuclear power plant in Bangladesh safety and security is a major consideration from the view of its small (1, 47,570Sqr-Km) densely populated and geographical area, proper site selection, Water management, natural disaster etc. The first and major consideration to set a RNPP is the area and density of the people. According to the international law the radius of the area of nuclear power station is 30Km.The area is divided in to three circular zone with 3.14(30)2=2,826 Sqr Km area. According to the zone, zone-1 is reactor area, zone-2 is security area and zone-3 is for planning disaster. The area of zone-1 is a circular area of 3.14 Sqr Km. This area is only for the people who are working with reactors, others entrance is strictly prohibited. The distance of zone-2 is 5 Km away from the center and the total area of is 3.14 (5)2=78.5Sqr Km. This area is prohibited for agriculture and industries and only 3 people can leave per Sqr. Km that is the total people of that zone will be only 200.The distance of zone-3 is 30 Km from the center. This 30 Km area must be free of population. If there are more people than there will be obstacles for rescuing the people. Developed countries nuclear power stations are free of population. This is for those reactors among 30Km is free from population. For example if there is an explosion in RNPP like Three Miles Island than people leaving there must be transferred 3.14(40)2=5024 Sqr Km area. So if 1000 people leave per Sqr Km then almost 1000000 people must me transferred from that area. It is quiet impossible. But the problem can be solved through changing some regulation. According to the international law some changes is applicable depending the situation. For example India has changed some regulation to build their nuclear power plant. The have changed the zonal area. The do this be- cause they have the same problem of large population like Bangladesh. But there is a considerable think that as per there total country area the population is to very big. Therefore Bangladesh can their policy can be a little bit safe.

The second major problem is earthquake and natural disaster. From the experience of Fukushima Daiichi NuClear Power plant in Japan 9.0 MW earthquake occurred at

14:46 JST on Friday, 11 March 2011 with epicenter near the island of Honshu. It resulted in maximum ground accelerations of 0.56, 0.52, 0.56 g (5.50, 5.07 and 5.48 m/s2) at Units 2, 3 and 5 respectively, above their designed tolerances of 0.45, 0.45 and 0.46 g (4.38, 4.41 and 4.52 m/s2), but values within the design tolerances at Units 1, 4 and 6. When the earthquake occurred, the reactors on Units 1, 2, and 3 were operating, but those on Units 4, 5, and 6 had already been shut down for periodic inspection. Units 1, 2 and 3 underwent an automatic shutdown when the earthquake struck. When the reactors shut down, the plant stopped generating electricity, stop- ping the normal source of power for the plant. The situation at impacted nuclear reactors is, in the words of IAEA, an "Accident with Local Consequences." The Japanese earthquake and tsunami are natural catastrophes of historic proportions. The tragic loss of life and destruction caused by the earthquake and tsunami will likely dwarf the damage caused by the problems associated with the impacted Japanese nuclear plants. From the experience of Japan Bangladesh is in an earthquake zone and Bangladesh experienced the four major earthquakes between 7-8.5 Mw. So there is a threat for nuclear power plant in Bangladesh. The subsoil investigations, geotechnical, site specific seismic hazard assessment are the specific areas for major consideration for the selection of the site. According to the seismic zoning map Bangladesh is divided in to zone-1, zone-2 and zone-3.Rooppur site is in zone-3 which is seismically quiet. No indication of surface faulting around RNPP has been realized. The peak ground acceleration (PGA) is estimated 0.18g for the return period of 2475 years which is much smaller than the designed basis PGA values of nuclear reactors. From the seismic hazard analysis and sub-soil investigation, any heavy structure like RNPP with the design basis PGA values above 0.2g-0.25g could withstand a 7.5-9.5 Mw earthquake and can damage the RNPP in future.

Experience from Japan tsunami is also a consideration for Bangladesh to establish nuclear power plant. But it is great relive for Bangladesh that the site which is selected for RNPP is out of tsunami. Most of the experts said that Bangladesh may face tsunami in the Bay of Bengal which can generate 7Mw in rector scale and may cause serious threat. If the earthquake occurred at a level of 7.5Mw then sea level of Nijhom Dip Island will be raised by 4-5 meter. The water level will raise 2-3 meter s in Cox's Bazar, Sundarban, Hatia and estuaries of Meghna .So these areas will be highly affected during tsunami. On the other hand RNPP will be located in Pabna which is situated in the South-Western Region of Bangladesh and there is no big and wide river which will affect the nuclear power plant even though there is tsunami.

The waste from nuclear power plant in Rooppur is a major consideration. The waste from nuclear power plant will be radioactive and the wastes will be radioactive. Radioactive wastes are wastes that contain radioactive material. Around 20–30 tons of high-level wastes is produced per month per nuclear reactor. There are some 65,000 tons of nuclear waste now in temporary storage throughout the U.S., but in 2009, President Obama "halted work on a permanent repository at Yucca Mountain in Nevada, following years of controversy and legal wrangling". There are three types of waste. High–level, Mill Tailings and Low level waste. Among these high level waste is most dangerous. During fission, very harmful radiation rays are released. The most harmful of which are gamma rays. When the human body is exposed to radiation, it can cause tumors and can do extreme damage to the reproductive organs. For this reason, problems associated with radioactivity can be passed on to the victim's children as well. That is why radioactive waste produced by nuclear power plants is so dangerous. Radioactive fission products could pose a direct radiation hazard, contaminate soil and vegetation, and be ingested by humans and animals. Human exposure at high enough levels can cause both short-term illness and death, and longer-term deaths by cancer and other diseases. So it has seen that radioactive waste can cause a great herm in Bangladesh if any disaster is occur in the future nu- clear power plant. But there is nothing to be worried about it. Because there are new waste disposal technologies invented now a days. Bangladesh can use Experimental Breeder Reactor II.A breeder reactor is a nuclear reactor that generates more fissile material in fuel than it consumes. Breeder Reactor II is being developed by Argonne National Laboratory in the US; almost 100% of the transuranic nuclear wastes produced through neutron capture can be caused to fission. Generally, the fission products created have shorter half-lives and are not as dangerous. This reactor, dubbed EBR-II, uses liquid sodium as a coolant, which means that the internal reactor temperature is much, much hotter than that of a normal PWR reactor, which uses water as a coolant. Another advantage of EBR-II is that its fuel is not weapons grade quality. When the transuranic wastes are separated from the other wastes in the spent fuel rods, the resultant mix of isotopes can not be used in a bomb. Thus, the mix can be used as fuel for EBR-II without a chance of it getting stolen by a terrorist group for use in an explosive device. Breeder reactors "breed" fuel.

That is, they are designed to create 239Pu from 238U through neutron capture. This "waste" can then be used as fuel. Terrorism is a great threat for Bangladesh. If RPP is implemented in this country, then there will be a threat of nuclear terrorism. So security will be a major consideration. According to the CRS report for congress (Received through the CRS Web) nuclear power plants licensed by NRC must be protected by a series of physical barriers and a trained security force. The plant sites are divided into three zones: an "owner controlled" buffer region, a "protected area," and a "vital area." Access to the protected area is restricted to a portion of plant employees and monitored visitors, with stringent access barriers. The vital area is further restricted, with additional barriers and access requirements. The security force must comply with NRC requirements on pre-hiring investigations and training. Bangladesh Government can follow their security policy for tight security. A terrorist attack on a nu- clear research facility or commercial nuclear power plant could lead to the release of nuclear material. So to with- stand the terror attack Bangladesh government can make a taskforce with civil and defense high officials to protect the future nuclear power plant in Bangladesh. After the 1979 accident at the Three Mile Island nuclear plant Congress required that all nuclear power plants be covered by emergency plans. NRC requires that within an approximately 10-mile Emergency Planning Zone (EPZ) around each plant the operator must maintain warning sirens and regularly conduct evacuation exercises monitored by NRC and the Federal Emergency Management Agency (FEMA).So Bangladesh can also keep the option of Emergency Response for the future RNPP.

Technology Evaluation

Day by day nuclear power technology is developing. After Genaration-1, 2 3 now at the latest moment fourth Generation technology is available. Various types of GEN-3 and GEN-4 pressurized water reactors are available and the most common are the advance PWR of Mitsubishi, Japan, CANDU of Atomic Energy Canada Limited, VVER(The VVER is the Russian version of the Pressurized Water Reactor (PWR). There are 3 standard designs - two 6 loop- 440 Megawatt [440-230 (older) and 440-213 (newer)] and 4 loop-1000 Megawatt output de- signs. As with PWRs, refueling is conducted with the plant shutdown, Europeans pressurized reactor of Siemens, France; AP-1000, USA etc. Among the GEN-3 reactors the VVER have been built in Taiwan and are being built in India.GEN-2reactors can be suitable for Bangladesh but it is not the better option. There are two major Generation II reactors that are, quite simply the basis for nuclear energy. These are the Pressurized Water Reactor (PWR) and the Boiling Water Reactor (BWR). There are some disadvantages of GEN-2 reactors. Be- cause this is a pressurized reactor, rather than a boiling water reactor, water must be held at high pressures to keep from boiling, Fission product activity in the core builds up to high a level; Uranium must be enriched, which is a fairly expensive process; A double loop sys- tem is required, Because there is a double loop system, there is considerable heat lost in the heat transfer, adding to inefficiencies; Danger in primary loop, in that the water would vaporize to steam if there was a rupture in the system; Inefficient re- activity at the operating temperature; In order to replenish the core with new enriched Uranium, the plant must be shut down; The water coolant has a tendency to react with the Uranium and other materials, possibly causing safety risks. Considering these disadvantages Bangladesh should built the GEN-3 or GEN-4 reactors with a consideration of system simplicity, economic competitiveness, economic benefits, economic liability, safety consideration, digital instrumentation and control system, compliments for the latest safety code for the consideration of severe accidents like Chernobyl and Fukushima disaster, Physical Protection and issues of nuclear security. So from the technical view Bangladesh should go Russian VVER-1000MW nuclear power.

The NPP construction is a complex activity which requires huge preparation and years of preparatory work. It is a highly capital-intensive undertaking and financing for such a huge project is not that easy to manage. The NPP project also requires early selection of NPP technology and the vendor which is one of the big challenges for a newcomer country. It is a reality that the construction activity starts before elaboration of the design and the new comer countries often face problems in the management of NPP construction activities during preparatory phase, construction phase (after concrete pouring) and commissioning phase. To meet the licensing obligations in accordance with the national and international techno-normative requirements for obtaining the siting license and the design and construction license from nuclear regulatory authority is another challenge. In addition, the procurement and contracting approach of new build projects reveals a correlation between the contract approach chosen and the customers' experience.

Determination of national position on contracting approach for the first NPP build is a challenging task. The proliferation risks associated with fuel cycle technologies and the proposals regarding the control over nuclear fuel cycle technologies have imposed a new challenge for assurances of supply and services related to front end and back end fuel supply. Moreover, the creation of national nuclear infrastructure in the areas of management, legislative and regulatory framework, safeguards, electrical grid up gradation, human resource development, environmental protection, nuclear fuel cycle, radioactive waste management, issues of owner's engineers to perform supervision and inspection, public awareness and support, industrial involvement and procurement also impose potential challenges on successful completion of (lie project. The IAEA has been supporting Bangladesh on its way to becoming the third 'new comer' country to start constructing its first nuclear power reactor in last 30 years, following the United Arab Emirates in 2012 and Belarus in 2013. Bangladesh government has taken a practical step for implementation of nuclear power program from the beginning of 2009. The early activities included a detailed road map addressing all infrastructure requirements. The country adopted the IAEA's Milestones approach and followed the steps required for each of the following 19 infrastructure issues to build Rooppur NPP:

I. National position

2. Nuclear safety

3. Management

4. Funding and financing

5. Legal framework 6 Safeguards

7. Regulatory framework

8. Radiation protection

9. Electrical grid

10. Human resource development

11. Stakeholder involvement

12. Site and supporting facilities

13. Environmental protection

14. Emergency planning

15. Nuclear security

16. Nuclear fuel cycle

17. Radioactive waste management

18. Industrial involvement Procurement

19. Procurement

Site Safety Assessment

Preparatory Stage Activities Of Rooppur Npp Construction The introduction of nuclear power into a country is accompanied by the need to build appropriate nuclear infrastructure for construction and operation of NPP in order to comply with the obligations for the peaceful uses of nuclear energy with regard to safety, security and safeguards. BAEC conducted Site Investigation of Rooppur NPP project for confirming its suitability through involving national institutions during 2009 - 2012. The Site Report of Rooppur NPP for prepared based on the site specific issues, namely demographic, transport, electric grid conditions, geotechnical, meteorological, morphological and hydrological features of the site.

The baseline data for environmental assessment were prepared. The IAEA Siting Mission (July 2011) was provided with the site reports and the mission recommendations for detailed investigations of the geotechnical aspects and geomorphology, hydrological hazards and river morphology based on the IAEA guidelines. After Fukushima NPP accident, it is given special emphasis on the site safety aspects and engineering solutions to increase resistance of plants to extreme events and cliff edge effects are required. The vendors are encouraged to revise safety features-into their designs with adequate features to increase robustness of their designs to extreme natural events. The site reports were also informed to the vendor organization of the Russian Federation. The most significant preparatory stage activities of the NPP project are site characterizations and environmental studies, Environmental Impact Assessment (EIA) and comprehensive feasibility study of NPP project/feasibility evaluation (FE). These studies are performed based on relevant domestic acts, regulations and guidelines, the techno-normative requirements the vendor country and the IAEA guidelines with regard to safety assurance of the construction site. The JSC Atomstroy export of Russian Federation was assigned responsibilities for performance of these studies based on the techno-normative requirements of the Russian Federation, the applicable rules and regulations of Bangladesh and the IAEA Siting Mission recommendations and IAEA guidelines. The seismic monitoring station, aero-meteorological and chemical monitoring stations were installed at the project site. JSC Atomstroy export performed necessary studies/ surveys to obtain the reliable input data on the natural and anthropogenic conditions of the construction area and site for elaboration of Feasibility

Evaluation, including EIA, and carrying out site engineering survey and environmental studies for the development of the package of the documentation, which were used by BAEC for obtaining licenses required for Rooppur NPR.

The documentations and materials obtained through these studies were used for developing the detailed reports for the investment project for construction of Rooppur NPP. The results of the studies are used for space planning and design solutions for the most complicated and safety related NIT buildings and structures and their protection engineering, as well as on "Rooppur" NPP components layout. The obtained materials and data will be used to produce and maintain a validated, referenced bank of data that can be used during the life time of the Rooppur NPP. The JSC Atomstroy export also assigned for the development of the design documentation of Rooppur NPP including Preliminary Safety Analysis Report (PSAR); Probabilistic Safety Analysis (PSA) Report and QA Programme and the first priority design and construction documentation and first priority working documentation for Rooppur NPP. The detailed site engineering and environmental studies for the design stage were performed to evaluate the site specific seismic design basis parameter and other site specific parameters particularly, relating to floods, temperatures, winds and other meteorological parameters as well as man-induced hazards for finalization of NPP layout drawings (general location plan and general layout); finalization of principal layout and structural solutions for the most complicated and safety related buildings/structures of the NPP and their engineering protection; assessment of impact of the NPP buildings and structures on the environment and population (natural environment, underground waters and water eco-system) at the design stage, first priority working documentations, elaboration of PSAR chapters and elaboration of necessary documentation. A Technical Assignment (TA) for elaborate design documentation of Rooppur NPP Unit-1 and Unit-2 based on AES-2006 type (Novovoronezh NPP-2) NPP with VVER-1200 reactors has been developed by the General Designer of the Rooppur NPP and the Contractor, JSC Atomstroyexport bears all responsibility for implementing the safety requirements in the design documentation. The TA establishes the scopes, requirements and provisions for development of design documentation for construction of Rooppur NPP, Units 1 and 2. BAEC submitted to Bangladesh Atomic Energy Regulatory Authority (BAERA) the relevant documentations on principal layout and structural solutions for the most complicated and safety related buildings/structures and their engineering protection, PSAR Chapters, PSA Reports, QA documents and training policy documents for the operator and maintenance personnel required for obtaining of license(s) for construction of the Rooppurt NPP.

BAEC also appointed JSC Atomstroy export for performance of first-priority construction and erection works of preparatory stage prior to the "First concrete" and completion of the works for the preparatory stage of Rooppur NPP construction. Working documentation for Pioneer and Construction-Erection Base-1 (CEB-1) and Industrial base developed and first-priority working documentation including documentation for provision of the "first concrete" developed. The physical works of the preparatory stage are civil and construction works at pioneer base and CBE-1 which are mainly land development temporary motor roads, office and administrative buildings, engineering buildings, integrated parking area, storage area for equipment and materials, garage, domestic building, truck mounted mixer and motor transport washing station, domestic fire water pipeline etc. The other works include the development of pit for Unit 1 and Unit 2 is completed.

Soil improvement works for main buildings of nuclear island and turbine island of Unit-1 2 and development of the other industrial base is on the way of completion. The target of the First Concrete of the Unit 1 is the October 2017. In addition to the civil and construction works at the Rooppur NPP site, the construction of accommodation facilities for contractor personnel and customer personnel, electrical and service facilities are also in line with construction schedule. Works are being performed with participation of Russian and Bangladeshi subcontractors.

Consruction of Rooppur NPP BAEC signed a General Contract for Rooppur NPP Construction with JSC Atomstroy export, Russian Federation on 25 December 2015. The Subject of the General Contract is the construction of the Rooppur nuclear power plant which will be an AES-2006 type (Novovoronezh NPP-2) NPP consisting of two power Units (Unit 1 and Unit 2) with WER-1200 reactors. Under the provisions of the General Contract for Rooppur NPP construction, the Contractor will perform the following activities:

-Detailed design and working documentation required for construction of Rooppur NPP Unit 1 and Unit 2;

-Equipment and materials supply and transportation up to construction Site and establishment of jetty;

-Civil and erection Works for the construction of the NPP Units, including the Works for the installation of the Equipment and process systems;

-Tests, Start-up and Adjustment Works, development of the required adjustment documentation, commissioning, technical support during the Guarantee period of the NPP operation ;

-Engineering works for Project Management of the NPP Units construction; Warranty operation;

-Supply of initial load and two reloads of nuclear fuel supply; Training of Rooppur NPP operation and maintenance personnel;

-Development of NPP industrial site and erection and assembly base-2

-Establishment of radiation monitoring and emergency response requirements;

The contractor is responsible for supply of equipment, devices, instruments and materials of equipment, nuclear fuel and also for providing training to the project management team and the NPP operational and maintenance personnel. The Project Management Unit of the General Contractor will execute the project activities in accordance with the Calendar time.

Figure 2.5: Construction of RNNN at the beginning phase

2.5 Development of National Nuclear and Non-Nuclear Power Infrastructure

2.5.1 National Nuclear Power Infrastructure

National Nuclear Power Infrastructure and Formation of Nuclear Energy Programme Implementing Organization (NEPIO)

The introduction of NPP is accompanied by the development and implementation of a wide range of nuclear infrastructure. Nuclear power infrastructure includes all the activities and arrangements needed to set up and operate a nuclear power in order to comply with the national and international obligations for the peaceful uses of nuclear energy with regard to safety, security and safeguards. Bangladesh has a clear understanding about the national obligations and the recommendations, guidelines and obligations of the IAEA for introduction of nuclear power. The country adopted the step-by-step approach for the development of national infrastructure for nuclear power. Bangladesh has already established NEPIO (Nuclear Energy Programme Implementing Organization) in the form of high level committees to coordinate the work of the organizations involved in infrastructure development created legislative and regulatory framework and established Bangladesh Atomic Energy Regulatory Authority (BAERA),appointed Bangladesh Atomic Energy Commission (BAEC) as the NPP Owner Organization, developed Rooppur NPP Project Management Unit (PMU) for implementation of the project and established Nuclear Power Plant Company Bangladesh Ltd. (NPCBL) as NPP operating organization, introduced nuclear engineering educations at undergraduate and graduate levels in the reputed academic institutions, establishment of nuclear energy information center. The nuclear regulatory authority is undertaking its responsibilities; it is developing the required competency to fulfill its oversight duties in ensuring the highest standards of safety and security. The PMU has experienced in managing the preparatory stage activities of Rooppur NPP and establishing its management systems based on the IAEA guidelines and presently, developing its competency to become a competent one and more responsible and accountable for the management of the Construction of Rooppur NPP. All other newly established departments/organizations have started their activities. The National Committee Chaired by the Hon'ble Prime Minister of the country has assigned responsibilities for providing necessary directives on the ownership pattern, project execution approach, funding mechanism, national nuclear safety and legislative infrastructure development, capacity building of the owner/operator organization and fulfillment all national and international obligations. Besides, the National Committee, a Technical Committee headed by the Minister, Ministry of Science and Technology (MOST) and a Working Group and eight Sub-Groups are also formed under the MOST to monitor and coordinate the activities of the concerned ministries/organizations. A special wing called 'Nuclear Power' to coordinate, implement and monitor the project activities of Rooppur NPP have been formed in the MOST. There is still considerable work to be done for national nuclear power infrastructure development before the Rooppur NPP is completed and connected to the grid. The key organizations: government (NEPIO), BAEC, PMU, NPBCL, BAERA and relevant organizations are further reviewed the required national infrastructure preparedness and drawn up an action plan on the basis of the past action plan of the 2000; recommendations and suggestions of the INIR Mission of the IAEA in November 2011; the IAEA Milestones document and the revised IAEA Milestone Documents; the Intergovernmental Agreement between the Government of the People's Republic of Bangladesh the Russian Federation for construction of NPP in the territory of Bangladesh signed on 2 November 2011 and the interagency agreement for cooperation in the areas of nuclear safety regulation between Russian Organization and the Ministry of Science and Technology in 2012 and the recommendations of the follow-up INIR mission in May 2016.The specific actions and activities as well as the responsible agencies/ministries were identified for establishing appropriate nuclear infrastructure so as to facilitate implementation of the Government's decision to generate nuclear electricity by 2022- 23 from the Rooppur NPR. The major specific actions are identified for the following aspects:

• Development and implementation of the Construction of Rooppur NPP Project

• Strengthening of National Legislative and Regulatory Infrastructure

• Establishing nuclear security infrastructure

• Development of Human Resources for National Nuclear Power Program

• Competency development of Nuclear Power Plant Company Bangladesh Limited, the NPP Operating Organization of Bangladesh

• Establishing Technical Support Organizations

• Bilateral and International Cooperation.

Figure 2.6: Construction of complex for the reactor of unit-1 at the Rooppur nuclear power plant

Legislative and Regulatory Framework

Bangladesh Atomic Energy Regulatory Act 2012 (BAER Act) was passed by the parliament and signed by the president on 19 June 2012. Based on this Act Bangladesh Atomic Energy Regulatory Authority was established in 12 February 2013. The senior executives namely, Chairman and Members are appointed by the Government. The regulatory body is legislatively and functionally independent and presently, acquiring competence and recruiting manpower. An agreement has been signed between ROSTECHNADZOR and the Ministry of Science and Technology on cooperation in the field of nuclear and radiation safety regulation in the peaceful use of atomic energy on 27 February 2012. In addition, BAERA is also going to start cooperation with AERB, India under bilateral agreement between India and Bangladesh.

Nuclear Power Plant Company Bangladesh Limited

Nuclear Power Plant Company Bangladesh Limited (NPCBL) has been formed following the Nuclear Power Plant Ordinance, 2015/enactment of the Nuclear Power Plant Act, 2015 (Act No. 19 of 2015). According to the Nuclear Power Plant Act, Bangladesh Atomic Energy Commission is the owner of the NPPs. The NPCBL assumes the responsibility for commissioning and operation of the Rooppur NPP and implementation of other nuclear power projects of the country. The owner (BAEC) and the operator, NPCBL are functioning independently. The company will provide qualified staff to work at nuclear power plants in Bangladesh including Rooppur NPP. In case of Rooppur NPP, a programme for human resource development has been developed in consultation with the General Contractor and necessary steps have been taken for recruitment and provide them with necessary training in Bangladesh and Russian Federation for work at Rooppur NPP. All manpower will be trained up and made available before commissioning of the first unit. The company will maintain the physical protection, nuclear safety and radiation protection practices in and around the plant so as to ensure the safety of the plant's employee and public as well environment around the site in accordance with domestic laws, regulations and international practices. It will establish an appropriate emergency plan and maintains necessary response preparedness in this connection as per domestic laws, regulations and IAEA requirements.

Manpower of Rooppur NPP Project Management Organization

Annual development project for Construction of Rooppur NPP was approved by EC-NEC on 06 December 2016. Manpower for project management unit (PMU) for construction and erection work, commission and start-up of Rooppur NPP was estimated. A considerable portion of the posts relating to project management is being filled up by engaging experienced personnel working at BAEC and currently involved in the Construction of Rooppur NPP (First Phase) through attachment. They will perform as the key personnel for project management during NPP construction and erection works, commissioning and operational stages of Rooppur NPP. Presently, about 80 personnel of different categories are involved for managing the activities of the Project. During preparatory stage of construction activities, necessary measures have been taken for developing and strengthening the competency of the utility project management setup of Rooppur NPP project through adopting the utility project management approach and implementation of the integrated project management system of the IAEA. Steps have taken for recruitment the required manpower of the project management.

Human Resources for Future Operating Organization

Year-wise recruitment and training programme has been developed under General Contract. Steps has been taken for recruitment of necessary technical personnel for project management and future operating organization, following the time-bound training schedule, as Executive Training (ET). After successful completion of training, the ET will be appointed as a regular employee of NPCBL. Key personnel (License, Fuelhandling, Safety and Operational) will be trained by the Contractor (Russian Federation) in the frameworks of the General Contract wherein required personnel will obtain license in compliance with Regulatory body. Administrative and common industrial personnel as well as general supporting staffs will be trained by the Bangladesh Atomic Energy Commission's (BAEC) trained instructors in Bangladesh as required. Instructors will be trained in Russian Federation under the General Contract. A Joint Training Advisory Commission (JTAC) was formed by both parties (Bangladesh and Russia) for the selection of candidates, arrangement of exams, assignment of positions, quality assessment, training of personnel for Rooppur NPP. Several JTAC meetings will be conducted every year for smooth implementation of the training programme. 59 personnel are identified for the first phase of 2017. Among them 19 for Capital Construction, 24 for Training Centre and 16 for Operation;

Manpower for National Nuclear Infrastructure Development

From the very early phase of NPP in Bangladesh, IAEA provided different fellowships, scientific visits, training etc. to the development of human resources for implementation of national nuclear power programme. More than 300 participations were made from BAEC in the area of project management, state governance and regulation in NPP, infrastructure policy in the technical area, contracting, public communication, human resources and trained under IAEA programme.

A higher education programme for nuclear physics engineering have been developed and being implemented. About 50 students were sent to Russian Federation to study

Nuclear Engineering at MEPhI (Moscow Engineering Physics Institute) under financial support of Government of Bangladesh. More students will be sent this year. They will work for nuclear power programme of Bangladesh after their return. Dhaka University has established the Department of Nuclear Engineering which began its journey in January 2012. This Department is the first of its kind in Bangladesh. The missions of the Nuclear Engineering Department are to develop high quality nuclear engineers and scientists from undergraduate through the doctorate level who are capable of contributing valuable engineering skills and knowledge toward the design, building and running of Bangladesh's nuclear power plants and to be Bangladesh's center of excellence in nuclear engineering education and research, and to lead Bangladesh's effort to develop its nuclear infrastructure, and to introduce nuclear power as a part of its energy mix. The Department of Nuclear Science Engineering of Military Institute of Science and Technology (MIST) has started nuclear engineering education at undergraduate and graduate level. 88 BAEC personnel have been completed Foundation Course on Nuclear Energy (FCNE) in India for Rooppur NPP project and national nuclear power program. Most of them are working in Rooppur NPP project through attachment from BAEC. This program will be continued. The Training Institute of BAEC is regularly organizing Basic Orientation Course on Nuclear Science and Technology for newly recruited professionals and some Advanced Courses on NPP Technological Areas in collaboration with international experts.

Public Communication Strategy and Stakeholder Involvement

Information and communication on nuclear power development is an important task that should be carried out systematically, frequently, continuously in long term to raise proper awareness, public consensus, to develop safety culture to contribute to the success of nuclear power development programme. Development and enforcement of a national nuclear public information policy and establishment and realization of a national long term and systematic public communication strategy are critical issues for successful implementation of nuclear power project. Bangladesh addresses the nuclear power public information policy issue in the Bangladesh Atomic Energy Regulatory Act of 2012. Bangladesh Nuclear Power Communication Strategy 2015-2021 has been formulated in collaboration with the vendor country and IAEA assistance for stakeholder management as well as implementing programme on popularizing basic knowledge of nuclear power development, the features, nature and socio-economic benefits of nuclear power; the history, achievement, experience, trend and status of nuclear power development in the world; the need of developing nuclear power. The information and communication activities are being conducted in accordance with the progress of the Rooppur NPP Project and the future nuclear power projects. A communication plan for 201415 and 2015-16 were developed and implemented. The implemented programmes were focused on popularizing basic knowledge of atomic energy and nuclear power at schools Rooppur NPP area. A short term communication plan for the period 2017-2018 has been developed and is being implemented. The main targets of this plan are promoting and expanding the activities of the programme on information and communication on nuclear power development to meeting the requirements of construction stages and commissioning of the Rooppur NPP Unit 1 and Unit 2. Bangladesh established and putting into operation the nuclear industry information centre at Novo Theatre campus on 1 October 2013 for direct information and communication on atomic energy to the general people.

Steps have been taken to establish the Counseling Office of Rooppur NPP near the construction site. There will be a head of the Counseling Office and visitor relations manager. The key tasks of the office are to provide answers to the questions about Rooppur NPP construction and nuclear energy in general; provide information and assistance with an exchange of opinions on NPP safety, security, radiation and environmental protection, management of radioactive waste and spent fuel management and organize a range of educational activities and events for the local community. Decision has been taken to establish Public Council involving civic organizations in the policy making process for nuclear power utilization, environmental protection and radiation safety. The Council includes scientists and academicians, members of civic and environmental organizations and local and national journalists, prominent figures all of whom participate on a voluntary basis. A preliminary structure of the Public Council has been formed headed by the Minister, Ministry of Science and Technology.

Security and Physical Protection Nuclear

"Security Physical Protection System (PPS)" for Rooppur NPP is the national responsibility. Bangladesh has taken necessary steps to implement, maintain and sustain a

Nuclear Security Infrastructure (NSI) for an effective and appropriate nuclear security regime. A program for Security and PPS for Rooppur NPP has been established. A Working Group (WG) comprising experts from various national security law enforcement agencies has been formed to develop Design Basis Threat (DBT) following the IAEA guidelines, BAERA provisions as well as applicable other domestic regulations. The DBT documents has been finalised and approved by the appropriate authority. This DBT document is the policy document for developing PPS system for Rooppur NPP. The Conceptual Design of the PPS of Rooppur NPP has been developed based on DBT document which is approved by the Government. Based on the DBT and Conceptual Design of PPS, the construction of PPS for Rooppur NPP will be established. A separate cell namely-Nuclear Security Physical Protection System Cell (NSPC) from Bangladesh Army has been formed for implementing the construction phase of PPS for Rooppur NPP. NSPC is performed as a coordinator for developed Interim Response Force of Rooppur NPP.The PPS of Rooppur NPP will be fully functional before the loading of first fuel rods for Unit 1 at Rooppur NPP.

Formation of Local Monitoring Team

A local monitoring team headed by the Divisional Commissioner of Rajshahi has been formed by the Governmentto monitor and resolvevarious local issues for smooth implementation of the project. In addition, this team is also looking after the local security aspects and raising public awareness for Rooppur NPP.

2.5.2 Bilateral Cooperation with India

An inter-governmental agreement between the government of the people's republic of Bangladesh and the government of the republic of India on cooperation in the peaceful use of nuclear energy" and an inter-agency agreement between Global Centre for Nuclear Energy Partnership (GCNEP), department of atomic energy, the government of India and Bangladesh Atomic Energy Commission (BAEC), ministry of science technology, the government of the people's republic of Bangladesh on -cooperation regarding nuclear power plant projects in Bangladesh"have been signed on 8 April 2017. Following scope of services are identified under the agreement: Department of Atomic Energy (DAE) through GCNEP would provide training services to BAEC personnel for supervision of design, construction, commissioning, quality assurance, operation and other related activities of Rooppur Nuclear Power Plant (Rooppur NPP) project; GCNEP would also provide consultants and owner's engineers for different agreed activities related to Construction of Rooppur NPP Project as per the requirement of BAEC; Services will be provided by GCNEP to BAEC on cost basis and on non-profit principles, for which BAEC will reimburse to GCNEP expenses related to institutional overheads incurred in the course of implementing this Inter Agency Agreement (IAA); An empowered Programme Management Board (PMB) will steer the implementation of this IAA. The PMB will have equal members from both Parties and will be authorized to take all decisions related with operationalization of this IAA;

2.5.3 Other Non-Nuclear Infrastructure

- Power Grid Company of Bangladesh (PGCB) is engaged to carry out grid studies for the modification and upgrading of the grid system specifically related to the inclusion of the NPP with the assistance of Russian concerned organization.
- Bureau of Economic Research (BER), Dhaka University worked for socio economic impact assessment of Rooppur NPP.
- Bangladesh Inland Water Transport Authority (BIWTA), Bangladesh Railway and Roads and Highway department are engaged to improve communication system for the transportation of equipment to Rooppur site according to transportation plan.
- Public Works Department (PWD) is assigned to construct the residential village at Rooppur NPP site.
- Bangladesh Telecommunication Company Limited (BTCL) has been working to set up external communication system for Rooppur NPP.

Chapter 3

Opportunities and Challenges of Rooppur NPP

3.1 Opportunities of Rooppr NPP

Over the years, the global energy market has experienced insecurity of energy supply due to several reasons. There are many different threats to energy security, for instance political turm oils in rich oil producing countries, the rise of new economic giants (like China and India those presently are in serious competition over energy sources), natural disasters, etc. There are also geological risks that refers to the possible exhaustion of an energy source. Oil and gas reserves are gradually decreasing day by day. These are risks which are linked to the potential government decisions to suspend deliveries because of deliberate policies, war, civil strife and terrorism. Moreover, there are environmental risks. These risks describe the potential damage from accidental oil spills or nuclear accidents, or emissions such as greenhouse gas emissions. It is generally assumed that industrial countries will need to reduce emissions by 60-80% or more by 2050. Given that within the EU 80% of all emissions are related to fossil fuel burning in the energy, transport, household and industrial sectors. Energy policy will increasingly be constrained by climate change objectives. Basically, energy security has two dimensions: long term energy security and short term energy security. Energy policy of a nation entails measures or strategies on the long-term and the short term energy security. Long term energy security means to increase energy security center on reducing dependence on any one source of imported energy, increasing the number of supply sources, exploiting native fossil fuel or renewable energy resources, and reducing overall demand through energy conservation measures. On the other hand, the short term strategy focuses on the prompt responses to sudden changes within the supply-demand balance. Energy security is a complex issue and each country determines its future energy security independently. Energy security is ensured when the nation can deliver energy economically, reliably, in an environmentally sound way, and safely in quantities sufficient to support the growing economy and national security. Lack of energy security is linked to the negative economic and social impacts. Bangladesh is one of the world's most densely populated countries with 165 million people. The economy of Bangladesh is traditionally based on fossil fuel (mainly natural gas, limited coal and imported liquid fuels). Power sector has always been facing problem with lack of supply of the primary energy sources. Only the adequate supply of primary fuels can guarantee future energy security.

In order to react promptly to sudden changes within the supply-demand balance for addressing short to mid-term energy crisis, the indigenous natural gas is playing a major role as primary energy followed by imported liquid fuels (HFO and HSD), very limited portion by domestic coal and electricity import from India.

In the last decade, the industrial development is getting momentum and a notable progress in the power sector has been made. The demand of power will continue to increase for materializing of the development visions of the nation through transformation of the economy by industrial growth, modernization of agriculture sector, transformation of rural economy, rapid urbanization and improved standard of living of the citizens. The long term strategy of energy security has become an urgent for footing the continuous accelerated growth with Bangladesh. It involves timely investment to energy supply in line with economic development. For creation of major investment opportunities, a comprehensive and holistic policy for long term energy security should be in place. For the long-term energy security, a suitable energy mix for power generation is essential. It is a reality that choosing of an appropriate fuel mix is a major challenge for Bangladesh. The reliability of power supply and reducing overall electricity cost to all end-users will be the main direction for energy security of our country. Evolution of the energy mix in favour of cleaner sources will be an another dimension. Diversifying energy sources and not to rely on a particular indigenous energy resource or import of a single energy source can be regared as the basic philosophy of the long-term energy security of the country. The government of Hon'ble Prime Minister Sheikh Hasina had prepared a sustainable generation expansion plan and started to implement power generation mega-projects during her third tenure, 2014 - 2019 to provide the reliable power supply for boosting up the economic growth of the nation. The Power System Master Plan (PSMP-2016) is finalized and updated to develop the power sector to cope with the demand. The updated PSMP-2016 suggested fuel mix in total net generation capacity for the High Case, Base Case and Low Case Scenarios. The fuel wise forecasted generation capacity in the High Forcasted Scenario is 94,100 MW for meeting up the demand of 82,292 MW in 2041. While, fuel wise forecasted generation capacity in the Low Forcasted Scenario 79,507 MW which will be requiring for meeting up demand of 72,379 MW in 2041.It is seen from the High Case Scenario, the share of the gas/LNG in total electricity generation will be 46%, 42%, 37%, 39% and 43% in the year 2021, 2025, 2030, 2035 and 2041, respectively. Coal, being the cheapest option, also dominates capacity development following the gas/CNG. The share of coal is forecasted to 17%,31%, 40%, 39% and 32% in the year 2021, 2025, 2030, 2035 and 2041, respectively. While, it is seen from the Low Case Scenario, the share of the gas/LNG in total electricity generation will be 52.6%, 47.41%, 44.6%, 44.35% and 43% in the year 2021, 2025, 2030, 2035 and 2041, respectively. The share of coal is forecasted to 10.9%, 24.8%, 37.7%, 37% and 32% in the year 2021, 2025, 2030, 2035 and 2041, respectively. In both the Scenarios, the total share of gas/CNG and coal will be about 75% beyond 2025. The import electricity will contribute from 10% to 15% beyond 2030 and the remaining proportion will be meet by nuclear and other sources. The out standing feature of PSMP 2016 is revised fuel mix. The country is getting experiences in the shortage of supply of gas and several gas based power generators are not operated with full efficiency in the winter. The commercial and industrial sectors of Bangladesh are also strongly dependent on indigenous natural gas. Due to over dependence to this valuable, the gas production has increased drastically. The country's indigenous natural gas resources is limited and the country has been able to explore and add very little to the natural gas reserves in the last decade. As a result, the production of this energy resource has already reached to its peak. The recoverable proven reserve is 20.9

TCF, of which more than 15.94 TCF had already been produced and consumed as of 1st July, 2018. Considering the proven and probable reserve, the total reserve of gas is 27.81 TCF. It is easily understandable that if no new reserves are added, the production will start falling soon. It is not a matter of surprise that this valuable energy reserves of the country might deplete within next two decades. On the other hand, the liquid fuel is controlled by major oil exporters. Many powerful countries are looking for long-term solutions to increase energy security by reducing dependence on foreign oil import. However, the present power generation scenario has satisfiedthe short to mid-term energy security of our country but it could not be continued for the long-term energy security.However, the energy security of our country isprimarily associated with the longterm supply of natural gas.There should have a clear idea about the gas reserve of the country, which should be done immediately. In the present energy scenario, no major breakthrough in the use of domestic coal is realized. The country has significant reserve of coal. Among 3565 million tons (MT) of coal reserves about 1700 MT are maximum extractable so far considering 50% recovery, although the rest of the coal may not be viable for extraction because of its depth beneath the Earth's surface. About 50% of the recoverable reserves could supply coal for generation of 10,000 MW over 30 years. The nation needs to make a clear plan to use domestic coal reserve. Renewable energy is still playing an insignificant role. In addition, the power supply pattern has to satisfy the conditions of the 3Es Trilemma (economic viability, environmental quality and energy security). Thus, it is necessary to evaluate the 3Es Trilemma (economic viability, environmental quality and energy security) and evolve the best en ergy mix through maximizing the 3E valuesbefore making any decision for the long-term energy mix focusing on utilization of the domestic energy resources including natural gas, coal and renewable energies as well as imported gas (LNG), coal, electricity import from neighboring country and nuclear energy for long-term development of power sector of the country.

Nuclear energy is an important component of electricity supply mixes. Nuclear power has been in use for several decades. With low levels of life-cycle GHG emissions, nuclear power contributes to emissions reduction today and potentially in the future. On the other hand, the fuel and operating costs of nuclear power generation are low compared to other base load power stations. Nuclear power plants deliver electricity 24 hours a day and 7 days a week (24/7), irrespective of weather and seasons. The performance of nuclear energy, based upon more than 18 000 reactor-years of experience world-wide is very satisfactory. There are 454 operational nuclear power reactors in 31 countries with 399354 MWe net installed capacity, , which providing about 11% of the world's electricity and about a third of overall low carbon electricity.

Bangladesh is gradually becoming an energy import dependence. The cost of generating electricity isa great concern for the nation. The guarantee of the long-term stability of supply and price of fuels are important. The price of nuclear fuel is comparatively cheap and stable. The market of front-end nuclear fuel is very rich. Moreover, the nuclear plant requires very small quantity of fuel. As a result, nuclear power generation cost is cheaper than its alternatives. Nuclear plants deliver jobs, boost economies, leave space for nature and help ensure a healthy environment. Energy security is strengthened if our nation uses more nuclear energy in the future. The country needs to strategize its power supply, which would reduce the energy security threat. A diverse energy sources is very important for a nation's energy independence. It needs to utilize optimum level of the domestic energy resources. Realistic planning of indigenous coal and natural gas and reducing over dependence on imported coal and LNG, which have more volatile market are the key concerns. Like India and China, Bangladesh can consider nuclear power as a vital component for energy mix. Nuclear power generation can help to reduce the over-dependency on gas/LNG. Bangladesh should consider an optimal energy mix for electrical energy generation from various energy sources, such as coal, natural gas/LNG, nuclear energy and power import. The balance of the energy sources is from renewables (hydro, biomass, wind and solar) and liquid fuel. Nuclear plants are considered as proven and reliable base load power station. The proposed energy mix can play an important role in supplying clean, reliable electricity that is delivered 24/7, so that people can meet their needs and aspirations without harming the environment. The nuclear energy can be considered as the third fuel. The proposed energy mix could ensure uninterrupted energy supply for achieving the development goals and targets envisioned in the "Vision 2021", "Vision 2030" and "Vision 2041".

3.2 Challenges of Rooppur NPP

It is inevitable that there are huge prospects of nuclear energy development in the rapidly growing economic conditions of Bangladesh. However, there remain certain obstacles and challenges to ensure the best usage of nuclear technology. They are:

3.2.1 Regulatory and Legal Concerns

The main law regarding nuclear power project is the Nuclear Power Plant Act 2015. The Act sets up the Nuclear Power Company of Bangladesh (NPCB) to operate the plant, however, BAEC will remain as an owner of the power plant [9]. However, the law does not contain any provisions for the consequences of any nuclear power plant disaster. Bangladesh needs a comprehensive law on nuclear power production which is necessary in order to guide the future safe energy production. The government should make clear policies to address the impact of nuclear safety regulations and liability rules. Besides, the agreement between the BAEC and Nuclear Export states that the contract is not a "settled value" contract but instead a "cost in addition to" contract [10]. As it were, as the development work continues, the merchant has the privilege to think of any cost acceleration (in addition to their net revenue) to be consolidated into the agreement sum. The agreement is not comprehensive of fuel costs, operation and upkeep costs, and decommissioning and radioactive waste organization cost toward the finish of its operational life cycle. In any occasion where the plant is mothballed, cancelled or accidentally damaged, the legal position of the contract between BAEC and ROSATOM enumerates that the government of Bangladesh have to repay the loan with interests. It cannot be denied in such case the risk is extensive, hazardous and improper.

3.2.2 Ensuring Reactor Safety through Technological Means

The government of Bangladesh wishes to develop, expand and enhance the internationally advanced fission technology and achieve localization. It cannot be denied that such process includes the development of technology from the phrases of the introduction, digestion, and demonstration. However, due to various reasons, currently, the types of imported reactor technology from ROSATOM is complex, and the lack of domestic human resource to deal with such technology will affect the nuclear energy production. Any fission technology will not provide efficient production without the proper domestic introduction and demonstration of such technology [11]. In general, lack of experts on nuclear technology can constitute a great challenge on the efficient production of nuclear power in Bangladesh. As ROSATOM is a partner for the first nuclear power plant in the country, most of the nuclear technologies adopted are the Russian technologies. The RNPP will be equipped with two VVER-1200 water-cooled, water-moderated power reactors of the AES-2006/V-392M design [3]. The RNPP incorporates the defence-in-depth protection system, which is a multi-layer protection and mitigation system [11]. Any human or man-made accidents can be mitigated using the system ensuring safety to the environment. The system includes five layers of barriers, which will prevent radiation exposure as well as protect people and the environment [11]. The five layers include: preventing, detection, and control of unnatural and suspicious operational failures within the design basis, traction of problematic plant conditions (e.g., preventing accident escalation), mitigating catastrophic events and their consequences, and—lastly—mitigating radiological impacts of significant off-site residuals of radioactive materials [12]. However, still there remains concern regarding the safety issues as the country has not yet developed its own human resources to deal with the insights of this challenging technology. Therefore, ensuring the safety will be a challenging task for the government of Bangladesh.

3.2.3 Nuclear Waste Treatment

Nuclear waste and spent fuel accumulation is rapidly growing. The new agendas of Europe and America present a negative impression towards nuclear technology, and thus, they are in the process to closing down some of their nuclear power plants. Such decisions of Europe and America will surely have an impact on the nuclear waste disposal and it is estimated that the growth of nuclear waste can cease [13]. The nuclear waste of the RNPP will not be a huge amount as Bangladesh has aimed for a limited nuclear power generation scale. However, the government should be clear about the policies and initiatives that should be taken for nuclear waste disposal. It is unfortunate that, until now the government has not initiated any related talks, research or policies that provide a comprehensive solution for the nuclear waste disposal. Strong guidelines or plans regarding the disposal of nuclear waste is a must to ensure the safety from radiation to the mass people. As the government will take more initiatives to establish more nuclear power plants, there will remain questions on the policies of the government to deal with the increasing amount of nuclear waste. The law of the Russian Federation prohibits any disposal of foreign nuclear waste in Russia—which means that all of the waste will have to be absorbed by Bangladesh. Furthermore, existing protocol does not hold Russia or India responsible. If any accident similar to Fukushima or Chernobyl occurs, Bangladesh has to assume all responsibility. [20]

3.2.4 Potential Threats and Risks against Nuclear Facilities and Initiatives

Although nuclear materials will be strictly supervised by the Government of Bangladesh, however, there remain a certain concern due to the increasing terrorism activities in the region. Only about 3% of uranium-235, which is the core nuclear fuel, is used in nuclear power plants to generate electricity. The usage of 3% of uranium-235 is far below that of the nuclear weapons (more than 90%) [14]. Furthermore, chain fissile reaction in nuclear power production have different control technologies which is very dissimilar from the technology that is used to design nuclear weapons. Hence, in general, there is no huge threat of the nuclear proliferation from the nuclear power technology, however, the increasing questions on security lead to an anxious public perception relating to the safety of the nuclear materials. In Bangladesh, there are a few environmentalist groups who always stand against the nuclear power. They do not cause real threats and risks to the nuclear facilities but do favouring the public to go against the nuclear plant. There exists some activists, extremists, criminals and terrorists groups in Bangladesh. Presently, the government has banned some criminals and terrorists groups realising their potential threats to the State. They include Horkatul Zihad Al-Islam, Jagrotto Muslim Janota Bangladesh, Jamaatul Mozaihidin Bangladesh, Horkatul Zihad Al-Islami Bangladesh, Shahadat Al-Hikmat and Ansarullah Bangla Team. Though their activities are banned, they may emerge as new groups with higher ideological, technical and economic capabilities. Analysing their past nature of attacking activities, they are still unaware of nuclear and/or radiological attack. However, it is not wise to undermine their capabilities who might plot nuclear threat. Even this would not be surprising of those adversaries who might use regional or international networks to do nuclear terrorisms. They could also use cross-border routes (land border, airports and seaports) for illicit trafficking of nuclear material and radioactive sources. There is no specific organisation for detecting as well as administrating the nuclear/radioactive material across the cross-boundary in the country. Nuclear power plants, research reactors and hospitals are the main targets for the terrorists in order to gain nuclear material or radioactive sources by various ways and means. These kinds of facilities always use category 1–3 of nuclear material as well as category 1–5 of radioactive sources that the adversaries can make nuclear weapons or explosive devices. If such nuclear material or radioactive sources could go to the criminals and terrorists' hands by any means, there would be serious nuclear and radiological consequences to the people, property, society and environment. [15]

3.2.5 Electrical Grid Reliability and Interface with Nuclear Power Plant

NPPs have some similarities to large fossil fuel power plants. The steam turbine, the generator and the large power transformers, and the arrangements for cooling via cooling towers or seawater, are similar. The nuclear reactor is the source of heat to produce steam, similar to the combustion chamber and boiler in a fossil fuel power plant. The key difference between NPPs and other power plants is that a nuclear reactor has the potential to cause serious harm to employees and members of the public and cause widespread damage to the environment, if it is not safely controlled. This was illustrated by the severe accidents that happened at Unit 4 of Chernobyl NPP in Ukraine in April 1986, and at Fukushima Daiichi NPP in Japan in March 2011. Hence nuclear safety is the primary consideration at all times in the design and operation of an NPP. An important characteristic of all nuclear power plants is that after a nuclear reactor is shut down, it continues to produce a significant amount of heat for an extended period. With current designs, the thermal power of the reactor immediately after shutdown is around 6.5% of the power before shutdown, although this reduces to around 1.5% after one hour, and 0.4% after one day. Hence the reactor cooling systems must continue to operate for several days after a reactor shuts down, to prevent overheating and damage to the reactor core. Therefore, reliable cooling arrangements must be provided, and this requires robust and diverse sources of reliable electrical supply. The prolonged unavailability of offsite electrical power and the failure of on-site power systems was a significant contributor to the damage to the reactors and release of radioactivity from Fukushima Daiichi NPP in Japan in March 2011. Depending on the plant design, electrical power is needed for most or all safety functions. The fundamental safety functions of a nuclear reactor safety systems identified are:

— Control of reactivity

— Transport of heat from the core

— Confinement of radioactive materials

— Control of operational discharges

— Limitation of accidental releases

The electrical power systems are needed during all modes of operation: startup; normal operation; during and after reactor shutdown; and as a high priority source of power during certain nuclear events. Special attention must be given during the periods when the reactor is shut down, that the electrical power systems continue to fulfil the applicable safety requirements. Special attention must also be given when parts of the transmission system near to the NPP are taken out of operation for maintenance or surveillance testing. The safety systems of the NPP are designed for continuous operation with limited variations in voltage and frequency from the nominal values. This operating area defines the initial values for pump speed (giving flow and pressure) in the thermo-hydraulic safety analyses for the NPP. Hence voltage and frequency of the electricity supply must also be controlled within a defined narrow range. [16] Because of this reliance on electrical power, nuclear plants are normally required by their operating licence to have multiple sources of electricity, including a minimum of two independent offsite power sources (i.e. two connections from the transmission system to the NPP), and onsite power sources (typically a combination of batteries and diesels or small gas turbines). Based on the operating experience gathered from extreme external events such as hurricanes, tornados, flooding, earthquakes and tsunamis, many NPP operators have taken additional measures to ensure availability of AC power. Some examples of such design improvements are to have hardened structures to house emergency power sources using diesel oil and gas, diverse electrical paths through overhead and underground cables, and connectivity to geographically separate electrical grid networks. Some modern advanced designs of NPP with passive safety features may not be required to have two independent off site supplies to satisfy their operating licence. However, for practical reasons (e.g. to allow maintenance on transformers and switchgear) it would be normal to have at least two connections. The full electrical load of the auxiliaries of a NPP is typically 5–8% of the NPP rated load. Hence the electrical connection to the NPP must be able to supply this load during reactor startup, and immediately after reactor shutdown, whether from a planned shut down or an unplanned reactor trip that may occur at any time. The transmission system is the source of power to the offsite power system. In Member States that already have operating NPPs, the transmission system is generally demonstrated to have higher availability and reliability than the on-site emergency power system because of the diverse and multiple generators connected to the transmission system. Hence NPPs generally consider offsite power as the primary source (preferred source) of power for cooling down the reactor during normal and emergency shutdowns. This means that the connections to the grid must have adequate capacity and capability to provide rated power to safety grade electrical equipment in the NPP to perform its function. The degree to which the grid can maintain an uninterruptible power supply to the NPP with sufficient capacity, and with adequate voltage and frequency, is the measure of grid reliability from the point of view of the NPP. The loss of all alternating current (AC) power to the safety and non-safety busses at a NPP involves the simultaneous loss of offsite power (LOOP), turbine trip, and the loss of the onsite power supplies. Such a condition is referred to as a station blackout (SBO). Risk analyses performed for NPPs indicate that a station blackout event is a significant contributor to the calculated core damage probability [17]. Although NPPs are designed to cope with a LOOP event through the use of on-site power supplies, LOOP events are considered precursors to station blackout. An increase in the frequency or duration of LOOP events increases the probability of station blackout and hence of core damage. Hence it is important that the transmission system can provide a reliable electrical supply to an NPP, with adequate capacity. Faults on the grid system at a significant distance from a NPP can be the cause of reactor trips or the loss of offsite power (LOOP). In addition to requiring the grid system and the grid connection to the NPP to be reliable, NPPs also require the grid supply to have sufficient capacity, and to be of an appropriate quality, with both voltage and frequency to be maintained within defined ranges. It may be a requirement of the nuclear regulatory body in the country that the NPP disconnects or shuts down if the grid frequency goes outside the acceptable range, or if the grid voltage becomes so high or low that voltages within the plant are unacceptable. NPPs also require a stable and reliable grid for other reasons:

— So that the number of unplanned trips of the nuclear unit from power caused by grid faults or unusual grid behavior is small compared with the total number of unplanned trips allowed in the design and safety assessments.

— For commercial reasons so that the nuclear units can achieve a high load factor, unconstrained by grid restrictions or grid faults, and that trips caused by grid behavior do not shorten the life of the plant.

3.2.6 The Issue of Cyber Security

The issue of cyber security is also critical. Cyber-attacks on nuclear power plants could have physical effects, especially if the network that runs the machines and software controlling the nuclear reactor are compromised. This can be used to facilitate sabotage, theft of nuclear materials, or – in the worst-case scenario – a reactor meltdown. In a densely populated country like Bangladesh, any radiation release from a nuclear facility would be a major disaster. Earlier in September, the Kudankulam Nuclear Power Plant (KKNPP) in Tamil Nadu, India, became a target of cyber-attack. Virus Total, a virus scanning website owned by Google's parent company Alphabet, has indicated that that a large amount of data from the KKNPP's administrative network has been stolen [18]. If this is true, subsequent attacks on the nuclear power plant could target its critical systems more effectively.

3.2.7 Creation of Skilled Manpower

The generation of skilled manpower can be the main challenges to operate this highly technical project because the country doesn't have experienced and skilled engineers in such a field. Therefore, when the plant goes into operation, Bangladesh has to depend on Russian engineers for the first few years, said the officials of the project. As the construction progresses, the creation of skilled manpower is becoming very challenging. There is also the possibility that the International Atomic Energy Agency will not give Bangladesh a license to operate the nuclear power plant if the required skilled manpower is not prepared in time. At least 1,600 trained engineers will be required to operate the two units of the Rooppur project. [19] Do we have the required personnel for the Rooppur project or are we planning to rely solely on foreign experts to handle our own nuclear power plant? Skilled local manpower is mandatory for the reliability of this kind of a power plant. Energy production is, after all, a matter of national security, and it has to be controlled by skilled Bangladeshis. Not even nuclear energy experts are qualified to work in a nuclear reactor plant because totally distinctive skill sets are required when it comes to operating, constructing and regulating nuclear reactors. Dr Abdul Matin, former chief engineer of the Bangladesh Atomic Energy Commission, questions whether we have enough people for project management, nuclear regulation, and the operation and maintenance of the plant, who satisfy the qualifications and experience specified by the IAEA guidebook. The answer is 'no'. Even the director-general of the IAEA, Yukiya Amano indicated about the lack of manpower in Bangladesh. [20]

3.2.8 Water Problem and Ultimate Risk

Another vital concern is the water bodies of Bangladesh. Farakka Dam is only 40km away from Rooppur. In the dry season, as India extracts almost 75 percent of the water of Padma, there is a huge possibility that the nuclear power plant may not have enough water at its disposal to meet the plant-cooling requirements. In case of an accident, the radioactive waste would contaminate the water not only from Hardinge Bridge to the Bay of Bengal but all water bodies of Bangladesh because of the structure of riverine interconnectivity throughout the country. The whole ecology would be totally destroyed. Moreover, in the case of an emergency, this kind of a nuclear power plant would need extra water. Does the Padma have enough water in the dry season? This power plant will rely on the Padma river to meet its requirement of 720,000 gallons of water to cool the reactor and dump the hot water back into the Padma [20].

3.2.9 Huge Financial Cost

It is common to not have a "fixed cost" model in a nuclear power plant. It is apparent in the US, France and other developed countries. In the US, the cost jumped 300 percent on average for every nuclear power plant they built between 1966-76. Rooppur nuclear power plant is not an exception—the cost has already increased. About USD 13.08 billion (BDT 11,100 crore) is going be allocated in the 2018-19 Annual Development Programme—BDT 964 crore (USD 1.1 billion) more than the previous year. The previous cost estimate was USD 12.65 billion. Russia is going to loan USD 11.38 billion, which is 90 percent of the estimated cost. Bangladesh has to repay the loan within 28 years with a 10-year grace period. The interest is 1.75 percent plus Libor rate (London interbank offered rate), and this interest rate will not go above 4 percent. Even if the cost does not go up, it would cost us no less than USD 20 billion. And, obviously, this cost will be higher when other costs like decommissioning are taken into account. For instance, in 2017, Ecnec approved a project of BDT 956 crore for river dredging in the Padma for the nuclear power plant's transportation related purposes. Once everything is added up, it is not cheap at all [20].

Chapter 4

Recommendations

The above analysis provides a fruitful picture for our following discussions on suggestions and recommendations:

4.1 Development of a Comprehensive Legal and Regulatory System

At present, Nuclear Safety and Radiation Control Division (NSRCD) is now working as the regulatory wing of BAEC [21]. There is an independent regulatory body established through Bangladesh Atomic Energy Regulatory Act 2012 [22] with a view to establishing a suitable organization having adequate independence to meet the IAEA/national obligations for ensuring nuclear safety and radiation control in the country. The body is known as BAERA. For the most part, the common law of torts decides the common risk for most accident related expenses [23]. Be that as it may, for accidents occurring at nuclear power plants, statutes in numerous nations extremely limit the utilization of tort law [24]. As the tort law does not exist in a legal form in Bangladesh, the regulations must also describe the role espoused by criminal law assigning meaning to people's activities on and proceeding the events of any disaster which might happen due to the negligence of the government or the operator. However, until now, the government of Bangladesh has not enacted any laws or regulations addressing such concerns. Accordingly, Bangladesh also needs a comprehensive Atomic

Energy Law [25] to strengthen nuclear safety laws. In addition, nuclear safety fund also needed to be set up in order to organise a comprehensive disaster management team and to compensate the victims on any disasters relating to nuclear power plants. Such laws should also provide optimal liability scheme for the Government of Bangladesh which expounds the following topical challenges: full strict liability for the operator; joint and several liabilities with upstream suppliers [22], with the upstream suppliers' liability [26] being restricted to a negligence standard [27] mandatory liability insurance to be provided by the market to some extent, and above this amount by the government. As the tort law does not exist in a legal form in Bangladesh, such regulations must also describe the potentially decisive role of criminal law in assigning meaning and context to actions of people during and after the occurrence of any disaster arising from negligence of the government, delegated contractors, operator(s), or other.

4.2 Enhancement of Domestic Nuclear Technology Development

The nature complex of fission technology is very hard to handle. Therefore, without proper management and efficient human resources, it is impossible to ensure the safety of nuclear reactors. In addition, the enhancement of domestic nuclear technology is also important to marginalise the expenses of nuclear power generation. Simultaneously, the localization process of imported technology will enhance the independent research and development (RD) of Bangladesh's nuclear power industry. Consequently, to achieve the sustainable goals through nuclear power production, it is imperative for the government of Bangladesh to take the initiatives to develop and localise the domestic nuclear technology. One of the fundamental points of immediate interest for Bangladesh will be the training and availability of qualified staff to meet the overwhelming needs of proceeding and extending programs. In any case, the 'human resource advancement' needs to incorporate every one of the issues that influence human execution, for example, initiative, administration frameworks, working society, nuclear information administration, and individual states of mind. Specifically, for the Bangladeshi landscape, it is imperative that a fruitful atomic power program possess a broad framework. Thus, the study will thoroughly analyse nuclear establishments, facilities, investigate associations, administrative facilities, government divisions in Bangladesh and will evaluate whether such bodies have atomic skills and instructive ability to operate the suitable nuclear preparing programs.

4.3 Cost Minimization of Nuclear Power Generation

Owing to various factors ranging from economies of scale, carbon lock-in, and sluggish development in nuclear technology, fossil fuel-based power remains substantially cheaper than nuclear power. In fact, the initial capital outlay in both construction, design, material procurement, and technological industry complex means that nuclear power projects can be undertaken only after a massive governmental commitment is made. By comparison, private ventures abound in the fossil fuel industries. However, it is undeniable that the increasing prices of gas, coal and oil provide a good prospect for nuclear energy in future. The efficient amount of power production through nuclear means cannot be discounted either. The short supply of oil and natural gas resource has initiated the developing countries to choose nuclear energy as their sustainable option. However, it is particularly important for Bangladesh to blend the nuclear technology with local expertise and enhance domestic technology to minimise its cost and improve its market competitiveness.

4.4 Establishment of a Cleaner and More Efficient Nuclear Technology

Managing nuclear waste will be a big challenge for Bangladesh though the country is targeting a small scale of nuclear power generation. It is also true that the amount of nuclear waste will drastically increase with the new installment of nuclear power plants in the approaching years. Hence, cleaner nuclear reactor and developed nuclear waste disposal technology must be initiated by the government.

Accelerate a More Efficient Process of Reactor and Nuclear Fuel Cycle Development The expected uranium demand in Bangladesh will be on a small scale, which could be met with the domestic uranium production supply. Bangladesh is expecting to discover limited amounts of uranium resources, which would actually be limited to less than 1% of the total resources of the world. Importing uranium is always an alternative approach that the government might take, however, it is very important to remember that such an approach conflicts with other international political issues. Therefore, it is always suggested to develop efficient reactors which can produce large amount of electricity with less uranium resources. Some of the aspects of fast breeder reactor technology, spent fuel recovery and utilization technology can be used to achieve this goal.

4.5 Need for Public Awareness Involvement

The Government of Bangladesh ought to likewise clarify explanations on their methodologies towards the most imperative focuses identifying with nuclear power plant, for example, radiological assurance of laborers, radiological insurance of open, radioactive waste administration and ecological radiological reconnaissance. Open mindfulness and contribution are likewise rudimentary before setting up the nuclear power plant. Though exceptionally progressed and refined new reactors may decrease perils in light of "characteristic" security features, for instance, "latently sheltered" measures made by the era III reactor, we assume that any country that does not give genuine straightforwardness and enable open commitment with respect to atomic issues ought to never use atomic vitality. Along these lines, the Government of Bangladesh should contribute convincing consideration work to keep up open responsibility. It should be yielded that atomic expert expansion is in the meantime social, political, and financial, and along these lines, the Government of Bangladesh should take the perspectives of masters in different fields before totally chipping away at the nuclear power era. Other than these huge steps, the organization of Bangladesh ought to moreover have strong state commitment in controlling fiscal change, centralization of national vitality masterminding, endeavours to interface imaginative advances to a national restoration, effect of technocratic conviction framework on course of action decisions, subordination of troubles to political administration, and low levels of urban activism which are convincing components in supporting the augmentation of atomic power. It cannot be denied that with the improvement of the domestic nuclear technology, the expenses of power production through nuclear means will be reduced and security measures will be enhanced. Hence, it is important for the government of Bangladesh to learn from the countries, such as the United States of America, Germany, France, South Korea, China and Japan, to carry out effective publicity to maintain public acceptance for nuclear energy in the future. Additionally, the government must efficiently manage and supervise the nuclear power operations in order to thwart the spread of nuclear material. Last but not the least, the government should fund and sustain nuclear research and develoIt cannot be denied that the Government of Bangladesh has taken the necessary regulatory initiatives to start their very first NPP project.

Chapter 5

Conclusion

The nuclear power plant stands on the border between humanity's greatest hopes and its deepest fears for the future. On one hand, atomic energy offers a clean alternative that frees us from the shackles of fossil fuel dependence. On the other, it summons images of disaster: quakeruptured Japanese power plants belching radioactive steam, the dead zone surrounding Chernobyl's concrete sarcophagus. Bangladesh's energy infrastructure is quite small, insufficient and poorly managed. The per capita energy consumption in Bangladesh is one of the lowest in the world. Non-commercial energy sources, such as wood fuel, animal waste, and crop residues, are estimated to account for over half of the country's energy consumption. Bangladesh has small reserves of oil and coal, but very large natural gas resources. Commercial energy consumption is mostly natural gas (around 66%), followed by oil, hydropower and coal. Nuclear power is desirable in Bangladesh, due to its underdeveloped and mismanaged energy infrastructure. Nuclear powers are much more rigorous than of other kinds of energy production. Moreover, Nuclear power is a unique source of energy for power production. It is also assume to have a wide application in hydrogen production. However, the future Nuclear power must be safe, much more efficient and no producing radioactive waste. Hence, Bangladesh has taken full preparation for implementation of Rooppur Nuclear Power Project. This article gather all such opportunities of installation of nuclear energy in Bangladesh despite several challenges. This work also points and those challenges and suggests plausible recommendations. Necessary survey and investigations have already been initiated to combat the hindrance to the development of nuclear power in the country .Law has been enacted in order to establish independent Regulatory Authority. IAEA is playing a considerable role in this regard. As the most important part of the preparation, an agreement has been signed with Russia as the vendor country. If the challenges of nuclear energy are solved, then it is anticipated that RNPP project will bring greater prosperity for Bangladesh.

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Appendix A

Abbreviations

NPP Nuclear Power Plant

RNPP Rooppur Nuclear Power Plant

IAEA International Atomic Energy Agency

KWh Kilo Watt Hour

GWe Giga Watt in electricity

TWe Terra Watt in electricity

BAEC Bangladesh Atomic Energy Commission

BPDB Bangladesh Power Development Board

WNA World Nuclear Association

IEEE Institute of Electrical and Electronic Engineers